The South African National Roads Agency Limited

CONSTRUCTION MONITORING MANUAL FOR BRIDGES AND STRUCTURES



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Comment on the Manual is welcomed, and should be submitted to bridges@sanral.co.za.

SANRAL will periodically issue addenda.

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FOREWORD

This manual is the result of a need that has existed for several years, if not decades. Having spent my life in the design and construction of bridges and other structures the need for a guide for site staff has always been an unfulfilled desire. In my present position as the person responsible for all structures under the jurisdiction of the South African National Roads Agency Ltd (SANRAL) I regularly see "the good, the bad and the ugly". When approached, SANRAL's CEO, Nazir Alli, enthusiastically agreed to SANRAL initiating and funding the compilation of such a manual to serve not only our organisation but the general construction community as a whole.

First, before going into why site staff should have a guide to help them, let us take a step back in time. One of the first recorded requirements of a building code is contained in an ancient written law known as the Code of Hammurabi, written in 1790 BC by the King of Babylon, King Hammurabi. One of these codes stated: *If a builder build a house for someone, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death; If it kills the son of the owner, the son of that builder shall be put to death.* Thankfully the sanction for not building something correctly is less severe today. However I confess that I could sometimes happily "murder" some contractors when I see the quality of their work!

In the ancient civilisations, spread throughout the continents, there are examples of very elaborate structures. The builders of old were very skilled people who built up their trades over decades. Craftsmen first spent many years as an apprentice before becoming a journeyman and the best finally some became master craftsmen. Whereas large palaces and other structures of old took a considerable time to build, today the adage of 'time is money' applies to almost all projects, with few exceptions. As a result, the need for quality control during construction is greater than ever and we can no longer assume it as a given.

At the start of my career I worked for the railways. As a young engineer it was expected of me not only to personally survey and stake out railway lines, walls and other structures, but to also check on the contractor, or departmental construction teams, appointed to do the work. However I had one great advantage over today's younger engineers. We had experienced clerks of works on site, men who had spent years as artisans in departmental construction before being promoted to the clerk of works position. They, in many senses, instilled a deep respect within me for men who I could only call *"the salt of the earth"*. They knew what bad construction was and what good construction was. The mentorship they enjoyed is all but missing for today's younger generation of engineers and supervisory staff. Whilst this mentoring gap cannot totally be replaced with a written manual, this publication will at least help to guide some of our younger engineers in determining what to check to ensure correctly built and durable structures.

This manual puts onto paper the years of collective wisdom, knowledge and experience of the authors of the various chapters. As such the styles of the various chapters do and should differ.

It is clear that contractors also have a mentoring problem with younger staff that they employ. It is therefore hoped that the manual will also be of some use to contractors, but it is primarily aimed at the supervisory staff employed by the consulting engineers or the employer's project managers.

Younger inexperienced supervisory staff are often pressured by contractors into accepting what they should not. This manual will help them resist being intimidated into accepting inferior work and will provide support when they insist that the work be built correctly the first time. To correct poorly constructed work later always leads to arguments and friction. Also, repaired structures are without doubt less durable than those constructed and finished off correctly in the first place. I remember one clerk of works who was on one of the first sites I was in charge of as a young engineer. I vividly recall the following incident: Mr B (full name withheld) was asked by the contractor to approve and sign off reinforcing steel of the first foundation we constructed. He walked up to the foundation, examined it

and promptly disapproved the casting of concrete. The contractor asked what was wrong, but Mr B, a rather abrupt man, refused to explain and asked the contractor to check the work and discover for himself what was wrong. That was the last time the contractor called Mr B for approvals without first ensuring that everything was correct and according to plan and specification. Ground lost early in a project can never be made up afterwards, and thus being strict from the start always pays dividends in the long run. Consultants must guard against the tendency to become the de facto quality control on behalf of the contractor. It is the contractor's duty to build according to plan and specification and it's the consultant's site staff's duty to ensure the employer gets the product and quality that is specified.

It is hoped that all site staff will read and absorb what is contained in the various chapters. Specifically we have also included a chapter on the contractual duties of site staff which should be considered compulsory reading for all involved in projects, even if there are no structures on the project.

We further trust that the manual will contribute to the advancement of the quality of site supervision. It is not aimed at the high-end complex structures but rather the construction of relatively routine type bridges and structures that constitute the majority of structures built on road projects. However it will be of use even for large complex structures, including those outside the roads industry. This manual will also be of use to small developing contractors who sometimes lack a clear understanding of what is acceptable or not. It is however not a manual on how to do the construction, but rather what is acceptable.

SANRAL fully acknowledges that the manual will not cover all aspects of construction and as such does not purport it to be faultless. It is the intention that the manual be a "living" document and positive critique and suggestions for improvement will always be welcome. For this reason the manual is only made available electronically to enable errata to be corrected and amendments to be made on a continuing basis.

Finally it has been a pleasure to be associated with the compilation of the manual. I wish all who use the manual well and trust that the bridges and structures we build will give us a sense of pride and accomplishment.

Edwin Kruger
Bridge Network Manager
South African National Roads Agency Ltd.

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It is an honour to particularly thank our colleague Edwin Kruger who made this Manual possible through his belief in the project and also being influential in motivating and initiating the publication. His enthusiasm sustained the project in a number of ways.

This Manual would not have been possible if not for the countless hours spent by the authors and reviewers of the various chapters. Grateful acknowledgement is made to Bruce Durow, Martin du Rand, Gerrit Els, Mick Latimer, William Martin and Dave Temple.

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It is also a pleasure to acknowledge my fellow review team members, Mick Latimer, Harry Viljoen, Edwin Kruger and Ravi Ronny, who spent countless hours reading through various draft versions of the manual. In particular Mick Latimer's role as chair of the review team and his overall editorial and compilation role of the document is appreciated.

To all who made available and gave their permission to use their photographs used in the Manual a big word of thanks.

Further we owe deepest gratitude to our many colleagues and friends in the industry, too numerous to mention here, for contributions, advice and support during the project.

Elma Lourens
SANRAL Project Co-ordinator
Construction Monitoring Manual for Bridges and Structures

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ADDENDA

CHAPTER 1 - INTRODUCTION

Construction monitoring is a key element of most construction contracts. It is most commonly performed by staff appointed by the project consulting engineers, and is carried out to monitor and ensure compliance with contractual programmes and specifications.

Over the years provincial roads departments and several South African consulting engineering firms have produced a number of construction-related manuals. Most of these focused on structural works, and provided useful information and guidance for both design and monitoring staff, as well as those undertaking the actual construction. Having been produced "in house", these manuals were however not freely available, and for a considerable period little has been done to update and expand their content.

The increased pace and competitiveness of today's construction industry has made it essential that construction monitoring be both thorough and effective, and has highlighted the need to develop and make available a comprehensive manual to guide and assist monitoring staff.

This Manual seeks to address this need. It has been prepared on behalf of the South African National Roads Agency Limited (SANRAL) and continues their policy of pro-actively compiling and updating relevant information, developing manuals and capacitating role players in the roads industry to ensure a sustainable road infrastructure network. It brings a welcome addition to a number of other widely used manuals and standards compiled by SANRAL (all available for download from www.sanral.co.za), including the following:

- *Procedure for road planning and design*, (2003)
- *Policy in terms of road planning and design*, (2003)
- *Geometric Design Manual*, (2002)
- *Code of procedure for the planning and design of highway and road structures in South Africa*, (2002)
- *Materials Code of Procedure M2*
- *Drainage Manual*, 5th *Edition* 2006

The Manual deals with the duties of construction monitoring staff involved with the structural works on road projects in South Africa. Such works typically include bridges, culverts, retaining walls, toll plaza structures and sign gantries, but may also include other miscellaneous structures required for erosion protection or other purposes. The Manual specifically excludes matters relating to the roadwork aspects of the works and concentrates on structures manufactured from concrete, the construction material most commonly used in southern Africa.

The aim of the Manual is to describe the duties and responsibilities of the monitoring staff, and to provide information and guidance to assist them in effectively executing those duties. It alerts readers to items requiring forward planning and formal approval, and contains useful check lists and control forms suitable for use on site. Although comprehensive, the Manual cannot however provide detailed coverage of all aspects of construction monitoring, and is not intended to cover the wide range of specialised construction systems and techniques available today.

The Manual will be of benefit to both junior and senior site staff, but its use in no way relieves them of the responsibility of ensuring that they have a sound understanding of the construction drawings and specifications applicable to the works, as well as their contractual and administrative responsibilities. Firms contracted for the monitoring should therefore not place excessive reliance on the Manual and still need to appoint competent and adequately trained and experienced staff. All such firms should be

aware that they are required to exercise all reasonable skill and that they still have a 'duty of care' in terms of their agreement with the Employer.

The arrangement and layout of the text has been selected in an effort to present the information in an easy to use format, which readers can readily scan to identify important items. The contents have therefore been presented in chapters, each focusing on a specific subject, using various levels of sub-headings to identify and organise the content. As each of the chapters is the work of a particular person, the writing styles and approach to the subject-matter may differ, but this is seen as a positive aspect of the work as a whole. Readers may also note that the text generally refers to the male gender. This has been done for brevity, and it is acknowledged that both men and women may fulfill any of the roles referred to.

All engineers and monitoring staff are encouraged to study and become familiar with the content of this Manual. Inexperienced persons being employed on site for the first time should in addition arrange for their mentor to brief them on the use of the Manual, remembering that the Manual is a guide, and is not intended to be prescriptive. This distinction is rather like the difference between knowledge and experience - knowledge is knowing that tomato is a fruit, experience is knowing that you don't put tomatoes in a fruit salad.

Application of the guidance presented is certain to reduce the likelihood of important items being overlooked, and will assist in identifying potential problems before they occur. Most importantly, the Manual will assist in achieving the goal of "getting things right first time".

It is intended that the Manual be updated regularly, and for this reason it is published in electronic format. Users should therefore print their own hard copy, and are free to customize the checklists to suit their own particular circumstances. All users are invited to submit comments and suggestions regarding the Manual to bridges@sanral.co.za. On SANRAL sites where structural work is being undertaken a hard copy of this manual is a prerequisite, and audits will be undertaken to ensure that this requirement is met.

CHECK LISTS

The checklists provided are not prescriptive, and may be modified to suit the particular needs and circumstances on the site. Two differing styles have been presented, and illustrate the differing levels of detail which can be captured. Separate MSWord versions of the check lists are also included.

CHAPTER 2 - CONTRACTUAL ASPECTS AND GENERAL DUTIES

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2.1 SCOPE

The purpose of this chapter is to give an overview of the contractual relationship between the parties to a contract and other roll players and the duties and responsibilities which flow from this contractual relationship with the emphasis on that applicable to the engineer's representative and his staff.

2.2 BASIS OF CONTRACT

In law, a contract is a binding legal agreement that is enforceable in a court of law. That is to say, a contract is an exchange of promises for the breach of which the law will provide a remedy.

The "promises" to which the aforesaid definition refers are commonly known as the Conditions of Contract and these are more formally defined to be the terms and conditions that set the rights and obligations of the contracting parties when a contract is awarded or entered into. These include 'general conditions' which are common to all types of contracts, as well as any variations, amendments and additions which are peculiar to a specific contract. These are set out in the Contract Data and are also referred to as the particular or special conditions of contract.

In South Africa and for the purposes of a construction contract, four standard forms of contract (conditions of contract) have been approved by the Construction Industry Development Board, viz New Engineering Contract (NEC), JBCC, General Conditions of Contract for Construction Works (GCC) and the FIDIC Conditions of Contract for Construction (FIDIC).

The parties to a construction contract are the employer and the contractor.

The **employer**, the one for whom the works are to be executed, is defined to be a natural person (human being) or a juristic person (a legal entity through which the law allows a group of natural persons to act as if they were a single person for certain purposes, e.g. a company, a partnership, a municipality, the government, SANRAL, etc.).

The **contractor** is the natural or juristic person whose offer for the execution of the work has been accepted by the employer.

The **engineer** is the natural or juristic person who has been appointed by the employer to act as the engineer for the purposes of the contract and to carry out the duties assigned to him in the contract [refer FIDIC clause 3]. Where the engineer is a juristic person a specific individual will be named to fulfil the duties of the engineer.

The engineer on his part will appoint an **engineer's representative** (traditionally referred to as the RE) and such additional staff as may be required by the circumstances (collectively referred to as the monitoring staff), to maintain a permanent presence on site and to perform the functions assigned to them by the engineer.

It follows that the monitoring staff should ensure that they have a sound knowledge of contract law and in particular the conditions of contract and should understand the nature of the contractual relationship between the employer and the contractor and the role of the engineer and monitoring staff.

2.3 RELATIONS

2.3.1 General

Joe Love, a renowned speaker and author on the subject of relations, had this to say:

"*As we move further into the 21st Century, it may well turn out that the success in the workplace pivots on the ability to tap into something very basic, something as old and entrenched as mankind itself: the need to establish relationships, to connect with someone else. Since our professional connections often are forced by time and circumstance to be our social connections as well, it is important for organizations to facilitate dynamic relationships in the workplace. Workplace relationships are personal, despite efforts to keep the personal and professional realms separate. Many of the same dynamics and difficulties exist for relationships in the workplace as do for those outside the workplace. Successful workplaces are the ones that create an environment that encourages people to create relationships. Quality relationships are what produce quality products and services. At the heart of it all is communication. There must however be a delicate balance between relationships and friendships. For example, managers should know not to become great drinking buddies with the people they supervise. Just as they should also know not to become close friends with the chairman. On the other hand, don't be aloof. Maintain a positive relationship that doesn't impose on you, the other person, or the work to be done."*

The monitoring staff will do well to keep the aforesaid in mind when they establish relationships with the various role players as listed below.

2.3.2 With Contractor

(a) The monitoring staff should use a courteous, businesslike and ethical procedure when dealing with the contractor. A good relationship is essential to gain the co-operation of the contractor.

(b) The monitoring staff should be confident that the best interests of both the contractor and the employer are being met under the terms of the contract.

(c) Enforcement of instructions will not be difficult if judgment is **fair and impartial** and knowledge of the work is thorough. This will have been accomplished by detailed examination and understanding of the plans and specifications. If the monitoring staff knows the plans and specifications thoroughly, the contractor's personnel will respect the engineer's representative's judgment in cases where interpretation becomes necessary. A satisfactory relationship between the employer and the contractor at all levels is an important result of smooth relations between the monitoring staff and the contractor's staff.

(d) Disputed instructions must always be referred to the engineer, and until a decision is received, the best judgment to the instruction should be applied.

(e) By dealing fairly and by recognizing and commending good work, the monitoring staff can usually secure the friendly **cooperation and respect** of the workmen, an important asset.

(f) The monitoring staff should ensure that any changes they suggest are for the benefit of the work, and not merely to show the authority of the monitoring staff.

(g) The monitoring staff must avoid "criticizing" the contractor's organization or discussing mistakes discovered with persons not involved with the contract.

(h) Notwithstanding the above, the monitoring staff should ensure that the work is done in strict conformance with the accepted engineering principles and in accordance with the drawings and contract documents.

(i) An incorrect method or procedure must be corrected the first time it is practiced rather than after it has been in use for some time.

(j) Conditions that may lead to unsatisfactory work should be **anticipated** whenever possible, and in any event should be pointed out (preferably in writing) to the contractor at the earliest opportunity, to avoid waste of materials, labour, and strained relations.

(k) In communicating with the contractor and the contractor's personnel, it is important that the engineer's representative take a clear position. It is far better to start on a basis of administering the contract firmly in accordance with the plans and specifications than it is to correct a situation caused by laxity later in the contract's life.

(l) Instructions should be given only to the authorized representative of the contractor (the contractor's representative, commonly referred to as the site agent). However, on minor and routine matters, and to an extent agreeable to the contractor's organization, instructions may be given directly to the work persons. However, the monitoring staff should not act as superintendent or perform duties for the contractor, nor interfere with the management of the work by the contractor. All orders or instructions should be confirmed in writing with a copy to the engineer.

BEWARE

All too often, and with the best intentions, monitoring staff issue suggestions / instructions / advice to site personnel who, whilst carrying out these verbal suggestions, incur the wrath of supervisory foremen etc, who are not aware of the input, and admonish the workman for deviating from instructions. It is human nature to offer help where necessary, but any such help should be confirmed ASAP with the relevant supervisor, preferably in writing.

(m) The monitoring staff may deal directly with the subcontractors to an extent agreeable to the contractor's organization. The contractor is legally responsible for the performance of the subcontractors. Any correspondence between the engineer and the subcontractor must be submitted through the main contractor.

(n) If any doubt exists about a contractual matter, the engineer's representative has an obligation to clarify in writing the employers' position for the contractor.

(o) The monitoring staff is cautioned to accept no personal favours from the contractor.

2.3.3 With Services Companies and Government Authorities

(a) Good public relations with internal and external stakeholders will have a beneficial effect in completing a construction project within scope, schedule and budget.

(b) Preconstruction discussions that may affect the contract should have involved all stakeholders. Once the contract has commenced the engineer's representative should encourage the contractor to make early personal contact and establish a good working relationship with staff of affected services companies (e.g. ESKOM, Telkom, Transnet, and other private companies) and government authorities. Such authorities may include: District Municipalities, Provincial Government regional offices, municipal and provincial traffic authorities, the local police and any other government agency with interest in the project. Early personal contact with staff from these agencies and groups will acquaint them with upcoming construction operations and will enable them to have input and schedule their work or services to the best advantage of all concerned.

(c) The engineer's representative should involve himself in the aforesaid but without assuming responsibility.

2.3.4 With Interested and Affected Parties

(a) Start public relations early by identifying those parties who are interested in and affected by the project. This information should be readily available from the Environmental Impact Assessment (EIA) process which preceded the contract. Be certain to note the concerns, objections and requests that were recorded at the time.

(b) It is a good idea to arrange at an early stage of the project a meeting with all interested and affected parties and to repeat such meetings periodically.

(c) The nearby property and/or business owners are the ones most affected by construction operations. By courteously listening to their problem, request, or question and by taking the time to explain or answer, the engineer's representative can generate faith that the employer is not an impersonal organization running roughshod over the general public or the individual. Sometimes this human approach will reduce unreasonable demands and complaints by such owners.

TIP

A concerted and visible effort to ensure a dust free atmosphere on domestic washing days will go a long way towards the development of good relations

(d) Construction operations (for example, temporary closures of streets and driveways) and construction noise or temporary construction lighting may have an adverse effect on nearby residents and businesses adjacent to the project. Informing business owners and residents near the project about the reason for, and the duration of, the activity will go a long way toward a higher degree of acceptance and tolerance. Timely notice is important. Also consider rescheduling construction activity around major business or public events.

(e) The fullest possible cooperation of the contractor's organization should be solicited to achieve good public relations most effectively.

(f) It is important to note that in day to day dealings with affected parties the engineer's representative should be very careful not to compromise the employer's position on any matter and not to agree to any request which falls outside the scope of the works or his delegated authority. The engineer's representative should make the limitations of his authority clear and such requests should be directed to the engineer for his further attention.

(g) If blasting or compaction of roadwork layers are to be undertaken which will induce vibrations, the engineer's representative in conjunction with the contractor and in the presence of, or with the knowledge of the owner/occupant, should do a survey of all nearby structures and record (by way of photos and measurement) all existing cracks and defects or the absence thereof.

(h) Refer Appendix 2A for guidelines with regard to permissible vibrations. The engineer's representative should ensure that the design of the blast or the equipment used for compaction will induce vibrations within the stipulated limitations. The placement of instruments (called vibrographs or seismographs) for the monitoring of ground vibration at strategic locations will assist in putting everybody's mind at rest.

2.3.5 With the General Public

(a) The main differences in public relations toward the property owners and the general public occur in the scope of coverage and the degree of personal contact. When construction information must be conveyed to large numbers of road users (including those who commute regularly over a particular route and those who use the route only occasionally), appropriate signage is paramount. In addition, to publicize the upcoming work consideration should be given to making best use of:

- the press and regional radio broadcasts,
- advertised telephone contact numbers,
- SMS services, and
- variable message signs

(b) Frequent notices and progress reports in the local press are also very common and effective methods of keeping the public informed of changing project conditions.

TIP
A report in the local press is 'free' and by inviting a reporter to observe an interesting aspect of the works, useful information can be conveyed to the public e.g. traffic arrangements.

(c) The engineer's representative is not authorized to issue press releases unless specifically authorised by the employer. From time to time the engineer's representative will be required to provide information or prepare a draft statement for the employer to issue press releases. In special cases the employer, through the contract, may prepare and distribute pamphlets to motorists who are delayed as they pass through construction.

2.3.6 With Site Staff

(a) Development and maintenance of good relations between monitoring staff is largely a matter of adequate communication and a clear division of responsibility. Site staff must know precisely what their responsibilities are, and they must be given the authority to handle these responsibilities.

(b) It is recommended strongly that engineer's representatives hold short staff meetings each week. At these meetings the engineer's representative should brief staff members on the week's operations, announce any changes or new assignments of responsibility, and discuss any other pertinent subjects.

(c) Engineer's representatives should provide personnel with an opportunity to demonstrate their strongest capabilities and highest capacity for responsibility. The engineer's representative should ensure that staff members have an opportunity to gain experience in the various construction phases.

(d) Assignment rotation, especially amongst the lesser experienced members of the team, is encouraged as long as the effectiveness of the overall operation does not suffer. Similarly, if feasible, assign personnel to operations different from those handled on previous projects. Newly assigned personnel should study the applicable portions of the standard specifications, project specifications, the drawings, this manual, and any other applicable publications of the employer and engineer. An individual should not be required to perform new duties until the engineer's representative is assured that the person is capable of performing them correctly and effectively.

2.3.7 With the Engineer's Office

(a) Communication is a two-way responsibility. The engineer's representative should adequately inform the engineer so that he is not embarrassed by learning about project events from outside sources. Conversely, good management practice requires that the engineer keep his personnel informed of decisions affecting an employee's area of responsibility. Communication has failed whenever an engineer's representative first hears about an engineers' decision from outside sources.

(b) An important aspect of internal relations is the necessity for working with other disciplines within the consultant's organization. People in other disciplines do their work with information available to them, just as construction teams do. They, too, have problems in their work. When there is a difference of opinion on some part of the project, whether it is about design, traffic handling, or some other feature, the engineer's representative should approach the other party with an open mind to discuss the problem.

2.3.8 With the Employer

(a) Monitoring staff should always keep in mind that they are representatives of the employer. As such, they are expected to conduct themselves in a manner that will command respect and be a credit to the employer's organization.

(b) Formal communication between the monitoring staff and the employer will normally be conducted via the engineer. However, monitoring staff should ensure that they clearly understand procedures to be followed when communicating with or making submissions to the employer. This will assist in the timely preparation, the use of the right format and the completeness of information required by the engineer.

(c) Neither the engineer nor the employer appreciates unexpected surprises and it is imperative that the engineer's representative informs the engineer at the earliest opportunity of any significant event or change in current trends, be it good or bad news. Of major importance are changes in expected expenditure, cash flow and progress. Other matters may include quality issues, potential delays and claims, potential variations, complaints from the public, environmental and safety incidents and accidents.

2.4 GENERAL DUTIES

2.4.1 Introduction

Under the general direction of the engineer, the engineer's representative and his staff, if any, is responsible for the contract administration and management, and construction engineering of the assigned contract. The duties of the monitoring staff with regard to construction engineering aspects are described in more detail in other chapters of this Manual.

The focus in this Chapter is therefore on those duties of the engineer's representative and his staff which in overview comprise of:

- Contract administration in accordance with the conditions of contract in so far as authority in this regard has been assigned to the engineer's representative, and
- Management of the contract under the headings of traffic accommodation, scope of the works, cost, time and quality.

2.4.2 Delegated Authority

The authority of the engineer is derived from the Conditions of Contract. This authority may be amended or limited by way of the Particular Conditions amending the General Conditions. The engineer may delegate some of his authority to the engineer's representative in accordance with the conditions of the relevant Conditions of Contract [e.g. FIDIC clause 3.2]. The delegated authority of the engineer's representative should be conveyed to him by way of a letter from the engineer in which his authority and the limit thereof, is spelled out clause by clause. An example is presented in Appendix 2C.

IMPORTANT
The engineer's representative must have a clear understanding of what authority **has not** been delegated to him by the engineer.

For the sake of sound contract administration a copy of the said letter should be given to the contractor for his information.

It is to be noted that the limitation of the engineer's representative's authority, and for that matter also that of the engineer, stems from the need of the employer to manage risk, financial risks in particular, at the appropriate decision making level. It should therefore not be viewed as a reflection on the individual's ability, but rather as a means of providing protection against excessive liability.

The responsibility of the engineer's representative to administer the contract in accordance with his delegated authority is immense and consequently he should be very familiar with the interpretation and application of the conditions of contract applicable to his project. Ideally he should have received some training in the principles of contract law.

Of equal importance is the fact that the engineer's representative has no authority other than that delegated to him and hence all instructions issued must be founded on and given in terms of an applicable clause of the Conditions of Contract.

The Conditions of Contract also serves to protect the rights of the contractor and inter alia entitles him to fair compensation for all work instructed and to claim compensation for damages suffered. The contractor may, but is not obliged, to refuse an instruction which exceeds the authority of the engineer's representative and therefore the engineer's representative should be acutely aware of the potential consequences in the event of him exceeding his authority.

The engineer's representative on his part, **may not** delegate any of the authority which has been given to him by the engineer, to any of his support staff members. Therefore, should the duties assigned to the support staff members necessitate communication with the contractor in terms of the authority derived from the Conditions of Contract, then such written communication must be channelled through the engineer's representative.

2.4.3 Project Briefing Meeting

Apart from his contract administrative duties, the primary duty of the engineer's representative and his staff is to manage the contract in the manner described in this manual. To this end it is important that the monitoring staff acquaint themselves fully with all aspects of the contract and therefore, prior to commencement of the contract, the engineer and his monitoring staff should meet with the project leader and his design team to be briefed on all aspects of the project. Attention should be given inter alia to the following aspects:

(a) The design philosophy adopted with reasons

(b) The scope of the works to be performed

(c) Construction restraints specified

(d) Health and safety considerations and risks

(e) Environmental considerations and management plan

(f) Matters effecting interested and affected parties

(g) Traffic accommodation strategy

(h) Specific construction procedures

(i) Considerations to be considered where procedures are at the discretion of the contractor

(j) Design parameters to be considered for temporary works and other items the design of which will be the contractor's responsibility.

(k) Project specifications which are out of the ordinary

(l) Special quality approval procedures required

(m) Measurement items. A copy of the measurement calculations for all items in the bill of quantities could be useful.

(n) Items in the bill of quantities which are based on assumptions and may vary substantially depending on actual site conditions.

(o) Items in the bill of quantities which may pose a financial risk to either the contractor or employer due to these rates or sums being substantially lower or higher than the estimated rate or sums.

(p) Requirements for and monitoring of contract participation goals in respect of goals set by the employer.

Prior to the commencement of construction, and in a similar vein, the monitoring staff should review the project with the contractor to:

- ensure that the contractor is familiar with all aspects of the contract,
- become acquainted with the contractor's plan of action and
- discuss anticipated difficulties.

2.5 TRAFFIC ACCOMMODATION

2.5.1 Introduction

The temporary traffic accommodation arrangements and the traffic-control facilities used must be in accordance with the specifications, the drawings and chapter 13 "Roadworks Signing" of the South African Road Traffic Signs Manual.

2.5.2 Objective

The objective of this section is to provide for worker protection and the safe passage of public traffic through and around construction with as little inconvenience and delay as possible.

2.5.3 Planning

Providing for worker safety and the safe movement of traffic through construction zones starts with planning at the design stage, and a traffic accommodation strategy with detailed traffic arrangement drawings should be included in the contract documentation.

2.5.4 Responsibilities and Procedures

The engineer's representative has the responsibility and authority for administering the traffic accommodation strategy and arrangement and he should perform the following administrative duties:

(a) Compare the plan for traffic accommodation to the actual conditions found at the site.

(b) Workshop the traffic accommodation strategy with the contractor with emphasis on:

- Permissible activities during peak hours, night time and weekends
- Restrictions on road and or lane closures either short term or longer term
- Pavement standard of temporary deviations and the maintenance thereof
- Confirmation of sign layout for various scenarios
- Quality, appearance and construction of temporary signs and facilities to be used and the maintenance thereof.

(c) It is advisable, jointly with the contractor, to also involve the local traffic authority at this stage by soliciting their comment on the proposed strategies in particular with regard to special operations which will necessitate their assistance (e.g. traffic management during beam launching operations) and law enforcement in general. It is important to note that whilst serious consideration should be given to any comment and recommendations made by the traffic authority, their explicit approval of the traffic accommodation arrangement is not a requirement.

(d) Modifications of the traffic accommodation strategy and arrangement may be considered at this point. Given the specifics of a contractor's needs, it may be possible to provide improved traffic service over the service originally contemplated. Changes requested by the contractor must provide at least equal traffic service to receive favourable consideration.

(e) Proposals for amendment of the traffic accommodation strategy must be approved by the engineer and if approved, must be covered by a variation order. Such ordered changes must include plans in sufficient detail to define all elements of the proposed changes and deviation design.

(f) Some unpredictable, immediate situations of a minor nature or short duration will arise during the work and will require good judgment to obtain optimum results. In these instances, formally approved plans are not required, but the engineer's representative should specify what is to be done and record in writing actions taken and orders given.

(g) Consider the contractor's proposal for the position of traffic safety officer. The complexity of the traffic accommodation strategy will dictate the qualifications and level of responsibility expected from the incumbent.

(h) Workshop the required procedures and responsibilities with the appointed traffic safety officer – refer to the project specifications for further guidance.

(i) To establish a record of the geometry, markings, devices, and signs that existed at any time during the project, maintain in sufficient detail a record of the placement into service, changes, and discontinuance of existing roads and deviations. The form of the record may vary according to the magnitude and complexity of the subject. Dated notations or revisions to plans may be helpful. Dated photographic or video tape records, particularly of points of transition or difficult situations, are very valuable and are required for accident records etc.

(j) If the contractor's operations interfere with or cause potential safety problems with vehicular or pedestrian traffic, contact the contractor immediately and request correction of the deficiency. If necessary, direct the contractor in writing to act at once to remedy the

unsatisfactory situation. A contractor's failure to perform is cause to order the cessation of the operations and/or the application of penalties as may be provided for in the specifications.

(k) Arrange jointly with the contractor, an information session with the local traffic authority to explain the various traffic accommodation scenarios that will be implemented and where and when their active assistance will be solicited. Agreement should also be reached regarding law enforcement especially with regard to speeding.

(l) Timely publicity can significantly improve traffic behaviour on a construction project. A motorist who is forewarned of construction conditions will be more tolerant of delay and inconvenience and will probably be more alert and responsive to construction zone control.

2.5.5 Guidelines for Traffic Accommodation Strategy and Arrangements

The engineer's representative will not normally be required to develop and design traffic accommodation strategies, deviation layouts and sign sequences. However, complaints and abnormally high accident rates may require him to critically evaluate the traffic accommodation arrangement with the view of proposing or making improvements.

2.6 SCOPE MANAGEMENT

2.6.1 General

Scope management is essentially the processes required to ensure that the project includes all the work required, and only the work required, to complete the project successfully. It is primarily concerned with defining and controlling what is or is not included in the project.

For the purpose of this manual the scope of the works is defined in the Description of the Works (Part C3), the Drawings, and the Pricing Schedule (Part C2.2). Further clarification of the scope of the works should stem from the project briefing meeting (refer paragraph 2.4.3)

In general, there are two types of specifications: "end-result/performance based" and "method/prescriptive." For work governed by end-result specifications, the engineer determines "what" and the contractor decides "how." Method specifications are more restrictive as to the contractor's options. Deviations from specified methods require variation orders. Deviations must also provide equal or better results while preserving the contract's integrity.

Scope management therefore also includes controlling the "how" and adequacy of various procedures that the contractor proposes to follow or is obliged to follow and is discussed in 2.6.4 under the heading of Method Statements. It also includes all temporary works as discussed in 2.6.5.

A variation of the original scope of the works may become necessary for a number of good reasons and may be initiated by the employer, the engineer or the contractor.

2.6.2 Procedure

The monitoring staff should perform the following procedures:

(a) Produce a work break down structure for the scope of the works.

(b) The break down structure should be in sufficient detail to facilitate:

- compilation of the contractor's program for the purpose of monitoring progress
- linking of each item of work to the specifications – refer quality management under paragraph 2.9.
- linking of each item of work to a payment item in the bill of quantities.
- calculation of quantities applicable to the relevant pay item

(c) From an analysis of the above said the following should follow:

- confirmation that all work has been included in the contractor's program
- confirmation of the logic and sequence of activities in the contractor's program
- confirmation or correction of all quantities in the bill of quantities in so far as they are not based on assumptions yet to be confirmed.
- confirmation of quantities sensitive to varying or actual site conditions
- identification of quantities and/or pay items which may have been inadvertently omitted and which will thus constitute a variation and / or claim.
- identification of details on the drawings which may be lacking or require clarification

(d) Check bending schedules with emphasis on the following:

- the critical bending dimension of bars which need to fit in between formwork faces, remember to consider the allowable bending tolerance.
- for identical units (e.g. wingwalls, beams, columns etc) check that the quantity of each bar type has been multiplied by the appropriate number of units.

(e) Check steel layout drawings with emphasis on the following:

- the practicality of fixing steel in the positions intended in areas which are congested with a high percentage of steel, e.g. bursting steel underneath bearings and behind stressing heads
- the available space to get concrete and vibrating pokers into areas where heavy bars overlap e.g. in heavily reinforced slender columns.

TIP

It is worth the effort to draw out critical areas or sections to a large scale e.g. 1:10, if not to full scale, showing actual steel diameters and bending radii to verify the actual position of bars and the available gaps for inserting concrete vibrating pokers.

2.6.3 Variations

Variations are per definition a deviation from the original intended scope of the work and can be classified as any of the following (for example refer FIDIC clause 13.1):

(a) Changes to the quantities (increase or decrease) of any item of work. [*but not on account of the actual measured quantities merely varying from that stated in the bill of quantities on account of inaccurate estimating*]

(b) Changes to the quality and other characteristics of any item of work. [*e.g. a revision of the desired concrete properties*]

(c) Changes to the levels, positions and/or dimensions of any parts of the works. [*e.g. revised founding level or revised extent of river bank protection*]

(d) Omission of any work [*e.g. a "nice to have" which is not necessary for the completion of the works or is no longer required for whatever reason. It is important to note that if work is omitted in order for it to be done by another contractor (e.g. routine maintenance contractor), the act of omission may constitute a breach of contract by the employer*]

(e) Any additional work necessary for the permanent works. [*typically this would be work which is necessary for the completion of the project but which may have been inadvertently omitted from the drawings or bill of quantities*]

(f) Changes to the sequence and timing of the execution of the works. [*only on account of the engineer's instruction or for reasons beyond the control of the contractor*]

Monitoring staff should be aware of the following:

(a) Only the engineer may issue a variation order and then only with the explicit approval of the employer – refer for example, procedure for variations in paragraph 12.8 of Part 1 of the SANRAL Works Contracts Manual of Procedures.

(b) The issue of a revised drawing may constitute a variation and thus the necessity for such drawings to be signed by the employer.

(c) Monitoring staff should thoroughly familiarise themselves with notice periods since these may vary for the different forms of contract. [e.g. unlike GCC, FIDIC does not require the contractor to confirm within 14 days that he deems an instruction to be a variation and the monitoring staff may only become aware of the contractor's contention when notice of a claim is received 28 days later].

When a variation is contemplated the monitoring staff should assist the engineer in the following manner:

(a) Define the scope of the variation

(b) Produce a draft motivation for the required variation

(c) Define the appropriate specification applicable

(d) Define the existing payment items applicable and where necessary, the need for new items

(e) Discuss the above with the contractor to solicit his agreement to the scope, specifications and applicable pay items. Note that if the contractor is not agreeable to any one of the above, the engineer should be informed and will give guidance on the way forward to reach agreement.

(f) Request new rates from the contractor where required. The contractor should be requested to provide the following:

- substantiation of the new rate by providing a breakdown of its labour, plant, equipment, material, overheads and profit components
- the production rates on which the labour and plant rates are based,
- the re-use and wastage factors for materials to be used.
- the de-escalation calculation
- all of the above for a relevant existing rate in the schedule as a basis for comparison.

(g) Clarify any of the above with the contractor and submit their recommendation to the engineer together with all substantiating information. Note that in order to prevent embarrassment; the monitoring staff should not agree any new rate with the contractor without the prior approval of the engineer who needs to seek approval from the employer before such acceptance of a new rate can be given.

It must be recognised that there is often a tendency for the above process to be dragged out ultimately to the frustration of all concerned. Generally no work is permitted without authorisation of the variation order. Consequently the process should be approached in a diligent manner and time limits (e.g. 7 days) should be placed on response times so that the matter can be concluded speedily.

2.6.4 Method Statements

The authority to request method statements from the contractor is derived from the Conditions of Contract, for example clause 4.1 of FIDIC states that "*The Contractor shall, whenever required by the Engineer, submit details of the arrangements and methods which the Contractor proposes to adopt for the execution of the Works"*. This authority should be delegated to the engineer's representative – refer paragraph 2.4.2

In exercising his authority to call for method statements the engineer's representative should apply sound judgment having regard to the proven expertise and competencies of the contractor. The perception must not be created that the contractor's know-how is in question or that the engineer's representative himself does not actually know how the work is to be done.

The following guidelines and principles should be adhered to:

(a) The focus of a method statement could be any one or a combination of the following:

- the technical procedures to be followed, i.e. method specification,
- to serve as a vehicle for the submission of designs for temporary works (refer also 2.6.5),
- quality when it is dependent on the choice of materials, workmanship and attention to detail,
- programming of activities when time is of the essence,
- resource allocation and planning,
- efficiency of traffic accommodation arrangements,
- safety of workers, general public and traffic, and

TIP
A method statement outlined on a white board and captured in a photo thereof will more than often serve its purpose.

- environmental considerations and risks.

(b) A method statement is for the benefit of all concerned – not just the contractor.

(c) It creates confidence that the work will be done right the first time.

(d) It promotes proper planning of resources required.

(e) It ensures that quality of the end product, which is method dependent, will be attained.

(f) If done jointly, it will incorporate all the best ideas.

(g) Monitoring staff should participate actively by making suggestions and asking what-if questions. They should take care not to assume any responsibility or liability.

(h) The procedure to be followed and the format in which the method statement is required should not create an unnecessary burden or drown the contractor in paper work.

(i) The ideal forum for discussing, agreeing and capturing method statements is at a technical meeting.

(j) Method statements for work which is of a repetitive nature, should be revisited to incorporate lessons learned.

(k) Adherence to an agreed method statement should be strictly enforced.

2.6.5 Temporary Works

Temporary works are generally defined to mean all work required for or in connection with the construction of the permanent works in accordance with the contract. It therefore includes work such as shoring of excavations, falsework (staging or scaffolding) and formwork (shuttering) for concrete elements.

Although it is a requirement of the contract that the contractor shall be solely responsible for the design, safety and adequacy of all temporary works, the engineer's representative nevertheless has a duty of care to ensure that the contractor meets his obligations, not only with regard to the quality and dimensional tolerances of the permanent works, but also with regard to the safety thereof in accordance with the Construction Regulations (refer also paragraph 2.10). It follows that the engineer's representative should ensure that the design, erection and maintenance of the temporary works are being done under the supervision of competent persons in accordance with the contractor's health and safety plan. He should also review the design and inspect the erection and maintenance thereof for obvious omissions and short comings.

Also of importance is the need to ensure that the contractor has been provided with all the information which he will need to do a proper design and which may not be readily available to him, for example, wind loading on super structures and super imposed traffic loading alongside an excavation. The engineer's representative is advised to consult with the engineer on these matters.

2.6.6 Changes to Designs

Major design changes are not likely to emanate from the site monitoring staff, but quite often minor design changes stemming from for example, a peculiar site geometry, constructability considerations, unknown services, or detailing errors on the drawings, may result in a desire to amend a design. Such an amendment, if approved, will be the subject of a variation and, as stated in paragraph 2.6.3 above, it requires the explicit approval of the design office, the employer and the engineer.

The process is normally initiated by the engineer's representative who will compile a motivation (with supporting sketches, photos etc) in the format of what may be referred to as a Field Change Request (FCR). The FCR should then be submitted to the design office via the engineer. If approved it will

result in a variation order issued by the engineer and may also include the issuing of additional or revised drawings.

The above will always apply to all structural concrete elements but not necessarily to non-structural elements. The engineer's representative should apply sound judgement and if in doubt, consult with the engineer.

2.7 COST MANAGEMENT

2.7.1 General

The purpose of cost management is first and foremost:

- to give effect to the relevant clauses in the conditions of contract which governs measurement and payment to the contractor [e.g. FIDIC clauses 12, 13 and 14], and
- to provide realistic information about expected expenditure and future cash flow.

2.7.2 The Schedule of Quantities

The schedule of quantities should ideally be in electronic format, preferably Excel or similar, to allow additional calculations to be performed as work progresses, refer example Appendix 2B.

Ensure that the schedule has been updated with amendments issued under notices to tenderers. It is a good idea to highlight or lightly shade item descriptions or numbers which have been amended by way of a notice to tenderers for the sake of clarity.

Ensure that the schedule adds up to the tender sum.

To reduce the number of printed sheets in a payment certificate, empty lines should be deleted and item description shortened to two or maximum three lines.

2.7.3 Quantities

The accuracy of quantities in the schedule and the completeness of the pay items provided, should be checked at the earliest opportunity so that if required, corrective action can be taken.

The Conditions of Contract may provide for adjustments in the amounts due to the contractor as a result of variations in measured quantities or additional work instructed exceeding certain limits. For example in the case of GCC the general items may qualify for adjustment [GCC clause 50] but in the case of FIDIC any item in the schedule may qualify for a new payment rate should certain criteria be met [FIDIC clause 12.3(a)]. Monitoring staff will do well to identify those items with the potential to qualify for a rerating and to monitor them carefully with the view of limiting quantity variations where possible or where variations cannot be prevented, to gather records which will assist with the determination of a new rate.

The estimated final quantities should be updated monthly, but in any event as soon as new information which will affect final quantities or sums becomes available. This is especially relevant in the case of provisional and PC sums and items with an element of risk which may contain a certain amount of 'fat'. In the case of items with an element of risk the estimated quantities should be adjusted gradually as the risk or uncertainty diminishes. The intent is to report gradual changes in the expected final contract expenditure. Sudden and large changes in expected expenditure either up or down are highly undesirable and may reflect negatively on the engineer's representative – refer also paragraph 2.3.8.

2.7.4 Measurement

The measurement of the works is governed by a relevant clause of the conditions of contract [in the case of FIDIC it is clauses 12.1 and 12.2].

It is important to note that the responsibility for measuring the work lies with the engineer (monitoring staff) and not with the contractor. The contractor has a duty to assist the engineer when measurement is to be done and to provide such particulars as may be required [FIDIC clause 12.1].

It follows that for work which can not readily be measured from the drawings, the monitoring staff should be proactive and measure when it is appropriate to do so and not leave it until the end of the month at which time the work may already have been covered up. Typical examples would be the depth of foundation excavations, the volume of concrete in a foundation plinth, and the like.

Although the electronic age presents many opportunities for measurements to be done using computer technology, the recording and record keeping of measurements remain very much a manual operation with hard copy evidence. The following procedure should be followed:

(a) For every pay item a separate sheet should be prepared on which is recorded the quantity measured for the month and a running total. Refer example in Appendix 2D.

(b) The calculations to substantiate the total measured to date should be filed with every pay item sheet.

(c) The contractor should be given the opportunity to examine the calculations and if he agrees with it, the quantities should be signed off as final.

(d) If the contractor disagrees with the quantities measured, the matter should be referred to the engineer who will either confirm or vary them.

(e) Completion of an interim certificate should not be delayed on account of a disagreement, but a conservative interim quantity should be agreed pending the engineer's decision.

2.7.5 Budgets and Cash Flow

The employer is dependent on reliable actual and expected expenditure reporting in order to manage its budget and cash flow effectively. Providing such reliable information is thus an important responsibility of the engineer's representative.

BEWARE
Contractors are notoriously optimistic about anticipated progress and are more likely to overestimate than underestimate cash flow.

The cash flow for the estimated outstanding expenditure is dependent on the contractor's program and is therefore usually determined by him. The engineer's representative should exercise caution when presented with these figures, because apart from the warning in the box alongside, payment is not due when the work has been done, but when it has been accepted. Matters such as non-conformances, waiting periods for test results, and measurement and payment disagreements, may cause actual cash flow to lag that of the program by a month or more. In addition, variation orders, claims and volatility in contract price adjustment and special material prices needs to be taken into consideration. This is especially important towards the end of the financial year when the employer is dependent on reliable information for balancing current year expenditure.

The cash flow graph (Fig 2.1) for the full extent of a contract in theory follows an S-shape and is a useful point of departure. The formulas are as follows:

$$C_{Ux} = C \times \left(Sin\left(\frac{M_x}{M} \times 2.215 - 0.751 \right) \times 0.596 + 0.407 \right)$$

$$C_{Lx} = C \times \left(Sin\left(\frac{M_x}{M} \times 1.288 - 1.402 \right) \times 1.147 + 1.131 \right)$$

Where: C = Contract value
M = Contract period (in months)
Mx = Month x
CUx = Upper value in month x
CLx = Lower value in month x
Note: Calculation of angle to be done in radians

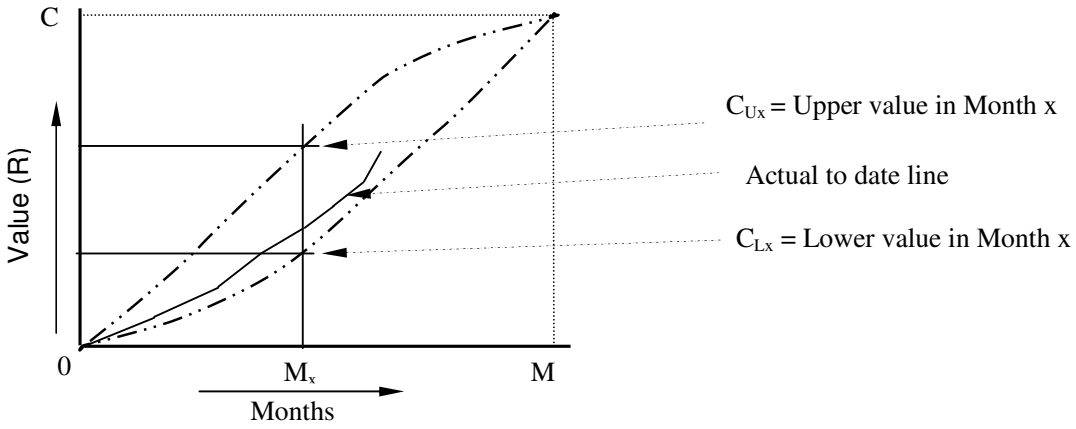


Figure 2.1: Cash flow graph

Contract price adjustment can contribute significantly to the predicted cash flow and the eventual contract amount, especially in periods of high or rising inflation. Since its value is based on uncertain future events which are beyond the control of all concerned, it is very difficult to predict with any measure of certainty. Nevertheless, the engineer's representative should make use of the best available information to estimate future contract price adjustments. The following is suggested:

- Keep a running record of historic (say last two years) contract price adjustment factors
- Using the statistical functions of Excel (e.g. TREND) to determine a trend line for the recent past performance of the CPA factor.

TIP
Historic price adjustment data can be obtained from SAFCEC (www.safcec.org.za) or SA Statistics (www.statssa.gov.za).

- Apply best judgment regarding the future trend (some insight in macro economic policy is useful)

Note that no two persons will arrive at the same answer but in order to justify significant deviations in predicted cash flow from actual cash flow stemming solely or partly from contract price adjustment, the engineer's representative must be able to show that he has applied his mind to the problem. Refer to Appendix 2E for an example with further explanatory notes.

Variations and claims will also have a significant impact on the final contract amount and provision for these needs to be made as soon as reasonable certainty exists that a variation will be required or a claim may be successful.

2.7.6 Reporting

The manner in which expenditure to date and future cash flows are to be reported is prescribed by the employer and entails the use of a set of standard forms for payment certificates, appendices to minutes of site meetings and the like. Details in this regard are not included in this manual.

2.8 TIME MANAGEMENT

2.8.1 General

Contract time management includes the processes required to ensure timely completion of the project. The time allowed for completion is stipulated in the contract and failure by the contractor to complete in time will result in the stipulated penalties being levied.

The development and maintenance of a contract time schedule, commonly referred to as 'the program', is an essential part of time management and monitoring staff should familiarize themselves with the processes and various tools and techniques which can be used.

2.8.2 Contract Time Schedule

The major processes in developing the contract time schedule are:

- Activity definition – identifying the specific activities that must be performed to execute the work, also referred to as a work breakdown structure.
- Activity sequencing – identifying the interactivity dependencies.
- Activity duration estimating – estimating the number of work periods (normally working days) that will be needed to complete individual activities.
- Schedule control – controlling changes to the contract schedule.

The development of the contract time schedule (contract programme) is the responsibility of the contractor (refer e.g. FIDIC clause 8.3). Depending on the complexity of the project the above processes can become very involved but most contractors follow a relatively simplistic approach.

The monitoring staff should refer to other literature for a detailed description of the theory of programme scheduling. For the purposes of the manual the following brief summary is given:

(a) Activity definition involves identifying and documenting the specific activities that must be performed to produce the deliverables identified in the work breakdown structure and will include constraints that limit the contractor's options.

(b) Activity sequencing involves identifying and documenting logical interactivity relationships. Activities must be sequenced accurately to support later development of a realistic and achievable schedule.

The sequences of activities are determined by dependencies which could be:

- Mandatory – those that are inherent in the nature of the work, e.g. it is impossible to erect the superstructure until after the foundations have been built, or
- Discretionary – those that involve a choice and may e.g. be dependent on the traffic accommodation strategy or the employer's preference as stipulated in the project specifications.

A typical tool and technique for activity sequencing is the precedence diagramming method (PDM). This is a method of constructing a project network diagram that uses boxes to represent the activities and connects them with arrows that show the dependencies as shown in Fig. 2.2.

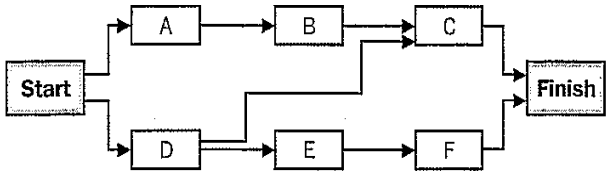


Figure 2.2:

(c) Activity duration estimating is the process of taking information on project scope and resources and then developing durations for input to schedules. It can be made a complicated exercise but is generally determined from the available resources (e.g. number of carpenter teams) and historic records of production achieved on previous projects for similar work.

(d) Schedule development means the determination of start and finish dates for project activities. This can be done manually but is best done using suitable computer software e.g. Microsoft Project.

The output of the schedule is usually in the form of a bar chart, also called a *Gantt chart*, as shown in Fig. 2.3.

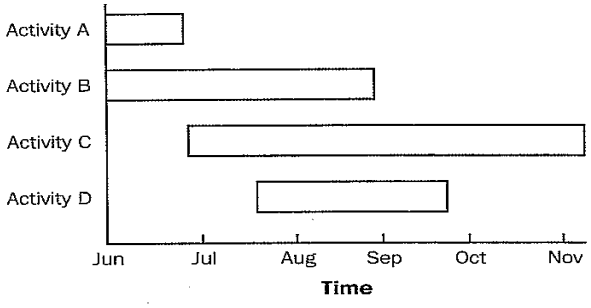


Figure 2.3: Example of a Gantt chart

There are many acceptable ways to display project information on a bar chart depending on the intended purpose. Computer software such as Microsoft Project is very powerful in the hands of a knowledgeable and experienced user.

For smaller and short term duration projects a computer programme such as Excel can also be used, but it has serious limitations when programme amendments and updating becomes necessary.

2.8.3 Approving or Verifying the Programme

It should be noted that some conditions of contract (e.g. GCC) requires the engineer to approve the programme while others, such as FIDIC, merely require the engineer to verify that it complies with the contract.

Monitoring staff should consider the following when presented with the programme:

(a) Presentation of programme

- Should be in electronic format with hard copy
- Provide details of hours per day and days per week on which programme is based.
- Provide details of production rates and resources used for major activities.
- Provide details of constraints such as activities with 'Start No Earlier Than' or 'Finish No Later Than' dates or activities which can only be done at night or on weekends for example
- The critical path should be clearly identified.

(b) Completeness of activity list

Compare the programme activities with the work breakdown structure compiled as described under paragraph 2.6.2. Minor items are often overlooked and these 'forgotten' items of work can be time consuming and pose a restraint on completion especially towards the end of the project when the contractor may be pressed for time.

(c) Logic of programme

The logic of the activity sequence should be thoroughly checked. Pay special attention to:

- Illogical links.
- Overlap (lag) of concurrent activities.
- Time allowed for mix design approval.
- Time allowed for critical information.
- Time allowed for curing and strength development of concrete.

TIP
The network diagram view in Microsoft Project is very useful for checking the logic of the program.

- Allowance for float – the ownership of float is always a debatable issue and the contractor is best advised not to show any initial float, especially on his critical path.
- Time allowed for inclement weather under the contract. Contractors have different ways of accounting for these in their programmes. The most appropriate method is to include additional time in the durations of the more weather sensitive activities on the critical path.

2.8.4 Updating

The original approved programme is only valid for as long as all goes according to plan, which is seldom the case. Consequently the programme needs to be updated with actual start and completion dates as the work progresses. This may have the effect that the anticipated completion date and/or critical path will change. Updating a programme manually is a laborious task which will eventually be neglected, hence the insistence that the contractor should use a purpose made computer program such as Microsoft Project.

Although the programme and its maintenance is fundamentally the responsibility of the contractor, it is good practice for the monitoring staff to run a duplicate programme for the sake of comparison and control.

Reviewing of the programme should be done at least monthly and the programme should be updated whenever a delay event occurs (refer paragraph 2.8.5 below).

If for whatever reason, the logic or sequence of activities becomes outdated and the programme no longer represents reality, the contractor may request or the engineer's representative may instruct that the programme be revised to reflect the fundamental changes. It is important to note that the programme should be updated to the agreed date of the change to establish a base date for the revised programme. It follows that the revised programme should only consider outstanding items of work.

2.8.5 Delays and Float

Delay events may be attributed to a cause brought about by the contractor himself e.g. a plant breakdown (non-excusable delay or contractor's delay) or the employer e.g. late information (excusable delay, employer's delay, relevant event or compensation event) or by circumstances beyond the control of both parties e.g. weather, war, etc (may be excusable depending on the terms of the contract).

The meaning of the word 'delay' is not always clearly defined and what may be a delay in terms of one form of contract may not be in another. It is generally accepted that a 'delay to completion' can be defined as a delay which causes the works to continue beyond the contractual completion date, or contractually extended completion date. The essential cause of the delay is a delay or extension of the duration of one or more critical activities.

A non-excusable delay (i.e. a delay event within the control of the contractor) is a contractor's risk for which he has to make provision in the duration of activities. This provision of time for possible delays is commonly called 'float' in the programme. It is common practice to 'hide' the available float in the original programme i.e. the end date of the last activity is equal to the contract completion date. As the work progresses and assuming that the work is completed in a shorter time than planned, the updated programme will show an earlier expected completion date and thus 'contract float' will develop between this date and the contractual completion date.

Non-excusable delays which may cause the projected completion date to exceed the contractual completion date, do not entitle the contractor to any claim for extension of time and he has to accelerate at own cost to make up the lost time.

Excusable delays on the other hand may entitle the contractor to an extension of time depending on inter alia the availability of 'contract float' and the never ending arguments regarding ownership thereof. A discussion of the circumstances which will entitle the contractor to an extension of time and the quantification thereof is beyond the scope of this manual. **What is however very important, is the fact that the assessment of delay claims has become very dependent on the proper management and updating of the construction programme.**

The monitoring staff must therefore ensure that:

- The current programme is relevant and is regularly updated.
- As soon as an excusable delay event occurs the programme should be updated up to the day of the start of the event and a copy thereof saved for future reference.
- Similarly, when the delay event is over a copy of the updated programme should be saved.
- The monitoring staff may not always realise that an excusable delay event has occurred and the value of comprehensive site diaries (refer paragraph 2.12.2) will prove their worth when programmes have to be updated retrospectively to a date somewhere in the past.

2.8.6 Reporting

The contractor will be required to report on progress and programme at each site meeting. The format and content of these reports is dependent on the needs of the employer and engineer and guidance is to be obtained from them in this regard.

For proper day to day planning the monitoring staff have different needs and the engineer's representative is advised to insist on the following:

- A revised programme submitted weekly and representing a 2-week window of the main programme and refined to show the planned daily activities.
- A revised programme submitted monthly showing milestone events (information required, method statements to be submitted, etc) for the next two months.

2.9 QUALITY MANAGEMENT

2.9.1 General

Quality management includes the processes required to ensure that the project will satisfy the needs for which it was intended (fit for purpose). It includes all activities that determine the quality policy, objectives and responsibilities and implements them by means such as quality planning, quality assurance, quality control and quality improvement.

In the subsequent chapters the quality aspects of the various project components are dealt with in detail. In this chapter the processes and principles applicable are therefore only described in overview. The monitoring staff should note that these principles apply as much to their own activities as it would apply to that of the contractor.

2.9.2 Quality Plan

At site level the quality plan is in essence a framework of all deliverables and identifies which quality standards are relevant and determines how to satisfy them. There are various approaches that can be followed but a good starting point would be the schedule of quantities. In order to qualify for payment under any item the contractor must meet certain requirements. A spreadsheet can therefore be produced showing the following:

(a) A list of all payment items with short description

(b) Reference to the applicable project specification clause, drawing, standard specification and other sources of knowledge (manuals) etc.

(c) The scope of the deliverable – what is included and what is excluded

(d) Method of evaluation – visual inspection, laboratory test, measurement with instruments, documentation or records to be produced, etc

(e) Frequency and time of assessment - e.g. for reinforcement at start of steel fixing and again 3 hours before casting of concrete.

(f) Number of tests or samples required - e.g. number of cubes

(g) Party or person responsible - distinguish between process and acceptance control.

(h) Method of communicating request for assessment – e.g. site note, request-for-approval book

(i) Method of and responsibility for reporting and record keeping

(j) Procedure for communicating (non)-approval and findings

The aforesaid implies that the engineer's representative should have at his disposal not only the applicable standard specifications (e.g. COLTO), but also relevant SANS specifications, TMH manuals etc.

The quality plan should be workshopped with the contractor to obtain his input (especially on process control) and buy-in on the procedures to be adhered to. The intent must be to ensure a clear understanding by all concerned of what is required so as to eliminate misunderstandings and surprises.

2.9.3 Quality Assurance

Quality assurance is all the planned and systematic activities implemented within the quality system to provide confidence that the project will satisfy the relevant quality standards and should be performed throughout the duration of the contract.

Typically the quality assurance activities will include:

- Visual inspections preferably with reference to a check list
- Collection of samples and conduction of tests and measurements both on site and in the laboratory.
- Produce and agree content of method statements
- Check and verify correctness and completeness of construction information and details for both temporary and permanent works
- Audits on procedures and testing methods

TIP
To keep track of each element of work, it should be given a unique number starting with the entry number in the Request for Approval book.

The extent and detail of quality assurance procedures required is dependent on the nature, size and complexity of a project. Typically and with reference to the quality plan as described above, procedures for the following actions should be implemented:

- Identification of all elements of work subject to quality evaluation – (schedule and work breakdown structure).
- Identification of applicable quality standard required – (project specifications)
- Identification of method of evaluation – (visual, laboratory tests etc)
- Identification of tools and equipment required for the methods of evaluation – (checklists, forms, computer programmes, laboratory equipment etc)

- Initiation of approval process and paper trail of progress – ('request for approval' book, to evaluation results, to payment, and to as-built information)
- Recording of work approved and control to ensure all work is covered – (diagrams or bar graphs with colouring, dates and unique element number).

2.9.4 Quality Control

Quality control involves monitoring specific project results to determine if they comply with relevant quality standards, and identifying ways to eliminate causes of unsatisfactory results. Project results include both *product* results, the works of the contractor, and *contract administration* results, such as cost (cash flow) and time-schedule performance.

Put in another way, quality control is about maintaining the required quality standard and taking corrective action whenever a deviation becomes evident. Useful tools in this regard would be graphs of the moving average and trend lines of results obtained.

The monitoring staff should have a working knowledge of statistical quality control, especially sampling and probability, to help evaluate quality control outputs. Among other subjects, the team may find it useful to know the difference between:

- Prevention (keeping errors out of the process) and inspection (keeping errors out of the end product)
- Attribute sampling (the result conforms, or it does not) and variables sampling (the result is rated on a continuous scale that measures the degree of conformity – the partial payment case)
- Special causes (unusual events) and random causes (normal process variations)
- Tolerances (the result is acceptable if it falls within the range specified by the tolerance) and control limits (the process is in control if the result falls within the control limits)

The monitoring staff must be careful not to confuse *quality* with *grade.* Grade is a category or rank given to entities having the same functional use but different technical characteristics. Low quality is always a problem; low grade may not be. For example, a formed concrete surface may be of high quality (hard durable and sound concrete surface) and low grade (as-stripped surface finish), or of low quality (powdery, blow holes or honeycombing) and high grade (high quality formwork panels for intended class F3 finish).

2.9.5 Laboratory

Access to a suitably equipped and accredited laboratory is essential and unless a commercial laboratory which meets the set standards, are available nearby, it is standard practice to establish a laboratory on site. The staffing and equipment is always subject to the approval of the employer.

The standard specifications (e.g. COLTO) makes a distinction between process control testing and acceptance control testing. The former refers to those quality control procedures which the contractor should exercise in order to satisfy himself and the engineer that the work being done meet or will meet the requirements of the specifications, whilst the latter refers to the testing done by the engineer on completion of the work to verify the acceptability of the work in accordance with the required standards specified. Process control and acceptance control therefore often implies duplication of the same test for example, the making of concrete cubes. Consequently it has become common practice for the engineer and contractor to have a combined laboratory under the control of the engineer, which will conduct both the process and acceptance control testing without duplication of results. As part of his process control responsibility the contractor is required to make a contribution towards the

establishment and running of the laboratory. The monetary value of the contribution and the ways in which it can be made, will be specified in the project document.

2.9.6 Non-conformance

A non-conformance should be formally registered using the appropriate form when work does not meet the required standard. However, monitoring staff should be aware that many contractors will rectify their mistakes without being prompted and dislike non-conformance reports which have been issued in an over eagerly manner. Normal practice is to issue such a report only when the contractor has submitted a request for approval and the work still does not meet the requirement, or in cases where the required corrective action is non-standard (e.g. epoxy repair) or may require a concession, reduced payment, or additional or varied work.

A non-conformance which cannot be corrected to its original intended standard, must be reported to the employer before a decision is taken on corrective action. Substandard work which is to remain in place must be authorised by the employer.

2.10 HEALTH AND SAFETY

2.10.1 General

Health and safety on site is governed by the Occupational Health and Safety Act No 85 of 1993 and the regulations made in terms of this act, the most notable of which is the Construction Regulations, 2003.

There are a number of other regulations which may also be relevant to the project regarding matters such as environment for workplaces, explosives, general safety, general administration, hazardous chemicals, noise, electrical machinery etc.

The act and associated regulations in essence are intended to focus on minimising the incidence of accidents and exposure to hazards in the workplace. Its focus therefore should be about preservation of life and not on the negative consequences of accidents in the workplace, the root cause of which is poor management.

In overview the Construction Regulations ensure that:

- Hazards or potential hazards to a healthy working environment are identified.
- These hazards are removed or reduced.
- Employees are trained to work safely in potential hazardous conditions

TIP

The engineer's representative should insist on a proper health & safety report to be tabled at each site meeting which demonstrates pro-active rather than re-active actions taken.

2.10.2 Responsibilities

The Construction Regulations ensure that not only the contractor but also the employer has a responsibility to provide a safe and healthy working environment for all employees. The Regulations also place a responsibility on the designer, irrespective of his involvement in the construction phase of the project, to ensure the safety of his design.

As the appointed agent of the employer, the engineer and by implication the monitoring staff, must ensure that the employer's responsibilities in terms of clause 4 of the Regulations are complied with. This responsibility commences at the design stage with the preparation of a health and safety specification. Once construction commences, the engineer's representative will, depending on his delegated authority, have the responsibility to:

- Ensure that the contractor is supplied with the necessary information to compile his health and safety plan.
- Recommend approval of and ensure that the contractor's health and safety plan is implemented and maintained.
- Recommend that the contractor be stopped from executing work which is not in accordance with the approved health and safety plan or poses a threat to the health and safety of persons.
- Manage changes to the health and safety plan of the contractor.
- Ensure that the contractor exercises a similar duty and responsibility towards his appointed sub-contractors.

In order to perform their duties to the required professional standard the monitoring staff should have a working knowledge of the Act and in particular the Construction Regulations. The employer may choose to appoint or permit the engineer to appoint an independent safety consultant to conduct periodic audits as a check on the regular audits conducted on site. The services of such a consultant will greatly ease the burden on the engineer's representative especially with regard to the many administrative requirements of the Regulations.

2.10.3 Health and Safety Plan

The contractor's health and safety plan should be based on the following principles:

- A proper risk assessment of the construction work.
- Pro-active identification of potential hazards and unsafe working conditions.
- Informing and/or training of employees in hazards and risk areas.
- Provision of a safe working environment and safety equipment.
- Ensuring the safety of his sub-contractors through their safety plans.
- Monitoring the health and safety on the construction works on a regular basis.
- Use of competent safety officers.

Monitoring staff should take note of the following:

(a) Most contractors will have a generic health and safety plan which will be amended to suite the current contract. This cut and paste exercise, if not done properly, results in 'nonsense' being included in the plan.

(b) The most important part of the plan is the project specific risk assessments. These must be properly done and should describe in sufficient detail:

- the nature of the risk identified and its potential consequences
- the possible alternatives available to mitigate the risk
- the procedures and measures decided upon

- the details of how these procedures and measures will be implemented - the way in which employees are to be informed, instructed, trained, and equipped.
- the control procedures to be put in place to enforce adherence.

(c) The health and safety plan must cover all the temporary works of the contractor.

(d) It is not possible to eliminate all risks but it must be shown that the contractor has applied his mind to the problem and has made a conscious decision as to how best to mitigate the risk.

(e) Risks not previously contemplated will be identified from time to time and these need to be dealt with as stated above in a speedy manner and incorporated in the health and safety plan.

(f) The health and safety plan may turn out to be nothing more than lip service because old habits tend to prevail. Health and safety consciousness requires a change in culture which must be driven by management in a disciplined manner. The engineer's representative should not hesitate to use the powers at his disposal (penalty clauses) to encourage such discipline.

(g) The weak link in the management chain is often the appointed 'competent employee' who must supervise the safety aspects of a particular aspect of the works. These persons often lack the necessary competence. The same may apply to the 'safety officer' who may be appointed on bigger projects.

(h) To be effective the health and safety plan must be managed in a pro-active manner. The engineer's representative should not allow the contractor to become merely reliant on prompts from the monitoring staff and audit reports before action is taken to rectify unsafe situations.

2.11 ENVIRONMENTAL MANAGEMENT PLAN

2.11.1 General

The purpose of the environmental management plan is to ensure that impacts associated with the construction phase of the project are kept to a minimum. In this regard, the environmental management plan sets environmental targets for the contractor and any nominated or selected sub-contractors, and reasonable standards against which the contractor's performance can be measured during construction.

The environmental management plan is an output of the environmental impact assessment process and will have been approved by the relevant national of provincial department (as applicable to the employer) responsible for environmental affairs acting in accordance with the National Environmental Management Act, 107 of 1998 (NEMA). Such approval is currently called the 'Environmental Authorisation'. Previously it was called the 'Record of Decision'. On certain contracts an environmental authorisation may not be required and the employer's generic environmental authorisation will then apply.

Other authorities who may also be involved are amongst others:

Department of Water Affairs: who may have to issue a Water Licence for activities such as:

- Impeding or diverting the flow of water in a watercourse; and
- Altering the bed, banks, course or characteristics of a watercourse

Provincial Heritage Authority: with regard to for example:

- alteration or demolition of any structure or part of a structure which is older than 60 years
- archaeological materials or objects
- any grave or burial ground older than 60 years

Department of Mineral Resources: with regard to borrow pits and rock quarries
Department of Agriculture: with regard to the use of agricultural land.

Any requirement from such other authorities will have been incorporated into or attached to the environmental management plan.

The environmental management plan is part of the contract documents and is thus a binding agreement between the contractor and the employer.

2.11.2 Responsibilities

2.11.2.1 Employer

The employer is ultimately responsible for the implementation of the environmental management plan and the financial cost of all environmental control measures. The employer must ensure that any person acting on their behalf complies with the conditions/specifications contained in the environmental management plan.

2.11.2.2 Engineer

The engineer as the appointed agent of the employer must assume the responsibility to act on behalf of the employer on all environmental matters and should address any site problems pertaining to the environment at the request of the engineer's representative and/or the environmental control officer.

2.11.2.3 Contractor

The Contractor shall have the following responsibilities:

(a) To implement all provisions of the environmental management plan. If the contractor encounters difficulties with specifications, he must discuss alternative approaches with the engineer's representative and/or the environmental control officer prior to proceeding.

(b) To ensure that all staff are familiar with the environmental management plan.

(c) To monitor and verify that the environmental impacts are kept to a minimum.

(d) To make personnel aware of environmental problems and ensure they show adequate consideration of the environmental aspects of the project.

(e) To prepare the required method statements.

(f) To report any incidents of non-compliance with the environmental management plan to the engineer's representative and the environmental control officer.

(g) To rehabilitate any sensitive environments damaged due to the contractor's negligence. This shall be done in accordance with the engineer's representative's and environmental control officer's specifications.

(h) On certain contracts the contractor is obliged to appoint a designated environmental officer who must assume responsibility for the obligations specified in the environmental management plan.

Failure to comply with the environmental management plan may result in fines and reported non-compliance may result in the suspension of work by the engineer.

2.11.2.4 Engineer's Representative

The engineer's representative should have delegated authority to act as the employer's on-site implementing agent and has the responsibility to ensure that their responsibilities are executed in compliance with the environmental management plan. Any on-site decisions regarding environmental management are ultimately the responsibility of the engineer's representative. The engineer's representative shall assist the environmental control officer where necessary and shall have the following responsibilities in terms of the implementation of the environmental management plan:

(a) Reviewing and approving the contractor's method statements with input from the environmental control officer where necessary.

(b) Monitoring and verifying that the environmental management plan and method statements are adhered to at all times and taking action if specifications are not followed.

(c) Keeping a photographic record of construction activities on site.

(d) Assisting the contractor in finding environmentally responsible solutions to problems with input from the environmental control officer where necessary.

(e) Ordering the removal of person(s) and/or equipment not complying with the environmental management plan specifications.

(f) Issuing fines for transgressions of site rules and penalties for contravention of the environmental management plan.

(g) Delaying any construction activity if he/she believes the integrity of the environment has been or is likely to be seriously jeopardised.

(h) Providing input into the environmental control officer's ongoing internal review of the environmental management plan.

(i) The engineer's representative shall communicate environmental issues to the environmental control officer.

2.11.2.5 Environmental Control Officer

The environmental control officer is usually a professional environmental consultant who was involved in the environmental impact assessment process and the drafting of the environmental management plan. His/her duties shall include, *inter alia*, the following (refer also to the environmental specifications in the document):

(a) Ensuring the necessary environmental authorisations and permits, if any, have been obtained.

(b) Advising the contractor and/or the engineer's representative on environmental issues within defined construction areas.

(c) Reviewing method statements.

(d) Undertaking regular site visits to ensure compliance with the environmental management plan and verifying that environmental impacts are kept to a minimum throughout the contract.

(e) Completing environmental checklists during site visits.

(f) Keeping a photographic record of progress on site from an environmental perspective.

(g) Assisting the contractor and/or the engineer's representative in finding environmentally acceptable solutions to construction problems.

(h) Recommending additional environmental protection measures should this be necessary.

(i) Keeping a register of complaints and recording and dealing with any community issues or comments.

(j) Giving a report back on the environmental issues at site meetings.

(k) Ensuring that the environmental affairs authority is informed of work progress on site.

(l) Reporting any incidents that may have caused damage to the environment or breaches of the environmental management plan to the environmental affairs authority.

(m) Preparing an environmental audit report at the conclusion of the construction phase.

The environmental control officer shall communicate directly with the engineer's representative. Should problems arise on site that cannot be resolved between the environmental control officer and the engineer's representative, the environmental control officer shall take the matter up with the engineer and/or the employer. If the employer does not respond the environmental control officer shall take the matter up with the environmental affairs authority.

2.12 GENERAL SITE ADMINISTRATION

2.12.1 Wayleaves

Generally a wayleave agreement is the formal written consent between two parties giving rights to install, inspect, maintain, alter or repair equipment or apparatus located alongside, across, over or under private or public land, which in this case would be the road reserve. Typical examples would be services such as power and telecommunication lines or cables, and water and sewage pipes.

A wayleave becomes relevant when an existing service is likely to be affected by the contract works.

The rights and obligations of the service owners are contained in the wayleave agreement but may also be subject to rights protected in accordance with current legislation. Consequently the obligations of the relevant parties and their respective responsibilities and contribution towards any costs, can be a complicated matter which should be resolved at the design stage. The engineer's representative can expect to be given full details of how each service is to be dealt with and should ensure that copies of all of the wayleaves are obtained from the employer. **No payments** should be made to service authorities without the approval of the employer.

In the event of a hitherto unknown services being found located within the road reserve and for which no wayleave can be produced by the service owner, the engineer's representative must advice the service owner to immediately apply for a wayleave and the employer must be notified and supplied with all the details.

2.12.1.1 Private Service Owners

In the case of services belonging to adjacent landowners the respective owners are normally required to protect or relocate their service at own cost in part or in full depending on the project specifications. The monitoring staff should ensure that the contractor:

- Gives early notice of his intentions
- Provides the service owner with reasonable assistance
- Does not cause interruption of the service without approval of the service owner.

2.12.1.2 Statutory Service Authorities

In the case of statutory service authorities the contractor may be required to apply for a 'wayleave' from these authorities in which would be stipulated matters such as:

(a) Where work is to be done by the service owner himself;

- the relevant time frame required.
- payment arrangements

(b) Where work is to be done by the contractor;

- the applicable specifications and arrangement for supervision by the service owner
- limitations with regard to type of equipment permissible over or below the service
- clearance limitations with regard to sensitive underground cables (vibrations) and high voltage overhead cables
- deposits' payable.

The duty of the monitoring staff is to ensure compliance with all of these stipulations.

2.12.2 Diaries

Diaries on a construction site are in essence a record of daily events and the importance of keeping complete and truthful diaries cannot be over emphasised.

The extent to which records of events are compiled will depend on the size and complexity of a contract, but whenever possible the following types of diaries (in order of importance) should be kept:

2.12.2.1 Contract Diary

This is an official daily record of events which are normally recorded on standard forms by the contractor. It should reflect at least the following information:

- For each major activity a brief description of work done with the plant and labour resources involved
- Major plant not available on the day
- Major materials received
- The weather conditions in the morning and afternoon
- Delays and frustrations experienced
- Written instructions received
- Accidents and incidents.

The contract diary should be completed daily and signed by both the site agent and the engineer's representative as a true record. Separate copies should be kept by the contractor, the engineer's representative and the engineer.

2.12.2.2 Progress Diary

This is a diary jointly compiled by the monitoring staff of actual progress with emphasis on:

- the starting date of activities,
- percentage progress or production achieved,
- delays or disruption experienced, and
- the completion date of activities.

The main purpose of this diary is to:

- periodically update the contract programme with actual progress to date
- determine the impact of delays on the critical path activities
- determine normal versus disrupted production rates
- reconstruct the sequence of past events should such a need arise
- evaluate delay and disruption claims.

An Excel spreadsheet is a useful tool for the purpose of this diary due to its flexibility and ease of distribution to other parties.

2.12.2.3 Engineer's Representative's Diary

This is a hand written diary kept by the engineer's representative in which the major events of the day are briefly recorded. A bound hard cover A4 book should be used for this purpose. The entries in the book should be continues with no gaps. At the end of the day a line is drawn across the page and the entries for the next day follows immediately thereafter.

The condensed way in which this diary should be kept renders it 'tamper proof' and consequently in a court of law it will carry more weight as a source of reliable evidence. As such it also provides reliable support for other forms of diaries which may be more susceptible to manipulation.

2.12.2.4 Personal Diaries

Each member of the monitoring staff should also keep a personal and private diary. A standard commercial diary book is suitable for this purpose. Apart from the normal entries such as appointments, it should also be used to record more private thoughts such as:

- Critical observations made
- Comment on inter personal relations
- Good ideas to be implemented
- Successes and failures – lessons learned.

Whilst the purpose of this diary is primarily for the benefit of the individual concerned, the issues that may develop on a site are often not only about the cold facts but are influenced by human nature and the personalities involved and hence the observations recorded over time may help to complete the picture and assist with a better understanding of the problem.

2.12.3 Photographs

Photographic records have become an essential part of the site records due to benefits such as low cost, speed, ease with which the information it portrays can be communicated, and flexibility with regard to filing and storage, to name only a few.

TIP
A short PowerPoint photo presentation of key events during the preceding month makes for an interesting progress report at site meetings.

In the case of an accident involving a 3rd party e.g. a traffic accident, it is recommended that the monitoring staff:

- Take a series of photos from various angles which records the road condition and all signs and road markings existing at the time.
- Ensure that the photos adequately cover the general surroundings.
- Ensure that the photos are date and time stamped.
- Submit a set to the employer as soon as possible for safe keeping and as proof of the originality thereof.

2.12.4 Written Communications

2.12.4.1 Site Correspondence Book

The traditional site correspondence book consists of a triplicate pen carbon book with a line drawn down the middle of the page – the contractor uses the one half and the engineer's representative the other half. The purpose of the book is to record in writing all interaction of a contractual nature between the site agent and the engineer's representative, be it information, a request, a reply, a proposal, a notification etc.

All entries by one party should be acknowledged by the other party.

IMPORTANT
The phrase '***as soon as possible'*** should never be used in any written communication. A party to a contract cannot be held liable for delays if no time was fixed for performance.

2.12.4.2 Site Instructions

The authority to issue an instruction is to be found in the Conditions of Contract and the authority of the engineer's representative in this regard is dependent on the extent to which the engineer's authority has been delegated to him (refer paragraph 2.4.2).

Per definition an instruction will have a clause in the Conditions of Contract as its basis and therefore all instructions will have contractual implications one way or another. The engineer's representative must be very careful not to unintentionally write something in the site correspondence book which can be interpreted as an instruction, the consequences of which may only come to light at a later stage.

Consequently it is good practice to separate instructions from other correspondence and the use of a dedicated, more formal, instruction book is recommended. A proper instruction should consist of the following:

- Short title
- Reference to the clause in the Conditions of Contract from which the instruction derives its authority
- Body text of the instruction setting out clearly the circumstances, specifications, drawings etc which may be applicable

- The applicable payment items if any, or method of valuation if applicable. It is important that an instruction should not be silent regarding payment and if the engineer's representative believes that no payment will be due he should clearly state so
- Due date for performance.

The instruction when it is delivered to the contractor, should be signed and dated by him. The contractor may not agree with the view of the engineer's representative on payment but by having acknowledged the engineer's representative's view on the matter he is obliged to react within a reasonable time in accordance with the provisions of the Conditions of Contract. In this manner payment issues can be resolved more speedily and without surprises.

2.12.4.3 E-mail

Communication by way of electronic media has become common place and will also have its use on site. Its advantages are numerous such as speed, disregard for office hours and location, and ability to be copied to any number of recipients, to name a few.

TIP
Keep an electronic index with key words of all correspondence. It makes it easier to trace the history of a subject

It also has some disadvantages the most important of which is that the time (and date) of delivery of the message and proof of receipt is beyond the control of the sender. For urgent matters there is thus no substitute for a hard copy written instruction placed directly into the hands of the site agent.

The recommended practice is that a paper copy of all e-mail messages to the contractor should be attached to an entry in the site correspondence or site instruction book and filed in the normal manner.

2.12.5 Meetings and Minutes

The primary purpose of meetings, be they formal or informal, is to exchange information and ideas and to make decisions. These discussions and decisions should be recorded to become part of the site records.

TIP
A voice recording of meetings is a valuable record of what was actually said. It also has a calming effect on speakers!

Formal meetings should be minuted and for some a standard agenda and format for the minutes are usually prescribed by the employer.

Informal meetings will normally not be minuted and the monitoring staff should make notes of these, usually in their personal diary.

2.12.6 Claims and Risk Management

A discussion of claims is beyond the scope of this manual. All contracts include a certain amount of risk and understanding the risks to which each party is exposed, will go a long way towards minimizing the extent of claims. Monitoring staff do not like claims because they may originate as a result of errors or omissions on the part of the consultant, the employer or contractor. However, the engineer and for that matter, the monitoring staff, have a duty to administer the contract within the terms thereof in a fair and unbiased manner. Their integrity in this regard should never be in doubt.

The main responsibility of the monitoring staff is to advise the engineer about the facts and circumstances relating to a claim as completely and truthfully as is possible. The quality of site records as discussed above, will largely dictate success in this regard.

2.12.7 Materials on Site

The contract normally provides for the contractor to receive payment for materials produced or delivered to the site for incorporation in the permanent works provided that certain conditions are met. The most fundamental conditions are:

- Satisfactory evidence of ownership. This can be problematic since contractors often have credit facilities with suppliers allowing them to delay payment. A letter of cession may be offered by the supplier but some consider this to be not worth the paper it is written on. Depending on the specific terms of the contract an indemnity in a form acceptable to the employer against any claim to or in respect of such materials may be a permissible alternative. Also worth considering if acceptable to the employer, is a surety from a financial institution. If in doubt guidance should be sought from the engineer.
- Satisfactory substantiation of the value of the materials. This should be based on invoices. However, the monitoring staff must ensure that the valuation is consistent with the rates to which the materials apply and that sufficient money remains in the item for the work to be done with the materials (in the event of the contractor being sequestrated or liquidated and others having to complete the work).

Other conditions to be considered are:

- The quality of the materials must appear to be acceptable as determined from inspection or tests.
- The material must be properly stored and protected against loss, damage or deterioration.

In the case of materials stored off-site e.g. precast units or structural steel elements, similar conditions will apply with the addition that the materials should be stored separate from that of other customers and must be clearly identifiable. The written permission of the employer should be obtained in all such cases.

2.13 CLOSURE

The activities and procedures described under this heading relates to all the information which needs to be collated as a record of what was actually constructed.

2.13.1 Record Drawings (traditionally referred to as "as-builts")

The final version issued of each drawing forms the basis of the record drawings. These are to be marked-up (in red) with all alterations to the drawing as actually constructed. The purpose of these records is inter alia to:

- obtain an accurate record in case it becomes necessary to analyse or assess the behaviour or structural integrity of the structure at a future date
- assist with the planning and design of possible future alterations (e.g. widening) of the structure
- determine the causes of rehabilitation measures that may become necessary in future.

TIP
Do not delay the preparation of as-built plans. Attend to them at the earliest opportunity and submit to the employer.

It follows that the records should accurately reflect that which is visually not obvious, easily determinable or measureable. On the other hand insignificant alterations (e.g. a single reinforcing bar replaced with two overlapping bars) or dimensional deviations from normal tolerances need not be

recorded. The monitoring staff should bear in mind that the provision of the record drawings is a very important matter and they have to ensure that all information provided is accurate. They therefore have to use sound engineering judgement and consult with the engineer if in doubt.

One aspect which is always of vital importance to record accurately for structures is the founding depth and founding conditions.

2.13.2 As-built Material Records

Standard forms (available in Excel format) are to be used for recording as-built material data. The engineer's representative should obtain these from the engineer who will advise what records are to be kept for the particular project.

Monitoring staff should record this information continually as the work progresses.

2.13.3 Correspondence and Photos

Hard copies of all correspondence should be filed throughout the contract period according to a predetermined filing structure which usually corresponds with that being used in Head Office. A similar structure should be used for electronic correspondence and these must now be transferred to a CD or DVD for storage with the files.

Photos, of which there may be thousands, are normally stored in date order or subject order and should also be transferred to CD or DVD.

2.13.4 Construction Report

A construction report is normally required with content and structure as prescribed by the employer. It is highly recommended that the engineer's representative, with input from other monitoring staff, writes this report in stages as aspects of the works are completed.

2.13.5 Guarantees

Where the contract calls for guarantees to be provided for specific items, these should be obtained before the works are certified to be complete.

2.13.6 Clearance Certificates

In all instances where land or property owners have been affected by the works (e.g. new boundary fence, service relocated or land temporarily occupied) a letter should be obtained from the owner stating that he/she has inspected the affected property and is satisfied with the condition in which it has been handed over. To expedite the process the engineer's representative should write the letters and present them to the owners for their signature. Remember to make a copy available to the owner for his records.

INDEX TO APPENDICES

2A - LIMITS FOR BLASTING VIBRATIONS

2B - SCHEDULE OF QUANTITIES

2C - DELEGATION OF POWERS

2D - QUANTITY MEASUREMENT

2E - ESCALATION TREND

APPENDIX 2A

LIMITS FOR BLASTING VIBRATIONS (Green, 1975)

Particle velocity V mm/s	Damage
0,5	Threshold of human perception unlikely to cause damage of any type
5,0	Limit for blasting adjacent to historical monuments
25,0	Limit for blasting near private dwellings in order to reduce disturbance to residents to a minimum
48,5	Limit for blasting adjacent to residential structures on good foundations
84,0	Limit for property owned by concern doing the blasting
119,0	Recommended level for blasting adjacent to sturdy reinforced concrete structures
305,0	Rock falls in unlined tunnels
635,0	Onset of cracking of rock
2540,0	Breakage of rock

These limits refer to the resultant peak particle velocity of the ground adjacent to the building and not to the vibration of any part of the building.

CONTRACT NO NRA XXX
REHABILITATION OF N1 BETWEEN CAPE AND CAIRO

PAYMENT CERTIFICATE NO 15

Item	Description	Unit	Quantity				Rate	Amount	Scheduled Amount	Estimated Final		Var Est vs Sched		Estimated Outstanding	
			Billed	Previous	Month	To Date				Quant	Amount	Quant	Amount	Quant	Amount
	SCHEDULE A: GENERAL & ROADWORKS														
1500	**ACCOMMODATION OF TRAFFIC**														
B15.01	Accommodating traffic and maintaining temporary deviations	km	7	7.30	0.00	7.30	19 300.00	140 890.00	135 100.00	13.30	256 690.00	6.3	121 590.00	6.00	115 800.00
B15.02	Earthworks for temporary deviations														
	(a) Shaping of temporary deviations	km	2	1.00	1.00	2.00	6 000.00	12 000.00	12 000.00	4.00	24 000.00	2.0	12 000.00	2.00	12 000.00
B15.03	Temporary traffic control facilities :														
	(a) Flagmen	Man-day	3 000	1 890	109	1 999	70.00	139 930.00	210 000.00	3 277.00	229 390.00	277	19 390.00	1 278.00	89 460.00
	(b) Portable STOP and GO-RY signs(900 mm dia)	No	6	2.00	1.00	3.00	550.00	1 650.00	3 300.00	4.00	2 200.00	(2)	(1 100.00)	1.00	550.00
	(h) Delineators (TW401 and TW402) 800 mm x 250 mm overall size:														
	(i) Single sided, reversible	No	300	223.00	71.00	294.00	80.00	23 520.00	24 000.00	294.00	23 520.00	(6)	(480.00)	0.00	0.00
	(ii) Double sided	No	500	467.00	38.00	505.00	95.00	47 975.00	47 500.00	505.00	47 975.00	5	475.00	0.00	0.00
	(j) Traffic cones, 750 mm high	No	50	8.00	0.00	8.00	110.00	880.00	5 500.00	15.00	1 650.00	(35)	(3 850.00)	7.00	770.00
	(n) Other traffic control measures ordered by the engineer:														
	(i) Provision of other signs or facilities	Prov sum	10 000		894.33	894.33	1.00	894.33	10 000.00	5 000.00	5 000.00	(5 000)	(5 000.00)	4 105.67	4 105.67
	(ii) Contractor's handling charges and profit on subitem 15.03(n)(i)	%	10 000				10%		1 000.00	0.00	0.00	(10 000)	(1 000.00)	0.00	0.00
15.04	Relocation of traffic-control facilities	sum	1	1.00	0.00	1.00	5 000.00	5 000.00	5 000.00	1.00	5 000.00	-	0.00	0.00	0.00
15.07	Blading by road grader of:														
	(c) Existing gravel shoulders used as temporary deviations	km-pass	6	11.80	0.00	11.80	1 000.00	11 800.00	6 000.00	11.80	11 800.00	6	5 800.00	0.00	0.00
B15.09	Maintenance of the bituminous surfacing and pavement of temporary deviations														
	(a) Repair of surfacing failure	m²	50	419.18	0.00	419.18	100.00	41 918.00	5 000.00	419.18	41 918.00	369	36 918.00	0.00	0.00
	(b) Repair of base failure	m³	8	14.50	0.00	14.50	1 500.00	21 750.00	12 000.00	14.50	21 750.00	7	9 750.00	0.00	0.00
	(c) Repair of potholes and edge breaks using e.g. Roadmix (cold coarse mix)	kg	100	939.00	0.00	939.00	20.00	18 780.00	2 000.00	939.00	18 780.00	839	16 780.00	0.00	0.00
TOTAL CARRIED FORWARD TO SUMMARY								**466 987.33**	**478 400.00**		**689 673.00**		**211 273.00**		**222 685.67**

APPENDIX 2C

PART 2. DELEGATION OF POWERS TO THE RESIDENT ENGINEER WITH REFERENCE TO THE FIDIC GENERAL CONDITIONS OF CONTRACT

SECTION A

The Resident Engineer may:

1. Furnish the Contractor with drawings, specifications and instructions necessary for the proper and adequate execution of the Works **Subclauses 1.8 and 3.3**

2. Ensure that the Contractor pays all fees and gives all notices as necessary **Subclause 1.13(b)**

3. Give further possession of Site from time to time to enable the Contractor to proceed with the Works in accordance with his approved programme **Subclause 2.1**

4. Require the Contractor to allow appropriate opportunities for carrying out work to other contractors and other persons **Subclause 4.6**

5. Furnish the Contractor with reference points, lines and levels. Check any setting out done by the Contractor and require the Contractor to rectify errors **Subclause 4.7**

6. Require the Contractor to provide necessary signs or directions along access routes **Subclause 4.15(b)**

7. Ensure that the Contractor has adequate equipment on Site and order, or consent to, the removal of major items **Subclause 4.17**

8. Ensure that the Contractor complies with the provisions and requirements regarding the use of land **Subclause 4.23**

9. Issue instructions to the Contractor concerning the action to be taken regarding fossils, etc. found on site. **Subclause 4.24**

10. Permit work outside normal working hours in terms of subclause 6.5(c) but not otherwise **Subclause 6.5(c)**

11. Ensure that the Contractor complies with the provisions of subclauses 6.6 and 6.7 in respect of his employees' welfare, health and safety and that the necessary records are maintained. Call for reports as and when required **Subclauses 6.6 & 6.7**

12. Require the Contractor to remove from Site any of his employees except the Contractor's Representative **Subclause 6.9**

13. Carry out all the duties of the Engineer as prescribed in clause 7: Plant, Materials and Workmanship, with the exception that the Resident Engineer may not employ other persons to carry out remedial work in terms of subclause 7.6 **Clause 7**

14. Require the Contractor to submit programmes and particulars and refer same to the Engineer for his approval **Subclause 8.3**

Appendix continues on next page…

15. Suspend progress of all or part of the Works for any of the following reasons:

(a) for the proper execution of the works,
(b) by reason of weather conditions on the site
(c) by reason of some default or breach of the contract on the part of the Contractor
(d) for the safety of the works or any part thereof, or
(e) for the safety of the public,

but not otherwise **Subclause 8.8**

16. Require the Contractor to clear the site on completion **Subclauses 4.23 & 11.11**

17. Measure the Works and require the Contractor to give such assistance and particulars as necessary **Subclauses 12.1 &12.3**

18. Order expenditure in connection with Provisional and Prime Cost Sums and require the Contractor to produce quotations, invoices, vouchers, accounts and receipts **Subclause 13.5**

19. Require the Contractor to make good his failure to carry out any of his obligations under the contract **Subclause 15.1**

20. Ensure that the Contractor indemnifies the Employer in respect of death, injury damage and loss in terms of subclause 17.1 **Subclause 17.1**

21. Require the Contractor to make good and repair loss or damage to the Works, Goods, or Contractor's Documents **Subclause 17.2**

22. Require the Contractor to submit acceptable invoices in respect of Special Materials **CONTRACT PRICE ADJUSTMENT SCHEDULE — item 4(1)**

SECTION B

With regard to the following matters the Resident Engineer shall have no power of decision but shall receive any submissions from the Contractor (where applicable) and refer the matters to the Engineer.

The Resident Engineer shall, therefore, have no powers to:

1. Explain or adjust any ambiguities or discrepancies in the Contract Documents **Subclause 1.5**

2. Permit the Contractor to assign the Contract or part thereof **Subclause 1.7**

3. Require the Contractor to disclose Confidential information **Subclause 1.12**

4. Agree or determine any matters in terms of subclause 3.5 **Subclause 3.5**

5. Approve Contractors designs and details or authorize deviations there from **Subclause 4.1**

6. Approve or withdraw approval of the Contractor's representative **Subclause 4.3**

7. Grant permission to the Contractor to sublet any part of the Works or to appoint and hire a subcontractor **Subclause 4.4**

8. Instruct the Contractor to assign the benefit of a subcontractor's obligations in terms of Subclause 4.5 **Subclause 4.5**

Appendix continues on next page…

9.	Make any decision regarding unforeseeable physical conditions	**Subclause 4.12**
10.	Approve or reject the Contractor's programme or revised programmes	**Subclause 8.3**
11.	Grant extension of time	**Subclause 8.4**
12.	Notify the Contractor regarding the rate of progress	**Subclause 8.6**
13.	Grant permission to the Contractor to expedite progress	**Subclause 8.6**
14.	Suspend the progress of all or part of the Works for any reason other than those described in item 15 of SECTION A of PART 2 of this document	**Subclause 8.8**
15.	Permit Works that have been suspended for more than 84 days, to proceed	**Subclause 8.11**
16.	Issue a Taking Over Certificate	**Subclause 10.1**
17.	Issue a Performance Certificate	**Subclause 11.9**
18.	Agree to, or determine, new rates or prices	**Subclause 12.3**
19.	Order any Variation or approve a Contractor's proposal for a variation	**Subclause 13.3**
20.	Certify payments to the Contractor	**Subclause 14.6**
21.	Grant extension of time for submission of a claim	**Subclause 20.1**
22.	Issue a ruling on a Contractor's claim	**Subclause 20.1**

APPENDIX 2D

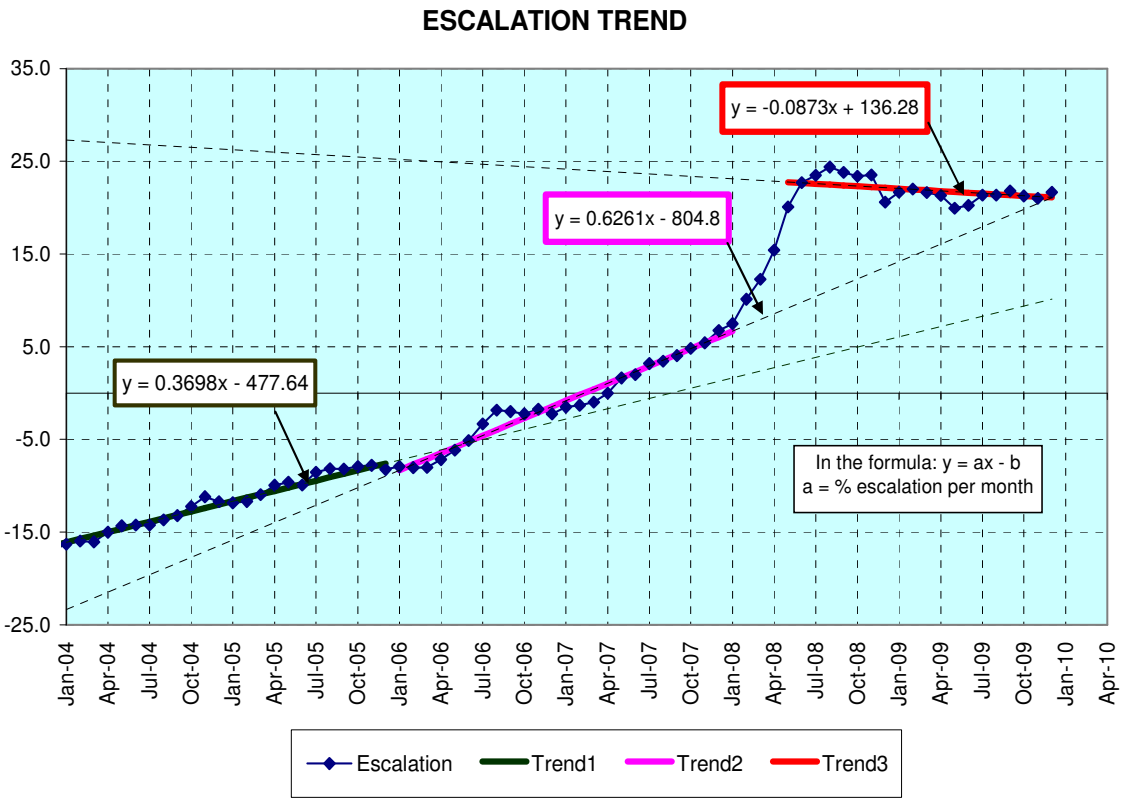
Summary of Measurement	Item No.:	
	Description:	
	Unit:	Tariff:
Contract No:	Quantity in Bill:	
Contract:	Final Quantity:	Amended Quantity:
Contractor:	Saving/Overspend:	

Payment Certificate	Position	Ref	Quantities				Agreed Quantities Signature	
			Interim	Final	Progressive		Contractor	Consultant
					Interim	Final		
Prepared by:						Page	of	

Using the contract price adjustment formula the graph below shows the adjustment factor F (x 100) for the period Jan-04 to Dec-09 with Apr-07 as the base month in this particular case.

$$F = (1 - x)\left(a\frac{L_t}{L_o} + b\frac{P_t}{P_o} + c\frac{M_t}{M_o} + d\frac{F_t}{F_o} - 1 \right)$$

Trend line 2 for the period Jan-06 to Jan-08 yields an average monthly escalation of 0,626% (7.5% per annum) resulting in a price increase of 5,6% in Jan-08 compared with the base month. However, thereafter escalation increased rapidly to reach a peak of 24,4% in Aug-08 before a new downward trend (no 3) was established.



Between Jan-08 and Jun-08 the average increase was an inconceivable 3,1% per month. Referring to the table below it can be seen that in Apr-08 the actual escalation factor was already double that of the estimated escalation factor based on trend 2. This illustrates the dilemma often faced by the estimator. Should he adjust the estimated monthly escalation for future expenditure using this new trend? How long will it last and what happens thereafter?

In the example shown in the table below, the estimated escalation factor for May-08 was corrected by making it equal to the actual factor for that month and thereafter applying the monthly increase derived from Trend 2 as before. As it happened the actual escalation trend turned negative after Aug-08 which eventually resulted in a reduced total escalation compared to what was predicted in May-08.

Appendix continues on next page…

Table showing an example of escalation prediction.

Avg Esc per mnth	0.62660000	7.52	per annum

Month	Cert No	Est. Esc Factor (1)	Actual/Rev Works (2)	Actual Esc Factor (3)	Actual Esc (4)	Revised Est Esc (5)	Cum Actual/ Revised Esc (6)
Aug-2007	0	2.5064		3.4530			
Sep-2007	1	3.1330	1 266 992	4.0476	51 956		51 956
Oct-2007	2	3.7596	1 940 045	4.8317	94 793		146 748
Nov-2007	3	4.3862	1 817 663	5.4283	96 629		243 377
Dec-2007	4	5.0128	1 051 402	6.7640	71 660		315 037
Jan-2008	5	5.6394	1 189 139	7.5030	81 829		396 866
Feb-2008	6	6.2660	2 607 362	10.1277	267 567		664 433
Mar-2008	7	6.8926	4 867 603	12.2763	570 084		1 234 517
Apr-2008	8	7.5192	793 182	15.4282	95 091		1 329 608
May-2008	9	20.0958	2 434 676	20.0983	448 241		1 777 849
Jun-2008	10	20.7224	2 570 889	#N/A		532 750	2 310 599
Jul-2008	11	21.3490	2 341 980	#N/A		499 989	2 810 589
Aug-2008	12	21.9756	4 089 627	#N/A		898 720	3 709 308
Sep-2008	13	22.6022	1 900 102	#N/A		429 465	4 138 773
Oct-2008	14	23.2288	3 149 052	#N/A		731 487	4 870 260
Nov-2008	15	23.8554	3 442 728	#N/A		821 277	5 691 537
Dec-2008	16	24.4820	2 509 175	#N/A		614 296	6 305 833
			37 971 617		1 777 849	4 527 984	6 305 833

CHAPTER 3 - DRAWINGS & SETTING OUT

GW Els

3.1 SCOPE

The objective of this chapter is to provide guidance for drawing and setting out control on site. These subjects are important because it is imperative that drawings be available on time and that the work be done in accordance with the latest revision thereof. Likewise accurate setting out is essential for a functional and aesthetically pleasing end product.

3.2 DRAWING CONTROL

3.2.1 Introduction

The project drawings together with the standard drawings, are part of the documents forming the contract and these various documents are to be taken as mutually explanatory of one another. For the purposes of interpretation these documents are given a sequence of priority which may vary depending on the terms of the contract. For example, in the case of the FIDIC Conditions of Contract as amended by SANRAL, the project drawings are subordinate to the project specifications but take priority over the standard specifications, the standard drawings and the schedules.

The drawings together with the Scope of the Works (Part C3) and the Pricing Data (Part C2) define the nature, extent, limitations, quality and quantity of the works to be performed. A drawing issued is akin to an instruction issued and it therefore follows that drawings are to be properly managed with regard to their authority, first issue and any subsequent revisions.

3.2.2 Authority

The drawings, like the specifications and other documents forming the contract, are in the custody and care of the employer. Consequently a drawing, to have any authority, must in the first instance be **signed by the employer** who will require that it also be signed by the responsible professional design engineer, before it may be issued to the contractor.

TIP
Monitoring staff must ensure that they are familiar with the employer's requirements for signatory for drawings, drawing revisions etc

The same would apply to subsequent revisions of a drawing but for the sake of expediency the engineer and employer may come to an agreement that revisions of a drawing be issued with only the signature of the design engineer on it. Should there be such an agreement then the contractor must be informed thereof in writing. Should a major revision be required, then the signature of the employer should also be obtained. Great care must be exercised by site monitoring staff not to take over the responsibilities of the engineer or designers as changes, however well intended, may have unintended negative consequences.

3.2.3 Drawing Register

The drawing register is fundamental to good drawing control on site. The engineer's representative is responsible for producing and maintaining the drawing register which should reflect the following data (see example in Appendix 3C):

- A complete list of all project and standard drawings with drawing number and description of each drawing that has or will be issued to the contractor
- The date of first issue

- The anticipated / required issue date of drawings not yet issued
- The sizes and number of copies issued
- The date and revision number of the latest revision issued.

It is important that a complete list of drawings be compiled at the start of the contract. Although not desirable, it is often the case that certain drawings, e.g. reinforcement layout, bending schedules, joint details etc., are not yet available when the site is handed over. Apart from being a record of drawings issued, the register is therefore also a management tool to be used for ensuring that outstanding drawings will be made available in good time.

Unless otherwise stated in the contract, it is customary to issue the contractor with one unreduced copy of each drawing. By way of a prior arrangement the contractor may request that additional copies be issued some of which may be in an A2 bound book format. Both ways the number and size of drawings issued should be recorded.

The register should be in electronic format so that extracts can be made of it for use as follows:

- At every site meeting a list should be tabled of all drawings issued since the previous meeting. The purpose inter alia is to record confirmation that the contractor has received these drawings.
- The list tabled should also show all drawings not yet issued to confirm that the anticipated or required issue date is still acceptable in accordance with the latest construction programme.
- The list of outstanding drawings with updated required issue dates should be communicated to the design office to ensure timeous completion thereof.

It must be noted that a contractor will be quick to give notice of his intention to submit a claim for delay and costs should construction drawings not be made available in good time. However, the contractor has a duty to give notice to the engineer whenever the works are likely to be delayed or disrupted if any necessary drawing is not issued to him within a reasonable time and on or before a specific date (refer e.g. FIDIC clause 1.9). In order therefore to make a valid claim for delay the contractor must first place a demand on the engineer that performance be made by a specific date. The engineer's representative should therefore insist that the contractor refrains from requesting drawings "as soon as possible" but that reasonable and realistic dates be determined based on the programme and with due regard for the lead time to order for example materials and equipment.

3.2.4 Revisions

It is almost inevitable that some of the drawings already issued, may require revisions. Such revisions may come about for a number of reasons, be it as a result of a proposal, a revised specification, a change in the scope of the works, an omission or the correction of an error. It can be initiated by the contractor, the consultant's team or the employer.

In this regard the engineer's representative plays a very important role, namely to advise the engineer on the financial and time consequences of a contemplated revision in so far as it will impact on the contractor's programme, possible abortive work, potential for delay and other not so obvious costs and implications. A revision may therefore imply a variation order in terms of the applicable conditions of contract.

The employer generally prescribes standard procedures for making revisions to a drawing (for example refer clause 4.13.5 of the "Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa").

In managing revisions the responsibilities of the engineer's representative are the following:

(a) Acknowledge receipt of the revised drawing.

(b) Ensure that the drawing has been numbered correctly and is signed.

(c) Ensure that the number and size of drawings required for own use and that of the contractor have been received.

(d) Ensure that all amendments or additions to the drawing have been identified and compile a list thereof.

(e) Withdraw the current edition of the relevant drawing from all sets amongst the monitoring staff, mark them clearly as "cancelled" and put them into the archives.

(f) Bring the amendments and additions to the attention of all relevant members of the monitoring staff.

(g) Issue the drawing to the contractor under cover of an issue slip and a site instruction or site note which draws attention to the amendments as identified in (d) above. The issue slip must be countersigned by the contractor and a copy kept on record.

(h) Update the drawing register.

(i) Initiate whatever processes are feasible to ensure that the revisions will be implemented.

(j) Ensure that in fast track multi-disciplinary projects, drawings are issued to all the disciplines involved.

Subparagraph (i) is very important. The engineer's representative does not have direct control over the manner in which the contractor manages his drawings and the dissemination of information to his staff. The only way therefore to ensure that a revision has or will be implemented is to monitor it at the work face. That is why it is so important that monitoring staff are aware of the actual nature of a revision so that they can pro-actively be on the lookout. Furthermore it is strongly recommended that check lists should include an item to verify the revision number of drawings being used by the workmen on site.

3.2.5 Supplementary Sketches

A distinction is to be made between revisions as described in paragraph 3.2.4 above, and supplementary sketches, the purpose of which are to amplify or clarify existing details on a drawing. Such sketches may be done on an A4 or A3 sheet either by the design office or the engineer's representative himself and even by hand. They will have no official status and will normally not be taken up on the as-built drawings. They should however be given a unique number and should be issued under cover of a site instruction or site note and thus become part of the site records.

If time is of the essence then it may happen that details of a revision will be put on sketches and sent electronically to site with the revised drawing to follow. The engineer's representative should obtain confirmation from the engineer before issuing such sketches and if given the go-ahead, he should follow the same procedure as described in paragraph 3.2.4 above.

3.2.6 Management of Own Drawings

The engineer's representative will decide how many sets of drawings and the size thereof he and his staff will require. As a general rule the number of sets should be kept to the absolute minimum. The more sets the greater the likelihood of some sets not being up to date.

Furthermore the drawings should preferably be unreduced (usually A0 size) paper copies of the original approved and signed drawings. It is customary to also request reduced size drawings e.g. A2

in a staple bound book format similar to the tender drawings, for the ease of their transport and use outside of the office. However, herein lies a danger in that cancelled drawings are not removed from the book and revisions are not properly bound and may become detached. It is therefore recommended that reduced size drawings also be issued loose. Those required to be taken with on an inspection can be "bound" using detachable clamps.

3.3 SETTING OUT CONTROL

3.3.1 Introduction

The purpose of setting out control is to ensure that the structure will be built in its intended position and to the intended profile, levels and dimensions.

In days gone by the geometry of structures were relatively simple and the instruments used for setting out and control (theodolites, dumpy levels, tapes etc) were readily understood and useable by all concerned. That is no longer the case. The geometry of structures have become more complex and with the advent of electronic instruments and GPS based systems, the instruments used have become specialised and require highly trained personnel (registered surveyors). Modern setting out procedures have become almost "peg-less". This however, should not deter the monitoring staff from establishing a setting out control system which will serve its intended purpose. This system should follow a two-prong approach, viz:

- Strategized audits by an independent registered surveyor
- Local reference pegs and lines for elementary checks.

3.3.2 Establishing Control

A control system consisting of strategically placed benchmarks will have been established when the original survey was done for design purposes. Prior to or shortly after site handover the engineer will arrange for a surveyor to verify the existing benchmarks and if necessary, put in more with the specific purpose of controlling the setting out of the structure. It is important that at this stage the engineer's surveyor check and verify that the bridge control system correlates with that which will be used for any adjacent works such as the approaches to the bridge or any other nearby structure.

The coordinates of these benchmarks will be made available to the contractor and the engineer's representative must ensure that the contractor adequately marks and protects them against any possible damage.

The contractor is responsible for the setting out and control of the position, line, level and dimensions of the structure to be built and to this end his surveyor will establish additional reference pegs. Prior to this exercise the engineer's representative should meet with the contractor's surveyor to discuss the approach and methodology which he intends to follow to ensure adequate control of each element and phase of the construction process. It is advisable that the independent surveyor appointed by the engineer and who will be auditing the setting out, attends this meeting.

The outcome of this discussion should be agreement on:

(a) The approach and methodology which the contractor's surveyor will be following taking into consideration the geometric and structural complexity of the structure and the topography of the site,

(b) The approach and methodology to be followed by the independent surveyor which should be different to that of the contractor's surveyor,

(c) The critical elements which will require checking by the independent surveyor and the timing thereof,

(d) The channel of communication and advance notice periods to ensure availability of the independent surveyor when required,

(e) The procedure for signing off and approving the setting out before further work may continue, and

(f) The position of sufficient reference pegs which will enable the bridge foreman and the monitoring staff to continually verify important corner points, dimensions and levels using elementary instruments such as a tape, a plumb bob and a level.

3.3.3 Exercising Control

The planning and strategy developed at the above mentioned meeting, should be recorded and converted into milestone events which are inserted into the contractor's programme and should also be incorporated in a checklist for use by the monitoring staff (refer Appendix 3B).

The monitoring staff should never lose sight of the following:

(a) It is common cause that there will be incorrect coordinates, dimensions and levels on the drawings. Therefore the joins between all coordinated points should be calculated and cross checked with the dimensions and levels given on the drawings to verify their correctness.

The equation for determining the horizontal distance between two coordinated points is:

$$L = \sqrt{(y_1 - y_2)^2 + (x_1 - x_2)^2}$$

where:
y_1x_1 are the coordinates of the 1st point and y_2x_2 that of the 2nd point.

(b) There is no easy or cheap solution for a foundation or column built out of alignment and the argument that it is the contractor's problem offers little consolation in practice. Therefore check and recheck – never assume anything.

TIP
Do not under estimate the value of a trained eye to detect a deviation from what should be symmetrical or uniform.

(c) The setting out must look right. This is especially true for smaller drainage structures, the stake distance and angle of which were determined from survey drawings compiled many months ago. Recent floods may have changed the watercourse characteristics which may necessitate a slight repositioning of the structure and/or the angle thereof. If in doubt the design engineer should be summoned to the site to investigate and a new survey should be done to amend the layout and design.

(d) Survey information is not accurate to the nearest millimetre. Therefore in the case of a structure for a road crossing over an existing rail or road, and notwithstanding the apparent accuracy of the setting out data on the drawing, the alignment of the new substructure must match that of the existing rail or road and the horizontal and vertical clearances must be equal to or greater than those given on the drawings.

(e) Similarly, when an existing structure is to be widened the new work must tie in with the existing. Therefore the dimensions and levels of the existing structure will take precedence over any dimension or reduced level given on a drawing in the event of a discrepancy. The document will normally have a clause which requires that the dimensions and reduced levels of the existing structure be verified before any new work is constructed so that in the event of any discrepancies, adjustments can be made timeously to the setting out data and the bending schedules in particular.

(f) A perfectly set out and aligned formwork will only yield an equally perfect concrete element if it is of adequate strength and stiffness and suitably braced – refer chapter 6 for further guidelines.

(g) Successive elements e.g. parapet panels, should be set out from the same base line and not from one to the next. Refer adjacent "TIP".

TIP
Beware of the cumulative effect of small errors

(h) Great care should be taken in ensuring that wall and column starter bars are correctly and accurately positioned as it is extremely difficult to rectify errors in their position.

(i) For a superstructure with a cross fall (bridge on a curve) the centre line at road level does not coincide with the centreline of the substructure.

(j) For contiguous precast beams with small gaps (e.g. 30 mm) between their ends, special care needs to be taken to match the actual length of the beams with the actual spacing between supports taking the allowable construction tolerances into account.

INDEX TO APPENDICES

3A - DRAWING CONTROL

3B - SETTING OUT CONTROL

3C - EXAMPLE OF DRAWING REGISTER

APPENDIX 3A

DRAWING CONTROL CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME (S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
• Complete list of required drawings					
• Drawing Register compiled					
• Number of sets & drawing sizes agreed					
• Control procedure for first issue					
• Control procedure for revisions					
• Control procedure for reporting at site meetings					
• Un-issued drawing events built into construction programme					
• Ongoing verification of drawing revisions being used on site					

SETTING OUT CONTROL CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME (S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
• Benchmarks verified & protected					
• Independent surveyor appointed					
• Approach and methodology for setting out agreed with Contractor					
• Approach and methodology for setting out audits agreed and programmed					
• Required reference lines and pegs for elementary checks agreed					
• Critical dimensions and coordinates on drawings cross checked for discrepancies					
• Levels and dimensions of existing features verified					
• Minimum clearances checked					
• Alignment & level of minor drainage structures to match actual site conditions					

REGISTER OF DRAWINGS ISSUED TO CONTRACTOR

CONTRACT NUMBER AND DESCRIPTION: NRA N001-XXX-XXX: RECONSTRUCTION FROM CAPE TO CAIRO

DRAWING DESCRIPTION	DRAWING NUMBER	No & Size	Date Required	Date Issued	Latest Revision	Date Issued	Previous Revision	Date Issued	Previous Revision	Date Issued
BRIDGE 1234										
Site Plan 2	H2580 - 20 - STA - 002 - C - 00	2A0,1A2		08/10/07						
General Arrangement Plan 1	H2580 - 20 - STA - 003 - C - 00	2A0,1A2		08/10/07						
General Arrangement Plan 2	H2580 - 20 - STA - 004 - C - 00	2A0,1A2		08/10/07						
Foundation Layout	H2580 - 20 - STA - 005 - C - 00	2A0,1A2		08/10/07						
Pier 2 Concrete Details	H2580 - 20 - STA - 006 - C - 00	2A0,1A2		08/10/07						
North Abutment concrete details 1	H2580 - 20 - STA - 007 - C - 00	2A0,1A2		08/10/07	01	23/11/07				
North Abutment concrete details 2	H2580 - 20 - STA - 008 - C - 00	2A0,1A2		08/10/07	01	23/11/07				
North Abutment reinforcement details 1	H2580 - 20 - STA - 009 - C - 00	2A0,1A2	16/11/07	15/11/07						
North Abutment reinforcement details 2	H2580 - 20 - STA - 010 - C - 00	2A0,1A2	16/11/07	15/11/07						
South Abutment concrete details 1	H2580 - 20 - STA - 011 - C - 00	2A0,1A2		08/10/07	02	15/01/08	01	23/11/07		
South Abutment concrete details 2	H2580 - 20 - STA - 012 - C - 00	2A0,1A2		08/10/07						
South Abutment reinforcement details 1	H2580 - 20 - STA - 013 - C - 00	2A0,1A2	23/01/08							
South Abutment reinforcement details 2	H2580 - 20 - STA - 014 - C - 00	2A0,1A2	23/01/08							
Deck Concrete Details	H2580 - 20 - STA - 015 - C - 00	2A0,1A2		08/10/07						
Deck Reinforcement Details 1	H2580 - 20 - STA - 016 - C - 00	2A0,1A2	08/05/08							
Deck Prestressing Details	H2580 - 20 - STA - 017 - C - 00	2A0,1A2	08/05/08							
Handrails and Barrier Details	H2580 - 20 - STA - 018 - C - 00	2A0,1A2	01/06/08							
Miscellaneous Details	H2580 - 20 - STA - 019 - C - 00	2A0,1A2		08/10/07						
Coping, pedestrian parapet and barrier RC details 1	H2580 - 20 - STA - 020 - C - 00	2A0,1A2	01/06/08							
Coping, pedestrian parapet and barrier RC details 2	H2580 - 20 - STA - 021 - C - 00	2A0,1A2	01/06/08							

CHAPTER 4 - FOUNDATIONS

BP Durow

4.1 SCOPE

Monitoring of the construction of foundations for road related structures is concerned not only with the verification of compliance with the design requirements, but also with the construction methods, permanent and temporary works and safety measures necessary to achieve adequate and economical foundations.

In this chapter guidance is provided about relevant design aspects and the issues which commonly arise during the construction of foundations for conventional spread footings. These foundations are usually located at depths not more than about 5 m below ground but in certain instances can be considerably deeper. The construction of piled foundations and caissons is dealt with in Chapter 5.

Sometimes it is economical to carry out soil compaction, replacement or other soil improvement procedures in order to found on weak soils at shallow depth. These specialised procedures are also briefly discussed in this chapter.

4.2 FUNCTION

The primary function of foundations is to provide adequate support to the structures which they carry. This implies sufficient load bearing capacity to safely resist the effects of the various combinations of permanent and transient loads transmitted to the founding strata, without excessive deformation, which could otherwise compromise the integrity of the structure or impair its use. The safe or **allowable bearing pressure** is therefore a function of the ultimate load bearing capacity of the ground at the founding level and the load-settlement characteristics of the underlying layers.

In the case of rock foundations the allowable bearing pressure is determined from rock mechanics principles, with due regard to the degree of weathering, the inclination of the rock strata, the presence of shear planes, fissures and clay gouges in the bedding planes, among other factors. On intact rock foundations, bearing capacity may be less critical than other criteria, such as safety against overturning of earth retaining components for example.

The interaction between the structure and the ground when founding on compressible soils is an important consideration regarding the articulation of the structure, usually to a greater degree than when founding on rock. The deformation of soils under load can vary greatly depending on the type, depth and characteristics of the soil, which are determined from in situ or laboratory tests. When it is uneconomical or unsafe to found at shallow depth due to the estimated magnitude of the deformation, it becomes necessary to resort to soil improvement or support on piles or caissons.

The safety of the foundations of river bridges and drainage culverts is also subject to the potential effects of scour. Resistance to undermining by scour is dependent on the nature of the support strata, the depth to founding and the protective measures, among other factors, which are beyond the scope of this chapter.

4.3 DESIGN AND CONSTRUCTION FACTORS

The factors which relate to the foundations and which influence the design of structures and subsequently become the concern of the contractor and those monitoring the construction of foundations, can be summarised as follows:

4.3.1 Founding Material

(a) Soil or rock.

(b) Degree of compressibility, expansiveness, porosity etc.

4.3.2 Depth of Founding

(a) Shallow: usually not more than about 3 m.

(b) Intermediate: usually between about 3 m and 6 m.

(c) Deep: usually greater than 6 m.

4.3.3 Location of Founding

(a) Land environments, which are further subdivided into those which are:

- remote from existing constructions, or
- adjacent or near to existing services (roads, railway lines, pipelines etc) or structures (buildings, bridges to be widened etc.).

(b) Water environments, in which the structure is required to be founded below water level, or in waterlogged or unstable ground.

4.3.4 Method of Construction

(a) Access to and drainage of the excavations.

(b) Open unsupported excavations.

(c) Excavations which require lateral support.

(d) Underpinning of existing structures.

(e) The method of excavation and removal of spoil.

The circumstances which render it unsafe or uneconomical to construct conventional spread footings and preferable to resort to piled foundations or caissons can vary greatly from site to site and are likely to be influenced by the rate of progress needed to meet tight programmes, especially in water environments subject to flooding.

4.4 GEOTECHNICAL INVESTIGATION

It is of the utmost importance to obtain adequate and reliable knowledge of the sub-surface conditions from well-planned geotechnical investigations. The information provided by such investigations is required initially for design purposes and later as a guide during the tender and construction stages.

REQUIREMENT
It is essential that the monitoring staff are in possession and aware of the contents of the geotechnical report.

At the design stage, information about the founding conditions is one of the main determinants in the selection of the structural form of bridges, the span lengths and the configuration of the components of these structures. At the tender stage the foundation and other site data are needed for the purposes of planning and pricing the permanent works and any temporary works required for safety during excavations. This information is carried through to the construction stage for implementation and the guidance of those monitoring the work.

4.5 SOURCES AND AVOIDANCE OF RISK

Foundation work is usually that part of the construction of structures which is the most uncertain and prone to risk. The sources of risk include factors which affect the safety of the work during construction and the utility of the structure on completion, such as the following:

(a) Inadequate or inaccurate data obtained from the geotechnical investigations.

(b) Inadequate or variable conditions encountered at the anticipated founding levels.

(c) The difficulties of access and drainage and the potential for inundation in water environments.

(d) The potential for the collapse of excavation sides, especially in the presence of groundwater and when excavations are adjacent to existing roads, railway lines or structures.

(e) Inadequate lateral support of excavations, which can lead to settlement damage of adjacent services or structures.

Unreliable foundation data can result in possible delays and additional costs in rectification, potential claims for delay and in extreme cases to foundation failure.

Notwithstanding extensive foundation investigations it needs to be remembered that geological conditions can be highly variable even over short distances. Founding conditions should therefore always be treated as uncertain prior to excavation.



Photo 4.1: Highly variable foundations in sandstone

Uniformity in foundations is necessary to avoid the risk of differential settlement and distortion of the structure. When founding conditions at the anticipated levels differ significantly from those anticipated, advice should always be sought from the engineer on the steps to be followed. A provisional sum for **Additional foundation investigation** should be included in the Bill of Quantities to cater for this contingency (such as COLTO Item 61.01, for example).

Identification of the specific hazards and risks of foundation construction and formulation of the means to counteract these are critical initial steps in the avoidance of risk on any project. This must be followed by the diligent application and monitoring of the contractor's health and safety plan, as discussed in the following sections.

4.6 MONITORING OF FOUNDATION WORK

The function and duties of the various personnel appointed to administer and monitor construction contracts are outlined in Chapter 2. However, during foundation work additional vigilance is required because of the difficulties and hazards often arising during this stage of construction.

It also needs to be borne in mind that the start dates of subsequent elements of the work are dependent on timely progress with foundation construction and therefore require prompt response by the monitoring staff to the contractor's requests for inspections, answers to queries, instructions regarding unforeseen conditions, approvals and so on.

In this chapter reference is made to the **contractor's competent person (CCP),** appointed to design, inspect and verify the adequacy of temporary works, such as lateral support, required during the excavation and substructure work. In terms of the Engineering Profession Act (No. 46 of 2000) the CCP is required to be registered and competent in relation to the services to be rendered.

The monitoring staff should therefore:

- ascertain that the contractor has acted upon any concerns they may have recorded about the design and installation of the temporary works;
- ensure that the CCP has inspected and signed off the temporary works, and
- regularly thereafter inspect the temporary works until and during removal.

WARNING

Whereas the responsibility for temporary works remains solely that of the contractor and does not devolve to either the engineer or to the monitoring staff, they have a duty to appraise the design, installation and removal of the temporary works.

Any signs of distress in the temporary works, such as undue deflection or the settlement or cracking of the ground behind lateral support for example, must immediately be reported to the contractor and the engineer as these are indications of incipient failure.

Monitoring staff who require more detailed information and guidance about all aspects of foundation engineering relevant to their duties are encouraged to study the references listed at the end of this chapter.

4.7 CONTRACT DOCUMENTS AND CONTRACTOR'S SUBMISSIONS

4.7.1 Contract Documents

Prior to the commencement of construction the monitoring staff will be furnished with the contract documents, which comprise: general conditions of contract, specifications, project document, drawings and relevant reports.

With regard to the foundations, they are expected to thoroughly familiarise themselves with the drawings, geotechnical reports, hydrological reports when applicable, and any special foundation construction requirements, in order to understand the requirements of the design and guard against anticipated difficulties and hazards.

4.7.2 Contractor's Submissions

At an early stage after the award, the contractor will be required to submit the following information and construction proposals:

(a) Construction programme.

(b) Health and safety plan.

(c) Environmental management plan.

(d) Temporary works drawings for lateral support (including calculations if required).

(e) Method statements, including diagrams if necessary, for access and drainage works such as: temporary river or stream diversions, causeways, islands, cofferdams and dewatering arrangements.

The monitoring staff are required to critically review these submissions with regard to the feasible sequencing of the work, practicality, safety, environmental constraints and inadvertent omissions. The contractor must be advised of any perceived shortcomings in these submissions and instructed to make adjustments if necessary.

It is important to carefully appraise the contractor's proposals for the removal of temporary lateral supports as the most hazardous conditions often arise during this stage of foundation work, which is usually undertaken simultaneously with backfilling operations.

The monitoring staff are empowered to instruct the contractor to update the abovementioned submissions if progress is delayed or circumstances change materially from those envisaged at the outset.

4.7.3 Health and Safety Plan

The formulation, implementation and monitoring of the contractor's Health and Safety Plan, as outlined in Section 2.10 of Chapter 2, has particular relevance to foundations because of the hazards and risks inherent in this stage of bridge construction.

Whilst monitoring staff are required to verify the contractor's compliance with all facets of the safety plan, they are encouraged to approach their task in a co-operative spirit, in which pro-active mitigation of risk is advocated rather than re-active fault finding.

WARNING
The collapse of unsupported trenches or excavations is probably the leading cause of construction deaths. Those that treat excavations without due care do so at their peril!

The monitoring staff are advised to familiarise themselves with the responsibilities of each of the parties, as set out in the Construction Regulations, and are required to ensure the contractor's compliance with all facets of the approved health and safety plan. In the event of transgressions of sufficient severity, such as to cause an imminent threat to the health and safety of persons, the engineer is empowered to stop the work.



Photo 4.2: Rockfall mitigation measures to protect the workforce and future road users

4.7.4 Environmental Management Plan

Foundation construction in environmentally sensitive areas such as rivers, dams, lagoons and wetlands is invariably subject to strict controls, whereas such work in less sensitive environments may require the application of 'good housekeeping' only.

As noted in Section 2.11 of Chapter 2, the Environmental Management Plan is likely to require special measures for foundation work involving stream diversions and for the construction and subsequent removal of access causeways and artificial islands. Likewise the location of excavation stockpiles will need to be strictly controlled to avoid environmental transgressions, when excavations are near to defined floodlines.



Photo 4.3: Planned access to river level for bridge repair required permission to remove and later replant mangroves

4.8 CONSTRUCTION

Issues likely to arise and points to watch during foundation construction are described in the following sub-sections in relation to the usual sequence of the work.

4.8.1 Setting Out

4.8.1.1 Accuracy

Setting out, as more fully described in Chapter 3, is a critical initial step required prior to the commencement of foundation excavations, to ensure the correct positioning and alignment of the substructure footings relative to the road staked line and in relation to each other.

It needs to be remembered that the geometry of the entire structure is dependent on the accuracy of setting out, which must be carried out in terms of and to the accuracy stipulated in the specifications.

4.8.1.2 Independent checks

Whereas the contractor is solely responsible for the setting out of the works, it is recommended that in the following cases the engineer should arrange for independent survey checks of the contractor's setting out, over and above any less rigorous checks carried out by the monitoring staff.

(a) Bridges which have complex plan geometry.

(b) Strut frame and arched structures which have inclined substructure elements and foundations, and for which the springing points are critical both in plan and elevation.

(c) Bridges which require the construction of causeways and artificial islands in order to gain access to the position of the foundations.

Any discrepancies between the initial setting out and the subsequent checks must be resolved before the commencement of excavations.

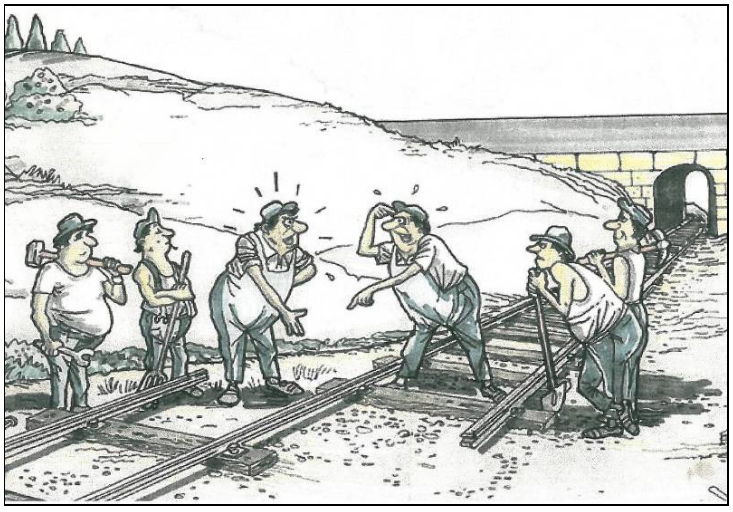


Photo 4.4: What to do now?

4.8.1.3 Foundation excavations

If the accuracy of foundation excavations is not indicated in the specifications, it must be inferred that the excavations should be set out to the same accuracy as specified for footings, when these are permitted to be concreted against ground.

When the engineer requires the side faces of the footings to be formed, the amount of side space beyond the perimeter of the footings allowed for measurement purposes is usually stated in the specifications (for example: 0,5 m in COLTO Sub Clause 6105 (c)). Any additional excavation arising from battering the sides of the excavations is to the contractor's account. In these instances the setting out and extent of the excavations at the ground surface are not the concern of the monitoring staff unless safety or environmental constraints are likely to be compromised.

4.8.1.4 Verification of setting out

As the initial setting out will have been carried out at the ground surface it is important that this should be rechecked at the founding level, which may be several metres below ground.

REQUIREMENT

Once the accuracy of setting out has been finally checked and corrected if necessary, verification of setting out should be signed off by the monitoring staff and the contractor on a print of the foundation drawings kept on site for As Built records.

4.8.2 Access and Drainage

4.8.2.1 Access

Access (as described in COLTO Sub Clause 6104 (b) for example) relates to the construction and subsequent removal of embankments, cofferdams and drainage facilities in locations where it would otherwise be impractical or unsafe to transport and operate plant and equipment needed for the excavations, or for the installation of piles or caissons.

In the case of running water it will usually be necessary to line the sides of embankments required for causeways or artificial islands with rock or other protective measures, in order to reduce the risk of erosion and thereby preserve the integrity and strength of the embankment. The choice of the level at the top of such embankments and the amount of freeboard above seasonal water levels is the contractor's risk alone. These levels will usually be sufficient to prevent inundation by minor floods, determined from information about previous floods if available, the size of the catchment and the duration of the work susceptible to flooding.

In the interests of safety in river environments, the contractor and the monitoring staff should regularly check weather forecasts, weather reports and water levels in order to effect timely evacuation and the removal of plant and equipment to minimise the risk of impending floods.

4.8.2.2 Drainage

The adequacy of the drainage measures adopted during construction can significantly influence the safety of the excavation work and can adversely affect the bearing capacity of the founding and underlying strata if not soundly planned and implemented.

Drainage of excavations (as contemplated in COLTO Sub Clause 6104 (c) for example) includes the following measures, which may suffice individually or may need to be implemented in combination depending on the rate of ingress of water, in order to keep the foundations dry or to control the ponding of water to a degree which can be managed during the construction of the permanent work.

(a) Exclusion of surface water from the excavations by the construction of berms and/or open drains.

(b) Gravity drainage of open unsupported excavations, where topography permits drainage from a sump in one corner on the downhill side of the excavation.

(c) Pumping from a sump formed outside the footprint of the permanent works. This is usually the most economical means of dewatering excavations.

(d) Additional exclusion measures such as the double lining of cofferdams or lowering the groundwater level, using sumps, wells or well points outside the excavations. These and other specialised drainage measures are described in the references.

If at any stage during the excavations the inflow of groundwater is perceived to render the work dangerous, the monitoring staff must bring the matter to the contractor's immediate attention, or instruct the evacuation of the excavation in the event of emergency. At the stage of inspecting the ground at the anticipated founding level, ponded or running water should always be removed by the installation of additional pumps if necessary, as verification of the adequacy of the foundations and subsequent concreting of the permanent works could otherwise be compromised.

4.8.3 Open Unsupported Excavations

This form of excavation is often the quickest, most economical and accessible for a foundation at shallow or intermediate depth in relatively stable soil, when space is not a problem. The main design consideration is that of the stability of the excavation side slopes, the safety of which must be verified in writing by the CCP in order to comply with the requirements of the OH&S Act Construction Regulations.

Unlike cofferdams, open unsupported excavations offer flexibility in the means of carrying out the excavations, including blasting when required, and of the removal of spoil. Likewise, backfilling operations can usually be carried out easily and safely, in contrast to excavations with lateral support in which props can be a hindrance and the subsequent removal of the support is often hazardous.



Photo 4.5: 8m deep open unsupported excavation: Side slopes determined by geotechnical specialist (CCP)

4.8.4 Ground Anchors

4.8.4.1 Types and applications

Ground anchors employed in the construction of foundations are subject to the provisions of the specifications and usually comprise two main types, viz:

(a) Post stressed tendons comprising threaded bars or strand, with alternative anchor configurations and differing arrangements for stressing, re-stressing or de-stressing.

(b) Soil nails comprising unstressed or lightly tensioned high yield stress bars, which are usually fully grouted and act together with a reinforced shotcrete membrane, which retains the material between anchors.

Both types of anchors can be used for temporary or permanent work. However, only post stressed anchors are employed to resist high forces imposed by retained soils and water pressures, or to impose high forces required to stabilise rock strata with inclined shear zones, for example. Untensioned soil nails are designed to give stability to excavated soil faces and are usually concealed behind precast concrete or similar facings when required for permanent, visible locations.

The range of applications, alternative types, technical requirements, design, installation and testing of ground anchors are described in detail in the references.

4.8.4.2 Duties of the various parties

In the case of ground anchors required as part of temporary lateral support work, the design will be undertaken by the CCP, but in the case of permanent rock anchors the design is the responsibility of the designer of the main structure, both of whom are referred to as the design engineer as follows.

The design engineer will determine the requirements of the ground anchor system as well as the responsibility of the contractor in terms of the performance of the anchor parts, the materials used, the transfer of the anchor force into the ground and the testing arrangements.

In response, the contractor is required to submit details of the proprietary anchor system proposed together with a method statement for approval by the design engineer.

4.8.4.3 Construction and monitoring

Normally the installation of ground anchors and the de-stressing of temporary anchors is undertaken by a specialist geotechnical contractor. In view of the importance and technical complexities of this element of foundation work it is essential that the work should be entrusted only to companies with the requisite skills and experience.

The duties of the monitoring staff relate particularly to the construction of permanent ground anchors to ensure that:

(a) The materials comply with the specified requirements, with particular regard to materials strengths, extension properties and corrosion protection.

(b) Drilling is undertaken in compliance with the required geometry.

(c) Anchors are assembled and protected as specified and installed (homing) as soon as practical after drilling.

(d) Grouting is completed as soon as practical.



Photo 4.6: Drilling for ground anchors in blocky sandstone. Assembled anchors awaiting installation.

The stressing and testing of prestressed ground anchors, including proving tests, when relevant, is required to be carried out in compliance with the approved method statement and is the most important aspect of this type of ground anchor construction, which requires diligent overview and record keeping by the monitoring staff.

When the acceptance tests prove the adequacy of a ground anchor this must be signed off by the contractor and the monitoring staff, following which the anchor head must be coated, sealed or concreted in the box out as specified.

WARNING
In the event of the failure of a ground anchor to meet the acceptance criteria, the matter must be promptly referred to the design engineer for a decision on the steps to be followed.

4.8.5 Lateral Support and Underpinning

4.8.5.1 Cofferdams

The function of a cofferdam is to provide safe working space down to the founding level when lateral support of the surrounding ground is required, and from which water is excluded sufficiently to provide access for workmen, plant etc, removal of spoil and the execution of the permanent work.

A cofferdam is usually a circular or rectangular enclosure which is driven into the ground prior to the commencement of excavation, to a safe depth in relation to the anticipated founding level, in order to provide lateral support and limit the ingress of ground water to a degree which can be controlled without excessive pumping. Cofferdams and caissons fall into the same class of structures, the main difference being that a cofferdam is generally a temporary structure, part or all of which is removed after construction, whereas a caisson is primarily a permanent structure, or one which is subsequently incorporated into the permanent work.

Cofferdams may be used down to depths of about 15 m below water level, depending on the nature of the surrounding soil. These structures offer the advantage of access for the purpose of inspection and verification of the quality of the foundations. However, the installation and removal of cofferdams can be slow and expensive and is often avoided in favour of construction using caissons or piles. Cofferdams are normally constructed using one of the alternative embedded wall systems listed in the following sub-section.

4.8.5.2 Lateral support systems

The factors which influence the selection of a lateral support system are those listed in sub-sections 4.3.1 to 4.3.3 and additionally include:

(a) The magnitude of the ground movement which can be tolerated by adjacent services and structures, when applicable, during and after construction.

(b) The availability of the skills, plant and materials needed for this specialist aspect of foundation work.

Lateral support systems fall into two main classes, viz:

(a) Embedded walls, which act either as vertical cantilevers to support the excavated faces, or which are successively braced or tied back by ground anchors at greater depths as the excavation proceeds.

(b) Reinforced soils, which comprise soil nails (high yield stress bars, fully bonded by grout in the retained soil) inserted into the ground behind the excavated face as the work progresses in stages, acting together with mesh reinforced shotcrete covering of the face. Other forms of reinforced soils, described in the references, are not normally applicable to the support of excavations required for road related structures.

The forms of embedded walls most likely to be used to support the excavation of bridge foundations are: steel trench sheets, steel sheet piles, precast concrete piles and steel soldiers with timber lagging.

Steel trench sheeting is manufactured in South Africa and is suitable as a means of support for shallow excavations, not normally exceeding a depth of about 4 m. Trench sheeting is an economical support system for narrow excavations often required for foundations between or adjacent to existing roads or railway lines. As this system can usually be installed and removed quickly, it is particularly convenient when railway occupations limit the frequency and duration of foundation work permitted near too busy export and commuter lines.

Steel sheet piling, braced by props or tied back by ground anchors, is the most common form of lateral support for intermediate and deep excavations, especially when it is necessary to exclude groundwater. Sheet piles have the facility to interlock and essentially form a watertight wall or enclosure. However, steel sheet piles are imported, expensive and sometimes difficult to procure, which can delay the start of construction. Precast concrete piles and steel soldiers with timber lagging are an alternative to steel sheet piles but do not exclude groundwater to the same degree.

TIP

Guardrail plates installed with a suitable pneumatic tool provide an effective and economical alternative support system for shallow excavations in sandy conditions.

In the case of bridge widening and doubling, it is often necessary to remove parts of existing road embankments and to support the remaining cut faces in order to provide safe working space for the construction of new foundations. Lateral support comprising soil nails with mesh reinforced shotcrete facings is particularly advantageous in these circumstances, as these can be installed very quickly at vertical increments of about 1,5 m as the excavations proceed. However, this system is not suitable in most instances below the water table or in the presence of soft clays or boulders.



Photo 4.7: Soil nail and shotcrete lateral support of excavations in an existing embankment

The references provide detailed information about the range of applications, advantages, disadvantages and comparative costs for the alternative lateral support systems available, as well as guidance about the design and installation of these systems.

4.8.5.3 Underpinning

The need for underpinning of existing structures can arise in several circumstances associated with roadworks, such as:

(a) The widening or doubling of existing bridges, which require new foundations adjacent to the existing foundations.

(b) The introduction of new traffic lanes in built up areas, where cuttings extend close to road reserve boundaries and affect adjacent buildings.

(c) Foundations of bridges or culverts which have been undermined by scour or piping of granular founding strata. In the case of culverts it will be necessary to compare the cost of the remedial work with that of replacement of the culvert in its entirety, before embarking on reinstatement of the support.

In the first two cases, the need for underpinning can be caused by the following:

(a) The reduction or removal of lateral support to the material under existing foundations.

(b) A change in the water table which affects the strength or the compressibility of the soil under existing foundations that may lead to unacceptable settlements.

(c) The possibility of settlements of structures due to underground excavations or vibration caused by blasting, pile driving etc.

The procedures currently available for underpinning are many and varied and are briefly outlined in the references. When the need for underpinning has been foreseen at the design stage, the proposed method of underpinning should be fully outlined in the drawings and project specifications. When the need for underpinning becomes apparent only during the foundation work, the procedure to be followed must be defined or approved by the engineer.

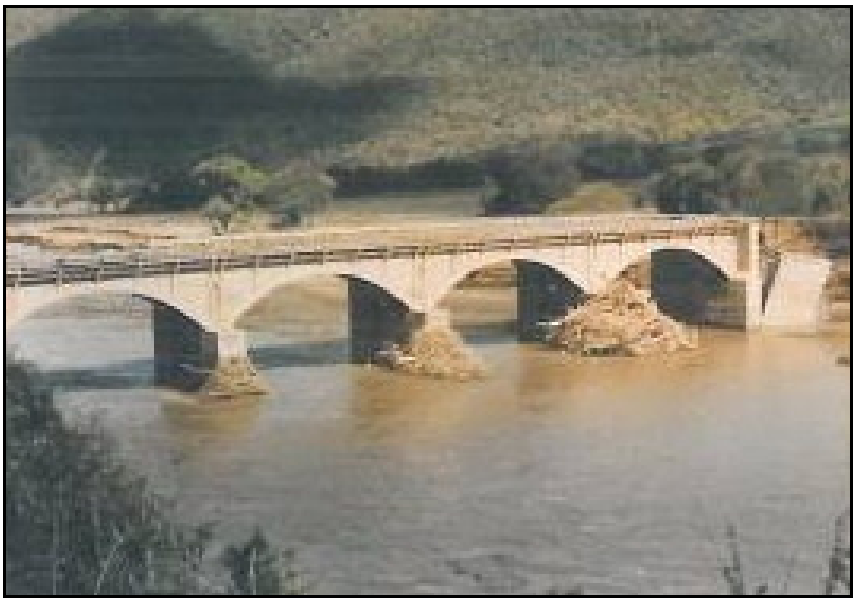


Photo 4.8: Sept-Oct 1987 flood damage to south abutment of the Josephine bridge over the Umkomaas River (R56), constructed ± 1895

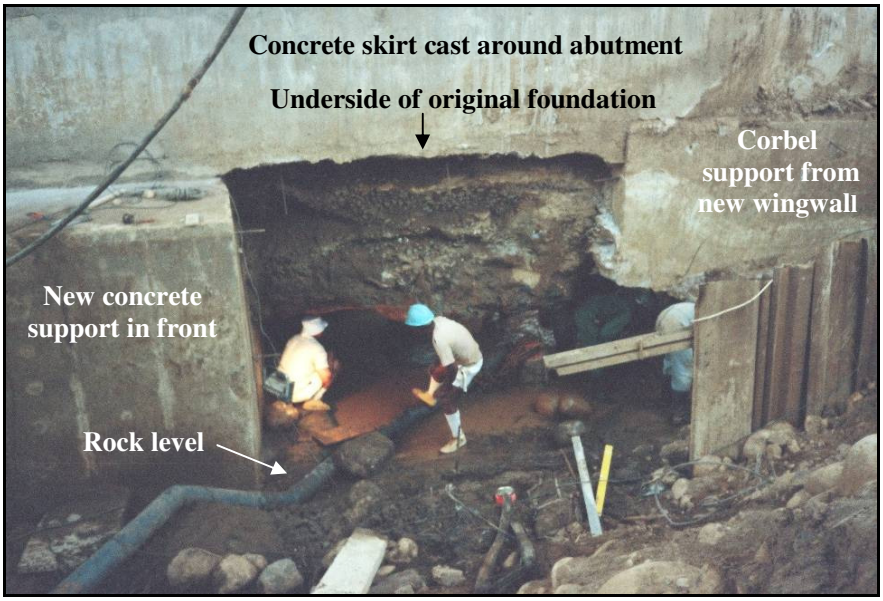


Photo 4.9: Underpinning of Josephine bridge south abutment Sept 1988, prior to mass concrete infill

4.8.5.4 Construction monitoring and verification of adequacy

Foundation work involving the construction and subsequent removal of lateral support systems and the work within the associated excavations falls into the category of **high risk** because of the significant lateral forces imposed on those systems by the retained soil and the potential for bottom surface "blow out". Underpinning the foundations of existing adjacent buildings or bridges is an equally risky operation.

Monitoring staff are required to pay special attention to the requirements of the applicable method statements and drawings to avoid any short cuts on the part of the contractor during the work associated with lateral support and underpinning. When underpinning is required it is essential that a detailed inspection and record of the state of the existing structure is made, including photographs, and that these are confirmed in writing by the contractor, monitoring staff and the affected property owner, when applicable. A similar inspection and record should follow completion of the underpinning and adjacent foundation work in order to avoid spurious claims or to substantiate claims.

4.8.6 Excavation

Prior to and during the process of excavation the monitoring staff, in co-operation with the contractor must establish, take note of, act, measure and agree on the following, as applicable:

(a) That the accuracy of the foundation setting out has been checked and confirmed.

(b) The surface levels of the undisturbed ground at the top of each excavation.

(c) Whether or not working space is required to be provided around the perimeter of the footings.

(d) The lateral support and drainage measures to be implemented during the work, including the inspection and signing off by the CCP.

(e) The protective barriers to be installed around the perimeter of excavations at surface level.

(f) The proposed method of excavation and the protective measures required by the engineer to be implemented when blasting is permitted.

(g) The engineer's requirements for backfilling of overbreak i.e. mass concrete or concrete of the same class as the footing.

(h) The quantities of the materials excavated in the relevant depth ranges and the classification thereof i.e. soft or hard (including the size and density of boulders when applicable).

WARNING
In the event of unforeseen conditions arising during the course of excavation, which are perceived to be potentially dangerous or which could give rise to extra cost, the monitoring staff should promptly advise the contractor and consult the engineer on the steps to be followed.

The monitoring staff are advised to compare the nature of the soil or rock strata encountered at succeeding depths with the borehole data, in order to judge whether conditions at the anticipated founding levels are likely to match the design requirements. The engineer should be advised of any significant discrepancies

A record must be kept and agreed with the contractor of any alteration to the method of excavation required by the engineer and of any additional hand work required when the excavations have been completed.

4.8.7 Founding

4.8.7.1 Verification of adequacy

When the excavation reaches a level at or near to the anticipated founding level shown on the drawings which is perceived to be suitable for founding in terms of the safe bearing pressure, the bottom of the excavation shall be cut and trimmed to a uniform surface and inspected by the engineer to confirm its adequacy. Following the engineer's confirmation of the suitability of the material for founding, the bottom surface levels should be agreed with the contractor and concrete screed or foundation fill, as required by the engineer, placed as soon as practical.

TIP
If the adequacy of founding is in doubt, monitoring staff members are encouraged to obtain the opinion of senior colleagues on site.

If the material at the anticipated founding level is deemed to be unsuitable by the engineer, this process should be repeated to the depth limit indicated by the engineer, below which the engineer will again advise on the steps to be followed. When the founding conditions differ materially from those anticipated it may be necessary to carry out additional foundation investigations and in extreme cases to redesign the affected part of the structure. At no stage should site monitoring staff undertake this redesign themselves.

IMPORTANT
In many instances, difficult or complex founding conditions may require that the geotechnical engineer visits the site to inspect and approve the foundations.

4.8.7.2 Additional measures

Prior to the placing of concrete screed or foundation fill the following additional measures should be implemented as shown on the drawings or as instructed by the engineer:

(a) Grouting of rock fissures.

(b) Installation of foundation dowels.

(c) Installation of foundation lining.

4.8.7.3 Foundations for box culverts

The foundation investigations for box culverts often requires careful planning to avoid difficulties which can arise when the alignment of these structures depart from the natural water courses at intervals because of the tortuosity of the streams. This can result in significant variations in the strength and compressibility of the founding materials along the length of a culvert. In coastal areas culverts are often founded on loose sands and soft clays which extend to significant depths.

In these circumstances it is usually necessary to remove weak soils or unstable ground to the depth of several metres and to install engineered rock fills. This measure will usually reduce the potential for settlement and embankment stretch to a degree which can be accommodated by the careful design and construction of the culvert joints. In order to avoid the ponding of water it is also advisable to pre-camber such culverts, but not to the extent of creating reverse gradients in case the anticipated settlements do not occur.

When foundation difficulties become fully evident only when the excavations for box culverts are in progress, it may be necessary to resort to one of the Alternative Precautionary Measures illustrated in the Appendix 4D.



Photo 4.10: Scour of unprotected culvert foundations

4.8.8 Backfill

Backfill to foundation excavations is an important final step in foundation work which must be strictly carried out as described in the specifications. In the case of bridge abutments, underpasses and box culverts the ultimate rideability of the road is highly dependent on the achievement of the necessary compaction densities in the backfill.

This is an item which is sometimes casually treated and which is deserving of constant vigilant attention on the part of the monitoring staff, who must ensure that backfill is frequently tested and removed and replaced when found to be non-compliant with the specified requirements.

In circumstances where any amount of settlement is highly undesirable, adding cement to the backfill material (dry soilcrete) may be justified.

4.8.9 Measurement and payment

BEWARE

Measurement for payment is an important duty of the monitoring staff and is required to be undertaken in good time for the preparation of payment certificates. Measurement of each billed foundation item should be promptly carried out on completion, before covering up, and thereafter agreed and signed off with the contractor. Any disagreement on either the quantity measurements or about interpretation should be referred to the engineer for a decision.

4.8.9.1 Standard and special items

The standard measurement and payment items for conventional foundations and ground anchors are described in the specifications. Project specific elements of the work, such as underpinning, which are required as part of the permanent work and which fall outside the scope of the standard items are described in the project specifications, together with the applicable units of measurement and a description of the work deemed to be included in the tender prices.

4.8.9.2 Tender and measured quantities

Because of the variability of founding conditions, the billed quantities included in the tender documents are often merely indicative. It is recommended that the monitoring staff should always be furnished at the outset with a copy of the original quantity calculations, for comparison with the measured quantities as the work proceeds. This information will assist the monitoring staff to assess and report to the engineer, when required, on overexpenditure or underexpenditure against the tender amounts and the reasons for the differences.

It is essential that measurement files should be systematic, comprehensive and kept up to date for both interim and signed off measurements for completed work items. These files are subject to periodic audit by the employer and provide important reference information in the event of disputes or claims.

4.8.9.3 Application of specific items

For the purpose of comment about the measurement and payment items for foundation work, the COLTO Standard Specifications for Road and Bridge Works for State Road Authorities is used as an example. Monitoring staff should note that the measurement and payment items for foundation work may differ in other standard specifications.

Excavation (COLTO Item 61.02)

It is noteworthy that the tendered rates for the various classes and depths of excavation are deemed to be all-inclusive with respect to the method of excavation, disposal of the spoil and protective measures etc. in completing the excavation.

With regard to the volume of excavation measured, no distinction is made between open excavations with unsupported sloping sides and those with vertical sides and designed lateral support, for example.

However, a distinction is made about the volume of excavation measured, which is dependent on whether:

(a) Placing of the footing concrete against the earth faces is permitted by the engineer, or whether:

(b) Formwork is required to be provided to the sides of the footing.

In the first case the volumes of excavation measured are required to be based on the net plan area of the footing, multiplied by the applicable depths. In the second case the plan area is extended by a width of 0,5 m around the entire perimeter of the footing, to provide for working space.

The designer's intention regarding these options is clearly indicated by the inclusion of formwork to the sides of the footings in the bill of quantities. However, this can be altered by the engineer during construction, if circumstances permit and economy can be achieved.

Clearly it will be necessary to allow for working space in the case of excavations which require designed lateral support down to the founding level, such as a cofferdam.



Photo 4.11: Excavation with excess working space beyond the base foot print (>500 mm)

Overbreak in excavation in hard material (COLTO Item 61.07)

When footing concrete is permitted to be cast against hard material the contractor is required to be compensated by extra payment under this item for overbreak. It must be noted that the unit of measurement for the excavation of overbreak and for the concrete fill is the square metre of the surface area of the vertical outer faces of the base, irrespective of the width or volume of the overbreak.

This payment method imposes a contractual risk insofar as careful work is required to limit the amount of overbreak. However, this element of foundation measurement is prone to claims for extra payment, which may be justified when the nature of the hard material encountered at the footing level is substantially different from that which could reasonably be anticipated from the borehole or other relevant tender data.

When working space is permitted around the perimeter of a footing, overbreak is not measurable and payable for the excavations, irrespective of the nature of the material excavated.

NOTE
COLTO Sub Clause 6105 (c) allows for mass concrete infill of the overbreak if so directed by the engineer. This implies forming of the sides of the mass concrete before casting the footing with a different concrete class, which may be more expensive than simply extending the base concrete to fill the overbreak.

Access and drainage (COLTO Item 61.03)

(a) Access is usually only required in water environments and is also an all-inclusive pay item, from which only excavation is excluded and paid separately in terms of COLTO Item 61.02.

(b) Drainage where no access has been provided is usually applicable in land environments.

Special Items : Lateral support and underpinning

Lateral support which is designed as part of temporary work required for the safety of excavation is deemed to be included in the rates tendered for COLTO Item 61.02 and is not separately measured.

In certain instances it may be preferable to separately identify the need for lateral support, in circumstances which should not be left to the discretion of the contractor, or in which the need for lateral support could escape the attention of the contractor at the tender stage. These circumstances are likely to include excavations for bridge widening or doubling, where new work is adjacent to existing substructure components or where new foundations require limited excavations into the sides of existing embankments.

REQUIREMENT
When, for any reason, the lateral support of a foundation is deemed to be mandatory, this should preferably be separately identified and measured in the Bill of Quantities.

When the need for underpinning is known at the design stage the required method should be reflected on the drawings and appropriate measurement items included in the bill of quantities. When the need for underpinning becomes evident only at the construction stage, the design and measurement items will be the subject of a Variation Order issued by the engineer.

Ground Anchors (COLTO Items 75.01 to 75.08)

When ground anchors form part of the contractor's temporary works for the safety of excavations, these are also deemed to be included in the rates tendered for COLTO Item 61.02 and are not separately measured. Ground anchors required as part of the permanent foundation work will be measured separately for payment in terms of COLTO Items 75.01 to 75.08 inclusive.

4.9 SOIL IMPROVEMENT

4.9.1 Purpose and Application

The purpose of soil improvement is to increase the load bearing capacity of loose or compressible soils to a sufficient degree to permit the founding of structures at comparatively shallow depth, in circumstances which would otherwise require the installation of piled foundations or caissons. The available methods are applicable to the foundations of small to medium span bridges and sign gantries, which impose comparatively light loads and are tolerant of a small degree of settlement or angular distortion. Soil improvement can also be used to reduce the settlement of embankments behind bridge abutments and thereby to diminish the down drag forces imposed on abutment piles, when the natural ground in these locations is compressible.

4.9.2 Soil Improvement Systems

The soil improvement systems which are suitable for the foundations of road related structures include the following:

(a) Vibratory or dynamic soil compaction methods to densify the soil at and below the anticipated founding level in order to reduce settlement and thereby increase the bearing capacity.

(b) Soil replacement methods, which involve the formation of compacted stone columns at predetermined spacings within the ground, using various techniques to remove and replace the compressible soils and thereby increase the bearing capacity of the entire area treated.

(c) Accelerated consolidation of clay substrata by the introduction of band or other suitable drains at predetermined spacings in the ground to reduce the length of the flow path for dissipation of pore water, followed by the construction of an embankment to preload the ground and increase the pore water pressure and thereby induce consolidation at an accelerated rate.

(d) Compacting grouting is achieved by drilling at close spacing through thin but shallow hard layers, such as calcrete, and high pressure injection of fluid grout to densify the underlying compressible soil and thereby increase load bearing capacity to a greater depth.

4.9.3 Information Required

Prior to the adoption of a soil improvement system as a means to permit founding at shallow depth in compressible soils the following information is required:

(a) Detailed information about the characteristics, layer thicknesses and overall depth of the 'problem' soils.

(b) The loads and load combinations to be supported.

(c) The total and differential settlements which can be accommodated by the structure.

(d) Knowledge of the available soil improvement systems, with particular regard to: the equipment required; the typical bearing capacity which can be achieved; the depth of application; limitations concerning the nature of the soils; comparative advantages and indicative costs of the alternative systems.

The technical details of the alternative soil improvement systems available in South Africa are fully described in Reference 3, together with guidelines about the applicability, design and implementation of these systems.

4.9.4 Selection of a Soil Improvement System

The following are some of the factors which need to be considered in determining which soil improvement system is the most suitable for a particular site:

(a) The time available to achieve the necessary soil improvement.

(b) The allowable bearing pressure on the improved soil.

(c) The number and spacing of the treatment points required.

(d) The depth of treatment and the degree of improvement necessary to meet settlement limitations and bearing requirements.

(e) The presence and level of the water table.

(f) The presence of very soft layers which cannot be treated mechanically, and the potential effects of boulders or other obstructions.

(g) The ease or difficulty in achieving the required depth.

(h) The sensitivity of the environs, including existing services or structures, to vibration and noise.

(i) Problems associated with the use of large volumes of water used in the treatment process.

(j) The combined cost of the soil improvement and the footings, compared with other methods of founding in poor soils or of accommodating the effects of significant settlement.

4.9.5 Construction

When a soil improvement system is specified as part of the foundation work, the required method and results will be fully documented as part of the project specifications. This work should be undertaken by specialist subcontractors who have the necessary equipment, knowledge and experience to achieve the desired results. It is incumbent on the engineer to approve only reputable subcontractors with the appropriate credentials for this type of foundation work.

In the case of vibratory compaction it is recommended that the spacing of the compaction points be decided upon by carrying out test compaction patterns together with 'pre' and 'post' compaction soil

strength measurements. This method of soil improvement is normally ineffective near the ground surface because of the dissipation of the vibratory effort. The depth of soil to be recompacted by impact roller or other means must be confirmed by testing.

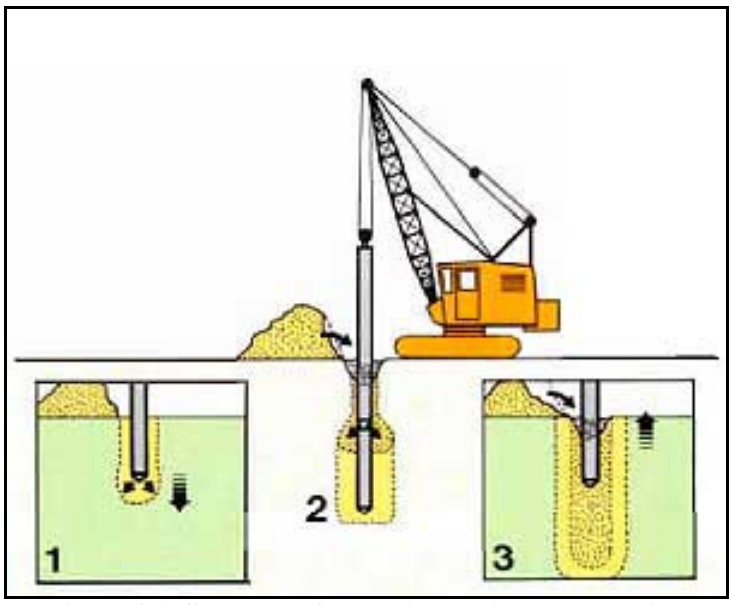


Figure 4.1: Sequence of operations to improve bearing capacity through vibratory compaction

The monitoring staff will be expected to ascertain that: the required depth and lateral extent are achieved and that the soil strength and other requirements of the particular improvement system are confirmed by adequate and appropriate testing. Soil improvement will be required to extend beyond the footprint of the footings by predetermined margins.



Photo 4.12: Typical dynamic compaction
(Note: this example is not related to bridge work)

Soil improvements by accelerated consolidation will require the input of monitoring staff well in advance of the commencement of the permanent structural work, firstly to oversee the installation of the drainage system and to confirm the compaction (density) of the preload embankment, and periodically thereafter to monitor the consolidation actually achieved.

The monitoring staff will be expected to keep detailed records of the extent of the soil improvement work, together with test results related to specific locations, for the purpose of re-analysis and additional soil improvement, if required, and for measurement and payment in terms of the contract.

4.10 CHECK LISTS

Check lists related to the foundations are included in the Appendices to this Chapter and are intended to serve as aide memoires to the monitoring staff and as convenient date related records for the signing off of completed work.

4.11 REFERENCES

1.) British Standards Institution; **Code of Practice for FOUNDATIONS**; CP8004, Latest edition.

2.) The South African Institution of Civil Engineers (Geotechnical Division); **Lateral Support in Surface Excavations, Code of Practice**; Latest edition.

3.) Frankipile South Africa (Pty) Ltd; **A Guide to Practical GEOTECHNICAL ENGINEERING in Southern Africa**; 4th Edition, 2008.

INDEX TO APPENDICES

4A - FOUNDATION CHECK LIST

4B - GROUND ANCHOR AND UNDERPINNING CHECK LIST

4C - GROUND IMPROVEMENT CHECK LIST

4D - BOX CULVERT FOUNDATION PROBLEMS : PRECAUTIONARY MEASURES

APPENDIX 4A

FOUNDATION CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1. SETTING OUT								
2. ACCESS AND DRAINAGE								
2.1 A & D: Drawings & Method Statement								
2.2 Drainage measures only								
3. TYPE OF EXCAVATION								
3.1 Platform								
• Batter slopes CCP								
3.2 Closed / supported (coffer dam or other lateral support)								
• Drawings, method statement CCP								
• Installation CCP								
• Removal CCP								
4. EXCAVATION								
4.1 Perimeter safety measures								
4.2 Blasting								
• Required safety measures CCP								
4.3 Working space required? Y/N								
4.4 Method adopted								
4.5 Additional work								
• Hand excavation								
• Excavation after completion								
• Overbreak in hard material								
4.6 Additional foundation investigation								
4.7 Adequacy of founding								
4.8 Top & founding								
• Depth ranges & classification								
5. ADDITIONAL MEASURES								
5.1 Grout fissures								
5.2 Foundation dowels (Drill, grout etc.)								
5.3 Foundation lining								
6. FILL								
6.1 Foundation fill: Type, thickness								
6.2 Backfill: Source, type, density								
7. MEASUREMENT AND PAYMENT								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

GROUND ANCHOR AND UNDERPINNING CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1. GROUND ANCHORS (Permanent)								
1.1 Proposed proprietary system								
• Type and configuration								
• Method statement								
1.2 Compliance checks								
• Materials strengths								
• Extension properties								
• Corrosion protection								
• System assembly								
1.3 Installation								
• Setting out drilling geometry, location, inclination, depth								
• Homing and grouting								
1.4 Acceptance tests and closure								
• Stress-extension record								
• Closure coating and sealing								
1.5 Measurement and Payment								
2. UNDERPINNING								
2.1 Drawings & Method Statement								
2.2 Record of structure to be underpinned								
• Inspection record and diagrams								
• Photographs								
• Signed confirmation (affected parties)								
2.3 Procedure and Records								
• Compliance with procedure								
• Monitoring of danger signs								
• Record of work								
2.4 Re-inspect on Completion								
• Signs of distress								
• Remedial measures agreed/completed								
• Photographs								
• Signed confirmation (affected parties)								
2.5 Measurement and Payment								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

GROUND IMPROVEMENT CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
(Compaction and Replacement Methods)								
1. SELECTED SYSTEM								
1.1 Method Statement								
2.2 Diagram								
2. PRE-INSTALLATION TESTS								
2.1 Trial test pattern depth and compaction tests								
2.2 Confirmation of pattern/depth								
3. INSTALLATION AND RECORDS								
(Attach record of each treatment point)								
3.1 Treatment points: number and spacing								
3.2 Depth of treatment								
3.3 Measurement diagram and materials quantities								
4. ACCEPTANCE TESTS								
4.1 Strength/settlement								
4.2 Recompaction of problem areas and upper layers?								
5. MEASUREMENT AND PAYMENT								

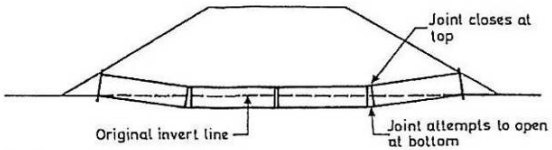
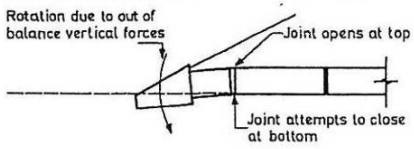
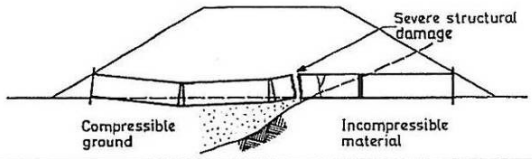
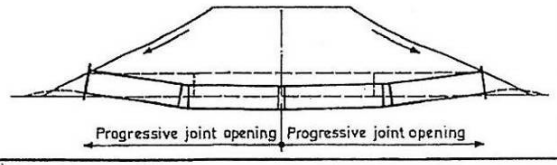
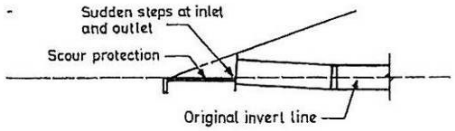
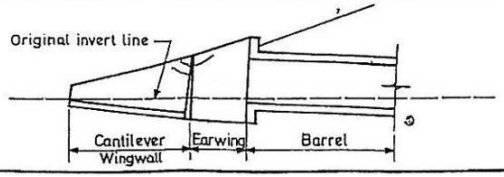
STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

BOX CULVERT FOUNDATION PROBLEMS : PRECAUTIONARY MEASURES

PROBLEM DESCRIPTION	DIAGRAM	ALTERNATIVE PRECAUTIONARY MEASURES
1. DIFFERENTIAL LONGITUDINAL SETTLEMENT This arises from variable embankment load on a culvert founding on compressible ground and results in opening and closing of joints, possible structural damage to the culvert barrel, deposition of silt in the barrel sag and possible loss of waterway area.		1. Camber invert upwards.(Check that a reverse gradient is not created in case the predicted settlement does not occur.) 2. Increase joint width. 3. Reduce joint spacing when predicted settlement is severe. 4. Articulate barrel by providing joint through complete section and enclose joint with a suitable collar around outer perimeter. 5. Consider the removal of unsuitable founding material to some depth to be replaced by stronger granular backfill
2. TILTING OF BARREL END PANELS Outward rotation of a culvert end panel may occur in very poor founding conditions due to the mass of the earwings hanging from the end of the barrel, resulting in opening and closing of the end joint and possible structural damage.		1. Increase length of culvert end panel. Recommended minimum length is 6m. 2. Reduce length of earwings. 3. Continue barrel base slab beyond end of barrel to provide greater bearing area. NOTE :- Each solution is aimed at adjusting the centroid of the total vertical loads or the centroid of the bearing area so that they coincide
3. VARIABLE FOUNDATION CONDITIONS Variable founding conditions, e.g. shallow depth to rock for portion of culvert length, may lead to severe structural damage and "broken back" type failure arising from severe differential settlement.		1. Introduce additional barrel joints on either side of foundation discontinuity. Treat joints as for 4 under problem 1. 2. Camber invert upwards for portion of barrel on compressible ground. 3. If a rock pinacle approaches barrel invert for a short length, consider removal of rock and replacement with weaker backfill material.
4. EMBANKMENT & CULVERT STRETCH This only occurs in conjunction with problem 1, although settlement may occur without stretch, depending on the shear strength of the insitu founding material. Stretch arises from the outward shear flow of the founding material and creep of the embankment and may result in tensile failure of the culvert bottom slab at the joints and the ingress of fines from the fill.		1. In general, provide a continuous base slab with tensile tie bars in the bottom slab equal in area to the distribution steel detailed in the barrel walls and slabs. Enclose the joint with suitable collars around the outer perimeter. 2. In very poor founding conditions treat the joints as for 4 under problem 1.
5. BARREL SETTLEMENT RELATIVE TO INLET & OUTLET SCOUR APRONS Barrel settlement as described in problem 1, may result in the inlet and outlet scour aprons "floating" at a higher level than the culvert barrel. In these cases concrete aprons may become severely cracked and silt deposited at the downstream end of the barrel resulting in a loss of waterway area.		1. In sandy founding conditions where settlements will be "instantaneous" (during construction) construct concrete apron slabs only after embankment fill over culvert is completed. 2. In clayey founding conditions where settlements may be "long term" depending on the rate of dissipation of pore water pressure, consider use of flexible aprons (e.g.gabions) laid late in the construction program and which could be relaid if settlement continues.
6. BARREL SETTLEMENT RELATIVE TO WINGWALLS Settlement of cantilever wingwalls may be associated with barrel and earwing settlements, resulting in the jamming of the top or bottom of the joint between the cantilever wingwalls and ear wingwalls as displayed by local shear cracking of the top or bottom corners of the walls.		1. Provide a sufficiently wide joint between the walls to prevent jamming and seal the back face with galvanised iron sheeting or similar to prevent the ingress of fines from the embankment. 2. In particularly poor founding conditions consider replacing the cantilever wingwall with gabions or reinforced earth walls which are tolerant of settlement.

CHAPTER 5 - PILES AND CAISSONS

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5.1 SCOPE

Monitoring of the construction of piles or caissons as the means to support road bridges is concerned with the achievement of adequate load bearing capacity and safety during construction in difficult founding conditions. Both these forms of foundation construction are subject to various degrees of financial, technical and physical risk because of the uncertainties and arising from deep foundations in ground conditions which can be highly variable and environments which often have high water tables or are subject to flooding.

Piled foundations are usually the first alternative considered when it is impractical, uneconomical or unsafe to found conventional footings at shallow or intermediate depths below ground. There is a sufficiently wide range of piling systems available from which to select appropriate foundation solutions in most types of ground conditions for road bridges which require deep founding. Piling is usually considered from depths of about 7 m and can reach depths of 50 m or more. This form of foundation is widely used in South Africa and is served by a well established industry.

Caissons provide an alternative means to achieve adequate founding at intermediate to significant depths in both land and water environments. This system has been frequently used overseas as the most practical means to found major bridges in deep water conditions and is employed in South African harbour engineering for the construction of wharves and quays. Whereas open caissons are now seldom used for bridges in South Africa because installation is comparatively slow, this form of foundation construction can be a viable option for depths of about 5 m to 9 m because of the very low establishment costs involved.

In this chapter guidance is provided about the design factors which affect the selection of particular types of piles for deep foundations and subsequently become the concern of the contractor and those monitoring the work, as well as about the issues which commonly arise during the construction of piled foundations. Similar commentary is also provided about the issues which arise during the construction of caisson foundations.

Monitoring staff who require more detailed guidance about all aspects of the design and construction of piled foundations or caissons relevant to their duties are encouraged to study the references listed at the end of this chapter.

5.2 PILES

5.2.1 Function and Form

The function of piled foundations is to transmit the applicable combinations of permanent and transient loads which are applied at the top of the piles, through weak compressible soil or fill materials onto stiff or dense soil strata or rock at lower levels, in such a manner as to prevent excessive settlement, horizontal displacement or rotation of the supported structure.

Piles are slender, 'column like' structural members, usually acting in groups, which are installed vertically or at a slope (rake) in the ground by various techniques, to sufficient depth to achieve the necessary load bearing capacity through frictional resistance along their sides, end bearing resistance at their bases, or combinations of both.

Traditionally the design of piles in Southern Africa has been based on Working Load methods, which embody a global factor of safety to accommodate uncertainties in both the load effects and the pile/ground resistance. In the future pile design is likely to follow the Limit State design methods

outlined in the relevant Eurocodes, in which the serviceability and ultimate limit states are considered with regard to the function and strength of the piling structure respectively.

Pile groups which are required to resist the combined effects of vertical and horizontal forces imposed on earth retaining structures such as bridge abutments for example, achieve the necessary resistance by the provision of raking piles installed at a slope in the opposite direction to the horizontal forces and/or the resistance to horizontal movement provided by the soil surrounding the piles and against the pile cap (subgrade reaction).

In circumstances when a pile is installed through compressible soil strata which undergo consolidation after the pile is in place, the downward movement of the consolidating soil and of any overlying soils relative to the pile will cause a downward drag on the shaft of the pile. This is termed 'negative skin friction'. These conditions sometimes arise in the case of bridge abutments, when the retained embankment causes down drag mainly on the rear piles of the supporting group.

In these instances it is necessary to determine from prior soils investigations, the depth to which consolidation will occur and thereafter to establish the magnitude of the induced down drag forces imposed on the piles. For the purposes of design, the capacities of the piles affected by such down drag are usually de-rated by the magnitude of the estimated down drag.

Whereas materials such as timber and steel are sometimes used for piles, in modern bridge engineering piles are predominantly formed from reinforced concrete and to a lesser extent from prestressed concrete, in some cases with steel tube casings depending on the method of forming and installing the piles. The principal piling systems, together with the various types of piles which have been developed by the specialist piling companies who carry out this type of work are discussed in section 5.2.5 of this chapter.



Photo 5.1: Typical installation of driven precast piles

5.2.2 Design and Construction Factors

Many of the factors which are described in Sections 3, 4 and 5 of Chapter 4 : Foundations, apply equally to the design and construction of piled foundations. However, in the case of piling it must be emphasised that, unlike conventional foundations the nature of the founding strata can usually not be visually inspected and it is often necessary to verify the integrity of the piles by indirect methods. The selection of the piling system most suited to the particular circumstances and the load bearing capacity

of the system adopted are therefore highly dependent on the adequacy of the geotechnical and subsequent investigations and indeed on the skill and experience of the specialist sub-contractor appointed to carry out the work.

5.2.3 Geotechnical and Subsequent Investigations

In all cases when piles are likely to be adopted as the method of founding bridge structures, it is essential that the planning (location, extent and type) and implementation of the geotechnical investigation and the analysis of the data obtained, should be entrusted to an appropriately experienced geotechnical specialist. The geotechnical report should provide advice about the alternative piling types most suited to the particular founding conditions.

The services of the same specialist should be utilised for subsequent advice or analysis when relevant, concerning:

- Overcoming difficulties encountered during the installation of the piles.
- Interpretation of the mixed strata extracted as spoil from bored piles for example, which may be difficult to classify for the purposes of measurement and payment.
- Pile testing procedures, measurements and interpretation.

REQUIREMENT

It is essential that a copy of the geotechnical report, including borehole logs, be available on site and that the monitoring staff are aware of its contents. This document provides important information about the obstructions and difficulties expected to be encountered during the installation of piles.

5.2.4 Factors which Influence the Selection of a Pile Type

NOTE: The permission of Messrs Franki Africa to reproduce the text contained in this section from their publication : A Guide to Practical GEOTECHNICAL ENGINEERING in Southern Africa (Reference 2) is acknowledged with thanks. It is advisable to have a copy of this publication on site for the guidance of the monitoring staff during piling operations.

"Before the design engineer can consider what type of pile is best suited to a project the following basic information is needed as a minimum requirement.

- Detailed geotechnical information
- Structural details and loadings
- Allowable total and differential settlements
- Knowledge of the site and its environs

Using this information, the engineer will need to consider the following points regarding the various piling systems so that the most suitable foundation system can be chosen for the project:

STRUCTURAL

- Range of pile sizes to suit the loading
- Founding level to meet the pile load capacity
- Founding level to meet the settlement criteria
- Spacing of piles
- The allowable rake of the piles if required
- The ability to resist tension forces if required

- The ability to resist horizontal forces if required
- The clearance from existing buildings
- The durability of the pile shafts

SOIL PROFILE

- If driven, whether driving will be easy, difficult or impossible
- If bored, whether temporary casings will be required
- If bored, the difficulty in penetrating to the required depth
- The presence of obstructions such as boulders
- The founding level to meet pile load capacity
- The founding depth to meet settlement criteria
- Very soft layers which can cause problems with cast-in-situ piles
- Rock-sockets
- Presence of groundwater, and at what level
- The presence of aggressive groundwater
- The potential for pile heave during installation

ENVIRONMENTAL

- The effects of noise pollution caused by piling equipment
- The effects of vibration caused by pile equipment installation

CONTRACTUAL

- Access to and on the site for equipment
- Headroom clearance on site for piling equipment
- The cost of the piles
- The cost of the pile-caps and ground beams
- The installation risks associated with a particular pile solution
- The remoteness of the site
- The availability of skills and plant to install the piling system
- Adequate plant and people resources for large contracts"

Whereas some of the factors listed above are the concern only of the bridge designer, many of these factors may come into play during the process of construction and therefore become the concern of the contractor, the specialist piling sub-contractor and the staff appointed to monitor the work. These factors should therefore be seen as a preliminary list of the points to watch out for during the installation and testing of piles.

5.2.5 Available Piling Systems



Photo 5.2: Augered pile with temporary casing in soft sand

Piles may be classified in various ways: the following schedule is based on the degree of displacement of the soil in which the piles are installed and which include various types related to the method of installation. Plant and equipment is available for each of the pile types listed, some of which are commonly used for bridge foundations in South Africa (marked thus *) and others are either seldom used for bridges or are comparatively new on the market.

CLASSIFICATION RELATED TO DISPLACEMENT

LARGE DISPLACEMENT (Cast-in-Place)	**SMALL DISPLACEMENT** (Driven Pre-Formed)	**NON-DISPLACEMENT** (Bored Cast-in-Situ)
* Driven cast-in-place pile (DCIP)	* Precast pile	* Auger pile
Driven tube piles	Steel H-pile	Underslurry pile
Full displacement screw pile		* Continuous flight auger (CFA) pile
		Forum bored pile
		* Oscillator pile
		Rotapile
		Micropile

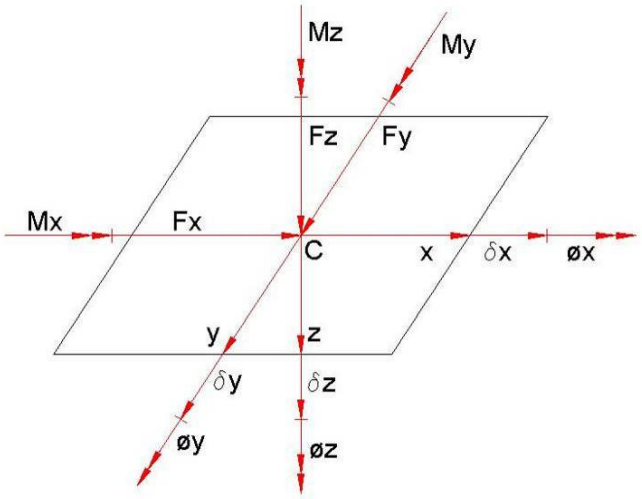
The details of the available pile types are summarised in Reference 2, in which the size range, typical working loads, maximum rake and depth range, cost indicators, use limitations, noise and vibration levels and site requirements are set out. The summary provides a convenient means of comparison to evaluate the suitable pile alternatives for a specific project. The summary is followed by detailed descriptions of the positive and negative features, standard and special installation procedures, potential problem areas and precautionary measures concerning each type of pile.

5.2.6 Selection of Piling System

5.2.6.1 Design data

The data required for the analysis and design of the proposed scheme and for future record purposes includes the following:

- Critical design-load combinations of the co-existent permanent and transient loads applied at the underside of the pile cap and the centroid of the pile group, relative to a defined system of axes, as shown in Figure 5.1. (Tabulated on the drawings for each pile group). Load tables should clearly state whether the loads are service or ultimate.
- Permissible movements which can be accommodated by the structure relative to the pile group centroid and system of axes, including: displacements in the horizontal plane, deflection vertically, rotation about any axis, as illustrated in Figure 5.1.
- Information required for the calculation of down drag forces on piles when relevant.
- Full details of the geotechnical investigation including borehole logs, test results etc.



NOTATION

Axes	: x, y, z
Forces	: F
Moments	: M
Displacements	: δ (x, y)
Settlement	: δ (z)
Rotations	: ø
Pile group centroid	: C

Figure 5.1

Note:
The piling design data included on the drawings should not be interpreted by contractors as an invitation to offer alternative piling designs. This information and the As Built piling records are required for future reference in the event of the need to subsequently widen or double bridges which have piled foundations.

5.2.6.2 Proposed design

Following assessment of the structural, geotechnical, environmental and contractual factors listed in sub-section 5.2.4, a piling system deemed to be best suited to the specific project is selected and thereafter analysed and designed on an iterative basis, which usually involves refinement of the pile layout and adjustment of the pile sizes, rake etc. The proposed design resulting from this process is shown on the drawings and described in the project specifications.

5.2.6.3 Alternative designs

Some specifications (COLTO Subclause 6113(c) for example) provide for the submission of alternative piling designs. The engineer needs to be aware of the potential risks of alternative designs, which may arise from the unsuitability of the type of piling proposed in regard to the particular foundation or other site conditions. The applicable specifications (COLTO Subclause 121 for example) also invariably indicate that an alternative will be considered only if a tender for the proposed design has been fully priced and completed.

WARNING
It is imperative that any alternative should be referred to both the design engineer and the geotechnical specialist, and that the employer's "in-house" specialist should agree to the acceptance of an alternative.

When alternative designs are permitted the engineer should ensure that the full details of the geotechnical investigation including borehole logs, test results, details of the groundwater regime, and all other factual geotechnical data are incorporated in the tender documents. Bearing in mind the limited time available during the tender period, contractors tendering for piling works should not be required, during the tender period, to visit an office to inspect geotechnical investigation reports and similar data; this information should be included in the tender documents for immediate access throughout the tender period.

Bona fide alternative piling designs which comply fully with specifications should be carefully reviewed, firstly in technical terms to ensure that these do not have any significant disadvantages compared with the 'proposed design', with regard to manufacture, quality of materials, ease of installation (including through boulder layers when relevant), structural capacity, testing procedures, durability and so on. Only when convinced of the technical merit and applicability of an alternative design should the engineer consider any financial implications of the alternative offer.

REQUIREMENT
Spurious alternative designs which are patently unsuitable for the foundation conditions should be rejected out of hand.

Even when an alternative piling system is deemed acceptable in general technical terms, the engineer should exercise caution unless it can be demonstrated that the plant and operators intended for the project are fit for the purpose and have the necessary skills respectively, in relation to the complexity of the foundation conditions and the size of the project.

Approval of the engineer's recommendation rests finally with the employer. Following such approval the basis of payment must be finalised and the detailed information required from the contractor (method statement, corrected working drawings etc.) must be provided prior to the commencement of the piling work. Costs of drawing and design are to the contractor’s account.

5.2.7 Construction

The various construction operations required for the different types of piles are described in the specification, which provide a guide to the monitoring staff. Issues likely to arise and points to watch are described in the following sub-sections in relation to the usual sequence of the work.

5.2.7.1 Access and drainage

Except in the case of stand-alone piling contracts, access and drainage do not apply specifically to piling operations, but relate to the project as a whole, as briefly discussed in 4.8.4 of Chapter 4. However, with regard to piling operations, which often require the use of very large and heavy rigs and other equipment, particular attention must be paid to the size, strength and stability of access causeways and artificial islands, which require careful planning in order to facilitate the setting up and movement between pile positions.

In this context drainage relates to the exclusion of surface water from the work areas, which can become difficult or unsafe when muddy or waterlogged.



Photo 5.3: Installation of 1,35 m dia bored oscillator piles with temporary casings. Note temporary working platform in river environment.

5.2.8 Establishment on the site for piling

Establishment on the site for piling is usually included in the specifications as a separate payment item, over and above the main contract establishment, and provides for any additional measures required, such as piling platforms, floating barges etc. and for establishing and subsequent removal of the specialised plant and equipment required for carrying out the piling operations.

At the tender stage it is important that the engineer should verify that the plant and equipment proposed by the contractor is sufficiently powerful and otherwise suitable to carry out the piling operations efficiently, especially in difficult and very deep founding conditions.

If after enquiry the proposed equipment is deemed to be inadequate, this should be addressed in the conditions of award. Underpowered piling plant can lead to delays in the piling work, with a corresponding effect on the main contractor's programme, giving rise to claims on various grounds. Even spurious claims in this context can be difficult to fully defeat, particularly if the geotechnical information provided in the tender documents is not sufficiently comprehensive.

IMPORTANT
Monitoring staff are advised to speak to a knowledgeable geotechnical engineer with experience in piling to determine whether the equipment is adequate.

5.2.8.1 Setting out

The accuracy of setting out of piles is a critical initial step which must be carried out to the accuracy stipulated in the specifications. It is recommended that the same procedural steps as generally outlined in 4.8.1 of Chapter 4, should be followed with regard to the independent checking, verification and signing off of the setting out of pile groups and individual piles.

WARNING
Particular care is advocated with regard to the checking of all aspects of the setting out and geometry of raking piles, to ensure that due allowance is made for the offset in the plan position of these piles at the platform level relative to the underside of the pile cap.

Setting out also involves the provision of adequate pre-installation frames and equipment from the standpoint of the geometry of the piles, as these frames must be designed to ensure that the piles can be installed in their proper positions and true to line and slope. These and the other functions of the pre-installation frames are subject to the approval of the engineer.

5.2.8.2 Installation

Prior to the commencement of the piling operations the monitoring staff are advised to inform themselves about the intricacies and method of construction of the specific piles to be installed as well as about the capabilities and automatic recording devices of the plant to be deployed. Additionally, information about the difficulties commonly encountered with the specific piles will forewarn them of the possible need to seek the advice or intervention of the engineer.

Engineer's approval and decisions

It needs to be borne in mind that all piling work is subject to the approval of the engineer. The most critical input of the engineer during the process of installation relates to the approval of the length and founding depth of each pile, to ensure that adequate load bearing capacity has been attained, without the potential for excessive subsequent settlement.

This is often a difficult decision when significant resistance to driving or other methods of installation are encountered at depths which are substantially less than indicated by the geotechnical investigation. This may arise from the presence of unidentified obstructions (e.g. the presence of boulder layers) or of comparatively thin but very dense sand or stiff clay or hard rock layers. In other instances the contractor may report inadequate driving resistance or other indicators of concern at the pile depths shown on the drawings.

In either event the decision on the steps required to overcome difficulties or to continue to greater depth rest with the engineer. This will inevitably follow consultation with the contractor and in the event of disagreement, the engineer may require the contractor to undertake additional foundation investigations, core drilling or other measures to settle the matter. Such additional measures are sometimes also required in order to settle disputes about the classification of materials when significant financial sums are involved.

The initial duties of the monitoring staff include the verification of:

(a) The adequacy of the access and drainage arrangements, and of any piling platforms as depicted on the contractor's drawings or described in the method statements.

(b) The adequacy of the contractor's plant and equipment in terms of the contract.

(c) The accuracy of the setting out and any other geometry controls or requirements.

(d) The adequacy of the contractor's safety arrangements in terms of the approved safety plan.

(e) The suitability of the contractor's provisions to meet the requirements of the Environmental Approval.

(f) The approval of the proposed concrete mix design.

(g) Mix designs may however be required to be redesigned for aggressive ground conditions.

REQUIREMENT
The use of grout in place of concrete must be approved by the engineer.

Throughout the process of piling the monitoring staff are expected to verify that:

(a) The quality, sizes and type of the materials, prefabricated components etc. are in compliance with the specifications, drawings and supplementary documents provided by the contractor.

(b) The contractor's work follows the dictates of sound practice in compliance with the drawings, specifications and method statements applicable to specific type of piles being installed and does not involve any short cuts which could impair the quality and load bearing capacity of the piles.

(c) It is important that the monitoring staff ensure that the lengths of all specified rock sockets are achieved.

REQUIREMENT
Any alteration of the specified socket lengths must be approved by both the engineer and the geotechnical specialist.

For all types of cast-in-situ piles, the monitoring staff should check that the reinforcing steel:

(a) Complies with the sizes, types and fixing shown on the drawings and is sufficiently rigid to withstand handling, insertion and suspension in place during in-situ concreting operations.

(b) Cages have sufficient central space to permit the placing of concrete by tremie pipe or other approved means.

(c) Is adequately spliced in order to meet length and strength requirements and that there is sufficient splice reinforcement available on site to permit this operation without delay.

(d) Is inserted to the correct length, level and position and rigidly held in place by approved roller spacers, immediately prior to the commencement of concreting operations for most types of augered, bored, driven in-situ or screw piles. (It should be noted that the reinforcement for CFA piles is inserted only after the concreting or grouting has been completed and must be carried out prior to the initial set of these materials).

Any tubing shown on the drawings for subsequent integrity testing or core drilling of the piles should be equally spaced around the inner perimeter and firmly attached to the main reinforcing bars.

With regard to the in-situ concreting of piles:

(a) All pile holes which are not lined with permanent casings and which are not self supporting require temporary casing for the full depth of the hole. During concreting such temporary casings must be carefully extracted to ensure that the trailing end is below the advancing concrete level by not more than about 1 m.

(b) Thin walled permanent casing is advocated in the case of raking piles which are especially prone to the collapse of the soil faces. Casing will also overcome the difficulty of installing reinforcement which can snag in the faces of raked holes.

(c) On river bridges when pile excavations are invariably full of water, concrete has to be placed using standard tremie techniques with high slump concrete. Whereas best practice should always be followed in construction using tremie methods, the avoidance of difficulties and the quality of the pile are highly dependent on the skill and experience of the operator and the support team.

(d) In the case of CFA piles some contractors prefer to use a sand/cement grout instead of concrete as it is easier to pump. However, in sandy soil conditions there is a much greater tendency for the grout water to migrate into the surrounds than in the case of concrete, which results in a drop in the level at the head of the pile and the need to add extra grout to maintain the top level. Most of the problems arising with this type of pile relate to necking of the pile shafts arising from the extraction of the flight at a greater rate than the inflow of concrete or grout through the hollow stem of the flight auger. Unless the piling rig is

modern and equipped with an on-board recording device which provides adequate control, the manufacture of this type of pile is largely in the hands of the operator.

Monitoring of precast pile fabrication requires special attention to:

(a) The position of coupling points, which should not be closer to the underside of the pile cap than permitted by the specifications or as instructed by the engineer. This point requires early discussion with the contractor about the lengths of piles to be precast in relation to the anticipated piling depth from ground and the level of the underside of the pile cap.

(b) The adequacy of the size and fixing of the reinforcement, the pile shoes and particularly to the accurate positioning and squareness of the pile coupler sockets.

(c) The lengthening of the piles by coupling. If the adjacent coupled sections are not truly axially in line, within the tolerance requirements, the faulty section or sections should be rejected and replaced.



Photo 5.4: Typical precast pile casting yard; note pile couplers vary in design for each piling contractor.

During the driving of piles the monitoring staff are expected to pay special attention to:

(a) The alignment of the piles and casing controlled by the pre-installation frames, in order to prevent the bending of precast piles in particular and their subsequent classification as defective if installed outside the specified alignment tolerances.

(b) The measures adopted to prevent splitting or other damage to the heads of precast piles or the trailing edges of casings.

(c) The limitations imposed on water jetting or pre-drilling through hard layers such as very dense sands, with specific reference to percentage of length limitations. **Note:** Pre-drilling is aimed at preventing damage to the piles in hard driving and must be approved by the engineer. It is recommended that the cross-sectional area of the pre-drilled hole should not exceed about 80% of that of the pile and that the loosened material should largely be left in the hole to ensure that the lateral support to the installed pile is not compromised.

(d) The installation sequence of the piles adopted by the contractor, which may result in the heaving of previously installed piles. In the event of heaving, the corrective measures shall be determined by the engineer.

(e) The achievement of the final set of precast piles, at which the adequate load bearing capacity of the pile is deemed to be achieved.

Note: The final pile set is the depth of penetration of the pile into the ground following the impact of a hammer of a certain mass, dropped through a certain distance to impart a certain number of blows. All of these amounts or numbers are predetermined for each precast piling project and are usually determined from the well known Hiley piling formula for short piles (about 20 m or less) or using the Wave Equation method for long piles (greater than about 20 m). An example of a trial pile load-settlement results for a pile driven to a pre-determined set is illustrated in Appendix 5D.

The final set and temporary compression diagram should be recorded as part of the pile record for each pile. It is recommended that when the piles are founded in saturated clay strata, the final set of a certain number of the piles should be rechecked after 24 hours by redriving to ensure that there is no subsequent increase in the set. Depending on the findings, it may be necessary to redrive all of the piles driven in the preceding 24 hours.

Augered and bored pile holes are required to be:

(a) Temporarily cased when there is a danger of collapse of the sides of the holes before or during concreting.

(b) Completed without the use of water unless permitted by the engineer.

(c) Cleaned out to obtain a firm and level surface and thereafter inspected by camera or by the engineer strictly in compliance with the applicable safety regulations.

(d) Underreamed after the initial inspection, as shown on the drawings, and thereafter again inspected and further cleaned out if necessary.

(e) Socketed into rock to the stipulated dimensions, when shown on the drawings. It is usually necessary to sink casings into the top part of the socket to prevent the ingress of saturated sand. The socket is formed within the casing by chiselling and removing the spoil is by means of a suction baler.



Photo 5.5: Ready to be lowered for inspection of bored oscillator pile



Photo 5.6: Soundly founded bottom of oscillator pile

5.2.8.3 Obstructions and difficulties

Obstructions are defined as identified if classified and described in the contract documents and included for payment in the schedule of quantities. The following materials are those classified as obstructions in the specifications (as defined in COLTO Subclause 6113(o) for example):

(a) Matrix

(b) Coarse gravel

(c) Boulders

(d) Rock formation.

These classes are defined in terms of sieve size and the latter three are usually required to be of at least R2 hardness in terms of the applicable rock classification in order to qualify. Rock must be further classified as R2, R3, R4 or R5 as applicable.

Unidentified obstructions by definition cannot be classified in terms of this Subclause and may be included in or excluded from the scheduled quantities for payment purposes. Payment for unidentified obstructions is usually related to the rates tendered for identified obstructions and determined from equivalent rates of penetration actually achieved, or alternatively in accordance with the provisions of the general conditions of contract.

Obstructions are the main cause of difficulty in the process of installation of any type of pile and in the case of driven displacement and prefabricated piles may result in the abandonment of a pile, if after the implementation of suitable alternative driving measures installation to the required depth still proves impossible. In this instance the engineer will inevitably order the installation of one or more replacement piles.

However, various other factors cause difficulties, delays and possible abandonment in the process of the manufacture and installation of piles. The best defence against these, as outlined in Section 5.2.4 is the selection of the type of pile best suited to the circumstances. Examples of these factors are:

(a) Heaving of previously installed driven piles due to upward movement of the surrounding soil caused by the driving of an adjacent pile. This occurs in saturated clayey and silty soils and can result in damage to the green concrete and reinforcement bond in newly cast piles. This can be avoided by predrilling, jetting or coring or by wider spacings between the piles, but must be addressed when found to occur.

(b) Splitting of the casings of driven steel tube piles, which can be avoided by top rather than bottom driving or by predrilling, jetting or coring in hard driving conditions through very dense or stiff soils.

(c) Necking of the concrete in CFA piles, as discussed above, and problems associated with blockages during the process of placing concrete by tremie methods, which can occur even when construction is undertaken by experienced teams and must be identified by integrity testing.

5.2.8.4 Determining pile lengths

The design of the piles and pile groups shown on the drawings of the 'proposed design' or on the approved alternative design and the quantities in the applicable schedule of quantities are based on the subsurface data shown on the drawings.

However the founding depth of the piles will be determined by the design engineer as the work proceeds, as discussed under Engineer's approval and decisions in 5.2.7.4 above. For this purpose the monitoring staff are required to promptly inform the engineer of the contractor's concern about the adequacy of any pile at the anticipated depth and indeed of any difficulties arising from obstructions or other problems arising during the manufacture and installation of a pile, following which the design engineer will prescribe the steps to be followed.

5.2.8.5 Piling data

For the purposes of measurement and payment and of the data required by the employer to be shown on the record (as-built) drawings, the monitoring staff are required to keep comprehensive records of the manufacture and installation of each pile and of the circumstances which give rise to delay and the possibility of a claim for extra work, including the standing time in respect of pre-installation frames when applicable.

The records are required to be in the form prescribed by the engineer for each pile and will generally include data such as set out in Appendix 5B (Piling Data Sheet). It is therefore essential that among other records the monitoring staff should record the following for the full length of each pile:

(a) The driving effort and penetration (set) for driven piles down to and including the founding level.

(b) The nature of the spoil extracted from augered and bored piles in terms of the classification of materials for anticipated obstructions. This record should also include the rate of penetration (m/h) through the different materials encountered down to founding level, including rock sockets when applicable.

(c) The length of each rock socket, when applicable.

Whereas the classification of materials as described in the specifications is clear cut and distinctive, in practice with large and deep piles which are required to penetrate through alternating layers of hard and soft materials of differing types, classification can be quite difficult and it is prudent to extract depth related samples from the spoil for the purposes of agreeing or later determining the classification and rock quality designation.

REQUIREMENT

It is important that piling records should be compared, agreed and signed off by the monitoring staff and the contractor as soon as practical following completion of each pile. In the event of disagreement about classification or the thickness of layers the matter should be promptly referred to the design engineer and geotechnical engineer for determination.

5.2.8.6 Stripping of pile heads

When it is intended to carry out load tests on piles it is preferable not to strip the pile heads as described in the specifications until such tests have been completed. Indeed it is preferable to place the concrete of those piles which are to be load tested to a level just above the top of the reinforcing steel.



Photo 5.7: Stripping of large diameter pile heads

When load testing is complete the stripping of pile heads can continue as described in the specifications followed by construction of the pile cap.

5.2.9 Pile Testing

In this section pile testing is deemed to include core drilling as well as static load testing and alternative methods of integrity testing. The main objectives of pile testing as part of bridge construction contracts are as follows:

(a) To check the structural integrity of the pile shaft and the quality of the pile/rock socket interface, when applicable.

(b) To verify that the pile's load/deflection performance meets the load capacity/deflection limitation requirements.

5.2.9.2 Core drilling

Core drilling through the entire shaft of a pile is usually considerably more expensive than integrity testing using sonic or cross-hole sonic testing methods and may not yield markedly better information when it is required to merely ascertain the presence of necking in the pile or cavities arising from blockages during concreting by tremie methods for example.

When core drilling is required to check the quality of the pile/rock socket interface of a large diameter oscillator pile it is recommended that three to four small diameter tubes are inserted in the pile to a level about 0,5 m above the bottom of the socket prior to concreting, as discussed above. Core drilling through the comparatively short length of concrete can be carried out on completion of the pile using one of the sleeves provided for this purpose.

If inadequate contact is found this should be rectified by pressure grouting using the cored hole and the results tested by coring through one of the other sleeves.

5.2.9.3 Load tests

Load tests carried out in terms of the requirements of the contract are required to follow the detailed procedures described in the specifications (refer to COLTO Subclause 8112(c) for example).

NOTE
It is often preferable to load test independent trial piles because of the difficulty of installing anchor piles or kentledge in the vicinity of a working pile which forms part of a group.

The ultimate test load defined in the specifications relates to the load at which the axial deformation of a pile under compression or tension suddenly increases disproportionately to the load applied or in the case of tension, the load applied produces a stipulated rise at the top of the pile, whichever is the lesser. This does not imply that the load should be applied to achieve these conditions but relates to that load at which the limits occur if this is lower than the maximum test load or allowable settlement stipulated on the drawings.

In the process of load testing a working pile, caution is advocated when loading the pile to more than one and a half times the working load as a test load of twice the working load can damage the pile if not applied in the correct manner, in which case the pile may have to be abandoned and replaced by one or more piles.

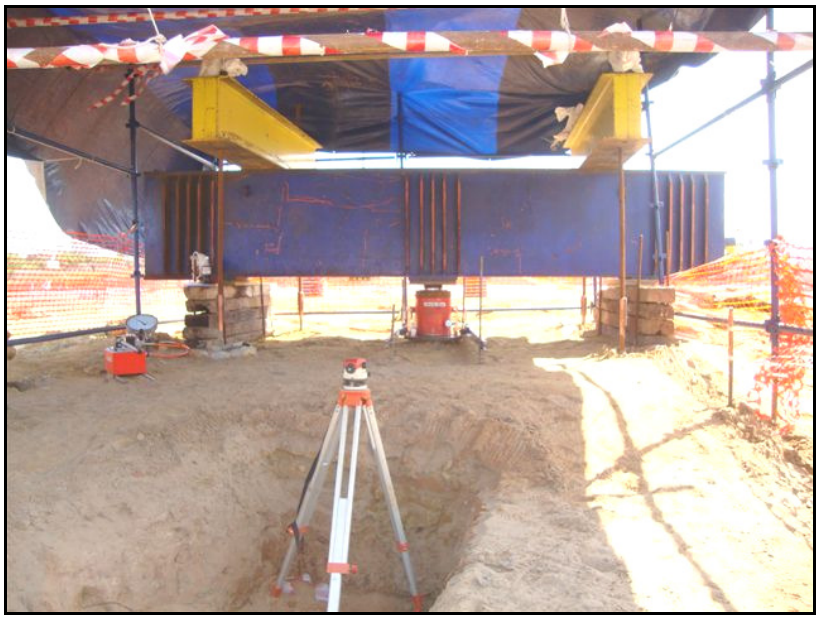


Photo 5.8: Load test of a driven precast trial pile using anchor piles

Trial piles constructed for the purpose of testing to actual failure are usually applicable only to large piling contracts because of the high costs involved. Static load testing procedures and configurations are fully described in Reference 2, as are the alternative methods of interpretation of the load test results. The most recent methods used for analysis of such results involve computer simulation of actual load test measurements in order to predict performance up to ultimate load, load sharing between shaft friction and end bearing and so on.

Piles may be found to be defective in terms of lack of compliance with specified geometric tolerances, damage caused during installation, load capacity or other deficiencies as determined by tests ordered by the engineer. Such deficiencies must be remedied at the contractor's cost by applying one of the methods specified by the engineer.

5.2.9.4 Pile integrity tests

Modern specifications usually provide for non-intrusive integrity testing of piles, which is undertaken by specialist companies experienced in this form of investigation. Pile integrity testing includes two alternative sonic methods viz: the Frequency Response (Pile Tapping) method and the Crosshole Sonic Logging (CSL) method.

The Frequency Response method is based on striking the pile top with an impulse hammer and simultaneously measuring the vibratory response, from which a response graph is drawn and analysed to indicate the depth of any defects. This method is applicable to piles with a minimum diameter of 250 mm and is typically limited to depths not exceeding 20 to 25 pile diameters.

The Crosshole Sonic Logging method requires the availability of minimum of three (preferably more) 50 mm diameter sleeves cast into and equally spaced near the outer perimeter of the pile, and lowering an ultrasonic transmitter and receiver into each pair of holes in turn, to log ultrasonic responses at sequential depths to detect defects. Depending on the findings of either method, the engineer will need to approve the piles or issue instructions regarding further investigations or remedial measures.

These methods should be applied to all bored piles and are quick and economical compared to load testing, which can be very expensive in the case of large diameter piles. It must be realised that the results of such integrity tests are merely indicators of structural defects and are subject to interpretation. Nevertheless they provide a useful and economical means of identifying materials and workmanship problems, which should be investigated further by more positive testing methods, such as core drilling.

The alternative methods of integrity testing of piles are described in References 2 and 3, which also outline the basis of operation of these methods and provide examples of the graphic representation of test results relating to sound and defective piles. Tests using these methods are required to be applied first to a calibration pile before testing working piles, which in turn must be tested prior to the construction of the pile cap for the pile group being investigated.

5.2.10 Measurement and Payment

The standard measurement and payment items for foundation piling are usually comprehensive (refer to COLTO Section 6100 Items 61.15 to 61.40 for examples) and need not be repeated in this text. However, it should be repeated that this is a facet of bridge construction which is the most susceptible to interpretation regarding the classification and quantities of excavated materials, standing times in the event of delays of the contractor's own making and arising from circumstances beyond his control etc. Piling work is therefore prone to the formulation of claims, whether justified or not.

The records made and kept by the monitoring staff must therefore be accurate and comprehensive in order to assist the engineer to make determinations which are fair and reasonable in relation to both parties to a contract involving piling.

5.3 CAISSONS

5.3.1 Function and Form

The function of caissons is essentially the same as for piles, viz to transmit the applicable combination of permanent and transient loads applied at the top of the caisson through weak compressive soil or fill materials onto stiff or dense soil strata or rock at lower levels, in such a manner as to prevent excessive settlement, horizontal displacement or rotation of the supported structure at the caisson cap level. In addition caissons are required to be founded at sufficient depth to prevent instability due to scour arising from major floods, when located in river environments.

Caissons for bridge foundations are usually cellular reinforced concrete structures, with circular, rectangular or more streamlined plan cross sections comprising one or more excavation compartments, and which are wholly or partly constructed at higher level and sunk in stages to the desired founding level, by internal excavation assisted by the application of kentledge. Caissons are invariably monolithic with the bridge substructure components which they support.

Small diameter concrete shafts comprising single open cells and constructed in the same manner as caissons are usually called cylinders. The distinction between cylinders and caissons is merely one of size and is necessarily arbitrary. Because of their smaller size (usually up to about 2,5 m diameter), cylinders lend themselves readily to precast concrete ring elements in their construction. This form of caisson construction can be very economical down to intermediate depths of about 7 to 8 metres because of the low establishment costs involved, but are not well suited to sinking through ground containing large boulders or with high water tables. Cylinders constructed with precast concrete rings are usually filled with reinforced concrete.

Kentledge refers to concrete blocks or similar heavy loads repeatedly erected on the top of the caisson walls in order to help overcome the frictional resistance of the soil surrounding the caisson during the stage by stage process of sinking the caisson into the ground.

5.3.2 Caisson Types and Applications

There are two principal types of caissons:

Open caissons

- Well type (top and bottom open to the air).
- Floating type (open top and closed bottom). During sinking operations, the chamber of an open caisson is exposed to atmospheric pressure.

Pneumatic caissons

- During sinking operations the internal air pressure of the closed chamber is maintained by compressed air at greater than atmospheric pressure in order to prevent water from entering the caisson working area.

Traditionally caissons are selected as the most practical method of founding long span bridges which impose heavy loads, in deep water environments. Even open caissons can be constructed to depths of 50 m or more depending on the soil conditions, whilst pneumatic caissons have been installed to depths well in excess of 100 m in other parts of the world.

In South Africa caissons have been successfully used in situations where the designs were best served by rigid support systems founded on dense sands or rock at depths ranging from about 20 m to 30 m in both land and water environments. However, along the KwaZulu-Natal coast there are a number of examples of scour related failures of bridges constructed in the period from about 1930 until 1960, which were supported on caissons sunk to inadequate depths and founded in alluvial deposits well above bedrock.

Caissons are generally deemed to be unsuited to ground conditions with a high incidence of boulders because of the tendency of one side of the caisson to hang up on boulders during sinking, with the danger of serious local damage to the cutting edge and the adjacent caisson wall. Nevertheless there are reported cases where single cell caissons have been sunk through dense boulder layers down to rock at depths of about 10 m, in which even oscillator piles were discarded as the possible means of founding, on the grounds of high cost and impracticality.

South African specifications (COLTO for example) generally describe the requirements for the construction of open caissons and exclude the construction of pneumatic caissons. This section therefore relates to the construction monitoring of open caissons only, but may need to be updated in the future to include guidance about the construction of pneumatic caissons, if the incidence of that type of caisson work is found to increase.

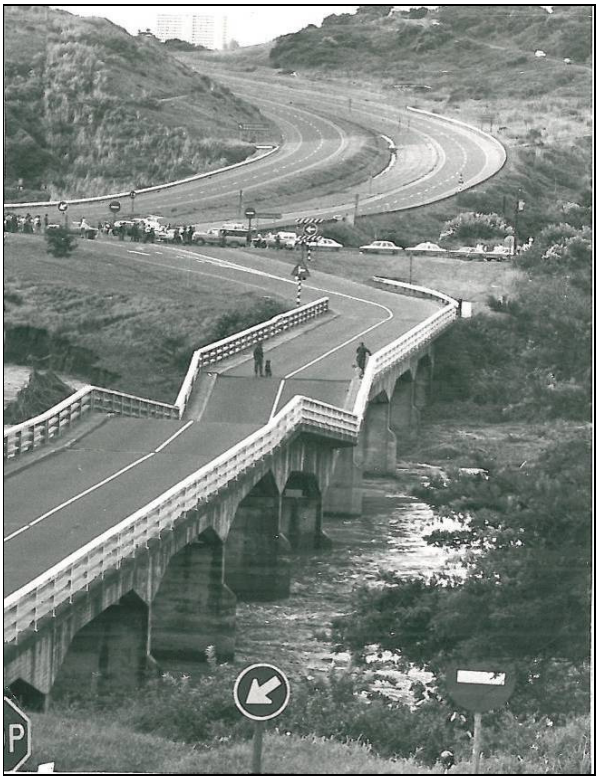


Photo 5.9: Scour failure of Illovo river bridge caissons,
(Main Road R102 along the KwaZulu-Natal east coast)

5.3.3 Design and Construction Factors

Many of the factors which are described in Sections 3, 4 and 5 of Chapter 4 : Foundations, apply equally to the design and construction of caissons. Likewise the design data outlined in subsection 5.2.6.1 of this chapter are required for the design of caissons.

However, the form, method of installation and structural behaviour of caissons are unlike those of piles. The designer, and subsequently the contractor and monitoring staff are therefore concerned with similar factors with respect to the foundation conditions but different issues concerning the forces to be resisted and the structural component design, construction and installation, such as:

(a) The nature and characteristics of the soil strata through which the caisson must be sunk with particular regard to the resisting skin friction and the obstacles encountered, including the level of the water table.

(b) The estimated maximum depth of scour when applicable, which should be conservatively established from recognised analytical methods or from model studies.

(c) The overall geometry of the caisson in relation to:

- the configuration of the substructure components to be supported;
- the mass required to facilitate sinking;

- the space required for the removal of spoil from within the caisson.

(d) The overall stability of the caisson and the supported structure for the most adverse combinations of loads and scour conditions.

(e) The bearing capacity and rigidity of the founding strata.

(f) The load combinations, including river forces when applicable, for which the caisson components must be designed during sinking and when complete in service.

(g) Durability considerations.

The basic elements of an open caisson in order of construction are:

(a) A cutting edge provided at the bottom of the outer perimeter of the caisson shaft, usually of structural steel, acting compositely with the adjacent concrete shaft wall.

(b) The shaft comprising the outer perimeter wall of the caisson.

(c) Internal walls, if applicable, which subdivide the well into different cellular compartments and stiffen the outer walls of the shaft.

(d) The bottom seal of the caisson, which is usually a thick mass concrete slab to close off the well when founding level has been reached, and locked in position by the provision of a large shear key or series of keys formed continuously around the inner perimeter of the shaft above the cutting edge.

(e) The backfill (ballast) to the caisson well, usually comprising clean river sand up to the underside of the caisson cover slab screed.

The cover slab is usually considered to be part of the substructure component supported by the caisson.

5.3.4 Geotechnical Investigation

Investigation of the foundation conditions for caissons is as important as that required for piled foundations and is required to provide detailed information about:

(a) The nature and characteristics (cohesive properties, angle of internal friction, density etc.) of the various soil horizons through which the caisson will be sunk.

(b) The depth of the water table and the presence of aggressive groundwater if any.

(c) The presence, classification and layer thicknesses of identified obstructions.

(d) The depth, safe bearing capacities and stiffnesses of potential founding layers.

5.3.5 Construction

The various requirements for the construction, sinking, sealing and filling of caissons are usually amply described in the specifications and do not warrant detailed repetition in this section. Brief additional comment is therefore provided as follows, which serve as points to be watched by the monitoring staff during the construction of caissons.

5.3.5.1 Access, drainage and establishment

Access and drainage as described in the specifications do not apply specifically to caissons, but relate to the project as a whole, as briefly discussed in 4.8.4 of Chapter 4. Establishment on the site for constructing the caissons is usually paid as a separate item over and above establishment on site for the project as a whole.

5.3.5.2 Setting out

The setting out of caissons is not measured and paid as a separate item but is of importance equal to that for any of the other substructure components and should therefore be given the same attention by the monitoring staff as outlined in 4.8.1 of Chapter 4.

5.3.5.3 Safety

The safety of personnel during the construction of caissons requires careful planning and constant vigilance because of the nature of the operations such as: working at increasing depth, often below the water table or in wet or submerged conditions, adjacent to a heavy structure which is in the process of being sunk into the ground and usually beneath buckets, grabs etc. used for the extraction of spoil. The degree of the danger which workmen face is related to the depth, rate of inflow of water, the size of the working space available within the well or its compartments and the manner and speed of their evacuation when dangers or difficulties suddenly arise.

The diligent implementation of the contractor's safety plan and the vigilance of the monitoring staff as well as the contractor's supervisors are of obvious importance in these circumstances. All cases of the emergence of dangers or difficulties during any of the construction operations require the prompt intervention of the engineer in consultation with the contractor.

5.3.5.4 Cutting edge

The quality, rigidity and strength of the caisson's leading cutting edge are of great importance to the subsequent success of the sinking operations through difficult strata and must be thoroughly checked by the monitoring staff regarding the quality of welds and connections and the embedments into the concrete to be cast subsequently. The cutting edge must be set dead level prior to the commencement of concreting.

5.3.5.5 Concrete work

It is preferable to decide on the height of the concrete lifts and the length of the vertical reinforcing bars and splices etc. only after consultation with the contractor in order to facilitate his construction operations.

In view of the significant forces and stresses to which caisson members can be subjected during sinking and when in service, the monitoring staff are expected to verify the highest quality of materials and workmanship on all facets of concrete work in compliance with the specifications. In particular they should pay attention to:

(a) The concrete mix design with particular reference to early strength.

(b) The concrete cover to reinforcement especially on the outside faces of the shaft.

(c) The quality and compliance with tolerances of the formwork on the shaft outer surfaces, which can significantly reduce or increase the skin friction resistances of the soil to sinking.

(d) The quality of the joints in the concrete which can be subject to tensile stresses at an early stage of concrete strength gain.

5.3.5.6 Sinking and excavation

Sinking

Once sinking commences three associated problems with the location and control of the caissons come into play, viz: tilt, twist and lateral shift. These are more pronounced and problematic during the early stages, for the following reasons:

(a) The caisson is not fully embedded in the ground.

(b) The caisson is often passing through soft layers which offer little lateral resistance and which may offer differential lateral or vertical resistance to sinking.

(c) In the presence of groundwater at a shallow depth, the effective weight of the caisson is reduced.

It is often worthwhile to ascertain the uniformity of the top three to five metres of the ground below top surface by dynamic cone penetrometer or other probes and to consider light but uniform recompaction of the top two metres of the soil. Estimates of the skin friction resistance of the soils at various depths should be made from the results of the geotechnical investigation in order to judge the timing of the need for kentledge in order to control and effect sinking.

The various ways of correcting the alignment of caissons during sinking are beyond the scope of this manual and are outlined in reference 1.



Photo 5.10: Sinking of 8 metre deep caissons in uniform sandy conditions

Excavation

It is usually recommended that caisson excavations should commence in the centre of the well and extend outwards towards the shaft and that excavations beneath the cutting edge should be effected simultaneously at geometrically opposite points. For large caissons the usual method of excavation in cohesive soils is by large clamshell grabs operated by a crawler crane or similar, whereas granular material can sometimes be more economically removed by sand pump. In either case, the excavation of material close to cutting edge can be facilitated by the use of jetting nozzles. These various methods can produce large volumes of water which must be handled by adequate pumping facilities.

5.3.5.7 Founding and sealing

The adequacy of the founding and sealing of caissons are important factors which have a significant influence on the load bearing capacity of these structures. The quality of the founding stratum and the means of achieving competent seating in the case of sloping rock foundations for example, must be verified by the engineer who should make a final inspection only after corrective measures have been implemented.



Photo 5.11: Caisson cutting edge concealed below wall.
Note continuous key to lock in bottom slab (seal)

5.3.6 Measurement and Payment

The standard measurement and payment items for caissons are usually comprehensive (refer to COLTO Items 61.41 to 61.49 for example) and need not be repeated in this text.

5.4 CHECK LISTS

Check lists related to piles and caissons and a pile data sheet are included in the Appendices to this chapter and are intended to serve as aide memoires to the monitoring staff and as convenient date related records for the signing off of the completed work. If required, a caisson data sheet should be prepared by the monitoring staff, similar in form to that provided for piles.

5.5 REFERENCES

1.) British Standards Institution; **Code of Practice for FOUNDATIONS**; CP8004, Latest edition.

2.) Frankipile South Africa (Pty) Ltd; **A Guide to Practical GEOTECHNICAL ENGINEERING in Southern Africa**; 4th Edition, 2008.

3.) SAICE Geotechnical Division; P**ILE TESTING Specification, Methods & Interpretation;** One-day Seminar; Fourways, 22 June 2004.

INDEX TO APPENDICES

5A - PILING CHECK LIST

5B - PILING DATA SHEET

5C - CAISSONS CHECK LIST

5D - EXAMPLE OF LOAD-SETTLEMENT RESULTS OF A TRIAL PILE

APPENDIX 5A

PILING CHECK LIST

CONSTRUCTION MONITORING

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1. DESIGN								
1.1 Postulated								
1.2 Alternative								
• Pile type, size etc.								
• Pile group configuration								
• Alteration to pile cap								
• Casing required								
• Founding : level								
: material								
: final set								
• Method of founding: bulbous base; underream; rock socket								
• Plant and equipment								
2. SETTING OUT (Prior to installation)								
3. PILING PLATFORM, PLANT AND EQUIPMENT								
3.1 Platform								
• Drawings and method								
• Installation CCP								
• Removal CCP								
3.2 Plant and equipment								
4. INSTALLATION ACCEPTANCE CRITERIA (Refer to pile data sheet)								
4.1 Materials and workmanship								
4.2 Geometry								
4.3 Embedments								
4.4 Founding								
4.5 Pile testing								
• Core drilling								
• Load test								
• Integrity : Frequency Response								
: Cross-hole sonic								
7. MEASUREMENT AND PAYMENT								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

APPENDIX 5B

PILING DATA SHEET

CONSTRUCTION MONITORING

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

PILE DATA	REMARKS
1. PILE DETAILS	
1.1 Type	
1.2 Cross section dimensions	
1.3 Materials	
• Concrete or grout : Mix; slump	
: Method of placing	
• Reinforcement : Mains	
: Stirrups	
• Embedded tubes : No; dia.	
1.4 Fittings, sleeves etc. : Rock shoe	
: Coupler (spacing)	
: Casing : dia. thickness	
2. INSTALLATION; GEOMETRY & FOUNDING	Date:
2.1 Geometry	
• Accuracy : Position	
: Inclination	
• Approved Levels : Top	
: Founding	
2.2 Method of founding and dimensions; bulbous base; underream; rock socket	
3. PILING EFFORT & RECORDS	
3.1 Driving effort and resistance to penetration at founding level (including compression diagram)	See attached record
3.2 Rate of penetration, particularly through obstructions (provide levels and strata thickness)	See attached record
3.3 Check for heave after 24 hours : Set after redriving	
4. SUBSURFACE DATA	
4.1 Depth to ground water	See attached record
4.2 Soil profile including thickness / depth of obstructions and rock socket	See attached record
5. PILE TESTING (indicate if trial pile)	
5.1 Core drilling; Remedial action if any	
5.2 Load test	See attached record
5.3 Integrity test : Frequency Response	See attached record
: Cross-hole Logging	See attached record
6. STRIPPING OF PILE HEADS	

Recorded by: Date:

Agreed by: Date

Note: Indicate N/A under remarks if not applicable

Note: This data is required for pile acceptance, measurement and payment and As Built records

APPENDIX 5C

CAISSONS CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1. CAISSON DETAILS								
1.1 Lift height								
1.2 Materials Concrete : Mix; slump								
2. SETTING OUT (Prior to sinking)								
3. ESTABLISHMENT								
3.1 Ground preparation								
3.2 Plant and equipment								
4. CONSTRUCTION								
4.1 Cutting edge								
4.2 Concrete work (per lift)								
• Formwork								
• Reinforcement including cover								
• Concreting and curing								
5. SINKING (Attach records)								
5.1 Position controls: tilt, twist, lateral shift								
5.2 Log of sinking including:								
• Rate of penetration								
• Ground water level								
• Soil strata levels and thicknesses								
• Obstacles and method of overcoming these								
• Application of kentledge:								
- Form								
- Weight (Lift No)								
• Excavation method								
6. FOUNDING								
6.1 Inspection and adequacy								
6.2 Founding level								
7. SEAL AND FILL								
7.1 Seal concrete and method placing								
7.2 Placing of sand fill								
7.3 Placing of concrete screed								
8. STRIPPING TO UNDERSIDE OF CAP								
9. MEASUREMENT AND PAYMENT								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

EXAMPLE OF LOAD-SETTLEMENT RESULTS OF A TRIAL PILE

CLIENT: **PROJECT:**

TRIAL PILE (No. 1) DATA

- 350 x 350 Precast concrete (50 MPa)
- Reinforcement : 4Y20
- Serviceability Load : 2000 kN
- Embedment depth : 23,9 mm
- Dense sand from 21,0 m

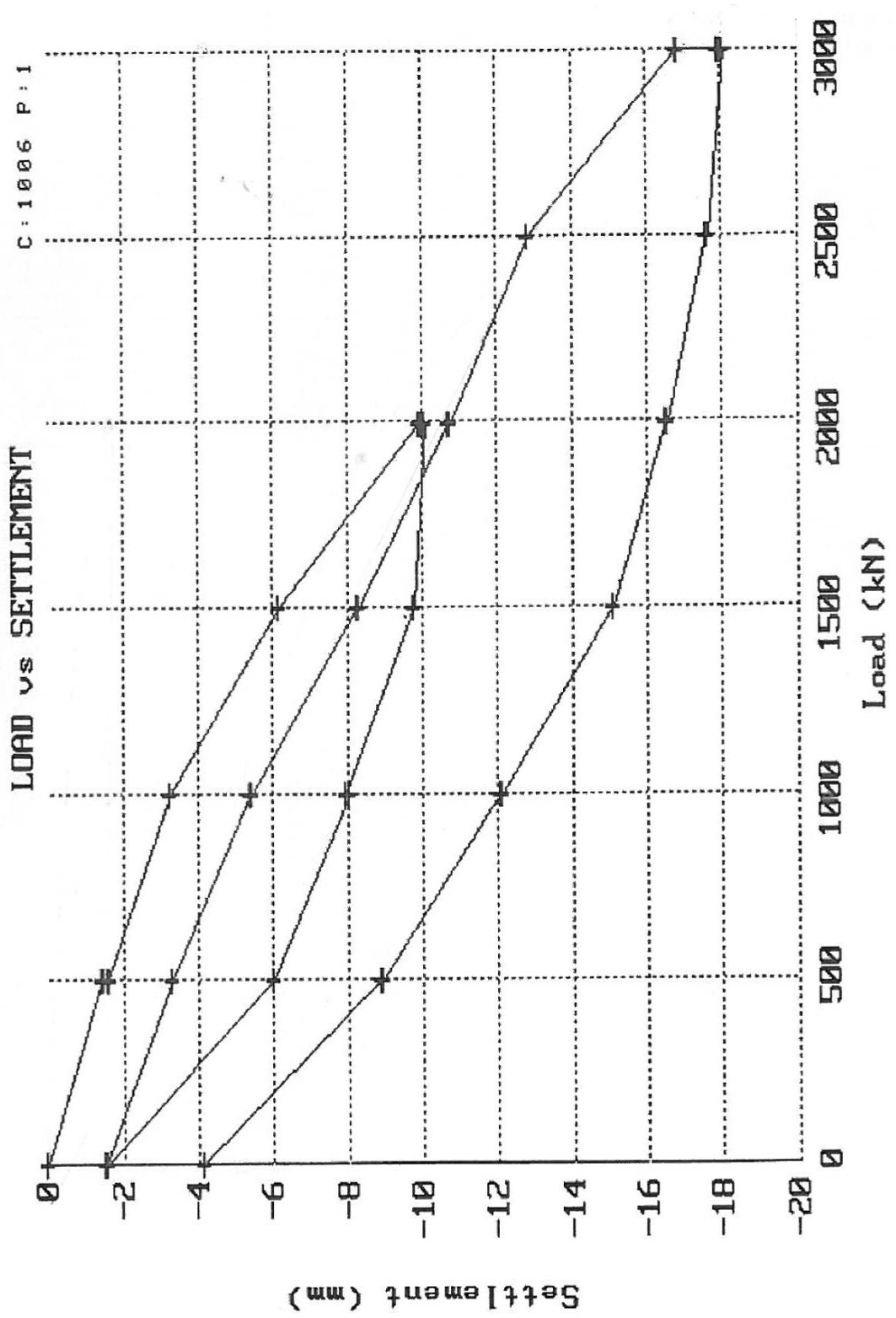
ESTIMATED FINAL SET

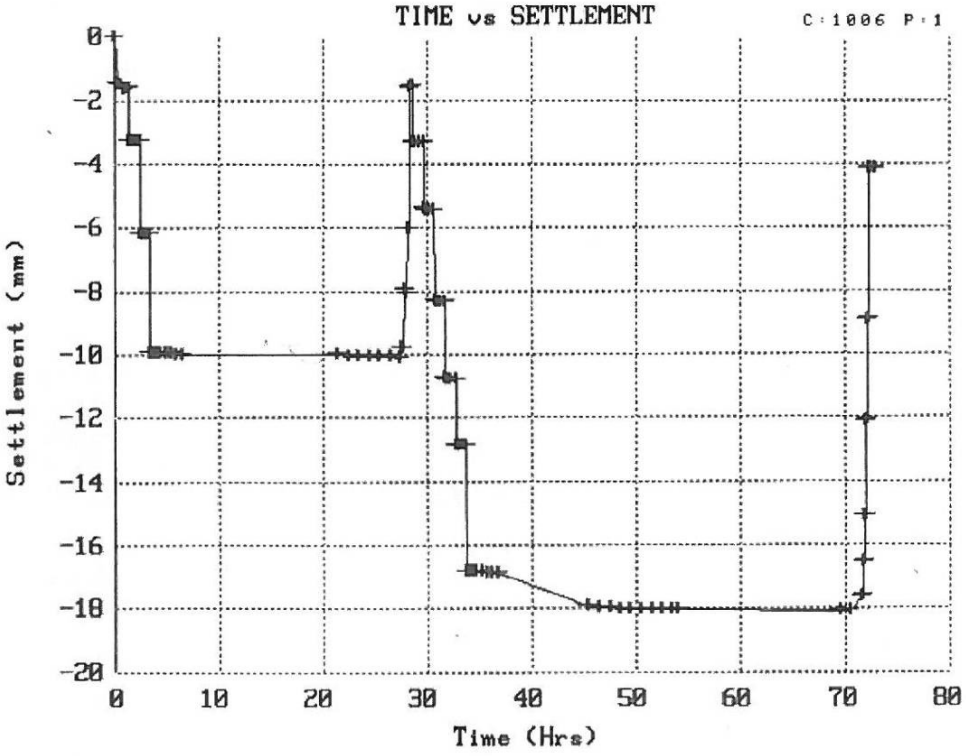
- 7,5 mm for final 10 blows (Determined from Hiley piling formula)
- Hammer mass : 50 kN
- Drop height : 600 mm

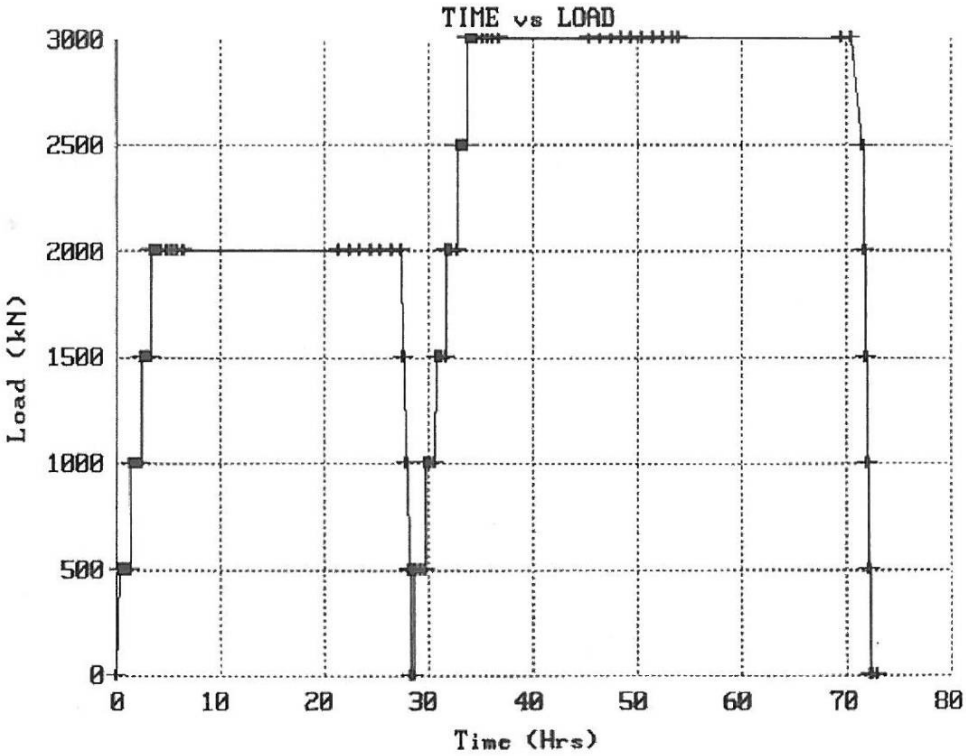
Load kN	**Settlement Acceptance Criteria**	
	Pile Head Settlement	**Residual Pile Head Settlements**
Nominal or Serviceability Load (2000 kN)	15 mm	6 mm
150% of Nominal or Serviceability Load (3000 kN)	23 mm	9 mm
200% of Nominal or Serviceability Load (4000 kN)	36 mm	12 mm

RESULTS

- 6,0 mm set for final 10 blows
- 100% service load : Pile head settlement : 10 mm
  : Residual pile head settlement : 1,6 mm
- 150% service load : Pile head Settlement : 18 mm
  : Residual pile head settlement : 4 mm


LOAD vs SETTLEMENT
C:1006 P:1
Settlement (mm)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
500
1000
1500
2000
2500
3000
Load (kN)


TIME vs SETTLEMENT
C:1006 P:1
Settlement (mm)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
80
Time (Hrs)


TIME vs LOAD
Load (kN)
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
Time (Hrs)

CHAPTER 6 - FALSEWORK, FORMWORK AND CONCRETE FINISH

DS Temple

6.1 SCOPE

This section covers the inspection and monitoring of Falsework, Formwork and Concrete Finish as per the applicable chapter of the Specifications. It also includes special attention which must be given to materials used, design and erection of falsework and formwork to be checked by the engineer's monitoring staff.

6.2 MATERIALS

The engineer's monitoring staff should confirm the suitability of proposed materials:

6.2.1 Falsework

- Steel Grade to be provided in accordance to Design Requirements.
- Timber Grade to be provided in accordance to Design Requirements.

Condition of all materials to be used should be checked by the engineer's monitoring staff to ensure that the materials are fit for purpose.

6.2.2 Formwork

The most commonly used materials for the manufacture of formwork are steel and timber. The monitoring staff should ensure that the surfaces of forms are clean and free of defects to ensure that the required surface finishes can be obtained. In order to obtain a good quality finish in accordance with the specifications, high quality materials must be used and attention to details and workmanship cannot be over-emphasized.

6.3 DESIGN

The monitoring staff should ensure that the contractor submits (within the period specified in the Project Specification) designs, drawings and calculations where required, for all falsework and formwork for review by the engineer. The design of all temporary works should be undertaken by the contractor, and the engineer through his representatives on site should only scrutinize the plans and pass comment on issues that may be non-compliant in terms of the specifications. No approval should be given for any temporary works as this could attract liability to both the employer and the engineer. Copies of all falsework and formwork designs should be placed on the safety file on site prior to the work being carried out.

The following matters should receive attention:

6.3.1 Falsework

6.3.1.1 Foundations

- Allowable bearing capacity of founding material for falsework supports to be confirmed by the contractor (Dynamic Cone Penetrometer or other suitable means).
- Allowance should be made for the wetting of the foundation material when determining the allowable bearing capacity of the founding material.
- Actual design bearing pressure for falsework supports to be provided by the contractor.
- Ensure all falsework for the erection of decks and slabs is provided with jacks for adjustment for line and level.
- For river bridges the stability of foundations under minor flood events should be considered.
- Falsework should always rest on sound founding material which is properly compacted and leveled to ensure no standing water will occur during rain.
- The adequacy of safety of the falsework should be signed off by the CCP.

6.3.1.2 Load Capacity

The load capacity and technical specifications of all elements making up the falsework including jacks, clamps and fittings should be provided with temporary works design. Ensure jack extension limits specified by the manufacturer of the particular type of jack in use are not exceeded.

6.3.1.3 Settlements

The contractor should provide with his calculations the expected settlements of the falsework due to elastic deformation of the founding material and falsework.

6.3.1.4 Deflections

Levels for the construction of falsework for the construction of slabs and decks should allow for precambering for expected long term/creep deflections due to dead loads, prestressing and superimposed dead loads. This provision should be in accordance with the design drawings and is especially important for very skew reinforced concrete decks. The monitoring staff should liaise with the design office to confirm requirements, and in instances where no precamber is specified, should ensure that this is confirmed by the designer.

- *Reinforced Concrete*

  The total deflection can normally be assumed to be 3 times the elastic deflection under Dead and Superimposed Dead Loads.

- *Prestressed Concrete*

  The monitoring staff should note that the precambering for prestressed concrete decks could be negative (in downward direction). The long-term deflection in prestressed concrete decks will generally continue in the direction of the initial deflection.

6.3.1.5 Overall Stability and Bracing

The monitoring staff should ensure that the contractor's design deals adequately with the overall stability and bracing of the proposed falsework taking into account wind loading and other horizontal actions as required.



Photo 6.1: Well designed falsework and bracing

6.3.1.6 Temporary Works Vertical and Horizontal Clearance

The minimum vertical and horizontal clearances as prescribed by the roads authority and employer should be adhered to by the contractor in his preparation of the temporary works design to be carried out by the contractor. Generally the clearances as specified in the SANRAL Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa should be used. However, where these clearances cannot be achieved the monitoring staff should refer to the engineer for final verification. Temporary guardrails, concrete barriers and other protection should be used to protect the temporary support work.

6.3.2 Formwork

6.3.2.1 Load Capacity

The proposed formwork should be capable of sustaining the loads due to wet concrete and superimposed loads due to construction activities and equipment without excessive deflection.

6.3.2.2 Deflection

The engineer's monitoring staff should ensure that the expected deflection of the forms as provided in the formwork design falls within the specified tolerances for surface regularity.

6.3.2.3 Grout Seals

Grout seals should be incorporated into the joints between individual formwork panels in all instances where the panels do not fit together with sufficient tightness to prevent leakage of fines.

6.3.2.4 Permanent Formwork

- On beam and slab decks using permanent formwork special attention should be given to bearing length.
- All permanent formwork should be designed to carry the loads resulting from the wet concrete and superimposed loads due to construction activities and equipment. The deflection under permanent loading should not exceed 50% of the construction tolerance.
- The strength and bracing of circular void formers should be sufficient to prevent distortion and resist all the loads they will be subjected to, and must comply with the requirements of the drawings and Specifications. The adequacy of the formers and bracing should be signed off by the CCP.
- Void formers must be tied down to the formwork bearers and should not be tied to or be supported on the reinforcement.
- In voided deck slabs the concrete should be cast in layers to reduce the effects of buoyancy and to reduce the movement of void formers.



Photo 6.2: Precast concrete permanent formwork in position before casting.

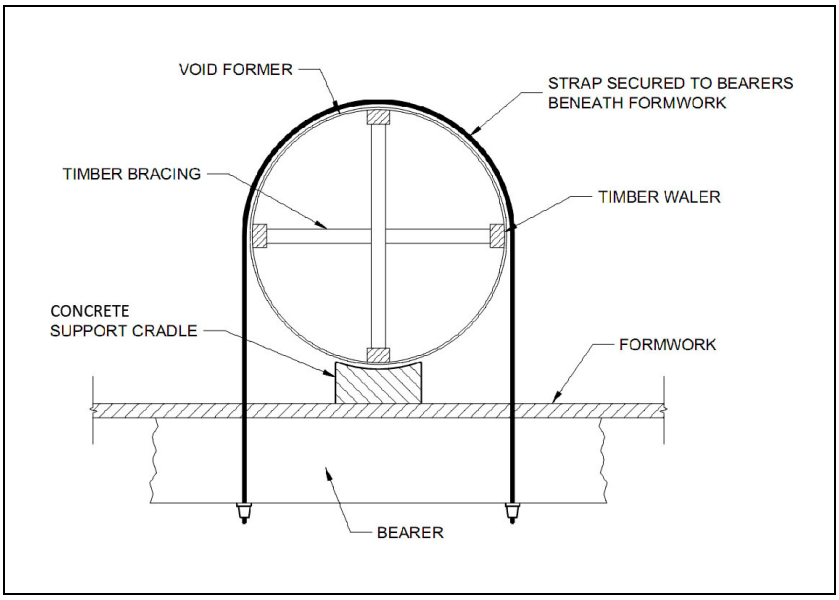


Figure 6.3: Bracing and installation of void formers

6.3.2.5 Stripping

Minimum stripping times for falsework and formwork must be in accordance with the Specifications. Any deviation in stripping times should be approved by the engineer.

WARNING
Inadequately braced void formers may collapse resulting in deck cross sections which do not conform to the design. This is likely to require demolition and reconstruction of the deck.

6.4 INSPECTION

The engineer's monitoring staff should inspect the falsework and formwork at the completion of erection and prior to the placing of concrete, and should insure that the CCP has signed off before concreting. The concrete finish should be inspected on final completion of each structural element (Refer to Chapter 8).

6.4.1 Falsework

(a) Confirm compliance with the design.

(b) Setting out - This is a very important aspect as it is fundamental to successful construction of the structure.

(c) Safe access - Should be inspected regularly as a part of the ongoing Site Safety.

(d) Foundations - Foundation conditions should be inspected before erection of falsework. All falsework should be inspected as soon as possible after inclement weather or flood event.

(e) Support elements - Should be inspected on completion of erection. Special attention should be given to connections, details and areas of transfer of stress and the provision of adequate bracing in accordance with the design. These should include the clamping of bracing and the safe reach of screw jacks.

(f) Line and level - Alignment and levels should be in accordance with the contractor's design.

(g) Falsework should be maintained in position for the times as prescribed in the specifications. Back propping after early removal of falsework should not be permitted.

(h) When the concrete is placed in the forms special care must be taken to ensure that no overloading of the formwork or falsework takes place due to the dumping of large piles of concrete in one particular position.

6.4.2 Formwork

(a) Confirm compliance with design requirements as specified on the drawings and specifications.

(b) Setting out, line and level to be confirmed.

(c) Condition of forms - Ensure forms are fit for purpose, sealed around edges where required and shutter release agent applied prior to fixing of reinforcement.

(d) Workmanship of shuttered areas (especially with reference to gaps where grout leakage may occur).

(e) Where high quality surface finishes are required i.e. F2 and F3, the use of grout seals is recommended.

(f) Permanent formwork - Confirm adequate support especially with regard to the holding down and bracing of circular voids.

(g) Removal of formwork - Ensure methods for removal of formwork are such that no damage occurs to the freshly cast concrete.

(h) Chamfers on exposed surfaces should be formed using new materials and be adequately secured in position during concreting.

(i) Kickers should be formed and cast monolithically with foundation concrete. Height to be between 75 and 100mm. The kickers should be of the class of concrete of the element above.

(j) At horizontal construction joints ensure the existing concrete surface is free from all grit and loose material prior to casting.



Photo 6.4: Unacceptable formwork & ferule pop out

6.4.3 Concrete Finish

The inspection of concrete finish should be undertaken on removal of forms to ensure compliance with specifications.

Where areas of substandard surface finish have been identified, remedial measures must be carried out in accordance with the Project Specifications and as directed by the engineer. Method statements for the expected repair of surface defects, e.g. honeycombing, etc. should be in place before any concreting commences to ensure that remedial measures can be implemented timeously.

NOTE
Bad formwork = bad finish
Good formwork & good concrete practice result in good finish



Photo 6.5: Very poor ferule patching

Unformed surfaces should be checked in terms of conformance to the surface finish as specified on the drawings and in the specifications.



Photo 6.6: Very poor workmanship

6.4.4 Conformance with Project Specifications

The monitoring staff should also ensure that all Project Specifications regarding formwork are complied with.

6.5 FALSEWORK, FORMWORK AND CONCRETE FINISH - CONSTRUCTION MONITORING CHECK LIST

The monitoring staff should use the "Falsework, Formwork and Concrete Finish - Construction Monitoring Check List" as far as possible to ensure the quality of the formed concrete surfaces.

INDEX TO APPENDICES

6A - FALSEWORK, FORMWORK AND CONCRETE FINISH CONSTRUCTION MONITORING CHECK LIST

FALSEWORK, FORMWORK AND CONCRETE FINISH CHECK LIST (1/2)

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. APPROVED DESIGN AND DRAWINGS AVAILABLE					
1.1 Design drawings					
1.2 Method statement					
1.3 Falsework design required					
1.4 Falsework drawings					
2. SETTING OUT					
2.1 Platform co-ordinates					
2.2 Platform / Bench dimensions					
2.3 Platform / Bench levels					
2.4 Layout of bases and supports					
3. EARTHWORKS					
3.1 DCP Tests					
3.2 Compaction tests					
3.3 Allowable bearing capacity					
3.4 In-situ support conditions wet/dry					
3.5 Adequacy of bearers					
3.6 Drainage of platform					
4. FALSEWORK					
4.1 Base jacks provided					
4.2 Base jack extensions					
4.3 Type of supports per drawing					
4.4 Alignment of supports					
4.5 Number of supports					
4.6 Bracing provided					
4.7 Connections in order					
4.8 Top jacks provided					
4.9 Top jack extensions					
4.10 Main bearers / Girders					
4.11 Line level and position					
4.12 Safe access for traffic					
4.13 Clearances for access (traffic)					
4.14 Protection for safe access (barriers)					

Check list continues on next page…

FALSEWORK, FORMWORK AND CONCRETE FINISH CHECK LIST (2/2)

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
5. FORMWORK					
5.1 Setting out of element					
5.2 Dimensions of element					
5.3 Type of formwork					
5.4 Condition of forms					
5.5 Cleanliness of box					
5.6 Chamfers					
5.7 Bracing of forms					
5.8 Sealing of forms					
5.9 Joint water tightness					
5.10 Ferrules, ties and cones					
5.11 Whalers					
5.12 Contraction joints and chamfers					
5.13 Access to placement point					
6. PERMANENT FORMWORK					
6.1 Type of formwork					
6.2 Support and tiedowns					
6.3 Bracing in circular void formers					
6.4 Connections					
6.5 Drainage of voids					
7. CONCRETE FINISH					
7.1 Honeycombing					
7.2 F1 Finish achieved					
7.3 Patching / Repairs required					
7.4 F2 Finish achieved (Fin removed, etc.)					
7.5 Patching / Repairs required					
7.6 F3 Finish achieved (rubbed)					
7.7 Patching / Repairs required					

CHAPTER 7 - STEEL REINFORCEMENT

DS Temple

7.1 SCOPE

This section covers the inspection of steel reinforcement to be used in the works as per the applicable chapter of the Specifications. It also covers the special attention which must be given by the engineer's monitoring staff to material requirements, placing, fixing, cover and supports, coupling and welding of reinforcement.

7.2 MATERIALS

The monitoring staff should ensure that the contractor submits a certificate of compliance for each type and batch of steel reinforcement used on the works.

7.3 INSPECTION

The monitoring staff should take cognizance of the following in the inspections of the reinforcement.

7.3.1 Storage of Materials

The reinforcement delivered to site should be stored neatly in a location specially prepared for this purpose. Reinforcement should be stored on a platform off the ground to prevent corrosion and contamination due to deleterious matter (mud, grease, oil, paint, loose rust, etc).

If the reinforcement is to be stored for a long period of time or where stored in a marine environment (within 10km of sea) the reinforcement piles should be covered.



Photo 7.1: Very poor storage of reinforcement

7.3.2 Condition of Reinforcement

The condition of the reinforcement should preferably be checked in the storage yard before delivery to the point of use. The reinforcement should be clean and free of all deleterious matter and cleaned by means of water jetting, degreasing or other method if required as the presence of the above will have an adverse effect on the bond of reinforcement to concrete.



Photo 7.2: Corroded reinforcement

It is very important that reinforcement is not corroded to the point that pitting of the bars is evident. Pitting is a potential flaw which under cyclic loading can reduce the life of the structure significantly. If pitting of steel is greater than that permitted by SANS 920, the reinforcement should be rejected or further guidance sought from the engineer.



Photo 7.3: Reinforcement damage during demolition

7.3.3 Bending Dimensions

Bending dimensions of reinforcement should be frequently checked to ensure that the bars will fit into the formwork and provide enough cover. The inside radius of bends is very important to ensure that the bars were not overstressed during bending. Monitoring staff should have suitable templates for checking radius available on site.

The minimum radii of bends are:

- High Tensile Steel = 3 Bar diameters
- Mild Steel = 2 Bar diameters

WARNING
Do not allow the use of heating to bend reinforcement.

7.3.4 Placing and Fixing

Placing and fixing of reinforcement into the forms for the structure is one of the most important aspects of the construction of a structure. Special care should be taken by the monitoring staff to ensure that the reinforcement is placed and fixed in accordance with the design by verifying the following:

(a) Type of steel (R or Y)

(b) Diameter of bar

(c) Bar mark

(d) Spacing of bars

(e) Concrete cover (refer to item 7.3.5 below)

(f) Laps as per drawing (refer to designer if in doubt)

(g) Grouping of bars to create space for placing and vibrating concrete.

(h) All reinforcement should be adequately tied together and properly supported to ensure that the reinforcement does not displace and move in position during the concreting process as this will affect the cover to bars and the effective functioning of the concrete member.

(i) Adequacy of stools and clips provided (need for stools where not provided).

(j) Where bars are detailed to project out of a member (such as parapet anchors) they must be accurately placed and held in position.

General neatness of the fixed reinforcement in the forms is always an indication of the accuracy of the placing and fixing and the contractor should be required to carry out corrective actions until the cages of reinforcement are fixed properly.

WARNING
Lack of cover on parapet anchors/starter bars results in loss of durability, pop outs and corrosion of reinforcement

7.3.5 Cover and Supports

The minimum cover requirements are usually given on the drawings and/or in the project specifications.

When checking the placing and fixing of reinforcement the monitoring staff must pay special attention to ensure that the specified cover to reinforcement is achieved. Cover has the most significant effect on the long term durability of reinforced concrete and therefore of the structure.

Excess cover should be avoided as micro cracking due to bending stress can result in the growth and development of cracks and resulting corrosion of reinforcement or member loss due to spalling. The correct cover is required to ensure that reinforced concrete members meet their specified design requirements.

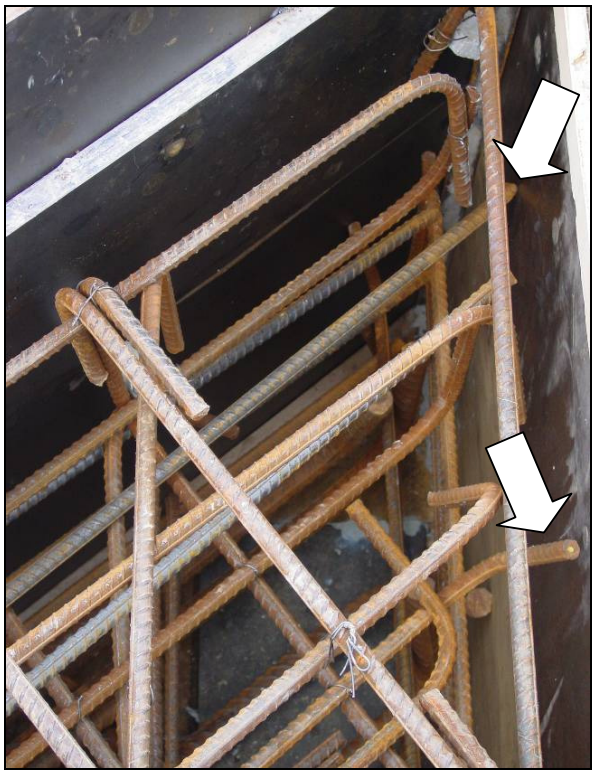


Photo 7.4: Insufficient cover to reinforcement cage in forms



Photo 7.5: Correct cover blocks in place

In order to ensure that the reinforcement does not move during concreting the Specifications give specific requirements for the types and specifications of spacer blocks and stools and these requirements should be strictly adhered to.





Photo 7.6 (a) & (b): Reinforcement corroding due to lack of cover

Special attention should be given to the cover blocks and their mix design. Samples of cover blocks should be submitted by the contractor to the engineer for approval before the work commences. Care should be taken to ensure that the cover blocks are made in such a way that they integrate with the parent concrete. Only concrete cover blocks as specified in the Specifications may be used.



Photo 7.7: Failure of member due to too much cover



Photo 7.8: Corroded reinforcement resulting in loss of concrete

Stools are not necessarily detailed on the drawings. They must be robust enough to perform well under concreting and other superimposed construction loads. The engineer has the authority to order the contractor to add additional stools to ensure the reinforcement is fixed securely and does not swivel or move during concreting. The provision of concrete cover to reinforcement stools should be checked.

WARNING

A wide range of plastic cover blocks are available but owing to problems associated with their use, are not permitted by a number of road authorities. If permitted they should only be used with great caution and subject to successful trials and ongoing monitoring. This is necessary as many are prone to bending or buckling under load and are sometimes clearly visible on the finished concrete surface.

Approved cover meters will generally be provided on site. Where specified in the project specifications, cover to reinforcement should be confirmed after casting of the concrete by the use of electromagnetic cover meters. If the cover is substandard the engineer may instruct the contractor to remove and reconstruct the concrete member or agree to acceptable remedial measures with the employer.

7.3.6 Laps and Joints

Laps, joints and splices should be placed as indicated on the drawings. As a general rule the lap length should not be less than 45 times the diameter of the smaller bar at the splice or lap. The lap positions should only be moved when the casting sizes are such that the contractor makes a specific request to do so. In all such cases any of these changes should be referred to the designer.

It is good practice for laps and splices to be staggered as indicated on the drawings. This facilitates better placing of concrete and improved stress distribution in the concrete section, but may not be preferred by the Contactor in terms of casting construction joints.

7.3.7 Welding

The welding of reinforcement is generally not permitted for high tensile steel as heating hot rolled bars causes brittle fracturing of the reinforcement. In the case of cold worked deformed bars, heating causes the reinforcement to revert to mild steel as it loses the effects of strain hardening. Welding may be permitted on mild steel in very specific cases, which should be referred by the monitoring staff to the engineer.

Where welding of reinforcement is specified on the drawing the monitoring staff should ensure that the welding is carried out strictly in accordance with the Specifications and that specialized testing is carried out as required.

7.3.8 Mechanical Couplers

Mechanical couplers may be specified where concrete members are coupled together due to staged construction processes, or where space restrictions do not permit normal laps and splices.

The contractor should submit to the monitoring staff (for approval by the engineer) all the test certificates for the proposed proprietary products as required in the Specifications.

7.3.9 Conformance with Project Specifications

The monitoring staff must check the Project Specifications for specific requirements related to types of reinforcement to be used, specific cover, cover block types, etc, and should ensure the compliance thereof for the duration of the contract.

7.4 STEEL REINFORCEMENT- CONSTRUCTION MONITORING CHECK LIST

The monitoring staff should use the “Steel Reinforcement - Construction Monitoring Check List” as far as possible to ensure the quality of the installation of steel reinforcement.

INDEX TO APPENDICES

7A - STEEL REINFORCEMENT

APPENDIX 7A

STEEL REINFORCEMENT CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. GENERAL					
1.1 Storage of reinforcement					
1.2 Condition of reinforcement					
1.3 Bending dimensions					
2. PLACING AND FIXING					
2.1 Type of steel (R or Y)					
2.2 Diameter of bars					
2.3 Bar marks					
2.4 Spacing / Number of bars					
2.5 Concrete cover (general)					
2.6 Laps (alternating)					
2.7 Grouping of bars (clearances)					
2.8 Fixing ties adequate					
2.9 Spacers					
2.11 Stools in place					
2.12 Projecting anchor bars					
2.13 Cleanliness of reinforcement					
3. COVER AND SUPPORTS					
3.1 Minimum cover as per drawing					
3.2 Spacer block type					
3.3 Spacer block positions					
3.4 Spacer block spacing / Number provided					
3.5 Stool spacing / Number provided					
3.6 Stool fixity					
4. SPECIAL REQUIREMENTS					
4.1 Welding procedure approved					
4.2 Welding quality					
4.3 Mechanical couplers					
4.4 Coupler type approved					
4.5 Installed correctly					
4.6 Other special requirements					

CHAPTER 8 - CONCRETE

WJ Martin

8.1 SCOPE

This chapter covers the manufacture and use of concrete in structures.

Site monitoring staff should read and obtain a sound understanding of the relevant section of the Standard Specification and the Project Specifications before applying this section of the manual. This chapter contains a substantial amount of information and requirements which are contained in the specifications. This is provided to assist monitoring staff in understanding "normal requirements": note that this does not take precedence over the specifications.

Other useful references include:

- Fulton's Concrete Technology: This deals in some depth in all aspects of concrete. (See www.cnci.org.za/booklets1.htm)
- Cement and Concrete Institute's courses (See www.cnci.org.za). The following course is particularly recommended for monitoring staff who do not already possess a sound understanding of concrete technology: SCT 30 Concrete Technology (5 days)

The chapter is laid out to follow the concreting process encountered on a construction site, and then deals with specific issues:

(a) *Mix Design:* Reviewing and approving the contractor's mix design.

(b) *Storing of materials:* Storing of cement, stone and sand on site.

(c) *Pre-concreting inspection*: Inspections of the works to ensure that it is ready for concreting.

(d) *Batching concrete:* The measuring and mixing process.

(e) *Placing and compacting:* Transporting, placing and vibrating the concrete.

(f) *Construction joints:* Approvals, positions, preparation, construction.

(g) *Curing and protecting concrete;*

(h) *Adverse weather conditions:* Cold and hot weather concreting;

(i) *Loading concrete;*

(j) *Monitoring concrete strength and durability;*

(k) *Specialist forms of concreting;*

(l) *Concrete cubes*

This chapter should be read in conjunction with the other chapters, specifically formwork, reinforcement and, where applicable, prestressing.

Note that various standard specifications refer to SABS documents which may now be out-dated or superseded. COLTO Standard Specifications is an example of this. In Table 8.1 below some typical superseded SABS documents along with the replacement document is given.

Description	*Superseded code*	*New code*
Cement: OPC, RHC	SABS 471	SANS 50197-1
Cement: PBFC	SABS 626	SANS 50197-1
Cement: PC15, RHPC15	SABS 831	SANS 50197-1
Cement: GBFS	SABS 1491 Part 1	SANS 50197-1
Aggregate	SABS 1083	SANS 1083
Drying shrinkage of aggregates	SABS method 836	SANS 5836
Drying shrinkage of concrete	SABS method 1085	SANS 6085
Aggregate size	SABS 1083	SANS 1083
Sulphate content: Aggregates	SABS 850	SANS 5850-1
Drilling cores	SABS 865	SANS 5865
Evaluate cores	SABS 0100 Part II	SANS 10100 Part 2
Load tests	SABS 0100 Part II	SANS 10100 Part 2

Table 8.1: Superseded SABS documents along with the replacement documents

8.2 MIX DESIGN

The contractor is responsible for the design of the mix and the constituent materials producing concrete with the specified properties. The design should be submitted on the standard form prescribed by the employer for concrete mix designs.

The contractor should submit samples of the constituent materials of the concrete and a statement of the mix proportions which he proposes to use for each class of concrete.

The contractor's mix designs and materials samples must be received early enough for the engineer and monitoring staff to review them and have independent tests done if this is considered necessary.

Generally the contractor should show that the mix design complies with the specifications by producing a statement of test results from an approved laboratory or, if acceptable to the engineer and employer, a report on previous use. Where relevant, product data sheets must also be supplied.

The following should be reviewed in the contractor's mix design:

8.2.1 Cement

Cement must comply with the new standard **SANS 50197-1:2000** code for cements: (refer to CNCI website www.cnci.org.za).
The application of cement types must comply with the specifications.
Blending of cements must comply with the specifications.

8.2.2 Aggregates

Source of sand or stone: Where these are not from recognized sources and records of compliance with the relevant specifications are not available, additional tests must be done by an approved laboratory.

Both stone and sand must comply with **SABS 1083**.

COMMENT
In some areas the geological source may be specified due to its superior properties with regard to for example, low shrinkage properties for prestressed concrete elements.

Drying shrinkage testing must comply with **SABS Methods 1085** and 836 and the relevant clauses of the Standard Specification. Drying shrinkage should not exceed:

- 0.040% when testing the concrete mix design, and
- 130% of that of the reference aggregate for both sand and stone for prestressed concrete, or
- 175% of that of the reference aggregate for sand in reinforced concrete and
- 150% of that of the reference aggregate for stone in reinforced concrete.

The flakiness index using **TMH 1 Method B3** should not exceed 35.

Aggregates should not contain any detrimental amounts of organic materials such as grass, timber or similar.

Alkali-Aggregate Reaction: Where there is a possibility of this occurring, test the mix design in accordance with the standard specifications. Total alkaline content (Na_2O-equivalent) should be limited as specified in the specifications (for example COLTO 8105(f)). Non-conforming mix designs should not be accepted.

The fineness modulus of the fine aggregates should not vary by more than +/- 0.2 from the approved modulus.

8.2.3 Water

Water must be free of detrimental amounts of:

- Chlorides (For reinforced and prestressed concrete the chloride content should not exceed 500 mg/l to **SABS method 202)**,
- Acids,
- Alkalis,
- Salts,
- Sugar, and
- Other organic or chemical substances that may adversely affect the concrete.

Where appropriate, the water must be tested in an approved laboratory.

8.2.4 Admixtures

Admixtures must comply with the following requirements:

- Must be of an approved brand and type,
- Must have a proven track record,
- Must be in liquid form,
- Must be mixed in with the water to an accuracy of +/- 5%,
- Must comply with **ASTM C494** or **AASHTO M194** and
- Must not contain chlorides.

8.2.5 Curing agents

Only approved curing agents should be used.

Test curing agents in accordance with **ASTM C156**.

Curing agents should comply with **ASTM C309**, except that the loss of water within 72 hours should not exceed 0.40 kg/m3.

Resin-based curing compounds should be avoided as they generally stain the concrete and reduce adhesion should future coating be required.

8.2.6 Mix proportions

Generally all concrete in current bridge design practice is strength concrete.

The following must comply with drawings, bills of quantity and specifications:

- Concrete cube strength
- Nominal size of course aggregate
- Maximum water:cement ratio (if specified)
- Minimum cementitious content (if specified).

Aggregate sizes must comply with **SABS 1083**.

Cement content should not exceed 500 kg/m3 of concrete.

Sulphate content should fall within the limits specified in the Standard Specifications.

8.2.7 "W" prefix durability concrete

Where durability concrete with a prefix "W" e.g. W40/19 is specified, it should comply with the project specifications.

The process associated with durability concrete includes:

- The contractor uses an approved laboratory to determine the mix proportions.
- Before any durability concrete is cast, this laboratory should test concrete specimens taken from trial panels using the concrete mix, for the relevant durability parameters as described in the specifications.
- When durability concrete is cast, further test panels are cast as described in the specifications. These panels will have concrete specimens cored out of them after 28 days. These specimens are then tested for durability.

NOTE

The process of getting the mix design for concrete approved can take up to two months or more. This applies to all concrete mix designs, including "W" concrete. The contractor needs to submit his sample materials and mix design as

COMMENT

Certain specified durability criteria such as the use of PFA or GGCS, max water-cement ratio and min cement content will invariably result in a higher cube strength than what is specified for strength concrete. The target strength as determined from the trial mix is therefore an important criteria for monitoring compliance with the W-specification. Whilst cube strengths below the target value may still meet the strength requirement (e.g. 40 MPa), the durability properties of the concrete will become suspect.

- If the specimens do not meet the relevant acceptance criteria, then cores are taken from the concrete component and tested.

Achieving "W" concrete is not a complex operation and is not high in risk. It is actually simple and has three components.

- Concrete mix design: This is easy to achieve and because of its high cement content makes up for a few shortcomings in the aggregates. Accurate batching and water dosing will achieve the requirements;

- Placing and curing: If the concrete is placed without delay after mixing and is properly vibrated and cured, the requirements for W Concrete will easily be achieved; and

- Formwork: If good quality well maintained formwork is used and left in place for the required curing period then the requirements will easily be achieved. Contractors that have commercial pressures to strip early will increase the risk of not achieving the W specification.

8.2.8 Trial mixes

Slump measurements in accordance with **TMH1 Method D3** should fall within the ranges specified in the Standard Specifications.

Bleeding should not be excessive. Limits to the amount of bleeding is given in the specifications.



Photo 8.1: Loss of durability due to excessive bleeding

In the above Photo 8.1 of the bottom flange of a precast beam, the concrete has bled excessively due to very poor grading of the sands in the mix. The bleed water has collected on the sloping face of the shutter. This has significantly reduced the durability as the bleed paths have reduced the effectiveness of the concrete cover resulting in porous cover concrete.

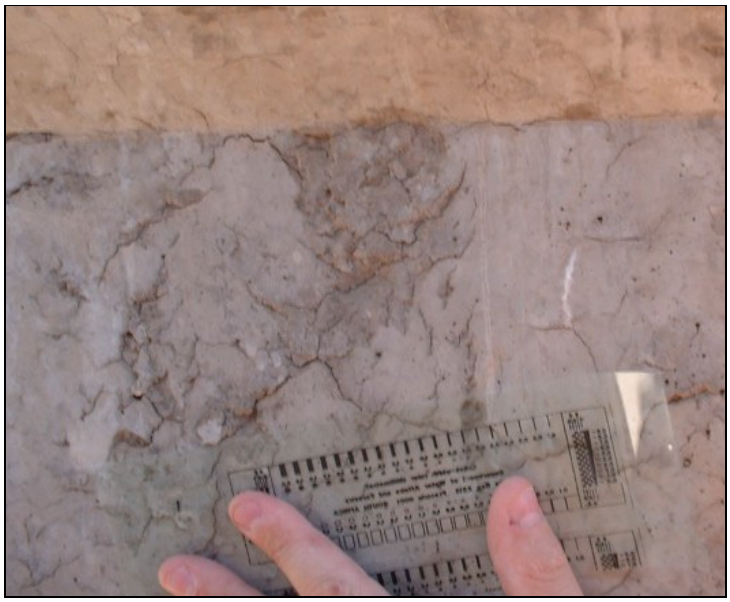


Photo 8.2: Very high shrinkage in concrete

The concrete in the above photo 8.2 has very high shrinkage due to a very poor stone combined with a high cement content. High bleeding contributed to the problem.

8.3 STORING OF MATERIALS

8.3.1 Cement

- Cement must be stored under cover. Cement must not get damp or wet.
- Cement bags must not be stacked higher than 12 bags and must not be in contact with the floor or walls. Doors must be opened as infrequently as possible and windows must be kept closed.
- Cement should not be kept in storage for longer than 8 weeks.
- Bulk cement must be stored in weather-proof silos. Bulk cement should also not be kept in storage for longer than 8 weeks.

8.3.2 Aggregates

- Aggregates of different sizes should be stored separately.
- Aggregates must not become contaminated by foreign matter e.g. the ground below the stockpile.
- Aggregates should be stored on a concrete apron slab at least 150 mm thick or similar approved.
- Aggregates exposed to sea air should be covered to prevent salt contamination.
- Sufficient material should be stored on site to ensure that no unintended construction joints are required in the structure.

NOTE

It is the responsibility of the contractor to ensure that he complies with the contract specifications and good practice. The Monitoring Staff must conduct the inspection in such a way that he does not perform the contractor's quality control duties. This can be done by ensuring that the contractor produces his own signed-off quality documents. When a component is found to be clearly not ready for an inspection, it is advisable to declare it not ready for inspection without giving specific lists of outstanding items, making it quite clear that this is the contractor's responsibility.

8.4 PRE-CONCRETING INSPECTION

Prior to batching and casting concrete, the works must be inspected to ensure that they are ready for concreting (Refer to the other sections of this manual and to the specifications.).

This inspection should include checking of the following.

8.4.1 Falsework

(a) Falsework design approved;

(b) Temporary foundations and supports adequate;

(c) Falsework in place and adequately braced;

(d) Falsework components adequate tightened;

8.4.2 Formwork

(a) Correct formwork in place;

(b) Correct quantity of shutter release agent applied (too much can retard and stain concrete);

(c) Ferule ties etc in place and adequately tightened. Note that cones should be used – refer to Chapter 7;

(d) Formwork adequately secured – will not kick or move;

(e) Sloping formwork will be able to withstand concrete hydrostatic pressure which may try to lift it up;

(f) Deck void formers etc adequately tied down and internally braced – must not move or collapse under concrete hydrostatic pressure;

(g) Dimensions and alignment correct and within tolerance;

(h) Chamfers in place and adequately secured;

(i) Drip grooves in place;

(j) Filled expansion joints properly prepared;

(k) Formwork clean, especially of debris and reinforcement tie wires;

(l) Existing concrete and construction joints properly prepared and pre-wetted.

8.4.3 Reinforcement

(a) Reinforcement in place according to the drawings;

(b) Reinforcement clean and only lightly corroded – no shutter oil or compressor oil etc;

(c) Reinforcement adequately tied – if you can easily kick or twist a bar out of place, it will move during concreting;

(d) Correct cover blocks in place and strong enough to support concreting loads – Refer to Chapter 7.

8.4.4 Ferrule ties and other pipes and conduits installed for the contractor's use

(a) Check that these have been approved by the engineer; [see the relevant clauses in the specification]

(b) Minimum clear gaps of 40 mm to ensure good concreting;

(c) Minimum concrete cover of 25 mm to ferrules and other pipes;

(d) Ends of the plastic ferrule tubes should be cut back to at least 50 mm (removable cups are preferred).

8.4.5 Additional components to be concreted in

All of the drawings need to be studied to ensure that any additional component is correctly fixed in place. These components can include:

(a) Starter bars for subsequent concreting in correct position;

(b) Drainage and electrical ducts and components;

(c) Bolt groups and fixtures for railways components;

(d) Bolt groups and fixtures for lampposts, pedestrian rails, guardrails, etc.

8.4.6 Concrete

(a) Materials and mix design approved;

(b) Batching procedure approved and equipment and operators ready;

(c) Testing procedure approved and equipment and operators ready;

(d) Placing procedure approved and equipment and operators ready;

(e) Compaction procedure approved and equipment and operators ready;

(f) Curing procedure approved and equipment and operators ready.

NOTE 1

The Monitoring Staff should not only rely on the methodical use of check-lists for the inspection, but should also apply their intelligence, judgement and experience to the work to be performed. The Monitoring Staff should stand back after the inspection and go through the whole process in his mind to ensure that nothing has been overlooked. This applies especially to anything that is unusual about the particular component being constructed.

8.4.7 Testing equipment ready

(a) Slump cone testing equipment;

(b) Concrete cubes – enough cubes, correct compacting rod, etc;

NOTE 2

It is not always necessary to do all of these inspections at the same time. For instance, for a bridge deck, all the procedures and mix designs etc should be reviewed and accepted early in the project, the falsework and formwork can be inspected at the next stage, the reinforcement later and the concreting process prior to concreting, etc.

8.5 BATCHING CONCRETE

8.5.1 Measuring materials

(a) Cement, stone and sand should be measured by mass. Accuracy to be within 3%. A standard bag of cement should be assumed to contain 50 kg.

(b) Water should be measured either by mass or by volume. The quantity of water should be adjusted to make allowance for the moisture content in the aggregates.

8.5.2 Mixing materials

(a) A mechanical mass-batch mixer of an approved type should be used.

(b) The operator should be experienced.

(c) The same procedure of charging the materials should be used throughout the construction.

(d) The mixing time should be 90 seconds unless otherwise approved. A suitable timing device should be used.

(e) When discharging, no segregation should occur. The mixer should be fully discharged before recharging the next batch.

8.5.3 Maintaining and cleaning the mixer

(a) If the mixer is stopped for more than 30 minutes, it should be thoroughly cleaned out. All hardened concrete should be removed.

(b) Worn or bent blades and paddles should be replaced.

8.5.4 Standby mixer [refer to the relevant clause in the Standard Specifications]

When sections are cast where it is important to continue without interruption, a standby mixer should be available to run on 15 minutes notice should the main mixer break down. This applies especially to large concrete foundations and bridge decks.

NOTE
Not all ready-mix suppliers are prepared to guarantee this compliance. The contractor therefore has to carry the risk of non-compliance. The Monitoring Staff need to discuss this with contractor and supplier during the mix-design approval process to ensure that the final product complies with the specifications.

8.5.5 Ready-mixed Concrete

This should comply with **SABS 878**.

8.6 PLACING AND COMPACTING OF CONCRETE

Before concrete is placed, the slump should be checked in terms of the specifications using the slump-cone test. For Ready-mixed concrete, the slump of each truck should be checked. This is important as each truck is batched separately and there has been known to be substantial variation in slump from one truck to another. With experience, it is possible to estimate the slump by eye. This is done by looking at the way the concrete slumps over the mixing blades in the mixer or Ready-mix truck. One can also see it in the way concrete "flows" in the formwork or around reinforcement. This check by eye is not a substitute for the slump test but is very useful to pick up problems early such as flash setting where the slump starts decreasing rapidly. Additional slump tests can then be called for to confirm the estimate by eye.

The methods used for transporting, placing and compacting of concrete should be such that segregation does not occur. The mix must remain homogeneous without the stone and paste separating.

Working at night time should be avoided. Where it cannot be avoided, adequate lighting needs to be supplied in advance. Workmen should not work double shifts.

Concreting should be under the direct supervision of an experienced concrete supervisor.

Concreting should be a continuous process between construction joints with no interruptions
Concrete should be placed within 50 minutes of mixing. Where retarders are used, this may be extended.

All absorbent surfaces such as concrete, timber, earth, etc, should be pre-wetted but should have no standing water.

8.6.1 Placing concrete:

The placing sequence, rate and layer thickness must be controlled to ensure that consolidation is effective and complete. Most surface defects are related to incorrect placement, and the inability of the poker to expel air and effectively consolidate. The poker vibrator cannot rectify what poor placement has done.

Where chutes are used to place concrete, they should not cause segregation. Baffles and spouts should be used to minimize segregation.

This also applies to tremie-pipes or "elephant trunks" where segregation can occur if the discharge at the bottom is not controlled. Photo 8.3 is an example of segregation caused by an "elephant trunk" that was incorrectly operated.

Moving concrete sideways with vibration should not be done without the engineer's approval. This will cause segregation.

When casting thick components such as bridge decks or large bases, the concreting procedure should be such that fresh concrete should not be placed against concrete which has been in position for more than 30 minutes. Where retarders are used, the time can be extended.



Photo 8.3: Segregation of concrete

Placing underwater should only be allowed in exceptional circumstances. Refer to specialist literature.

8.6.2 Compacting concrete

NOTE
Ideally, all concrete should be re-vibrated within one hour of placing.

(a) Concrete should be fully compacted by vibration. Where other methods of compaction are used, refer to specialist literature.

(b) Internal vibrators (pokers) should operate at more than 10 000 rpm while external vibrators attached to the formwork should operate at more than 3 000 rpm.

(c) External vibrators should ensure efficient compaction and should not cause surface blemishes.

(d) Vibrators should be operated by experienced workmen.

(e) There should be sufficient vibrators on site to allow for breakdown.

Good practice in operating a vibrator includes the following:

(f) The vibrator is lowered into fresh concrete until it just penetrates the previous placed and compacted concrete;

(g) It is slowly removed while the air bubbles come to the surface;

(h) Once all the air bubbles are out of the concrete, the sound emitted by the vibrator changes. The concrete is now compacted;

(i) The vibrator is pulled out slowly so as not to leave a hole behind;

(j) The vibrator is placed again into the concrete not more than 400 mm from the previous position for large vibrators (75 mm and larger). For small vibrators, this distance should be reduced. The necessary spacing can be determined by looking at the zone where the air comes to the surface and ensuring that there is overlap of these zones.

Where there are high areas of reinforcement congestion such as in prestressing anchorage zones or where multiple layers of reinforcement are used in a reinforced concrete beam, special attention should be given to compaction to ensure that no "honeycombing" occurs. Where necessary, a mix containing a smaller stone should be used.

Concrete is properly compacted when:

- It is worked around reinforcement, prestressing, embedded fittings, etc, with no voids;
- There is no honeycombing; and
- There are no planes of weakness between successive layers.

COMMENT
A concrete mix which tends to bleed excessively should be re-vibrated to a depth of 300 mm within 1 hour of placing to close up the pores through which the water has escaped. Refloating the concrete surface is also encouraged

Concrete should not be disturbed for 4 to 24 hours after compaction. Any vibration or movement will weaken the bond that is forming between the concrete and reinforcement. Sources of vibration to be avoided include heavy machinery, generators, traffic, etc.

8.7 CONSTRUCTION JOINTS

All construction joint positions should be as marked on the drawings or as approved by the engineer. No other construction joints should be allowed.

All construction joints, especially horizontal joints, should be formed with straight edges, usually by fixing a strip of timber to the formwork.

Where concreting needs to be stopped due to unforeseen circumstances such as a change in the weather, a construction joint should be formed at the place of stoppage such that it will have the least impact on the structural design, durability, appearance and proper functioning of the concrete. The design engineer must first be consulted to check if this is acceptable.

Stub columns, stub walls, stays on footings and kickers should be cast integrally with the footings and not afterwards.

Kickers, typically 75 mm high, will generally be in the areas of highest stress and therefore need to be constructed properly as mentioned above. Their purpose is to:

- Prevent honeycombing by ensuring that the following column or wall does not leak cement paste at the bottom;
- Prevent the formwork from kicking by supplying a face against which the formwork can be tied or braced; and
- Assist in assuring that starter bars are in the correct position.

8.7.1 Preparing construction joint surfaces:

Where the concrete is still green, the concrete laitance should be removed to expose the stone without disturbing the stone using a water jet and light brushing.

Where the concrete has hardened, suitable hand held mechanical means should be used.

The method of preparation should not disturb the stone or cause internal and surface cracking and damage. The prepared surface should be sound and roughened. The surface should be washed with clean water to remove dirt and loose particles.

8.7.2 Placing fresh concrete at construction joints:

If the existing concrete at a construction joint is more than a day old, it will absorb water from the fresh concrete, forming a plane of weakness. The following good concreting techniques must be followed to avoid this:

- Keep the construction joint constantly wet for at least 6 hours before concreting restarts. If the concrete is more than a month old, this period should be increased to 24 hours. There must be no free surface water when concreting restarts.
- The construction joint should be washed to remove all dirt and loose particles. On no account must shutter release oil or other contaminates be applied to the construction joint.
- The first batch of fresh concrete cast against a horizontal construction joint should have 25% less stone than the normal mix to ensure a paste-rich high slump concrete. This should form a 25 mm thick layer of fluid concrete.

NOTE

Generally, the use of epoxy resins is NOT recommended for bonding new concrete to old concrete owing to the high incidence of failure of this system. Where it is used, it is essential that the manufacturer's recommendations be strictly adhered to. If the epoxy is left too long before concreting, it will not serve its intended purpose and will form a weak layer. If concrete cannot be cast within the allowable time, the epoxy must be completely removed and reapplied.

8.8 CURING AND PROTECTING CONCRETE

Curing is the process of limiting early loss of water from concrete. The best form of curing is to keep a component immersed under water for at least 7 days. Losing too much water too early in the life of a concrete component causes high creep and shrinkage, and may even cause a significant loss of strength. Most importantly, poor curing is detrimental to the durability of the concrete, particularly the outer concrete which is required to provide protection to the embedded reinforcement.
In general, the longer the period of curing, the better will be the quality of the concrete. This applies not only to its compressive strength, but also to its durability, impermeability, its resistance to wear, weathering and chemical attack, and to its freedom from crazing and shrinkage cracking.
Concrete therefore needs to be kept moist, both by the prevention of loss of moisture due to evaporation, and by the provision of extra water from outside the concrete. Concrete also needs to be maintained at a suitable temperature for the hydration process to continue.

There are two general forms of curing:

- Keeping all concrete surfaces wet to prevent moisture loss; and
- Creating a barrier to prevent moisture loss.

One or more of the following techniques should be used to prevent loss of moisture, subject to compliance with the requirements of the standard and project specifications:

(a) Retaining formwork in place;

(b) Ponding exposed surfaces with water. This must not be done when air temperatures are below 5℃;

(c) Covering with sand or moisture-retaining material and then keeping constantly wet;

(d) Constantly spraying with water;

(e) Using a curing compound applied according to the manufacturer's instructions. Note that where a surface will subsequently be waterproofed, coated or gunited, curing compound should not be used as it will be highly detrimental to bond. Curing compounds are generally not as effective as other forms of curing;

(f) Steam-curing. This is usually only applied to precast units; and

(g) Wrap in plastic. This method is very effective for slender elements such as columns.

The curing period should be continuous for at least 7 days for normal concrete. Concretes which gain early strength slowly should be cured for at least 10 days. This includes cements containing blast-furnace slag.

When the air-temperature falls below 10℃, the concrete reaction slows appreciably. The curing period should be extended by the period that the temperature falls below this limit.

For sliding formwork and other specialist forms of concreting, refer to appropriate literature.

NOTE
Deck surfaces and other large exposed surfaces are especially prone to moisture loss and special care needs to be taken to ensure good curing. Wind can speed up the loss of moisture significantly. Often two systems are used, such as wetting and covering in plastic in addition to applying a curing compound.

If impermeable curing membranes are to be used as a curing method, they should be installed at the same time as formwork is removed and no portion of a concrete surface may be left unprotected for a period in excess of 2 hours. If the surface is an unformed finish e.g. top of deck slab, then the surface should be protected immediately by appropriate methods approved by the engineer after it is finished,

without damage to that surface, since it is vulnerable to plastic shrinkage cracking due to high rates of evaporation while the concrete is still in a plastic state. Plastic shrinkage and settlement should not be permitted on any of the structural elements since it compromises the durability of the concrete. In order to prevent early settlement and shrinkage of the concrete, the concrete placed should be revibrated after initial compaction while the concrete is still in a plastic state. Any remedial measures shall be as approved in writing by the engineer.

On bridge decks, the top surface should be cured by constantly spraying the entire area of exposed surfaces with water

.

All durability concrete prefixed 'W', should be cured in the same manner as the test panel.

Note that sometimes the concrete needs protection against moisture loss before the concrete has set. This applies especially to deck slabs during strong wind or high temperature when evaporation is particularly high. Protection can take the form of water sprays or covering the concrete before it has set.

8.9 ADVERSE WEATHER CONDITIONS

Refer to the standard and project specifications for manufacture and placement of concrete in adverse weather conditions. Additional information and guidelines are provided in 8.9.1 and 8.9.2 below.

8.9.1 Cold weather concreting:

When concrete falls below 10℃, the chemical reaction and rate of gain in strength slows considerably.

When fresh or green concrete freezes, the water within the mix expands and severely fractures the concrete. This concrete must be removed and replaced.

Special measures are therefore required for cold weather concreting and specialist literature should be consulted. However, the following guidelines can be given:

- Where the concrete temperature may fall below 10℃, heating or thermal protection is required;
- Concrete temperature when placed must be above 10℃ and preferably above 15℃ to ensure that the chemical reaction takes place. The chemical reaction will also generate additional heat;
- Water, stone or sand may be pre-heated to a maximum of 30℃ to raise the mix temperature; and
- Heat loss from concrete can be reduced by insulating the member with timber formwork, polystyrene sheeting, or other suitable materials.

8.9.2 Hot weather concreting:

Where the air temperature is above 30℃, the temperature of the placed concrete should not exceed 30℃.

This can be achieved by using a combination of the following techniques:

- Shading the aggregates;
- Spraying the aggregates to cause evaporative cooling;
- Adding ice to the mix water.

Curing should receive special attention and should start as soon as possible during hot weather.

8.10 LOADING CONCRETE

No loading should be applied to concrete until it has attained sufficient strength. Any loading that needs to be applied before the 28 day concrete cube strengths have been approved, should first be approved by the engineer.

Refer to paragraph 8.13 below regarding additional cubes.

8.11 MONITORING CONCRETE STRENGTH AND DURABILITY

Refer to the relevant sections of the Standard Specifications

With regard to the 28 day cube strength, the concrete should satisfy the relevant requirements in the Standard Specifications for:

- Full acceptance; and
- Conditional acceptance.

The concrete should also comply with the relevant specifications regarding durability.

8.12 SPECIALIST FORMS OF CONCRETING

Where the form of concreting is highly specialized, refer to specialist literature.

These forms include:

- Concreting using sliding formwork;
- Concreting using climbing formwork;
- Low temperature concreting;
- High temperature concreting.

8.13 CONCRETE CUBES

The COLTO Standard Specification specifies that test cubes should be made in accordance with TMH1 method D1. It furthermore specifies the number of concrete samples that has to be taken and requires that samples be taken in a stratified random pattern as per TMH 5, Sampling for Road Construction Materials. According to TMH 1 a sample consists of 3 cubes and these have to be taken from the same batch of concrete, that is, from the same wheelbarrow or bucket.

The lot size for sampling should be determined by the engineer, but normally a lot will be equal to the volume of concrete of a given mix design cast in a day e.g. see COLTO Table 8206/2 for lot size. The method of random sampling as described below is recommended.

(a) Determine the volume of concrete of a given mix design to be cast on a specific day

(b) Use the volume to determine the number of batches that will be cast, e.g.:

- If a ready mix truck contains 6 m3; and
- Volume of concrete to be cast = 40 m3,
- Therefore 40/6 = 7 batches or trucks will be cast, so x = 7.

(c) The Standard Specifications require 6 samples of 3 cubes each for a lot size of 40 m3, therefore n = 6.

(d) Start at the top of the list of random numbers in TMH 5 and multiply the first n numbers by x.

(e) Round the answer up to the nearest whole number.

(f) Note down these n numbers for these are the trucks to be sampled.

(g) If a number occurs more than once, a truck could be sampled twice, or the next random number in the list could be multiplied by x and this number used as the next truck to be sampled.

(h) Continue with the list of random numbers the following casting day.

Where an early indication of concrete strength is required (such as early loading or prestressing), additional cubes should be made. Cubes tested at 7 days would typically be 70% of the 28 day strength, depending on the type of cement and temperature.

Cubes should be made, cured, stored and transported in accordance with the latest version of TMH1. Cubes should be made by a trained workman. The cubes should be made in a sheltered location to prevent rain or wind or site operations from causing damage. The cubes should be stored in a temperature-controlled bath.

Since a cube crushing machine is not always available on site it is sometimes necessary to transport cubes to a nearby laboratory. Cubes should not be transported before the age of three days, but if this cannot be prevented, the cubes need to be placed securely in sandbags to prevent them from knocking against each other or being damaged during transportation. Cubes older than three days should be placed on and covered with wet hessian bags before being transported.

Each cube should be marked with the date, cube number and concrete element, in permanent ink, before being placed in the curing bath. It is recommended that the cubes be numbered consecutively from the start to the end of the contract to prevent confusion. All the relevant information regarding the cubes e.g. the number, date of casting, concrete element, approximate position in the element, slump, truck number, site arrival and departure time, date of testing, mass, compressive strength and any irregularities that occurred, should be recorded in a cube book kept on site. This information is useful when cube failures occur to assess the extent of the damage.

Cube results should be analyzed in accordance with the relevant section of the Standard Specification.

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CONSTRUCTION MONITORING CHECKLIST

MIX DESIGN CHECK LIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1 Mix design and materials received					
2 Cement complies					
3 Stone, including durability, complies					
4 Sand complies					
5 No Alkali-aggregate reaction					
6 Water complies					
7 Additives comply					
8 Mix proportions comply					
9 For "W" concrete, trial panel test results comply					
10 Cube strength and slump measurements comply					
11 Bleeding complies					
12 Independent laboratory confirms concrete mix design					

PRE-CONCRETING CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1 Dimensions, positions, levels and precamber comply					
2 Falsework and formwork comply					
3 Reinforcement and concrete cover complies					
4 Additional components correctly installed (Drip grooves, drainage pipes, kickers, bolt groups, etc)					
5 Concrete mix design approved					
6 Method of curing approved					
7 Position and details of construction joints approved					
8 Kicker formwork in place					
9 Construction joints have been correctly prepared					

Sketch

APPENDIX 8C

CONCRETING CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1 Pre-concreting check list approved					
2 Enough concrete cement, sand, stone, additives etc available					
3 Concrete batching plant/Ready mix trucks fully operational and capable of delivering required concrete quantity					
4 Enough concrete cube moulds and slump cones available					
5 Enough time to complete the pour or suitable lighting for night-work					
6 "W" concrete site requirements comply					
7 Enough staff and equipment to place and compact the concrete					
8 Chutes, conveyor belts, wheelbarrows, etc required to place concrete fully operational					
9 Materials for curing ready for application					
10 Construction joints have been correctly prepared and pre-wetted as required					
11 If adverse weather conditions is expected, are the necessary measures in place					

CHAPTER 9 - PRESTRESSING

WJ Martin

9.1 SCOPE

This chapter covers the supply and installation of prestressing.

Site Monitoring Staff should read and obtain a sound understanding of the relevant section of the Standard Specification and the Project Specifications before applying this section of the Manual.

This chapter contains a substantial amount of information and requirements which are contained in the specifications. This is provided to assist monitoring staff in understanding "normal requirements": note that this does not take precedence over the specifications.

This section deals mostly with grouted internal post-tensioning, the most common form of prestressing in South Africa. For any of the following systems, refer to the relevant project specifications and specialist literature:

- Pre-tensioning;
- Un-bonded tendons; and
- External prestressing.

Other useful references include:

- Prestress supplier's handbooks

This section is laid out to follow the process encountered on a construction site:

(a) Information provided by the designer;
(b) Prestressing system, materials and equipment;
(c) Contractor's prestressing drawings;
(d) Supplying and storing materials;
(e) Installing prestressing;
(f) Checks prior to prestressing;
(g) Stressing of cables; and
(h) Grouting of cables.

9.2 INFORMATION PROVIDED BY THE DESIGNER

The monitoring staff should check that the following design information is provided to the contractor, usually on the drawings:

(a) Alignment (horizontal and vertical) of each tendon or group of tendons;
(b) Prestressing system on which the design is based;
(c) Tensioning sequence including any partial tensioning;

(d) Tensioning force and force after transfer, expressed in MN and as a percentage of characteristic strength;

(e) Tendon extensions, E-modulus and wedge pull-in;

(f) Friction loss coefficients for friction and wobble;

(g) Elastic factor (This is only really relevant for simply supported structures);

(h) Creep and shrinkage factors;

(i) Relaxation of prestressing;

(j) Anchorage types and positions;

(k) Bursting reinforcement. Note that this is reinforcement supplied in terms of TMH7 Part 3 Clause 4.8.5 and does not refer to the spiral that is required by some prestressing systems to prevent concrete crushing. This latter reinforcement should be detailed by the prestressing supplier;

(l) Precamber at quarter points or closer;

(m) Concrete compressive strength at transfer; and

(n) Type/grade of prestressing steel used in the design.

9.3 PRESTRESSING SYSTEM, MATERIALS AND EQUIPMENT

The site monitoring staff should ensure that the contractor has supplied full details of his prestressing system for approval. This should be received within one month of the tender having been awarded.

For testing of prestressing steel, anchorage assemblies, couplings and grout, refer to the relevant section of the Standard Specification.

9.3.1 Proprietary Prestressing System

The contractor's system should meet the following requirements:

(a) The system should be a proprietary system with a proven track record; and

(b) It should comply with the specifications including BS EN13391. (Note that this document supersedes BS 4447).

9.3.2 Prestressing Strand

The contractor should show that the prestressing strand complies with the relevant specifications. Note that the specifications for prestressing in COLTO 6503 (b) (ii) and (iii) is not in accordance with the latest standards. (These standards have been superseded and some of the strands and bars are no longer available.) Refer to the drawings or project specifications for the latest standards.

The contractor should test the prestressing strand and keep all records of these tests for each batch of prestressing supplied.

The calculation of prestressing extensions should be based on the prestressing cross-section area and the E-modulus determined in these tests.

9.3.3 Prestressing Anchorages

Prestressing anchorages are required to distribute the prestress forces into the structural member without damage. When damage does occur it usually falls into two categories:

(a) Concrete crushing directly behind the anchor: The prestressing supplier should provide details of any reinforcing coils and minimum concrete strength required to prevent this from happening; and

(b) Concrete bursting or splitting: This typically occurs in the zone between 200 and 1000 mm from the anchor. The designer usually designs and details reinforcement to control this behaviour.

When checking the prestressing system, the site monitoring staff should check that both these forms of reinforcement have been detailed and supplied.

9.3.4 Prestressing Sheaths

Prestressing sheaths are required to meet the following requirements:

(a) They should be grout-tight;

(b) Sheaths must enable bond forces to be transferred from the prestressing tendons to the concrete. Sheathing should therefore be deformed on both the outside face and the inside face. Sheathing with only one smooth face should not be used. This applies especially to plastic sheathing;

(c) The sheathing should not react with the prestressing steel to cause a corrosion cell. Metals such as aluminum should therefore not be used. Galvanized sheathing is generally not permitted;

(d) The flexibility of the sheaths should be sufficient to form the required curvature, but should not reach levels where wobble increases friction loss beyond the design limits;

(e) The sheaths should be strong enough to resist handling and prevent damage during placing and vibrating of the concrete; and

(f) The cross-section area of the sheath should be at least twice the area of the prestressing strands. For vertical tendons, this should be increased to three times the area of the strands.

9.3.5 Prestressing Supports

The function of the prestressing supports is to provide the necessary support and secure fixing of the prestressing sheaths at the required position and level. Their design and supply is the responsibility of the contractor.

The supports should comply with the following requirements:

(a) They should be able to carry all loads imposed on them, especially during concreting, without bending or buckling; and

(b) Normal web reinforcement should not be used to support the prestressing.

Prestressing supports typically consist of R12 or R16 reinforcing stirrups with lugs welded on at the correct level. A reinforcing bar is then tied to the tops of these lugs and the prestressing duct is supported on top of the bar. It is sometimes necessary to support the ducts by hanging them under the bar, such as at locations where two ducts pass each other vertically.

9.3.6 Vent Pipes

The function of vent pipes is to release air and grout from the prestressing ducts. Good practice includes the following:

(a) Vent pipes should be provided at least at both ends and at all crests and low points of ducts of multi-span continuous ducts;

(b) The pipes at the crests should be at least 25 mm diameter;

(c) They should be able to withstand a pressure of 15 bar;

(d) They must be fitted with standpipes at least 500 mm long but preferably 1 200 mm or more above deck level. The provision of adequate height is important as it is necessary to provide a "reservoir" to accommodate the bleed water above the cable ducts. This bleed water accumulates because the heavy cement particles tend to settle and move towards the valleys of the duct profile (sedimentation) whilst water and air bubbles collect at the high points (bleeding). Considering that bleeding of 3 to 4 per cent of the volume is not uncommon, it is fairly obvious that several metres of duct at the high points will only be partially filled with grout if no "reservoirs" at a higher level have been provided.

(e) Short, thin plastic vent pipes have in many instances been proved insufficient to serve as effective bleed reservoirs; and

(f) The inclusion of expanding agents in the grout mix does not eliminate the above requirements.

9.3.7 Grout

Grout should comply with the following requirements:

(a) The relevant clauses in the Specification;

(b) Chloride ions in water should be less than 500 mg per litre;

(c) Only CEM I with 15% or less slag should be used;

(d) Aggregate, where used, should be very fine sand or finely ground limestone. Generally, aggregates are not used;

(e) Only approved additives that do not cause damage should be used;

(f) Viscosity and bleeding should be within accepted limits specified in the Standard Specification; and

(g) Cube compressive strength should exceed 20 MPa at 7 days.

Although grout mix specifications are generally performance-based, specifying viscosity, bleeding and strength, good grout usually falls into the following categories:

- The water cement ratio W/C is usually in the range of 0.36 to 0.45; and
- An approved admixture will improve fluidity and reduce bleeding. Air entrainers are often used for this. Although only chlorides are limited in the specifications, admixtures should not contain nitrates, sulphides or sulphites.

9.3.8 Unbonded and External Tendons

Refer to relevant project specifications and specialist literature.

9.3.9 Prestressing Equipment

Prestressing equipment should comply with the following requirements:

(a) Should be able to measure the prestressing force to an accuracy of +/- 2%;

(b) Force should by measured using a load cell (direct reading dynamometer). Note that the hydraulic jack is generally a form of load cell, once its internal losses such as friction are known;

(c) Pressure gauge to be at least 150 mm in diameter and should be used in the range of 50% to 90% for maximum pressure;

(d) The hydraulic circuits should have self-sealing connections;

(e) The tensioning equipment should be calibrated before use and at frequent intervals thereafter. The contractors should provide the calibration certificates; and

(f) Extension of tendons should be measured to +/- 2% or +/- 2 mm, whichever is more accurate.

9.3.10 Grouting Equipment

Grouting equipment should comply with the following requirements:

(a) The mixer should be mechanically operated;

(b) The screen should have openings not exceeding 1 mm;

(c) Where the mixer is too small to fill the duct on one mix, a mechanical agitator should be used;

(d) The grout pump should be of the positive displacement type capable of at least 10 bars of pressure;

(e) The grout pump should have a pressure gauge to ensure that the grouting pressure is at least 10 bars/1 000 kPa;

(f) There should be a safety device to prevent the grout pressure exceeding 20 bars; and

(g) The hydraulic circuits should have self-sealing connections.

9.4 CONTRACTOR'S PRESTRESSING DRAWINGS

The contractor is required to prepare and submit prestressing drawings. These should be received at least two months prior to commencing prestressing work, and should be checked for the following:

(a) Layout and alignment of individual tendons;

(b) Details of cable supports;

(c) Modifications to bursting and other reinforcement. Note that spirals directly behind the anchor to control concrete crushing are NOT bursting reinforcement. These spirals must be detailed by the prestressing supplier;

(d) Anchorage recesses;

(e) Tensioning sequence;

(f) Tensioning loads and extensions, based on the measured prestressing areas and E-modulus;

(g) Wedge pull-in; and

(h) Each tendon should be separately numbered for identification.



Photo 9.1: Reinforcement at prestressing anchor. The spiral behind the anchor is detailed by the prestressing supplier while the clips are detailed by the designer. Note that the clips should be anchored around a bar of its own diameter.

The site monitoring staff should check the contractor's prestressing drawings for any clashes of transverse and longitudinal cables with each other or with reinforcement, especially at the anchors.

9.5 SUPPLYING AND STORING MATERIALS

Prestressing supplied to site should comply with the following conditions:

- Prestressing strand is supplied to site in coils of large diameter in such a way that they are protected against damage or corrosion;
- If corrosion inhibitor is used, it should not affect the steel, grout or concrete and it should not affect the bond between steel and grout or concrete;
- The prestressing should ideally be free of rust but some light surface rust that is not flaking could be acceptable. This however may increase the friction losses;
- The depths of imperfections or pits should be less than 0.1 mm on wires and 0.2 mm on bars; and
- Prestressing should be weld-free. Where prestressing has been welded to assist in handling, the welded portions should be cut out.

Prestressing bars, wire or strand should be stored under roof and off the ground to minimize the formation of rust that can reduce the strength. In locations close to the coast, prestressing should be stored in an enclosed shed.

The contractor should provide copies of the test certificate of each cheese of prestressing strand to be used as well as the delivery note with the cheese numbers. (A cheese refers to a role of prestressing

strand, usually supplied in a steel frame or on a wooden drum.) The Contractor must also provide at least a 2 meter length of strand from each cheese that will be used. This should be colour-coded and properly marked with the cheese number so that one can easily determine which strand is placed in which duct.



Photo 9.2: Storing of cheeses of prestressing strand: Prestressing should not be stored as shown in the photograph

9.6 INSTALLING PRESTRESSING

Prestressing should not be exposed to heat treatment on site. Prestressing strand or bars should be cut using cutting disks, and should not be flame-cut or cut with a welding torch.

All materials including prestressing, anchorages and sheaths should be clean and free from loose mill scale, loose rust and other harmful matter.

BEWARE
No welding operations should take place close to prestressing as even minor contamination from hot weld splatter may cause rupture of the wire during tensioning.

9.6.1 The Use of Soluble Oil

The prestressing strand should be free of sand and rust and as clean as possible before being placed in the ducts in order to minimise friction during stressing. Flushing the cable with clean water before stressing will help. However, if sand particles do get stuck in the hollows of the duct, it may be impossible to remove them. If necessary the ducts can also be flushed with soluble oil, which must then be washed out with clean water before grouting. Note that the use of a detergent for flushing should not be allowed since it is more difficult to remove than the oil. It is recommended that the ducts be flushed out twice using fresh water as it has been found that if ducts are flushed out the day before grouting occurs, more oily solution (green) will be visible in the water the next morning because more oil comes loose overnight.

9.6.2 Prestressing Hangers or Supports

Hangers and supports on which to position the prestressing ducts should be formed to the correct dimensions before being put in place. The Contractor should not be allowed to do welding on these

once in place with the prestressing cables. The ducts should be securely tied to the hangers to prevent displacement during casting.

9.6.3 Pulling/Shooting Through of Strand

In some cases such as in incrementally launched bridges, the empty ducts are cast into the concrete and the strand is only inserted afterwards. Before concreting, the ducts need to be checked for holes and dents. All the joints also need to be properly sealed, and special attention paid to the connections between the ducts and anchors.

Once the concrete is cast, the ducts need to be checked to ensure that they have not been blocked by concrete paste that may have entered a hole in a damaged duct. This can be done in a number of ways including flushing the duct with water.

The strand can either be pulled into the prestressing duct as a group, or the individual strands can be shot through. For both systems, care must be taken to ensure that the strand stays absolutely clean. No sand must enter the duct as this increases friction.

Shooting strands through ducts with many low and high points has caused problems in the past. For example, when shooting strands through a three-span deck, the strands become intertwined, making shooting further strands difficult. It also gives a force-extension curve that is not straight. In these cases, it is better to pull the strands through as a group.

9.6.4 Wedges and Swages

On placement, wedges should be oil free on the inside to prevent slippages from occurring. Wedges should be clean on the outside to allow movement between the wedge and the anchor. The wedges should be knocked tightly in place with a piece of metal tubing so that they grip the strand equally.

Crimped wedges or swages are often used at dead ends and couplers. It is very important to make sure these are installed the right way around, the teeth pointing against the direction of stressing, since it is virtually impossible to rectify a swage which fails during stressing without de-tensioning the whole cable. A failed swage, if not identified during stressing, will also lead to over-stressing of the remaining strands.



Photo 9.3: Seating prestressing wedges: This is best done with a tube around the strands rather than as seen in the photograph

9.6.5 Prestressing Ducts

It is important to check that the prestressing cables are laid to the specified profile. In case of simply supported beams it is sufficient to check at midspan, at the anchorages and also at quarter-points. Between these points the cables should follow a smooth parabola which can be easily judged by eye.

In the case of skew slabs, whether simply supported or continuous, and of continuous beams or slabs, more careful checking of the profile is necessary. Here the cable positions must be checked at all supports (high points), at centre of all spans (low points), at the points of contraflexure, and at the anchorages. A few random checks at other intermediate points are advisable.

The cable profile in relatively thin slabs (150mm to 250mm), e.g. deck slabs of box girders, must be fixed and checked with the utmost care. Allowance must be made for the fact that the centroid of the wires or strands do not coincide with centre-line duct.

The permissible tolerance in placing the cables should comply with the Standard Specification.

The prestressing ducts must not move during concreting, either due to the weight of the concrete or due to buoyancy. If it is possible to push the duct around with one's foot or deflect it appreciably, the duct should be considered inadequately fixed.

Prestressing cables must enter the anchorages at right angles and approximately the last 1 000 mm of cable before the anchorage or cone (trumpet) must be straight. Therefore anchorage recess formers such as wooden wedges or boxes and polystyrene must be cut and fixed to the formwork with the utmost care.

9.6.6 Check Prestressing Ducts After Concreting

Immediately after concreting, the contractor needs to show that the ducts are clear and that concrete paste has not entered any of the ducts. This can be done by flushing the duct with water or by checking the movement of the strand within the duct. While the paste is still weak within the first two

hours of hardening it is relatively easy to remove the blockage. If the blockage is left for several days, it may be necessary to break into the duct to clear it, or abandon the duct.

9.7 CHECKS PRIOR TO PRESTRESSING

Prior to prestressing, all the various details and information regarding the prestressing system should have been submitted by the contractor, as previously stated in 9.3. These must be reviewed to confirm that the contractor has shown that his system fully complies with the specifications and drawings. Prestressing may not start until the site monitoring staff have given their approval.

The contractor should provide a stressing programme so that the site monitoring staff can have the opportunity of monitoring the prestressing operation. In this, the contractor should confirm that the jacks, dial gauges and pumps are in working order and calibrated and that the pressure grouting equipment is also in working order. The programme should also state at what age of the concrete stressing should commence and that the cube-testing machine will be in working condition at the anticipated day of stressing.

NOTE: Prestressing is the pre-compression of concrete, and can only be fully achieved if the concrete member is allowed to shorten.

Timber formwork does not restrain this shortening appreciably, but steel formwork can have undesirable effects. Sideforms, especially if made of steel, should therefore be stripped prior to stressing. Steel soffit formwork, particularly in case of slab superstructures, must be able to shorten without restraining the concrete excessively.

Similar considerations also apply to the staging supporting the formwork, but are generally only relevant in the case of longer superstructures.

Monitoring staff should also check that bearings are free to move in order to accommodate the movements which occur during the elastic shortening of the superstructure. This applies especially to bearings which have temporary fixity such as transportation brackets.

Additional concrete test cubes should be manufactured and tested just prior to stressing to confirm that the concrete has reached adequate strength (usually 35 MPa is required). Lower strengths may lead to concrete crushing behind the anchor and concrete cracking and splitting.



Photo 9.4: Crack in end of precast beam: The effect of the prestressing causing the beam to hog with all the self weight being carried by the ends combined with the beam not being able to slide on the casting bed has caused the end of the beam to crack. Ideally the bed supporting the end of the beam should be sufficently compressible to relieve the high end pressures.

9.8 STRESSING OF CABLES

The stressing operation should be done in increments and the calculation of results done continually to avoid over-stressing of a strand. Before starting, the strands protruding from the anchor should all be marked at the same distance from the anchor, or all cut to the same length, in order to see if slippage occurs.

During stressing the cable extension and the tensioning force should be carefully measured and recorded to check that there is acceptable agreement with the predicted values. The accuracy with which the extension should be measured should be in accordance with the specifications. The gauge pressure versus extension should be plotted on graph or squared paper during the prestressing operation in order to identify changes in slope which may indicate blockages which come free or strands breaking or slipping.

WARNING

Prestressing is a potentially dangerous operation as there is the possibility that strands or wires break, wedges fail, hydraulic hoses burst or come loose, concrete behind an anchor can burst, a curved duct can pull out of the concrete, etc. The contractor should include his prestressing operations in his Occupational Health and Safety Plan. This plan should include requirements that only the necessary personnel are allowed in the immediate vicinity of a prestressing operation and no one (including site monitoring staff) should stand behind the prestressing jack during stressing.

In the case of strange or anomalous prestressing results, the piece of strand that represents the cheese from which the prestressing strands were taken, can be sent away for testing if necessary. Note that the Contractor should keep a record of which cheese is used in which duct and provide the monitoring staff with this information. As far as possible, strand from different cheeses should not be placed together in the same cable. If this happens, the weighted averages of the modulus of elasticity and area values should be used in the calculations.

If the actual cable extension is excessively larger than the calculated value and falls outside the allowable range of variation, then the following checks should be carried out immediately:

(a) Check the accuracy of pressure gauge;

(b) Check the actual E-modulus of steel verse the assumed one in extension calculations;

(c) Check for damage or distortion of anchorages; and

(d) Check for indications of single wire or strand fracture.

The following remedial measures can be applied:

If, after correction for the first two items, the variation is within allowable limits, the prestressing can be accepted.

If on the other hand the discrepancy is still out of specification and no evidence of faulty anchorages or fractured wires can be found, then a very low friction and a minus tolerance in wire diameter is likely. In this case the cable should be released and locked off at the specified force.

If damage to anchorages or fracture of wires or strand has been established, the cable should be completely de-tensioned, the extent of damage investigated and remedial action proposed by the contractor. In the interim stressing of the remaining cables may proceed.

If the actual cable extension is much less than the calculated one (say -8% and less), then check the following:

(a) Actual and assumed E-modulus as above; and

(b) Tolerance in cross-sectional area of the wire.

The following remedial measures can be applied:

If, after correction for the above two items, the discrepancy falls outside allowable tolerances, then excessive friction or blockage in the duct must be suspected. In this case it is prohibited to increase the cable force in order to obtain the calculated extension. Instead, the cable should be completely released and re-stressed (twice if necessary) and the extension measured again. If the extension now falls within tolerance, the cable can be accepted. However, if there is no marked improvement then the duct should be flushed with water-soluble oil, the cable released and re-stressed again. If the extension now falls within tolerance, the duct should be repeatedly flushed with water to remove the oil, and then accepted.

If, after the remedial work, the extensions do not fall within allowable tolerances, they should be referred to the design office to check the implication on the structure.

Tensioning at Both Ends:

The designer's drawings often require that cables in long beams and continuous superstructures be tensioned from both ends. If both ends are stressed simultaneously, it is almost impossible to get a straight force-extension curve. This straight curve can only be achieved if both jacks start simultaneously and work at the same rate of increase of force. The stressing force diagrammes in Figure 9.1 illustrate the problem.

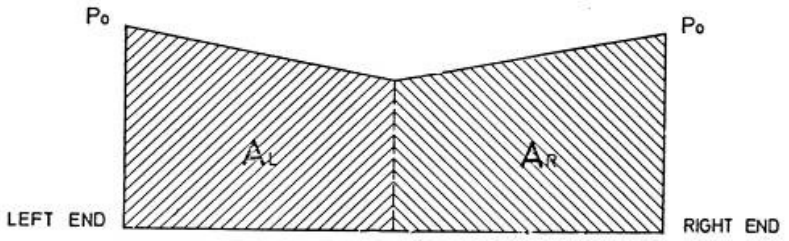


FIG.1. Identical rate of increase of force.

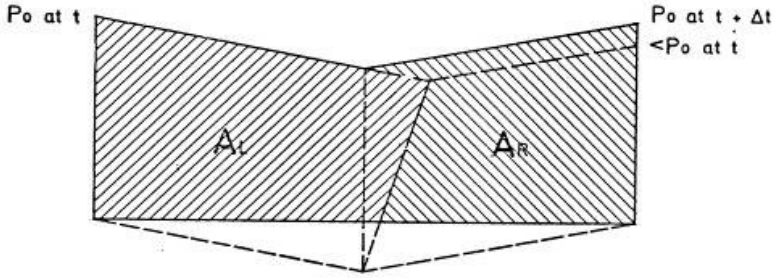


FIG.2. Right jack slower but catching up whilst left jack held.

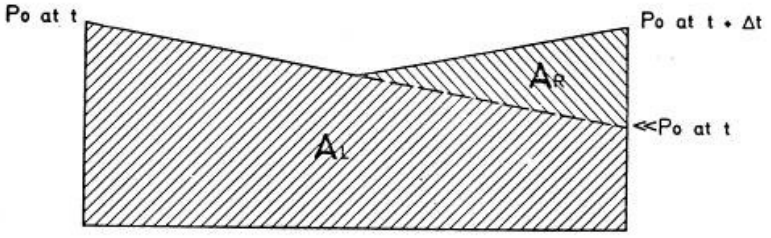


FIG.3. Stressing left end first, then right end.

Figure 9.1: Stressing tendons from both ends

In Figure 9.1, the cable extension at each end is the appropriate area (hatched AL of AR) under the force diagram divided by AS x ES, i.e.

$$\Delta \ell = \int_0^x \frac{P_x \, dl_x}{A_s E_s} \quad \therefore \quad \Delta \ell_L = \frac{A_L}{A_s E_s} \quad \& \quad \Delta \ell_R = \frac{A_R}{A_s E_s}$$

This does not include the additional extension due to the elastic shortening of the concrete, which has only to be considered if all cables are stressed in one operation.

In FIG.1 both ends are stressed simultaneously and exactly the same rate. This is the ideal situation but does not happen in practice.

FIG.2 shows what is more likely to happen: One jack is faster than the other and the extensions at the two ends are quite different from each other.

It could be shown that if one jack gains force about 10% faster, the extension of that end will be about 60 to 70% of the total instead of the theoretical 50% with a corresponding low value at the other jack, depending on friction loss and length of member. However, the final force diagramme will nevertheless be as assumed in design. Irregularities of friction losses are, of course, not considered in the above.

Because of this, it is recommended that stressing be done from one side at a time. This is shown in FIG.3 of Figure 9.1. The force-extension curve at the first side, plotted as the cable is stressed, will behave normally and the normal procedures for checking and calculating apply. The plot should be straight.
The extension at the second side will be quite different. Initially, only the extension in the jack will be measured. In other words, the only cable that will stretch is that length between the wedges at the anchor plate and the wedges at the back of the anchor.

The wedges at the anchor will only lift off once the force in the jack is greater than the force in the cable at the anchor caused by the first stressing plus any force needed to overcome the friction of the wedges. This wedge friction could be quite high, resulting in the dial measuring the jacking force climbing up quite quickly and then jumping down as the wedges lift off. Only after this will the cable in the deck start extending. The plot of extension will not be a straight line because initially the extension only causes an increase in cable force over a short distance from the jack, extending further along the cable as stressing progresses. The plot will therefore follow a convex curve.

The plotted readings should always follow a smooth curve. The force-extension can easily be pre-calculated using a spreadsheet and then checked on site for conformity.



Photo 9.5: Broken prestressing wires due to prestressing wedges being too hard and damaging the strand

Failure of wedges or wires:

After stressing, the monitoring staff should check that all of the cables are properly prestressed. This includes checking for:

- Broken wires: This is shown if Photo 9.5. When this happens, the other wires will slip past the broken wire as tensioning continues, leaving the end of the broken wire sticking out beyond the ends of the other wires;
- Wedges which have not seated properly: Here it can be seen that the three sections which make up each wedge have not pulled in uniformly. Instead, one section is sticking out relative to the others; and
- Wedges have not gripped the strand properly: This can be seen when looking at the ends of the strands after prestressing. Before prestressing, the strands are all marked at one spot, either with a hacksaw blade or with spray-paint. After prestressing, these marks must extend by the same amount. If one has not extended as much as the others, the wedges on this strand have slipped.

Stressing members on "Elastic" staging:

In some situations where a member is supported on high formwork, the staging shortens elastically as the member is cast. When the member is stressed, it lifts the member and transfers the weight to the bearings or piers. If the elastic shortening is greater than the amount by which the prestressing lifts the member, then under full prestressing, the full self-weight will not be acting. This has led to the member cracking due to tension.

In situations like this where members are on "elastic" staging, common practice is to partially release the props after applying about 65% of the prestressing.

9.9 GROUTING OF CABLES

The importance of the grouting operation cannot be overemphasized. The grouting of cable ducts entails the complete filling of the ducts with a suitable grout mixture to ensure bond and, above all, corrosion protection of the prestressing wire or strand.

A major problem that has affected prestressing in bridges is corrosion occurring behind the anchors, at construction joints in segmental construction and at voids in the grout. This seriously weakens the prestressing after several years. The problem was found to be so severe that some authorities in England did not allow internal prestressing for many years. This extreme action was taken because prestressing corrodes very rapidly under stress and tends to fail suddenly without prior warning. Prestressing can also fail without oxidation due to embrittlement by nascent hydrogen – this is associated mainly with galvanizing.

Cable ducts should be grouted as soon as possible after tensioning of the steel, generally within seven days. If, for structural reasons, grouting has to be delayed for more than seven days, temporary protection of the prestressing by methods or products which will not affect bond or durability, should be used, e.g. flushing of the ducts with water soluble oil.

General practice for grout mixing is as follows:

- The cement should be added to the water in the mixer drum;
- The mixing time should be at least 4 minutes.
- Admixtures should be added 2 or 3 minutes after commencement of mixing.

It has become common practice to use an admixture in prestressing grout, or even proprietary grouts. These generally contain corrosion inhibitors, plasticisers and retarders. Bleeding is also significantly less.

On completion of concreting, all cable ducts should have been flushed with water to detect and remove blockages which may have occurred due to duct leakages. The water must immediately thereafter be blown out with compressed air. Prior to grouting this procedure should be repeated, this time in order to wet the surfaces of the tendons and ducts. If this is not carried out sufficient water may be extracted from the advancing head of grout to cause thickening of the grout and blockage of the duct. Drainage or grout injection pipes at low points of ducts, if provided, should be opened to drain excess water in the ducts.

The ideal grout injection points are the low points of the duct profile. However, most prestressing systems have a grout injection nozzle hole in the anchorage. Injection should be slow enough to prevent segregation (say 6 to 12m per minute) and should be continuous. As injection proceeds, diluted grout or even clear water will first issue from successive bleeder tubes (stand-pipes) and at the far-end vent opening. This occurs due to water trapped in the corrugations of the ducts which usually

cannot be entirely removed by compressed air. As soon as grout of normal consistency emerges at the intermediate vents these should be closed. When normal grout flows from the end-vent, this should also be closed and finally all vents hermetically closed and the grouting pressure increased to 10 bar prior to closing the injection nozzle.

NOTE
Vent pipes must be closed (or clamped) at the upper end of the pipe, (not near the bottom) to give space for the bleed water to migrate.

After about 1½ hours the grout level in the standpipes should be checked. If the grout has settled below deck level, regrouting or perhaps topping up is necessary. Re-grouting should commence while the grout is still fluid but not later than 2 hours after the first grouting and care must be taken that the hose from the pump does not contain any air when reconnected. The grout mix also needs to be modified to reduce bleeding.

In case of hold-ups, e.g. break down of grout mixer, the grout may be used if it is not older than ¾ hour (½ hour in hot weather) and must be remixed.

If a blockage occurs during grouting, the duct must be flushed out immediately with water and preferably in the opposite direction. Pumps developing a pressure of 10 bar are likely to be required.

Grouting During Low Temperatures:

In frosts, standing water in the cable ducts must be avoided. If the temperature is less than 5°C, grouting should be delayed. If, however, particular circumstances require that grouting be done or continued under such conditions, special precautions should be taken. The ducts should be flushed with warm water having a temperature not exceeding 50°C until it is likely that the concrete around the ducts has a temperature of at least 5°C. Thereafter the water should be blown out with compressed air. Warm water should be used in the grout mix such that the temperature of the grout prior to injection is about 25°C. Alternatively a frost-proof grout containing a certain proportion of entrained air (generally 6 to 10%) may be used.

If the temperature is likely to fall below 2°C within 48 hours after injection, the member should be protected to avoid frost effects.

After grouting, the anchorages will be enclosed to ensure that they cannot corrode.

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APPENDIX 9B - PRESTRESSING CHECK LIST: PRIOR TO CASTING CONCRETE

APPENDIX 9C - PRESTRESSING CHECK LIST: PRESTRESSING OF TENDONS

APPENDIX 9D - PRESTRESSING RECORD - SAMPLE

CONTRACTOR'S PRESTRESSING DRAWINGS CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1 Prestressing system is a proprietary system					
2 Complies with the relevant specifications (BS EN 13391)					
3 Prestressing strand complies					
4 Prestressing supports comply					
5 Vent pipes comply					
6 Grout mix design complies					
.7 Grout equipment complies					
8 Prestressing equipment complies					
9 Contractor's drawings contain the required information					
10 Spacing and type of cable supports comply					
11 Designer has reviewed changes to the original design					
12 Prestressing bursting reinforcement, where required, is detailed and does not conflict with other reinforcement					

PRESTRESSING CHECK LIST: PRIOR TO CASTING CONCRETE

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1 Prestressing system has been approved					
2 Prestressing ducts are to line and level					
3 Prestressing anchors are installed at correct angles					
4 Prestressing ducts are firmly tied and watertight					
5 Prestressing vent pipes are installed correctly and are of correct size and length					
6 Bursting reinforcement is correctly installed					

PRESTRESSING CHECK LIST: PRESTRESSING OF TENDONS

CONSTRUCTION MONITORING CHECKLIST

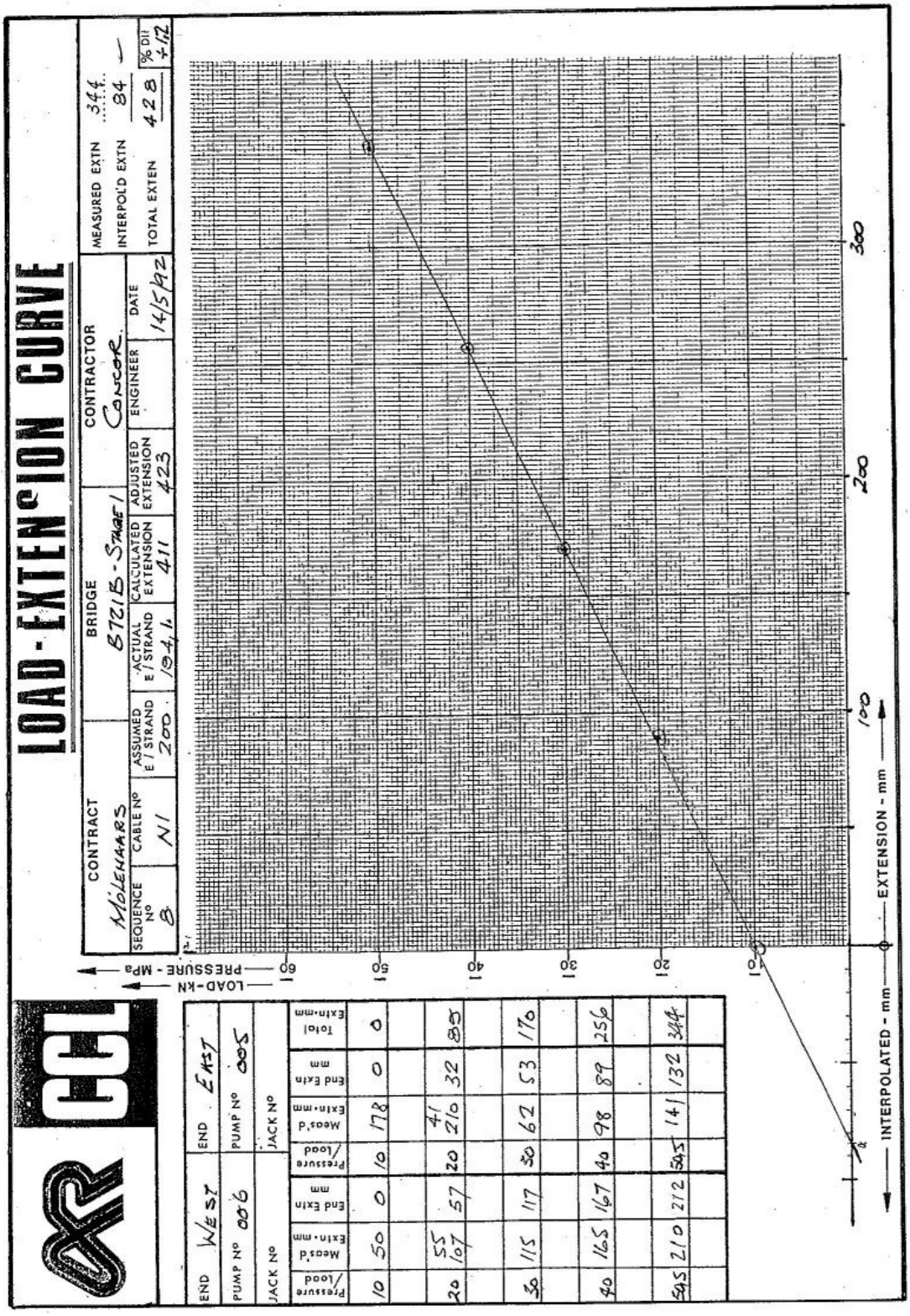
PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1 Prestressing system approved					
2 Pre-concrete check approved					
3 Ducts have been checked after concreting					
4 Correct number of strands in each duct					
5 Calculated prestressing load cell readings and cables extensions approved					
6 Prestressing programme approved					
7 Structure is free to shorten under prestressing					
8 Bearing temporary fixity has been removed where required					
9 Concrete has reached the required strength					
10 Prestressing equipment complies and is calibrated					

PRESTRESSING RECORD - SAMPLE



CHAPTER 10 - PRECAST ELEMENTS

WJ Martin

10.1 SCOPE

This chapter covers the manufacture of precast elements such as:

- Precast beams;
- Precast parapets and barriers;
- Precast piles;
- Precast culverts; and
- Other precast components.

Precast elements such as precast kerbs, precast pipes, block paving and precast segmental construction are not included.

Site monitoring staff should read and obtain a sound understanding of the relevant section of the Standard Specification and the Project Specifications before applying this section of the Manual.

This chapter is not written to be a stand-alone reference, but aims to give information and advice on precasting that is not included in other chapters of the manual. For formwork, reinforcement, prestressing and concrete, refer to the relevant chapters in the manual. This applies especially to curing of the precast elements – the unformed concrete surface should be protected against evaporation immediately after casting.

10.2 GENERAL PRACTICE IN PRECASTING

The two factors which have the greatest impact on the operation of a precast yard are:

- Formwork: The importance of extremely well made and accurate formwork cannot be stressed enough; and
- Concrete: A good mix design and careful placing to avoid air bubbles and good consolidation are the keys to successful precast elements.

If the contractor deviates from these two principles he or she will not achieve the success that is aimed for. These two principals cannot be stressed enough.

10.2.1 Concrete Quality and Cover To Thin Sections:

Precast components are generally thin. Concrete quality and cover is therefore very important and needs to be monitored carefully. Monitoring staff should be aware that:

- If there is too little cover, the component has a reduced lifespan before corrosion starts; or
- If there is too much cover, the designed lever-arm to the reinforcement is reduced and the component may not be strong enough.
- Poor concrete quality will lead to reduced long term durability performance of the concrete

Where precast units are manufactured off-site and only periodic inspections of the manufacturing process are made, it is advisable to carry out comprehensive cover meter checks on the units delivered to site. Where durability concrete is specified, regular durability testing in terms of the project specifications should be undertaken during manufacture of precast elements.

10.2.2 The Unformed Face of a Precast Component:

In precasting, all of the faces except the top one are shuttered in formwork. The concrete is placed in the top face and is then wood-floated or steel-floated. This face will always appear different to the other faces. The selection of the un-formed face should therefore be made with this in mind, and is usually as follows:

- For precast beams, it is the top face as this will have the deck slab cast on it and is not visible;
- For precast parapets it is the narrow top face, which is then steel floated to give a uniform appearance;
- For precast sidewalk panels it is the bottom surface. The component is cast upside-down; and
- For precast noise barriers it is the bottom or back face.

10.2.3 Early Removal of Formwork:

Precast formwork is often removed the day after casting to speed up the construction process.

If concrete laitance stick to the formwork, it is likely that too much shutter oil, which is a retarder, has been used; or the wrong type of form release agent has been used; or the formwork has been removed too early. In the latter case, the formwork needs to be left in place longer or the concrete temperature needs to be raised to increase the rate of strength gain.

Where formwork is removed early, curing becomes critical to avoid excessive shrinkage with its associated cracking. Common curing methods include:

- Steam curing – the component is enclosed and steam-laden air with more than 100% humidity is circulated. The elevated temperature increases the rate of strength gain;
- Continuous spraying with microjets for at least 7 days – if there is a strong wind, this method is not effective;
- Wrapping in plastic or other impervious layer; and
- Wrapping in a water absorbing material such as carpet underfelt and wetting it regularly.

Although curing compounds do reduce water loss from a concrete section, they are not as effective as the above methods or leaving a concrete section in its formwork. Curing compounds alone should therefore not be used when formwork is removed early.

NOTE

When steam curing, the concrete must not be overheated as this may cause severe damage. Steam curing typically raises the concrete temperature to between 60°C and 70°C.

10.2.4 Moving and Transporting a Precast Component:

The moving and transporting of precast components are generally considered to be temporary works activities. If a component has not been designed to be precast or if the contractor changes the specified lifting points, it is the contractor's responsibility to show that the component is adequately reinforced and strong enough to be moved.

For example, a 2 m high cast in-situ sound-barrier panel may only have been designed to resist wind loads and will therefore be lightly reinforced. If it is constructed on its side (i.e. horizontal) and will then be lifted up from the top, it may need additional reinforcement to prevent cracking.

Lifting hooks and connections need to be strong enough and placed in the designed position, otherwise they may fail, causing the component to crack or break.



Photo 10.1: Precast pedestrian bridge deck being lifted in place.
Lifting points typically coincide with the designed support positions.

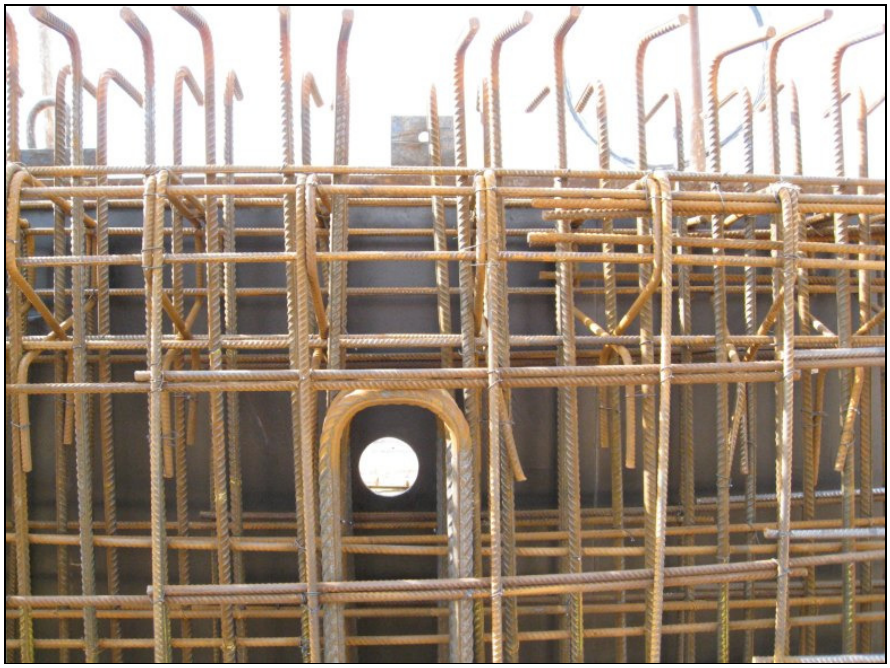


Photo 10.2: Reinforcement around a lifting point in a precast beam.

Prior to moving or transporting a precast component, the contractor should provide the following information:

- Method statement of how the works will be executed;
- All lifting arrangements, showing that they have been properly designed; and
- Occupational health and safety plan showing that all safety aspects have been addressed.

The site monitoring staff may need to liaise with the designer regarding the acceptability of the above information.

10.2.5 Uneven Creep and Shrinkage During Storage:

If a concrete component is stored for a long period in a situation where the sun or wind acts predominantly on one side of the member, the creep and shrinkage effects will vary across the member, resulting in distortions which can cause problems during installation. Components such as long precast beams and match-cast precast deck segments are particularly sensitive to this. It is therefore preferable to store such members in an orientation which results in uniform sun and wind exposure.

Poor stacking of precast elements can also cause the lower, more highly stressed elements to deform more due to creep. This often occurs when components are stacked with incorrectly positioned timber spacers.

Site monitoring staff should ensure that the contractor's storage and support arrangements are approved. This applies especially to precast beams where incorrect temporary support points may adversely affect the stresses in the beam.

10.3 PRECAST YARD

Construction within a precast yard generally yields improved quality and higher rates of production since materials, equipment and staff are all close by, and the work tends to be highly repetitive.

The precast yard can be either:

- A precast supplier's yard, in which case it is a permanent facility; or
- A temporary precast yard established on site, where all materials and equipment are close at hand.

By its very nature, precast yards can produce components at a very rapid rate. For example, several precast parapets can be cast each day. Quality control is therefore very important.

The precast yard operator must have a quality system in place whereby each stage of the operation is inspected by the operator and signed off before moving to the next stage. These check-points can include:

- Prior to closing formwork: Reinforcement, prestressing, inserts, formwork quality, etc;
- Prior to casting concrete: Formwork, cleanliness, etc;
- Prior to prestessing; and
- Prior to lifting and moving the element.

The site monitoring staff need to visit the precast yard regularly to ensure that the QC system is being maintained and that the paperwork is being signed only after an inspection has actually taken place.

In the case of precast yards established on site, the contractor should obtain prior approval of the casting yard before establishing it. The details required to be submitted for approval include:

- Plans demarcating the layout;
- Layout of the works and storage areas; and
- Flow diagramme for construction stages and storage.

10.4 PRECAST BEAMS

10.4.1 Precast Beds

Precast beds should be suitably shaped to take any precamber requirements into account. If precamber is not given on the drawings, the requirements must be obtained from the designers of the beams.

Precast beam beds should have sufficient longitudinal reinforcement to control transverse shrinkage cracking. If not, cracks in the bed will form marks on the beam soffit, and when erected, the beams themselves will appear to be cracked.

10.4.2 Stressing of Precast Beams

When precast beams are stressed, they need to shorten. The precast bed in contact with the beams must therefore be very smooth with an appropriate bond-breaker/release agent applied. Concrete beds require a steel trowelled finish.

When precast beams are stressed, they tend to hog, transferring their weight to the ends of the beams. This part of the casting bed should be strong enough to carry these loads. Soft material should be placed at the very ends of the precast bed to prevent point loads from the hogging action spalling off the very end of the beams.

10.4.3 Transporting and Placing of Precast Beams

The operations of transporting and placing precast beams are temporary works activities and are therefore the responsibility of the contractor. Strength and stability are the major considerations, and all components making up the lifting equipment, including connection points, straps, cables and cranes, must be able to safely carry the loads. At all times the beam and crane must have an adequate factor of safety in terms of stability.

The contractor must provide full details of his lifting points, lifting straps, transporting and placing procedures for review. Calculations should be called for if there is any doubt about the strength of these components.

In order to pick up a precast beam, some form of lifting point is required. Typical lifting points include:

- Lifting eyes in the form of large diameter reinforcing bars which can deform to fit the shape of the lifting hook;
- Lifting bars threaded through a horizontal hole in the beam end with a double strap around the bar;

- Proprietary lifting connections.

If the lifting straps are not vertical the lifting points must be designed to carry the weight of the beam plus the horizontal component of force. For a 45 degree strap, this increases the force acting on the lifting point by 41%.

During the handling of a precast beam, there is always a danger that the beam may topple over. This has happened several times in the past and can lead to permanent damage to the beam and serious injury to people. It is therefore essential that the contractor's procedure ensures that the beam remains stable during all stages of the construction. Mistakes to be avoided include:

- The connection point to the beam is below the centre of gravity. This occurs with a lifting bar passing through a hole in the beam is too low. In such situations, while the beam is vertical, it will be in unstable equilibrium with no factor of safety against overturning. However, as soon as the beam tilts slightly, it becomes unstable and falls over.
- The beam is placed on flexible bearings and its weight is taken off the lifting points before the beams have been braced. This rather obvious error has been made often.

During the handling of slender precast beams there is also the danger of the beam buckling. This can occur when the compression flange is narrow and is not sufficiently restrained to prevent lateral buckling. Guidance regarding this behaviour is given in TMH7 Part 3 clause 3.3.1.3, which gives proportions of length to depth to width that ensure lateral stability. Buckling can also occur when the concrete to the in-situ slab is cast.

Where traffic is affected, the contractor needs to provide a traffic accommodation plan for erection of the precast beams. An action plan needs to be provided should there be a possibility that a change in the erection method statement will be required in order to maintain free flow of traffic during erection.

10.5 CONCRETING AND CURING

Normal concreting practice should be followed. Note however that curing requires special attention if formwork is struck early. This is discussed earlier in this chapter.

The method of curing must be approved by the engineer.

10.6 PRESTRESSING

Normal prestressing procedures and approvals should be followed.

The site monitoring staff should ensure that they receive all the prestressing results certificates within 7 days of stressing. These certificates should include records of the following:

- Tendon forces and extensions;
- Cube crushing strengths; and
- Age at transfer.

10.7 PRECAST PARAPETS AND BARRIERS

Once installed, the line of the precast parapets, and especially their top rail, must appear smooth to the eye and must follow the designed profile. This is especially the case where additional creep and shrinkage is expected and the parapets are set out to allow for this. Balanced cantilever bridges are particularly sensitive to this. This is of great importance as the top line is close to the motorist's eye-

height and any misalignment is easily seen. The contractor's method of installation must therefore allow for fine adjustment of the alignment before concreting the precast parapet into position.

The checking and acceptance of the alignment should always include careful visual checks made by sighting along the upper edges of the parapet/handrail. It is advisable that a generous length of parapet be erected before casting the connection, as this will enable minor alignment imperfections to be easily detected and rectified.



Photo 10.3: Precast parapet with formwork being struck.

Special attention should be given to the accurate setting out of the connection bars which join the precast parapet and the deck. This is of great importance, and considerable difficulties will be experienced if adequate tolerances are not provided to enable the necessary meshing and overlapping of the connection bars to be achieved. These bars are particularly prone to corrosion in instances where inadequate attention is given to the placing and quality of the connection concrete/grout. The concrete or grout used in the connection must therefore match the quality of the concrete in the parapet and must be properly placed and cured. If this is not done, shrinkage cracks are likely to occur and rain water flowing along the edge of the parapet will make its way to the reinforcement. The entire connection arrangement and process must be critically examined to ensure that there is no possibility of air entrapment within the connection area, as this will weaken the connection and may result in the corrosion of reinforcement.



Photo 10.4: Precast parapet top rails being stored in a precast yard.

10.8 PRECAST PORTAL CULVERTS

Good references for precast portal culverts, as well as pipes, are "Concrete pipe and portal culvert handbook" and "Concrete pipe and portal culvert installation handbook, both by the Concrete Manufacturer's Association (www.cmapipes.co.za). Other useful information is also available from this site.

Precast culverts are designed as fit-for-purpose: Depending on the class (75S to 200S), they are required to withstand specific loadings to SANS 986. This is usually done in the precast yard. The precast supplier will have a quality system in place as previously discussed. The site monitoring staff should attend some of the load tests and review the results of all the load tests as well as the documentation for the quality system.

Precast culverts must be labeled correctly. This avoids the incorrect culvert being installed in the incorrect position. The site monitoring staff should check that the labeling is correct, both when delivered to site and when installed.

When the culverts are being constructed, lifting points must be included to suit the contractor's proposed installation process on site. This usually consists of one or two holes in the top slab to take a fabricated steel lifting hook. Lifting points consisting of looped mild steel reinforcement can also be cast in. Note that culverts must butt up flush with each other so slings around the top slab will not work.

Culverts must be properly stored on site to prevent damage or distortion. If a culvert is not supported evenly under the legs, the culvert can twist due to creep. If culverts are not stacked correctly, they can crack or distort.

Culverts can be easily damaged on site. They are heavy and just need to touch another object while being lifted for a corner to spall off. This must be avoided. Care needs to be taken during the entire process of handling the culvert so as not to damage them: from handling them within the precast yard, to transporting them, to storing them on site to finally installing them. Any minor spalls on culverts must be repaired before installation. If there are major spalls or cracks, the culverts must be rejected.

10.9 PRECAST PILES

The largest loads on precast piles usually occur during handling and driving. The reinforcement that is detailed by the designer is usually for the pile in its final position. The contractor needs to provide additional reinforcement for handling the piles on site and for driving the piles on site.

Precast pile couplers need to meet the same durability requirements as the remainder of the pile. The piles have been designed to last 50 to 100 years: the connections must meet the same criteria.

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APPENDIX 10A - PRECAST YARD CHECK LIST

APPENDIX 10B - CRANE ERECTION CHECK LIST

NOTE

For formwork, reinforcement, concrete, prestressing, etc., the standard check-lists apply.

APPENDIX 10A

PRECAST YARD CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1 Quality system in place					
2 Concrete mix design approved					
3 Formwork well-made and accurate					
4 Concrete vibration system approved					
5 Control of concrete cover suitable					
6 Procedure and timing for removing of formwork approved					
7 Curing procedure approved					
8 Lifting method and points approved					
9 Transporting and storing system approved					

APPENDIX 10B

CRANE ERECTION CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1 Traffic accommodation and control approved, signs and barriers ready for placement, Road closure permits in place, Public notifications in place					
2 Municipal/provincial traffic officers notified and will be on site					
3 Sufficient staff including flag-men and OHS officer on site					
4 Cranes are of sufficient capacity and can be rigged on site (sufficient foundation strength, space, boom reach, obstacles etc) Crane load test certificate and maintenance compliance received					
5 Crane lifting procedure approved, including safety of staff and public, stability, etc)					
6 Channels of communication and responsibilities between crane operator, traffic control, contractor and the resident engineer clear and in place					
7 Programme for procedure approved along with deadlines, after which the lift is abandoned					
8 Site is taped off to prevent non-essential personnel entering the area of operation					
9 As-built dimensions and levels have been checked to ensure component will fit in, including bearings, supports, etc					
10 Procedure to ensure stability of component during erection approved					

CHAPTER 11 - ABUTMENTS, WING WALLS, PIERS AND RETAINING WALLS

DS Temple

11.1 SCOPE

This section covers the inspection and monitoring of Reinforced Concrete Abutments, Wing Walls, Piers and Retaining Walls. It also covers the special attention which must be given by the engineer's monitoring staff to the specific requirements of setting out of these major bridge elements, the special requirements (as noted elsewhere in this manual) for excavations, backfill, falsework and formwork, reinforcement, concrete and ancillary components relating to these elements.

11.2 ABUTMENTS, WING WALLS, PIERS AND RETAINING WALLS

11.2.1 Setting Out (Refer to Chapter 3)

In addition to the requirements of Chapter 3 the following should be checked as being specifically relevant to these bridge elements.

11.2.1.1 Levels

- Top of blinding.
- Top of foundations.
- Top of abutment bridge seat and piers for bearings. Adjustments may have to be made for precamber of decks (refer to Chapter 6).
- Top of wing walls and retaining walls.

11.2.1.2 Setting out Points

- Centre line of bearings on abutments and piers to verify span lengths on drawings.
- Front face of wing walls and retaining walls to road centerline for final horizontal clearances as applicable.

11.2.2 Foundations (Refer to Chapter 4 & 5)

- The foundations for these substructures should be verified in accordance with the requirements of the adequacy of the bearing strata for spread footings in accordance with Chapter 4. The monitoring staff must ensure that any required measures such as foundation fill, mass concrete, etc have been carried out before the foundations are constructed.
- Ensure that the contractor has pumps available to dewater foundation excavations as required.

11.2.3 Falsework & Formwork (Refer to Chapter 6)

- Formwork should conform to the Project and Standard Specifications. The use of corner fillets and other finishing details are generally required and their provision must be checked.
- Provision should be made on retaining walls for a precamber towards the back of the wall to provide for deflection under earth loads.

- Propping and support of formwork against the sides of excavations should always be checked to ensure that the formwork remains in position during concreting.
- Striking of formwork and curing should be undertaken strictly in accordance with the Specifications.

11.2.4 Steel Reinforcement (Refer to Chapter 7)

In the case of river bridges the reinforcement cages should only be placed or fixed when the risk of flooding of the excavations is small.

Should there be flooding of excavations before casting the foundations and after reinforcement has been fixed, the water should be pumped out and the formwork and the reinforcement thoroughly cleaned to ensure that no debris whatsoever is trapped in the foundations during casting. If it appears that movement of reinforcement has occurred in foundations or other parts of the sub-structures, the formwork should be removed and the reinforcement adjusted to fit.

In some cases (columns and piers) reinforcement should be checked before the formwork is erected.

The accuracy of placing of starter bars is critical, as it is impossible to correct incorrectly placed bars after the concrete is cast.

Some sub-structures, especially slender columns, can be highly reinforced and special attention should be given to ensuring that the concrete can be properly placed and compacted.

Cover to reinforcement is of critical importance for the buried parts of sub-structures as defects in this area are rarely seen until problems occur later in the life of the structure.

11.2.5 Concrete (Refer to Chapter 8)

The correct class and size of aggregate should be confirmed with the contractor before casting of sub-structure elements.

The importance of the correct slump for the application should be carefully controlled and confirmed with the contractor. Low slump concrete in sub-structures is always preferred, however, a higher slump in members with highly congested reinforcement is recommended.

Members of great height (either columns, piers or walls) require that great care be taken during casting. Generally columns and piers adjacent to roads should for aesthetic and structural reasons be cast in one lift. Only in cases where the designer grants specific approval or has specifically designed the column, pier or wall with a horizontal joint feature should the casting of the element be permitted in lifts.

Repairs to concrete defects discovered after stripping should be repaired as soon as possible. This is so that the repair mortar will bond and blend with the parent concrete without differential shrinkage occurring. A method statement and concrete repair methodology should be submitted to the monitoring staff for review before the concrete work starts on the project so that the Engineer can authorize repairs timeously.

11.2.6 Backfill behind Abutments

It is always preferred (unless otherwise specified on the drawings or in the Specifications) to backfill behind abutments up to the bearing seat level before casting of the screen wall. This is to ensure that the expansion gap between the deck and abutment is not reduced if slight movement occurs.

The type, quality and compaction of selected backfill behind abutments and retaining walls are important factors in limiting settlement behind these structures and the engineers' monitoring staff should therefore check that the quality and compaction of the backfill material conforms to the Project and Standard Specifications.

Backfill with boulders should not be permitted as this will create local stress concentrations in the structures. Compaction of backfill material behind abutments and retaining walls should be carried out up to a distance of 3 meters from the concrete faces using hand operated compactors to the density as specified.

11.2.7 Ancillary Components (Refer to Chapter 14)

11.2.7.1 Bearings

The monitoring staff should ensure that during the construction of sub-structure elements all bearing seats and tops of columns and piers are properly finished off (as described in Chapter 14) to the correct levels so that the bearings can be installed correctly. The contractor should submit shop drawings of bearings for review prior to manufacture.

11.2.7.2 Expansion Joints

Most bridges are provided with closed expansion joint systems which are built into the decks and abutments at the level of the surfacing. These joints form the dual purpose of preventing debris from jamming the movement of the bridge and waterproofing the movement joints so that staining of the concrete surfaces and other parasitic effects do not occur.

11.2.7.3 Drainage

Drainage behind substructures such as abutments, wing walls and retaining walls is of paramount importance. These structures are generally not designed to resist pore pressures and therefore the sub-surface drainage systems including weepholes, drainage pipes, etc, must be installed properly and should be clean and in working condition when inspected.



Photo 11.1: Inadequate drainage at bridge abutments

The unnecessary ponding of water on abutment bearing seat beams should be avoided and the drainage pipes draining these areas must be properly installed and fit for purpose. If this is not checked, ponding can lead to unnecessary staining of the concrete and the promotion of parasitic effects such as Alkali Silica Reaction (ASR).

11.2.7.4 Services

Service ducts for future and planned services (such as lighting) should be installed correctly inside the reinforcement as specified and indicated on the drawings.

11.3 INSPECTIONS

The engineer's monitoring staff should use the abutment, wing walls, piers and retaining wall checklists or the checklists as provided for in the relevant Chapter of this Manual for each structural element of every substructure.

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APPENDIX 11A - ABUTMENTS

APPENDIX 11B - WING WALLS

APPENDIX 11C - PIERS

APPENDIX 11D - RETAINING WALLS

ABUTMENTS CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. SETTING OUT AND FOUNDING					
1.1 Setting out					
1.2 Foundations:					
• Excavation safety					
• Allowable bearing pressure					
• Foundation Fill					
2. CONCRETE MIX DESIGNS					
2.1 Review concrete mix designs					
3. FOUNDATIONS					
3.1 Formwork					
3.2 Reinforcement					
3.3 Concrete tests					
4. ABUTMENT					
4.1 Formwork					
4.2 Reinforcement					
4.3 Concrete tests					
4.4 Concrete finish					
5. OTHER ITEMS					
5.1 Tie into existing structures					
5.2 Bearing plinths					
5.3 Joint sealing					
5.4 Bridge numbers					
5.5 Drainage systems					
5.6 Backfill					
5.7 Bridge deck expansion joint recesses					

APPENDIX 11B

WING WALLS CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. SETTING OUT AND FOUNDING					
1.1 Setting out					
1.2 Foundations:					
• Excavation safety					
• Allowable bearing pressure					
• Foundation Fill					
2. CONCRETE MIX DESIGNS					
2.1 Review concrete mix designs					
3. FOUNDATIONS					
3.1 Formwork					
3.2 Reinforcement					
3.3 Concrete tests					
4. WING WALLS					
4.1 Formwork					
4.2 Reinforcement					
4.3 Concrete tests					
4.4 Concrete finish					
5. OTHER ITEMS					
5.1 Tie into existing structures					
5.2 Joint sealing					
5.3 Bridge numbers					
5.4 Drainage systems					
5.5 Backfill					
5.6 Bridge deck expansion joint recesses					

APPENDIX 11C

PIERS CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. SETTING OUT AND FOUNDING					
1.1 Setting out					
1.2 Foundations:					
• Excavation safety					
• Allowable bearing pressure					
• Foundation Fill					
2. CONCRETE MIX DESIGNS					
2.1 Review concrete mix designs					
3. FOUNDATIONS					
3.1 Formwork					
3.2 Reinforcement					
3.3 Concrete tests					
4. PIERS					
4.1 Formwork					
4.2 Reinforcement					
4.3 Concrete tests					
4.4 Concrete finish					
5. OTHER ITEMS					
5.1 Tie into existing structures					
5.2 Joint sealing					
5.3 Bridge numbers					
5.4 Drainage systems					
5.5 Backfill					

APPENDIX 11D

RETAINING WALLS CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. SETTING OUT AND FOUNDING					
1.1 Setting out					
1.2 Foundations:					
• Excavation safety					
• Allowable bearing pressure					
• Foundation Fill					
2. CONCRETE MIX DESIGNS					
2.1 Review concrete mix designs					
3. FOUNDATIONS					
3.1 Formwork					
3.2 Reinforcement					
3.3 Concrete tests					
4. RETAINING WALLS					
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5.5 Backfill					
5.6 Expansion joins					

CHAPTER 12 - SUPERSTRUCTURES

MG Latimer

12.1 SCOPE

This Chapter covers the construction of superstructures of bridges and culverts.

In the first portion of this chapter six common types of bridge decks are dealt with, each having particular features which need to be considered and monitored. Attention is drawn to these features, and additional explanatory information is provided where necessary. To assist monitoring staff in the execution of their duties, the guidance presented for each deck type is arranged under separate headings for “planning” and “construction”.

The second portion of the Chapter deals with general aspects of construction which are of particular relevance to bridge superstructures.

12.2 SOLID SLAB DECKS

12.2.1 Description and General Features

As the name suggests, solid slab decks comprise of a solid section, without beams or voids. This type of deck is commonly used in the construction of short span bridges and culverts, and is illustrated in Photo 12.1.

The construction of solid slab decks is usually straight-forward and uncomplicated, and the formwork is very simple to construct. Reinforcement layouts seldom result in congested areas, and the placement of concrete should therefore present no difficulties. Concrete volumes may be large.



Photo 12.1: Soffit of cast in-situ concrete slab deck. Note untidy construction joint line and surface blemishes.

12.2.2 Planning

The following points should be considered when planning the construction of solid slab decks:

(a) Falsework and formwork are usually subjected to heavy loading.

(b) Deflection and settlement of formwork and falsework must be contained within acceptable limits.

(c) Solid slabs often consume large volumes of concrete and may result in long concrete pours, sometimes extending into the hours of darkness. Consideration should therefore be given to the possible need for lights.

(d) The concrete supply rate, placement sequence and procedure must enable thorough compaction to be achieved and must ensure that no cold joints are formed.

(e) Standard deck items:

- The exposed surface area of the concrete deck is usually large, and rainfall during concreting can therefore present serious problems. Expected weather conditions should be checked in advance and on the day of the pour.
- Plan for the possibility of plant breakdown or delays in the supply of concrete (lights required?)
- Consider suitable positions and details for emergency construction joint in case these are required.
- The arrangements to achieve the required level control, surface finish, and curing must be planned and agreed.
- Under unfavourable weather conditions (wind, heat) some concrete mixes may be prone to plastic shrinkage cracking. Re-vibration of the concrete is recommended.
- Check that the provision of drip moulds at the edges of the deck has not been overlooked.

NOTE

Planning should include the control of personnel access and movement on the deck. N.B. Ensure that parapet starter bars are not disturbed or used as hand-holds during placement and finishing of the concrete (this is detrimental to anchorage and bond of the reinforcement).

12.2.3 Construction

The standard monitoring items contained in Chapter 6 Formwork, 7 Reinforcement and 8 Concrete are applicable. Monitoring staff should in addition pay particular attention to the following during construction:

(a) Thick slabs impose heavy loads on formwork, falsework and falsework supports. The construction and performance of these elements therefore deserve special attention.

(b) When pouring large volumes of concrete ensure that the supply rate is not excessive as this leads to loss of control over the placing and compaction of the concrete.

(c) Accurate setting out and alignment of parapet starter bars is of the utmost importance. These bars must not be disturbed during concrete placement and finishing.

(d) Check for signs of settlement cracks, and if noticed ensure revibration to eliminate these.

(e) Level control, surface finish, and curing.

12.3 VOIDED SLAB DECKS

12.3.1 Description and General Features

Voided slabs are characterised by the presence of voids within the slabs, their function being to reduce the volume of concrete and thereby the self-weight required to be carried by the slab. The voids are generally cylindrically shaped, and constructed using hollow thin-walled steel sections placed within the slab.

NOTE

It is important to note that void formers are subjected to large buoyancy forces when the concrete is cast. These forces must be resisted by straps tied to the bearers below the formwork.



Photo 12.2: Voided slab deck under construction. Tie down straps not yet installed.

12.3.2 Planning

When void formers are incorporated within concrete slab decks, both contractor and monitoring staff should ensure that they have a sound understanding of the forces acting upon the formers, straps and formwork during concreting. Major difficulties can arise when these forces are not satisfactorily provided for, sometimes requiring that the entire deck be demolished and reconstructed. It is therefore essential that the arrangement be properly designed and that the formers be sufficiently rigid, sealed and tied down before casting the concrete.

The following points should be considered when planning the construction of voided slab decks:

(a) Tie-down of formers to resist buoyancy. Ensure that tie-down devices are:

- Properly designed.
- Tied to bearers below formwork.
- Adequately distributed along the length of the formers.

- Applied in a manner which will not deform or damage the formers.
- Provided with sleeves/cones to enable the ties to be removed/cut back to ensure adequate cover to all steel. The arrangement must enable the concrete surface to be neatly repaired and finished off.

(b) The provision of drainage holes at the low points in all void formers.

(c) Concrete should be placed and compacted in layers rather than "full depth" in order to reduce buoyancy forces.

(d) The placement sequence and procedure must be planned and tightly controlled to ensure that concrete below the formers is well compacted and that no cold joints develop.

(e) Ensure adequate, but not excessive, concrete supply rate.

(f) Falsework and formwork can be subjected to heavy loading.

(g) Deflection and settlement of the formwork and falsework.

(h) Large volumes of concrete may result in long concrete pours, extending into hours of darkness. Consider the need for lights.

(i) Standard deck items (refer 12.2.2 (e)):

- Check weather conditions in advance and on the day of the pour.
- Possibility of plant breakdown or delays in concrete supply (lights required?).
- Emergency construction joint positions and details.
- Level control, surface finish, and curing.
- Control of personnel access and movement on the deck (ensure that parapet starter bars are not disturbed).
- Re-vibration of concrete to eliminate plastic shrinkage cracking.

12.3.3 Materials

Ensure that void formers:

(a) Have adequate robustness and will not deform under the action of buoyancy forces and the tie-down strapping.

(b) Will not deteriorate or soften when wet.

(c) Can resist the forces they will be subjected to.

(d) Are adequately braced to maintain their shape.

(e) Are sealed to prevent ingress of water or grout.

(f) Have adequate drainage outlets at their low points.

12.3.4 Construction

The standard monitoring items contained in Chapter 6 Formwork, 7 Reinforcement and 8 Concrete are applicable. Monitoring staff should in addition pay particular attention to the following during construction:

(a) Performance of tie-down devices.

(b) Movement of formers during concrete placement.

(c) Falsework and falsework supports.

(d) Accurate setting out of parapet starter bars.

(e) Concrete placement sequence and procedure.

(f) Level control, surface finish, and curing.

(g) Check for signs of settlement cracks, and if noticed ensure revibration to eliminate these.

12.4 CAST IN-SITU BEAM & SLAB DECKS

12.4.1 Description and General Features

Cast in-situ beam and slab decks comprise of deck slabs supported by cast in-situ beams. The beams provide the strength and stiffness required for the span, and enable the slab to be relatively slender and economical to construct. The number of beams utilised is dependent upon several factors, such as the width of the deck and the slenderness of the beams.

Formwork for cast in-situ beam and slab decks is more complicated than that required for solid or voided slab decks.

12.4.2 Planning

The following points should be considered when planning the construction of cast in-situ beam and slab decks:

(a) The design of the falsework and formwork must cater for the substantially differing load intensities of the beam and slab portions.

(b) Casting procedure and sequence.

(c) To assist compaction of concrete in beams, the leading face of the pour should not be steeply inclined.

(d) The concrete in the region of the web-slab junction should be re-vibrated to close settlement cracks which tend to form at these positions. The timing of the re-vibration is critical to the success of this exercise. Refer to Figure 12.1.

(e) Standard deck items (refer 12.2.2 (e)):

- Check weather conditions in advance and on the day of the pour.
- Possibility of plant breakdown or delays in concrete supply (lights required?).
- Emergency construction joint positions and details.
- Level control, surface finish, and curing.
- Control of personnel access and movement on the deck (ensure that parapet starter bars are not disturbed).

- Re-vibration of concrete to eliminate the possibility of settlement cracks and plastic shrinkage cracking.

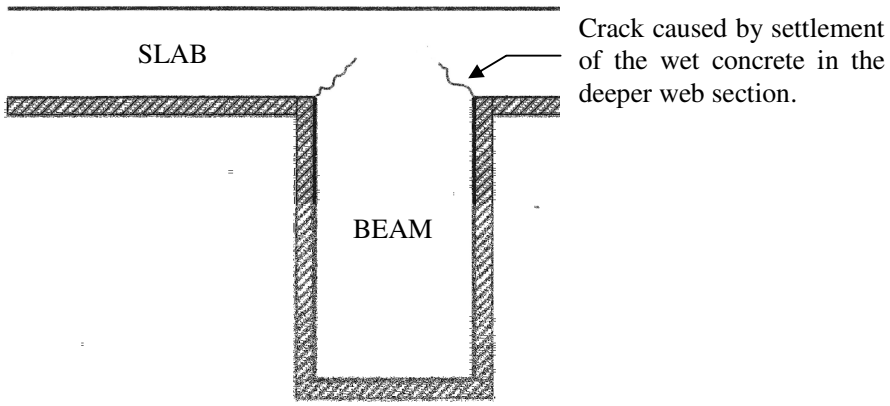


Figure 12.1: Section through beam showing crack at web-flange junction.

12.4.3 Construction

The standard monitoring items contained in Chapter 6 Formwork, 7 Reinforcement and 8 Concrete are applicable. Monitoring staff should in addition pay particular attention to the following during construction:

(a) The performance of falsework and falsework supports.

(b) Accurate setting out of parapet starter bars.

(c) Concrete placement sequence and procedure.

(d) Compaction and re-vibration to prevent settlement cracks.

(e) Level control, surface finish, and curing.

12.5 PRECAST BEAM & SLAB DECKS

12.5.1 Description and General Features

Precast beam and slab decks are similar to cast in-situ beam and slab decks, but utilise precast beams to support the deck slabs. Refer Photo 12.3 and 12.4. During concreting of the deck slab, the formwork is usually supported by the precast beams, requiring that the precast section alone be designed to carry the combined weight of both beam and slab.



Photo 12.3: Precast T-beams erected on pier.



Photo 12.4: Soffit of beam and slab deck (with transverse diaphragms)

Occasionally, designs may require that the beams be temporarily propped until the slabs have been cast and have gained strength. Under these conditions the self weight of the slab only acts on the structure when the props are removed, and is therefore carried by the composite (combined) beam and slab section.

Slender precast concrete slab panels or fibre-cement boards are sometimes used as permanent slab soffit formwork.

A variation of this deck type is the contiguous beam deck, in which the beams are butted against one another to obtain a flat soffit. Refer Photo 12.5. This is commonly employed on bridges over electrified railway tracks in order to minimise work above the exposed electrification.



Photo 12.5: Soffit of Contiguous Beam Deck.

12.5.2 Planning

The following points should be considered when planning the construction of precast beam and slab decks:

(a) Note any specified propping, casting or formwork requirements.

(b) Programme for beam manufacture, erection, slab construction, formwork removal.

(c) Surface preparation required (beam top surface, diaphragm construction joint surfaces, and soffit bearing areas at the beam ends).

(d) Precamber requirements.

(e) Beam storage arrangements.

(f) Be aware of possible lateral curvature of the beam due to shrinkage and temperature (differential strains occur if only one side of the beam is exposed to the drying effects of direct sunlight or wind).

(g) Position and detail of lifting hooks/devices.

(h) Transport, erection and safety.

(i) Temporary bracing requirements to ensure beam stability during erection. This is a critical item and must be designed and signed off by the Contractor's Competent Person (CCP).

(j) Checks on beam length, curvature, and the position and height of the protruding reinforcement prior to erection.

(k) Bedding material at bearings.

(l) If permanent slab soffit formwork panels are used:

- Ensure adequate tolerance on seating area. Note that the beam spacings may vary slightly, and that beams may not be perfectly straight. Note also that sunlight can cause lateral temperature differentials and curvature.
- Ensure that panels are secured and cannot be displaced.
- Ensure panel seating detail incorporates a grout seal.

(m) Re-vibration at diaphragms (to prevent settlement cracks at slab-diaphragm junction) – timing critical.

(n) Standard deck items (refer 12.2.2 (e)):

- Check weather conditions in advance and on the day of the pour.
- Possibility of plant breakdown or delays in concrete supply (lights required?).
- Emergency construction joint positions and details.
- Level control, surface finish, and curing.
- Control of personnel access and movement on the deck (ensure that parapet starter bars are not disturbed).
- Re-vibration of concrete to eliminate plastic shrinkage cracking.

WARNING

Ensure that the stability of each precast beam is assured during all stages of construction. This usually requires that secure bracing or props be provided and that the beam lifting points ensure that the beam remains stable when lifted. The adequacy of arrangements to ensure stability should be signed off by the contractor's competent person.

12.5.3 Materials

When permanent formwork panels are utilised it is advisable to consult with the bridge designer to ensure that the details and materials are acceptable. Monitoring staff should ensure that the strength and stiffness of the panels are adequate, and that the necessary concrete cover is obtained.

12.5.4 Construction

The standard monitoring items contained in Chapter 6 Formwork, 7 Reinforcement and 8 Concrete are applicable. Monitoring staff should in addition pay particular attention to the following during construction:

(a) Safety aspects during beam erection.

(b) Check and confirm beam positions and levels after erecting the beams (N.B. Also check level of protruding bars at top as this can be critical in achieving the required finished level of the roadway).

(c) Accurate setting out of parapet starter bars.

(d) Cleanliness of beam reinforcement before casting slab.

(e) Seating and sealing of permanent slab formwork panels (if applicable).

(f) Check below deck during casting of the slab to identify possible leakage of fines.

(g) Compaction and re-vibration at diaphragms to prevent settlement cracks.

(h) Control of concrete slab thickness.

(i) Control of cover to reinforcement.

(j) Level control, surface finish, and curing.

12.6 CONCRETE BOX GIRDER DECKS

12.6.1 Description and General Features

Concrete box girder decks utilise a section comprised of one or more hollow boxes (usually rectangular or trapezoidal in shape). In its most common form, the deck has a single box (Photo 12.6 and 12.7) with cantilever slabs, but for wider bridges, the box is often subdivided into two or more cells.

This type of deck has high torsional stiffness, and the presence of both top and bottom slabs provides capacity for both sagging and hogging moments.

When constructing cast in-situ concrete box girder decks, the lower slab and webs are usually cast first, followed by casting of the top slab a few days later.



Photo 12.6: End of incomplete Concrete Box Deck.



Photo 12.7: Trapezoidal shaped box deck. Note textured surface finish obtained using tongue-and-grooved timber.

12.6.2 Planning

The following points should be considered when planning the construction of concrete box girder decks:

(a) Compliance with any specified casting or formwork requirements.

(b) Compliance with any specified time limitations relating to casting, stressing and removal of formwork. Note that the specifications/drawings usually require that the top slab be cast within 7 to 10 days of casting the webs in order to limit differential shrinkage stresses. Delays in the casting of the top slab should therefore be avoided.

(c) Compliance with any specified requirements relating to the fixity of the decks (on continuous multi-span decks it is sometimes necessary to temporarily fix sliding bearings).

(d) Falsework and formwork may be subjected to heavy loading.

(e) Deflection and settlement of formwork and falsework.

(f) Precamber requirements.

(g) Concrete placement sequence and procedure must be planned and tightly controlled to ensure that concrete at the bottom slab-web junction is well compacted. A horizontal or inclined top shutter is commonly provided at the bottom of the web formwork to help retain the concrete in the web.

(h) Surface preparation required at construction joints.

(i) Some locations may be fairly congested due to prestressing and reinforcement. Ensure that thorough vibration can be achieved.

(j) Drainage holes should be provided at the low-points in each cell.

(k) Timing of falsework and formwork removal.

(l) Arrangements for removal of “internal” formwork (i.e. formwork to the top slab between webs). This may require openings in diaphragms and bottom slabs, or temporary openings in the top slab. For temporary openings, control should be exercised over the bending of reinforcement within the opening area.

(m) Standard deck items (refer 12.2.2 (e)):

- Check weather conditions in advance and on the day of the pour.
- Possibility of plant breakdown or delays in concrete supply (lights required?).
- Emergency construction joint positions and details.
- Level control, surface finish, and curing.
- Control of personnel access and movement on the deck (ensure that parapet starter bars are not disturbed).
- Re-vibration of concrete to eliminate plastic shrinkage cracking.

12.6.3 Construction

The standard monitoring items contained in Chapter 6 Formwork, 7 Reinforcement and 8 Concrete are applicable. Monitoring staff should in addition pay particular attention to the following during construction:

(a) Congested areas: ensure sufficient space for concrete placement and compaction.

(b) Check on concrete placement and compaction at web/bottom slab junction.

(c) Check level of bars at the top of the webs and slab as this can be critical in achieving the required finished level of the roadway.

(d) Accurate setting out of parapet starter bars.

(e) Cleanliness of beam reinforcement before casting top slab.

(f) Check below deck during casting to identify possible leakage of fines.

(g) Control of concrete slab thickness.

(h) Control of cover to the reinforcement in the top slab.

(i) Compaction and re-vibration at diaphragms to prevent settlement cracks.

(j) Level control, surface finish, and curing.

WARNING

Keep a close watch over compaction in the region of the web/bottom slab junction. Note that there is often a tendency to undervibrate this area as the vibration increases the flow of concrete from the web into the bottom slab. Undervibration results in poor compaction, particularly if prestress tendons are present.

12.7 TWIN SPINE BEAM DECKS

12.7.1 Description and General Features

Twin spine beam decks utilise two spine beams to carry the deck slab. Refer to Fig 12.2. The beams and slab can be constructed from either reinforced or prestressed concrete.

The spine beams commonly comprise of solid concrete sections, but often utilise void formers to reduce their cross-sectional area and increase their efficiency.

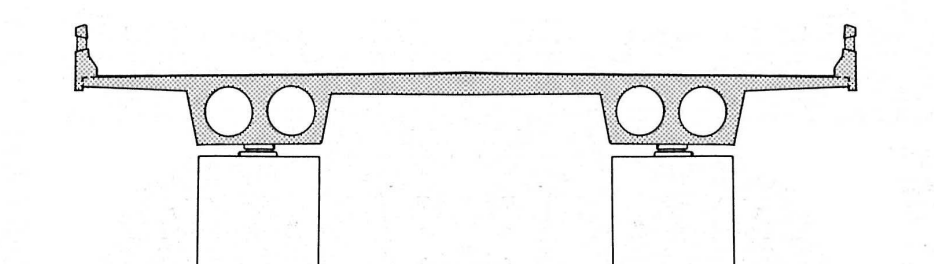


Figure 12.2: Twin spine beam deck.

12.7.2 Planning

The following points should be considered when planning the construction of twin spine beam decks:

(a) Falsework and formwork supporting the spine beams may be subjected to heavy loading.

(b) Deflection and settlement of the falsework and falsework supports.

(c) Precamber requirements.

(d) To assist compaction of concrete in the spine beams, the leading face of the concrete pour should not be steeply inclined.

(e) Ensure that all concrete will be thoroughly compacted. Note that some locations may be difficult to compact due to high concentrations of prestressing and reinforcement.

(f) The concrete in the region of the web-slab junction should be re-vibrated to close settlement cracks which tend to form at these positions. The timing of the re-vibration is critical to the success of this exercise.

(g) Surface preparation required at construction joints.

(h) Standard deck items (refer 12.2.2 (e)):

- Check weather conditions in advance and on the day of the pour.
- Possibility of plant breakdown or delays in concrete supply (lights required?).
- Emergency construction joint positions and details.
- Level control, surface finish, and curing.
- Control of personnel access and movement on the deck (ensure that parapet starter bars are not disturbed).
- Re-vibration of concrete to eliminate plastic shrinkage cracking.
- Compaction and re-vibration at diaphragms and slab/web junctions to prevent settlement cracks.
- Surface finish and curing.

12.7.3 Construction

The standard monitoring items contained in Chapter 6 Formwork, 7 Reinforcement and 8 Concrete are applicable. Monitoring staff should in addition pay particular attention to the following during construction:

(a) Congested areas: ensure space for concrete placement and compaction.

(b) Check level of top slab bars, to ensure that the specified cover is obtained.

(c) Accurate setting out of parapet starter bars.

(d) Check below deck during casting to identify possible leakage of fines.

(e) Control of concrete slab thickness.

(f) Control of cover to reinforcement in the top slab.

(g) Level control, surface finish, and curing.

12.8 GENERAL CONSIDERATIONS FOR SUPERSTRUCTURES

12.8.1 Advance Planning

The importance of advance planning for the construction of bridge superstructures cannot be over-emphasised. Monitoring staff should ensure that they are in possession of all construction drawings and specifications, and that these are clearly understood. They are advised to actively engage with the contractor to ensure that the necessary method statements and proposals are prepared and submitted timeously.

Advance planning meetings between the monitoring staff and the designer can be very helpful, as these present an opportunity to obtain clarifications and to communicate matters of importance.

Planning should consider all aspects of the construction, including falsework and formwork, casting sequence, construction joint positions, bearings, movement joints, recesses, drainage ducts etc. Possible requirements for approvals from railway or other authorities, and advance testing or component approvals should not be overlooked.

12.8.2 Access and Safety

Refer item 2.9 in Chapter 2.

The construction of bridge superstructures almost always involves working at height, and safety aspects related to the provision of adequate safety railings, access ramps and ladders must receive the necessary attention.

Special consideration should be given to access arrangements when working over water, and to ensuring that both environmental and safety requirements are satisfied.

When working over roadways suitable protection measures must be put in place to safeguard motorists or pedestrians below.

12.8.3 Setting Out & Levels

Refer Chapter 3.

The geometry of bridge superstructures is often complex, and setting out calculations and checks may need to take account of varying crossfall, vertical and horizontal curvature, and the effects of the “tilt” of box sections and beam webs.

Formwork levels should allow for the deflection of supporting beams or girders, as well as the bedding-in and elastic shortening of falsework supports.

It is advisable that independent checks be made of critical setting out points.

12.8.4 Precamber and Casting Sequence

On all but the most elementary structures it is advisable to consult the design office to confirm and if necessary obtain approval for precamber requirements.

Reinforced concrete members usually require upward precamber to allow for downward elastic and creep deflection. Prestressed members usually require downward precamber to allow for upward elastic and creep deflection.

In instances where the superstructure being cast is carried by temporary girders which will deflect under the weight of freshly cast concrete, consideration should be given to the affect that this deflection will have on any concrete which is setting or has already set. Such concrete is prone to cracking, as it is no longer able to deform to accommodate the changing profile caused by the deflection. It follows that the ability of the concrete to tolerate this deflection without distress is dependent upon the rate and sequence of casting, as well as the time at which the concrete starts to set. An obvious further consideration is the flexibility of the supporting girders, which should be contained within acceptable limits. These aspects should be carefully considered, and guidance obtained from the design office where necessary.

12.8.5 Falsework

The contents of Chapter 6 : Falsework, Formwork and Concrete Finish are applicable and should be referred to.

The following items have particular relevance to the falsework to superstructures, and should not be overlooked:

(a) Stability, wind resistance, bracing.

(b) Falsework is often required to remain in place for a long period. The bedding of falsework base pads must therefore be protected against erosion by wind and rain, and should be regularly checked.

(c) On river bridges, falsework located close to the banks must be resistant to erosion and designed to resist debris and impact.

(d) Possible vehicle impact should be considered when construction takes place above or adjacent to roadways.

(e) Timing of removal of formwork (consult design office).

12.8.6 Effect of Elastic Support on Prestressed Members

In general, when prestressing is applied to members carried by rigid supports, the members lift off the supporting formwork when the prestress loading is applied. When this occurs the weight of the concrete is immediately transferred from the formwork onto the member itself, counteracting the upward forces imposed by the applied prestressing. This behaviour enables member stresses to be contained within acceptable limits.

However, when members are cast on formwork supported by very tall scaffolding towers or flexible beams/girders, the elasticity of the support influences the above behaviour, and the weight of the concrete may be only partially transferred onto the prestressed member. Unless this behaviour is properly evaluated and accounted for, tensile stresses at the top of the member may exceed allowable values causing cracking of the member.

It is therefore essential that monitoring staff are alert to the potential for such situations and consult with their design office regarding the necessary evaluations.

12.8.7 Formwork

The contents of Chapter 6 : Falsework, Formwork and Concrete Finish are applicable and should be referred to.

The following items have particular relevance to the formwork to superstructures, and should not be overlooked:

(a) Bridge superstructures are usually very visible and special attention should therefore be paid to the quality of finish, uniformity of colour and texture etc.

(b) Monitoring staff should be on the lookout for variations in the quality, texture and surface finish of timber formwork used to form visible concrete faces. Note that the surface colour and texture of concrete cast on "first-use" timber often differs from that of "second or third-use" timber. This effect can result in a very "patchy" appearance.

(c) Formwork boards or panels for visible faces should be arranged in a pleasing and regular pattern. The formwork material and panel layout should be discussed and approved well before formwork material is ordered and delivered to site.

(d) If tongue-and-grooved timber formwork is used the concrete surface should be left "as struck" (no rubbing).

(e) Formwork (particularly timber formwork) should be treated with care in order to prevent damage during handling or fixing of steel reinforcement. Reused formwork should be regularly inspected for possible defects.

(f) Note that dust, dirt and contaminants from rusting reinforcement can lead to staining of the concrete surface. The cleanliness of horizontal formwork to exposed surfaces should therefore be monitored, and the long term storage of reinforcement on formwork should be discouraged.

(g) Pay special attention to the fixing, neatness and alignment of chamfer strips in all prominent locations such as the edges of decks.

(h) Poorly constructed construction joints can be very unsightly. Pay attention to alignment, fixity of soffit formwork, provision of grout seals etc.

(i) Ensure that local overloading of formwork does not occur.

NOTE
Ensure that the provision of drip grooves near the edges of decks is not overlooked (consult with the design office).

12.8.8 Concreting

The contents of Chapter 8 : Concrete are applicable and should be referred to.

Attention should be paid to the following:

(a) Approvals required prior to placing concrete.

(b) Planning the movement of workmen during concreting to prevent unnecessary disturbance of reinforcement (especially parapet starter bars). Walking on the freshly placed concrete should not be permitted.

(c) Provision for and removal of adequate screeding rails (limit disturbance when the rails are removed).

(d) Provision of sufficient experienced "finishers" to operate the screed rails and complete the surface finishing.

(e) Consider and plan for unfavourable weather conditions (rain, wind, cold, heat). Deck concrete should not be poured when there is a likelihood of rainfall during the casting and setting period.

(f) Planning for possible equipment failure, concrete supply problems (availability of lights?), emergency construction joints.

(g) Compaction at congested locations.

(h) Monitor possible leakage of fines at soffit, panel joints etc.

(i) Possible need for revibration of concrete to prevent plastic shrinkage cracking, especially during hot or windy conditions.

12.8.9 Deck Surface Levels

Planning and construction should consider the importance of obtaining the correct deck levels, recognising the permissible tolerances. The actual levels achieved should be checked after concreting, as deviations from the specified levels may require that remedial work be carried out and that the parapet levels be amended. Refer Item 12.8.13 below.

12.8.10 Curing

The contents of Chapter 8 : Concrete are applicable and should be referred to.

Monitoring staff should pay attention to the following:

(a) The area to be cured may be extensive.

(b) Suitability of proposed curing method. Note that the top surface of bridge decks should be cured by constantly spraying the entire exposed surface with water.

(c) Application method and timing of application.

(d) Consider the affect of wind, weather etc.

12.8.11 Time of Stressing

Prior to stressing, prestressed concrete members usually have limited resistance to cracking as these members are young and often contain only small quantities of steel reinforcement. It is therefore not advisable to allow the application of prestressing to be unnecessarily delayed. The design office should be consulted for advice in situations where requirements are not specified on the drawings or in the specifications.

12.8.12 Parapets

Parapets are probably the most visible of all bridge components, and are often viewed from close range. Even minor blemishes and defects are therefore easily noticed. It follows that special attention should be paid to the quality of construction, including both alignment and finish.

Monitoring staff should pay attention to:

(a) Provision for joints, cover plates, lighting ducts and supports etc.

(b) Both horizontal and vertical alignment MUST be very good.

(c) Correct setting out of parapet starter bars is of great importance (errors can result in lack of cover).

(d) Concrete cover must be tightly controlled (lack of cover can in time lead to unsightly stains and concrete spalling - both unacceptable on parapets).

(e) Chamfers, edges, alignment etc. must be carefully checked before concreting.

(f) Monitor surface finish achieved, surface blowholes etc. and take prompt action to rectify any problems.

(g) Curing.

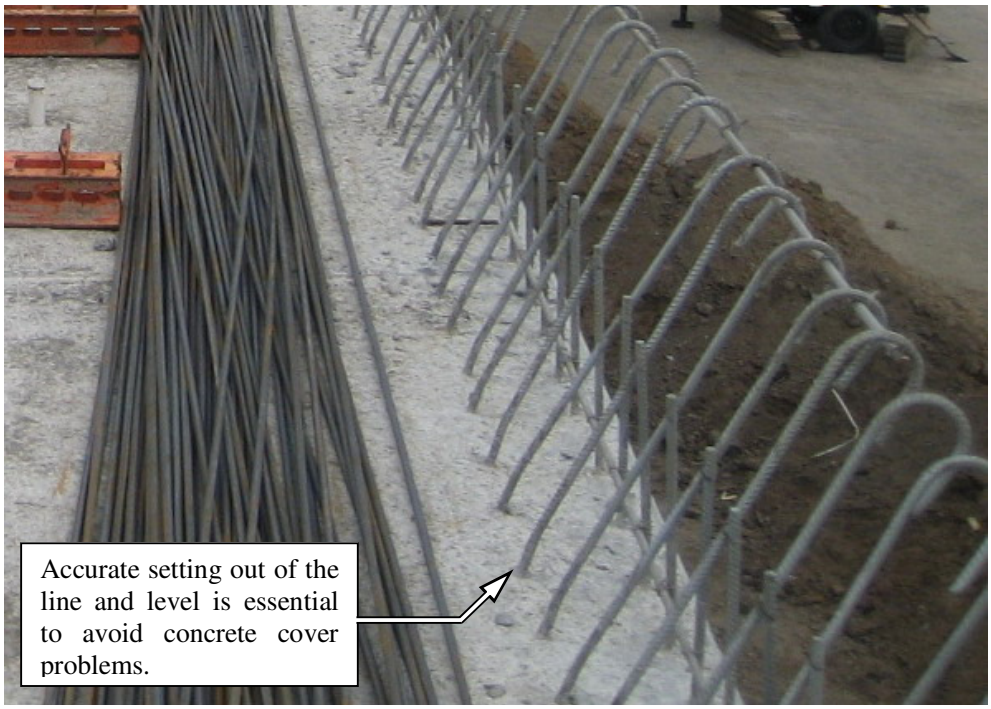


Photo 12.8: Parapet starter bars.

12.8.13 Asphalt Surfacing of Decks

Planning and construction should consider:

(a) Programme and approval of asphalt mix design.

(b) Arrangements at expansion joint recesses to permit placing of asphalt over the joint gap. Note that it is normal practise to complete the asphalt surfacing before installing expansion joints.

(c) Quality of surface finish required on deck concrete.

(d) Checking of concrete surface levels to confirm acceptability. High spots may require remedial work to lower the surface level (ensure that required concrete cover is maintained),

and low spots may require local asphalt levelling layer. In severe cases, a cementitious screed may need to be applied.

(e) Concrete surface cleaning and tack coat.

(f) Monitoring the application of the tack coat to ensure that kerb/parapet is not contaminated.

(g) Approval of compaction equipment to be used on bridge deck (the operation of vibratory compaction equipment on the deck should not be permitted, unless special circumstances require this and the designer's approval is obtained).

(h) Monitoring the operation of compaction equipment to ensure that kerb/parapet edges are not chipped or damaged by steel wheels of rollers.

(i) Compatibility of materials where asphalt is in contact with sealants (isolation membranes may be required if the materials are not compatible).

12.8.14 Expansion Joints

Refer to Chapter 14 : Ancillary Components for detailed guidance.

There are numerous important points to consider and monitor. These include:

(a) Guarantee requirements.

(b) Ensure that drainage pipes required to drain water percolating through the surfacing adjacent to the joint nosings (at low points) are not overlooked.

(c) Importance of level control to ensure good rideability etc.

(d) Normal practise is to complete asphalt surfacing before installing expansion joints. If this practice is not followed it is unlikely that good alignment will be achieved.

(e) Control the movement of construction traffic over joints which are under construction and protect the sawn edges of the asphalt surfacing.

(f) Ensure that reinforcement in joint recesses is not abused by the joint installer.

(g) Protect and cure freshly cast concrete joint nosings, and prevent traffic loading until concrete has attained acceptable age and strength. Consult with design office.

INDEX TO APPENDICES

APPENDIX 12A - SUPERSTRUCTURES CHECK LIST

NOTE
For formwork, reinforcement, concrete, prestressing, etc., the standard check-lists apply.

SUPERSTRUCTURES CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1. ACCESS								
1.1 For personnel								
1.2 Control and exclusion								
1.3 Traffic arrangements								
2. SAFETY								
2.1 Compliance with OHS & Const Regs								
2.2 Safety screens, catch nets								
3. FALSEWORK, FORMWORK & CONCRETE FINISH								
3.1 Chapter 6 checklist completed								
3.2 Levels								
3.3 Screed rails & surface finish								
3.4 Temporary support requirements								
3.5 Precamber								
4. STEEL REINFORCEMENT								
4.1 Chapter 7 checklist completed								
4.2 Accurate setting out of parapet starter bars								
5. CONCRETE								
5.1 Chapter 8 checklist completed								
5.2 Casting sequence								
5.3 Revibration to close settlement cracks								
6. PRESTRESSING								
6.1 Chapter 9 checklist completed								
6.2 Effect of elastic support								
7. ANCILLARY COMPONENTS								
7.1 Bearings installed correctly								
7.2 Drainage pipes, ducts, attachments								
7.3 Provision for expansion joints								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

CHAPTER 13 - MECHANICALLY STABILIZED EARTH WALLS AND PATENTED EARTH RETAINING SYSTEMS

DS Temple

13.1 SCOPE

This section covers the inspection of mechanically stabilized earth walls and other patented earth retaining systems as per the applicable chapter of the Specifications. It also covers the special attention which must be given by the engineer's monitoring staff to the specific requirements of setting out, excavations, backfilling, foundations, precast concrete elements, reinforcing slopes and the erection of wall panels.

13.2 PATENTED EARTH RETAINING SYSTEMS

The engineer's monitoring staff should obtain from the patent holder of such systems the checklists and other Quality Assurance documentation before commencement of the construction. The monitoring staff should ensure that the work is carried out and signed off in accordance with the requirements of the specific system and the applicable Specifications.

13.3 INSPECTIONS

Inspections in accordance with the Manufacturers Check Lists should be carried out relating to:

13.3.1 Excavations

Excavations for patented earth retaining systems are generally not very deep and are more related to leveling the site so that the wall foundations (leveling pads) are stepped to form a base for the wall.

The dimensions and levels of these excavations are therefore important to ensure that the precast elements can be constructed properly to line and level.

Compaction of the existing material or imported foundation fill to the requirements of the design should be verified.

13.3.2 Foundations (Leveling Pads)

Verify the foundation or leveling pad elevations. Ensure that formwork, reinforcement and concrete (Class) is carried out in accordance with the specifications. Where no period is specified for the foundation concrete before wall elements are placed, a minimum of 3 days curing time is required. It is important to have a high quality of surface finish on the top of the foundations to ensure that the wall elements are erected to line and level.



Photo 13.1: Correct leveling pad

13.3.3 Precast Concrete Panels and Blocks

These panels and blocks are usually manufactured in a factory to stringent quality assurance systems. The engineer's monitoring staff should however ensure that the elements have been cast to the dimensions required on the drawings. The concrete strengths of the panels / blocks must be verified by factory QA records to ensure that the panels / blocks are fit for purpose. The monitoring staff should make at least one factory inspection during the period that concrete elements are being manufactured for the project.

Reject all panels / blocks that do not comply with the drawings and specifications.



Photo 13.2: Correct panel storage

13.3.4 Backfill

The engineer's monitoring staff should check that the quality of the backfill material conforms to the Project and Standard Specifications. The type, quality and compaction of the backfill are important factors in the overall design of the wall and these aspects are of critical importance to each of these patented systems.

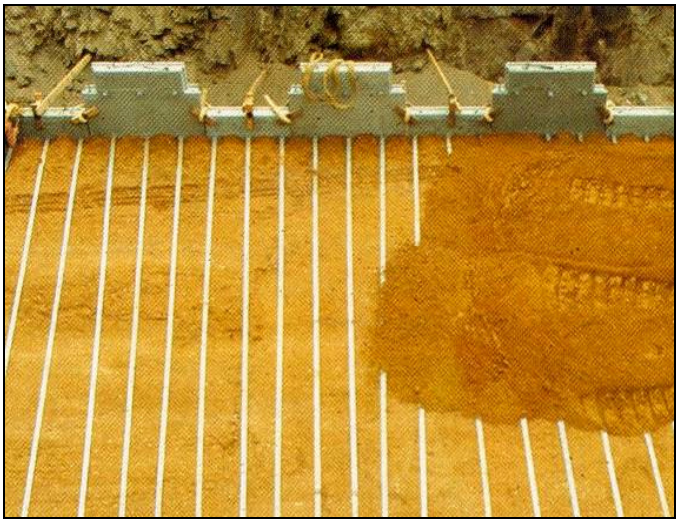


Photo 13.3: Correct backfilling

Compaction within two metres behind the retaining wall systems should be carried out to the specified density using only hand operated compactors. Compaction of backfill in front of the wall should be carried out in a similar manner to prevent washaways during rainy conditions as movement in the leveling pad will adversely affect the performance of the wall.



Photo 13.4: Within 2m of the panels, only small rollers may be used

13.3.5 Reinforcing Strips

The engineer's monitoring staff should ensure that the size and grade (length and thickness) of the reinforcing materials are in accordance with the drawings and specifications.

Good site housekeeping practices should be adhered to for the storage and handling of all elements required for the construction of the wall. These measures must at least meet the requirements of the manufacturer / supplier.



Photo 13.5: Correct storage of reinforcement strips



Photo 13.6: Unacceptable storage and backfilling

13.3.6 Erection of Panels / Blocks

The engineer's monitoring staff should ensure that each layer of panels or blocks is adjusted to line and level prior to the construction of the subsequent layer. Only wooden wedges should be used so that panels / blocks do not spall. The wedges should be removed timeously as the wall progresses in height, otherwise they become difficult to remove after more than 3 levels are supported on them.

It is very important that vertical walls be constructed with a slight tilt to the inside in accordance with the design so that the wall is vertical after construction.



Photo 13.7: Correct wedge placing (2 rows are adequate)

13.4 TESTING REQUIREMENTS

The engineer's monitoring staff should ensure that the materials hereunder are tested in accordance with the specifications.

13.4.1 Backfill

Patented earth retaining systems require that a zone of backfill behind the retaining wall system is constructed using a very specific quality of material and is compacted to a given density. Monitoring staff should ensure that the number and frequency of tests are adequate to ensure compliance.

13.4.2 Reinforcing Strips

The supplier of the various types of reinforcing strip should supply all relevant test certificates to cover the batches of materials used to manufacture the strips and fasteners.

13.4.3 Panels / Blocks

Where precast concrete panels are constructed on site the requirements of the Specifications should apply. Where elements are supplied from commercial sources the supplier should supply Quality Assurance data and certificates to verify compliance with his specifications. Random checks related to cover, strength, etc. should be carried out as required on site.

INDEX TO APPENDICES

13A - MECHANICALLY STABILIZED EARTH WALLS
AND PATENTED EARTH RETAINING SYSTEMS

CONSTRUCTION MONITORING CHECK LIST (1/2)

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. FOUNDATION PREPARATION					
1.1 R.E. wall setting out					
1.2 Compaction to specified density					
1.3 Confirm allowable bearing pressure					
1.4 Foundation Fill					
2. DRAINAGE SYSTEM					
2.1 Drainage installed as per drawing					
3. LEVELING PAD					
3.1 Excavation of leveling pad area					
3.2 Leveling pad set to the proper vertical elevation and horizontal alignment per drawings (elevation tolerances +3 mm to -6 mm)					
3.3 Leveling pad cured for a minimum of 24 hours					
3.4 Horizontal lift between step-up pads					
4. PANEL ERECTION					
4.1 Confirm correct panels used					
4.2 Confirm correct clamps and bracing in place (initial course only)					
4.3 Confirm panel batter					
4.4 Confirm correct placement of wooden batter wedges					
4.5 Confirm correct joint spacing					
4.6 Confirm vertical and horizontal alignment every 10 panels					
4.7 Wooden wedges removed after full erection of the upper panel					
4.8 Confirm wall vertical alignment for each additional row of panels					
5. JOINT MATERIALS					
5.1 Filter fabric placed correctly to cover horizontal and vertical joints					
5.2 Bearing pads placed in panel grooves					

Check list continues on next page…

CONSTRUCTION MONITORING CHECK LIST (2/2)

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
6. REINFORCING STRIPS					
1.1 Are reinforcing strips properly galvanized					
1.2 Are reinforcing strips placed to correct lengths and number per drawings					
1.3 Are straps are placed perpendicular to the wall or skewed per drawings					
1.4 Is the placement of connections, bolt, washer and nut correct					
1.5 Are splices of correct length					
7. BACKFILLING					
7.1 Quality of selected backfill material					
7.2 Loose backfill thickness not to exceed 250 mm					
7.3 Compacted backfill 50 mm above tie strip level					
7.4 Backfill to slope 300 mm behind first layer of each row of panels					
7.5 Compaction within 900 mm of the back face with suitable compaction equipment as specified					
7.6 Confirm backfill placed parallel to the wall panels					
7.7 Backfill testing frequency of one test for each lift and every 15m length of wall					
7.8 Confirm backfill compaction to 95% Mod AASHTO density					

CHAPTER 14 - ANCILLARY COMPONENTS

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14.1 SCOPE

In this chapter guidance is provided about the compliance with the design requirements and the various issues which commonly arise during the procurement, construction, installation and replacement of the following ancillary components for road related structures:

(a) Joints (excluding construction joints which are dealt with in Chapter 8).

(b) Bearings.

(c) Balustrades, railings and sidewalks.

(d) Drainage.

(e) Attachments to structures.

Detailed guidance about the formwork, reinforcement and concrete operations required for the construction of ancillary components is provided in the appropriate chapters of this manual.

14.2 CONSTRUCTION MONITORING

The ancillary components are functionally essential and aesthetically important in the design of bridges and other road related structures. The design requirements and the functions which these components perform are briefly described in the following sections of this chapter.

It is evident that no other single component of bridges has caused as many service problems as expansion joints, which require intermittent replacement despite regular inspections and maintenance. Bridge bearings fall into the same category but to a lesser degree as these are not as directly exposed to wear and tear caused by the constant impact of vehicle wheels.

Balustrades, railings and sidewalks are important with regard to the safety of vehicles and pedestrians using a bridge and comprise a visually dominant part of the structure. Any proposals by the contractor concerning the details and construction of these components, which may constitute a departure from the employer's standards or which may influence the appearance of the structure are required to be submitted to the engineer and the designer for approval.

Monitoring staff who require more detailed information and guidance about all aspects of structural bearings and expansion joints for bridges relevant to their duties are encouraged to study the reference listed at the end of this chapter.

NOTE

The ancillary components as a whole usually constitute a disproportionately small percentage of the cost of a bridge compared with their importance to the performance, utility and safety of the structure but are difficult and costly to replace in the event of damage or malfunction.

These components therefore demand special attention by the monitoring staff regarding compliance with all facets of the applicable specifications to ensure the quality of their construction.

14.3 JOINTS

14.3.1 Function

14.3.1.1 Primary function

The primary function of joints in structures is to permit movement of the structural elements, in order to prevent the development of excessive stresses caused by materials behaviour acting in conjunction with load effects, which would otherwise result in cracking or other forms of structural distress. The movements to be accommodated include displacement, translation or rotation of the structural components arising from the effects of shrinkage, creep, thermal actions, elastic shortening, deflection, settlement etc.

14.3.1.2 Conventional movement joints

In addition to the accommodation of movement, vertical joints in bridge abutments, culvert barrels, wing walls and independent retaining walls are required to be watertight in order to prevent the leaching of the retained soils and the unsightly staining of the exposed surfaces.



Photo 14.1: Sealing of replacement roadway joint; note the pre-installed plug beneath the seal

14.3.1.3 Bridge expansion joints

The functional requirements of bridge expansion joints installed at the road surface are as follows, to:

(a) Bridge the variable gap due to expansion or contraction of the deck in such a manner as to prevent unacceptable discontinuities in the riding surface of the carriageway.

(b) Ensure the riding quality in terms of comfort and safety of all classes of road users for which the structure is designed.

(c) Withstand the loads and movements due to traffic, vibration, impact, shrinkage, creep, settlement etc. without causing excessive stresses in the joint or elsewhere in the structure.

(d) Prevent the potential for skidding, excessive noise or vibration.

(e) Either be sealed against the ingress of water and debris, or to have provision for drainage and cleaning.

(f) Be easy to clean and maintain.

(g) Be economical in their total cost, including capital outlay and maintenance.

14.3.2 Joint Types and Movement Range

14.3.2.1 Conventional filled joints

Conventional filled joints which are required to accommodate minor movements due to concrete shrinkage etc. should be filled and sealed as described in the specifications.

When these joints are also required to prevent the leaching of backfill they should additionally be covered on the retained fill side by an appropriate flexible waterproof membrane attached to the concrete face and covered by a 3 mm thick galvanised steel sheet attached to the wall on one side of the joint by appropriate galvanised fasteners.

14.3.2.2 Bridge expansion joints

The types of expansion joint which are typically used for bridge decks are summarised as follows in relation to the movement ranges which they can accommodate:

Less than 10 mm (very small movements)

(a) Buried joints in which the surfacing is taken across the joint and a waterproof bond breaker is installed at the top of the deck concrete to limit the crack widths in the surfacing.

10 mm to 25 mm (small movements)

(a) Concrete nosings with silicone seals.

(b) Asphaltic plug joints. (These joints are unsuitable at locations where traffic becomes stationary or on pedestrian sidewalks).

25 mm to 80 mm (medium movements)

(a) Elastomeric cushion joints, with anchored steel housings.

(b) Claw type joints, with preformed neoprene seals and anchors concreted into rebate channels.

Greater than 80 mm (large movements)

(a) Coupled elastomeric cushion joints.

(b) Multi-element claw type joints, with rails supported by folding trellis linkages or by beams with various spacing options.

(c) Toothed (finger) joints, either cantilevered or supported and which require separate provision for the collection and disposal of surface water and grit.

(d) Rolling leaf joints.

The technical literature provided by the suppliers of proprietary expansion joints, including asphaltic plug joints, must be consulted regarding the method of construction, limitations regarding movement range and applicability to skew, gradient, climatic conditions etc.

NOTE

The types of joints permitted by the employer and for which Agrément SA accreditation is required, must be confirmed. Agrément SA is an independent organisation whose primary business is the certification of non-standard construction products, through technical assessments that verify whether the products and systems are fit for purpose (refer: www.agrement.co.za).

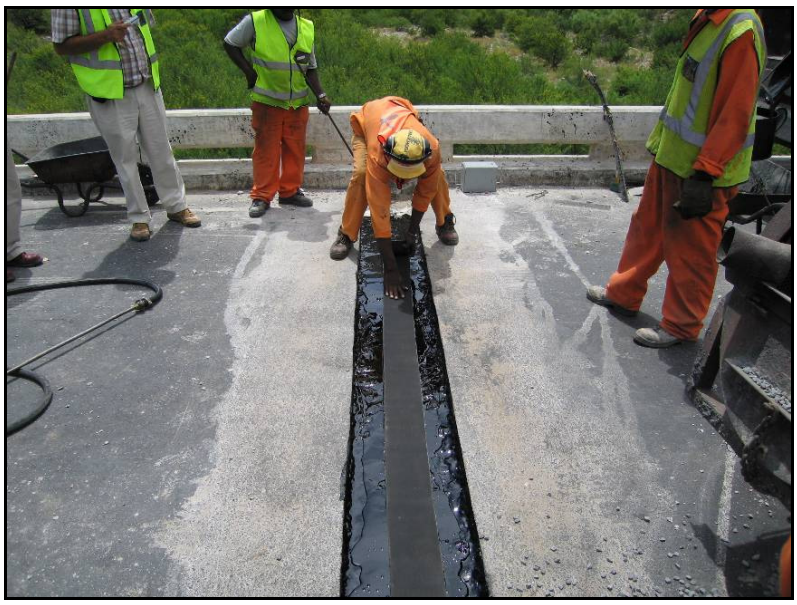


Photo 14.2: Installation of a square asphaltic plug joint showing steel bridging plates embedded in bituminous membrane prior to placing and compaction of asphalt/stone plug



Photo 14.3: Rutting problem arising in an asphaltic plug on a highly skew joint

14.3.3 Construction

The following are the main issues which require the attention of the monitoring staff prior to and during the construction or installation of bridge joints.

14.3.3.1 Compliance with specifications and drawings

With regard to all types and forms of joints the monitoring staff are required to verify that:

(a) The materials proposed for forming, constructing and sealing the joints comply with the applicable specifications and are approved by the engineer.

(b) In the case of proprietary expansion joints:

- Compliance is confirmed by the provision of independent test certificates or warranties.
- The supplier has the necessary Agrément accreditation, if required by the employer.
- Prior to the commencement of fabrication of proprietary expansion joints, the drawings, method statements etc. provided by the specialist supplier conform in all respects with the design requirements with regard to the type, size, overall geometry, movement capacity, installation procedures etc. and have been approved in writing by the engineer.
- Prior to completion of the joints, guarantees required in terms of the contract must be provided.

In the case of bridges with sidewalks the attention of the monitoring staff is also directed to clause 14.5.3.2 of this chapter, with regard to the joints in the sidewalks.

14.3.3.2 Geometric accuracy

The monitoring staff must ensure that for general movement joints:

(a) The joints are precisely located at the positions shown on the drawings, with adequate cover to the reinforcing steel when applicable and that the required orientation (vertical, horizontal, slope or skew in plan) and width are achieved.

(b) The forms required to construct the joints are secure and cannot be dislodged during concreting or other operations but can be easily removed on completion of construction of the joint.

(c) The edges of the joints have the required chamfer sizes, when applicable.

It needs to be borne in mind that even minor joints can detract from the appearance of a structure if these vary in width or alignment beyond permissible tolerances. Misaligned joints cannot be adequately corrected merely by chipping back and regrouting.

14.3.3.3 Joints with embedded anchors

Almost all roadway joints required for the medium to large movement range have anchors which are embedded in the concrete of the main components required to house the joints. It is recommended that the monitoring staff should consult with the designated supplier/installer of prefabricated joint assemblies regarding the potential clash of the reinforcement in the main support components with the joint anchors. It is possible with care to avoid such a clash, failing which it is necessary to cut or displace some of the main reinforcement and to grout in new U-bars and install bars threaded through

the anchors in order to achieve the necessary anchorage strength. Any such adjustments must be approved by the engineer.



Photo 14.4: Assembly of multi-element claw type joint prior to installation



Photo 14.5: Checking alignment of claw joint prior to concreting

14.3.3.4 Installation of proprietary expansion joints

Unless otherwise approved by the engineer, proprietary expansion joints shall be installed only by an experienced subcontractor approved by the joint supplier and only after the construction of the bridge deck final surfacing. Saw cuts in the asphalt surfacing must be accurately carried out parallel to the joint centre line, and after removal of the surplus asphalt the vertical faces of the cuts must be carefully protected to prevent damage by the passage of workmen, wheel barrows etc.

It is essential that prior to the fabrication of these joints the supplier should accurately measure the As Built width and skew angle of the structure, including road and sidewalk dimensions, camber details, kerb heights etc. and that these dimensions should be independently verified by the monitoring staff.

Before placing of the concrete infill below and behind claw type joints the monitoring staff should:

(a) Use a suitably long straight edge laid on the asphalt surfacing to ensure that the joint is perfectly aligned.

(b) Ensure that the joints are rigidly held vertically and horizontally in position by temporary beam supports laid on the surfacing, at such spacing as to prevent deflection or dislodgement during concreting.

14.3.3.5 Concreting and sealing of joints

An important point to confirm prior to these operations is that the surfaces of the original concrete against which concrete nosings or infill concrete are required to be cast or seals installed are sound, clean, free of loose material or contaminants etc. which could otherwise impair the bond of the concrete or sealing compound within the joint. The concreting and sealing operations must be implemented strictly in terms of the applicable specifications and method statements previously approved by the engineer.

Traffic must be prevented from crossing concrete nosings or infill concrete until these have gained adequate strength, preferably for a period of at least 10 days.

14.3.3.6 Water tightness tests

Water tightness tests required in terms of the specifications or instructed by the engineer must be undertaken before signing off of the joints.

14.3.3.7 Cover plates required on the faces of balustrades at the positions of bridge expansion joints are discussed in sub-section 14.5.

14.3.4 Replacement

Complete replacement of bridge expansion joints becomes necessary when the concrete or metal parts of the joint exhibit advanced fatigue damage or other forms of significant distress. It may also be decided to replace an existing joint in the event of the widening of a bridge deck, when it is found that joints of the original type and form are no longer available or if the road level needs to be raised.

Replacement in these circumstances invariably entails accommodation of traffic and working in half widths and in some cases raising of the concrete required to house the joints.



Photo 14.6: Replacement of old joints; note concrete failure plane above edges of embedded water stop

The operations involved in the replacement of existing joints essentially require the same procedural steps, care and monitoring overview as original construction. In addition, careful work is required in the process of breaking out existing joints and concrete in order to preserve reinforcement and not to damage concrete in the vicinity of prestressed concrete anchorages.

14.4 BEARINGS

14.4.1 Function

The function of a bridge bearing is to:

(a) Transmit loads or forces from one member of the structure to another.

(b) Provide restraint against specific directional or rotational movements, or

(c) Allow freedom of such movements in specific directions.

Bridge bearings are typically required to transmit vertical loads from the superstructure to the substructure supports, with specific restraint or freedom of movement in the horizontal plane in the designated longitudinal and transverse directions. Restraint of movement in any direction is associated with the transmission of a horizontal force from the superstructure to the particular support in that direction.

The design of the bearings for a bridge therefore reflects the degree to which the designer has decided to articulate the structure as a whole (continuous or simply supported spans) and the locations at which it is intended to resist longitudinal or transverse forces imposed by the superstructure on the substructure components.

14.4.2 Types and Configurations

Numerous types of bridge bearings have been developed over the years, some of which are illustrated in Appendix 4E at the end of this chapter. The following are the most commonly used bearings in South Africa today for all but the smallest structures:

(a) Elastomeric bearings

(b) Pot bearings

(c) Spherical bearings

For very small bridges several layers of roofing felt, or similar arrangements, are quite frequently used for bridges on lower class roads. The other forms of bearings shown in the Appendix are either special application bearings, which may be difficult to procure, or are found only in older forms of bridges. Concrete hinges, which are not illustrated, fall into the latter category and have largely fallen into disuse.

NOTE

Normally employers require the provision of top and bottom adaptor plates to house pot and spherical bearings, in order to facilitate their periodic replacement. When adaptor plates are specified the monitoring staff do not have the authority to decide on their omission, which requires the express approval of the design engineer and the employer.

14.4.3 Movement and restraint

The translational, rotational or restraint functions provided by the various types of bearings in relation to a designated (x, y and z) system of axes is summarised in Appendix 14F.

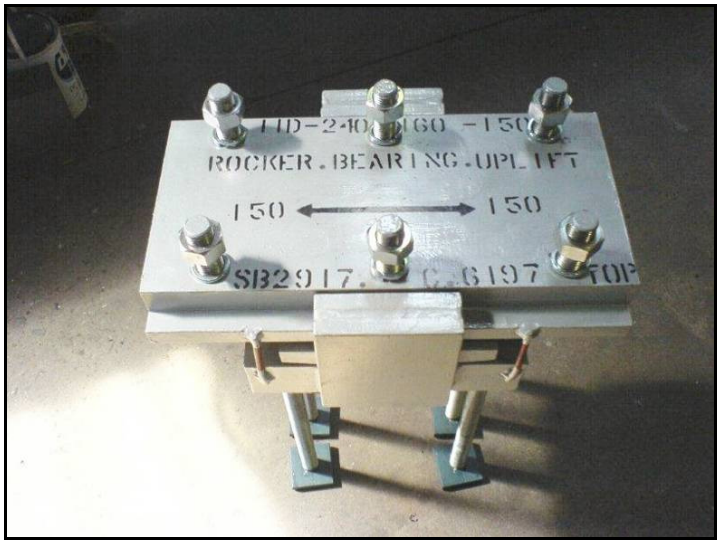


Photo 14.7: Uni directional rocker bearing; provision for 150 mm of longitudinal movement both ways; restraint against uplift of steel deck; note temporary side straps.

14.4.4 Designation of Bearings

The restraint or freedom of movement in the horizontal plane gives rise to the following designations of bearings commonly used in South Africa.

(a) Fixed bearings are those which provide restraint against movement in any direction.

(b) Unidirectional bearings are those which provide restraint against movement in one designated direction and freedom in the other (the designated direction can be longitudinal or transverse as stipulated by the designer).

(c) Multidirectional bearings are those which provide freedom from restraint in any direction.

It must be noted that no bearings provide absolute freedom of movement in any direction as the movement is resisted to a small degree by the friction between the moving parts of the bearings.

14.4.5 Determination of Loads and Movements

The loads or forces imposed on the bearings together with the movements which these will be required to accommodate are obtained from analysis of the effects of the various actions applied to the selected form of the structure and the degree of articulation required by the designer.

The actions imposed on bridges can be categorised as permanent and long term, short term and transient, such as the following:

(a) Permanent and long term actions include dead load (superstructure self weight), superimposed dead loads, earth pressure, differential settlement of foundations, prestressing effects, creep and shrinkage.

(b) Short term actions include the temperature range applicable to the structure, the temperature gradient through the individual members and construction loads.

(c) Transient actions include traffic primary loading (with an allowance for dynamic effects), braking forces, traction forces, centrifugal forces, wind loads, water forces, vehicle impact and earthquake excitation.

For the purpose of tenders the most unfavourable combinations of the maximum and minimum vertical loads and co-existent horizontal loads, together with the maximum values of the reversible and irreversible movements and rotations about each designated axis are summarised on the drawings for each bearing.

14.4.6 Setting Out

14.4.6.1 Plan layout

The plan layout of the bearings is usually depicted in diagrammatic form on the drawings, in which each bearing is given a discrete number and annotated with appropriate symbols, such as illustrated in Appendix 14F, in order to indicate the designated axes (x and y) in which specified freedom of translational and rotational movements are required or are to be restrained.

In the case of a square bridge the orientation of the bearing x and y axes will invariably correspond with the longitudinal and transverse axes of the structure. However, in the case of a skew bridge or one which is curved in plan, the setting out of the bearing axes will often be rotated in relation to a reference line parallel to a pier or an abutment front face. In these instances the exact angular orientation of the bearing axes and plan location of the bearing centre line relative to such reference lines are usually shown on enlarged plan details.

14.4.6.2 Presetting of bearing top plates

It is often found from analysis that the combined action effects on a bridge superstructure will cause the top plates of multidirectional or unidirectional bearings to be predominantly offset in one direction along the x axis, in relation to the centre line of the bearing.

When the estimated offset is deemed to be significant, the designer will usually stipulate a 'preset' of the bearing top plate at the time of installation of the bearing (in the opposite direction to the offset), to ensure that the centre line of the top plate will essentially match that of the bearing at average ambient temperature in the long term. The required amount and direction of the 'preset' will be indicated on the drawings.

The purpose of this step is to essentially minimise the size of the bearing top plate, which would otherwise need to be larger to accommodate the expected movements.

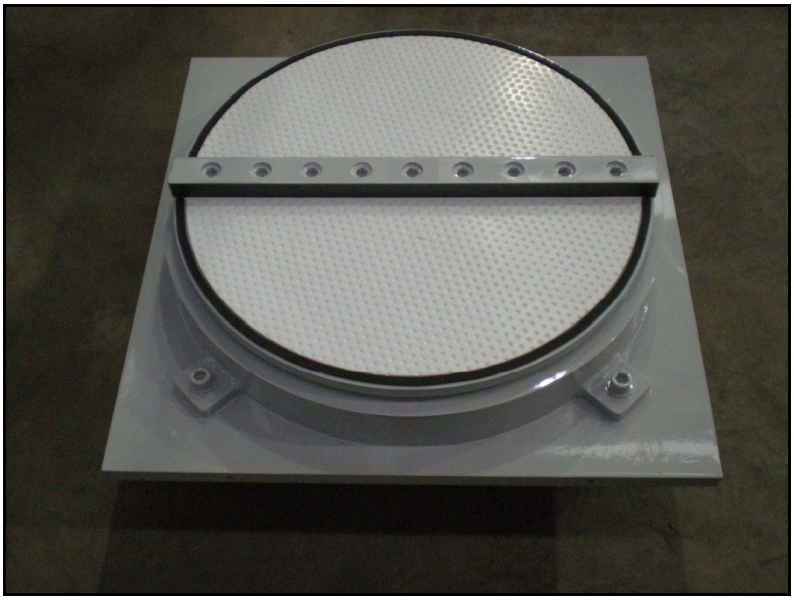


Photo 14.8: Uni-directional pot bearings showing Teflon sliding surface with top plate removed



Photo 14.9: Fully assembled unidirectional pot bearing without adaptor plates

14.4.7 Construction

The following are the main issues which require the attention of the monitoring staff prior to and during the construction or installation of bridge bearings, dowels and guides.

14.4.7.1 Compliance with specifications and drawings

With regard to all types and forms of bearings, dowels and guides the monitoring staff are required to verify that:

(a) The materials proposed for the construction and fabrication of these components comply with the requirements of the applicable specifications and are approved by the engineer.

(b) In the case of proprietary bearings, dowels and guides, such compliance is confirmed by the provision of independent test certificates and/or warranties of compliance.

(c) Prior to the commencement of fabrication of these components, the drawings, method statements etc. provided by the specialist supplier conform in all respects with the design requirements in terms of the load capacity, restraint or movement capacity, preset requirements, adaptor plate configuration, durability coatings and method of attachment etc. and have been approved in writing by the engineer.

(d) The test loading and subsequent saw cutting into quarters of the stipulated number of elastomeric bearings by an independent testing organisation, as required by the project specifications, has demonstrated the adequacy of the bearings in terms of:

- the load-deformation characteristics and the absence of de-bonding;
- the correct thicknesses of the elastomer layers, steel reinforcing plates and outer elastomer casing;
- the correct overall dimensions.

(e) The specified maximum average service load pressure on the elastomer layer of pot bearings will not be exceeded under the action of the load combinations stated on the drawings.

14.4.7.2 Specified and alternative bearings

Unless the required type of bearing has been unequivocally stated in the documents and on the drawings (elastomeric bearings for example) a tenderer may base his tender on any bearing which complies with the requirements of the specifications.

Before approval of the bearings proposed it is essential that the monitoring staff in co-operation with the designer should recheck the space available for the bearings, both in terms of the vertical space between the superstructure and the relevant supports and the lateral dimensions of the supports.

In particular it needs to be confirmed that there is sufficient vertical space to adequately cater for the bearings, top and bottom adaptor plates, grout and levelling plinths below the superstructure components. Equally it needs to be checked that there is not excessive space, to ensure that the entire bearing arrangement does not dominate and detract from the appearance of the structure. In the horizontal direction it must be confirmed that the edge of the adaptor plates do not compromise edge distances with regard to spalling or bursting of the concrete and that anchor bolts or lugs do not clash with reinforcement.

Any alterations to the concrete dimensions arising from these considerations must be approved by the engineer and made in good time.

14.4.7.3 Concrete hinges

In order for concrete hinges to operate satisfactorily for the entire service life of a bridge it is essential that these are constructed to the highest standard of workmanship and precision as set out in the specifications, under the diligent scrutiny of the monitoring staff.

14.4.7.4 Installation

Checking the setting out of bearings is possibly the most important duty of the monitoring staff in relation to the installation of these components. In the first instance it is essential that each proprietary bearing should be adequately identified by permanent numbers or letters inscribed on the upper surface as well as by arrows or other suitable markings to indicate the correct orientation with regard to the required directions of movement or restraint and the direction of the preset, if applicable. Inadequate markings must be put right by the specialist supplier before the bearings are hoisted into place on the respective substructures.

Once installed in place, the monitoring staff should double check that the bearings have been correctly placed with regard to centreline position, movement direction, preset, line and angle in relation to setting out lines, and level, and thereafter adequately secured in position. **It is surprising how often bearings have been incorrectly installed, at 180° to the required direction for preset and even at 90° in relation to the required movement direction, for example.**

Unless otherwise shown, bearings are required to be set horizontal. Special care needs to be taken when bearings are required to be installed at a slope in relation to the horizontal.

Precast beams should be adequately supported by hardwood chocks or other devices to establish the correct height above the bearings before grouting between the beams and the tops of the bearings. In all cases the stability of the superstructure should be considered with regard to the restraint provided by bearings during the construction process, particularly in the longitudinal direction.

WARNING

Only once the setting out has been checked and confirmed should the bearings be grouted in place. For large bearings special care is required to ensure that the bearings are fully bedded and that no air is trapped below the bearing or the bottom adaptor plate.



Photo 14.10: Well installed unidirectional pot bearing

WARNING
The straps provided to maintain the correct planes of the upper and lower plates of proprietary bearings should be removed only when instructed by the engineer.



Photo 14.11: Line rocker bearing with failure to tighten lower holding down bolts



Photo 14.12: Line rocker bearing partly covered by concrete leaked through the shutters at the time of deck construction

The failure to tighten holding down bolts, as seen in photograph 4.11, can be a problem in the case of high horizontal loads. The bearing design is not based on the shear strength of the holding down bolts, but on the clamping force required to keep the bearing in place.

The poor quality of construction illustrated by photographs 14.11, 14.12 and 14.13 reflects poor training of the construction team as well as negligent supervision on the part of the monitoring staff!

14.4.8 Replacement

The replacement of bearings is a normal maintenance operation required periodically during the service lives of bridges. Bearing replacement should preferably be catered for at the original design stage by providing suitable 'strong points' at which the superstructure can be safely lifted by jacks and which do not restrict access to the bearings which are to be replaced. However, in the case of precast beam and slab bridges and certain older forms of bridges it is usually necessary to re-analyse the structure in order to determine the location and means of lifting the superstructure.

For the purpose of planning the operations to lift a bridge deck in order to replace the bearings, the following information is required:

(a) Copies of the As Built drawings and original calculations, if available.

(b) The amount of lift required to remove the existing bearings and install the replacement bearings.

(c) The form of the structure i.e. simply supported, continuous etc. and whether any of the pier columns are monolithic with the deck.

(d) The configuration of the deck i.e. slab, voided slab, beam and slab, box girder etc.

(e) Investigate whether:

- Jacking can be safely carried out from abutment bearing seats and pier caps.
- Balustrade dowels or services across expansion joints may hinder lifting operations.
- Deck expansion joints can be salvaged during lifting operations.

- Replacement of the bearings must be carried out under full traffic, restricted traffic or without traffic.

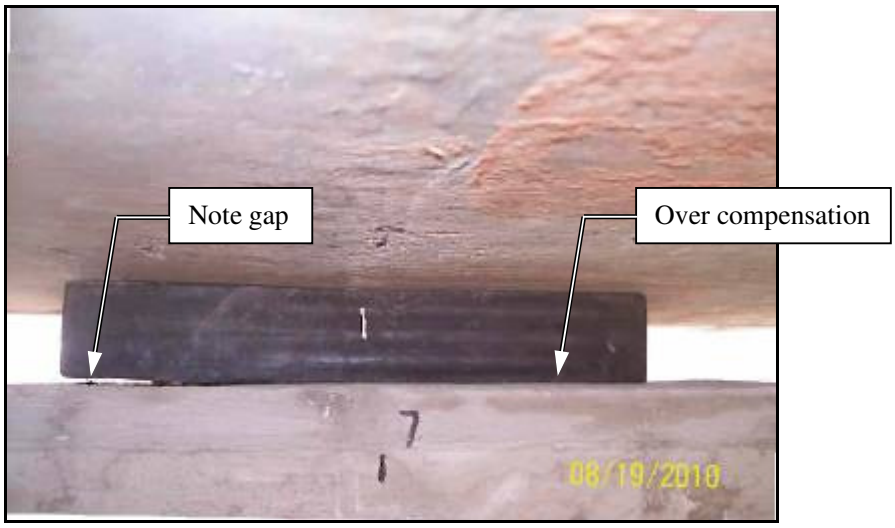


Photo 14.13: Elastomeric bearing installed without bedding mortar between uneven concrete surfaces: early replacement seems inevitable!

The methods available for the lifting of bridge decks are many and varied and are beyond the scope of this manual. However, in all cases of the lifting of bridges certain information must be established from adequate analysis regarding specific requirements, limitations, or restrictions during the necessary operations to prevent damage to the structure and ensure safety. The information which is required by the contractor for purposes of planning, pricing and implementing the work includes the following:

(a) The points at which jacking or support of the deck will be permitted, together with the loads to be lifted and the amount of the lift required.

(b) The need for the strengthening of any parts of the superstructure or substructure, depending on the proposals submitted by the contractor.

(c) The maximum incremental lift permitted at any lifting point and the maximum differential lift which will be permitted between designated lifting points in order to prevent the development of excessive stresses in the structure.

(d) Any mandatory steps regarding the stability of the span being lifted or of the individual jacks, taking into account the longitudinal gradient of the deck and expansion or contraction of the deck due to temperature or other effects during the lifting or lowering operations.

The contractor is required to submit detailed drawings and a method statement to adequately describe the proposed method of work and demonstrate compliance with the design requirements. Following approval of these submissions, including any amendments required by the engineer, the work may proceed.

During this type of work the monitoring staff are expected to check that all design requirements are met and in particular to ensure that restrictions or limitations are observed. In the event of any signs of distress in either the structure or the support work the engineer should be promptly consulted on the steps to be taken. Thorough records must be kept of the jacking forces at each lifting point and the associated vertical displacements, for the purposes of further analysis if necessary.

14.5 BALUSTRADES, RAILINGS AND SIDEWALKS

14.5.1 Function

The main function of balustrades and handrails is to prevent traffic and pedestrians respectively from crashing or falling over the edge of a bridge deck or its immediate approaches. Balustrades are also required to minimise the consequences of an accident, by deflecting an out of control vehicle in such a manner so as to prevent its overturning into the path of oncoming traffic. The road-side profile of balustrades adopted as standard by particular employers is configured for that purpose.

The function of a sidewalk is to provide safe passage for pedestrians on a raised area adjacent to the balustrades or handrails for the full length of a bridge. The space between the sidewalk paving and the top of the bridge deck is usually filled with clean sand and provides space for the installation of services.



Photo 14.14: Precast concrete balustrade unit showing method of attachment to deck

The balustrades are a visually prominent part of a bridge and should therefore complement the features of the other structural components to achieve an aesthetically pleasing result.

14.5.2 Typical Details and Working Drawings

The details of the bridge balustrades and median barriers shown on the working drawings are usually adapted from typical detail drawings issued by the employer, which show the required configurations of these components together with alternative forms of construction (in situ or precast) and methods of attachment.

It is left to the designer to adjust the longitudinal geometry of the standard details (joint positions, length of panels and end blocks etc.) to suit the particular project and to decide on whether these components should be cast in situ or precast and in the latter case, the means of attachment to the supporting structure.

WARNING

Contractors frequently request approval of a change in the method of construction and attachment of concrete balustrades to bridge decks (from in situ to precast for example). Such changes should be referred to the bridge designer regarding risk, adequacy and appearance of the proposed design and accepted only with the express approval of both the designer and the employer.

Design and drawings of changes approved in principle should be undertaken by the contractor's competent person, at the contractor's expense, for final scrutiny and acceptance by the engineer.

Each employer's typical details for handrails (steel or concrete) and sidewalks must similarly be adapted for use on particular projects.



Photo 14.15: Concrete balustrade in place; note the housing of a light pole and the high quality of joint sealing and geometric alignment.

The embedments and attachments commonly applicable to bridge balustrades and median barriers include the following:

(a) Expansion joints and their cover plates.

(b) Service ducts in balustrades and barriers (location, size and the provision of draw wires).

(c) Inspection eye spacings and cover plate details.

(d) Housings and cover plates for the attachment of guardrails to end blocks.

(e) Plinths, holding down bolts and cover plate details for the required attachments.

(f) Bridge number plates.

In the case of the different forms of additional attachments to bridge decks and incorporated as part of the balustrades, the proposed support details (e.g. plinths, brackets etc.) must be approved by the employer and the service owners, if applicable. Typically these elements include lighting masts, sign supports or gantries, security screens, wind deflectors, noise abates and the like.

14.5.3 Construction

14.5.3.1 Balustrades and handrails

As previously noted, guidance about the quality of the material and workmanship of the concrete components is provided in the relevant chapters of this manual. In relation to the construction of in situ balustrades and the installation of precast balustrades the monitoring staff are required to pay particular attention to:

NOTE

Prior to use, concrete cover meters must be regularly calibrated against test panels in which the thickness of the covercrete has been confirmed by prior measurement, coring or drilling, especially if these instruments are to be used for the purpose of reduced payments or rejection of work.

(a) The long term durability requirements as these are the most susceptible of all bridge components to environmental conditions. If these components do not meet **minimum acceptance criteria** for concrete durability and reinforcement cover they should be rejected and replaced.

(b) Compliance with regard to the geometric tolerances applicable to the profile of the top concrete rail and the width and verticality (if applicable) of the joints. If these fall well outside the permissible tolerances they should likewise be rejected and replaced.

(c) The adequacy and accuracy of the particular method of attachment to the deck and the quality and thoroughness of the grouting of precast balustrades. Great care must be taken with the spacing and slope of the groups of bars required to be grouted into metal sleeves and likewise for the spacing and alignment of overlapping looped bars in bottom channels, to avoid the need for rectification of the lack of fit.

The quality of the materials and workmanship of handrails likewise requires careful control and overview.

14.5.3.2 Sidewalks

The particular issues to watch during the construction of sidewalks are:

(a) The accuracy of construction of the roadside kerbs regarding both line and level.

(b) The careful sealing of joints of the service ducts, with particular regard to the male/female expansion detail at the position of the deck expansion joint; the provision of draw wires.

(c) The construction of the transverse concrete closures at the position of the deck expansion joints, including the housing of these joints and the turn ups at the parapet faces.

(d) The provision of drainage of the areas beneath the sidewalks, as shown on the drawings.

(e) The adequacy of the compaction of sand fill beneath the sidewalk and of the bedding of the paving slabs to achieve a regular and uniform walking surface.

14.6 DRAINAGE

14.6.1 Function

The function of drainage is to dispose of sub-surface and surface water via designed outlets through various bridge components, in order to prevent the development of water pressure behind earth retaining structures or the accumulation of water on bridge decks which could prove hazardous to road users. In other locations drainage outlets are required to dispose of water which has percolated through joints, deck surfacing or fill beneath sidewalks, to avoid entrapment and durability problems.

14.6.2 Location

The specific components which require the provision of drainage facilities are:

(a) Abutments, retaining walls and culvert barrels, behind which drainage filters and pipes are required to collect ground water and dispose of this through weepholes.

(b) Abutment girder beds which require the provision of collector channels and outlet pipes to remove water which has leaked through expansion joints or has arisen from driving rain or condensation.

(c) Deck roadway surface subject to direct rainfall, which must be disposed of via drainage scuppers, supplemented in certain instances by grid inlets and concealed drainage pipes.

(d) Deck concrete surface on the uphill side of concrete nosings, asphalt plug joints or proprietary joints, which cause the entrapment of water which has percolated through the asphalt surfacing and must be disposed of through small drainage pipes.

(e) Deck concrete surface on the uphill side of the transverse concrete housings for the expansion joints which seal off the area beneath the sidewalks and entrap water which has percolated through the sand fill and must be disposed of through drainage pipes.

(f) Drip notches in the underside of deck cantilevers, strictly in compliance with the configuration and positions shown on the drawings. The careless omission of drip notches can lead to the defacement of the soffits and sides of bridge decks through runoff water laden with silt and other contaminants even before construction of the balustrades.

(g) Drainage of the voids of voided slab decks is discussed elsewhere in this manual.

14.6.3 Construction

The details of the drainage measures shown on the drawings indicate their precise location, fixing in place and the nature of each element which has been adapted from the set of typical drainage drawings developed by the employer.

The monitoring staff are expected to verify that the particular products proposed by the contractor comply with the specification and that when installed are adequately secured in place to avoid being dislodged during the concreting and backfilling operations.

The uPVC pipes to be used for girder bed drainage or as deck scuppers should be pale grey or alternatively a colour approved by the engineer.

14.7 ATTACHMENTS TO STRUCTURES

14.7.1 Bolt Groups for Electrification Brackets

Particular care is needed to ensure that the bolt groups required in precast concrete beams are installed in the correct positions as shown on the drawings and are adequately protected during the process of concreting and erection.

14.7.2 Other Attachments

It is important to ensure that the size and spacing of bolt groups required for the attachment of fixtures such as light poles required by other service owners, should be confirmed and signed off prior to the casting of these bolts in place or the provision of pockets for the subsequent installation of the bolts.

14.8 MEASUREMENT AND PAYMENT

The standard measurement and payment items for the ancillary components are described in the applicable specifications. Special elements of the work which are required as part of the permanent work and which fall outside the scope of the standard items must be described in the project specifications, together with the applicable unit of measurement and a description of the work deemed to be included in the tender prices. The replacement of joints or bearings for example, would fall into this category.

14.9 CHECK LISTS

Check lists related to the ancillary components are included in the Appendices to this chapter and are intended to serve as aide memoires to the monitoring staff and as a convenient date related record for the signing off of completed work.

14.10 REFERENCES

1.) Ramberger, Günter; International Association for Bridge and Structural Engineering IABSE; Structural Engineering Documents No 6 : **STRUCTURAL BEARINGS AND EXPANSION JOINTS FOR BRIDGES;** IABSE-AIPC-IVBH, Zurich, Switzerland; ISBN 3-85748-105-6; April 2002.

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14C - BRIDGE BEARINGS CHECK LIST

14D - BALUSTRADES, RAILINGS, SIDEWALKS, DRAINAGE AND ATTACHMENTS CHECK LISTS

14E - CONFIGURATION OF COMMONLY AVAILABLE BRIDGE BEARINGS

14F - MOVEMENT AND RESTRAINT FUNCTIONS OF BRIDGE BEARINGS

APPENDIX 14A

BRIDGE EXPANSION JOINT CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1 COMPLIANCE WITH SPECIFICATIONS								
• Materials qualities and corrosion protection								
• Test certificates / warranties								
• Supplier Agrément accreditation								
• Supplier drawings:Type, size, geometry movement capacity etc.								
2 INSTALLATION								
• Site measurement of joint housing								
• Fixing in place:								
• Alignment								
• Levels								
• Rigidity								
• Joint Gap								
• Concreting in place								
• Water tightness tests								
3 MEASUREMENT AND PAYMENT								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

APPENDIX 14B

ASPHALTIC PLUG JOINT CHECK LIST

CONSTRUCTION MONITORING

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1. ACCREDITATION								
• Supplier Agrément accreditation								
• Engineer approval of applicator								
2. PRE-PREPARATION								
• Rebates formed in all concrete components to suit joints, as applicable								
• Deck asphalt surfacing completed								
• Rebates in balustrades and end bocks sawn during joint installation								
3. COMPLIANCE WITH PROJECT SPECIFICATIONS								
• Drawings and method statement approved by engineer								
• Materials comply with specification and method statement								
4. INSTALLATION								
• Asphalt accurately cut parallel to joint centreline at required widths								
• Surplus removed and concrete cleaned								
• Protection of joint edges								
• Installation of plug below bridging plates and bituminous membrane seat to bridging plate								
• Installation of bridging plate and natural rubber cover strip								
• Filling and compaction of asphaltic plug								
- flush with roadway surface								
- to required depth in sidewalks								
• Installation of cover plates to balustrades, sidewalks and kerbs, as applicable								
5. MEASUREMENT AND PAYMENT								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

BRIDGE BEARING CHECK LIST

CONSTRUCTION MONITORING

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1 COMPLIANCE WITH SPECIFICATIONS								
• Materials qualities and corrosion protection								
• Test certificates / warranties								
• Supplier Agrément accreditation								
• Supplier drawings: Type, size, load capacity, preset etc.								
• Pre-installation alignment markings								
• Adaptor plates required?								
2 ELASTOMERIC BEARINGS: COMPRESSION & SHEAR TEST RESULTS								
3 CONFIRMATION OF ADEQUACY OF SPACE FOR BEARINGS & ADAPTOR PLATES								
4 INSTALLATION								
• Positioning: Alignment, level, preset, rigidity of supports and straps								
• Grout anchor bolts and bed								
• Chock supports for precast beam decks								
• Removal of bearing straps								
5 MEASUREMENT AND PAYMENT								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
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F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

BALUSTRADES, RAILING, SIDEWALKS, DRAINAGE AND ATTACHMENTS CHECK LIST

CONSTRUCTION MONITORING

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1. BALUSTRADES, RAILINGS AND SIDEWALKS								
1.1 Manufacture / Fabrication								
• Formwork quality								
• Reinforcement: attention to cover; covermeter								
• Concrete: durability requirements								
• Rigidity of embedments								
• Metal railings: compliance with specifications / drawings								
1.2 Installation								
• Accuracy with respect to tolerances: line, level, joint widths etc.								
• Precast components: checks, importance of grouting								
• Housing of joints and other attachments								
1.3 Measurement and Payment								
2. DRAINAGE								
2.1 Compliance with specifications and drawings								
• Materials, size, colour								
• Location and protrusion								
• Rigidity of fixing before concreting								
2.2 Measurement and Payment								
3. ATTACHMENTS TO STRUCTURES								
3.1 Compliance with specifications and drawings								
• Materials, size, corrosion protection etc.								
• Accuracy of anchor bolts								
3.2 Measurement and Payment								

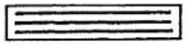
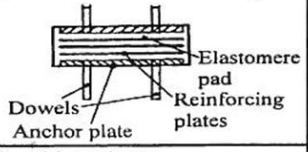
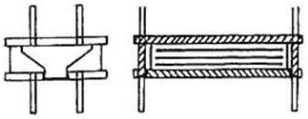
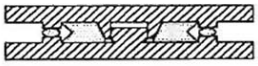
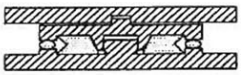
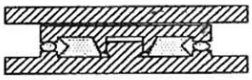
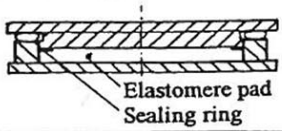
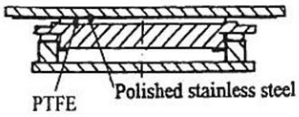
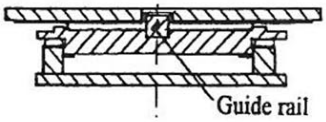
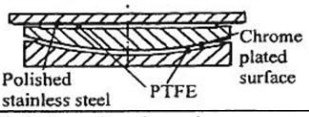
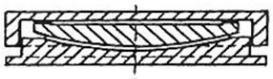
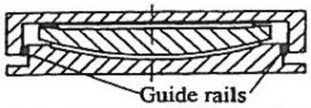
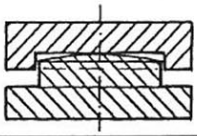
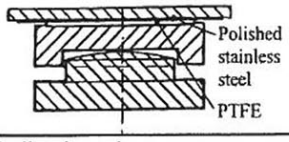
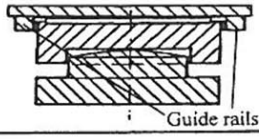
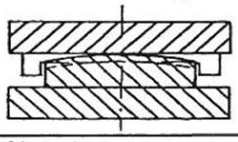
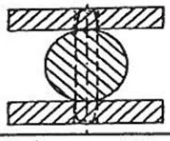
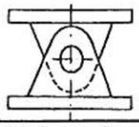
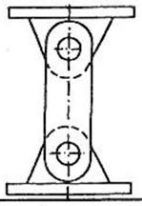
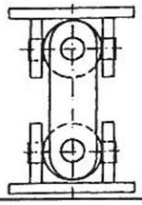
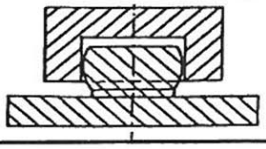
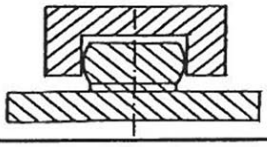
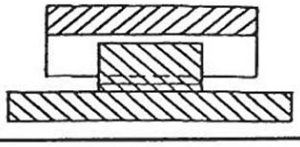
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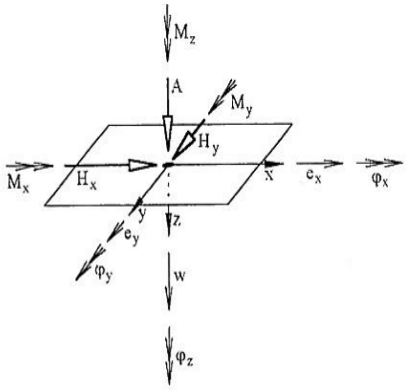
CONFIGURATION OF COMMONLY AVAILABLE FORMS OF BEARINGS

		Standard type	Combinations	
Bearing	Elastomeric	Reinforced elastomeric bearing  Anchored elast. bearing 	Elastomeric bearing with fixing device all translations fixed 	movement in one dir. 
	Disc	Fixed bearing 	Uni-directional guided 	Multi-directional non-guided 
	Pot	Pot bearing 	Free pot sliding bearing 	Constr. pot sliding bearing 
	Spherical	Free spherical bearing 	Fixed spherical bearing 	Constr. spherical bearing 
	Point rocker	Point rocker bearing 	Free point rocker bearing 	Constr. point rocker bearing 
	Line rocker	Line rocker bearing 	Roller bearing 	
	Leaf, Link	Leaf bearing 	Link bearing 	Link bearing with universal (cardan) joints 
	Horiz. force	Horizontal force bearing 	Guide bearing 	

APPENDIX 14F

BEARING MOVEMENT AND RESTRAINT FUNCTIONS

Nr	Symbol	Function	Construction	A	H_x	H_y	w	e_x	e_y	M_x	M_y	M_z	φ_x	φ_v	φ_z
1		All translation fixed Rotation all round	Point rocker bearing Pot bearing; Fixed elastomeric bearing; Spherical bearing	X	X	X	0	0	0	0	0	0	X	X	X
2		Horizontal movement in one direction Rotation all around	Constr. point rocker sliding bearing; Constr. pot sliding bearing; Const. elastomeric bearing; Constr. spherical sliding bearing	X	X 0	0 X	0	0 X	X 0	0	0	0	X	X	X
3		Horizontal movement in all directions Rotation all round	Free point rocker bearing; Free pot sliding bearing; Free elastomeric bearing; Free spherical sliding bearing; Link bearing with universal joints (tension and compression)	X	0	0	0	X	X	0	0	0	X	X	X
4		All translation fixed Rotation about one axis	Line rocker bearing Leaf bearing (tension and compression)	X	X	X	0	0	0	X 0	0 X	(0)	0 X	X 0	(X)
5		Horizontal movement in one direction Rotation about one axis	Roller bearing; Link bearing (tension and compression); Constant line rocker sliding bearing	X	X 0	0 X	0	0 X	X 0	0 X	X 0	(0)	X 0	0 X	(X)
6		Horizontal movement in all direction Rotation about one axis	Free rocker sliding bearing; Free roller bearing; Free link bearing	X	0	0	0	X	X	0 X	X 0	0	X 0	0 X	X
7		All horizontal transl. fixed Rotation all round	Horizontal force bearing	0	X	X	X	0	0	0	0	0	X	X	X
8		Horizontal movement in one direction Rotation all round	Guide bearing	0	X 0	0 X	X	0 X	X 0	0	0	0	X	X	X



System of Axes

CHAPTER 15 - GABIONS, EROSION PROTECTION

GW Els

15.1 INTRODUCTION

The focus of this chapter is the practical aspects of the more commonly used bank protection and erosion protection techniques. For design principles and more detailed applications reference should be made to the appropriate manuals, brochures and the websites of manufacturers and suppliers.

The products to be discussed are gabions and mattresses, riprap, stone pitching, block paving and concrete paving.

15.2 MATERIALS

15.2.1 Gabion Boxes and Mattresses

Gabions are baskets made of hexagonal woven wire mesh. They are filled with rock at the project site to form flexible, permeable and monolithic structures such as retaining walls, channels and weirs for erosion control projects. In order to reinforce the structure, all mesh panel edges are selvedged with a wire having a greater diameter than the mesh wire. The gabion is divided into cells by means of diaphragms positioned at approximately 1 m centres.

The wire is heavily zinc coated and for added protection can also be PVC coated. Stainless steel wire is also available on special order. The gabions boxes are supplied in various sizes, 2 m long by 1 m wide by 1 m high being the most popular size. The diameter of the wire used can also be varied within limits.



Photo 15.1: Gabion boxes with mattresses for scour protection along embankment

The gabion mattresses, also known as reno mattresses, are of similar construction.

As their name suggests they are used to cover large areas and are primarily used for river bank and scour protection as well as channel linings for erosion control. The gabion mattresses are supplied in various sizes, 6 m long by 2 m wide by 0,3 m high being the most popular size.

NOTE
In river courses it is recommended that 2,7 mm diameter mesh be used in order to provide improved durability.



Photo 15.2: Gabion boxes and mattress at spill through abutment

PVC coated gabions will normally be specified in applications requiring additional protection against corrosion for example in the tidal zone of rivers, or when additional wear and tear protection is required against boulders transported by flood waters. It is important to be aware that transported cobbles and boulders can cause severe damage to the mesh and its coatings, reducing the life of the gabion considerably. For more severe exposure to sea water, stainless steel wire should be considered.

The rock to be used for filling the gabion boxes and mattresses are normally obtained from sources on or near the site and should be durable and of sound quality ranging in size between 100 mm and 250 mm for boxes and between 75 mm and 150 mm for mattresses. A well packed gabion can have a very neat appearance.

For a complete specification and the various sizes available, reference should be made to the literature published by the various manufacturers and suppliers.

A geotextile filter layer of non-woven fabrication is normally required at the interface of the gabion boxes and the native soil or backfilled embankment. Its purpose is to release any water pressure without leaching or washing out of the soil from behind or below the gabions. Depending on the application, a geotextile layer may also be required below mattresses. The geotextile specified will normally have a minimum mass of 210 g/m^2 which is equivalent to a grade A5.

15.2.2 Riprap

Riprap is an alternative method for providing river bank and scour protection. It consists of sized and graded rock placed in a layer or in the shape of a berm.

To be effective the riprap needs to be designed for a particular application. In simplistic terms the design theory is based on a fundamental force balance. At equilibrium, or incipient motion, the drag force which the flow exerts on a riprap particle, is balanced by a component of the particle's mass which is dependent on the natural angle of repose of the riprap material. Factors which are taken into consideration include the bank angle, the natural angle of repose of the riprap, the flow depth, the hydraulic energy slope, the size of the riprap and the relative density thereof.

For river bank protection a typical critical mass for dumped riprap is 250 kg.

Rock suitable for riprap can be sourced from quarries, from screening oversized rock from earth borrowpits or from collecting rock from fields. Screening borrowpit material and collecting field rocks present different problems such as rocks too large or with unsatisfactory length to width ratios for riprap. Quarry stones are generally the best source for obtaining large rock for riprap.



Photo 15.3: Rip rap combined with grouted stone pitching, gabion mattresses on the slope and a gabion box cut-off along toe line

15.2.3 Stone Pitching

Stone pitching as it applies to road and bridge construction is in essence uniform sized stone placed shoulder to shoulder on a prepared surface. The stones used must be sound, tough, durable and clean and are normally sourced from rock quarries. Rounded river boulders may also be suitable although they tend to have a more cobbled appearance. The stone should have a minimum dimension of 200 mm.

Depending on the particular application the stone pitching can be laid in a number of ways, viz:

(a) Laid directly on the soil surface and firmly bedded into it and using stone fragments or topsoil to fill in the spaces between the larger stone (plain stone pitching). Typical applications would be on slopes not subjected to water erosion and where re-establishment of vegetation is desirable.

(b) Laid on a cement mortar bed with the spaces between stones filled with cement grout of the same composition as the mortar (grouted stone pitching). Stone pitching laid in this manner is not flexible and typical applications would therefore be on stable slopes requiring protection where vegetation is not likely to establish such as at spill through abutments (not river crossings).

(c) Laid on a concrete bed of at least 75 mm thick with a light steel mesh reinforcement to provide structural continuity. The spaces between stones are filled with cement grout as before (reinforced grouted stone pitching). This application is suitable for approach fill protection subjected to flooding in combination with deep cut-off walls and other measures to prevent undermining of the stone pitching. It is also suitable for the lining of side drains and for erosion protection at down pipe and down chute outlets.

(d) The stones may be laid with a flat side facing up to form a reasonably smooth and pleasing in appearance surface. On the other hand, when used to line a channel or at outlet structures a rough surface may be advantageous to assist with energy dissipation.



Photo 15.4: Grouted stone pitching

15.2.4 Block Paving

Segmental block paving of the interlocking type consisting of class 25 concrete paving blocks, are commonly used in applications similar to that described in paragraph 15.2.3(b), i.e. approach fill slopes at spill through abutments on road over road or road over rail structures.

The main advantage of block paving is the fact that the paving blocks are:

- readily available from commercial sources
- uniform in shape and size resulting in an aesthetically pleasing appearance for some, but others may find it to be unnatural and dull.
- skilled teams are readily available to lay them to the required specification.

A significant and annoying disadvantage is the fact that they are prone to theft and their use is now discouraged by many employers. Furthermore, their relative smooth surface can be slippery, presenting a danger to inspectors.

15.2.5 Concrete paving

Concrete paving as a means of bank and fill slope protection against erosion is limited to canal crossings having controlled water flow characteristics. For river crossings with its highly variable flow characteristics and difficult to predict scour potential, the more flexible and easier to maintain techniques mentioned above are preferred.

Concrete paving for erosion control is thus limited to paved side drains the paving of which extends up to the edge of the surfaced roadway as is commonly found on major roads.

15.3 PRINCIPLES & TECHNIQUES

15.3.1 General

The principles and techniques described below are by no means comprehensive and the monitoring staff should refer to other literature, text books and manuals to gain a complete understanding of the complexities of erosion and scour protection.

This is particularly true in the case of river crossings where the bridge structure and its approach fill may be subjected to unprecedented flood levels and forces. The whole science and art of constructing hydraulically successful roadworks rests heavily with the designer but the engineer's representative has his part to play and if he plays it badly success cannot be achieved. The following are of great importance:

- The engineer's representative must have a clear understanding of the intent of the designer and the principles on which the design was based and hence the details shown on the drawings and associated specifications.
- An understanding of the design parameters will enable him to recognise site conditions which may be at variance to that known or assumed at the time of the design and consequently to seek advice from the designer with regard to possible adjustment of the layout and details of the erosion protection works.
- The engineer's representative must ensure that the contractor strictly adheres to all aspects of the specifications for protection works. The stability of riprap for example, is sensitive to small changes in the slope of the embankment on which it is placed.

15.3.2 Good Practices

The monitoring staff should pay special attention to the following:

15.3.2.1 Gabion boxes and mattresses

(a) The proper technique for erecting gabion boxes and mattresses are clearly shown on the appropriate standard drawings and should be studied. Being a labour intensive operation, the contractor may well subcontract this work to an emerging subcontractor with limited previous experience of gabion work not to mention the local labour that may be employed for this purpose. The engineer's representative is strongly advised to instruct that a trial gabion box and mattress be assembled and packed at a convenient location before starting with the permanent works. In this manner off site training can be done until the engineer's representative is satisfied with the end product. The trial assembly should remain to serve as the norm for all subsequent work.

(b) A group of assembled gabion boxes should be stretched to their proper length, width and height as described on the standard drawings. A sturdy frame should be used along the open side (the side not attached to an already packed box) to maintain the required height. In applications where not only the functionality but also the aesthetic appearance is important, it is highly recommended that the frame be faced with a solid board. This will go a long way to ensure an exposed gabion face with minimal bulging and unevenness's in its alignment.

(c) To prevent bulging of the visible side of a box bracing wires must be used as shown on the drawings. This is particularly important when rounded stone is used which results in less internal friction. Although not called for on the standard drawing, it is good practice to brace all boxes, exposed or not, in this manner because it will assist them in maintaining their shape in case of flood damage or settlement.



Photo 15.5: Gabion mattress construction – note protruding bracing wires

(d) The exposed side of a box should be lined with stone of near equal size neatly packed with a flat side up against the mesh. If rounded river stone is being used a special effort will be required to select flat faced stone for this purpose.

(e) Gabion boxes should not be filled with mechanical equipment. The functionality of a gabion box is inter alia dependent on its mass which must be maximised by hand packing the stone in a manner that will minimise the voids. Smaller size stones should therefore be packed in between the larger stones. When working with rounded stone it has been found that oval shaped stone works better than spherical shaped stone in general.

(f) The structural integrity of a gabion wall is dependent on its ability to function as a unit. The weakest link in this unit is the lacing together of the individual boxes and special attention needs to be given to this aspect.

(g) Gabion mattresses on a slope must be laid with the 1 m spaced diaphragms parallel to the slope even though this may result in more cutting and lacing having to be done. In this manner there is less chance for the stone to be displaced by gravity and water forces towards the lower side. For similar reasons mattresses laid flat should be laid with the diaphragms square to the direction of flow.



Photo 15.6: Gabion mattress protection – note incorrect diaphragm orientation opposite culvert outlet

(h) For mattresses the normal spacing of the brace wires is one brace per 1 m^2. When working with rounded stone it is recommended that the brace spacing be halved.

(i) Where gabion mattresses are laid on a slope and the top edges are to be fixed to a concrete element e.g. slope protection for a low level river structure, a detail will have been provided on the drawings for the manner in which the mattresses are to be fixed to the concrete element. The mattresses should be fixed to the concrete element in the manner specified before they are filled with stone because once they are filled they will tend to slump slightly and an undesirable gap will develop between the top edge and the concrete which cannot easily be rectified.



Photo 15.7: Gabion mattresses. Note displacement of rock due to inadequate brace wires and too small rock sizes used.

(j) For added protection against wear and tear caused by boulders transported by flood waters, a concrete screed on top of the gabion mattresses may be specified. A dry mix which will not unnecessarily penetrate into the mattress and placed to a thickness of 50 mm above the wire mesh, works well. Dry joints should be formed at 1 meter intervals to maintain some measure of flexibility and to allow for seepage water to escape. This technique applied to small patches (say 300 mm by 300 mm) in a regular pattern will also discourage theft of the wire mesh.

15.3.2.2 Riprap

(a) Not all quarries can produce large stone because of rock formation characteristics. Because quarrying generally uses blasting to fracture the formation into rock suitable for riprap, cracking of the large stones may only become evident after loading, transporting and dumping at the construction site.

(b) The stone shape is important and riprap should be blocky rather than elongated, platy, or round.

(c) Onsite inspection of riprap is necessary both at the quarry and at the construction site to ensure proper gradation and material that does not contain excessive amounts of fines.

(d) The objectives of construction of a good riprap structure are (1) to obtain a rock mixture from the quarry that meets the design specifications and (2) to place the mixture on the slope of the bank in a well keyed, compact, and uniform layer without segregation of the mixture. The best time to control the gradation of the riprap mixture is during the quarrying operation. Sorting and mixing later in stockpiles or at the construction site is not satisfactory

(e) Inspection must ensure that a dense, rough surface of well keyed graded rock of the specified quality and sizes is obtained, that the layers are placed such that voids are minimised, and that the layers are the specified thickness. Typically, the project specifications will call for a 50% increase in layer thickness if the riprap is to be placed underwater.

(f) Because most riprap failure results from scour or undermining at the toe of the slope, the filter layer and riprap must extend below the anticipated scour depth. In situations where riprap can not be installed below the bed level, then sufficient riprap must be stockpiled at the toe to be available to be launched into the scour hole as it develops.

(g) Where a geotextile is used as filter layer, the dumping of riprap should be limited to drop heights of less than 300 mm to prevent tearing of the geotextile fabric.

(h) Along the bankline, the geotextile should be placed so that the upstream strips of fabric overlap downstream strips, and so that upslope strips overlap downslope strips. The overlap should be at least 300 mm when working on dry ground, and twice that amount when placement is under water.

(i) Dumped riprap means placing each sequential lift immediately on the previous lift with relatively little rearrangement of the rocks to avoid segregation. Dumping rocks at the top of the slope and pushing down the slope with a dozer or front-end loader is not acceptable and the dump trucks should be lowered down the slope with a cable attached to a tractor winch. In other cases, riprap may be dumped at the toe and a dozer used to push it up the slope. The procedure would depend on the quality of the rock and whether the continuous traffic of the dozers would break down the rock. If the rock is hard and not affected by the traffic, the riprap may be consolidated into a more tightly interlocked mass.

(j) For packed riprap backhoes or cranes equipped with clamshells or orange-peel grapples, are preferred to achieve precise placement of individual stones.

15.3.2.3 Stone pitching

(a) As in the case of gabions, stone pitching is labour intensive and thus lends itself to done by an emerging subcontractor. However, the laying of stone pitching in an aesthetically pleasing manner is a craft which is not readily available. The engineer's representative therefore should instruct that a trial section first be done to master the technique.

(b) The advantage of stone pitching over block paving if done skilfully with the right type (colour) of stone lies in its more natural appearance and its ability to blend in with the natural environment.

INDEX TO APPENDICES

15A - EROSION PROTECTION CHECKLIST

EROSION PROTECTION CHECK LIST (1/2)

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. GABIONS					
1.1 Verify the scope of the works					
1.2 Verify specifications e.g. wire thicknesses and protective coatings					
1.3 Verify layout and orientation of mattresses					
1.4 Verify stone sizes, shape and quality thereof					
1.5 Construct trial box to verify packing technique, bracing and shape control					
1.6 Verify founding conditions for gabion walls					
1.7 Verify stretching of assembled boxes to their proper dimensions					
1.8 Verify adequacy of lacing					
1.9 Verify technique and methodology of tying to structure where applicable					
1.10 Verify concrete mix and methodology for concrete screeds where specified					
2. RIP RAP					
2.1 Confirm scope of work					
2.2 Verify stone mass, shape and quality					
2.3 Agree method statement for handling and placing technique					
3. STONE PITCHING					
3.1 Confirm scope of work					
3.2 Verify size, colour, shape and quality of stone					
3.3 Verify trimming, shaping and preparation of area to be paved					
3.4 Agree method statement with regard to stone orientation, bedding, grouting and finishing					
3.5 Construct trial section to verify technique and workmanship					

Check list continues on next page...

EROSION PROTECTION CHECK LIST (2/2)

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
4. BLOCK PAVING					
4.1 Verify scope of works					
4.2 Verify size, colour and quality of proposed blocks					
4.3 Verify trimming, shaping and preparation of area to be paved					
4.4 Verify layout, dimensions and specifications of edge beams					
4.5 Construct trial section to confirm workmanship					

CHAPTER 16 - GANTRIES

DS Temple

16.1 SCOPE

This section covers the inspection of Sign Gantries as specified in the applicable chapter of the Specifications. It also covers the special attention which must be given by the engineer's monitoring staff to the specific requirements of setting out, excavations foundations, backfill and, manufacture and erection of the structural steel gantries.

16.2 FOUNDATIONS

16.2.1 Setting Out (Refer to Chapter 4)

The setting out of the gantries should be carried out in accordance with Chapter 3 of this document. However the following points should be noted.

16.2.1.1 Location

The gantry location (e.g. km distance) on the structural drawings must tie in with the location given on the road works drawings.

16.2.1.2 Horizontal Clearances

Horizontal clearances must be checked prior to the casting of the gantry foundation plinths.

16.2.1.3 Vertical Clearances

The vertical clearances as specified on the design drawings should be checked by the Monitoring Staff on site.



Photo 16.1: Gantry foundation

16.2.2 Excavations (Refer to Chapter 4)

Note that it is preferred that the foundation concrete is cast directly against the sides of the excavation.

16.2.3 Formwork & Falsework (Refer to Chapter 6)

16.2.4 Steel Reinforcement (Refer to Chapter 7)

16.2.5 Concrete (Refer to Chapter 8).

Note that durability concrete should be used only in extreme situations.

16.2.6 Built-in Items

- The Monitoring Staff should confirm the orientation of the Holding Down Bolt Groups.
- Confirm the position of ducts, gantry number and any other built-in items indicated on the drawings.



Photo 16.2: Completed gantry foundation

16.3 STRUCTURAL STEEL GANTRIES

16.3.1 Materials

The Engineer's Monitoring Staff should ensure that the contractor submits a certificate of compliance for:

- Structural steel for manufacture of gantry
- Holding down bolts

16.3.2 Corrosion Protection

The corrosion system as specified on the drawings must be confirmed with the Contractor. The Monitoring Staff should ensure that the manufacturer's Quality Assurance records are made available with the delivery of the gantries. Hot dip galvanizing could be specified as a corrosion protection measure but should be used with caution as this process is still in the experimental stages. Buckling of thin plates occurs during the dipping process due to stress relief in the plates and therefore extreme care should be taken before using this method of corrosion protection.

16.3.3 Shop Drawings

The Monitoring Staff should ensure that shop drawings of the gantry and holding down bolts are submitted for review timeously.

16.3.4 Factory Inspection

It is a requirement that monitoring staff inspect the structural steel during the manufacturing process. The following important aspects should be checked and verified against the design drawings:

- Dimensions and thicknesses of the steel plates.
- Number and spacing of the beam and column stiffener plates.
- Type, size and quality of all the welds as specified on the drawings.
- Diameter and length of anchor bolts, as well as the dimensions of the anchor bolt cage.

The Monitoring Staff should ensure that the correct grade steel for the anchor bolts and structural steel gantry structure is used. All certificates pertaining to the grade and quality of the steel should be obtained from the manufacturer for construction record purposes.



Photo 16.3: Gantry manufacturing

16.3.5 Erection

- The Monitoring Staff should ensure that the Contractor submits for review a complete method statement for the erection of the gantries.
- Accommodation of traffic measures should be submitted in accordance with Road Traffic Signs Manual, Chapter 13.
- Monitoring Staff should ensure that the gantry is erected within the specified tolerances.

16.4 CHECKING AND TESTING

The Monitoring Staff should visit the manufacturing facility during manufacture to ensure that the gantries are being manufactured according to the Manufacturer's Quality Plan.

16.4.1 Corrosion Protection

- Reference should be made to the notes on the Detailed Design drawings for the corrosion system to be used.
- Surface preparation to SA 2.5 should be checked prior to the application of any corrosion protection.
- Ensure that the contractor's proposed system for the painted, galvanized or sprayed metal coating conforms to specified requirements.
- Random testing of the thickness of the various coats of the corrosion protection system should be carried out in the paintshop as well as on the delivered elements and especially on the site painted areas (welded site connections on gantry beams).
- Records of the tests carried out on the dry film thicknesses (DFT) should be kept.

16.4.2 Welding

The Monitoring Staff should ensure that the process control adopted by the manufacturer complies with the Project Specification. This can be achieved by including notes on the shop drawings for welding procedures. All QA records of process control of the welds should be provided to the Engineer.

Proof of the welder's qualifications should be provided.

Ultrasonic testing should be carried out on the following welded connections:

Column & base plate connection
Column & beam haunch connection
At least 10% of the seam welds in the columns*
At least 10% of the seam welds in the beams*
Gusset plate connections*
Site welds**

*Where ultrasonic testing is not possible magnetic particle testing should be carried out on at least 50% of the seam welds.

**At the very least site welds should be inspected and approved by an independent qualified person. Where possible ultrasonic testing (preferable) or magnetic particle testing should be carried out. It should be noted that these must be done before painting and after the steel has cooled.



Photo 16.4: Gantry erection

16.5 GANTRY STRUCTURES - CONSTRUCTION MONITORING CHECK LIST

The Monitoring Staff should use the "Gantry Structures - Construction Monitoring Check List" as far as possible to ensure the quality of the gantry structures.

INDEX TO APPENDICES

16A - GANTRY STRUCTURES

GANTRY STRUCTURES CHECK LIST(1/4)

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
1. EARTHWORKS					
1.1 Setting out					
• Km distance					
• Depth of excavation relative to edge of road					
• Distance from edge of road to foundation centre					
• Can foundation be cast directly against side of excavation as is preferred					
• If not has work space been agreed with Engineer					
1.2 Bearing pressure					
• DCP Tests done					
• Is soil improvement required					
• If so describe					
• Soil improvements tested					
• Provide estimated foundation bearing capacity in kPa					
1.3 Blinding layer					
• Depth to blinding layer relative to edge of road					
• Plan area of blinding layer					
2. REINFORCEMENT					
2.1 Footing – Bars parallel to road					
• Are they Top 1 and Bottom 1					
• Bar spacings - 125mm					
• Bar type bottom					
• Bar type top					
• Alternative bar reversed (top bars)					
2.2 Footing – Bars perpendicular to road					
• Bar spacings - 250mm					
• Bar type bottom					
• Bar type top					
• Alternative bar reversed (top bars)					
2.3 Plinth					
• Are there the correct number of "U" bars					
• Orientation					
• Location					
• Bar projection height					
• Secondary bars, i.e. clips & stirrups					

Checklist continues on next page…

GANTRY STRUCTURES CHECK LIST(2/4)

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
3. ANCHOR BOLTS					
3.1 In workshop					
• Diameter					
• Steel Grade of bolt					
• Bolt cage dimensions					
3.2 On Site					
• On site orientation					
• Location within plinth					
• Projection of bolts					
• Top portion of bolt corrosion protected					
4. FORMWORK					
4.1 Footing plan dimensions					
4.2 Is footing formwork required and approved					
4.3 Footing thickness					
4.4 Plinth plan dimensions (parallel and perpendicular to road)					
4.5 Height of plinth					
4.6 Level difference between top of plinth & road edge					
4.7 Cover to rebar - footing 50mm bottom, 75mm sides					
4.8 Cover to rebar - plinth 50mm sides and top					
4.9 Plinth shutter - adequately propped					
4.10 Plinth off shutter surface finish OK					
5. SPECIAL CAST IN ITEMS					
5.1 PVC ducts provided if detailed on the drawings					
5.2 Location in plinth (plan)					
5.3 Projection above plinth concrete					

Checklist continues on next page…

GANTRY STRUCTURES CHECK LIST(3/4)

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
6. CONCRETE					
6.1 Pre concrete inspections					
• Concrete as per specification & mix design (obtain copy of delivery note)					
• Concrete Class W30MPa					
• Plinth concrete: 50mm < slump < 70mm					
• Proposed curing method					
• Proposed curing period					
6.2 Post concrete inspections					
• Cracks					
• Spalling					
• Honeycomb					
• Shutter kick					
• Repair method					
7. STRUCTURAL STEEL					
7.1 Prior to dispatch to site					
• Steel grade certificate and markings					
• Column height plust the beam section					
• Beam length (less the beam section attached to column/s)					
• Column cross section dimensions					
• Beam cross section dimensions					
• Plate thicknesses columns					
• Plate thicknesses beams					
• Special attachment size & plates					
• Stiffener plates, thickness, spacing, fitment					
• Welds visually acceptable and according to drawing					
• Chamfering and preparation for welding					
• Holes setting out					
• Ultrasonic testing of welds - certified					
7.2 On site					
• Method of erection approved					
• Traffic accommodation approved					
• Site welding method approved					
• Site welding quality approved					
• Anchor bolt tightening torque (provide Nm)					
• Grout under base plate - type approved					
• Grout under base plate - installed correctly					

Checklist continues on next page…

GANTRY STRUCTURES CHECK LIST(4/4)

ACTIVITY AND DETAILS	APPROVAL			SIGNED	DATE
	Y/N	N/A	Comment		
8. CORROSION PROTECTION					
• Inland or coastal specification					
• Paint specification approved					
8.1 Prior to dispatch to site					
• Abrasive blast cleaning					
• Primer - paint type and DFT certified					
• Approval of application of second coat prior to dispatch					
8.2 On site					
• Patch repairs- paint type and DFT certified (NB repairs at site welds)					
• Second coat - paint type and DFT certified					
• Final coat - paint type and DFT certified					
• Final coat colour					
• Anchor bolts corrosion protected					
9. AS-BUILT DATA					
• Name and address of Main Contractor					
• Name and address of Steelwork Fabricator					
• Name and address of Painting Contractor					
• Paint system used					
• Foundation material and safe bearing capacity					
• Date of steel structure erection					
Least favourable results of test certificates:					
9.1 Structural steel					
• Steel grades					
• Ultimate tensile strength (MPa)					
• Yield strength (MPa)					
• Elongation at fracture (%)					
9.2 Anchor bolts					
• Steel grades					
• Ultimate tensile strength (MPa)					
• Yield strength (MPa)					
• Elongation at fracture (%)					
9.3 Data included an "As-built" drawings					

CHAPTER 17 - SPECIALIST CONSTRUCTION SYSTEMS

WJ Martin

17.1 SCOPE

Specialist construction systems refer to the construction systems falling outside of the normal reinforced and prestressed bridges that make up the bulk of bridges in South Africa. These structures generally fall outside of the experience of the average South African resident engineer.

Specialist construction systems include:

- Bridges constructed using the Incremental Launch Method (ILM);
- Balanced Cantilever bridges (BC);
- Precast Segmental construction (PSC);
- Jacked bridges;
- Cable stayed bridges and suspension bridges;
- Concrete arch bridges;
- Steel bridges and composite steel bridges;
- Bridges constructed from timber, brick, stone or composite materials

Although the other chapters in the Construction Monitoring Manual cover many aspects which are applicable to the above specialist construction systems, they do not cover all of the requirements on the construction site. This chapter deals very briefly with the specialist requirements but, as very few bridges of this nature are constructed in South Africa, this chapter cannot be considered as comprehensive.

FOR THESE SPECIALIST CONSTRUCTION SYSTEMS, SPECIALIST LITERATURE SHOULD BE CONSULTED.

17.2 VOIDED SLAB DECKS

Although voided slab decks are relatively common, problems do occur with the void formers. Because of this, it is discussed in more detail below. These comments also apply to any other formwork which may have resultant concrete pressures which are not horizontal.

17.2.1 Void formers

In order to understand the need to have void formers that are strong and properly tied down, it is necessary understand the buoyant or hydrostatic properties of wet concrete. Wet concrete is about 2.5 times denser than water; therefore it is 2.5 times more buoyant than water. If you imagine the forces on a void former in water, then the forces of the same void former in concrete will be 2.5 times greater.

When a void former is immersed in wet concrete, the hydrostatic forces trying to crush the void former are very large. Adequate stiffening inside the void former is required. Originally this used to be timber cross-bracing but recently polystyrene disks at frequent centres are used.

The closures at the ends of void formers also need to withstand this hydrostatic pressure and be water-tight. It is not adequate to have a few pop-rivets around the circumference – there need to be quite a

few closely spaced pop-rivets. If two void formers are butted up against each other, with a small gap, the hydrostatic pressure will be the same as if there was a large gap. Once again, the ends need to be adequately fixed.

While concrete is being cast, the voids will want to float on top of the concrete. They must be tied down with sufficient ties to withstand this buoyancy.

If concrete is cast higher on one side of a void than the other, as is inclined to happen, the void will want to move sideways as well. The ties must be able to resist this sideways movement.

In summary, the site monitoring staff need to ensure that the contractor has considered the following:

- There is sufficient bracing inside the void formers;
- The ends of the void formers are firmly attached to the void formers;
- The ties holding the void formers down can resist the buoyancy forces; and
- The ties holding the void formers down will restrain lateral movement.

17.3 INCREMENTAL LAUNCH METHOD (ILM)

ILM bridges have become more common recently.

This section does not give guidance on construction monitoring of ILM bridges. It only highlights some major construction aspects that need to be monitored. When monitoring the construction of and ILM bridge, specialist literature must be referred to. Some of the major construction aspects include:

- Construction tolerances – these are more critical than in normal construction. Special attention and accurate surveying is required to ensure millimetre accuracy.
- Temporary works: This is highly specialized – Launching nose, temporary bearings, launching jacks, braking system, etc.
- Pier deflections: This must be limited to avoid damage to the piers and excessive movement when bearing friction is overcome.
- Launching nose and connection: This is a critical piece of equipment and needs to be properly fabricated and installed. If its stiffness varies from the design launching nose, it needs to be checked.
- Emergency stop equipment: When something goes wrong such as a bearing pad installed incorrectly, the launching must be stopped immediately to avoid damage or injury.
- Construction loads and superimposed dead loads (parapets, etc): do these comply with the design requirements?
- Cumulative deck length: allowance needs to be made for shortening due to prestressing, creep and shrinkage.
- Stability during construction: This is significant during the first few launchings. Lateral and longitudinal fixity between launches is also a consideration.
- Launching downhill will require braking and restraining devices.
- Launching bearing pads must resist rotation.
- Installation of the permanent bearings needs consideration.
- Concrete strength before prestressing and launching is an issue.

17.3.1 Construction Tolerance

For ILM construction, the accuracy of the sliding surfaces and alignment plays a primary role in creating a stress-free construction site. Many problems during launching can be traced back poor accuracy or poor alignment.

Incorrect deck or segment lengths: If there is an error here, especially if the shortening due to prestressing, shrinkage and creep has not been taken into account, then the deck ends up being too short and the bearing diaphragms or bearing attachments are in the incorrect position.

- Allow for shortening due to prestressing, creep and shrinkage; and
- Check the length of the bridge between launches, starting from the front of the deck.

Levels on sliding surfaces in casting yard not to specification: If the levels are out, this causes additional friction and makes it difficult to feed the launching bearing pads in correctly.

Horizontal alignment is not to specification: If the horizontal alignment between segments is out, this causes part of the deck or all of the deck to curve inwards or outwards during launching. This leads to problems with feeding in the side guide sliding pads. This occurs with curved decks as it is much easier to align straight decks.

It also leads to problems where at some of the piers, the deck can be out transversely by more than 70 mm, affecting the positioning of the temporary launching bearings and the permanent bearings.

Vertical alignment is not to specification: This can change the bearing reactions during launching significantly. It may overload some bearings, causing cracking in the deck and damage of the sliding surfaces. It will also increase the horizontal loads which can damage piers.

Casting yard foundations too elastic: This affects the vertical alignment as discussed above. Before a segment is cast, the sliding surface levels are checked in the casting yard and found to be within specification. However, when the segment is cast, the foundations deflect downwards and sometimes tilts, causing the vertical alignment to now be out of specification.

Launching bearing pad thickness: When the bearing pads arrive on site, their thicknesses should be checked against the specifications. Furthermore, they should be sorted in terms of thickness to the nearest 0.2 mm so that on each pier, all of the pads used are of similar thickness. This will reduce friction and bearing overload and make it easier to feed the pads in.

17.3.2 Launching nose

The contractor needs to produce calculations showing that the launching nose is strong enough to withstand the launching forces including any additional forces due to lack-of-fit caused by the construction tolerances.

The prestressing in the launching nose connection should be correctly stressed. Too little stress will lead to the connection opening up and increasing the load on the next pier.

- The prestressing force in the launching nose connection should be checked from time to time between launches.
- During launching when the bending force in the launching nose is approaching its maximum, the connection should be checked for the nose lifting off the deck.

17.3.3 Monitoring pier deflections

If pier deflections are within specification, this means that the friction generated during launching falls within design limits. When pier deflections exceed specification, this means that something has gone wrong. It is therefore important that pier deflections be monitored continuously during launching.



Photo 17.1: Zambezi River Bridge constructed using ILM

17.4 BALANCED CANTILEVER CONSTRUCTION (BC)

Very few balanced cantilever bridges have been constructed in South Africa. The Mfolozi River Bridge on the north coast of KZN is an example.



Photo 17.2: An abnormal load crossing the Mfolozi River Bridge

Some issues needing specialist consideration include:

- During construction, the deck levels change continuously. Very careful calculation is required to ensure that the bridge reaches its required vertical alignment.
- Creep and shrinkage affects the vertical alignment and needs to be continually monitored on site. Constant correction is needed to ensured correct vertical alignment.
- The contractor's construction sequence and weight of temporary works will affect the alignment if these are different to the design assumptions.
- Stability during construction is an issue. Until the cantilevers are joined up, they are vulnerable, especially to wind loading.

17.4.1 Vertical alignment during construction

As the deck is constructed, each load added or moved causes the deck to deflect. Creep and shrinkage increases the deflection. Once the joints between the cantilevers are closed and the deck made continuous, the deck continues to deflect due to creep and shrinkage. The objective is to get the vertical alignment correct for some stage after construction, usually when the bridge is opened to traffic or at some time after that.

17.5 PRECAST SEGMENT CONSTRUCTION (PSC)

One of the first PSC bridges in South Africa was the Buffalo River Bridge in East London. The Gautrain Viaducts were also constructed using this method.

Some issues needing specialist consideration include:

- Segments need to be match-cast and glued together.
- Temporary prestressing is required during the gluing process.
- Operation of the launching gantry is important to prevent overloading of the segments during prestressing.
- Prestressing across the construction joints need attention to ensure durability.



Photo 17.3: Buffalo River Bridge at East London: One of the precast segments can be seen in the foreground

17.6 JACKED BRIDGES

It is becoming more common to construct jacked bridges under railway line embankments these days.



Photo 17.4: Bridge on the N17 about to be jacked under the rail embankment

Some issues that need specialist consideration during bridge jacking include:

- Railway tracks need to be supported so that rail traffic can continue during construction.
- Jacking forces need to overcome very high friction between the sides of the structure and the retained earth. These forces need to be resisted in some way.
- The foundations need to be constructed first through the embankment, usually by pipe-jacking. These form the sliding surface during construction.
- Stability of the front excavation face needs careful consideration

CHAPTER 18 - REHABILITATION AND REPAIR OF STRUCTURES

M du Rand

18.1 SCOPE

Repair of structures is not defined as reinforced shuttered concrete. Margins for error are smaller and the work must be correct the first time. Repair is done using proprietary products each with their own characteristics. It is of paramount importance that technical representatives monitor and ensure their products are applied in accordance with the manufacturer's instructions and that the applicator has previous repair experience. Each product has a data sheet and this must be on site and understood by the applicator. Material suppliers should submit a written report to the Contractor after each visit and at a minimum of monthly intervals. It is not necessary that the Resident Engineer receives a copy, but be aware that the materials are correct for the application and are being correctly applied. The Resident Engineer is not the Contractor's foreman or policeman. Contract Document Specifications are often generic and due care and diligence is needed in the application. Experience is pivotal to success. It is good practice that the Contractor's skilled personnel have attended a short competency or product knowledge course by the Supplier on site or at their premises.

18.2 MORTAR REPAIR

(a) Preparation is important;

(b) Edges must be neatly saw-cut at least 10 mm;

(c) Substrate must be sound and wet;

(d) Not all systems require a primer;

(e) If primed the primer should not have exceeded its pot-life;

(f) Mortar application thicknesses are limited and material may require scratch coats;

(g) Mixing should be done by mechanical tools or mixers;

(h) Dosing of material, water or polymers is critical and should be done exactly with measuring devices, beakers or measuring jugs are examples;

(i) Material that has exceeded its pot-life or mixing life, should be discarded and a fresh batch mixed;

(j) Polymer modified mixes do not require curing as they form curing membranes;

(k) Hot weather, cold weather and wind can affect application, Supplier can advise;

(l) Attend a supplier's training session for some insight into the process;

(m) Mortar repairs should be worked as little as possible. Excessive wood and steel trowel floating to obtain aesthetic look are bad because it draws water from the mix to the surface and increases the water cement ratio on the surface skin. This will result in crocodile cracking before the end of the defects period. Work as little as possible.

18.3 GROUT REPAIRS

(a) Grout is simpler than patch repair and more suited for larger repairs;

(b) Preparation is standard as in mortar repair;

(c) Mixing and water calibration very important. Pumping of grout is good as it extends mixing;

(d) Repair contractors do not always have a structural awareness of how far they can demolish columns, slabs or beam. Method statements on structural elements must define demolition limits to maintain structural stability;

(e) Soffits, underwater work and foundations need extra care and experience. Soffit repairs require methods to avoid air entrapment;

(f) Grouts give high early strengths. Some more than others and some proprietary grouts pump better than others. Different equipment will vary effect slightly.

(g) SANS 1200 does not have a specified procedure for testing grout cubes. RE should agree indicative methods of testing with supplier and contractor – 100 mm x 100 mm x 100 mm cube moulds are one practical method. Drop in indicative strengths are often caused by excessive water content. Water dosing accuracy is critical;

(h) Quality Assurance plan of contractor should record batch numbers. Shelf life of product should not be exceeded. Supplier product failures are very rare. Problems usually occur in incorrect product selection or incorrect application. In Africa the human element plays a big role and applicators tend to get complacent. As in mortars the manufacturer plays an important role in ensuring the correct product is correctly applied with random checks;

(i) Splitting of kits are not recommended but can be done if carefully managed and measured.

18.4 COATINGS

(a) Coatings are basically pure chemistry developed over years by the supplier's chemists. The window of latitude is limited as is wind, temperature, moisture content and application method. If correctly applied there will be no problem;

(b) Coatings fall into various categories and may depending on the designer and supplier consist of two differing products for one coating system. In civil engineering a coating has a primary function of protection and secondary of aesthetics. Do not try and work coatings once applied. Their chemistry starts quickly and should not be disturbed;

(c) Coatings are generally Cementitious, Epoxy, Polyurethane, Silicones or Acrylics. Preparation involves one of water jetting, sand blasting, wire brushing, flail scabbler and in limited cases no preparation. Trial sections with supplier and manufacturer helps establish a baseline and develop a method statement. Coatings have developed to a point where very few require curing with water;

(d) Overnight freezing can affect the day's coating. Wind-chill factors or excessive wind can cause damage. Heat from adjacent machinery or excessively hot day temperatures can cause damage. The supplier is best to advise and in some circumstances can do a minor adjustment to their batch process.

(e) Coatings such as epoxy and polyurethane that go onto steel need to be applied away from dew point. Coatings that are trowel applied need a higher level of skill than block brush applications. Generally coatings are thin. Spread is important. Ten percent variation on a five hundred micron coating is close to the contractor's profit or can be below the client or manufacturer's specification. More risk exists in coatings than repair material for the client and contractor. The most practical method is to mark out the coverage for an area a kit size can cover then the applicator is to apply the material evenly. Kit sizes should be selected for the area to be covered. Large kits can be split but must be measured with science not the eye. On steel stripe coats edges are very important. Sloping, vertical and soffits require more skill. Complex structures need attention to even coverage;

(f) Mechanical equipment does sometimes get used to apply coatings but is sophisticated, is expensive to purchase and maintain. Operators are often not freely available. Blockages often result in addition of water or thinners to assist application which destroys the product's

operational characteristics. Supplier monitoring of equipment applied product should occur on a regular basis.

18.5 MEASUREMENT & PAYMENT

(a) Keep an accurate check of product used. The theoretical coverage is a good correlation to actual measured if there is very little wastage;

(b) Agree and sign off quantities regularly. Do frequent checks initially to establish a credible system and don't leave it to month end;

(c) Quiz the contractor on his programme and resources to check stock levels, especially if some distance from supply. Try not to store too much material on site when in summer at elevated temperatures or rainy season. As a general rule two months' stock on site is rule of thumb, depending on geographic location.

18.6 ACCESS

(a) Some repair projects are called access projects. This occurs when the cost of access or complexity exceed the repair product value. If rope access is used the product and method of preparation and application should match the circumstances. Mixing and storage of product should not overload the system or create conditions where artisans cut corners because they run out of water or primer, or access must be removed for road or rail operation;

(b) Most access is priced as a lump sum. Serious problems and claims occur if the quantity of repair or coating increase considerably resulting in more access or longer access. Unresolved issues like this create discord. It is important an RE continually establishes the facts of the matter, contractual progress and site circumstances and communicate these to his engineer and client. Contractual issues are best resolved early and not at the end of the project when facts can become a little cloudy. Fairness from all parties must prevail.



Photo 18.1: View of spalled concrete before repairs



Photo 18.2: View of spalled concrete before repairs



Photo 18.3: Saw cutting around repair area



Photo 18.4: View of reinforcing coated with zinc rich primer



Photo 18.5: Removing damaged concrete



Photo 18.6: Removing damaged concrete

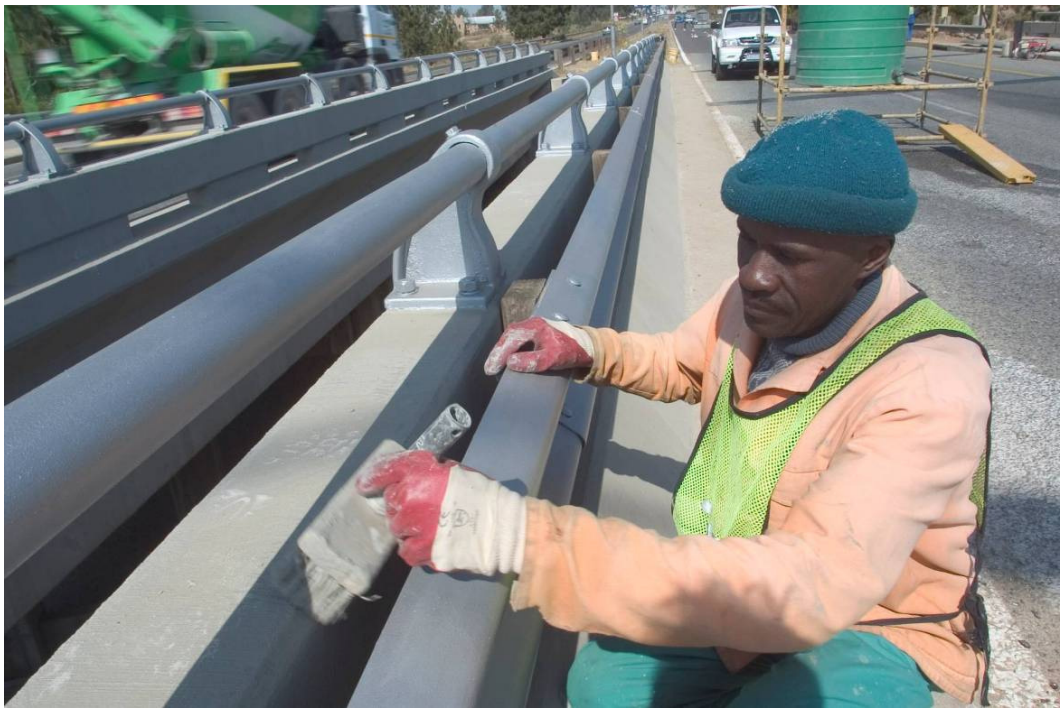


Photo 18.7: Applying protective coating



Photo 18.8: Removal of damaged concrete



Photo 18.9: Access scaffold



Photo 18.10: Preperation of repair area



Photo 18.11: Preparation of steel railing before painting

CHAPTER 19 - DEMOLITION

MG Latimer

19.1 SCOPE

This chapter focuses on the demolition of concrete in structures, where distinction can be made between the following categories of demolition:

- the full demolition of an entire structure
- the full demolition of a portion of a structure e.g. a deck span or column
- the partial demolition of a structural element e.g. cutting back into the face of a concrete surface to a depth behind the reinforcement.

Although much of the guidance presented in this chapter is applicable to all the above categories, emphasis is given to the partial demolition of a structural element as this requires that particular precautions be taken to protect and preserve the integrity of both concrete and reinforcement within the retained portion.

The guidance presented is not intended to provide detailed coverage of the subject, and specialist literature should be consulted where this is required.

Reference should be made to COLTO Series 12000: Rehabilitation of Structures and Bridges.

19.2 PLANNING

Numerous items need to be considered in the planning of demolition work, their applicability and extent being dependent upon the nature of the work and the particular circumstances of the site. Generally, consideration should at least be given to the following:

(a) Access and safety.

(b) As built details of the structure.

(c) Confirmation of presence/absence of prestressing.

(d) Necessity for initial exploratory work or reinforcement cover checks to locate reinforcement.

(e) Equipment and methods to be used.

(f) Method statements required.

(g) Sequence of operations.

(h) Possible temporary support requirements.

(i) Possible protection requirements.

(j) Environmental compliance.

(k) Disposal of materials.

(l) Consultation with the design office.

19.3 EQUIPMENT

Demolition equipment should be appropriate for the purpose. Powerful and highly destructive equipment such as that illustrated in Photo 19.1 can be used when an entire structure is demolished. However for partial demolition the use of heavy impact equipment should be carefully controlled as this can cause unacceptable damage to the preserved portions of the structure. It is therefore essential that monitoring staff ensure that the suitability of the equipment be discussed and approved during the planning stage. In general, it will be necessary to utilise lighter, less-destructive equipment when working close to the preserved face of the structure.



Photo 19.1: Powerful highly destructive equipment used for demolition of an entire bridge



Photo 19.2: Demolition of bridge parapet using hydraulic impact hammer.

Monitoring staff should be aware that fracturing/micro-fracturing of concrete will occur where percussion/impact equipment is used. The use of such equipment on or close to the preserved portions of the structure should therefore be carefully controlled to ensure that the degree of fracturing is contained within acceptable limits. Close inspection, experience and good judgement are necessary in the control of this aspect of the work. Tapping of the surface with a hard object should enable loose concrete to be audibly detected, and in situations of particular importance a bonding test can be performed to determine whether a weak zone has been created. Photo 19.3 shows the demolition of a portion of a wall, and illustrates the severity of damage which can be sustained when inadequate control is exercised.

Other equipment and techniques may include large diameter diamond-blade saws, diamond wire-cutting, stitch core-drilling and pre-splitting techniques. Where thermal cutting techniques are employed in partial demolition, care should be exercised to ensure that the process does not damage the reinforcement or concrete bond within the retained concrete.

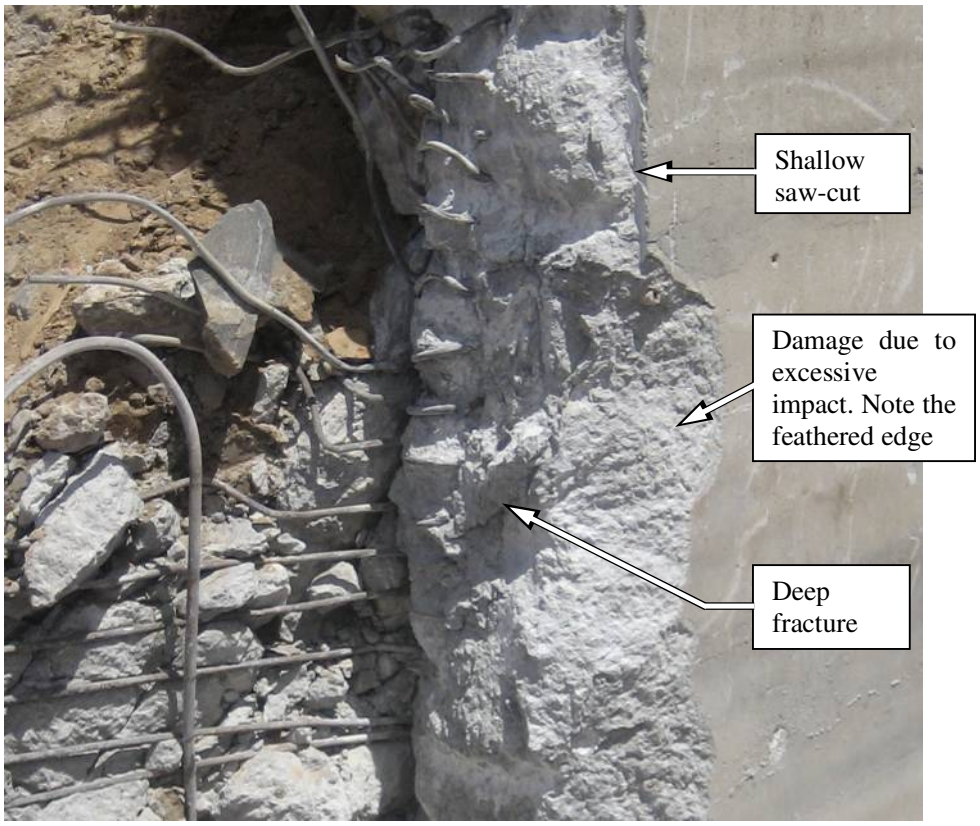


Photo 19.3: Poorly controlled demolition of portion of wall.

19.4 CARE AND SAFETY

Demolition operations are often hazardous and it is therefore essential that the methods employed and the precautions taken recognise that the safety of construction personnel and members of the public is paramount. The relevant requirements of the OHS Act and Construction Regulations must be fully understood and complied with. Attention is drawn to the following:

- Section 12 “Demolition Work” of the Construction Regulations.
- Limitations and control of noise and dust when working in built up areas.

Monitoring staff should be aware that demolition workmen sometimes may not appreciate the need to prevent damage to portions of the structure. It is therefore important that steps be taken to educate and inform workmen of the specific requirements of the work, and of the importance of working with the necessary care.

19.5 PRESTRESSED CONCRETE

Special considerations apply to the demolition of prestressed concrete members, and it is essential that the presence/absence of prestressing be established early in the planning stages.

The type and location of all prestressed tendons and anchorages should be established, and the Contractor called upon to submit a full and detailed method statement for the demolition work. This should include details of the proposed sequence of operations and the methods and equipment to be employed. It is advisable that the Contractor's method statement be examined and approved by an engineer experienced in the design of prestressed concrete members.

It is important that the difference in behaviour of bonded and unbounded tendons is clearly understood. In the case of unbonded tendons, the presence of high strains and forces within the tendons requires that the sudden release of energy be avoided, as this can result in considerable danger. For such tendons, it is common practice to carefully expose the strands/wires at a suitable location, and then release the energy by gradually heating them until they deform plastically.

The behaviour of tendons in pretensioned members and post tensioned members effectively bonded by cement grouting is very different. Here the energy is released incrementally as demolition of the member proceeds.

In certain circumstances it may be necessary that the member being demolished be propped to provide support when the prestress force is released. In such cases, the props should be tightly fitted to ensure that individual props are not overloaded.

19.6 PROTECTION WORKS

Monitoring staff should ensure that where necessary, suitable physical protection (boards, sandbags etc.) are provided to protect portions of the structure which are to be preserved. Protection measures may also be required to safeguard infrastructure below the demolition area (e.g. roadways, sidewalks etc.).

In general, demolition should not be permitted above areas open to pedestrian or vehicular traffic. When it is unavoidable that work be carried out above such areas, the work should be kept to the minimum and only light equipment should be used. Suitable screens/catch-nets etc. should be installed to prevent equipment or debris falling onto the areas below. Checks should be made to ensure that these do not reduce the required vertical clearance. Roads should be closed to traffic when heavy equipment is utilised and in all cases where substantial demolition is required. The need to obtain authorization for road closures and to provide adequate advance notice should not be overlooked.

When working over rivers, the importance of adhering to all environmental requirements must be emphasised and debris or waste material (both solid and liquid) must not be permitted to fall into the river. The provision of suitable screens or catch nets will usually be required in order to satisfy these requirements.

19.7 TEMPORARY SUPPORT REQUIREMENTS

In certain instances it may be necessary to prop or provide other temporary support measures to members being demolished. Such measures may be necessitated by temporary stability and safety considerations, or by the need to maintain control over falling concrete or debris.

When reinforced concrete members are required to be only partially demolished, precautions should be taken to ensure that the preserved portion is not damaged by bending of the protruding reinforcement. This form of damage is illustrated in Photo 19.4 and can easily occur if the protruding reinforcement remains attached to falling concrete. This action can cause severe spalling of the soffit concrete, particularly when reinforcement is located close to the bottom of the member. The resulting feathered edges can be difficult to repair.



Photo 19.4: Damaged soffit caused by bending of bottom reinforcement.

19.8 PRESERVATION OF STEEL REINFORCEMENT

It is often necessary that reinforcement be preserved in portions of the structure, such as at locations where new reinforced concrete is required to be connected to partially demolished members. Monitoring staff should ensure that the Contractor has a clear understanding of which bars are required to be preserved, and that measures are in place to ensure that these are not damaged by breakers, drilling, cutting etc.

It should however be recognised that even where considerable effort is made to comply with this requirement, some reinforcement damage is likely to occur. The design should therefore make provision for additional reinforcement to be doweled into the existing concrete.

Excessive and unnecessary bending of steel reinforcement should not be permitted.

19.9 SAW-CUTS

When a portion of a concrete element is to be demolished, it is common practise to define the limit of demolition by first making shallow saw-cuts on the surfaces. Refer Photo 19.5. These saw-cuts reduce the occurrence of feathered edges and clearly define the demolition edge.

Monitoring staff should ensure that the depth of cut is controlled and does not damage reinforcement required to be preserved. All saw-cuts should be straight, neat and regular.



Photo 19.5: Shallow saw-cut to define edge of break-out.

19.10 WATER JET CUTTING

Water jet cutting is a specialised method of cutting concrete, and utilises a fine jet of water discharged from a nozzle at extremely high pressure. Refer to Photo 19.6. The method involves no impact, and therefore has the advantage that it does not cause fracturing of the adjacent concrete. It is however very slow and expensive, and requires that stringent safety requirements be applied.

When correctly applied and controlled, the method does not damage steel reinforcement, but the presence of reinforcement does constrain access for the cutting jet and hinders the cutting action. If required, steel reinforcement can be cut by feeding a cutting-agent into the water stream.

Specialist literature should be consulted and advice obtained when planning for the use of this method.



Photo 19.6: Cutting concrete with high pressure water jet.

INDEX TO APPENDICES

19A - DEMOLITION CHECK LIST

DEMOLITION CHECK LIST

CONSTRUCTION MONITORING CHECKLIST

PROJECT NO. / NAME: .....

INSPECTOR'S NAME(S): .....

STRUCTURE: ..... **ELEMENT**: .....

ACTIVITY AND DETAILS	STATUS						SIGNED	DATE
	A	B	C	D	E	F		
1. ACCESS								
1.1 For personnel								
1.2 Control and exclusion								
1.3 Traffic arrangements								
2. SAFETY								
2.1 Compliance with OHS & Const Regs								
2.2 Safety screens, catch nets								
3. AS-BUILT RECORDS EXAMINED								
4. METHOD STATEMENTS								
4.1 Exploratory work (e.g. checks for reinft)								
4.2 Equipment								
4.3 Method/technique								
4.4 Temporary support requirements								
4.5 Protection of retained concrete								
4.6 Other necessary protection measures								
4.7 Demolition of prestressed members								
5. ENVIRONMENTAL COMPLIANCE								
5.1 Disposal of materials								
5.2 Noise								
5.3 Dust								
6. WORKMEN AWARENESS								

STATUS INCLUDES

A Contractor's submission received
B Engineer's appraisal
C Inspected / Tested
D Compliance Verified
E Approved / Rejected
F Signed Off

CCP : Contractor's Competent Person

Note: Indicate N/A under Status if not applicable

ADDENDA

SANARL may from time to time issue addenda to this manual which is to be inserted in this space below. Such addenda will be placed on SANRAL's website www.sanral.co.za and it remains the user's responsibility to download these.

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