DIRECTORATE GENERAL OF HIGHWAYS
MINISTRY OF PUBLIC WORKS
REPUBLIC OF INDONESIA

AUSTRALIAN
INTERNATIONAL DEVELOPMENT
ASSISTANCE BUREAU

BRIDGE MANAGEMENT SYSTEM

BRIDGE MANAGEMENT SYSTEM
BMS
A PROJECT JOINTLY FUNDED BY INDONESIA AND AUSTRALIA

BRIDGE CONSTRUCTION SUPERVISION MANUAL

JANUARY 1993

SMEC
SNOWY MOUNTAINS ENGINEERING CORPORATION LIMITED

SMEC - Kinhill Joint Venture

KINHILL
KINHILL ENGINEERS PTY LTD

TABLE OF CONTENTS

PART 1

PART 2

DIRECTORATE GENERAL OF HIGHWAYS
MINISTRY OF PUBLIC WORKS
REPUBLIC OF INDONESIA

BRIDGE CONSTRUCTION SUPERVISION MANUAL

PART 1

ADMINISTRATIVE AND PROCEDURAL MATTERS

BRIDGE MANAGEMENT SYSTEM
BMS
A PROJECT JOINTLY FUNDED BY INDONESIA AND AUSTRALIA

JANUARY 1993

DOCUMENT No. BMS9-M.E

TABLE OF CONTENTS

PART 1

1. INTRODUCTION

1.1 SCOPE OF CONSTRUCTION SUPERVISION MANUAL

This Manual describes procedures to be followed for Supervision of Bridge Replacement and Bridge Rehabilitation projects undertaken by the Directorate General of Highways (DGH). Projects are usually carried out by contract but much of the content of this Manual is also applicable to works carried out by force account.

The Manual is divided into two parts. Part 1 (Sections 1 to 11) covers administrative and procedural matters associated with supervision of projects. Part 2 (Sections 12 to 26) covers technical aspects of construction supervision.

1.2 OBJECTIVE OF MANUAL

The objective of the Construction Supervision Manual is to strengthen the management of the bridge construction process and improve the quality of bridge construction. The Manual contains standard procedures and guidelines for the supervision of bridge projects. Application of uniform and adequate supervision procedures will assist to ensure bridges are completed within time and budget constraints, and will be constructed in accordance with the specifications.

Improvement in the quality of construction will lessen the need for repair and rehabilitation of bridges early in their service life.

1.3 OUTLINE OF MANUAL

The Manual describes the components of the supervision process in a logical and ordered manner. Standard forms are included which can be used for inspection and testing carried out as part of the supervision of construction work.

The Manual is divided into the following sections:

PART 1

PART 2

APPENDICES

TABLE OF CONTENTS

2. GENERAL ASPECTS OF CONSTRUCTION SUPERVISION

2.1 GENERAL

Effective and uniform supervision and management of bridge construction activities involves financial, technical, scheduling and contractual controls.

This Section presents an overview of the supervision process and introduces the other Sections of the Manual.

2.2 PLANNING AND SCHEDULING OF PROJECTS

Project planning covers the planning that is necessary to ensure that a project is organised and carried out in an efficient manner.

If the construction works are to be carried out in an organized manner, *a Construction Time Schedule* is required. This shows the various tasks and activities required to complete the bridge and the relationships between these tasks. The dependence of one task on another dictates when individual tasks can be carried out.

If resources required for each task are included, *Resource Schedules* can be prepared.

Section 4 of this Manual describes in more detail how the various Schedules are prepared and how they are used as a control device during construction.

2.3 RECORDING AND REPORTING

The collection and processing of data gathered during the supervision process is an integral part of supervision on construction projects.

Supervision on a construction project requires :

- monitoring of the progress of the work compared to the Contractor's time schedule
- monitoring to ensure compliance with the technical requirements of the Specification (Quality Control), and
- monitoring the overall cost of the project.

The inspection reports and test results gathered by the Supervising Engineer and his staff are used to assemble a picture of progress on the project. In addition, this data records what occurs on the project as the work progresses. Details such as the effects of weather, industrial disputes, and delays due to the Employer's failure to provide materials on time etc,. are recorded and may be used if a dispute arises with the Contractor to show what actually did occur.

This data is also used as the basis of Monthly Progress Reports and other Reports which are required by the Employer from time to time.

Recording and reporting is described in more detail in Sections 9, 10 and 11.

2.4 PROJECT SUPERVISION

Project supervision includes not only Quality Control but also monitoring of the project in general, the Contractor's progress, and the methods used to carry out the work required under the Contract.

It is usual for the Supervising Engineer and his staff to monitor the progress of each activity using the Time Schedule which was submitted by the Contractor as required by the General Conditions of Contract. This Schedule is used as the basis against which progress is compared.

The Contractor should be requested to supply detailed schedules for all major activities, in an appropriate format.

The type, availability and productivity of the Contractor's equipment should be recorded and reported. Any significant changes should be discussed with the Contractor.

Information on the classification and number of labour used on the project is also gathered to establish that the Contractor is able to complete the tasks on time and to the specified quality. For example, if there are too few carpenters on the site, then there may be potential problems with construction of formwork in the timeframe nominated by the Contractor.

Weather records should include the actual weather conditions such as the daily maximum and minimum temperatures, amount of rainfall etc. and also should indicate the effect on the project. There can be quite a different effect on the project caused by 50 mm of rain falling at 6pm to that caused by 30 mm of rain falling at 7am. Details of the time lost (when the Contractor could not work) should be included.

Records should also be kept of the resources for major activities on the project. Activities such as concrete work on decks, erection of superstructure and pile driving etc should be analyzed. The number of manhours per unit of measurement, the number of equipment hours per unit of measurement and the output per unit of time (eg, the number of metres of piling driven per hour) should be recorded for future use.

These records are valuable in the case of a dispute with the Contractor over rate of progress, and will also be useful to prepare a database of information for use by Engineers in preparing future Owner's Estimates (OE). OE's are required for each project which goes to tender. They are used in Bid Evaluation as one criterion for selecting the Contractor. Records from previous (similar) projects form the basis for the preparation of the OE's for future projects. This is a better method of preparation of an Owner's Estimate than using the unit rate from the previous project.

The authority and responsibilities of the Supervising Engineer and his staff are described in Sections 5 and 6 of the Manual.

Section 8 of the Manual describes in detail the administrative procedures which should be followed for supervision of bridge construction projects.

2.5 QUALITY CONTROL

Quality Control means the assurance that all work carried out by the Contractor and accepted by the Engineer conforms to the requirements of the Drawings, Specifications and other documents and instructions from the Engineer which may be issued as the Contract progresses.

By progressively carrying out checks and tests of the Contractor's work, the Employer can be assured that the Works will be built to the specified standards of quality.

The level of quality achieved is often directly proportional to the amount of supervision effort by the Engineer and his staff. The Contractor will generally try to satisfy the requirements of the Specification with the minimum of effort, and it is essential that the Supervising Engineer and his staff ensure that these requirements are actually achieved. Often it is necessary to advise the Contractor that the quality target of the Specification will be unlikely to be met if the Contractor does not also meet interim quality requirements, eg. the specified standard of surface finish of concrete requires that the material used for formwork does not have surface defects and other imperfections. The use of unsuitable materials is not necessarily cause for rejection by the Engineer at the stage that the material is used, but it may make compliance with the requirements of the Specification extremely difficult or perhaps impossible.

Most bridge contracts use large quantities of materials. The overall standard of bridge construction work is largely controlled by the quality of the materials. Section 7 of the Manual describes requirements for materials handling and control.

2.6 FINANCIAL CONTROL

Although the Rates or Sums for the items of work bid by the Contractor are substantially fixed, there are a number of matters in which the Supervising Engineer can exercise control over the final cost of the project.

Measurement of quantities is carried out monthly (or more often if required) as a check on the progress of the work and to verify the figures contained in the Contractor's claim for his Progress Payment.

Measurements may be made separately or as part of a joint inspection. The accuracy of these measurements will dictate the value of the payment to the Contractor in a Schedule of Rates Contract.

If the Contractor is instructed to carry out additional work on a Dayworks basis, careful recording of equipment labour and materials used is necessary to control the cost. As a general rule, Dayworks should be avoided and a *Variation* to the Contract issued. The Contractor usually includes rates for his equipment and labour in the Schedule of Dayworks which are considerably higher than those used to make up his original bid. An agreed Rate or Sum for a Variation is generally preferred unless the scope of the additional work cannot be defined. In this case, there is no alternative to carrying out the work on a Dayworks basis.

The Supervising Engineer should ensure that records of equipment and labour productivity etc., are kept during normal operations to assist with the pricing of Variations.

The Supervising Engineer should ensure that all the Employer's obligations under the Contract are met in a timely manner so as not to give rise to any future claims for additional costs and/or time.

2.7 FINALISATION OF PROJECT

At the end of the Contract there are several administrative tasks which must be carried out by the Engineer and his staff. These are described in more detail in Section 11 of this Manual.

TABLE OF CONTENTS

3. CONTRACT ADMINISTRATION

3.1 GENERAL

Administration of Contract Works is a complex procedure. The two main principles which should be remembered are :

- the Contract is a legally enforceable agreement between two parties, the Contractor and the Employer, wherein the Contractor agrees to carry out certain Works which are detailed in the Contract Documents, in return for payment by the Employer at rates or prices submitted in the Contractor's Bid; and

- the Engineer for the Contract is *not* a party to the Contract. He must be impartial and independent. It is his responsibility to oversee the correct execution of the Contract. This means ensuring the Contractor carries out the Works in accordance with the Drawings and Specification, and that the Employer promptly and correctly pays for this work. The Employer is also obliged to provide explanations if discrepancies are contained in the documents. This explanation will normally come from the Engineer. The authority of the Engineer is described in the Contract Documents.

For Contracts awarded by the Directorate General of Highways, the Engineer is often an employee of the Employer, so the role of the Engineer is a difficult role. However, he must strive to preserve impartiality and must realise that he has no authority to amend or waive any of the provisions of the Contract without the agreement of both parties to the Contract.

The Engineer must be member also that the Contractor has signed the Contract and has therefore agreed to carry out the Works in accordance with the Drawings and Specification for the amount in his Bid.

The Engineer may be responsible for coordination of several contractors on some projects.

3.2 TYPES OF CONTRACT

Two types of Contracts are commonly used for bridgework :

- **Schedule of Rates Contract**

The Employer prepares a Schedule of the estimated quantities of the different components of the Works, based on the Contract Drawings. The Contractor enters in his Bid a Rate of Payment against each item in the Schedule, and extends the items to obtain the amount of the Bid. In this type of Contract, the Rate governs, not the amount, and the Final Price is calculated by measuring the actual quantity of each item of work carried out and applying the Bid Rates.

- **Lump Sum Contract**

With this type of Contract, the Contractor bids a single Lump Sum for carrying out the Work shown in the Drawings.

A Schedule of Rates Contract allows more scope for changes which may be necessary during construction. Changes are often required because it is difficult to include for all contingencies at the bid stage. Under a Lump Sum Contract, the Bill of Quantities is used as the basis on which the value of changes is determined.

Lump Sum Contracts are especially useful for small jobs, where the Work can be fully detailed and there is little likelihood of any changes being required (eg, supply of bearings or prestressed concrete beams).

If a Variation is required on a Schedule of Rates or a Lump Sum Contract and the Contractor and Engineer cannot agree on the value of the Variation before the work is carried out, then the work may be carried out on a Dayworks basis. In this case, careful records must be kept of all labour, equipment and materials used in executing the additional work.

It is important that a comprehensive record is kept of all Variations and work that is likely to be in dispute as a Variation. This will enable costing of the work to be carried out later if necessary. These records should include the number of employees engaged on the work and their trade classifications, the equipment being used and the times it is used as well as the time on standby, and materials used.

3.3 CONTRACT DOCUMENTS

The Contract Documents which constitute the official agreement between the Contractor and the Employer usually consist of the following :

- Introductory Documentation
- General Conditions of Contract
- Specifications
- Bid Schedule (including Schedule of Dayworks)
- Drawings
- Addenda.

3.3.1 Introductory Documentation

Instructions for Bidders - lists the requirements for submission of a valid bid.

Form of Bid - the form on which the Bidder confirms *his offer*.

Form of Agreement - the legally binding agreement between the Employer and the Contractor. It is signed by both parties and is usually executed under seal.

3.3.2 General Conditions of Contract

The General Conditions of Contract are the legal basis of the Contract.

They define the responsibilities, obligations, rights and privileges of all parties to the Contract.

3.3.3 Specifications

The Specifications give a detailed, technical description of the work to be carried out. The Specifications normally define the required standards for materials to be incorporated in the Works and, either the methods to be employed in carrying out various tasks or the acceptance criteria for completed work (the latter is preferable).

The Specifications for DGH Contracts generally comprise three Sections in two Volumes.

The First Volume contains the main Specification clauses and the Special (project-specific) Specification clauses relating to bridge works. The Second Volume contains roadworks Specification clauses.

The intent is that the same Standard Clauses are used on all Contracts, and that *Project-* or *Site-specific* requirements (eg. locations of storage depots) are included in the Special Specifications. The Special Specifications should also include modifications, additions or deletions to the Standard Clauses.

3.3.4 BID SCHEDULE

The Bid Schedule sets out the quantities of the different types of work to be performed under the Contract. It includes the Contractor's Bid Rates for each item of Work, which are used when making payments under the Contract.

3.3.5 Drawings

The Drawings must give an accurate and unambiguous picture of the Work to be carried out. The Drawings must be kept up to date and superseded Drawings must be clearly marked.

The Drawings included in the Contract are the Drawings in the Bid. These should be retained to assist in the costing of Variations ordered after the award of the Contract.

3.3.6 Addenda

This part of the Contract Documents contains Addenda to the Contract issued during the Bid period, and copies of correspondence exchanged between the parties prior to signing the Contract.

The Addenda may include letters of clarification submitted by the Contractor in response to questions from the Employer during the Bid evaluation period.

3.4 SUBCONTRACTS

The Contractor is required to obtain the approval of the Engineer for any of the works which are to be subcontracted.

Notwithstanding such approval, a subcontractor who is selected and engaged by the Contractor to execute portions of the Works on behalf of the Contractor is entirely responsible to the Contractor and has no legal relationship with the Employer. The Contractor is still responsible for the proper execution of the Works.

Supervision of subcontracted work is carried out as if the work were being done by the Contractor. All directions and orders by the Engineer are directed to the Contractor, not to the subcontractor.

TABLE OF CONTENTS

4. PROJECT PLANNING

4.1 GENERAL

This Section describes the Programming and Scheduling processes. Some planning activities must be carried out if the project is to be executed on schedule with maximum efficiency and minimum delay.

Most of this work should be carried out by the Contractor, but the Engineer and his staff must be aware of these tasks and should discuss pre-construction activities with the Contractor to ensure smooth commencement of the project.

4.2 PROGRAMMING AND SCHEDULING

4.2.1 General

The General Conditions of Contract require the Contractor to produce several Construction Schedules for the project. The format of these Schedules should be as prescribed in the Specifications. The Schedules should be presented in such a way as to show the order in which the various activities will be carried out and how the activities are interrelated. This is often supplemented by sub-programmes which detail particular aspects of the construction, eg. pile driving, superstructure erection etc.

The Contractor should also be requested to provide a list of the resources to be used on the most important activities. This allows the resource utilisation to be checked for any significant clashes, eg. if the same resource is required to be used simultaneously on two (or more) activities.

Because the Contractor's Schedules are an indication of how the work is expected to proceed, they should be used as the basis for all reporting and monitoring.

The Engineer needs to carefully check the Schedules for logic errors and omissions. It is important that sufficient detail is included in the Schedules to allow progress on each structure to be monitored, but not so much detail that the programme becomes difficult to follow. The use of overall Schedules and sub-programmes is recommended, but care must be taken to ensure that dependencies of activities in different sub-programmes are reflected in the overall Schedule.

A Schedule of works is essential to :

- provide a plan for the execution of the work and the order in which it is carried out within the specified time frame
- identify the key activities
- communicate the plan to other parties
- measure and report on progress
- provide a tool for monitoring, and

- provide a basis for estimating labour, equipment and material requirements and for financial control.

Section 12 of the Construction Techniques Manual discusses basic scheduling techniques and their application to DGH projects.

4.2.2 S-Curve

The rate of progress of a typical project is usually quite slow after commencement of work, accelerates to a higher rate of production and then slows again near the completion of the works. A plot of progress or cumulative value of payments against time will give a curve which is a basic S-shape. This curve is usually referred to as an "S-curve" and it reflects the typical life cycle of a construction project.

The use of the S-curve to monitor progress is widespread in DGH and indicates how the Contractor is performing. The usual S-curve shape is modified if the Mobilisation Advance is included because this figure may represent twenty percent of the Contract Value.

Therefore it is usual to ignore the Mobilisation Advance when preparing an S-curve.

A typical S-curve is shown in Figure 4.1

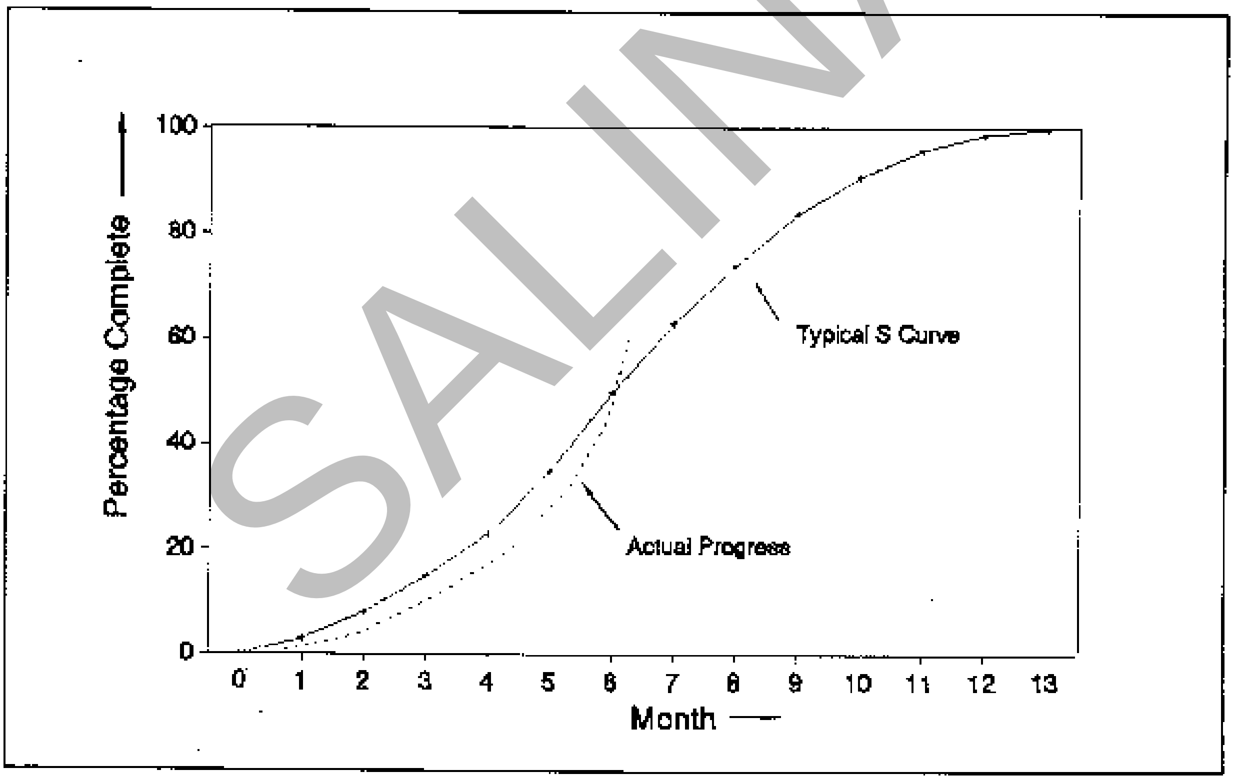


Figure 4.1 - Typical S Curve

The Contractor usually prepares his Contractual Schedule in the form of a bar chart showing the same activities as the Pay Items in the Bid Schedule. This may be convenient for monetary calculations but is not necessarily the best presentation as several significant work items may be aggregated into one Pay Item.

The Contractor calculates an equivalent rate of progress, usually on a pro-rata basis, for each activity shown on the bar chart and this is used to calculate and plot the initial or Programmed S-curve.

As construction progresses, the programme is updated by calculating the percentage completion of each activity on the bar chart. A second line is then drawn which indicates the actual rate of progress. This may be compared with *the Programmed curve and the* overall rate of progress assessed. If the Contractor falls behind his target (ie. the actual S-curve is below the Programmed S-curve), then the Engineer should request the Contractor to advise what action he proposes to take to make up the lost progress.

The S-curve is used as an indicator of lack of performance by the Contractor and the Engineer may call a "*Show Cause Meeting*" when the Contractor is between 10 and 20 percent behind his programme. If the Contract is less than 70 percent complete and the Contractor falls 25 percent (or more) behind his programme, the Employer should give consideration to terminating the Contract in accordance with the provisions of Clause 59 of the General Conditions of Contract.

A summarised form of the S-curve is often used as the basis for reporting in the monthly report of the Supervising Engineer.

4.3 SITE PREPARATION

Before construction work can be started, there are several aspects of the site which must be considered. These are listed as follows :

- **Right of Way**

  Where land acquisition is required, it is necessary that the formalities be completed prior to the start of construction. This will require certain procedures to be followed and it is essential that the Engineer, as part of pre-construction planning, determines the current status of land acquisition and the effect, if any, of giving the Contractor possession of the site.

- **Fencing**

  Fencing is not usually required on contracts awarded by DGH. Where fencing is required either to delineate the area of the works or to provide security, the standard and type of fence required should be determined by the Engineer.

- **Removal or Relocation of Services**

  Although the responsibility for removing and/or relocating services is that of the service authority concerned, there is obviously a need to programme the relocation works so as to cause minimum delay to the Works. The Engineer should discuss the relocations with the Contractor and ensure that adequate steps are taken to liaise with the appropriate service authorities.

- **Offices, and Accommodation**

  The Engineer should request the Contractor as early as possible to provide details of the location of his offices, accommodation etc. The Engineer is required to give his consent to these locations. They should be located as close to the bridge site as possible. There should be suitable access from these facilitate to the nearest public road and to the bridge site. Offices and accommodation should be well-drained.

4.4 CONTRACT REQUIREMENTS IN PRECONSTRUCTION PHASE

The General Conditions of Contract and the Specifications together prescribe the actions to be carried out by the Contractor, the Engineer and/or the Employer prior to the commencement of Works.

Many of these tasks are related to Bonds and Insurances being submitted by the Contractor. Others relate to tasks that the Engineer must perform, eg, Delegation of Authority from the Engineer to the Engineer's Representative(s).

TABLE OF CONTENTS

5. AUTHORITY OF THE SUPERVISING ENGINEER

5.1 GENERAL

The Engineer is usually the Project Manager for Bridge Replacement (Pemimpin Proyek Penggantian Jembatan).

The Engineer's Representative is usually the Supervising Engineer, a Consultant appointed by DGH to carry out the supervision of the Contract. The Supervising Engineer has the responsibility for the day to day running of the Contract but does not have the power to approve Variations or to make Final Payments.

The authority of the Supervising Engineer will usually be defined in the Contract Documents (usually the General Conditions of Contract) or as delegated from time to time by the Engineer. The supervisory staff must be fully aware of the limitations of their authority in carrying out supervision of the Contract.

Delegation of authority from the Engineer to his Representative must be notified in writing to the Contractor, and the Supervising Engineer and must ensure that they act only within the limits of the delegated authority. The authority delegated may vary from contract to contract.

The job of the Supervising Engineer is to ensure that the work is carried out in accordance with the Drawings and the other Contract Documents within the limits of authority delegated.

5.2 AUTHORITY NORMALLY DELEGATED TO THE SUPERVISING ENGINEER

Authority is normally delegated to the Supervising Engineer to :

- approve shop and field drawings prepared by the Contractor
- prepare change orders for extra or omitted work
- prepare reports (including recommendations) for the Engineer on Contractor's claims
- prepare reports (including recommendations) on design changes
- prepare monthly Progress Payment Certificates
- accept or reject work done by the Contractor on the basis of compliance or non-compliance with the *Specifications*

5.3 AUTHORITY NOT NORMALLY DELEGATED TO THE SUPERVISING ENGINEER

Authority is generally not delegated to the Supervising Engineer for the following :

- to approve design changes
- to approve Variations to the works
- to grant Extensions of Time
- to approve Progress Payment Certificates
- to approve claims by the Contractor for additional payment
- to negotiate directly with the Contractor for new rates of payment for extra work for which there is no applicable rate in the Schedule of Rates.

TABLE OF CONTENTS

6. DUTIES OF THE SUPERVISING ENGINEER

6.1 GENERAL

It is the duty of the Engineer to administer the Contract between the Employer and the Contractor impartially, with no bias towards either party.

If it is made clear from the commencement of the Contract that this is the Engineer's intention, then a good working relationship with the Contractor *will be established*.

The Engineer should firmly apply the requirements of the Specification and must ensure that the Contractor is notified of Drawing amendments as soon as possible.

It is essential that the Supervising Engineer (as Engineers Representative) applies the Specification in the manner in which it is actually written. The Engineer or Supervising Engineer's must make all decisions promptly and firmly so as to cause minimum delay to the Works. He should also ensure that the Contractor is paid promptly for all work satisfactorily completed.

If there is a dispute, such payments as are possible without prejudicing the position of either party should still be made.

The Supervising Engineer and his staff must never place themselves under any obligation to the Contractor by accepting favours and should ensure that instructions are only issued to the Contractor or his official representative and not to any subcontractor or employee. All instructions to the Contractor must be confirmed in writing, to minimise the possibility of disputes.

Checklists for Construction Supervision are included in Appendix 2.

6.2 SUPERVISION BY ENGINEER

6.2.1 General

The duties of the Engineer are as follows :

- ensure that all staff involved in supervision (including consultants) carry out proper checks on the Contractor's work at all stages of construction and that approvals for all stages of the work are carried out to accepted procedures
- ensure that progress is properly recorded on standard forms and to standard formats
- monitor expenditure
- approve Progress Payments to the Contractor *for completed work*
- ensure the requirements of the Specification are achieved
- monitor the time schedule of the project and draw the Contractor's attention to delays

- correspond with the Contractor on matters of concern
- preside over regular site meetings with the Contractor, Consultant and senior site staff
- ensure Progress Payments are based on measured quantities
- issue acceptance certificates
- evaluate Contractor's claims for variations and extra payments

6.2.2 Project Officer

The duties of the Project Officer include:

- Liaison with the Supervising Engineer about variations in quantities.
- Liaison with the Supervising Engineer and the Engineer about changes to design of the Works.
- Assistance to the Engineer in the administration of the Contract.

6.2.3 Inspector

The duty of the Inspector on the Contract is to provide an independent report to the Project Officer on daily activities at the project site.

6.3 SUPERVISION BY SUPERVISING ENGINEER

6.3.1 General

The duties of the Supervising Engineer are as follows :

- provide clarification of the Specification and Drawings if necessary.
- provide information requested by the Contractor.
- inspect materials and work promptly.
- ensure testing of materials is carried out to acceptable standards.
- ensure materials are supplied on time and to the appropriate standard.
- check setting-out
- report non-compliance with Government or other regulations.
- notify the Contractor of non-compliance with the Drawings or Specifications.

- keep necessary records.
- supply measurements and information for monthly Progress Payments.
- measure extra and reduced work as directed by the Engineer.
- complete As-Constructed Drawings
- ensure the Engineer is informed of all developments on the project, by timely and adequate reporting.

These duties are detailed in following sub-Sections.

6.3.2 Drawings and Specifications

The Supervising Engineer must use the Specifications and Drawings as the main terms of reference and should become familiar with them. Working through him in detail can be tedious, but if the effort is made at the start of the Contract, it will assist him throughout the job.

If a discrepancy or ambiguity is noticed, or if any are found by the Contractor, they should be immediately reported to the Engineer.

If there is any doubt in the interpretation of the Drawings or Specifications, the Supervising Engineer should seek advice from the Engineer.

6.3.3 Information requested by the Contractor

If the Supervising Engineer is unable to provide information requested by the Contractor, reference should be made to the Engineer. The information should be given promptly to the Contractor to avoid delaying his work. All information requested and given should be recorded with times and dates.

6.3.4 Inspection of Materials and Work

Inspection of materials includes sampling and the carrying out of field tests (Refer Section 7). If the test procedures are set out in Standards (such as AASHTO) or Standard Specifications, copies should be kept on the site. It is important that procedures are followed exactly as specified, otherwise the tests may be of little value. The Contractor should be given access to the results of all tests, but results which may require skilled interpretation should not be supplied to him until they have been expertly examined.

The Supervising Engineer should forward all samples for testing to the laboratory promptly. It is particularly important that concrete samples be forwarded for testing at the appropriate time (ie. concrete tests at 7 days and 28 day).

Inspection of particular work such as formwork and reinforcement placing should not be delayed until completion. The Supervising Engineer should observe the work as it progresses, and if it is obvious that the work is not correct, the Contractor's engineer or foreman should be advised so as to avoid costly rectification later. The Supervising Engineer and his staff must not issue instructions directly to workmen or sub-contractors as this could be construed as an employer/employee relationship and could lead to receipt of claims from the Contractor and possibly the breakdown of the Contract.

6.3.5 Notification of Non-Compliance with Drawings and Specifications

Notification should be in writing and a copy of the notice to the Contractor retained. Even minor matters should be noted in the daily diary. If the Contractor does not rectify the non-compliant Work, the Engineer must be advised.

6.3.6 Checking of Setting-Out

Under the requirements of the General Conditions of Contract, the Contractor is required to set out the work and take responsibility for its accuracy.

It is important to leave the responsibility with the Contractor even though the Supervising Engineer is often asked to do setting out work for the Contractor because the Contractor has no skilled personnel on the site. The Contractor must be instructed to bring his surveyor to the site to do the work.

It is important that bench marks are not established or transferred by the Supervising Engineer and his staff without the work being checked by a Surveyor.

6.3.7 Non-Compliance with Regulations

Failure to comply with Government or other regulations should be reported to the Engineer.

6.3.8 Keeping Records

The types of records and methods of reporting are described in Sections 9, 10 and 11

6.3.9 Information for Monthly Progress Payments

At the end of each month, the Supervising Engineer should prepare a list of the quantities of work completed for each item of the Contract Schedule. This is best carried out by obtaining a copy of the quantities which the Contractor intends to include in his Progress Payment Claim and comparing them with the quantities given in the measurement book. The Contractor's quantities should be checked and corrected if necessary. The quantities should be certified correct by the Contractor and the Supervising Engineer.

The monthly Progress Payment certificate is prepared by the Supervising Engineer using the standard format for the particular Contract (payment in local currency or local and foreign currencies).

6.3.10 Variations or Changes to the Works

The Supervising Engineer usually does not have the authority to order extras and omissions to the Contract. These are ordered by the Engineer and measured by the Supervising Engineer and his staff.

Changes to the Works - amendments, omissions and extra work - may be ordered by the Engineer at any time. The Engineer is given this power under the General Conditions of Contract which provides guidelines on how changes to the work are to be handled.

In the case of extra work, every effort should be made to mutually agree on the costs before the work is begun.

All amendments occurring during construction must be adequately recorded by the Supervising Engineer and his staff.

Payment for extras and missions are made on the basis of :

- Rates in the Schedule of Rates
- Negotiated items or rates
- Day Works Rates

a. Schedule of Rates

The Schedule Rates are set out in the Contractor's Bid and these should be used to assess the extras and omissions if the type of work is the same as that described in the Schedule. If the increase or decrease in the quantity of work exceeds the limits set out in the General Conditions of Contract,then a new Rate for those items may be required.

b. Negotiated Items or Rates

If any of the work involving extras is not of the same type of work provided for in the Schedule, or if there is no Schedule Rate for the work, the Rates to be paid are negotiated between the Contractor and the Engineer.

c. Day Works Rates

If the Contractor and Engineer cannot agree as to the price to be paid for any item of extra work, the Engineer may direct the Contractor to carry out the work by Day Works. In this case, the Contractor is paid for the actual cost of the work plus a margin for overheads and profit.

For Day Works, the Supervising Engineer and his staff must be careful to record :

- details of number of men, hours worked and classification of each man (skilled, unskilled, etc.).
- quantity of materials used.
- the make, class and hour worked by each of equipment

6.3.11 As-Constructed Drawings

As-Constructed Drawings show the location and dimension of all additional work and all amendments to the Drawings. Details of revised levels are recorded for all footings, piles and other foundations.

6.3.12 Reporting

Reports submitted by the Supervising Engineer to the Engineer are described in Section 10.

TABLE OF CONTENTS

7. HANDLING OF MATERIALS

7.1 PROCUREMENT OF MATERIALS

The Specification requires the Contractor to submit for the approval of the Engineer, details of materials, suppliers and samples of materials intended for use on the Contract.

The Contractor may also be required to submit a programme showing timing of procurement of the major materials to be used.

7.2 CONTROL OF MATERIALS

Physical control is required to prevent materials being wasted, damaged, lost or stolen.

Responsibility for the control of materials until they are incorporated in the Permanent Works generally remains with the Contractor. The Contractor should have an inventory control system for materials which pass into and out of his storage areas.

If payment is to be made for materials-on-site, an accounting system is needed to ensure that the materials paid for are in fact used in the Works. The Supervising Engineer and his staff should have some identification and inventory system for such materials. It is important that materials which require protection from sun and rain are stored under suitable cover.

The Supervising Engineer and his staff should carry out periodic checks to determine the quantity and condition of materials which have been paid for in previous Progress Payments and which are still in storage pending future use.

7.3 STORAGE OF MATERIALS

The Contractor is required to store materials to be used in the Works in accordance with the Specifications. Details of the storage method and the area to be used for the storage should be submitted to the Engineer for his approval.

7.4 HANDLING OF MATERIALS

The method of handling many materials is covered in detail by the Specifications, in order to avoid damage due to improper handling by ignorance or negligence. A typical case is the method of handling and pitching precast reinforced concrete piles. If the piles are lifted at the wrong points, severe damage to the piles can result.

The Supervising Engineer and his staff should monitor the Contractor's activities during handling of such materials to ensure compliance with the Specification or recommended procedures.

7.5 TESTING OF MATERIALS

Materials supplied by the Contractor for use on the Contract are required to comply with the Specification.

Compliance testing of materials is carried out as part of the supervision process. In some instances, testing is limited to a visual examination, only whilst in others detailed laboratory testing is required. Some materials may be delivered to the site accompanied by manufacturer's test certificates and it is essential that the materials are matched with the certificates.

On some Contracts, there will be a requirement for the Contractor to erect a laboratory for the Engineer, for him to carry out the usual tests on soils and aggregates together with slump and compressive strength testing of concrete. More complicated tests on steel, elastomers etc. are usually carried out in laboratories off site, either at the DPU laboratory in the provincial capital or at a specialised laboratories elsewhere.

It is the responsibility of the Supervising Engineer to sample or supervise the sampling of materials in the correct manner and to ensure that representative samples are taken for testing.

The method of sampling should be as set out in the Specifications or contained in the appropriate AASHTO, ASTM or other Standard Test Method.

The methods of sampling and testing described in the Standard are to be strictly followed. If this is not done, the results of the test will not give fair or consistent results. If the Contractor or supplier is aware of deficiencies in sampling and/or testing, the results of the tests will not be able to be used as the basis for quality control. In addition, the results from a sequence of tests may contain excessive errors due to the sampling and testing being carried out incorrectly and a comparison of the results of different tests on supposedly similar materials will be meaningless.

TABLE OF CONTENTS

8. ADMINISTRATIVE PROCEDURES FOR SUPERVISION OF BRIDGE CONSTRUCTION

8.1 GENERAL

This Section covers a number of administrative aspects of Bridge Supervision which are common to all projects. Technical Supervision procedures required for Bridge Construction works are described in Part II of the Manual.

8.2 PROGRAMMING AND CO-ORDINATION

It is the responsibility of the Contractor to supply the Engineer with a program for the completion of the Works within the Contract period, and to adhere to this program. The Engineer should ensure that matters which could give rise to claims for extension of time, such as design changes or unforeseen foundation conditions, are shown on subsequent updates to the Contractor's program. The Contractor should provide sufficient data to allow effective monitoring of his activities to be carried out.

The actual format and minimum requirements of the program will be as set out in the Specifications.

When a Contract includes a large amount of materials (eg. steel superstructure components) to be supplied by the Employer, it is important that adequate thought be given to timing. This will ensure that the Contractor is not delayed due to the lack of materials. The Contractor's program should clearly show the dates he expects to receive materials which are to be supplied by the Employer.

8.3 ACTION PRIOR TO COMMENCEMENT OF WORK

The Engineer and/or the Supervising Engineer should:

(a) Obtain a copy of the letter of Acceptance and note any special provisions contained therein.

(b) Discuss the job with the design engineer to familiarise himself with reasons for various design features.

(c) Satisfy himself that access is available to the site of the bridge and any conditions which may restrict access (such as heavy rainfall).

(d) Check that the Contract has been signed and Security Deposit lodged.

(e) Request the Contractor to supply evidence that the insurance policies required by the General Conditions of Contract have been effected. A copy of the Policies should be obtained to ensure that they comply with the requirements of the General Conditions.

(f) Check on the existence of utilities which may be affected by the work. Obtain copies of correspondence with utilities authorities. Where the Employer is responsible for moving utilities, ensure that the work is done in time to avoid delay to the contract works.

(g) Check that survey pegs are in position and, if necessary, arrange for their re-establishment.

(h) Check materials which are to be supplied by the Employer, to ensure supply will be on time.

(i) Arrange to send a letter delegating authority to the Supervising Engineer (the Engineer's Representative).

(j) Check with other engineers who have had dealings with the Contractor. This may disclose particular aspects which will need close attention.

(k) Request the Contractor to supply samples of concrete aggregates and his proposed concrete mix design at an early date. Otherwise, he may be delayed awaiting approval for his mix design.

(l) Arrange for an initial site meeting with the Contractor.

8.4 INITIAL SITE MEETING

The initial site meeting should be held well in advance of the commencement of work on the site. This meeting should be attended by the Engineer, his assistants, the Supervising Engineer(s) and the Constractor's Representatives.

The purpose of this meeting is to discuss the Construction Schedule, equipment to be used, and general organisation of the job.

The Contractor should be asked to supply the Construction Schedule and details of major formwork and falsework for approval.

8.5 SITE MEETINGS GENERALLY

Site meetings should be arranged at monthly intervals to review progress and discuss problems which arise. Special site meetings should also be called if necessary to deal with specific problems.

Minutes of site meetings should be an accurate record of the proceedings of the meeting, and should be written immediately following the meeting. A copy must always be sent to the Contractor with a covering letter requesting his comments as to their correctness. Minutes of site meetings have considerable importance on matters in dispute, and it is essential that the Contractor be given the opportunity to comment on their correctness. Lack of comment can be taken as agreement to the correctness of the record.

8.6 SETTING OUT

The Contractor is completely responsible for setting out the works with respect to position, line, level, dimension etc., but the Engineer must instal the minimum number of basic control points to enable setting-out to be carried out.

Control points should be permanent (eg. concrete blocks) in positions that will not be disturbed by the construction operations. They should include markings on the centreline each side of the bridge construction activities.

The Contractor's setting-out should be periodically checked by the Supervising Engineer and his staff. Approval to proceed with the work should be given only when the checking is successfully completed. Checking by the Supervising Engineer does not relieve the Contractor of ultimate responsibility.

Checking of setting-out may just involve the use of tape, level, plumb bob and stringline or it may require detailed survey work. The Supervising Engineer should call for specialist assistance if required.

8.7 SAFETY ON THE JOB SITE

8.7.1 General

The safety of employees on the job, and of the general public using areas adjacent to or affected by the Works and the safety and adequacy of the Works themselves, including any temporary works, are the direct responsibility of the Contractor. It is the duty of the Engineer to check and ensure that all necessary safety measure are taken. However, in no way does this relieve the Contractor of complete responsibility for the Works.

The Contractor must comply with all statutory requirements covering the safety and well-being of employees and sub-contractors. The Supervising Engineer should ensure that all relevant notices required under the various regulations are given and requirements complied with. If this is not being done, the Contractor should be instructed to immediately comply and as a last resort, the Engineer may order that work be stopped until it is done.

It is important that public safety be guaranteed at all times and public inconvenience kept to a minimum. Subject to the requirements of the Specifications, the Contractor is responsible for watching and lighting the Works and for all signing, lighting, barricading etc. of any roads or paths affected by the Works. This is especially important where side tracks and detours are involved and reference should be made to the Specifications for the methods of signing to be used under the Contract. If, in the opinion of the Engineer, measures taken by the Contractor to provide for public safety are inadequate, the Contractor should be instructed to immediately make good the inadequacies. Failing this, the Engineer may carry out the necessary work, at the Contractor's cost.

The design of all temporary works, formwork, falsework, cofferdams etc. is the responsibility of the Contractor but it is usual for the Engineer to require drawings of major items to be submitted for checking in advance of construction. It is also important, after checking, to ensure that the temporary works are built in accordance with the Drawings, or approved variations, as temporary works often get changed during erection.

8.7.2 Job Safety

A safety program should be implemented at the preconstruction stage of planning to ensure compliance with statutory requirements and safe working standards.

A safety committee for a major project could be organised at this early stage, to review the arrangements for safe working and to arrange for appropriate training if required.

Standard procedures for such things as scaffolding, rigging, maintenance of equipment, disposal of rubbish, fire fighting, site communications and first aid facilities must be formulated and maintained.

Safety training for job employees should generally concentrate on the need for the use of personal protective equipment, correct lifting procedures and good housekeeping practice. Special courses for riggers, scaffolders, plant operators, powder monkeys and first aid attendants can be arranged when required.

8.8 TRAFFIC CONTROL DURING CONSTRUCTION

8.8.1 General

Adequate provision should be made for the safe passage of all traffic, through or around the site, with minimum delay. Pedestrian movement should also be considered.

Where an existing road is affected by the works and a separate side track is not provided, the existing road must be maintained in a safe and trafficable condition.

If roads need to be closed to allow construction to proceed, advance warning should be given to the public.

8.8.2 Travelling Public

Road users have the right to expect :

- Reasonable and safe passage through and around the site.
- Minimum inconvenience.
- To be guided by traffic control devices such as signs and barriers which clearly indicate the travel path, under both day and night conditions.
- To be warned of dangers and changes in the road ahead.

- Courteous treatment and co-operation from employees of DPU, the Consultant and the Contractor.

Property owners have the right to expect reasonable access to their property. Disturbance or damage to their access must be made good, *to a condition at least equal to or* better than its condition before work commenced. The aim is to receive the owners co-operation. The best way to achieve this to discuss the matter with them before the work commences and to :

- Advise them of the nature of the proposed work and the intended construction program.
- Assure them that every effort will be made to cause the least possible inconvenience.
- Encourage them to discuss any problems they anticipate or encounter at any time during the course of the work.

8.8.3 Side Tracks

Side tracks should be cleared, aligned, formed, graded, and drained to enable the vehicles using the road to travel freely and without difficulty. Clearing should be extended to give a 2 m minimum clearance each side of the track and a 6 m vertical clearance to any overhang. The surface of the side track should be constructed with a crossfall of not less than 2% for drainage and should be sealed or otherwise treated to reduce dust and to restrict ingress of moisture during the planned life of the sidetrack.

Temporary culverts or adequately concreted or gravelled floodways must be provided at watercourses, whether running or dry, over the full width of the formation, together with suitable guide posts located at the limits of the construction. Guide posts at submersible crossings should be marked with paint to indicate the depth of water at the crossing.

The standard of formation and paving used for the side track will depend on such factors as traffic volume, commercial vehicle use and job duration. If a side track on a heavily trafficked road is to be used for a long period, the sidetrack and its approaches should be sealed and line marked.

Where bituminous surfacing of side tracks is intended, the preparation and compaction of the gravel pavement and the surfacing should be carried out to appropriate standards.

All side tracks and crossings of watercourses should be maintained in good condition with a smooth running surface. Consideration should be given to the required flood immunity standard of the side track in order to reduce traffic disruption to a minimum.
The increased cost of construction to a higher standard should be considered in relation to expected frequency and duration of inundation.

Provision must be made for early warning when the side track is inoperable.

8.8.4 Detours

The requirements for side tracks should generally be applied to traffic detours.

Detours must be clearly sign posted in accordance with appropriate standards. In built-up areas, where there are alternative route choices the preferred route should be clearly defined by adequate direction signs.

Consideration must be given to the effect of traffic on the detour, in particular with respect to damage to the road pavement and also the effect of the generated traffic on local inhabitants.

Approval to use a particular road as a detour must be sought from the authority which controls the road, and agreement reached on compensation for any damage resulting from the redirected traffic.

8.8.5 Warning Devices

Work being undertaken on a road under traffic requires the use of temporary warning devices and traffic controllers to give advance warning of hazards and guide traffic safely past the site, and to protect workmen. These arrangements are necessary for both small isolated groups of men are carrying out minor maintenance and when major construction work is in progress.

Warning devices such as delineators, pavement marking signs, lights and barricades should be provided and located to provide adequate warning and guidance to traffic.

Where bridgework is in progress above a roadway carrying traffic, adequate precautions must be taken to safeguard against falling rocks or other materials.

Temporary warning lights are required during the hours between sunset and sunrise, in addition to normal signs, barriers and other traffic control devices. Lights shall be kept lit at all times and shall be of an approved design emitting either a flashing light or a steady light, as required. The light should be of sufficient intensity to be visible from a distance of at least 100 m under normal atmospheric conditions during the hours of darkness.

Signs which are to be used for the warning and guidance of traffic at night should be retro-reflective and be regularly cleaned.

When blasting operations are being carried out, all traffic must be stopped at a safe distance, but not less than 200 m from the site of blasting. The road should preferably be completely barricaded across and signs such as "Blasting-Stop", "Await Signal", etc. erected at the barricades. A workman dressed in a highly visible safety jacket is necessary at each barricade to ensure that the signs are displayed in a suitable manner and that the traffic complies. He can also remove the warning sign when the "All Clear" has been given and signal the traffic to proceed when conditions are safe.

Where electric detonators are being used, warning signs such as "Blasting Area", "Switch Off Radio Transmitters" and "End of Blasting Area" are to be erected on each approach, at least 200 m on either side of the blasting area. The signs are to be kept in position until all the electric detonators have been fired or have been removed from the site.

Where a single lane is used to carry traffic in both directions, it is necessary to provide facilities to permit the traffic to be alternately stopped or to proceed. Control of the traffic can be carried out using traffic controllers, temporary traffic signals or police, as appropriate.

Each traffic controller should wear a coloured safety jacket (fitted with retro-reflective markings if used at night). He should use a suitable sign board painted red (for STOP) on one side and green (for SLOW) on the other side.

Defective signs, lights or barriers should not be used on the work at any time. Warning devices should be retained in their correct position, day and night. If necessary, checks on the warning devices should be arranged outside normal working hours to ensure their effectiveness.

Only competent persons should be appointed as traffic controllers and they should be properly instructed in the correct procedures in controlling traffic.

All temporary warning devices should be removed promptly when it is safe to do so.

In cases where traffic is permitted to use any portion of the existing road or bridge deck during construction, all movable equipment must be removed from the roadway or deck at night. When it is unavoidable to leave equipment at night within 7 m of the edge of the traffic route, it must be lit by a suitable number of red lights.

In addition to the normal safety precautions, when equipment is operating at night on roads under traffic, it may be necessary to floodlight the work area.

8.8.6 Bridge Widening

If it is not possible to detour traffic off a bridge during widening, special precautions must be taken to protect both the workmen and the traffic and to ensure the integrity of the new work. Precautions must to be taken to prevent premature encroachment of traffic on to the new work and to minimise the effects of vibration caused by passing vehicles. These requirements can be achieved by the use of one or more of the following:

(a) Placing substantial barriers between old and new work.

(b) Leaving enough space between the barrier face and the new work.

(c) Restricting the speed of traffic to less than 5 km/hour, especially during placement of fresh concrete. In some cases it may be necessary to stop the traffic entirely for a short period and, in this case, it is advisable to give as much advance warning as possible.

(d) Working, at night when the volume of traffic is low.

As much of the widening work as possible should be carried out before the old kerb and fence are removed. For example, it is often possible to complete the substructure for the widening before it is necessary to disrupt the traffic flow over the existing structure. It should be remembered however, that confusing and dangerous conditions for motorists can arise in bridge widening work and every precaution should be taken to avoid the possibility of accidents.

8.9 FINAL INSPECTIONS

The situation should be avoided whereby the Contractor is continually being requested to return to carry out correction work.

The following procedure is recommended :

(a) the standards of finish required should be established at an early date. At this stage, the Engineer should satisfy himself that the Supervising Engineer is achieving the standard required.

(b) The Supervising Engineer should inspect each section of the work in detail, and should not allow scaffolding to be removed until be is satisfied that each section is up to standard.

(c) Prior to issuing the Certificate of Substantial Completion, the whole of the works should be inspected by the Engineer. At this stage, the Contractor should be given a written list of the work remaining to be completed. This work must be done before the Certificate of Final Completion is issued.

TABLE OF CONTENTS

9. USE OF REPORTING FORMS

9.1 GENERAL

The establishment and maintaining of a good system of recording and reporting by both the Engineer and the Supervising Engineer and his staff is very important. This becomes very apparent if a dispute arises, when all forms of records, from official correspondence, supervisor's diaries, test results, etc. are used to establish what actually did take place.

Great care is needed to ensure that reports and Minutes of meetings are written in clear concise terms. Only matters which are factual should be described, without emotional expressions of opinion. It is most important to understand that in legal proceedings, the meaning of a report can only be based on the words and expressions used. Any ambiguity in writing can be seized upon and a suitable interpretation presented to an arbitrator. Any matters included in reports which have been based on hearsay without acknowledgement of the source can also be misinterpreted as fact, in legal proceedings.

Examples of various reporting and recording forms are included in Appendix 1.

9.2 DRAWINGS AND SPECIFICATIONS

9.2.1 General

The Supervising Engineer must make himself thoroughly familiar with the Drawings and Specifications for the Works, and the requirements of the General Conditions of Contract. He should report immediately to the Engineer any discrepancy or ambiguity he may discover in these documents.

The Supervising Engineer's copy of the Drawings and Specifications must not be altered unless authorised in writing by the Engineer. Any doubt in the interpretation of the Drawings, Specifications or other matters connected with the work should be referred to the Engineer for his decision.

9.2.2 Drawings Issued

A detailed record including Date of Issue must be kept of all revised drawings issued to the Contractor, as these can have an important bearing on Contractor's claims.

9.3 ADMINISTRATIVE FORMS

9.3.1 Diary

The Supervising Engineer and his staff must keep diaries to record the day-to-day progress of the job, including notes on all discussions with the Contractor. It is especially important that on-site supervisors keep a detailed, daily record of job progress with notes on the number of men, types of plant etc. on site. This information can be very valuable for determining the validity of any future claims for additional payment.

The Supervising Engineer must keep a daily diary which will provide a permanent detailed record of the progress of the work. The following information should be recorded:

- numbers and classifications of men and equipment engaged and their locations on the site
- materials supplied to the Contractor and Materials-on-Hand (see also Section 9.3.3)
- delivery, installation and removal of Contractor's equipment, and details of major plant breakdowns and return to service;
- location and description of operations carried out each day;
- dates of commencing and finishing various sections of the work;
- details of dates of notification of authorised amendments to the Drawings or Specification;
- details of any instructions or warnings given to, and important conversations held with the Contractor or his Representative;
- date and method of despatch of test samples;
- results of field and laboratory tests on materials;
- details of materials rejected or work condemned, and disposal of rejected materials;
- particulars of detours including their condition and the date of opening or closing;
- particulars of any restrictions on horizontal or vertical clearance, including dates imposed and removed;
- photographs taken at the direction of the Engineer (eg. photographs of works in dispute; temporary signs indicating their locations; and existing signs, pavement markings, boundary fencing and other items to be removed or replaced);
- weather conditions, including approximate rainfall and temperature readings and their effect on the progress of the work, including any standdown period;
- flood levels and times;
- details of any emergencies or accidents;
- details of any delays which occur on the work and the reasons for them;
- details of any unusual features of the work or associated incidents;

- dates of visits to the site by the Engineer, other DPU staff and important members of the Contractor's company;
- instructions received from the Engineer; and
- where similar materials are drawn from different sources, the locations of these materials in the Works.

Diaries are to be written using a standard format.

At intervals required by the Engineer, the Supervising Engineer should forward the original sheets of his diary to the Engineer. The carbon copy of his diary is be kept on the site until the completion of the work. The diaries can be used in the preparation of regular Progress Reports by site staff to the Engineer.

9.3.2 Correspondence

A complete record of correspondence sent to and received from the Contractor must be maintained. This will include letters sent issuing Drawings, giving or confirming site instructions, giving details of progress payments and confirming Extensions of Time.

The Supervising Engineer must keep copies of his outgoing correspondence in an interleaved correspondence book.

Correspondence received must be kept in a filing system, and copies must be sent to the Engineer.

9.3.3 Measurement Book

The Supervising Engineer should make all necessary measurements and keep records of receipt and use of materials to enable him to certify that the specified amounts of the various materials have been incorporated in the Work. He must ensure that the Contractor understands the basis of measurement in each case.

For this purpose, he should keep an interleaved measurement book to record (in duplicate):

- all measurements of completed work;
- quantities and types of materials as they are received;
- details of duly authorised deductions and extras;
- details of any work being carried out by the Contractor on an actual cost basis, with a reference to the authority for the work; and
- details of the materials rejected or work condemned, and disposal of rejected materials.

In recording details of work carried out by the Contractor on an actual cost basis, the Supervising Engineer must show separately, for each job:

- the number of men engaged, the hours each man works, his classification and the rate of pay;
- the amounts of materials used and their cost to the Contractor at the work site;
- the make, class and other relevant particulars of each equipment item used, and the time worked by it; and
- a description and final measurement of the work completed.

The Supervising Engineer should indicate the source of his information for the items mentioned above and must check the items with the Contractor, or his Representative, who is required to acknowledge the correctness of the information by signing the record of work carried out.

On the first day of each costing period, the Supervising Engineer should send the original records for the previous costing period to the Engineer, and retain the carbon copy for his own use.

9.3.4 Payments

A comprehensive record of details for Progress Payments must be kept. This includes details of measured quantities, Variation Orders and Dayworks Orders. Details of the Contractor's calculations and the Supervising Engineer's calculations should also be kept on file.

9.3.5 Security

The Supervising Engineer must ensure that all reasonable precautions are taken to make his site office secure against breaking and entering. Particular attention should be paid to the security of valuable items, such as survey instruments and cameras, which should not be left in the office overnight or at weekends and public holidays. When the office is unoccupied for a long period, it must to be kept locked.

The Project dairies, contract correspondence, and copies of any reports to the Engineer must be treated as confidential and kept in locked drawers or cabinets when not in use.

9.4 TECHNICAL FORMS

Appendix I contains examples of standard technical forms which can be used for the supervision of bridgeworks.

Some of these forms relate to the results of standard tests carried out either by the Supervising Engineer and his staff on site or in the site laboratory or in other laboratories. Other forms relate to the results of inspections carried out by the Supervising Engineer and his staff during the project. Not all of the forms are required on every project and the Supervising Engineer will normally determine which forms are to be used and will summarise the requirements of the Specification as to *the types and frequency of testing* and inspection. Examples are the number of test specimens to be taken per cubic metre of concrete placed (obtained from the Specification) and the stages at which the Contractor's setting out is to be checked (a procedural requirement laid down by the Engineer or the Supervising Engineer).

The use of these forms is discussed in more detail in other sections of the Manual.

9.5 TEST RESULTS

Copies of all materials test results (for example soil compaction, aggregate gradings etc.) should be kept on site. Other important on-site measurements such as pile driving records, prestressing strand tensioning etc. should also be kept. These results confirm that the structure complies with the Specification and also serve as useful references if there are any future problems.

It is usual to give the Contractor a copy of all test results, both successful and unsuccessful, which enables him to modify his construction methods if necessary.

9.6 PHOTOGRAPHIC RECORDS

Regular dated photographs should be taken to build up a pictorial history of progress and to assist in providing evidence in the case of disputes.

Step-by-step photographs of innovating or interesting construction techniques are useful.

Video records are also valuable for photographic records.

9.7 JOINT INSPECTIONS

Joint inspections are inspections carried out jointly between the Engineer and the Contractor (or more usually between the Supervising Engineer's staff and the Contractor's staff).

Joint inspections offer several advantages over inspections carried out independently by the Engineer and the Contractor.

If the two parties agree that the method and location of testing is appropriate, then the results of such tests are normally beyond dispute.

Independent testing often gives rise to the argument that the tests were improperly carried out and/or that the locations of the tests were not representative of the element of work being tested.

In many instances the testing process involves considerable effort and independent tests may require repetition of such tests before agreement between the parties is reached.

The most useful application of joint inspections is in the area of measurement. If the Supervising Engineer and the Contractor carry out joint measurements and agree on the measurements then it is only the actual calculation of the quantity which can be in dispute. This usually requires considerably less effort to reconcile differences than repeating the whole measurement process.

The Supervising Engineer and his staff must resist the attempts of the Contractor to use these 'joint inspections' as an easy way to get work done by the Supervising Engineer. A particular instance of this is in setting-out the bridge works.

Notwithstanding the above, it must be remembered that ultimately it is the responsibility of the Engineer to inspect and measure the Works.

TABLE OF CONTENTS

10. PERIODIC REPORTING PROCEDURES

10.1 REPORTING BY THE SUPERVISING ENGINEER AND HIS STAFF

10.1.1 Progress Reports

The Supervising Engineer should, at monthly or other intervals directed by the Engineer, make a Progress Report with the required number of copies and in the appropriate format. He should retain one copy and forward the remaining copies to the Engineer.

The Report may be in the form of a brief written summary, supplemented by a reduced scale Drawing of the side elevation and plan of the bridge, coloured to show the work done to date.

Other records should also be sent to the Engineer, including weather records, plant and labour returns, productivity figures for the period being reported, copies of the daily diary and weekly summary, and any other items of significance. Details of Variations and design changes should also be included.

10.1.2 Progress and As-Constructed Drawings

The Supervising Engineer should mark progressively on his copy of the Drawings, or on progress charts, details of the work completed. He should also plot (in a distinctive colour) on his copy of the Drawings, all amendments to the Contract.

The amendments should be plotted and dimensioned so as to permit accurate computation from the Drawings alone of all extra or reduced quantities of material, excavation, etc., involved. On completion of each portion of the structure containing an extra or deduction, a separate computation should be recorded in duplicate in the Measurement Book and initialled by the Contractor or his Representative. Any additional work done by the Contractor for his own convenience and not ordered by the Engineer should be shown in the Measurement Book and separately marked on the Drawings. At the conclusion of the work, the Drawings must be forwarded to the Engineer who will arrange for the preparation of As-Constructed Drawings.

10.2 REPORTING BY THE ENGINEER

The Engineer's Representative should produce a Monthly Progress Report on the bridge or bridges being constructed and forward the required number of copies to the Engineer.

The general format of these Reports is as follows:

- Description of the Project
- Progress this month
- Status of each bridge in the project
- Monthly Certificate and Progress Payment

- Program for next month

Appendices:

- Location Map
- Projected and Actual Progress of Mobilisation
- Contractor's Equipment
- Contractor's Labour
- Projected and Actual Progress of Construction
- Contractor's Programme
- Record of Meteorological Data
- Summary of Change Orders
- Summary of Contractor's Claims
- Summary of Escalation Payments
- Summary of Dayworks Orders
- Summary of Contract Value
- Photographs of Project site(s)

This Report will be the only source of information about the project for many persons and the Report needs to be both complete and concise to provide details of the status of the construction works.

The Report should highlight any anticipated problems as well as any current problems.

TABLE OF CONTENTS

11. PREPARATION OF PROJECT COMPLETION REPORT

11.1 FINALISATION OF CONTRACT

11.1.1 General

At the end of the Contract the Engineer must ensure that all details of the Contract are finalised as quickly as possible.

11.1.2 Provisional Handover

On DGH contracts, it is usual to have a Provisional Handover Committee consisting of representatives from the Employer, the Engineer and the Contractor which carries out a formal inspection of the Works prior to the issue of the Certificate of Substantial or Practical Completion by the Engineer .

The Project Manager sends a standard letter to the Contractor and formally sets up the Committee. The Provisional Handover Committee issues a process-verbal (in one or more parts) setting out the results of the visual examination and quality control testing of the Works, and informs the Contractor as to the defects and deficiencies which require remedial action.

A grace period may be given to the Contractor to comply with these requests. A subsequent process-verbal declares that the Works are complete and nominates the date of Provisional Handover. This date marks the start of the Maintenance or Warranty period.

The process of inspection and repair of the Works is set out in the General Conditions of Contract.

A final measurement of the Works must be agreed and the Contractor paid any outstanding monies, including refund of Retention Money as required by the General Conditions of Contract. Generally a final Change Order is issued to include all Day Works, delete the balance of any remaining contingency items etc. and to confirm the final Contract Sum. If there are any matters of dispute still outstanding, payment should be made where possible without prejudicing the Employer's position and a statement of the position made so that any remaining action is then in the hands of the Contractor.

At the conclusion of the Contract the Engineer should ensure that the As-Constructed Drawings and the Bridge Completion Report have been finalised.

11.1.3 Final Handover

The only remaining matter to finalise the Contract is a thorough check of the job at the end of the Warranty Period. Any defects must be corrected by the Contractor. The Certificate of Final Completion is then issued and the balance of Retention Monies and Security or Maintenance Bond refunded to the Contractor.

11.2 AS-CONSTRUCTED DRAWINGS

The marked-up copies of the Supervising Engineer's Drawings are forwarded to the Engineer to allow preparation of the As-Constructed Drawings (Refer 10.1.2).

11.3 COMPLETION REPORT

A Bridge Completion Report is required for every individual bridge, regardless of the ease of its construction or the good performance of the Contractor.

The content of the Report will depend upon the nature of the bridge and the difficulties encountered in its construction. Simple bridges will only require the recording of essential details while complex bridges and Contracts with major variations will require extensive reporting.

Reports should generally be divided into four major sections as described below. Colour photographs of the completed structure should be attached, as well as photographs taken during significant stages of construction. A copy of the General Arrangement Drawing from the As-Constructed Drawings should also be attached.

The Bridge Completion Report will provide data on the completed structure for input to the Bridge Management System and reporting of costs, time of construction etc. will be contained on standard report forms for each bridge.

11.3.1 Contract Details

This section of the Report is a brief summary of the contract details in a form suitable for future reference or for incorporation into a database.

The details required are :

(a) Names of Contractor and approved sub-contractors. For combined road and bridge contracts, the Contractor listed should be the firm that actually constructed the bridge.

(b) Initial design criteria, type of contract and references to standards, codes and specifications etc.

(c) Cost of contract including details of increases in cost and factors related thereto.

(d) Changes in the scope of the Works during construction and the reason(s) for such changes.

(e) Original Construction Schedules and any deviation there from and the reasons for the deviations.

(f) Contract Period including approved extensions.

(g) Actual duration of the Contract.

This data will be required for each bridge and is to be filled out on standard report forms.

11.3.2 Construction Details

This section lists basic information for future reference.

Details required are :

(a) actual contract levels for piles and footings (an A3 copy of the relevant sheet of the As Constructed Drawings is satisfactory);

(b) any significant variation from the Drawings, such as deck levels, concrete strength, prestressing arrangement, etc which may affect future maintenance or upgrading of the bridge;

(c) details of actual items installed where approved alternatives are permitted by the Contract Documents, e.g. aluminium/steel railing, bearings, expansion joints and other proprietary items; and

(d) any instrumentation or permanent measuring devices installed on the bridge.

(e) soil and material data.

(f) technical problems and remedial measures taken.

11.3.3 Comments on Design and Construction

In this section are listed :

(a) any significant changes to the design or specified construction procedure which were approved, and the benefits

(b) any areas where changes to the design or specified construction procedure could have saved time, expense or unnecessary repairs;

(c) any construction difficulties for which there appear to be no practical solutions;

(d) any innovative construction procedures adopted by the Contractor. Photographs should be provided where appropriate; and

(e) any difficulties attributed to defects or omissions in the Bid Documents.

11.3.4 Comments on Contractor's Performance

If this section of the report is critical of the Contractor to such an extent that the Contractor's future prospects of work may be affected (by reduction of prequalification, for example), then it should be written as a separate, confidential supplement, personally signed by the Engineer. It should be noted, however, that any formal action proposed as a result of the Contractor's poor performance should be the subject of a completely separate submission.

The Contractor's performance should be assessed in the following areas :

(a) Organization and planning - was the Contractor able to complete the Works within the Contract Period (including approved extensions) and without causing excessive variations, and did the Contractor provide evidence of a sound planning base by supplying credible bar charts/programmes, etc throughout the Contract ?

(b) Physical capacity - did the Contractor supply appropriate plant and sufficient manpower to complete the contract on time ?

(c) Technical capacity - did the Contractor employ supervisors with sufficient technical expertise to ensure the work was carried out satisfactorily ?

(d) Attitude - did the Contractor approach the contract with a spirit of co-operation or confrontation ?

This section should conclude with a recommendation as to the suitability of the Contractor for future works. This recommendation could also address, with regard to the Contractor's performance, the appropriateness of the Contractor's current prequalification limit.

LIST OF REFERENCES

1. *Field Supervisor's Duties and Responsibilities - Volume II* (Contract Bridgeworks) NAASRA 1982

2. *Bridge Inspector's Handbook* Indonesian Australian Steel Bridge Project, 1987

3. *Civil Engineering Management* J M Antill, 1973

4. *Training Manual for Bridge Foremen* Department of Main Roads NSW, Australia, 1973

DIRECTORATE GENERAL OF HIGHWAYS
MINISTRY OF PUBLIC WORKS
REPUBLIC OF INDONESIA

BRIDGE CONSTRUCTION SUPERVISION MANUAL

PART 2

TECHNICAL ASPECTS OF CONSTRUCTION SUPERVISION

BRIDGE MANAGEMENT SYSTEM
BMS
A PROJECT JOINTLY FUNDED BY INDONESIA AND AUSTRALIA

JANUARY 1993

DOCUMENT No. **BMS9-M.E**

TABLE OF CONTENTS

PART 2

12. GENERAL ASPECTS OF TECHNICAL SUPERVISION OF BRIDGE CONSTRUCTION

Part 2 of the Construction Supervision Manual covers the technical supervision of bridge construction. Part 1 contains the administrative procedures and guidelines to be used for supervision of construction projects.

This Part of the Manual considers the major types of work associated with bridgeworks (replacement, rehabilitation or repair) and discusses some of the problems and solutions that arise in the normal course of construction. It is assumed that problems are not related to management of the project (these are addressed in Part 1) but that they are related to technical matters.

Several standard forms have been suggested for use by engineers and supervisors on bridge works. These forms cover the major areas of inspection which are carried out to ensure the quality standards required by the Specification and are included in Appendix I.

Not all of the forms are needed on every project and it is up to the Supervising Engineer to decide which forms are to be used and to assign responsibilities for the supervision and inspection of the different parts of the bridge works.

The following sections contain basic descriptions of various construction methods and techniques and the corresponding supervision and inspection required to ensure the finished product is of the required quality.

A more detailed description of some construction techniques and methods, many of which are specific to Indonesian practice and the types of bridges constructed in Indonesia, is included in the Bridge Construction Techniques Manual.

TABLE OF CONTENTS

13. SETTING-OUT OF BRIDGEWORKS

13. SETTING-OUT OF BRIDGEWORKS

13.1 INTRODUCTION

The construction of a bridge requires the construction of all its structural elements in the correct position.

The transformation of a design represented on a set of Drawings into a structure on the ground requires that :

- there must be a set of ground survey control marks the location of which is related to a consistent reference system;
- the bridge design must be related to the same reference system.

By measuring and levelling from the survey control marks, temporary site control marks can be established near the bridge site from which the final position of elements can be set out.

If the setting-out information shown on the Drawings is not clear or is ambiguous or is not in a form convenient for setting-out, the site engineer should refer the matter to the designer for clarification. The Contractor is responsible for the setting-out but the site engineer must ensure that the correct information is available to the Contractor and that sufficient control marks have been installed.

13.2 HORIZONTAL GEOMETRY

Horizontal geometry is based on either a control line system or a system of coordinates or sometimes a combination of both systems.

13.2.1 Control Line System

In this system, the setting-out geometry is related to a reference line which in many instances is the centreline of the bridge. Offset control lines may also be used.

Key points on the setting-out diagram are located by chainages, by offsets and by direct measurement of distances and angles along the reference line.

Control lines need not necessarily be straight; they often incorporate circular or spiral curvature. In these cases, a tabulation of the critical point coordinates, chainages, bearings and curvature data is included on the alignment drawings.

13.2.2 Coordinates System

In this system, coordinates define the key points on the setting-out diagram. To locate these positions in the field, distances from survey control marks are calculated using the 'northings' and 'eastings' (X and Y co-ordinates) specified.

13.3 VERTICAL GEOMETRY

Levels are determined from bench marks. Construction control bench marks may be placed either on a local datum or on an integrated datum.

The vertical geometry of the control line is usually defined. This information details the vertical tangent point chainages, finished surface levels and grades. Vertical curve geometry is often omitted if the vertical geometry is regular, and reduced levels are given at regular short intervals along the design lines.

13.4 SURVEY CONTROL MARKS

A survey control network is established to cover the whole site and marks are placed in positions appropriate to the construction involved. Distances between control marks should normally be of the order of 50 metres.

Survey control marks should be located close to the bridge site but clear of the works area to avoid disturbance by mobile plant and equipment. They should be checked regularly. Movement of survey control marks may also occur in tidal and reclaimed areas, in embankments overlying compressible soils, and in ground subject to large variation in moisture content.

13.5 SETTING-OUT OF STRUCTURAL ELEMENTS

13.5.1 General

The location of major elements such as abutments, piers, and the superstructure are defined relative to the adopted reference system.

Offset reference marks should be established for each pier and abutment. The position of each reference mark should be carefully described on site to provide convenient re-establishment of pier and abutment positions throughout the construction works, and so that they are unlikely to be disturbed.

Minor elements such as kerbs, parapets and drainage pits are set out relative to the major elements by measurement.

All setting-out of major elements must be checked. Check surveys should be independent ie. carried out by the Engineer's staff and using instruments other than those used in the original setting-out

It is also advisable for the Contractor to check his own setting-out using a method different from that originally used. To avoid errors of incorrect identification of pegs, incorrect marking or errors in the original survey, measurements of length and levels should be checked through the job from one end to the other and tied into the original survey. Measurements should not be made from one end only or from both ends separately.

The basic principles of surveying should always be used, particularly over large distances. Instruments should be levelled accurately and angles measured on both face-right and face-left. Survey instruments should be checked regularly for adjustment. In levelling, backsight and foresight distances should be approximately equal whenever possible.

13.5.2 Piles

Setting-out of foundations is critical. Dimensions such as distance between pile caps should always be checked in relation to the superstructure dimensions before commencing construction, particularly if the superstructure is not horizontal.

Special care should be taken when a control line is offset from the bridge centreline. Care should also be taken to ensure that skew angles are turned from the correct line especially when skews are between 40° and 50°.

Pile locations are normally defined at the plane of the underside of pile cap or abutment. Therefore, when setting-out raked piles, adjustment of the pile position at natural surface or pile frame location must be made to account for the level difference between the underside of pile cap or abutment and the natural surface or pile frame.

Control of pile location after driving has commenced is difficult and judgement is often required with initial set-up of raked piles to ensure that the driven position is located as specified. Raked piles tend to move in the direction of the rake with driving. They often tend to increase in rake. Adjustment to raked outer piles in a group may be warranted, to minimise the risk of the pile being too close to the edge of the pile cap necessitating *enlargement of the pile cap (see also Section 14). The first raked pile driven may be used* to check the amount of movement from the design rake.

13.5.3 Footings and Pile Caps

Reference lines should be established on the footing or pile cap centreline and the column centrelines. Reference points established before the pile driving commences should be rechecked after driving to ensure that no disturbance has occured.

The formwork for the starters or nibs of columns should be carefully set. If the column starter is located precisely and accurately dimensioned, verticality of the column can be controlled directly from the starter.

13.5.4 Columns

Verticality may be controlled from accurately-constructed column starters as described above, or with plumb lines, or where possible, with theodolite observations in two directions.

Spirit levels should not be used to check verticality. Plumb lines suspended over the full height of the column provide the best form of control and can even be used for the construction of taper columns.

Column height may be controlled by either tape measurement or by levelling.

13.5.5 Crosshead

The horizontal location of a crosshead may be set from fixed stations on the tops of columns using coordinates, or from centrelines transferred from the baseline by theodolite.

Soffit formwork is set using a level and staff, with allowance being made for expected settlement and deflection of falsework and formwork.

Bearing pedestals are sometimes cast monolithically with the crosshead, but because of the tight tolerances required in positioning pedestals, it is preferable to cast them after the crosshead. Where dowel holes are to be formed in the crosshead, these should be located carefully and checked using direct measurement from pier to pier to ensure the proper fitting of beams.

Except in special circumstances, the upper surface of bearing pedestals is horizontal. The reduced level of bearing pedestals to support prestressed concrete girders may require adjustment to account for unexpected variation in girder hog. (Refer to Section 13.5.8.)

13.5.6 Bearings

Bearings are accurately positioned on the bearing pedestals on which centreline marks have been previously established.

Some designs require beams or girders to be supported on temporary bearings. Setting-out of temporary bearings is carried out in the same way as permanent bearings.

13.5.7 Beams and Girders

Marks for setting-out beams are transferred from the ground to the crosshead.

For segmental girders post-tensioned on falsework, initial profiles should be specified on the Drawings to provide for the design profile after stressing.

Cast-in-place superstructures are set out from fixed stations on the crossheads of columns. For the level control of cast-in-place box girders, a grid is marked out on the soffit formwork which is adjusted while a staff is observed at the grid points. Allowance must be made for settlement and deflection of falsework and formwork.

13.5.8 Decks and Parapets

Horizontal deck geometry is set out from the centreline of the bridge transferred to convenient locations on permanent work such as crossheads, curtainwalls, deck slabs and so on.

The vertical profile of decks in which prestressed beams are used can vary from the design profile due to factors such as age of units, construction times and climatic conditions. To achieve the correct deck profile it may be necessary to adjust the design deck levels to account for variations in beam hog from design values, by adjusting the levels of bearing pedestals or varying the thickness of the deck slab. Any adjustment proposed must be approved to by the Engineer.

Where the vertical profile of the deck does not match the design profile, adjustment to the depth of kerbs and parapets may also be necessary to improve appearance.

Adjustments should be made for long term creep and shrinkage deflections as these can be significant.

When forming kerbs and parapets, it is good practice to extend and align formwork as far beyond the construction joint as practical, so that lines and levels set by measurement can be checked by eye.

Kerbs and parapets should not be set out until after the deck soffit formwork and falsework have been released and the resulting settlement taken place.

It is good practice to critically appraise lines by eye. Inspection may pick up errors in setting-out. A good 'rule-of-thumb' is that if a line or curve looks wrong, it is likely to be wrong.

TABLE OF CONTENTS

14. FOUNDATIONS

14.1 GENERAL

The capacity of a bridge to carry heavy traffic and to withstand the effects of floods etc., depends to a large degree on the integrity of its foundations. Although allowance is sometimes made for minor settlement in simply-supported bridges, large settlement of a pier or an abutment inevitably causes over-stress and damage to bridge elements. If a bridge has been designed as a continuous structure, settlement of the substructure may lead to a reversal of stresses in the bridge girders and the deck. If excessive, these settlements will result in damage to the structure.

The aim of the bridge builder is to construct unyielding foundations, a task that demands the utmost care during each stage of bridge foundation work. Precautions should be taken at the time of construction to prevent faults developing during the life of the bridge. It should be remembered that once a bridge is opened to traffic, repair or strengthening of its foundations is usually a difficult task.

Faults to be avoided include the following:

- the founding of friction piles at insufficient depth;
- the over-driving of piles founded on hard rock;
- the use of excessive driving energy when penetrating relatively soft ground, resulting in the cracking of concrete piles;
- damage to concrete piles caused by improper handling and pitching and driving methods;
- the corrosion of unprotected steel piling due to aggressive water or ground conditions;
- the corrosion of reinforcement resulting from insufficient concrete cover;
- instability in a pier or abutment caused by water flowing at high velocity and scouring material from around the piles or footings;
- the inclusion during construction, of zones of weak concrete or of foreign material during the casting of insitu piles;
- neglect of protective treatment of timber piles which may be subject to termite attack and marine borers;
- the shifting of foundations due to ground movement;
- settlement or rotation of spread footings due to insufficient bearing capacity or inadequate removal of loose or unsuitable material;
- the failure of piles due to down-drag caused by the settlement of approach embankments;

- the failure of expansion joints caused by clogging with foreign material, or the failure of bridge bearings resulting in overstress in the substructure.

14.2 SPREAD FOOTINGS

14.2.1 General

Spread footings, as distinct from piled foundations which transmit loads to greater depths, distribute load directly onto the soil at relatively shallow depths.

From the available geotechnical information, the designer determines the design bearing capacity of the soil or rock. This capacity is usually shown on the Drawings. Based on that value, the size of the footings is calculated. The bridge builder then has the responsibility to check that the foundation material on which the footings are to be constructed measures up to the designer's estimate of bearing capacity.

As a guide to field identification, "rule of thumb" methods for estimating the bearing capacity of non-cohesive soils, cohesive soils and rock, are given in Tables 14.2.1, 14.2.2 and 14.2.3 respectively.

It is emphasised that these estimated values should not be used for design purposes.

14.2.2 Soils

It may be necessary to make adjustment to the allowable bearing pressure to take account of the effects of the presence of groundwater, an adjacent slope, inclined or eccentric loads, and underlying softer soils.

When dealing with soils of lower strength (very soft to firm cohesive soils and very loose to medium dense cohesion soils), settlement and not bearing capacity may be the principle criterion governing the design.

Small instruments such as a pocket shear vane or pocket penetrometer may be useful in assessing the properties of cohesive materials.

14.2.3 Rock

The values given in Table 14.2.3 are for unfractured and generally defect-free rock. Reductions to the values must be made to account for clay seams, highly weathered zones and fracturing. Bearing pressures of the magnitude given in the Table should only be used in conjunction with unconfined compressive and point load tests.

14.2.4 *Trimming and Preparation Work*

Excavation is usually taken at least 150 mm into solid strata. After the base has been levelled and the sides of the excavation cut to the dimensions shown on the drawings, the bottom is swept and hosed to expose the surface for inspection. It may be necessary at this stage, for heavily loaded footings, to take cores below the base of the footings for examination. The recommended depth is 1.5 times the least dimension of the footings. These may be supplemented by small diameter drilled holes from which scrapings are taken. If the rock quality is in question, unconfined compression tests on cored samples may be required. In general, the heavier the loading on a footing, the greater is the need for proving tests. Visible clay seams in rock should be cleaned out and replaced with mass concrete. If poor quality material has to be removed from one area of a footing, the base of the footing should be stepped vertically, the stepped areas being infilled with mass concrete.

A 'blinding' layer of mass concrete, 50 mm thick, is often placed over the base of the footing excavation to form a clean level surface on which to commence construction. Provision should be made for drainage of the excavation by providing a sump below the footing level. If foundation material is self supporting, the footing can be cast directly against the sides of the excavation. In this instance, care is needed in carrying out the excavation to minimise overbreak.

Where footings are required to be keyed into the founding material to resist sliding, it is imperative that the key be cast directly against the sides of the excavation.

Precautions should be taken to prevent excavated or embankment material sliding into, or being washed by rainwater into the excavation, particularly after reinforcement has been placed. If formwork is to be used around the full perimeter of the footing, the blinding layer of concrete should be constructed accurately to shape, line and level. The side forms can then be placed hard-up against the edge of the concrete blinding layer. This practice speeds up construction and helps to minimise loss of mortar at the base of the formwork during concreting.

Table 14.2.1. - Non-Cohesive Materials (Gravels and Clean Sands)

Density	Rule of Thumb Field Identification	Allowable Bearing Pressure (kPa)
Very Loose	Almost no resistance to shovelling	50
Loose	Easily penetrated with 12 mm bar pushed by hand. Small resistance to shovelling.	50 to 100
Medium Dense	Easily penetrated with 12 mm bar driven with 2kg hammer. Considerable resistance to shovelling.	100 to 200
Dense	Hard penetration with 12 mm bar to 300 mm, driven with 2 kg hammer. Hand pick required for excavation.	200 to 350
Very Dense	Penetration only up to 75 mm with 12 mm bar driven with 2 kg hammer. Power tools required for excavation.	350 to 600

Table 14.2.2. - Cohesive Materials (Silts, Clays, Sandy Clays)

Consistency	Rule of Thumb Identification	Allowable Bearing Pressure (kPa)
Very Soft	Easily moulded by fingers. Distinct heel marks lef on freshly exposed surface. Geologist's pick can be easily pushed up to its handle.	25
Soft	Easily penetrated with thumb. Moulded with strong pressure. Faint heel marks on freshly exposed surface. Geologist's pick (sharp end) can be pushed in up to 30 mm or 40 mm.	25 to 50
Firm	Indent by thumb with effort. Very difficult to mould with fingers. Geologist's pick (sharp end) can be pushed up to 10 mm Slight penetration with hand spade.	50 to 100
Stiff	Penetration by thumb nail. Cannot be moulded with fingers. Geologist's pick (sharp end) makes slight indentation when pushed. Hand pick required for excavation.	100 to 200
Very Stiff	Indentation by thumb nail difficult. Slight indentation with blow of geologist's pick (sharp end). Power tools required for excavation.	200 to 400
Hard		400

Table 14.2.3. - Rocks

Description	Rule of Thumb Field Identification	Allowable Bearing Pressure (kPa)
Very Soft	Material crumbles under firm (moderate) blows with geologist's pick (sharp end). Can be peeled off with knife.	1500
Soft	Indentation 1 mm to 3 mm with firm (moderate) blows of geologist's [sharp end]. Can just be peeled and scraped with knife.	1500 to 2500
Hard	Hand held specimen can be broken with hammer end of geologist's pick with single firm (moderate). Cannot be scraped or peeled with knife.	2500 to 3500
Very Hard	Hand held specimen breaks with hammer end of geologist's pick with more than one blow.	3500 to 5000
Extremely Hard	Hand held specimen requires many blows with geologist's pick to break through intact material.	5000
Note : Many variables can effect allowable bearing pressure in rock. Therefore, this Table should be referred to with discretion.		

14.3 DRIVEN PILES

14.3.1 Dynamic Formulae

Many different equations have been developed in an attempt to predict the ultimate capacity of a pile while it is being driven into the ground at the site. None of the equations is consistently reliable or reliable over a wide range of pile capacity.

Most practical pile driving formulae are simplifications of a general equation and contain a number of empirical "constants" and coefficients.

The traditional method of predicting pile capacity by dynamic means has been to drive a pile, record the driving history and then load test the pile. More recently methods of instrumenting the pile and carrying out complex calculations using a computer while driving is in progress have offered a viable alternative.

After the ultimate capacity of the pile has been calculated, a suitable factor of safety is chosen to determine an estimate of working capacity. The choice of the factor of safety is itself open to question and wherever possible it should be determined by the Designer.

The Danish formula is often specified for the calculation of ultimate pile capacity. It is recognised as being one of the most reliable formulae used to predict ultimate pile capacity.

The ultimate capacity may be calculated as

$$R_u = \frac{e \times H \times W_r}{s + (0.5 \times s_0)} \quad \textit{where} \quad s_0 = 1000 \times \sqrt{\frac{2 \times e \times H \times W_r \times l_p}{A \times E}}$$

where:	R_u	=	Ultimate pile capacity in kiloNewtons
	W_r	=	Weight of ram in Newtons (9.81 x Mass of ram in kilograms)
	H	=	Height of free fall of hammer in metres
	e	=	Efficiency of fall of hammer
	E	=	Modulus of Elasticity of the material of the pile (in MegaPascals)
	l_p	=	Length of pile in metres
	A	=	Cross sectional area of the pile in square millimetres
	s	=	Final set of pile in millimetres per blow using an average of 10 consecutive driving blows, or the first 5 full retest blows
	s_0	=	Temporary compression allowance in millimetres as calculated from the above formula

For diesel or steam hammers, the rated hammer energy (in Newton metres or Joules) may be used for the product W_rxH. The value of l_p is the actual length of the pile for lengths greater than twenty times the cross sectional dimension of the pile. For smaller lengths, l_p is taken as 20 times the value of the cross sectional dimension of the pile. A for a steel pipe pile is the area of the steel pipe.

The values of the coefficients e and E, which are dependent upon the type of equipment used and the batter of piles, are given in the Specification as:

e	=	0.75 for drop hammers
e	=	0.90 for steam hammers
e	=	0.95 for diesel hammers
E	=	21 000 MPa (2.1 x 10^5 kg/cm^2) for concrete piles
E	=	210 000 MPa (2.1 x 10^6 kg/cm^2) for steel piles

This formula is based on the pile being driven vertically. If the pile is being driven on a rake, allowance must be made for both the reduction in the vertical force exerted by the hammer, and the loss due to friction between the hammer and the leads.

A reasonable estimate of the coefficient of friction is 0.10.

The net value of W_r is thus : W_r x (cos[arctan(1/R)] - 0.1 x sin[arctan(1/R)]) for a pile driven with a rake of 1 in R. This is illustrated in Figure 14.1.

eg, where the pile is driven on a rake of 1 in 10 (1 horizontal to 10 vertical), the value of W_r is 0.985 times the actual weight of the hammer.

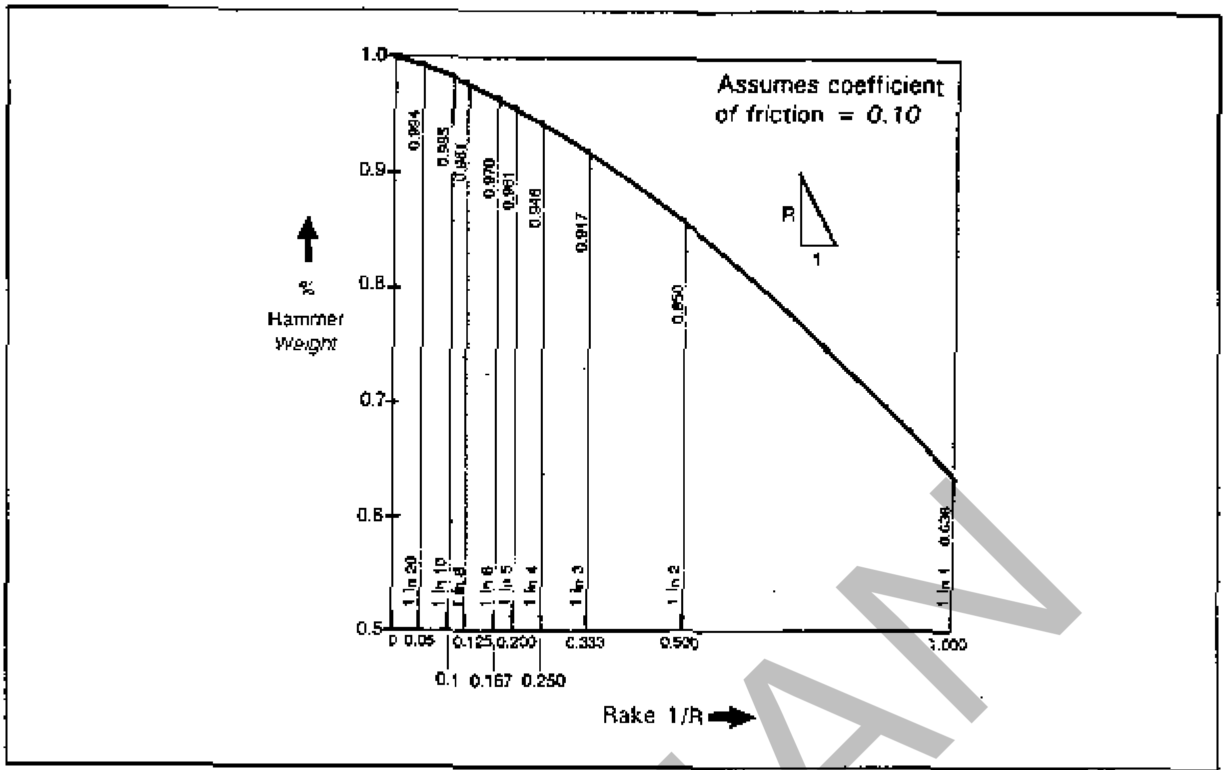


Figure 14.1 - Reduction in W_t for a rake of 1 in R

14.3.2 Pile Driving Operations

a. Selection of Equipment

The equipment to be used to drive steel, concrete or timber piles is basically independent of the type of pile.

In general, the basic equipment comprises :

(i) leaders to support the pile and provide guidance during driving;

(ii) a pile driving frame to support the leaders;

(iii) a hammer - drop, steam, compressed air or diesel powered;

(iv) a pile helmet, which may also be guided, to transmit the blow of the hammer to the pile;

(v) winches or a crane to lift the pile into position and to raise the hammer.

Mobile equipment is generally used for driving of piles on land, although stationary pile frames are still used in some instances.

i. Stationary Pile Frame

Pile frames comprise a tower with a set of leaders and a winch. They are normally of low capital cost but are awkward to set up, move and operate and therefore result in a slow rate of progress. The leaders must be sufficiently high to take the pile and the hammer plus an allowance for hammer drop.

The frames can be of timber or steel construction and are often custom built to suit a particular job. The leaders may be fixed for either vertical or raked driving or adjustable to allow both. Guy ropes are often used to set up and stabilise the tower over the pile position and to hold the leaders firmly in place during driving.

ii. Mobile Crane with Hanging Leaders

This system usually comprises a tracked crane with a set of steel pile leaders or guides hung from the boom. The base of the leaders is braced back to the crane by an adjustable stay. The crane must be able to position the pile hammer in the leaders and to lift and position the pile under the hammer. This usually requires the use of a large capacity crane as the leaders, pile and hammer must all be lifted into position.

A sketch of a typical mobile pile-driver is shown in Figure 14.2.

The pile is positioned under the hammer with the leaders resting on the ground on timber supports. The unit is thus completely self-contained. In some instances, and for safety of operation especially with long piles, a second mobile crane is used to assist with lifting the pile into position under the hammer. The tracked pile driver can also be operated from a barge if the tracks are securely bolted or chained to the deck.

In operating a diesel hammer on raking hanging leaders, the leaders must have sufficient rigidity to prevent bowing (due to the weight of the hammer) when the hammer reaches the midpoint of the leaders or when the trip mechanism does not operate.

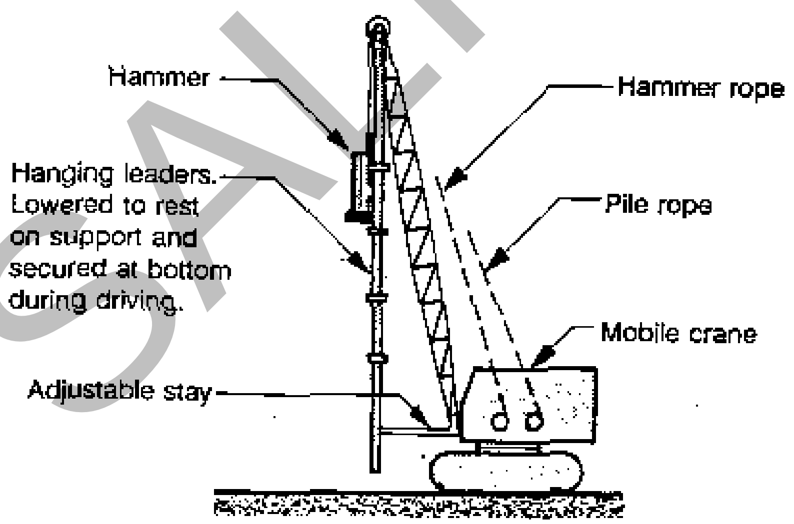


Figure 14.2 - Typical mobile pile driver

iii. Pile Hammers

Regardless of the type of pile, it is essential to use a hammer large enough to overcome the inertia of the pile. For efficient and economical pile driving, a substantial part of the kinetic energy should be available to drive the pile into the ground after deducting losses due to impact and other causes.

Drop hammers and diesel hammers are the most common types used.

Drop Hammers

Drop hammers have a relatively low capital cost and virtually no maintenance. The energy input is readily calculated as the product of the hammer weight, the height of fall and an efficiency factor which is dependent on the method of operation of the hammer. A trigger release operation approximating a free fall of the hammer is more efficient than a winch operated fall.

Hammers are made in a variety of shapes and are manufactured from large blocks of cast iron or steel or of laminated steel sections which allow for adjustment of the weight of the hammer by the removal or addition of plates.

Some hammers are guided by slots cast into the sides of the block, others from a projection at the back which fits between the leader guides. For the latter, two horizontal *timber "keepers" are driven tightly through two holes cast in the rear projection.* Sometimes a steel plate and retainer bolts are used.

Drop hammers are available in a variety of sizes from 0.5 to 8 tonnes. The final selection will depend on the weight and size of the pile to be driven. The hammer is suspended by a rope attached to the top, hoisted by a winch to a pre-determined height and then released to drop onto the head of the pile.

Every hammer should be clearly marked with its weight.

The ratio of drop hammer weight to pile weight recommended for steel and reinforced concrete piles is as follows:

- Piles up to 7.5 tonnes - hammer to pile ratio minimum two thirds.
- Piles 7.5 to 12 tonnes - hammer to pile ratio minimum one half.

For reinforced concrete piles up to 7.5 tonnes weight the product of the distance the hammer drops freely in metres and the weight of the hammer in tonnes should not exceed 5 metre-tonnes. For steel and heavier concrete piles the maximum energy may be determined by the Engineer.

For timber and prestressed concrete piles the weight of the drop hammer should be approximately that of the pile.

Diesel Hammers

Diesel hammers have a higher initial capital outlay than drop hammers and do require maintenance, but with a driving rate of 45 to 60 blows per minute are usually faster and more economical for larger piling works. The length of stroke is directly proportional to the pile resistance. The harder the driving, the more energy is exerted by the hammer. Extremely soft driving can be a problem because the lack of resistance means that the hammer cannot reactivate itself. In such cases the hammer is lifted and dropped by crane until firmer driving is encountered, sufficient to activate the hammer.

Diesel hammers have a vertical cylinder open at the top in which a ram moves up and down. At the lower end is an anvil. The ancillary equipment includes a fuel tank, a fuel pump, a tripping device and (on some models) a water jacket for cooling the cylinder.

The method of operation of a diesel hammer is explained in most of the proprietary handbooks and is shown in Figure 14.3. Note that some hammers have provision for varying the energy input by throttling the fuel supply.

The recommended hammer size for a diesel hammer is determined by choosing a hammer with a ram weight not less than one third of the weight of the pile being driven.

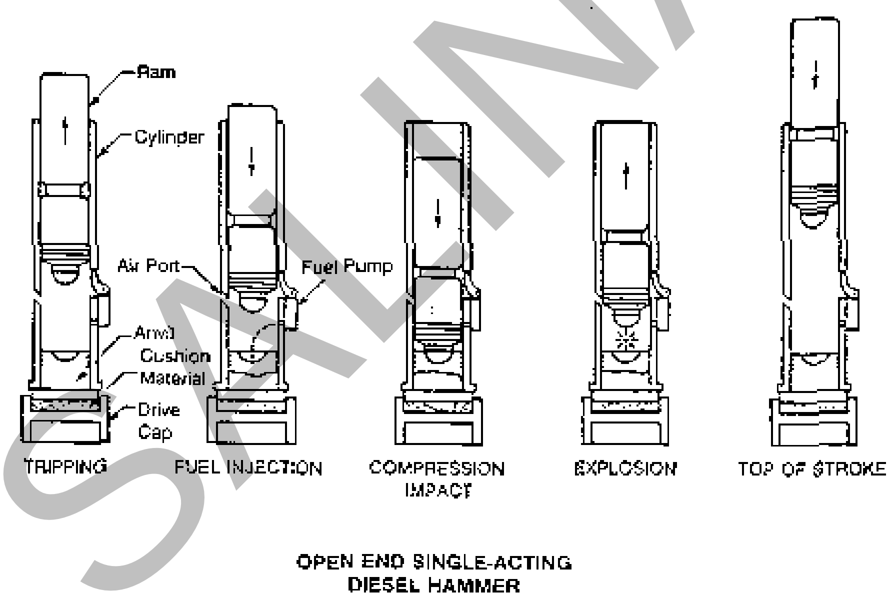


Figure 14.3 - Operation of Diesel Pile Hammer

A list of the characteristics of some of the more common makes of diesel hammer is given in Table 14.3.1.

Table 14.3.1 - Characteristics of Piling Hammers

Maker	Type	Mass of Ram	Energy of blow	Maximum striking rate
		(kg)	(N-m)	(Blows per minute)
Delmag	D12	1 250	31 000	40 - 60
(Germany)	D22	2 700	55 000	40 - 60
	D30	3 000	33 000 - 75 000	39 - 60
	D36	3 600	42 000 - 102 000	37 - 53
Kobe	K13	1 300	37 000	40 - 60
(Japan)	K25	2 500	75 000	39 - 60
	K35	3 500	105 000	39 - 60
	K45	4 500	135 000	39 - 60
Mitsubishi	M14	1 350	36 000	42 - 60
(Japan)	M23	2 295	60 000	42 - 60
	M33	3 290	88 500	40 - 60
	M43	4 290	116 000	40 - 60

iv. Helmets and Dollies

Helmets

The helmet is the steel block used to protect the head of the pile during driving. Suitable packing is placed in the top of the helmet to act as a cushion between the hammer and the pile and to distribute the blow over the full area of the pile head. This is usually referred to as the 'cap block' although occasionally it may be called the 'dolly' (see below for alternative meaning of dolly).

The helmet is manufactured to suit the type of pile being driven and may comprise a horizontal 50 mm thick steel plate with 25 mm thick steel boxed sides extending 300 mm above and below the strike plate. The helmet must be loose-fitting on the pile to avoid inducing stresses in the pile if it rotates during driving. The upper cavity of the box is tightly packed with hardwood timber, Novasteen or Micarta blocks with the end grain exposed to the hammer (the cap block). Timber should never be used such that the hammer falls perpendicular to the end grain as pieces of timber may fly off and act as small missiles.

Protection to the head of concrete piles must be provided by at least 150 mm of packing. This may be oregon or pine or similar softwood boards, coiled manila rope, layers of rubber belting, hessian bags, bags of sawdust or layers of caneite. Depending on the duration and hardness of driving the packing may need replacing after the driving of each pile. Steel or timber piles do not require packing to the head of the pile.

The helmet should have suitable lifting lugs attached to allow easy installation and removal.

A typical capblock and helmet arrangement for a concrete pile is shown in Figure 14.4.

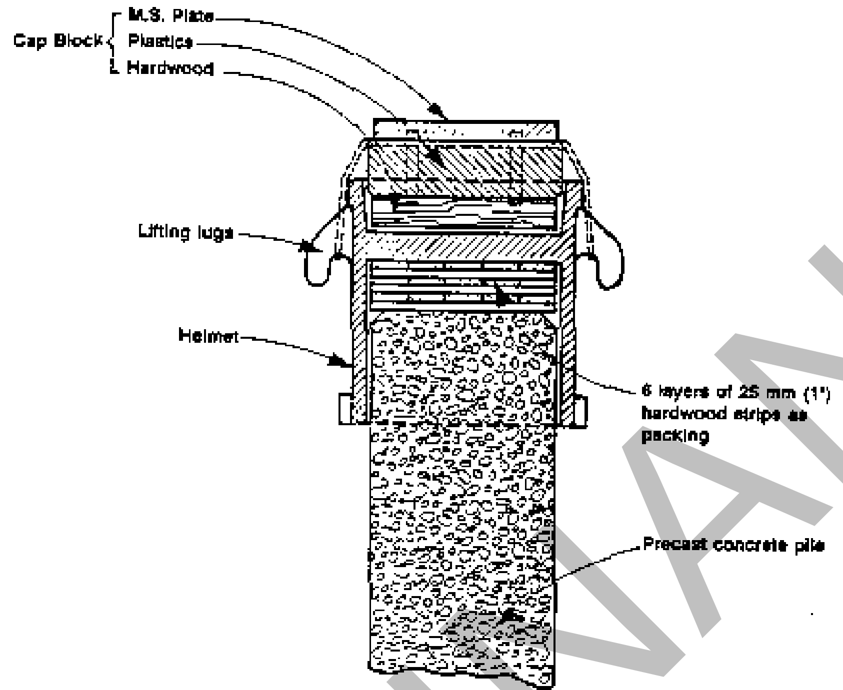


Figure 14.4 - Typical Cap Block and Helmet for precast concrete pile

Dollies

The dolly (or follower) is a temporary extension to a pile to enable it to be driven below water or below ground. The dolly fits into a helmet on top of the pile and may be made of round hardwood timber or of steel. Where possible the use of a dolly should be avoided as some loss of energy occurs at the dolly to pile connection and the "articulated" joint can lead to loss of directional control.

Some pile leaders have provision for bolting short extension pieces below the bottom of the leaders to allow the helmet and hammer to travel down below the normal end of travel. This should really only be carried out if it is considered that the pile will achieve the required set before penetrating too far into the ground to easily splice.

v. Water Jetting Equipment

Water jetting equipment can be used to aid penetration of piles in compact sandy soils.

A steel pipe is pushed down next to the pile, as the pile is driven, and connected to a water supply. The pipe is usually 30 to 50 mm in diameter with a 10 to 15 mm nozzle at the lower end.

The jet is positioned at the toe of the pile to loosen the soil ahead of the pile thus allowing the pile to penetrate under its own weight or with only light driving.

Often two or more jets around the perimeter of the pile are used to provide better control over the alignment of the pile.

A pipe can also be cast centrally into a precast concrete pile to direct water to four jets, one in each face of the tapered point. The pipe is fitted with a 90 degree bend approximately one metre below the head of the pile for supply of water under pressure to the jets.

Jetting should be discontinued about 0.5 m above the final toe level and the pile then driven to its final position.

Suitable water flow rates for jetting are in the order of 7.5 litres per second per nozzle at a pressure of about 70 kPa measured at the nozzle.

b. Pre-boring

The pre-boring of holes with mechanical augers is now a common procedure as an aid to founding piles at specified depths, and to achieve greater accuracy in driving. The drilling operation must be done with accuracy as to position, verticality and rake, and to pre-determined depths. The diameter of the holes must not be greater than the diagonal dimension of the pile less 50 mm. Over-depth drilling must be avoided. The final depth may have to be decided by experiment. The aim is to achieve the specified set or refusal, when the toe of the pile reaches the design level. It is normal for pre-boring to cease one metre above design toe level. On completion of driving, cavities around the pile are filled-in with clean sand, shovelled in, while being hosed or otherwise inundated with water.

c. Equipment for Cast-in-Place Piles

i. Driven and Cast-in-Place Piles

The rigs used to install driven and cast-in-place piles are similar in most respects to the types previously described but modifications are often made to suit the specific requirements of the different proprietary types of piles.

The piling tubes are of heavy section, usually designed to be driven from the top by drop or diesel hammers but Franki piles are driven by an internal drop hammer. The leaders of the piling frames are often adapted to incorporate guides for a concreting skip.

Driven steel-cased piles, designed to be filled with concrete, are driven more effectively by a hammer operating from the top than by an internal drop hammer acting on a plug of concrete at the base. In addition top driven piles can be driven open-ended which greatly reduces the end bearing resistance during driving.

ii. Bored and Cast-in-Place Piles

Drilling equipment is usually crane or truck mounted but special purpose barge or sled mounted equipment is sometimes used. The depth of the hole is limited by the length of the kelly bar (rod supporting excavation tool at base of hole) and 50 metres is usually a practical maximum value.

The depth and diameter of holes which can be drilled are dependent on the system of drilling used and the power of the driving equipment. Rotary excavation using augers and drilling buckets is the quickest and most economical method when ground conditions permit. They are suitable for installing bored piles in clay soils and may be used in open or lined excavations or under bentonite for soft rock and material other than rock.

Various types of bucket are available for use with rotary augers. The standard type has scoop bladed openings fitted with projecting teeth. The rock bucket has a large opening designed to pick up rock broken by raising and lowering the chopping bit on the kelly bar.

Enlarged or under reamed bases can be cut by rotating a belling bucket within the previously drilled straight sided shaft.

Special rotary drilling equipment is required for excavation in rock. An alternative is to use cable tool equipment employing rock chisels, bailing buckets for slurry removal and clamshell grabs. There are many types of cable tools available to suit various uses and they have the advantage that they may be operated at great depths.

14.3.3 Pile Groups

If a number of piles are to be driven in a group, it will be found that the driving of the first piles affects the driving of subsequent piles. This is particularly so if piles are being driven into tight sand. In these circumstances, each successive pile may pull up shallower than the previous pile. As a general rule, piles in a group in sandy soils should be driven starting with those piles nearest to the centre of the group and progressing outwards.

14.3.4 Difficult Ground and Obstacles

a. Hard Uniform Ground

Claystone strata and some shales, while readily augured, may resist pile driving. Pre-boring is then a prerequisite to the driving of the piles.

b. Gravels

Alluvial gravels or gravels with clay-sand matrix may prove difficult to penetrate with displacement piles and may require pre-boring with special equipment and the use of temporary or disposable casing of the holes to reach acceptable depths. Their presence may even require a radical piling solution such as a change from concrete to steel displacement piles or the use of cast-in-situ piling.

c. Sands

Pure sands can present the most difficult ground to penetrate with a driven displacement pile. The jetting of piles may be the only solution to achieving suitable depths.

d. Buried Timber

Buried logs are identified when a noticeable rebound is encountered during driving. They may require removal or alternatively it may be possible to split or break the timber with a heavy steel chisel. In some circumstances, it may be possible to shatter the timber by a small explosive charge. As a last resort the pile may have to be relocated to avoid the obstruction.

e. Floaters

These are isolated hard boulders generally foreign to the strata. The solution to overcoming these obstacles is similar to that for buried timber.

f. Downdrag

Downdrag on a pile occurs after driving whenever the surrounding soils settles relative to the pile. The magnitude of the effect may be increased if additional fill is placed on an *embankment after pile driving through it has ceased. Downdrag may also occur if the* ground water level is lowered. Downdrag tends to reduce the maximum allowable load the pile can carry. Placing of fill for abutments should be completed well in advance of pile driving.

g. Heave

Driving of groups of piles can result in significant soil heave at the ground surface as well as causing uplift on piles due to subsequent driving of adjacent piles.

Level checks should therefore be made on each pile after driving and again after driving of neighboring piles. Any pile found to have risen significantly must be redriven to its original depth.

14.3.5 Final Location of Piles in Group

On completion of driving of the piles in a group, the Contractor should be requested to prepare and submit to the Engineer a plan showing the location of each pile where it meets the underside of the pile cap and the final cut-off level of the pile head. This is to allow the Supervising Engineer to check that all piles have been driven within the specified tolerances and will be completely enclosed by the pile cap and that sufficient length of pile will enter from the under side of the pile cap to the design cut-off level.

Any proposed adjustment to the size of the pile cap, additional pile length to be spliced etc, must be approved by the Engineer and will usually be at the Contractor's expense.

Piles which have been driven outside the required tolerance may be accepted provided the pile cap is enlarged and/or splices made to the driven piles to allow sufficient encasement inside the pile cap. This work would normally be at the Contractor's expense.

14.4 BORED AND CAST IN PLACE PILES

Bored piles are non-displacement piles, installed by first removing the soil by a drilling process (see Section 14.3.2.c) and then constructing the pile by placing concrete or some other structural element in the drilled hole. The simplest form of construction consists of drilling an unlined hole and filling it with concrete. However complications often arise (for example difficult ground conditions, presence of water etc.) and the hole must be supported prior to the placement of concrete, typically by lining with a steel tube.

In stable ground an unlined hole can be drilled by hand or mechanical auger. If reinforcement is required a light cage is then placed in the hole and the concrete placed. In many soils, casing is needed to support the sides of the borehole.

In some cases, especially in stiff clays and weak rocks, an enlarged base can be formed to increase the end bearing resistance of the piles. This enlargement may be formed by hand excavation or by a rotating expanding tool. The size of under-reamed holes excavated by hand is limited by the practical considerations of supporting the sloping sides of the base.

Where the base of a pile cannot be cleaned by hand (eg. under water or in bentonite), the pile base may be cleaned with air lifting equipment.

For reasons of economy and the need to develop skin friction on the shaft, it is the normal practice to withdraw the casing during or after placing the concrete. This procedure needs care and conscientious workmanship to prevent the concrete being lifted by the casing and thus resulting in voids in the shaft or inclusion of collapsed soil.

Reinforcement in bored piles is needed if uplift is to be resisted. The spacing between the reinforcing bars must be sufficiently large to ensure that the concrete does not jam between bars.

14.5 WELL CAISSON CONSTRUCTION

A caisson is a structure which forms part of the permanent works, comprising one or more vertical wells. It may be constructed of steel, reinforced concrete, or precast concrete sections, progressively stressed together. Concrete is normally preferable, because its greater weight assists in the sinking of the structure to the required depth. The majority of caissons used on bridgeworks in Indonesia are reinforced concrete with relatively thick walls. The area of the caisson in relation to that of the superstructure it is to carry must be sufficient to permit some deviation from its true location during the sinking process, for it is virtually impossible to sink a long caisson precisely in its correct location.

Caissons are classified according to type. An open caisson has the wells open at the top and bottom during sinking. Its stability depends upon the friction between its sides and the surrounding soils. When sunk to the required depth, the bottoms of the wells are sealed with concrete plugs to increase stability. A typical example of an open caisson in common use in Indonesia is shown in Figure 14.5.

A box caisson is closed at the bottom and open at the top, and is merely a variation of the suspended cofferdam (see Section 22). Box caissons are usually precast concrete structures which are floated into position, sunk and then filled with ballast.

Open caissons may be sunk to any depth through suitable ground. Soft rock or larger boulders and stiff clay present difficulties and the caissons are usually sunk by dredging from the inside, usually by means of a grab. In extreme cases the material may require drilling or even socketing. In these cases, it is apparent that a caisson foundation is not the best choice of foundation type.

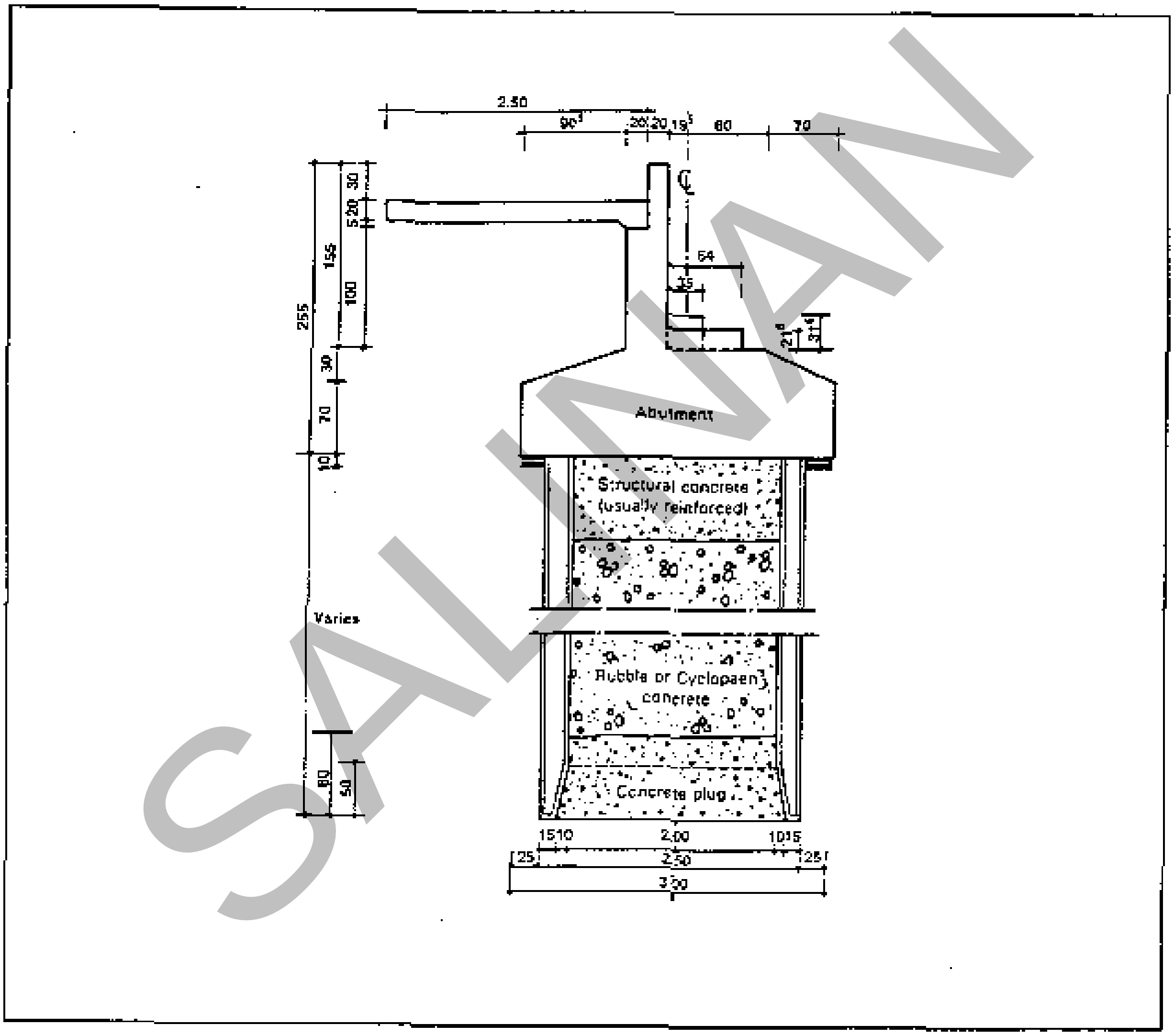


Figure 14.5 - Typical Caisson

The sides of a caisson must be parallel and straight, and its cross-section accurately maintained, to avoid overstressing and running off position during sinking. The walls must be designed to withstand all possible stresses during the sinking process. The lower end, which is known as the cutting edge, usually has the walls tapered in thickness to assist penetration into the ground. This section of wall is more heavily reinforced and often protected with a steel shoe. The actual width of wall presented to the ground depends upon the expected nature of the strata - it must be sharp enough to cut into the ground, but should present sufficient width to prevent the caisson from uncontrolled sinking.

Skin friction is not directly related to the type of soil encountered, and is usually assumed to be in the range 10 to 25 kPa. This friction is of course reduced by the passage of water or air between the outside wall of the caisson and the surrounding ground. It will be increased if the caisson is stationary for any considerable length of time, and undercutting of the cutting edge plus high pressure jetting may be required to enable sinking to recommence.

Whether the caisson is sunk through water or on land, the site must be levelled and cleared of obstructions, and the caisson built as high as practicable before excavation begins. Thereafter the excavation is carried out as uniformly as possible, and should not be taken any further below the cutting edge than is necessary to keep the caisson moving downward uniformly. As the caisson sinks, it is built upwards, thus adding weight to assist the operation. If necessary, additional weight or kentledge (for example steel reinforcement bars or concrete blocks) can be added to help in overcoming skin friction. If jets are used, caution must be exercised to avoid causing the caisson to "run". When the top of the completed portion approaches ground level a further section of concrete is cast on, and the process is repeated until the caisson has reached the required depth.

When the caisson has reached the required depth the base of the excavation is smoothed off as evenly as possible and the concrete floor placed. If the interior of the open caisson cannot be dewatered, a concrete seal is first poured by tremie (or other suitable underwater process), and the floor proper placed on top of this concrete seal. When dewatering of the open caisson is feasible, it may be achieved by direct pumping and the whole floor may then be placed in the dry. Caissons may be sunk as a simple open cylinder or alternatively, the compartments may be constructed as part of the caisson, thus dividing it into separate wells. The latter method has distinct advantages in ground liable to blow in, for the partition walls prevent the blow in from spreading into other wells.

A more detailed description of caisson construction is included in the Construction Techniques Manual.

TABLE OF CONTENTS

15. CONCRETE

15. CONCRETE

15.1 BASIC PRINCIPLES OF REINFORCED CONCRETE

15.1.1 General

There are many structural requirements for which plain concrete does not give the most satisfactory solution. Reinforced concrete is able to meet many more loading conditions than plain concrete. It can also be used to limit deflections and to reduce the size of cracks.

While the designing and detailing of reinforcement is the job of the design engineer, it is important that those who supervise the fixing of reinforcement of the job site have an appreciation of the basic principles of reinforced concrete. This will help them to understand why it is necessary that reinforcement is correctly handled and correctly fixed in the position indicated on the Drawings.

Reinforced concrete is a building material which is designed to combine concrete and steel into one structural entity in such a manner as to use the characteristics of each of these materials to the best advantage.

Characteristics of Concrete:

- Plastic and mouldable when fresh
- High compressive strength when hard
- Low tensile strength
- High resistance to fire
- Inexpensive.

Characteristics of Steel:

- Can be made into rods suitable for embedding in concrete
- High compressive strength
- High tensile strength
- Low resistance to fire
- Expensive.

The aim of the reinforced concrete designer is to combine steel reinforcement with concrete in such a manner that just enough of the expensive steel is used to resist tension forces and excess shear forces, while the comparatively inexpensive concrete is used to resist compressive forces.

Steel and concrete combine together successfully because:

- Upon hardening, concrete bonds firmly to steel reinforcement and the two act as though they are one when a load is applied. This means that any tendency for the concrete to stretch and crack in a region of tensile stress can be directly counteracted by steel rods embedded in that area.

- When subjected to changes in temperature, concrete and steel expand or contract by similar amounts. If this were not so, they would separate because of differential expansion and no longer act as one material. If this occurred, the lack of bond between concrete and steel would prevent tensile stresses in the concrete being transferred to the steel reinforcement and the concrete would crack and collapse.

- Concrete, having a high resistance to damage by fire, protects the steel reinforcement embedded in it, preventing it from losing its strength at high temperatures.

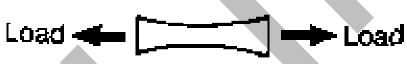
15.1.2 Types of Stresses found in a Structure

The following are the principal types of stress which develop in structural members:

a. Compression

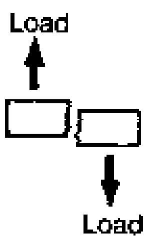
Compressive stresses tend to cause concrete to crush.

b. Tension



Tensile stresses tend to cause concrete to stretch and crack.

c. Shear



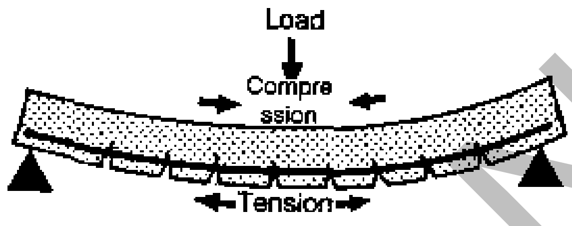
Shear stresses tend to cause sliding between adjacent sections of concrete.

15.1.3 The Design of Reinforced Concrete

The designer of a structure examines how it deflects under the design load. He determines where tensile stresses and excessive shear stresses occur, and determines the area of steel reinforcement to be placed in these areas to resist these stresses.

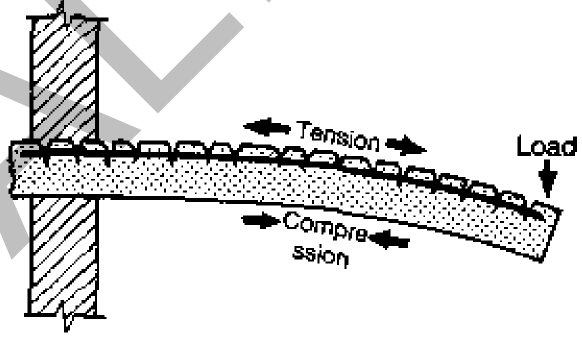
An examination of how the following structures bend shows where reinforcement should be placed to resist tensile cracking.

a. **Simply Supported Beam or Slab**



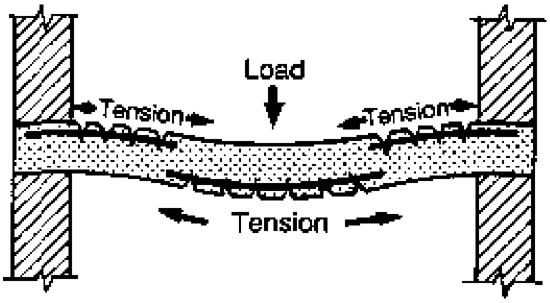
When a simply supported beam is either centrally or uniformly loaded, it tends to bend as indicated in the diagram. This causes the top to compress and the bottom to stretch. Steel reinforcement is therefore placed near the bottom of a simply supported beam or slab to prevent tensile cracking.

b. **Simple Cantilever**



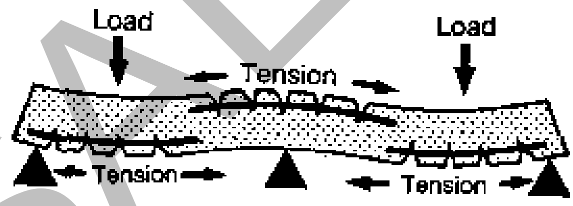
When a cantilever beam or slab is loaded as shown in the diagrams, it tends to bend downwards, as indicated. This causes the top of the beam to stretch (tension) and the *bottom to compress. Steel reinforcement is therefore placed in the top of the cantilever* to resist tensile cracking.

c. **Fixed Ended Beam**



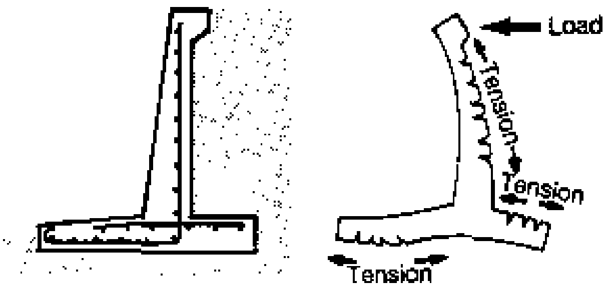
A fixed ended beam is held rigid at its ends and tends to bend as indicated in the diagram. Tension will occur in the top of the beam close to the supports. Steel reinforcement must therefore be placed near to the top of a beam at fixed supports (see diagram). The centre of the beam tends to sag causing tension in the bottom. Steel reinforcement must also be placed here.

d. **Two-Span Beam or Slab**



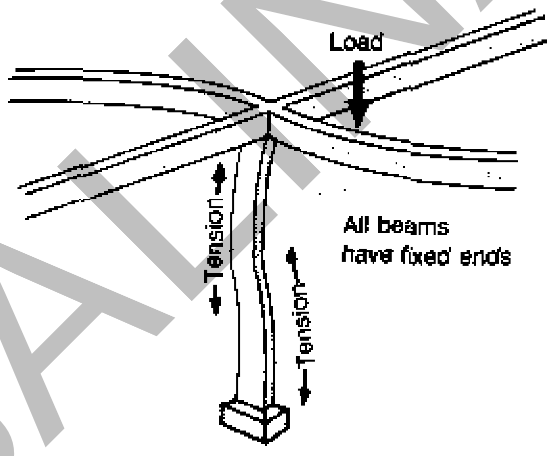
If both spans are loaded, a two-span beam will tend to bend to the shape indicated in the diagram. Above the central support, this bending will cause the top of the beam to stretch and the bottom to compress. Steel reinforcement must therefore be placed in the top of a beam or slab over intermediate supports. The centres of the spans sag and are reinforced in a similar manner to simply supported beams.

e. **Retaining Wall**



The earth pressure behind a retaining wall and the soil pressure under the footing tend to cause the wall and footing to bend in the manner shown in the above diagram. Reinforcement is placed in the regions of tensile stress.

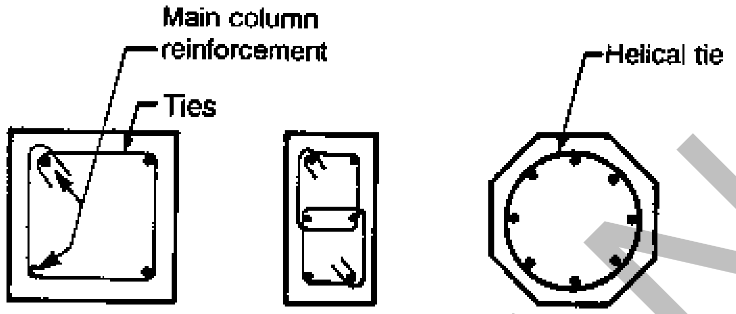
f. **Columns**



Columns under load can bend in any direction, depending upon the load distribution of framing beams. Reinforcement is therefore placed near the outer faces of all sides. In the diagram, if the load is moved to another beam the stresses in the column will change to conform with the new mode of bending.

Lateral reinforcement in the form of ties or helixes is required in columns (or concrete piles) to:

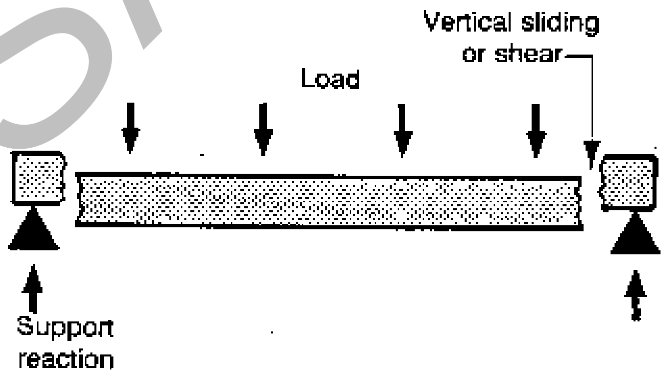
- hold the main reinforcement firmly in position during concreting.
- prevent lateral bursting of the column under high axial compression.



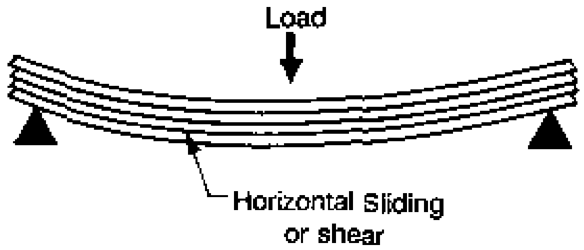
Shear Reinforcement

Shear stresses may be of two types:

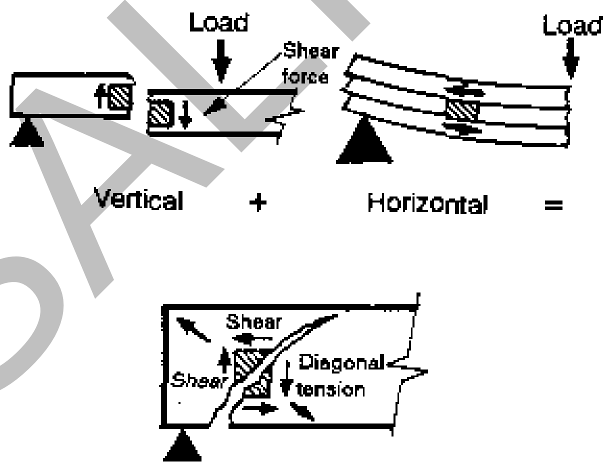
- vertical shear stresses as demonstrated in a simply supported beam occur near supports as a result of heavy loads tending to cause the central section to slide vertically downwards relative to the end sections of the beam.



- Horizontal shear stresses result from the tendency of the beam to bend under load and split into horizontal laminations.

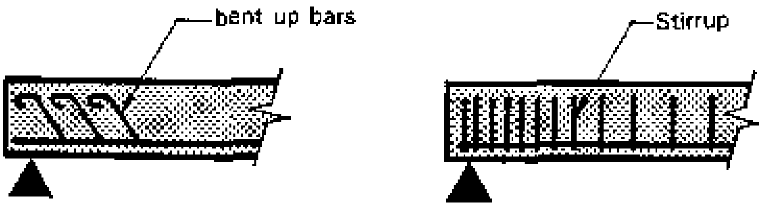


At the ends of the beam a combination of vertical and horizontal shears results in diagonal tensile stresses which cause diagonal cracking (see diagram below).



Diagonal tensile cracking

To prevent diagonal cracking at the ends of beams or adjacent to any support, it is often necessary to either bend up some of the tensile reinforcement or to use stirrups as indicated below.



15.2 INSPECTION AND QUALITY CONTROL OF MATERIALS

The quality and types of materials used in concrete construction are defined in the relevant Specifications or Drawings.

Sampling and testing of materials is usually arranged by the Contractor. Representative samples of local materials such as aggregates and water should be submitted to a materials laboratory to ensure compliance with the specified requirements. Typically, a minimum sample of 20 kg of each size of aggregate, taken in accordance with AASHTO Test Method T2, should be submitted at least six weeks before the material is to be used. Bags used for transport of samples must be clean and free of clay particles, sugar and other deleterious materials.

Water for concrete must be free from any material which is harmful to concrete or steel such as oils, acids, alkalis, salts and organic materials. If a new source of supply is to be used, a sample should be forwarded for testing to the materials laboratory in a clean glass jar.

15.3 MATERIALS

15.3.1 Cement

The type of cement in normal use in Indonesia is Ordinary Portland Cement.

There is only small effect on the mix design due to the use of alternative types of cements.

The Supervising Engineer should ensure that the contractor complies with the requirements of the Specifications with respect to storage and age of cement.

15.3.2 Aggregates

a. General

The selection of suitable aggregates is important for the production of suitable concrete.

Concrete aggregates should consist of clean, hard, durable particles strong enough to withstand the loads imposed on the concrete. In general, they should consist of either natural sands or gravels, or crushed rocks.

Concrete aggregates should be:

- strong and hard enough to produce concrete of the required compressive strength and to resist abrasion and wear
- durable to withstand the action of the weather and cycles of wetting and drying
- chemically inert so that they do not react with the cement and cause deterioration of the concrete
- clean or free from impurities such as organic matter which can inhibit the setting and hardening of the cement. Silt and clay can weaken the concrete. Weak, soft particles can reduce the strength and may break down when exposed to the weather. Surface coatings of clay or other weak material can reduce the bond between the aggregate and the cement paste.

b. Grading

Aggregates for concrete are classified usually as fine or coarse. Fine aggregates pass a 5 *mm mesh sieve while coarse aggregates are retained on the 5 mm mesh sieve.* The grading of an aggregate is determined by passing a sample of it through a series of sieves and weighing the amount retained on each sieve. These amounts are expressed as a percentage of the total sample weight.

It is usual to specify fine and coarse aggregates which contain a range of particle sizes, that is they should be graded. Graded aggregates produce workable concretes which are not usually subject to segregation or bleeding. Gap graded aggregates are those aggregates or a combination of aggregates in which a range of intermediate particle sizes is omitted. These aggregates can often be used to produce a very workable concrete with an improvement in other concrete properties. Unfortunately concretes made from gap graded aggregates are usually more difficult to control as the workability is more sensitive to changes in water content, there is a danger of segregation in mixes which are too wet and the mortar between the coarse aggregate particles is likely to craze unless the mix is relatively dry.

It is generally accepted that coarsely graded sands are the most desirable. On the other hand, all sands must contain a sufficient quantity of fine particles to assist the cement in producing good workability. A grading of sand in which one or two particle sizes predominate should be avoided. Such sands have large void contents and therefore require large amounts of cement paste to produce a workable mixture.

c. Particle Shape and Surface Texture

The particle shape and surface texture of the aggregates will affect the workability of the concrete. For good workability, particles should be smooth and well rounded, as in water worn gravels, or cubic in shape as in crushed rocks. Angular flaky particles not only reduce workability but lead to segregation and should be avoided. Maximum strength, with some loss of workability, is achieved with crushed aggregates due to the interlock obtained between the irregular faces of the stones.

d. Maximum Size

The greatest economy is achieved when the largest maximum size aggregate possible is used. The factors limiting size are the ability of the mixing, transporting and placing equipment to handle the larger sizes and the clear spacing between the formwork and reinforcing bars. Maximum aggregate size should not exceed one fifth the minimum dimension of the section, or two thirds the clear spacing between bars or three quarters the concrete cover to the reinforcement. In the specifications, restrictions are placed on aggregate sizes for concrete used in various parts of the works which reflect the above limits.

Many projects in Indonesia use coarse aggregates which are far too big, especially for concrete in the superstructures. It is common to see 75 mm uncrushed river aggregates being used for deck concrete. This causes areas around scuppers, fence posts, deck angles etc. and the space between the side forms and the reinforcement bars to be filled with cement paste only and no aggregate, and the concrete strength in these areas will almost certainly be less than that specified.

This clearly contravenes the Specification and the remedy is in the hands of the Supervising Engineer, that is to reject the aggregate as unsuitable.

15.3.3 Water

Water used for concrete should not contain excessive amounts of salts, dissolved organic matter or other impurities which will interfere with the hydration of the cement.

Water fit to drink is usually satisfactory. Where doubt exists, a trial batch of concrete should be made and tested to compare its rate of hardening and ultimate strength to those of similar concretes made with fresh water.

Sea water should not be used in reinforced concrete as it will promote corrosion of the reinforcement.

15.3.4 Air

The presence of voids in concrete greatly reduces the strength. As little as 5 percent of voids can lower the strength by 30 percent and even 2 percent can reduce the strength by 10 percent.

Voids in concrete are either :

- bubbles of entrapped air, or
- spaces left after excess water has been removed. These depend on the water cement ratio of the mix.

The air bubbles are governed by the grading of the finest particles in the mix and are more easily expelled from a wetter mix than a drier one.

There is an inverse relationship between the strength of the concrete and the volume of air in the concrete. The volume of air is reduced with compaction but is usually in the range 1 to 3 percent.

Entrapped air bubbles in concrete are relatively large (about 1 mm in diameter) and are often trapped under the lower surface of the coarse aggregate particles.

It has become common practice to deliberately entrain air (up to about 8 percent) into concrete using suitable admixtures. These air bubbles are much smaller (0.05 mm diameter) than those accidentally included or trapped and are discrete or separate so that no channels for the passage of water are created and the permeability of the concrete is not increased.

Entrained air will cause some reduction in the compressive strength of the concrete but does result in a more workable mix for a given water cement ratio. Alternatively, the water cement ratio can be reduced for the same workability and so offset the reduction in strength due to the additional entrained air. The entrained air reduces bleeding and segregation of the concrete when wet and lowers the density of the concrete, offering an economic advantage. It also increases the durability of the concrete.

15.4 STORAGE OF MATERIALS

15.4.1 Cement

Cement must be stored in a cement silo or a weather-proof building and arranged so that it can be used in the same order as delivery. Cement in store for more than four months should be re-tested before use.

15.4.2 Aggregate

Aggregate should be stored in bins or stockpiles adjacent to the work with each size positively separated from its neighbour to prevent intermixing. Floors of stockpiles must be well drained and surfaced with gravel or similar to prevent contamination of the stockpile by soil.

15.4.3 Reinforcing Steel

Reinforcing steel must be stacked clear of the ground on adequate timber supports so as to keep the bars free of clay and other matter deleterious to good bonding. Loose surface rust or dirt must be removed prior to installation.

Reinforcing steel should be checked for compliance with the bar schedules well in advance of installation in the works.

15.4.4 Prestressing Strand and Bar

Prestressing steel should be stored under permanent cover if possible. Storage in the open is acceptable only for short periods, approximately one month maximum duration, provided it is stored clear of the ground and covered with a waterproof fabric or film.

Bars should be supported at sufficient points to prevent permanent bending and threads should be protected against damage, by wrapping or other means.

15.5 CONCRETE MIX DESIGN

15.5.1 General

The concrete mix is normally designed on the basis of the aggregate grading of the material available on the job. Further information on a typical mix design method is included in the Construction Techniques Manual.

Trial mixes should be tested at least four weeks prior to concreting operations. The trial mix design should also define any admixtures or flyash to be used.

The site engineer should ensure that he has complete details of the approved design gradings and should check these periodically against the materials being used. If significant variations occur, the cause should be investigated and the Contractor directed to take prompt steps taken to correct the gradings. As a last resort it may be necessary for the Contractor to redesign the mix and resubmit the mix design for the approval of the Engineer.

There must be no departure from an approved concrete mix unless authorised in writing by the Engineer.

15.5.2 Mix Design

There are a number of different methods of carrying out a mix design but they all basically follow the philosophy set out in Figure 15.1. This philosophy is intended to produce an economical concrete mix, making optimum use of available (local) materials to comply with the requirements of the concrete specification.

The first step is thus a study of locally available materials and their properties to select suitable cement, coarse and fine aggregates, water and admixtures (if any) complying with these requirements.

The second step is to arrive at the target strength for the concrete mix (usually the compressive strength at 28 days). This is done by adding to the characteristic strength a suitable multiple of the standard deviation (determined by the level of control of concrete production).

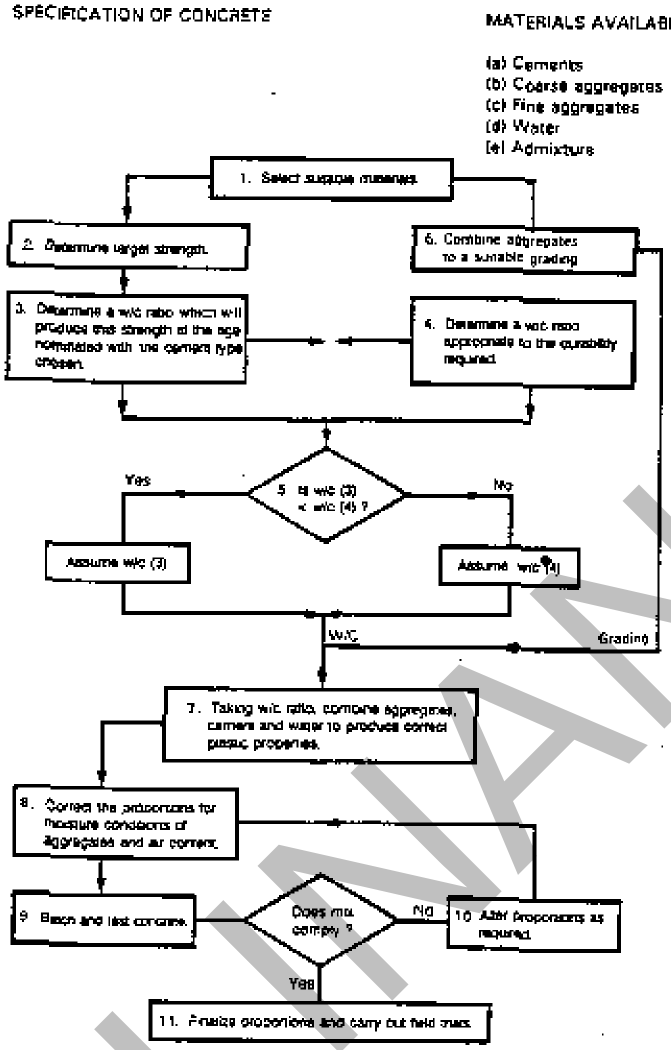


Figure 15.1 - Mix Design for Concrete

The next step is to determine a suitable water/cement ratio which will produce this target compressive strength with the given cement and aggregates. A water/cement ratio which will give the appropriate durability is also chosen and compared with that relating to strength.

The coarse and fine aggregates are combined in proportions which will give a concrete mix with the desired plastic properties. This will generally relate to a slump determined by the location where the concrete is to be placed.

The mixing water, aggregate proportions and cement requirement can then be calculated.

A trial mix is next prepared, the mix design checked and, if necessary, modified to produce concrete with the desired properties. The results of the mix design are then used for a field trial. This procedure is set out in the Specifications for concrete.

The mix design will generally be carried out by the Contractor and will be submitted for checking by the Engineer.

15.5.3 Chemical Admixtures

It is often possible to change some of the properties of the cement by the use of a suitable additive, known as an *admixture*.

A large number of proprietary products are available. Many are in regular use by larger ready-mixed concrete plants to produce concrete with the specified properties but at a lower cement content or fine aggregate content than if a mix with no admixture was supplied.

The use of admixtures, while common in larger concrete operations, requires that care be taken in the type and amount used. Accordingly, chemical admixtures should only be used if approved by the Engineer.

They must comply with the requirements of AASHTO M154, M194 or similar. Admixtures containing Calcium Chloride should not be used in reinforced or prestressed concrete.

Admixtures are classified according to the purpose for which they are used in concrete.

ASTM C 494, 'Specification for Chemical Admixtures in Concrete', classifies admixtures into seven types:

- Water Reducing (Type A)
- Retarding (Type B)
- Accelerating (Type C)
- Water reducing and retarding (Type D)
- Water reducing and accelerating (Type E)
- Water reducing, high range (Type F)

and

- Water reducing, high range, and retarding (Type G)

Accelerating admixtures commonly shorten the time of setting of concrete and also increase the early strength of the concrete. Accelerators may give similar high early strength to that obtained with Type III cement. In addition however, accelerators will often give an early set, sometimes as little as a few minutes.

Set retarders are commonly used to delay set and allow the concrete to be worked for longer periods after mixing. They are used where temperatures are higher and/or the exposed working face of concrete is large and it is necessary to keep the face 'alive' for a longer time, thus preventing 'cold' joints. Care must be taken in using these admixtures as if used in the wrong quantities, they can completely prevent the setting and hardening of concrete. In addition, some retarders tend to increase plastic shrinkage and resultant cracking.

Water reducing admixtures allow a reduction in water cement ratio for a given slump. They are commonly used to reduce the water content (thereby increasing concrete strength) and at the same time achieving a workable mix. They can be used to increase the workability of a mix for a given water content.

Superplasticisers (or high range water reducing admixtures) have the ability to give concrete with a very high slump (in excess of 200 mm) to allow the concrete to flow into forms with little or no compaction. This is a temporary effect only and after about 30 to 60 minutes the slump of the concrete will reduce to the value it had before the addition of the superplasticiser. They are commonly added to the concrete at the job site. They are *relatively expensive and should be used only when required for a specific purpose.*

Air entraining agents break up entrapped air into minute bubbles and improve the workability and durability of the mix. They are particularly useful for concrete placed in bridge decks due to problems encountered in Indonesia with high temperature concreting and the inability to fully compact the concrete under such conditions.

Admixtures should be accurately measured by means of a suitable dispenser which is regularly calibrated. Delivery dockets and/or batching records must clearly show the brand name and type of admixture and the dosage rate or total quantity for each batch.

15.5.4 Fibre Reinforcement

Polypropylene fibres have been used in a number of concrete bridge decks in Indonesia. These fibres have the ability to reduce plastic shrinkage cracking and the permeability of the concrete. They are not intended to replace any of the main moment-resisting reinforcement.

The use of fibres in concrete will not solve problems due to a poor mix design or poor concrete production. The fibres will only be effective if they are uniformly distributed throughout the concrete.

A typical dosage rate for polypropylene fibres is around 1 kilogram per cubic metre of concrete. The manufacturer's information should be carefully checked for recommended dosage rates.

15.6 CONCRETE PRODUCTION

15.6.1 General

The aim of all batching and mixing procedures is to produce uniform concrete containing the required proportions of materials. To attain this it is necessary to ensure that:

- materials are maintained in an homogeneous and nonsegregated state prior to and during batching.
- the equipment provided will accurately batch the required amounts of *material and the amounts can be easily changed if and when required.*
- the required proportions of materials are maintained from batch to batch.
- all materials are introduced into the mixer in proper sequence.

- all ingredients are thoroughly intermingled during mixing and all aggregate particles are completely coated with cement paste.
- the concrete, when discharged from the mixer, will be uniform and homogeneous within each batch and from batch to batch.

15.6.2 Ready-Mixed Concrete

Ready-mixed concrete must comply with all the requirements of the Specifications. Ready-mixed concrete has the advantage that better quality control is possible at a large plant than can be achieved under the conditions on most bridge sites. Most ready-mixed concrete plants use a weigh batching plant for batching and truck-mounted transit mixers for mixing.

However, bridge projects which are at isolated sites remote from any fixed plant will require the use of an on-site batching plant. This includes a large number of bridge construction projects carried out in Indonesia.

15.6.3 Site Batched Concrete

Site batched concrete is usually batched and mixed on the site in a mechanical mixer.

The concrete batching and mixing plant is best situated at a location and elevation which facilitates the feeding of aggregates into the hopper and the delivery of the mixed concrete to the work. The most convenient location for weighing hoppers is between the aggregate bins and the mixer so that discharge can be made directly into the mixer.

Weigh-batching of all concrete ingredients should be a normal requirement. Water may be volume-batched. The water supply should preferably be fed by gravity from the metering source to the container on the mixing plant.

Bagged cement must be fully protected from the weather at all times. It may be stacked each day on a timber platform large enough to accommodate up to one day's production and with direct access to the weighing or mixer hopper. Cement not used should be returned to the store at the end of the day's work.

Before commencing each batching and mixing operation, the plant must be checked to ensure that it is in good running order and clean, particular attention being paid to the mixing drum.

The Contractor must calculate the required quantity of each component of the concrete for each pour and must have at least that quantity (including allowance for losses) available before concreting is allowed to commence.

15.6.4 Batching and Mixing

a. Batching

The essential requirement in batching is that the specified proportions of material be maintained from batch to batch within the given tolerances to produce uniformity in the resulting quality of concrete. Fluctuations in sources of supply should be avoided.

The supervisor should ensure that tests for moisture content and grading are regularly made and that batch properties are adjusted to give uniform quality concrete. Check tests occasionally by the supervisor will be helpful in tightening up the Contractor's control measures especially in relation to the operation, condition and accuracy of batching devices.

b. Mixing

Almost all concrete, even for small jobs, is mixed by machine in batch mixers of various capacities. Mixers have been brought to a high state of efficiency, producing satisfactory results at a minimum cost of labour and power. Small changes in the speed of the mixer have little effect on the strength of the concrete and it is largely the time of mixing, not the rate of rotation of the mixer, that influences the strength and quality of the concrete.

Tests show that the strength of concrete is increased by longer periods of mixing. There is a rapid increase in strength up to a mixing time of about two minutes. In addition thorough mixing will yield more uniform concrete, concrete which is more watertight and concrete which is more workable. It should be noted however, that over mixing, ie. mixing for too long a time, is likely to lead to grinding of the aggregates, as well as reducing production of concrete.

The main aim of mixing is to ensure that materials are uniformly distributed within the mass of the concrete. This will require that materials be mixed for not less than 1.5 minutes in the mixer which should be discharged completely before it is recharged. This period must be increased (adding 15 seconds per 1 m^3 of mixer capacity) for mixers larger than 1 m^3.

The uniformity requirements for a concrete mix are given in the Table below.

It is permissible to reduce the mixing time below 1.5 minutes if the mix can consistently meet the uniformity requirements given in Table 15.1, with that reduced mixing time .

Stationary mixers should be equipped with a metal plate or plates on which are clearly marked the mixing speed of drum or paddles and the capacity in terms of volume of mixed concrete. In addition, they should be equipped with a revolution counter or timer.

Transit mixers and agitators should have a metal plate or plates attached in a prominent place showing the range of mixing speeds and the number of revolutions at each mixing speed to obtain the uniformity specified in Table 15.1.

When concrete is mixed in a transit mixer, the volume of the mixed concrete should not normally exceed 63 per cent of the gross internal volume of the drum. When concrete is centrally mixed and then transported in a transit mixer, the volume of mixed concrete should not exceed 80 per cent of the gross internal volume of the container.

Table 15.1 - Requirements for uniformity of concrete

Test	Requirement, expressed as maximum permissible difference between results of tests of samples taken from two locations in concrete batch
Slump	
If average slump is 80 mm or less	25 mm
If average slump exceeds 80 mm	40 mm
Air Content, per cent by volume of concrete	1.0
Coarse aggregate content, portion by mass of each sample retained on 4.75 mm test sieve, per cent	6.0
Mass per unit volume of air free mortar, per cent	1.6

The basic purpose of all mixers is to mix concrete uniformly within the time specified and the order of addition of materials should be suitable for mixing within that specified time. Generally, the water should be added into the mixer over the full period of materials loading, preferably beginning just before and ending just after loading. The dry materials should be loaded as quickly as practicable, without loss of materials.

When the supervisor determines from observations of the concrete mix or from slump tests that the mixing time is not sufficient, he should arrange for uniformity testing of the mixer to determine the required mixing time.

The supervisor must be aware that greater mixing time may not improve uniformity. At the same time it will reduce mixer output, may increase the air content and may cause some grinding action, particularly with softer aggregates. It is good practice to establish maximum mixing time. If the batch is to be delayed longer, the mixer should then be operated only at intervals.

A slump test is required from the first batch of concrete mixed, before any concrete is placed in the work. A slump test is also required from the second batch of concrete mixed and additional tests from subsequent batches as deemed necessary. Temporary stoppages of the work, changes in the weather and other unusual circumstances affecting the mixing operations should always be followed by the taking of additional slump tests. All slump tests should be carried out by experienced operators.

If any slump test does not comply with the value specified within reasonable limits, the batch of concrete which it represents should not be used in the Work.

Whenever mixing is stopped for more than 30 minutes, the mixing drum must be thoroughly washed with clean water.

15.6.5 Emergency Mixing

It is desirable to have an emergency mixer available for use in case the mixer breaks down. The emergency mixer should be started and operated periodically to ensure that it is in good mechanical condition and it should have sufficient capacity to ensure that fresh concrete can be supplied and maintained over the full extent of the working face should the main mixer break down during a concreting operation.

If no emergency mixer is available, a mixing board for emergency hand mixing can be used to enable the concrete in the work to be finished to a point where a construction joint can be placed. In such emergencies, the cement content of the mix should be increased by about ten percent.

15.6.6 Record of Materials Used

Records must be kept of all materials used for each day's work. These records should include the quantity of cement used and the number of batches mixed and their location in the Works.

If ready-mixed concrete is being used, the delivery dockets should record all relevant information. These must be checked before discharge and filed for future reference.

15.6.7 Cleaning Up

At the completion of the day's work, the mixing plant should be thoroughly cleaned, all used cement bags collected and stacked or otherwise disposed of, and the aggregate heaps and runways to and from the mixer made tidy.

15.7 HANDLING, PLACING AND COMPACTING CONCRETE

15.7.1 Handling Concrete

It is essential when handling concrete that delays be minimised and that concrete be prevented from drying out or segregating.

If long delays are expected, consideration should be given to the use of a set retarder in the mix and special precautions may have to be taken to keep the concrete cool during the period of the delay. Under no circumstances should concrete be placed in forms if workability has been lost, that is the original slump has been significantly reduced by drying out or by initial setting, as this will lead to weak, porous concrete. Water must never be added during handling as it cannot be effectively intermixed and could severely weaken the concrete.

Segregation is the separation of the coarse aggregate from the mortar. To prevent segregation, the following precautions should be taken :

- ensure proper mixing;
- transport without excessive jolting or vibration;

- place the concrete as close as possible to its final position in the forms; do not force it to flow sideways with excessive internal vibration. If concrete must be moved in the forms, use shovels. Note: An exception to this is concrete being placed in the anchorage zones of post-tensioned prestressed girders where concrete may need to be placed clear of the congested reinforcement and moved laterally to allow effective observation of compaction around the anchorages.

- use a hopper and tubular placing guide when the height of drop is 2 m or more (see Figure 15.2).

- avoid discharging concrete against vertical reinforcing mats.

- ensure the forms are sealed to prevent water and mortar loss.

- insert and withdraw internal vibrators vertically.

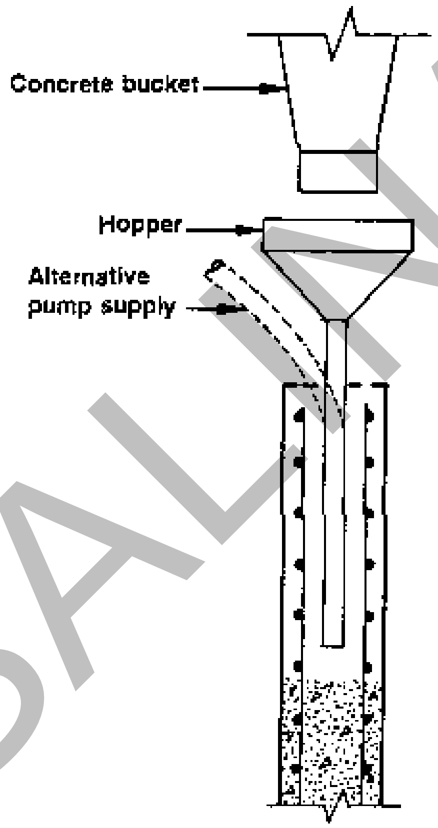


Figure 15.2 - Placing Concrete in Walls and Columns

15.7.2 Concrete Placing Equipment

At the site, concrete is either discharged directly into formwork or discharged via equipment such as tremie tubes, buckets positioned by crane, concrete pumps, hoists, dump buggies, wheelbarrows, chutes and the like.

The choice of equipment is dependent on site conditions and requirements. Precautions should be taken to minimise concrete segregation and premature drying.

The most common methods of placement are by use of buckets and concrete pumps. Smaller quantities of concrete may be placed by workers pushing wheelbarrows and/or chutes. Larger chute systems can be effective when the topography is favourable. An angle of 25 to 30 degrees is ideal for concretes with 40 to 50 mm slump.

Placement using a crane and bucket is a simple and effective means of placing larger quantities of concrete. The buckets are round or square in cross section and have a narrower section at the base with a gate arrangement to regulate the flow of concrete into the forms.

The buckets may have an angled discharge chute for working in confined areas. Straight discharge chutes are more appropriate for lower slump concrete.

Concrete can be placed accurately and continuously by pump using a two man team - one controlling the pump and the other directing the discharge - working in front of vibrator operators and concrete finishers. Pumps are usually self-contained, truck-mounted units with delivery capacities varying from 10 up to 100 cubic metres per hour. Delivery pipes are generally of steel or rubber with quick-release couplings for ease of assembly and access to blockages. Some units have booms up to 30m long.

There are several types of concrete pumps. One system delivers the concrete by a squeezing action whereby hydraulically operated rollers extrude the concrete along a flexible tube. In another system, the concrete is drawn into a hopper and mechanically pushed along the delivery tube by a piston action regulated by a system of inlet and outlet valves. The latter system is now the more common system in use.

15.7.3 Pumped Concrete

Pumping is being used increasingly as a method of placing concrete. The pump supplier should be consulted well in advance of the pour and informed of the slump requirement, the placing rate and the positioning of pump(s) to ensure concrete supply to all parts of the pour. The design of a concrete mix intended for pumping requires expert knowledge and normally requires a higher sand content than a mix designed for placing by crane and skip. The consequences of failure of a pump should be considered. It is essential to have a pump on standby or on call, a crane rigged to continue the pour by means of a concrete skip or an alternative means of placing the concrete.

It should be noted that well-designed mixes may be readily pumped at low slump and increasing the slump of such a mix may make it more difficult to pump.

15.7.4 Placing Concrete in Forms

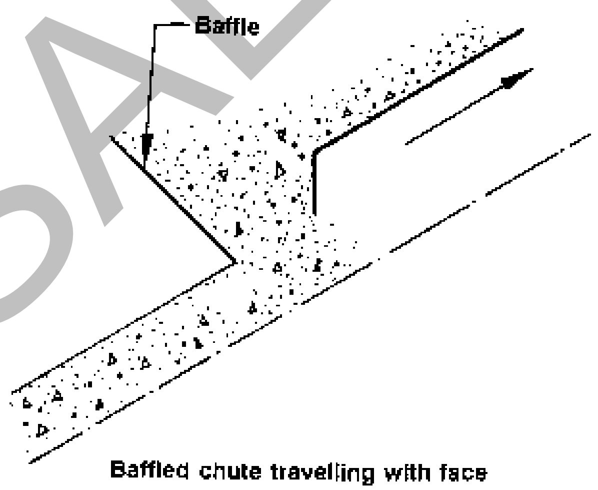
Before concreting commences, the forms should be thoroughly cleaned by means of an air jet or water jet to remove loose rubbish, especially tie wire. It may be necessary to provide temporary clean out holes in the base of formwork to allow proper cleaning.

Placing must be carefully supervised to ensure that formwork and reinforcement are not damaged or displaced and that the concrete does not segregate. Where concrete is placed in vertical forms for columns and walls, the rate of placing must be carefully controlled to ensure the rate does not exceed that adopted in the formwork design (refer Section 23).

Figures 15.3 and 15.4 give guidance as to the correct method of placing concrete in sloping and horizontal forms.

The method of placing concrete in the forms must be capable of covering the entire area over which concrete is to be placed. For larger volumes of concrete, one or more concrete pumps or cranes using bottom-dump buckets or skips of 0.5 to 3.0 m^3 capacity are convenient. For smaller volumes, concrete pumps, pneumatic tyred barrows, or chutes may be used. Runways for barrows etc. should be adjustable with "deliver" and "return" routes laid out to prevent interference, and with sufficient width for tipping and turning where necessary.

Access holes in the bottom flanges of beams and other similar locations may be required to properly compact the concrete and to ensure that the concrete has completely filled the forms. A method sealing the access covers and holding them in position until the concrete has set must be employed. Where access for compaction is not required, a round hole about 15 mm diameter may be drilled in the upper part of the bottom flange to check that concrete has filled the flanges. These holes may then be subsequently plugged with rubber or wooden plugs.



Baffled chute travelling with face

Figure 15.3 - Placing Concrete on Sloping Face

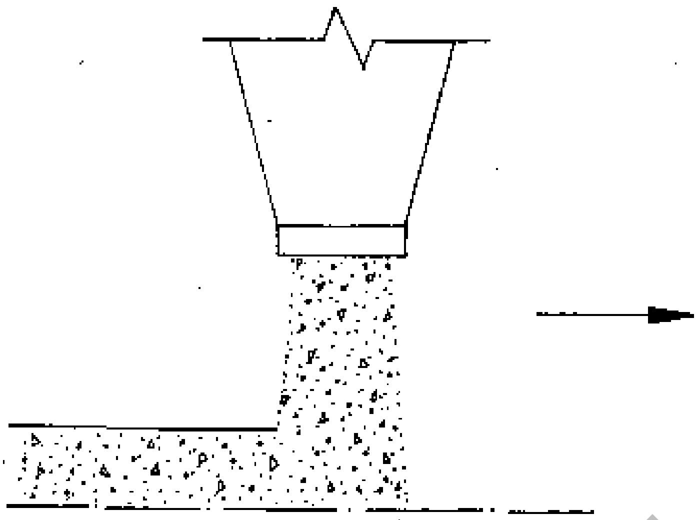


Figure 15.4 - Placing Concrete on Horizontal Face

15.7.5 Placing Concrete Underwater

Concrete can be successfully placed underwater by pumping or by using a tremie (see *Figure 15.5*).

A tremie is a water tight pipe 150-300 mm in diameter with a hopper at the top and a valve or other device at the base which prevents the surrounding water from mixing with the concrete during the initial charge. The base of the tube must sit on the foundation while the initial charge is made and the tube and hopper needs to be completely filled with concrete before the base valve is opened for the first discharge of concrete. The lower end of the tremie must remain below the surface of the rising concrete at all times.

The tremie must be capable of controlled movement at the discharge end in both lateral and vertical directions and must be capable of rapid lowering at any time to decrease the discharge rate of the concrete. The flow of concrete can be regulated by adjusting the depth so that the discharge end is submerged below the surface level of the concrete already placed.

Tremie concrete should be placed as a continuous operation. Should any interruption occur or should the base of the tremie inadvertently rise above the concrete surface, placement should cease. The inferior concrete at the top of the pour should be removed, after hardening, before the placement of any additional concrete on top. This may require the use of a diver in areas which cannot be dewatered. For tremie concrete, a cement-rich mix (usually Class K 225 concrete) is required which is designed to give a slump of about 180 mm. This high slump is required to facilitate flow of concrete in the tremie and to completely fill the form, especially through the reinforcement. Vibration must not be used as it will cause segregation in the concrete or intermixing of the inferior concrete at the top where it is in contact with the water.

The upper layer of concrete placed by tremie tube underwater is invariably of poor quality and must be removed by breaking back to dense concrete, in the dry, before proceeding with further concreting.

Where concrete must be placed in a foundation covered by shallow, still water, concreting

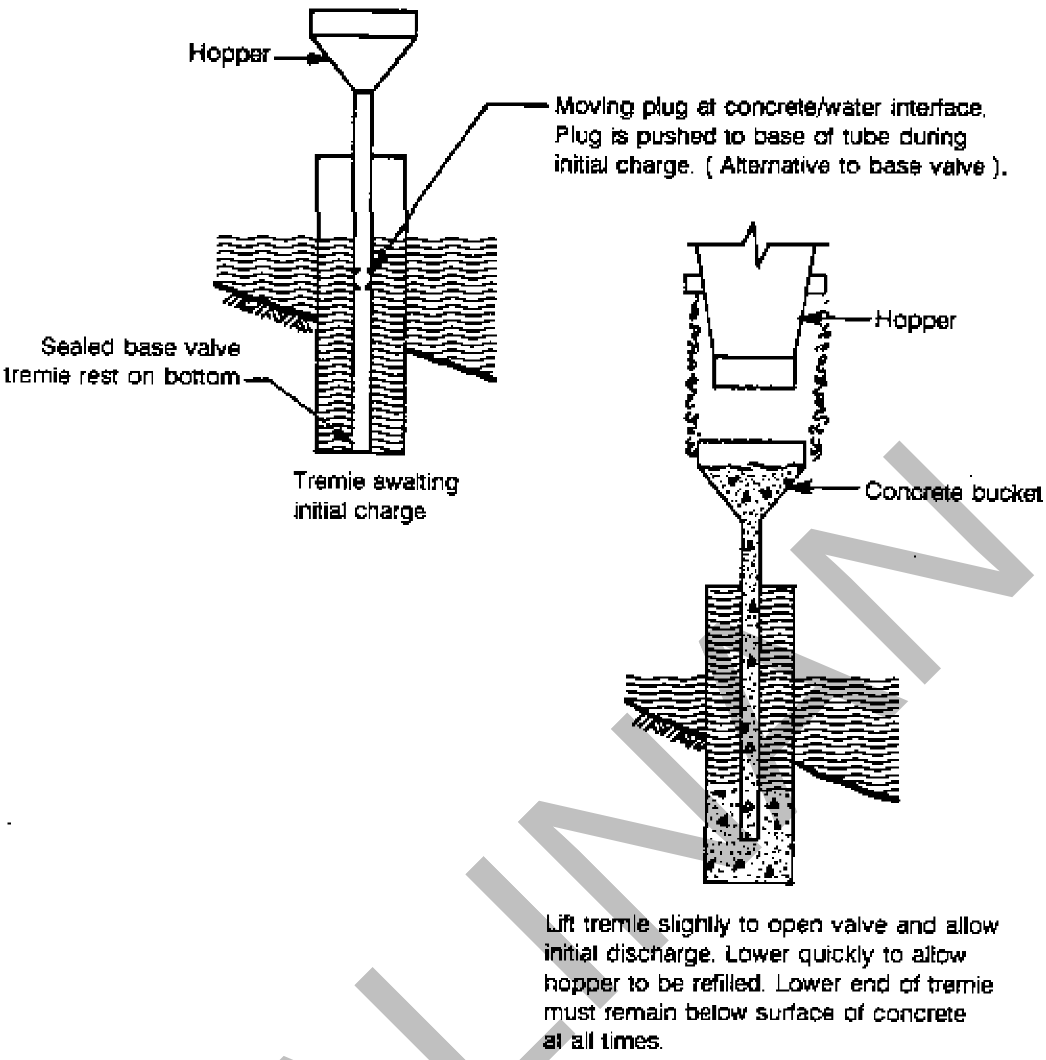


Figure 15.5 - Underwater Concreting

should start in one corner and the water displaced by the advancing face of concrete.

If water is flowing through a foundation, the water must be diverted or the foundation filled and treated as an underwater pour. A good method of diverting flow coming up through the base is to set a pipe into the fissure and to lead the pipe out through the side of the foundation.

15.7.6 Transit Mixers

It is preferable that transit mixers discharge directly into forms in order to minimise handling. Trucks must not stand in the hot sun for long periods as this reduces workability and shortens the effective time available for placement and compaction. If delays occur, the batch plant should be contacted as soon as possible and deliveries rescheduled. Prior to discharging concrete, the transit mixer should be operated at mixing speed for at least one minute.

15.7.7 Compaction

a. General

The objective of compacting concrete is to ensure that maximum density is obtained and that complete contact between the concrete and the surface of reinforcing steel and formwork is achieved.

Thorough compaction is most important as it leads to:

- maximum strength
- sound, watertight concrete
- sharp detail at corners
- good surface appearance
- good bond with steel reinforcement, and
- sound protective cover to steel reinforcement.

Concrete must be properly compacted to ensure that the specified strength, durability and surface finish are achieved. Compaction can be accomplished by immersion or 'poker' vibrators, external form vibrators, surface vibrators, vibrating screed boards, or by hand rodding. (Hand rodding should not be used for structural concrete).

In congested zones of reinforcement, such as at anchorages in post-tensioned concrete work, special measures may be required to ensure thorough placement and compaction of the concrete. Such measures may include :

- a redesign of the mix;
- a reduction in the size of coarse aggregate;
- the use of superplasticisers or other additives;
- adjustment of the spacing of reinforcement;
- an increase in the intensity of vibration.

Most compaction is carried out by high frequency vibrators applied internally or externally to the concrete mass.

External electric or air operated vibrators which are rigidly attached to the formwork are commonly used in precasting work where cross-sections are thin and heavily reinforced. Their main purpose is to provide a high standard of surface finish to the precast unit. They are usually used in conjunction with internal vibrators.

External form vibration should only be used on purpose-built forms properly reinforced at vibrator mounting points. Improper use of external form vibrators can cause severe damage to forms with corresponding effects on the shape of the formed concrete surface.

Internal vibrators provide the most effective means of compacting concrete. The standard vibrator has an eccentrically balanced shaft which is driven at high speed (5,000 to 13,000 cycles per minute). They are powered by electricity, compressed air or internal combustion engine and are manufactured in various sizes from 25 to 150 mm diameter.

Vibrating screed boards are not sufficiently effective to be used alone, and surface vibration should be supplemented by internal vibration around the edge of slabs, kerb upstands, and other thick regions. They are used to shape the upper surface of concrete and require the accurate placement of screeds to give the required surface profile.

15.7.8 Emergency Construction Joints

The placing sequence for concrete must be organised so that the length and area of the working face of the concrete is minimised, enabling a construction joint to be conveniently formed in an emergency. Before starting the placing operation, there must be sufficient formwork material available on site to form such a joint.

15.7.9 Hot Weather Concreting Precautions

High temperatures cause acceleration of hydration of the cement resulting in reduced setting times. Water is also lost by evaporation, particularly in windy conditions. These effects lead to a rapid loss of workability in the concrete with consequent difficulty in placing, compacting and finishing. This in turn will result in weak, porous concrete and may give rise to a pattern of shrinkage cracks. Spray-on films are available to delay evaporation and permit finishing work to proceed over a longer period.

If the ambient temperature is likely to exceed 32°C, some or all of the following precautions should be adopted to inhibit premature setting of the concrete.

- placing the concrete when the ambient air temperature is likely to be below 32°C (early in the morning or at night - especially for deck slab pours).
- shading aggregate stockpiles.
- spraying water on coarse aggregate stockpile.
- addition of crushed ice in lieu of portion of the mixing water.
- injection of liquid nitrogen into the mix whilst in the mixer.
- insulating or burying water supply pipes.
- painting water tanks white.
- cooling reinforcement and formwork by damping with water sprays.

- shading of work areas and water tanks.
- erection of wind breaks.
- reducing the time for placing and finishing.
- covering of finished work without delay.
- prompt commencement of curing.

Concrete should not be placed on a job when -

- The ambient air temperature is above 35°C.
- The ambient air temperature is likely to exceed 35°C within 2 hours of placement.

15.8 CURING OF CONCRETE

15.8.1 Reason for Curing

The object of curing is to retain moisture inside the concrete while the cement hydrates, and thereby achieve the desired structural strength and level of impermeability required for durability. An uncured concrete surface will abrade much more quickly than one properly cured and, in aggressive environments, its higher permeability is more likely to lead to corrosion of the reinforcement. Reduced curing also results in increased concrete shrinkage.

15.8.2 Curing of Concrete

a. General

After concrete is placed and compacted it must be adequately protected and cured in accordance with the specifications.

All the properties of concrete such as strength, watertightness, wear resistance and volume stability improve with age as long as conditions are favourable for continued hydration of the cement. The improvement is rapid at early ages but continues more slowly for an indefinite period. Two conditions are required:

- the presence of moisture
- a favourable temperature.

Evaporation of water from newly-placed concrete can cause the hydration process to stop. Loss of water also causes concrete to shrink, thus creating tensile stresses at the drying surface. If these stresses develop before the concrete has attained adequate strength, surface cracking may result.

b. Curing Methods

Concrete can be kept moist by a number of curing methods:

- methods which supply additional moisture to the surface of the concrete during the early hardening period. These include ponding, sprinkling and wet coverings (such as hessian, earth, sand or straw).
- methods which prevent loss of moisture from the concrete by sealing the surface. This may be done by means of waterproof paper, plastic sheets, liquid membrane-forming (spray-on) compounds, and forms left in place.
- high temperature curing, such as steam curing and autoclaving. The high temperatures accelerate the chemical reactions and the moisture is provided by the steam or is retained by the autoclave chamber.

Curing must continue uninterrupted for as long as practicable but at least for the minimum period specified (usually seven days), commencing from the time the concrete has had the initial finish applied.

15.8.3 Steam Curing

High strength concrete, steam cured to 30 MPa or more for prestress transfer or demoulding, does not normally require further curing.

Steam curing is usually carried out only in precasting yards because of the elaborate equipment and instrumentation that is required to ensure the strict control necessary to prevent damage to the newly cast concrete by the high temperatures involved. Steaming must not commence until the concrete has reached its initial maturity. The temperature of the concrete must be raised at a controlled rate. The steam must not be allowed to impinge directly onto the concrete or the forms and thus cause local over-heating.

The temperature under the steam covers must not exceed 80°C, and the covers must not be removed until the surface temperature of the concrete is within 40°C of ambient. Recording thermometers, adequate test samples and complete records are essential for satisfactory steam curing.

15.9 TESTING CONCRETE

15.9.1 Reasons for Testing

Quality control tests are to be carried out in accordance with the appropriate AASHTO test method in the Specification. In addition to testing the material components of concrete, concrete is tested during manufacture for consistency and workability, and after hardening, for compressive strength and other properties.

Visual inspection of concrete delivered to the site, by experienced foremen or inspectors, is also a very important aid in detecting errors in batching. Any observed change should lead to immediate slump testing and the manufacture of additional test cylinders if this is considered necessary.

15.9.2 Slump Test

Testing the slump of freshly mixed concrete is the main method used for checking consistency and workability. Slump tests should be carried out on the trial mix and an acceptable range of slump should be determined at that time. Generally, concrete with slump less than 50 mm requires a lot of effort to achieve adequate compaction while concrete with slump more than 100 mm is not usually specified except for pumped concrete or for tremie concrete which is placed under water.

A slump test should be carried out on each batch of concrete supplied by a transit mixer before placing in the forms. If slumps are too high or too low, the reasons should be determined immediately and corrected. Concrete with a slump outside the specified range may be rejected.

15.9.3 Compressive Strength Tests

Compressive testing of hardened concrete is required throughout the construction period to ensure that the design assumptions for compressive strength are being met. The number of test specimens to be taken from each concrete pour should be in accordance with the Specification. Samples should be taken from the discharge chute of the mixer or truck. Samples should not be taken from the first or last quarter of the concrete in the mixer or truck. The specimens must be carefully compacted, finished and clearly marked for subsequent identification with the batch and truck number and the location of the concrete represented by that sample.

Specimens must be kept continually moist until just prior to testing. They may be demoulded after 18 hours, if necessary, and carefully transported to the test laboratory whilst covered with wet hessian or sealed in plastic to prevent drying out.

15.9.4 Time of Testing

Normally, concrete acceptance is related to its 28 day strength.

However, as construction sequences are generally of short duration and further concrete will be jointed to the existing concrete less than 28 days after the previous casting, additional testing earlier than 28 days may be required. The Supervising Engineer must do his best to ensure that each section of concrete is of adequate strength and quality before it is built over by other portions of the structure, as this would make remedial measures difficult to implement if understrength concrete was subsequently discovered. In such cases, the Supervising Engineer must determine, by prior testing, the *strength-gain versus time* curve for the concrete being used so that comparative assessments can be made at an age earlier than 28 days. An example of this relationship is shown in Figure 15.6 but this chart is not accurate enough for site use. This relationship should be investigated early in the contract to determine the relative 3/5/7/14/28 day strength ratios. An indication of the variation in strength gain with different curing methods is also shown.

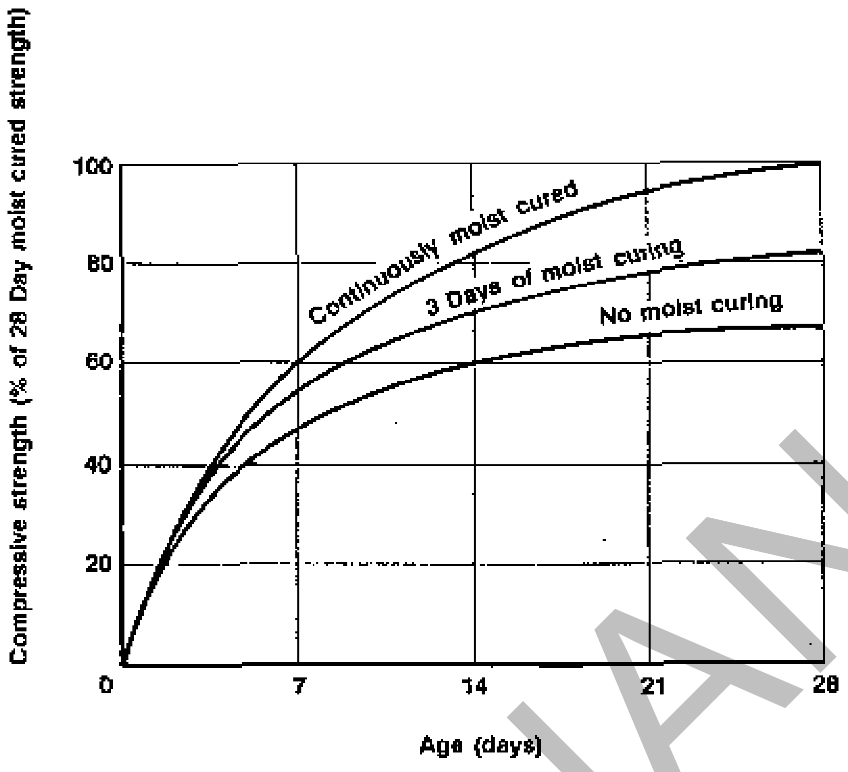


Figure 15.6 - Concrete Age and Strength

15.9.5 Acceptance and Rejection

Concrete is a material of variable strength and the normal method of specifying the required strength is the 95 percentile or "characteristic" strength, i.e. the strength such that 95% of all tests would exceed the specified strength (and 5% would fall below the specified strength). For a large number of tests, (more than 40) the actual characteristic strength of the concrete can be determined as follows :

Characteristic strength (Fc') = Target Strength - 1.64 x (Standard Deviation of all the test results).

A suitable formula for the calculation of the standard deviation is :

$$s = \sqrt{\frac{\sum_{b=1}^{N} (\sigma_b - \sigma_{bm})^2}{N-1}} \quad \text{and}$$

$$\sigma_{bm} = \frac{\sum_{b=1}^{N} \sigma_b}{N}$$

where s = standard deviation
σ_b = Individual compressive strength test of concrete specimen
σ_{bm} = Mean of compressive strength test of concrete specimens
N = Number of test specimens (N should be greater than 10 for statistical accuracy).

This formula is from the Indonesian Concrete Code N.I. 2 - 1971.

The target strength is selected having regard to the degree of quality control which can be expected over the materials and handling of concrete in the field.

The Specification should be consulted for guidelines on the choice of standard deviation and the circumstances under which concrete should be rejected.

15.10 FORMWORK

15.10.1 Design

Section 23 includes guidelines for the design and construction of formwork.

15.10.2 Cored Holes, Holding Down Bolts and Fittings

Where bolts or other metal fittings are required to be cast into concrete, jigs should be used to hold all related components securely in their relative positions. The jig must be firmly attached to the formwork, true to level and alignment. Alternatively, the jig may be designed to be attached to the previously cast concrete and remain permanently cast into the new concrete.

Cored holes may be formed using plastic disposable tubes, by foam cores (which are removed by dissolving with solvent) or by using slightly tapered, reusable formers, fixed to the formwork. After stripping, all reusable parts should be cleaned, greased and carefully stored.

Alternatively, holes may be drilled after casting using an impact or diamond drill. Holding down bolts may be grouted in using epoxy grouts.

15.10.3 Stripping and Cleaning

Formwork should not be stripped until the concrete has achieved the specified strength as verified by testing or until after the specified period of time. Kerb forms, because of their low height and the need for a high standard of finish (often requiring hand treatment), are normally excluded from these restrictions.

Test specimens which are used to check the strength of concrete for the purpose of early stripping, and specimens used to determine concrete strength for prestressing, should be cured at the same temperature as the parent concrete.

Forms should always be cleaned, oiled and carefully stacked between uses. Similarly, form fittings should be inspected for damage, oiled and stored in drums.

15.11 CONCRETE SUPERSTRUCTURES

15.11.1 Introduction

The superstructure comprises that part of the structure from the bearings upwards, excluding the bridge barriers and railings.

15.11.2 Precast Units

Precast units are generally manufactured off site and in sufficient quantity to justify the use of durable, high quality formwork. Typical precast items in bridge superstructures are deck planks, deck slabs, girders, deck soffit slabs, kerb units and posts. Structural items such as deck planks and girders are usually prestressed, and are discussed in Section 16.

Uniformity of quality, shape, colour and general appearance is desirable in precast work, and these characteristics are affected by formwork quality, types of form oil and release agents, changes in the nature or proportions of the raw materials used, the amount or type of vibration, type of curing, age at stripping or even weather changes.

Forms for precast items are used many times and therefore need to be strong, stiff and mortar-tight. It is important to be able to strip and re-assemble the form many times and retain the same shape and dimensions, mortar-tightness and quality of finish. The finish required controls the type of facing material used, easy cleaning of which is also an important criterion.

The Supervising Engineer should check that cast-in fixing components are correctly set, and that they cannot move during placing and vibration of concrete. When steam curing is used, that they fixing bolts must be removed after initial set and before steaming commences, to allow for differential movement between the form and concrete.

Discolouration may be caused by incompatibility of curing compounds, waterproofing additives or form release agents. Pre-production testing of combinations of these chemicals is desirable, and should be carried out under factory conditions including the effect on the facing material used in the formwork.

Every effort must be made to reproduce in each batch of precast items the identical manufacturing cycle of previous batches so that consistency of quality and appearance results.

Precast units are easily damaged in handling, stacking and transporting. If lifting devices are provided in the unit they must be used. If points of support during stacking are not shown on the drawings, advice must be sought from the designer. Supporting at more than two points can cause serious damage. When stacking similar units, supports should be placed exactly one above the other. Packing should be of inert material, or if hardwood timber, should be wrapped in plastic to avoid staining. Sagging or twisting of long slender units is likely if sufficient care is not taken in the design of the support system during storage. Relative movements of prime mover and trailer must be considered when transporting units to prevent torsional cracking, crushing or chafing.

15.11.3 Deck Slabs

a. Formwork

Deck forms may be removable or left in place. The latter are usually galvanised steel, compressed fibre-cement or concrete.

Galvanised steel formwork that is to be left in place will usually be steel trough decking supported on stringers and cross girders. The underside of the concrete deck with left-in-place formwork cannot be inspected and thus there is need for extra care in the placement and vibrating of the concrete to eliminate the possibility of porous concrete on the underside.

Cantilevered decks and footpaths are the most visible parts of a bridge. Bridge girders deflect when the deck slabs are being poured, and this deflection must be allowed for when setting the edge forms, so that the deck edge presents a smooth line, on grade or with slight positive camber at centre span. Deck forms must be supported from girders and not from the ground, piers or abutments.

Whilst the deck is being cast, it is essential to protect the outer girders and bearings against the effect of torsional moments caused by rotation of cantilevered decks and footpaths. This is simply done by tying the tops of the girders together with welded reinforcing bar and strutting at the level of the lower flange.

It is often found that in a span of a beam-and-slab type bridge, girders which are intended to be identical have significantly different vertical profiles, caused by differential hogging. If the hog of one or more of the girders in the span is greater than allowed for in the design, the whole deck span will have to be raised to accommodate the excess hog, and risers will have to be cast on the other girders. The change might also affect adjacent spans. It will be necessary to measure, by carrying out some form of survey, the profile of all the girders and to draw up a long section of the deck profile to establish the deck levels.

b. Reinforcement

After the formwork for the deck slab has been completed and checked for strength, workmanship, mortar-tightness, levels and cleanliness, reinforcement may be placed. It is necessary that dimensions are checked frequently during site bending, or immediately after delivery to site if bent off-site. Use of timbers, steel racks or other supports will keep the reinforcement out of the dirt or mud until ready for use. Paint, oil, grease, mud, loose mill scale or loose rust will reduce the bonding properties of plain bars in particular, and must be removed. Cover is most important especially in relatively thin deck slabs - too little cover could result in rusting of the bars and subsequent spalling of concrete, whilst too much cover may result in the assumed design strength of the slabs not being achieved.

Wire ties are just as susceptible to rust as ordinary bars, and the ends of the ties must be kept well away from the surface of the concrete.

Mortar blocks and plastic chairs are used to maintain cover in preference to plastic tipped steel chairs. Some plastic chairs have inadequate base areas, and may crush under load especially in hot weather. When used in the horizontal position to hold vertical reinforcement, they tend to rotate unless carefully fixed.

The reinforcement must be supported in such a way that it is not moved, distorted or damaged in any way during casting of the deck slab.

c. Casting Sequence

Planning of the casting sequence should give consideration to the following:

(a) Transversely - commence concrete placement at the centre, moving outwards in a balanced manner.

(b) Longitudinally - place concrete to maximise deflections early so that the initially-set concrete will not be affected by deflections caused by subsequent concrete placement.

If the deck being poured is not level, it is usual practice to work from the lowest to the highest point.

d. Concreting

Checks to be made before concreting the deck slab include the following:

(a) check that all rubbish, dirt, old concrete, wire tie off cuts etc. are cleaned out of the forms.

(b) confirm that runways are supported clear of the reinforcement.

(c) if adverse weather conditions exist, especially hot weather, check that work can proceed without contravening the Specifications.

(d) ensure that adequate arrangements have been made for artificial lighting if concreting cannot be completed in daylight.

(e) check that sufficient timber is on hand to make a stop-end if concrete supplies are interrupted.

(f) ensure that personnel and facilities are available to sample materials or concrete as required by the Specification.

(g) confirm that chutes are metal or metal lined and that concrete will not segregate in the chute or be permitted to drop more than 1.5 metres.

(h) check that adequate standby plant, including vibrators, is available and in good working order.

Concrete can be mixed on site or elsewhere, and can be placed using barrows on runways, chutes, monorail conveyors, from buckets lifted by crane or hoist, or pumped. Concrete should be full depth in the forms as close as possible to its final position so that it does not have to be moved excessively with screeds or vibrators.

Experienced vibrator operators and close supervision are required to ensure that concrete is compacted immediately after placing. Following internal vibration a well-compacted deck and dense, durable concrete can be achieved either by the use of a vibrating screed and hand floating or by hand screeding and a power float.

If the deck is to have bituminous surfacing, a slightly roughened surface will improve bond between concrete and bitumen and this can be obtained by dragging a stiff broom transversely over the surface before it hardens. Careful timing of this operation is essential to achieve the desired effect.

Curing procedures are best initiated immediately initial set has taken place.

Additional consideration is required where the flanges of precast prestressed T-beams form part of the deck slab. After the girders are erected, longitudinal infill sections are installed. Great care is required at the construction joint between the precast girder edges and the infill concrete. The precast edges should be roughened in the casting yard and wetted immediately before the infill concrete is cast. Despite care, the shrinkage of the concrete and the flexibility of modern prestressed sections frequently results in cracking at the construction joint, so that an impervious membrane is usually applied to the deck before asphalting.

The deck slab concrete adjacent to the expansion joint nosings must be cast at the same time as the main deck pour. The practice of omitting the concrete within 300 mm or so *of the joint should not be permitted by the Engineer because the concrete added after the* main concrete cannot be satisfactorily bonded to the main deck concrete and problems with the expansion joint will occur early in the life of the structure. Similarly, the practice of omitting the concrete around concrete fence posts during the main deck concrete pour should not be allowed.

The practice of placing a mortar layer on the deck formwork prior to placing concrete should not be permitted by the Engineer. This results in a weak layer of mortar will usually crack and fall off at an early stage.

15.11.4 Forming Voids

Voids are formed in concrete bridge superstructures to accommodate post-tensioning cables, to accommodate services, to lighten the structure, to displace concrete near the neutral axis in which there is little load, or to provide access for maintenance. Services may also be carried in plastic or metal tubes cast into the superstructure, laid under footpaths, or subsequently attached to the bridge externally.

Ducts to accommodate post-tensioning cables are dealt with in Section 16 of this Manual.

Polystyrene foam plastic is suitable for forming voids where the purpose of the void is to lighten the structure and the foam can be left in place if desired. It can easily removed by a combination of cutting out followed by the use of a solvent on the edges which adhere to the concrete. Foam formers are also suitable for short access openings.

Voids must be self-draining unless they remain completely filled with the material used for forming.

Depending on the size, shape and application, voids may also be formed by waxed cardboard formers or by conventional methods, using sacrificial or removable forms.

Void formers tend to float during concreting and must therefore be carefully fixed to the reinforcement to prevent floating or being dislodged by vibrators. Larger voids, or a number of smaller voids, can cause sufficient flotation to distort reinforcing cages, and therefore require hold down devices independent of the reinforcing to counter the effect. Special care must be taken at joints in the formers, and particularly at the ends, to ensure mortar-tightness as leakage can result in a restriction in the void, causing difficulty in the installation of cables or services, or producing sharp projections which could damage them.

During concreting, care must be taken not to damage formers, particularly with vibrators. Flexible ducts may deform, causing an internal projection which in turn may cause difficulty with electrical cables, or other services. Rigid ducts may crack and allow mortar to leak in, causing a blockage. Whatever the method of forming, it should be sufficiently rigid to ensure that no reduction in void size occurs.

15.12 CONSTRUCTION JOINTS

15.12.1 General

Construction joints are used to allow concrete to be placed in reasonable stages. Discontinuity in the matrix of the concrete is unavoidable at the joint and special care is necessary to ensure as complete a bond as possible between the new and old concrete.

15.12.2 Location of Construction Joints

Joints should not be located in regions of high shear or bending stress if possible. The location of critical construction joints should be specified by the designer. If this has not been done, or if additional joints are required, the Engineer's approval for the location of the joint should be obtained.

15.13 SURFACE FINISH

15.13.1 General

Acceptable surface finishes can usually be achieved in several ways. The Engineer must ensure that the provisions of the Specification are met. The use of excessive plastering with mortar in an attempt to hide poor surface finishes should be prohibited by the Engineer.

Screeding guides attached to formwork should be set accurately to finished surface level, profile or grade.

The specifications for concrete classify surface finishes into a number of classes. Each class has limits placed on surface imperfections, joints, deflections and methods of repair.

Methods of obtaining the various surface finishes are described in Section 15.13.7 of this Manual.

The classes are:

- Unformed Surface Finish
- Class 1 Surface Finish (Unexposed Formed Surface Finish)
- Class 2 Surface Finish (Ordinary Formed Surface Finish)
- Class 3 Surface Finish (Rubbed Formed Surface Finish)

All formed concrete must receive at least a Class 1 surface finish. Unless otherwise approved by the Engineer, the surface of the concrete must be finished immediately after the removal of forms.

Except where other surface finishes are shown on the Drawings or ordered by the Engineer, surface finishes Class 1, Class 2 and Class 3 should be used as follows :-

Unformed Surfaces

- Unformed surfaces should be compacted and tamped so as to flush mortar to the surface, screeded off and finally dressed with a wooden float to an even surface. Care should be taken to drain or otherwise remove promptly any water which comes to the surface. Capping with mortar should not be permitted.

Substructure

- The rear surface of abutments, culverts and wingwalls should receive Class 1 surface finish.
- All exposed surfaces of abutments, wingwalls and piers from 300 mm below ground level should receive Class 2 surface finish, except that in cellular structures the faces of wingwalls and ends of piers or walls only should receive Class 2 surface finish. Upper surfaces of concrete bearing pedestals should receive Class 2 surface finish.

Superstructure

- Beam and Slab Deck

  The underside of the deck between beams and vertical faces of beams other than the outer face of outer beams should receive Class 1 surface finish. The outer faces and underside of the beams, the edges and the underside of the cantilevered deck slab, the interior and exterior faces of kerbs and the upper surfaces of the kerbs should receive Class 2 surface finish.

- Box Girders

  The inside surface of box girder webs, floor and deck should receive Class 1 surface finish. All external surfaces of the box girder, including kerbs and excluding the deck surface, should receive Class 2 surface finish.

- Above Deck

  All surfaces above the tops of kerbs should receive Class 3 surface finish. End posts should receive Class 3 surface finish. Precast parapet units and associated cast-in-place concrete should receive Class 3 surface finish.

Precast Concrete

- Precast crown units should be given a Class 1 surface finish. Precast parapet units should be given a Class 3 surface finish. Precast units other than crown units and parapet units should receive Class 2 surface finish. All precast units should receive this finish within forty eight hours of removal of forms.

15.13.2 Concrete Finishing Equipment

Obtaining a good surface finish on a bridge deck is a skilled operation which can be assisted by the use of a vibrating screed and a power float. However, satisfactory finishes can be obtained using a timber screed and suitable timber floats.

The vibrating screed is normally a heavy steel section to which a vibrator is attached. The screed travels on guides which are supported off the formwork and which determine the finished profile of the deck.

After the concrete has hardened sufficiently to be walked on without leaving an impression on the surface, a power float may be used to remove any local irregularities and to rework any shrinkage cracks.

15.13.3 Initial Finish

Initial finishing should be completed as soon as possible after placing and compaction by internal vibration. Levels should be checked with a straight edge between templates and adjusted as necessary.

A vibrating screed board can be used with concrete having a slump less than 80 mm. However, care must be taken to keep concrete continually at the front of the screed but it should not be allowed to accumulate there to a depth greater than about 50 mm.

15.13.4 Final Finish

Final finishing includes edging, jointing, floating, trowelling and brooming operations. These operations must not start until initial set has taken place, which is indicated by the disappearance of free surface water and the loss of surface sheen.

In windy conditions, it may be necessary to close surface cracking by refinishing.

Cement must not be used to absorb surface moisture as this can result in a weak, crazed or powdery surface.

15.13.5 Finishing After Removal of Forms

Forms should be removed carefully to avoid damage to the concrete surface.

Immediately following removal of forms from any part of the work, the surface of the concrete should be given a final finish in accordance with the Specifications.

If further curing time is required, the surface should be kept moist or sprayed with an acceptable curing compound immediately after these finishing operations.

15.13.6 Protection of Fresh Concrete Surfaces

If rain begins falling on a concrete surface which has not yet achieved final set, it should be covered immediately with plastic sheeting which must be placed without dragging. Alternatively, heavier materials such as tarpaulins may be rigged above the surface. Precautions must also be taken if the air temperature rises above 35°C.

15.13.7 Surface Finishing of Concrete

The Specifications include a number of different types of surface finish.

A *Class-1* finish is basically an off-the-form finish with repairs as required. A *Class-2* finish requires a greater degree of control on the form deflections etc. A *Class-3* finish requires a still greater degree of control of the formed product together with the requirement that the concrete be rubbed down with a carborundum stone and "bag washed" with wet hessian.

Following the removal of formwork from surfaces exposed to view (Class 2 finish), the surface should be cleaned up and dressed to present a neat and pleasing appearance. All fins and other unwanted projections should be ground off to provide a smooth surface. Any pockets or honeycombed areas accepted by the Engineer subject to satisfactory remedial work are treated as detailed in Section 15.14.1.

A Class 3 surface finish will require that the concrete surface be improved by bagging with a sand-cement grout consisting of equal parts of cement and fine sand passing a 600 μm sieve, mixed with an approved bonding additive and water to produce a plastic mix. It is applied uniformly to the surface using a pad of hessian or similar material so as to fill all air holes and other minor surface blemishes. The surface must be kept damp while the initial application is still plastic by rubbing with a dry mix of the same proportions leaving residual material only in depressions and none on the surface. Bagging should be undertaken within four hours of the removal of formwork. Curing should commence immediately forms are stripped or bagging is completed.

There are many surface finish treatments which can be specified. Some of the more common types are discussed below :

- Off-the-form finish can be obtained using steel or timber formwork. The form lining material determines the surface characteristics. Sawn timber boards create an interesting textured surface transferring the grain pattern of the timber to the finished concrete. Boards may be of uneven thickness and random width to create special effects. When the intent is to obtain a uniform off-the-form finish boards are inferior to ply and will require significant amounts of (additional) hand finishing to comply with the requirements of the Specification.

- For smoother surfaces, coated plywood or steel lining is required. Care should be taken in matching and sealing joints between sheets. It is almost impossible to disguise the location of joints even with good workmanship, and so it is important that the layout of panels on the surface is regular with continuous rather than staggered joints. Off-cuts should not be used to make up panels on exposed surfaces. Likewise, it is important to place all ties and anchors in a regular pattern.

- Where sandblasting or bush hammering is specified, it is important to maintain good workmanship because joints will still show out. Sand blasting or bush hammering will not disguise bad workmanship.

- Super smooth surfaces with a glass-like appearance can be achieved using fibreglass or plastic form lining. It is essential to ensure full compaction of the concrete against such surfaces because any air bubbles or inconsistencies will be conspicuous. Filling and repairing of imperfections can be equally conspicuous.

- Patterned or sculptured surfaces can be created by the use of blockouts of timber, polystyrene, plastic, fibreglass, rubber, or rope. Blockouts have to be carefully designed so that the formwork can be stripped without damaging the surface. Trials may also be warranted to determine the optimum time at which the formwork should be stripped.

Good workmanship and good materials are essential requirements for surface finish and for most structures, off-the-form finish (Class 1) should suffice without further cosmetic treatment. When uniformity of colour and texture is of paramount importance, the use of applied surface coatings may be warranted. There are a variety of proprietary lines of surface coatings available - some for purely cosmetic purposes, and others which give some protection from an aggressive environment.

It is important that all sheets used for forming a concrete surface be of the same quality and have been used a similar number of times. Otherwise, differential moisture absorption rates or a different surface texture will create a non-uniform finish.

For some work in urban areas, anti-graffiti coatings may be applied to the concrete surface to assist in the removal of graffiti. These coatings tend to darken the colour of the concrete. Light sand blasting has been demonstrated as an effective method of graffiti removal.

15.14 MISCELLANEOUS

15.14.1 Repair of Defects

Defects can be divided into two classes :

- Minor surface blemishes, scratches and spalls which effect only the outer part of the cover concrete and do not expose reinforcement.
- Major repairs involving concrete around and behind the reinforcement.

In the first case, minor repairs can be made using a suitable mortar usually incorporating a commercial bonding agent, or by filling with an epoxy resin putty. If surface uniformity is required, special care must be exercised to obtain a colour match.

Major repairs can be effected by placing and compacting concrete of the same or better quality as the original concrete. The defective area must be cut out and the hole "squared up" to obtain a key for the new concrete. It is highly desirable to coat the surface of the hole with a "wet-to-dry" epoxy resin before placing the fresh concrete.

Epoxy resins should not be used alone as a filler for major repairs as they do not provide the passivating chemical environment that cement does, and the differing coefficients of thermal expansion mean that cracking almost always occurs at the concrete-resin interface, with the risk of corrosion of the reinforcement.

Additional information on repair of defects in concrete is contained in the Bridge Construction Techniques Manual.

15.14.2 Dimensional Tolerances

Tolerances are specified for the following purposes :

- to enable precast components to fit together;
- to promote adequate standards of workmanship and prevent wastage of materials;
- to ensure adequate cover to reinforcement for durability;
- to ensure adequate section size for strength and to prevent excessive loads due to oversize components;
- to achieve an acceptable appearance on lines and surface.

The Supervising Engineer must be aware of the tolerances required and the reason for specifying them.

Construction within tolerance is more critical in some areas than others. For example, provided strength and durability criteria are met, tolerance levels are obviously less important in areas subsequently hidden from view than they are for exposed faces. As it is inadvisable to specify a multitude of different tolerances to cover all circumstances arising in the field, occasions will arise where it is necessary for the construction supervisors to use their own discretion.

15.14.3 No Fines Concrete

No fines concrete consists of a mixture of coarse aggregate (usually 10 or 20 mm in size) plus cement and water. It is used primarily as a drainage filter layer and so it is essential that its open texture be preserved during placing and finishing operations. Consequently vibrators must not be used for compaction. Curing is required for at least 4 days but wet sand should not be used for this purpose as it can fill the voids.

TABLE OF CONTENTS

16. PRESTRESSED CONCRETE

16. PRESTRESSED CONCRETE

16.1 GENERAL

16.1.1 Introduction

Concrete is strong in compression but relatively weak in tension. Thus concrete can resist quite heavy loads which tend to compress it but only relatively light loads which tend to stretch or bend it.

In prestressed concrete, the ability of the concrete to resist compressive forces is used to advantage. An external compressive force is applied to the concrete to keep it permanently in compression during its normal life to prevent tensile stresses occurring when loads which tend to stretch or bend the concrete are applied.

In effect, initial compressive stresses are set up in the concrete which cancel or reduce the tensile stresses which result from dead weight or service loads.

In reinforced concrete the steel takes all the tension stresses plus any excess compressive stresses which cannot be taken by the concrete. In prestressed concrete the steel is used primarily as a means of introducing compressive stresses into the concrete.

A prestressed member is permanently under compression - this effectively eliminates most cracks. If the member is slightly overloaded and tension cracks form these will close on removal of the overload (provided the steel has not been overstrained). With reinforced concrete the steel is not permitted to operate at a high level of stress as elongation of the steel will create cracks with obvious undesirable effects on durability and deflection.

Prestressed concrete members are usually smaller than equivalent reinforced concrete members. This smaller size reduces the quantities of steel and concrete but is counteracted to some extent by the need to use high strength materials.

There are two systems of inducing a prestress in concrete, either by stressing before the concrete is cast or by stressing after the concrete is cast. These are referred to as pretensioning and post-tensioning respectively. In both cases the stressing is carried out before application of the dead and live loads on the member.

16.1.2 Systems of Prestress

a. Pretensioning

Pretensioning is any system of prestressing in which the steel tendons are tensioned before the concrete is placed around them. This method requires the tendons to be temporarily anchored after tensioning to suitable abutments on the stressing bed before concrete is placed. When the concrete has attained a specific strength the tendons are released and the forces in them transferred to the concrete, thus inducing the compression already referred to.

The tension is induced in the steel tendons by means of pulling using a hydraulic jack. The amount of tension is measured by the elongation of the tendon from a pre-determined point and is checked by either pressure gauge or dynamometer (load cell). It should be noted that the tensioning processes for both pretensioning and post-tensioning are similar.

The mechanism of the transfer of prestress is described in the Bridge Construction Techniques Manual.

b. Post-Tensioning

Post-tensioning is a system of prestressing in which the steel tendons are tensioned after the concrete has been placed and has attained a specific strength.

Post-tensioning requires the provision of preformed ducts or voids in members to contain the tendons. When the tendons are tensioned, the forces in them are transferred to the concrete by means of anchorage plates or cones. The ducts or voids are pressure grouted after completion of tensioning operations in order to protect the tendons against corrosion.

This method of prestress does not require a stressing bed and the work can be done either in a factory or on site.

There are a number of patented post-tensioning systems in Indonesia but the most common is the VSL system, an example of which is shown in Figure 16.1.

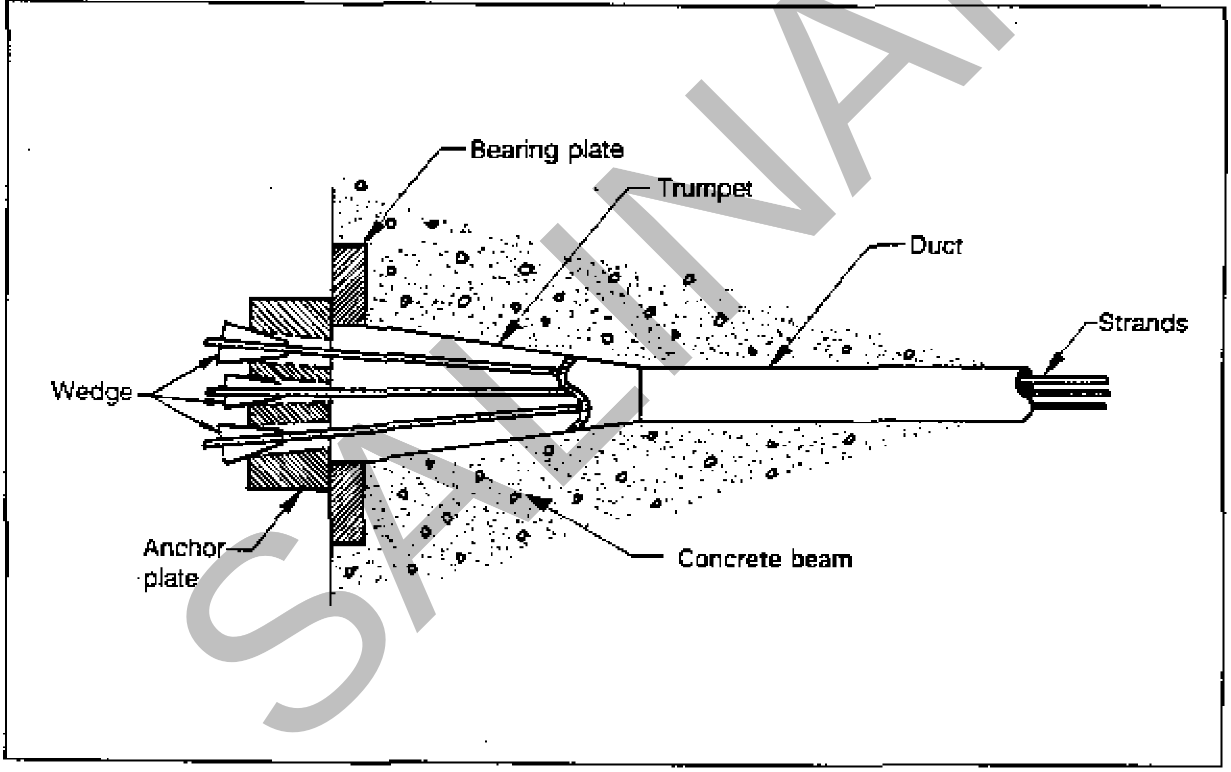


Figure 16.1 VSL Post-Tensioning System

A threaded bar system is also used, mainly for transverse post tensioning of precast deck units.

Details of the stressing and grouting operations are described in the Bridge Construction Techniques Manual.

16.1.3 Materials

a. Concrete

The use of high strength concrete allows efficient use of the potential created by high strength steel. To achieve high concrete strength requires detailed attention to the batching, mixing, placing and compacting of the concrete. The dimensions of a prestressed concrete member will be smaller than a reinforced concrete member of equivalent strength. This increases the difficulty of placing and compacting stiff mixes into narrow forms partly filled with reinforcement and prestressing tendons or ducts. The use of wet mixes increases the cost of supplying the nominated strength of concrete as well as increasing the drying shrinkage and decreasing the durability of the concrete.

Because prestressed members can be made considerably smaller than reinforced concrete units, the minimum size is often governed by cover requirements and the size and spacing of reinforcement steel and stressing steel or ducts. The increased durability of high strength concrete allows the concrete cover to steel to be reduced. As the cover may be reduced to as little as 20 mm, increased care in bending and fixing reinforcement is required.

b. Steel

Usual methods of applying prestress are by tensioning wire, strand or bar. All steel used in prestressing is of a considerably higher ultimate tensile strength (UTS) than mild steel. The UTS varies from approximately 2 000 MPa for fine wire to 1 500 MPa for 7 mm wire.

High tensile steel shows no definite yield point, unlike mild steel which has a well defined yield point. Elongation at failure is about 5 percent for high tensile stress relieved steel compared with about 25 percent for mild steel.

Strand is a combination of smaller wires. Generally circular cross section wires are used but sometimes a modified shape is produced by passing the complete strand through a die. This compacting process reduces the strand's overall diameter. The diameter of strand is a nominal diameter and is measured across the crowns of the opposite wires, that is the maximum diameter.

The smaller strands (8 to 15 mm diameter) usually consist of 7 wires. The larger strands (up to 30 mm diameter) are often 19 wires in various group arrangements. As an example, a typical breaking load for a 12.5 mm strand is 184 kN. With the minimum area of 12.5 mm strand (101.2 mm^2) this breaking load would produce an average steel stress of 1818 MPa.

Strand is used to provide large forces in restricted areas. It also reduces the amount of handling when compared with multi-wire systems. Strand has good bonding characteristics as it provides a mechanical key in addition to giving a greater surface area than an equivalent size bar.

Bars are also used to provide large forces in restricted areas. They are relatively easy to handle, simple to couple with threaded connections and there are no draw-in losses. Bars are suited to short length stressing or where restressing or coupling is required. The ultimate tensile strength of high strength bars is generally lower than strand and wire, usually of the order of 1 000 MPa.

16.1.4 Prestress Losses

There are certain conditions peculiar to prestressed concrete which necessitate the use of relatively high strength concrete (30 MPa and above) and high strength steel (e.g. 2000 MPa). The major reason for using these high strength materials is the reduction in the initial prestress due to one or more of the following causes:

Cause of Prestress Loss	Applicable to Pre-Tensioned System	Applicable to Post-Tensioned Systems
1. Shrinkage of Concrete	Yes	Yes*
2. Elastic Shortening of Concrete	Yes	No
3. Creep of Concrete	Yes	Yes
4. Relaxation of Steel	Yes	Yes
5. Anchorage draw-in	No	Depends on System
6. Jack Losses	Rarely	Rarely
7. Frictional Losses in Duct and Anchorage	No	Yes

* Depends on age of concrete at stressing.

- **Shrinkage of Concrete**

After concrete has cured and begins to dry out, it undergoes a reduction in volume. In a pre-tensioned unit all concrete shrinkage is shared by the stressed steel. As the steel shortens there will be some loss of prestressing force. In post-tensioned concrete some of the concrete drying shrinkage will be of no consequence - only shrinkage occurring after stressing will reduce prestressing forces.

- **Elastic Shortening of Concrete**

As a prestressing force is applied, the concrete will shorten. In pre-tensioned units the shortening of the concrete immediately after the steel is released will give a corresponding reduction in the initial prestressing force. With post-tensioned work elastic shortening during stressing is automatically compensated by the extension of the jack ram and does not have any effect on the initial prestress.

- **Creep of Concrete**

When concrete is loaded there will be an immediate elastic shortening (see above). However, if a load is maintained the concrete will "creep", that is there will be a permanent shortening. The rate of creep or plastic flow is dependent on the time it has been applied. Creep effects gradually diminish and after several years are virtually zero. As creep is a long term effect it applies to both systems of tensioning.

- **Relaxation of Steel**

When steel is tensioned to a high stress and then held at a constant length under that stress there will be a loss of steel stress as the steel "relaxes" under the load. The effect is similar in concept to the creep of concrete under compression except that in this case the steel is in tension. Relaxation occurs with both tensioning systems; however, its effects can be reduced by holding a slight over-stress for a short period. Some post-tension systems have provision for restressing at a later stage and these systems can be used to minimise steel relaxation and other long term stress loss effects. Steel must have adequate protection from damage and corrosion during the delay period.

- **Anchorage Draw-in**

With some types of anchors, notably the wedge type, there will be some "draw-in" as the anchorage takes up its load. The amount of draw-in is small (for example 5-10 mm for 15 mm strand, up to 20 mm for 30 mm strand), however it may be significant on short cables. On longer cables there is usually a sufficient margin of safety on the steel to allow overstressing to provide the additional elongation.

- **Jack Losses**

With most types of stressing jacks the force is measured by a pressure gauge attached to a hydraulic pump. The pressure given by the gauge will be more than that applied to the steel due to internal losses and friction within the jack. These losses are usually allowed for by calibrating the system or alternatively the force can be measured by another method, e.g. dynamometer or cable extension.

- **Frictional Losses in Duct and Anchorage**

In post-tensioned work there will be some loss of stress in the steel due to friction between the steel and the duct. With some types of anchorages there can also be frictional losses as the cable is pulled through the anchorage during stressing. With double end jacking, the stress applied at the ends will diminish towards the centre of a beam, and with single jacking the steel stress will decrease towards the "dead end", that is the end which is not jacked.

The amount of loss in ducts depends on several factors:

(i) length of cable from jacking end.
(ii) type of cable - size, shape, cleanliness.
(iii) type of duct - material, diameter.
(iv) "wobble" of duct - that is departure of duct profile from theoretical curve due to errors in setting out and aligning duct.
(v) curvature of duct - sharp radii obviously increase losses.

Magnitude of Prestress Losses

The effects of causes 1 to 4 in the table above are primarily dependent on type of concrete, method of curing, type of steel and levels of stress in steel and the concrete. As a very rough approximation, the shrinkage and creep of concrete reach half their ultimate value within one month and 75% of the ultimate value after six months. Typical losses for causes 1-4 are 15% for post-tensioned work and 20% for pre-tensioned work. In post-tensioned work the total loss would be considerably greater than 15% where no provision was made to compensate for draw-in on short cables.

Total prestress losses would also be much high than 15% in long ducts - particularly those with sharp radii, high friction surfaces and uneven profiles. The effects of causes 5-7 are related to the type of equipment and practical procedures and must be treated individually.

With typical prestressed concrete systems, losses of 15% would represent steel losses of about 300 MPa. As the yield point of mild steel is a little over 300 MPa, it is apparent that even with levels of initial stress close to the steel yield point there will still be a great or complete loss of prestress. As a factor of safety must be applied, mild steel becomes impractical as a prestressing material.

When only low strength steels and concrete were available the mechanism of creep, relaxation and drying shrinkage were not fully understood. It is only the relatively recent development of high strength materials which has allowed prestressing of concrete members to become a safe and efficient construction practice.

16.2 PRECAST MEMBERS

Where concrete elements of bridge superstructures are precast, the requirements are generally the same as for reinforced concrete described in Section 15.

Forms for prestressed girders which allow one side form to be erected in its final position independent of the other will make the fixing and checking of the reinforcement, post tensioning ducts, holes and blockouts easier.

The major difference between forms for ordinary precast concrete and forms for prestressed concrete is that in the latter, provision must be made for the shortening of the member due to prestressing, and for the concentrated load condition at the ends of members brought about by hogging after stressing. During stressing, bearing plates and other projections will move relative to the form and the casting bed, and allowance must be made for this by first stripping the side forms of girders or side and internal forms of U-shaped girders or removing panels to ensure that none of the stressing load is absorbed by the formwork.

Stripping time will usually be specified by the designer but in general will be between 1 and 2 days. However, if appearance is important, the age of the concrete when stripped should be the same for each unit.

16.3 REINFORCEMENT

Normal reinforcement in prestressed girders and slabs is usually relatively light, except in the end blocks of post-tensioned girders, which are heavily reinforced to withstand bursting forces in the anchorage zone. Light reinforcement cages are flexible and therefore must be rigidly supported vertically and horizontally to prevent movement and deformation. Specified cover is normally near the minimum value permitted by the Bridge Design Code, so the dimensions of the reinforcement after cutting and bending must be accurate. Inaccuracy or displacement which reduces the cover can seriously damage the long term integrity of the member. If baseplate bolts, anchorage fixings or cones, or lapping of reinforcing bars interfere with the placing of heavy end block reinforcement, the designer must be consulted. As with all reinforcement, the requirements of the Specifications with respect to flame cutting or heating must be strictly observed.

16.4 CONCRETE

16.4.1 General

The high strength concrete used in prestressed members demands a correspondingly high standard of supervision through every stage, from provision of materials, at batching, mixing, placing and finishing to curing, with adequate sampling of the mixed concrete at the placing stage.

16.4.2 Cement

Because of its lower early strength, the use of blended cement containing flyash is not usually considered for prestressed concrete. If it is to be used, the method of batching and mixing the flyash and cement must be strictly controlled. Curing also becomes more important. Cement older than four months from the date of manufacture or containing lumps should not be used. Sufficient cement to complete the job must be available at the mixer before starting.

16.4.3 Sampling and Testing

Concrete for prestressed concrete is sampled more frequently during placing than for ordinary concrete, a typical rate being one sample for every four cubic metres. It is essential that the method of taking the samples and making, storing, transporting, curing and testing the specimens is strictly in accordance with the relevant Standard, because if specimens fail, subsequent rejection of concrete may be subject to challenge by the Contractor.

If test samples fail, load testing may be acceptable as proof of satisfactory performance of the unit. If the unit is to be post-tensioned, cores may be taken and tested before tensioning. If core testing shows the concrete to be acceptable, the holes must be satisfactorily repaired before post-tensioning begins.

Excessive honeycombing, caused by bleeding of cement slurry from inadequate forms, or surface cracks may make the unit unacceptable for use in a major structure.

16.4.4 Compaction

Portable internal vibrators are the best method of compacting most concrete sections, the significant exception being thin sections cast flat. External vibrators are often used in conjunction with internal vibrators, especially in precasting yards. Although they produce good external finishes, the effect of the external vibrators at a distance from the surface depends greatly on the design of the formwork, and is not easily judged. It is essential that personnel operating internal vibrators be experienced, conscientious and systematic in their work to prevent sections of concrete being under-vibrated. On the other hand over-vibration can cause segregation, reducing the development of bond. Vibrators can also cause serious damage to ducts, voids formers or cast-in components. Where plastic foam inserts are used to form voids to permit temperature expansion of bridge superstructures, the foam should be protected from accidental damage from internal vibrators by plywood or similar material. Vibrators must not be left operating in concrete unattended. Windows may be required in some situations, such as very tall narrow sections, through which vibrators can be inserted.

High strength concrete suitable for prestressed construction must be cured properly. Premature loss of water from the concrete must be prevented. Unformed surfaces are subject to immediate loss of water, and formed concrete begins to lose moisture as soon as it is stripped.

Surfaces may be wrapped or covered with plastic sheeting or sprayed continuously with water. Plastic sheeting must be fixed so that it cannot be disturbed by winds, and so that a drying wind cannot get underneath it. Loss of water due to hydration must be prevented for at least 7 days, and preferably longer.

16.5 PRECAST PRETENSIONED DECK UNITS

Deck units in common use are 280 mm or 300 mm thick, 600 mm wide and spans varying from 5 metres to 16 metres. They may be voided or solid.

The deck units are placed side by side making the deck formwork simple and minimal. Difficulties can however occur due to differences in the hog or bow of adjacent units. These differences can result from variations in concrete and differences in the position of prestressing tendons within the unit caused by formwork inaccuracies and distortions.

Incorrect storage and stacking, especially during the period when the concrete is still gaining strength, can result in twisting of the unit which tends to become permanent. This also causes difficulties in the positioning of the units.

The ease of placement of the transverse bars for stressing the units together relies on the accurate positioning of the holes. Therefore the method of forming the holes should enable them to be accurately duplicated in all units even after stripping and reassembly of the formwork many times.

Keys between the units are sometimes packed with dry mortar after the units have been positioned and before placing deck reinforcement. Concrete should be placed as uniformly as possible across the full width of the deck to limit deflections between adjacent units.

16.6 TRANSVERSE STRESSING

The most common application of transverse stressing is the post-tensioning together of rectangular planks. Generally, single strand tendons are used in this application, and the main problems are to arrange the best match of adjacent duct openings and to ensure that these openings for post-tensioning are kept clear. The hog of each deck unit and the accuracy of ducts along the length of each unit is checked before placing the units in position. The units are then arranged in the order which will give the best match of adjacent duct openings.

The planks have a blockout which is filled with mortar prior to post-tensioning to ensure even bearing along the planks and a polystyrene or similar packer around the duct to prevent grout leaking from the ducts.

Gaps between adjacent holes must be sealed to prevent the cement mortar or epoxy mortar packing material placed between the units from leaking into the ducts.

TABLE OF CONTENTS

17. STEEL STRUCTURES

17. STEEL STRUCTURES

17.1 FABRICATION OF STEELWORK

17.1.1 General

Fabrication is the term used to describe the manufacture of the various component parts of a steel structure from steel plates or sections. It incudes the processes of cutting, forming, drilling, punching, joining and any other operations performed to convert simple plates and sections into finished components.

17.1.2 Drawings

The design drawings provide a detailed concept of the structure. For major fabrication, shop drawings are required to give the complete information required for fabrication, including the dimensions and the locations, type and size of all welds and holes. These drawings must be accurately and carefully detailed to avoid problems during fabrication and erection and must be checked before fabrication commences. The shop drawings are prepared by the Contractor from the design drawings and will reflect his proposed method of fabrication.

17.1.3 Fabrication Procedures

a. Identification of Steel

All steel used in the fabrication of a bridge must conform to the relevant Codes as set out in the Specification.

This can be checked by referring to the heat number or other coded number of the steel which is stamped on the steel at the time of rolling. This number can be related to the manufacturer's test certificates which give the physical properties and the chemical composition of the steel.

In the absence of such identification, it may be necessary for the fabricator to arrange for samples of the steel to be tested at an approved laboratory.

b. Straightening

Bent or otherwise distorted steel must be corrected in a manner which will avoid damage to the steel. Should material require straightening to maintain tolerances and fit, either before or after fabrication, it is general practice for this to be done by mechanical means at ambient temperature, although minor kinks and bends in normal strength steels may be corrected by limited heating *under careful supervision.*

The heating of high strength steels to achieve straightness or remove distortions should not be attempted without investigating the effect on the steel.

Hydraulic presses, applying forces either horizontally or vertically, and rollers are usually used for straightening.

c. Marking-Off

The marking-off of steelwork, including the location of holes, may be done from shop drawings or by the use of templates. A template is a full-scale pattern or guide, made of cardboard, plywood, sheet metal, timber strips or hardwood.

d. Bending

The presses and rolls used in the straightening process can also be used to permanently shape structural members. Steel tubes for pile casing are usually formed in a plate roll and the seam is welded.

e. Cambering

Cambering of rolled steel members may be achieved by the same processes used for straightening and bending.

Cambers for plate girders are produced by cutting the web plates to the required shape.

Camber of a girder may be measured with the girder on its side or with the girder supported at its bearing points. Measurement of camber should make allowance for deflection resulting from self-weight.

f. Cutting

Steel may be cut by shearing, sawing, or flame cutting.

Shearing of plates is normally not permitted except in a direction perpendicular to the direction of the main stresses in the plates.

The cut edges should be free from burrs, gouges, and other defects which may adversely affect the serviceability of the member. Any stress raising notches must be removed where this is called for in the Specification.

Flame cutting, with a suitable mixture of a gas such as acetylene and oxygen, is commonly used for cutting structural sections. The flame may be guided manually or by the use of automatic, self-propelled equipment.

Flame cutting is also widely used for bevelling the edges of steel plates for weld preparations.

g. Bolt Holes

Holes may be either drilled full-size or reamed to full size after sub-drilling or sub-punching to a diameter approximately 5 mm smaller than the final hole diameter.

To ensure compatibility of holes in main members, adjoining components are fastened together by clamping and then match drilled.

For minor members, holes may be drilled using a template.

h. Assembly

Assembly of components is generally either by welding or bolting. In shop-work, welding is normally used.

To minimise distortion of members, a balanced pattern of welding of permanent fasteners is necessary. These requirements are generally outlined in the Specification.

There are several methods of assembly of welded girders. These methods depend upon the size of the unit, the capacity of the fabricating shop and the required welding techniques. Generally, the components are tack welded into place and the girder is then positioned for a continuous welding process at the preferred angle for welding. This positioning may be on fixed supports or on specially constructed trunnions on which the girder may be turned to any angle.

17.2 WELDING

17.2.1 General

All the steel grades listed in the Specification are weldable.

Welding procedures for the higher strength grades involve the use of higher preheat temperatures and low hydrogen welding rods, particularly as the member thickness increases. These requirements are to ensure satisfactory strength and the toughness in the heat affected zone (HAZ).

Detailed guidelines on the welding of bridges are given in the AASHTO/ANSI 'Bridge Welding Code' and general welding guidelines in other ANSI/AWS standards.

17.2.2 Preheat

Preheating of steel before welding may be required, particularly for thick plates. Generally a region of approximately 75 mm on either side of the joint is required to be preheated.

The purpose of preheat is to diminish the rate of cooling of the weld metal as the heat from the weld is transmitted away from the weld through the plate. Excessive rates of cooling can lead to extra hardness and brittleness in the weld metal and in the heat affected zone of the parent metal.

The requirements relating preheat and welding energy input for various types of plate and electrodes are given in the American Welding Institute (AWI) Welding Codes.

17.2.3 Distortion

During welding, the laying down of a weld produces a heating and cooling cycle which causes shrinkage in both the base metal and weld metal and shrinkage forces developed tend to cause a degree of distortion. Distortion generally appears as longitudinal shrinkage and transverse shrinkage.

If the shrinkage is not uniform through the thickness of the weld, angular distortion results. When shrinkage acts in a direction that is not along the neutral axis of the member the result is bowing.

There are many factors which affect distortion during welding, such as :

- heat input
- restraint
- residual stresses.

A detailed guide to control of distortion is given in the AWI's referenced document(s).

Excessive distortions can be minimised by pre-setting the components, so that after distorting they attain their correct shape, or by restraining the components from distorting using clamps and braces.

Welded metal also shrinks as it cool and can cause shortening of members. The shrinkage of longitudinal welds in plate girder can cause a shortening of the order of 1 mm for every 4 m of girder.

Joints which are expected to have the largest shrinkage should be welded first with as little restraint as possible.

17.2.4 Qualification of Welding Operators

Welding must be carried out by competent operators who have had suitable training and practical experience.

Generally, visual inspection of the welder's technique and the weld will indicate the quality of the welder. With the exception of occasional undercut, surface defects such as insufficient throat, overlap etc., should not be evident in welding carried out by a competent operator.

Welders who are engaged on butt welding or unconventional types of welding are normally required to prepare test specimens which duplicate as far as possible the actual condition of the work.

17.2.5 Qualification of Welding Procedures

As well as testing the competency of the operator, it is normal practice to test the actual procedure to be followed in making a weld. Procedures for common types of welds may be approved on the basis of previous experience. Procedures for less common types of welds are verified by fabricating test assemblies.

Procedure details include :

- operator's name
- type and make of equipment
- plate preparation
- type and size of wire or electrode

- type of flux
- preheat temperature
- welding speed
- welding current
- welding voltage
- weld size and number of passes.

Once a procedure has been approved it should not be substantially altered.

17.2.6 Electrodes

Electrodes used in a weld are generally required to give properties in the weld metal of not less than those of the parent metal being joined, unless the use of a lower strength grade of electrode is shown on the Drawings. Each packet of electrodes will have a maker's brand and a printed panel showing the electrode classification.

Electrodes which have become separated from their packets should not be used as such electrodes will not be identifiable. Loose electrodes are likely to have had their flux damaged and may be contaminated with water.

An experienced welder's selection of an electrode will usually be satisfactory, provided it conforms with the Specification. For welding structural steel in the downhand position, a general purpose electrode will be satisfactory. However, for special circumstances an electrode with particular properties may have to be used.

For example, in the welding of notch ductile steels, low hydrogen electrodes are normally specified. These electrodes produce a weld metal of increased ductility.

17.2.7 Inspection and Weld Repairs

The position of Welding Inspector carries great responsibility. He must ensure that the welders are suitably qualified for the type of work they are doing, and that the required procedures are being followed. The area to be welded should be checked for cleanliness and alignment before work starts. The finished welds should be cleaned and then inspected for faults both visually and by other methods as may be specified. The inspector must ensure that the method of cleaning does not obscure or cover up cracks or other flaws. Areas to be repaired must then be marked clearly, in a manner that all personnel involved understand, and the marks should be sufficiently permanent to be visible after repairs have been done. Welds showing cracks should be rejected, regardless of the length or location of the crack.

Faulty weld material can be chipped, ground or gouged out. The exposed surface should then be checked to ensure that all faulty material has been removed. The repair can then be made by rewelding the affected section. This reweld is then subjected to the same tests as if it were an original weld.

A guide to permissible methods of repairing faulty welds can be found in the American Welding Institute 'Structural Welding Code", D1.1-88, clause 3.7.

17.3 INSPECTION OF FABRICATED STEELWORK

17.3.1 General

The inspection of fabricated steelwork and the protective treatments is usually carried out at the place of manufacture. The inspectors are responsible for checking materials, equipment, dimensions and workmanship to ensure that they conform to the requirements of the Specification.

Steel Inspectors will normally have had practical experience in the welding of structures and will be familiar with fabrication methods and equipment. They will also have knowledge of the defects which can occur in fabrication and of satisfactory methods to be used for the correction of these defects.

17.3.2 Inspection of Welding

Inspection of welding involves consideration of the following points :

- welding equipment, materials and processes and their limitations
- joint preparations
- welding procedures
- correct fusion and penetration
- weld defects and the methods of correction
- non-destructive testing and interpretation of results

17.3.3 Defects in Welding

Details of defects in welding are given in AWI Codes.

A number of weld defects can be detected by visual inspection. These include undercut, incorrect profiles and surface defects. An inspector can employ other methods to assist him in the detection of welding defects which are not apparent from visual inspection.

These are :

- Dye Penetrant Tests - for detection of surface cracks

- Magnetic Particle Tests - for detection of surface cracks or under certain conditions, cracks which can be just below the surface.

- Radiography - X rays or gamma rays - for detection of sub surface defects.

- Ultrasonic Inspection - for detection of subsurface defects. This has the disadvantage that no permanent record is made but on the other hand, large areas can be covered.

Detailed information on the non-destructive testing of welds is given in various standard welding handbooks.

17.4 PROTECTIVE TREATMENT

17.4.1 General

The protective treatment of the steelwork should be applied in accordance with the Specification or relevant Standard. The surface treatment and thickness of protective layers should be inspected and measured by paint thickness gauges.

17.4.2 Surface Preparation

An adequate degree of surface preparation, dependent on the environment to which the structure will be exposed, is essential because the adhesion of the painting system is determined by the surface preparation.

Unless dirt, dust, oil, grease and other surface contaminants are removed, the paint applied to the surface will have poor adhesion, with subsequent breakdown of the paint system and exposure of the substrate to attack. Paint must always be applied as soon as possible after the surface preparation and no later than on the same day.

Abrasive blast cleaning is the normal method of surface treatment on steel bridges.

17.4.3 Primers

Primers provide a coating which must

- be adherent to the surface of the steel
- retard corrosion of the surface by either inhibiting the corrosion process or by acting as a cathodic sacrificial barrier, and
- provide a base to which subsequent coats of paint will adhere.

The primers normally used on new steel bridges are zinc rich primers. These primers protect steel because zinc is electro-positive with respect to iron. Provided there is electrical contact between the two metals, the zinc will corrode sacrificially instead of the iron. Zinc rich paints therefore should contain a maximum of finely divided pure metallic zinc powder dispersed in a minimum of stable binder. They must be applied to a freshly blast-cleaned surface, in accordance with the Specification, to ensure effective electrical contact.

Zinc rich primers fall into two classes according to the nature of the binder. The more durable are those based on inorganic binders. The second group are based on organic binders. These binders are derived from a number of resins but the two-pack epoxy variety is normally used for patching and for repainting work.

17.4.4 Undercoats

Undercoats are sometimes called tie coats or barrier coats and are used where it is necessary to ensure adhesion of two otherwise incompatible coatings. Old gloss alkyds form a poor base for recoating with fresh gloss alkyd unless an undercoat is used. Paints with strong solvents such as vinyls and chlorinated rubbers cannot be applied over new oil based or alkyd primers unless a barrier coat is interposed to resist the swelling action of the strong solvents on the alkyd binder of the primer.

17.4.5 Finishes (Top Coats)

a. Iron Oxide

The properties of finishing or top coats are determined by the combination of various pigments and vehicles. The most utilitarian of pigments is Micaceous Iron Oxide, often abbreviated as M.I.O.

Because of its dark grey, almost charcoal colour, only grey or muddy colours are available. This iron oxide pigment has a flakey form like that of mica, hence the name. These flakes lie in a paint film like scales and provide a physical barrier to the penetration of water and to the ultra violet rays of sunlight which are particularly degrading to organic binders.

b. Vinyl

Vinyl coatings are capable of giving good protection if applied over zinc rich primers. However, their successful use depends on proper application and their recoating will present problems if the exact type of vinyl used is not known, and a suitable formulation is not available for repainting. There are two basically different types of resin-based coatings on the market which are not necessarily compatible with each other and both are marketed as vinyls. Only spray application is possible.

c. Chlorinated Rubber

Chlorinated rubber coatings are available in both high-build and sealing coats, and these must be applied as specified by each manufacturer. They dry quickly, are easily recoated and have good resistance in marine and industrial environments. They are suitable for application by either brush, spray or roller, but spraying is the preferred method.

d. Epoxy

Two-pack epoxy resins are suitable for high-build coatings and have excellent resistance under marine conditions. They require considerable care in recoating to achieve proper adhesion of the over or top coating system to the existing coated surface.

e. Galvanising

Galvanising of heavy and long members, such as steel bridge girders, may be an economically attractive alternative to other forms of protective treatment.

Consideration needs to be given to the following if galvanising is used.

- loss of girder camber
- *distortion resulting from hot dip galvanising* and *methods of correction*
- need for masking at joints which are to be field welded
- possibility of colour differences if a girder is double dipped, where the length of the galvanising bath limits dipping to half the length of a girder at a time.
- rethreading of nuts and bolts after galvanising.
- repair of damage to the galvanising caused during the handling or erection operations.

17.5 HANDLING AND STORAGE OF STEELWORK

During transport of the steelwork from the fabrication shop to the site, the greatest care must be taken to avoid damage. Fabricated members may be damaged easily by careless handling or improper storage. Loading and unloading from vehicles, lifting and all aspects of transport and storage must therefore be closely supervised.

For temporary storage, steel components are normally stacked on platforms or skids on firm, well-drained and accessible ground. They must be so positioned that they do not hold water and are protected from mud splashes otherwise the shop coat of paint will deteriorate, and there will be extra work in cleaning and preparing for the field protective paint treatment.

The steelwork fabricator should supply a diagram showing the correct marking of all members and parts (girder segments, span, upstream or downstream members or sides and top or bottom etc.) and these markings should correspond with the actual markings on the members and with the fabricator's shipping lists. It is also preferable to mark each piece with its weight, especially when heavy members are involved. Deliveries should be made, if possible, in the order in which the components are required by the contractor carrying out the erection of the steel work.

17.6 ERECTION OF STEEL STRUCTURES

17.6.1 Girder Erection

This Section is relevant to small and medium size bridges. These can be erected with simple techniques using readily available equipment. For large bridges, erection methods are usually specified as part of the design, and the use of specialised equipment and techniques is required.

Girders may be lifted directly into position by a mobile crane traversing alongside the bridge if the ground conditions are suitable, by fixed cranes positioned in the vicinity of the support positions, or by flying fox. If a flying fox is used, a lifting girder should be placed between the fox and the main girder to enable approximately vertical lifts to be applied to the main girder. For smaller components a lifting girder is not required.

Launching of girders requires either falsework or a temporary launching girder to carry the tracks for the trolleys or roller on which the girders are moved. With girders continuous over two or more spans, it is possible (by fitting rollers on the abutment and pier supports) to launch girders without using falsework. Launching methods should be fully detailed and approved by the Engineer before their use is allowed.

Lifting points are usually specified for steel girders, and the steel must be protected where slings are attached so that the protective coating will not be damaged. The provision of lifting lugs will reduce damage to painted surfaces.

If the girder has been fabricated as a completed span, it can be lowered directly on to holding down bolts and bearing plates which have been set temporarily in the appropriate positions. If the girder is to be spliced insitu, falsework will be required to support the joint or perhaps the complete girder sections depending on the method specified by the designer.

Falsework foundations must be adequate and protected from damage by debris and scour if over a river, or by traffic if over a road.

The falsework structure should be checked regularly for signs of settlement, and all faults corrected before bolting or welding of the main structure commences.

Members should be fitted together without undue strain or distortion, and should be correctly aligned longitudinally, vertically and transversely, and with the centreline of the bridge.

Provision of jacks, ropes and/or wedges is required for adjusting joints if necessary in all three planes, in preparation for welding, bolting or fastening.

During the movement of individual girders into position and until such time as they have been connected by the cross girders and braces, they should be securely strutted and/or guyed against overturning. Timber or steel frames, designed to prevent both lateral movement and overturning of the girders, and connected to the substructure, are suitable for this purpose. Frames should be built in such a manner that they can be easily removed, and should be positioned to give full support to the girders before the lifting tackle is removed.

Long slender girders may require temporary lateral stiffening whilst being lifted and placed into position and until transverse bracing is fixed. A system of horizontal trusses using rods, turn-buckles and struts can be installed on each side of the girder for this purpose.

17.6.2 Truss Erection

Erection Manuals are available for each of the different types of truss bridge currently being used throughout Indonesia. These Manuals describe in detail the methods of erection and aspects of construction relevant to the type of truss being used. The Construction Techniques Manual contains further information on the assembly and erection of the Australian, Hollandia Kloos and Austrian trusses.

In general, trusses may be built and launched into position or built as a cantilever from one abutment. The 80m and 100m Australian truss spans are designed to be erected as two half-spans. In either case, an anchor span and possibly kentledge (dead weight as ballast) are required to ensure stability.

Any of the truss types (other than the 80 m or 100 m Australian trusses) may be rolled out from one bank on erection rollers supported on falsework, and jacked down onto the permanent bearings. Alternatively, the truss may be assembled on the falsework and jacked down onto the permanent bearings (for the Australian trusses only - following completion of assembly and casting of the in-situ concrete deck). If falsework is to be used, the guidelines given in Section 23 of this Manual should be followed. It is important that the use of falsework in a river be carefully assessed as loss or damage to the falsework may mean a consequent loss of the partially completed structure. This is especially important for construction during the wet season.

17.6.3 Cross Bracing

Cross bracing may be in the horizontal plane between flanges of trusses or box girders, or in the vertical plane between adjacent girders. It may consist of structural shapes, fabricated plate girders, or triangulated systems.

It is usually fixed by welding or bolting with high strength bolts or patent fasteners as soon as possible after erection of girders. Until that time the girders must be protected against lateral instability and in the case of long slender girders, against lateral buckling under external loading.

Steel box girders require fixed internal bracing to support the slender webs, and substantial horizontal crossbracing to provide torsional resistance during loading, transport and erection. The design may allow for the removal of the latter bracing after the top flanges are held laterally by the deck, but often this is not considered economical.

Access for fixing crossbracing can be provided by suspending a cage from a crane, a truck mounted platform, a fixed platform on scaffolding or staging supported from the main structure. If the cross bracing is to be welded, protection against wind and rain must be provided on the staging.

17.7 FIELD SPLICES

17.7.1 General

Steel members may be joined on site by either high strength friction grip bolts or by field welding. The use of field welding requires the availability of skilled welding operators and suitably qualified site inspectors.

17.7.2 High Strength Bolting

a. General

High strength bolting may be classified by two types, a "friction grip" type with no slip, and a "bearing" type in which an initial slip is allowed. Generally, bolted connections of major structural elements of modern bridges are designed as friction grip joints. The steel used in the bolts is a special alloy which will stand much higher stresses than structural steel and it will elongate considerably before failure. The nuts are made of suitable material and the washers are specially hardened to resist scuffing when the bolts are being tightened.

The tension in the bolt creates friction between parts of the joint and the friction can transmit forces through the joints. If the tension in the bolt and the coefficient of friction between the plates are known, the force which can be transmitted without any movement of the parts can be calculated. All high strength friction grip bolted joints work on this general principle, independent of the number and arrangement of the bolts in the joint.

The higher the clamping or tension force created by the bolt and the higher the friction between the components, the more force can be transmitted between the parts of the joint. To bring this principle to a practical level, the designer assumes a lower limit of bolt tension and a reasonable value for the friction coefficient between the mating surfaces.

The minimum bolt tension which must be obtained for different bolt diameters is normally stated in the bridge construction specification. The coefficient of friction between the contact surfaces of steelwork in reasonable condition is known. Provided the bolt is correctly tightened and the specification is followed by keeping the contact surfaces clean of dirt, loose rust, grease etc., the bolt will transmit the force as expected by the designer.

Bolts which have been fully tightened must never be reused as friction grip bolts and should be immediately disposed of.

b. High Strength Bolts

The tightening of high strength bolts is normally controlled by using one of three methods - the Load Indicating Washer method, the "Part-Turn" method or the "Torque Control" method. Further information on bolt tightening methods for each of the different types of steel superstructure is included in the Bridge Construction Techniques Manual.

It is important that the full area of the contact surfaces at all joints be roughened by vigorous wire brushing (or similar method) and that the direction of brushing be across the flange or web of the member being connected.

c. Tightening of Bolts - Load Indicating Washer Method

In the load indicating washer method, the bolts are assembled with the load indicating washer under the bolt head with the projections bearing against the bolt head and a hardened flat washer placed under the nut. The bolts and nuts must be properly lubricated to ensure that the load indicating washer is able to close properly under load. If re-lubrication is required, the part must be cleaned and an extreme-pressure oil, grease or wax used. The contact surfaces must be kept clean and any oil must be cleaned off immediately using a suitable solvent.

The holes to all plies of each joint must be properly aligned before the bolt is inserted (by the use of suitable drifts). The bolts are initially "snug-tightened" using a podger or similar spanner. Snug-tightening is the tightening achieved by the full effort of a man using a standard podger spanner.

No final tightening is undertaken until the whole of the connection complies with the requirements of camber, fit and member arrangements.

The bolts are finally tightened using special spanners as appropriate. Tightening is carried out by turning the nut and not the bolt head (the head of the bolt may need to be held to prevent it turning). Each bolt is tightened until the gap measured at the load indicating washers falls within a predetermined range (usually 0.15 mm to 0.25 mm). This gap should be checked with feeler gauges. The tension is applied evenly and completely to each bolt in the connection. Tightening should commence at the centre of any group of bolts and progress outwards.

d. Tightening of Bolts - Part Turn Method

In the part turn method the component parts are firstly brought into close contact termed the "snug-tight" condition, by hand or by impact wrenches. After all the bolts in a joint are snug tight, each bolt is given a final tightening. The final tightening for the usual diameter and length of bolts is an additional half turn of the nut relative to the bolt.

e. Tightening of Bolts - Torque Control Method

The torque control method for bolt tightening is not as accurate as the load indicating washer method. Very small variations in the friction coefficient of the threads can result in large changes in bolt tension. Contamination of the thread, or a different batch of bolts can make the results of the tensioning quite inaccurate. If the wrong length of bolt is used and the nut reaches the end of the thread, the torque will be reached on the indicator, yet the bolt may still be loose. In the case of galvanised bolts, the tension required may not be reached at all and the bolt will break due to the twist produced by the applied torque. Bolts are usually supplied with lubricated nuts if this method is to be used. Regular calibration of torque applied and the corresponding bolt tension should be carried out.

The "Torque Control Method" of tightening can give an incorrect indication of bolt tension for galvanised bolts if suitable thread lubricant is not used.

17.7.3 Field Welding

Site welding procedures and methods are generally the same as corresponding shop welding. However, the on-site situation gives rise to special difficulties. Generally, manual arc welding is used because of the portability of the equipment.

Procedures should be chosen such that distortion and residual shrinkage stresses are minimised. This requires a deposition sequence in which the applied heat is balanced about centres of possible movement. In some cases, two welders can work on opposite sides of a joint to achieve this. Low hydrogen electrodes are used for joints where additional ductility is required.

Often the welding procedure can be varied (to improve weld quality and reduce distortion) after a few joints have been made and examined. Joints which are expected to have large shrinkage should be made first while the connecting members have little restraint.

The staging provided for welders should be of a high standard because a welder may have to spend a considerable period of time working at a joint. As a consequence, a welder requires a comfortable as well as secure working platform to achieve a high standard of workmanship.

Portable drying cabinets (to ensure that the electrodes remain dry) may be necessary near the work, depending on the type of electrode and the distance to the main electrode store. Weather shielding may increase the speed and quality of the work on jobs of long duration, by protecting the welder and the welding operation from rain and wind.

Clamping devices consisting of pieces of drilled angle, bolt clamps, long bolts, dogs and wedges may be useful in "drawing in" and aligning members before welding.

17.7.4 Repair of Protective Treatment

Where the protective treatment of steel members (paint or galvanising) has been damaged during handling or erection, it must be repaired in accordance with the Specifications. Some bridges are designed to have the final coat(s) of paint applied after erection, the steel being painted only with a primer prior to erection.

TABLE OF CONTENTS

18. BEARINGS AND EXPANSION JOINTS

18.1 BEARINGS

Bridge bearings are difficult and expensive to repair or replace once they are installed. Great care is therefore required at every stage of their handling and installation.

The Supervising Engineer should check immediately on delivery that the specified type of bearing has been supplied, that it is the right size and shape, that there are no visible faults, that the holes are the right size and in the right place and that the specified test certificates are available. Finally, he must ensure that the bearings are carefully stored so that they are safe from physical damage.

Survey marks should be placed on abutments and piers immediately adjacent to bearing positions so that the position, alignment and level of each bearing can be checked easily before it is grouted or epoxied in. These marks should take into account minor discrepancies in the measured length between bearing plates on each girder and any variation in girder depth which might affect bearing levels.

For concrete bridges, he must ensure that there is contact over the whole area between the substructure and the lower plate, and between the upper plate and the girder. This can be achieved by packing with non-shrinking mortar or epoxy. Sliding and rolling surfaces should be carefully cleaned and lubricated (if appropriate).

Before the bearings are fixed in their final position by grouting or epoxying the holding down bolts, he must ensure that they have been set to the required longitudinal and transverse gradients, that the specified allowances have been made for temperature and creep and that these allowances have been made in the correct direction.

18.2 EXPANSION JOINTS

Unless properly installed and maintained, expansion joints wear, become loose, seize up, break, bend and generally require frequent attention and repairs during their service life. It is therefore essential to follow carefully the manufacturer's instructions for installation of expansion joints to minimise these problems.

Bolts must be set in the correct position and at the correct height. When the structural concrete is cast, special care is required to ensure complete filling and adequate vibration in the heavily reinforced areas around the bolt anchors.

The upper surface of the expansion joint must be set exactly to both the specified transverse and longitudinal gradients of the bridge deck.

It is desirable that the asphalt overlay sealing coat adjacent to the joint be slightly higher than the joint itself to reduce the effect of wheel impact and to allow for the gradual decrease of the thickness of the seal caused by consolidation under traffic. The road surface should never be lower than the joint.

TABLE OF CONTENTS

19. RAILINGS AND BARRIERS

19. RAILINGS AND BARRIERS

19.1 GENERAL

The final appearance of a bridge is influenced to a very large extent by the profile of the railing as this is the most visible line seen by the motorist. Accordingly, great care should be taken to ensure that it is erected to smooth curves, both horizontally and vertically. This applies to all types of railing but particular attention should be paid to steel rails with site-welded members to ensure that a smooth profile is obtained after welding. Erection tolerances on railing are usually very tight but they are important and should be achieved by the Contractor.

Tolerances should be stated in the Specification but, if not, appropriate tolerance are :

- variation from true plan position of posts ± 5 mm
- variation of dimensions in elevation ± 3 mm
- variation of line of rails from specified vertical and horizontal profile ± 5 mm

There are a large number of different types of barriers and railings used on bridges, both traffic and pedestrian. These range from simple timber railing and standard "Armco" type guardrails to specially fabricated steel or aluminium rails and concrete "New Jersey" style barriers.

19.2 STEEL RAILS

These includes *'Armco'* type guardrailing as well as fabricated traffic or pedestrian rails.

Standard Armco guardrailing can be erected on either timber or steel posts. Mounting details vary, but typically are U-bolts cast in the edge parapet of the bridge. Timber posts *should be inspected to ensure the timber is sound and free from any defects and correctly* treated. Steel posts are pre-fabricated and should be checked to ensure all dimensions are correct and that the surface treatment is undamaged.

Holes in posts for mounting bolts must be drilled and slotted vertically to enable the rail to be correctly aligned.

Railing should initially be assembled for the full length of the bridge but only loosely fastened together to enable the profiles to be adjusted before tightening up. Guardrail panels must be assembled with the laps arranged in the direction of traffic movement to reduce the possibility of a vehicle being impaled following an accident. Finally, all bolts must tightened and terminal sections correctly installed.

The correct design and installation of guardrail terminal sections is very important. They must anchor down the end of the railing so that it can act correctly as a continuous tensile ribbon and also serve as a cushion for any vehicle impacting the end of the rail directly.

Other steel railing will normally be fabricated off-site. The railing should be checked during manufacture and particular attention should be paid to the surface treatment for compliance with the Specification. After delivery, a check should be made for damage during transit. Erection can be on bolts or sockets cast into the parapet. The rail should be erected loosely using packers or shims to get the correct profile before bolting and welding. All steel and timber packers must be removed to eliminate the possibility of subsequent staining. Cement fibre or galvanised packers may be left in place.

Finally, sockets should be grouted and base plates mortar-packed. Packing should be with dry-pack mortar rammed hard into place. Wooden rammers should be used to prevent damage to surface treatment.

The erection of long, continuous lengths of steel railing without expansion joints sometimes gives problems in attaining the correct profiles because of temperature movements. In such circumstances, expansion joints should be installed at not more than approximately 45 m centres.

For site welding and repairs to surface treatment, refer to the Specifications. Some Specifications require the final coat of paint to be applied on-site after the repair of damaged surfaces. This gives a uniform appearance to the rail. Care must be taken during painting to ensure that there is no staining of the surrounding concrete.

19.3 ALUMINIUM RAILS

Aluminium is used both for complete railings and for the top rails to concrete barriers. Both extruded sections and castings are used. Manufacture is by a specialist fabricator. The railing should be checked during manufacture to ensure that dimensions are correct and that satisfactory welds and castings are being achieved. It is normal to load-test a sample of the castings to check for imperfections. Aluminium railings do not normally require treatment, but if treatment is preferred for aesthetic or other reasons, the railings may be anodised or painted. Checks should be made on uniformity of surface preparation and on the thickness and colour of coatings.

Erection of aluminium railings is similar to steel with the only additional precaution being that the aluminium should be effectively insulated from any steel fixtures such as mounting bolts to prevent galvanic action. Plastic tapes, sleeves and washers may be used.

19.4 CONCRETE RAILS AND BARRIERS

Concrete "post and rail" type railings have been used on many bridges but are now being replaced by steel and aluminium due to their high cost and ineffective action. "New Jersey" type barriers are a type of concrete guardrail.

These railings can be cast as part of the edge parapet, when an additional metal top rail may be required, or they may form an inner barrier to a footpath. They are also used as median barriers on both bridges and roads to prevent "cross-over" type accidents. In this case, the barrier will be double sided.

Concrete barriers should be cast after completion of the bridge deck to ensure that the correct profile and line is attained. Reference may be made to Section 23 for guidance on formwork construction, reinforcement and concreting.

When casting concrete barriers it is most important that the forms are accurately made and located, and are of rigid construction. This is to ensure that the final lines of the barrier are straight and true with a clean, smooth surface. Even so, it is difficult to avoid surface air bubbles on the sloping face and often it is necessary to resort to bagging and stoning to obtain an acceptable surface.

Control joints should be provided in the barrier to control the location and size of temperature and shrinkage cracks. The joints provide a plane of weakness to encourage cracking in that position. A groove or other feature should be provided on the surface to camouflage the crack.

Concrete edge and median barriers may be precast. Precast concrete median barriers are set on a thin layer of mortar, directly on the bridge deck. The individual units should be keyed into one another and asphaltic concrete laid against the base to provide lateral restraint. Edge barriers are usually supported on levelling bolts cast into the concrete deck. A cast-in-place reinforced section is used to rigidly connect the deck to the barrier.

TABLE OF CONTENTS

20. TIMBER CONSTRUCTION

20. TIMBER CONSTRUCTION

20.1 INTRODUCTION

Timber bridge construction is diminishing in Indonesia but timber is still used for some new bridge construction even though timber construction has been largely superseded by concrete and steel. There are many old timber bridges still in service which have to be repaired and maintained. Temporary timber bridges are sometimes used in an emergency or during construction works and existing bridges may require extensive upgrading.

Timber bridges can be constructed from either round timber in its as-felled condition (with the branches removed) or from sawn timber. Round timber has greater strength and durability compared to sawn timber and is therefore often used for the more important structural elements such as piles and stringers.

It is still possible to construct timber bridges at a competitive price compared with concrete or steel, provided there is adequate timber convenient to the bridge site and skilled tradesmen are available. As long as the bridge is designed for adequate stiffness there should be no problem with durability over the design life of the structure.

Some terms relating to timber bridge construction are shown in Figure 20.1.

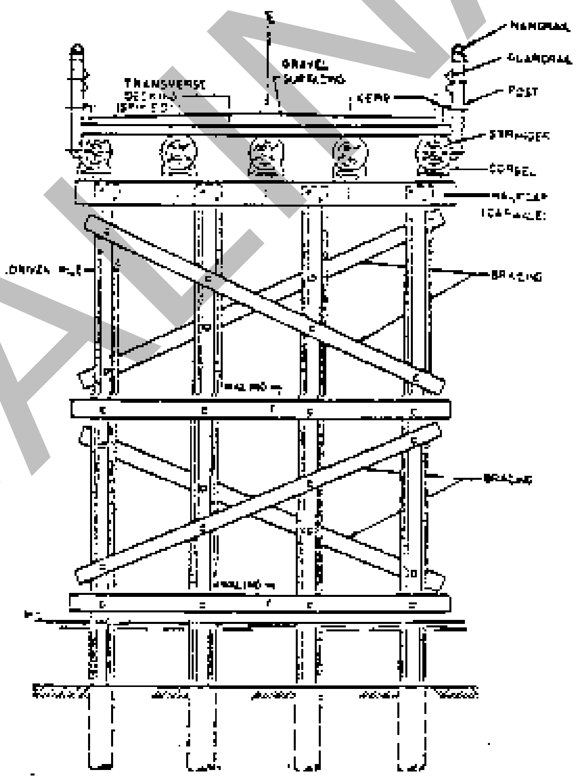


Figure 20.1 - Typical Timber Bridge Elements

20.2 SELECTION OF TIMBER

Most provinces of Indonesia have timber which has been used satisfactorily in timber bridges over a period of many years.

The Standard Bridge Specifications include the requirements for the selection and use of timber.

20.3 INSPECTION

Round timber logs should be checked after felling for size, damage, straightness and rot.

Timber should also be checked immediately after delivery to site to ensure that it is in accordance with the Specifications and has not been damaged in transit. If there is any doubt as to the species of timber, the supplier should be requested to supply appropriate documentation naming and identifying the timber.

When unloading long timbers, slings should be located such that the member does not suffer any damage. Under no circumstances should long timbers be 'barred off' trucks because of the damage that can result. Any timbers so handled should be rejected.

20.4 STORAGE

The timber storage area should be at a convenient location, well-drained and cleared of all flammable material. To avoid extra handling, there should be adequate space at the storage site for cutting and squaring.

The supplier should be requested to band the ends of all round timber with steel straps and to coat the ends with a liberal application of hot petroleum jelly as soon as possible after cutting, to prevent splitting. The ends of all sawn timbers should be similarly coated immediately after stacking. The ends of timber cut on site should be recoated with hot petroleum jelly as soon as possible after cutting.

Timber must be stacked clear of the ground on bedlogs, spaced at centres such that there is no excessive settlement of the bedlogs and there is no permanent warping of the supported timbers. In addition, sawn timber should be stacked with 25mm thick battens (pieces of timber) between the layers and 25mm spacing between individual pieces to allow proper ventilation for seasoning. If possible the timber should be covered (with tarpaulins or galvanised iron) for protection against the weather.

It is advantageous if all timber, especially decking, is delivered to site as early as possible to give the longest possible time for seasoning before incorporation into the structure.

In susceptible areas, timber stacks should be inspected frequently for infestation by termites or other wood borers. A visual check for nests, galleries etc. will usually be adequate.

20.5 PRESERVATION

20.5.1 General

Timber is subject to deterioration both from rot and attack by insects as well as from normal wear and tear.

Rot is the breakdown of the physical structure of the timber caused by fungal attack. Fungus spores are present in the atmosphere and can enter timber through cracks or unsealed holes. Under conditions of heat, moisture and lack of ventilation, they can multiply rapidly.

Insect attack is primarily from termites on land and marine borers in tidal waters. Both are a serious problem in susceptible areas as they can quickly seriously weaken bridge members with little warning.

The designer should be aware of the problems and should have specified timbers which are not susceptible to attack and should have detailed preventive measures required. However, it is important that construction and supervision staff understand the problems and ensure *that preservative measures are properly carried out.*

20.5.2 Rot

The principal method of preventing rot is by preventing the conditions that encourage its growth. This means sealing the timbers and keeping them dry, or introducing chemical fungicides. The best way to ensure maximum service life is for all timber to be pressure treated by one of the available commercial processes, for example, using creosote, creosote in furnace oil, Pentachlorophene in petroleum oil or Copper-Chrome-Arsenate (CCA) compounds. Penetration of the preservative into the timber will vary, depending on the species and moisture content of the timber, but should be checked against the specified value.

If pressure treatment is unavailable or impracticable, then timbers can be brushed or sprayed with creosote although this is a much less effective treatment. Creosote will also have to be applied to all cut surfaces or previously treated timbers for example, at notching, rebates, seatings and joints etc. Two coats should be applied, preferably when the timber is as dry as possible and the creosote permitted to dry out between coats.

A better alternative to creosote for on-site applications is the use of one of the copper napthalate (CN) compounds now available. These can be applied in either a liquid or paste form.

20.5.3 Termites

Pressure impregnation treatments also help to protect timber from termite attack, but the best protection is to prevent the termites reaching the timber. This is done by providing a toxic soil barrier at the abutments and around piles not standing in water.

The treatment consists of saturating the soil behind the abutments with a chemical insecticide for a minimum width of 200mm to a depth of 1m. Any gravel surfacing on the deck should be similarly treated. Chlorinated hydrocarbons are the preferred insecticides, diluted and applied as specified.

20.5.4 Marine Borers

There is great danger to timber bridge piles in tidal waters in Indonesia from attack by a variety of marine borers such as Toredo. Some timbers are more resistant to attack than others (for example belian from Kalimantan), but the only methods to offer reliable protection are either a two-stage pressure impregnation with both CCA and creosote, or by completely sealing the timber against borer attack.

The required method of protection should be detailed on the Drawings.

The length of pile which has to be protected extends from below the mud line to above high water mark. If using treated piles, care must be taken that the timber in this region is not cut or damaged. If the piles are to be physically protected then the protection must be continuous over this length and should allow for any anticipated scouring of the river bed. The usual methods of physical protection are either pipe sleeves of concrete, fibre reinforced cement, fibreglass filled with sand or proprietary wrapping tapes and membranes. Protective jackets can also be constructed by pumping cement mortar into nylon zipped stockings fitted to the piles.

20.5.5 Safety

Creosote and all other chemicals mentioned above can be hazardous, and proper precautionary measures must be taken when handling and using them. This involves the use of barrier creams and full protective clothing.

An additional hazard with CCA-treated timber is that when it is burnt it gives off poisonous fumes of arsenic pentoxide. It should therefore be disposed of by burning only in the open and must not be burnt in enclosed spaces or used as fuel for cooking purposes.

20.6 CUTTING, SQUARING AND TRIMMING

20.6.1 General

Before cutting any piece of timber for incorporation into the finished work, it should be checked for size and defects. It should then be laid out so it can be cut to best advantage.

20.6.2 Round Timbers

Piles normally require pointing and shoeing of the toe, and either the head being shaped to accept the piling helmet, or a heavy steel anti-splitting band fitted. The main consideration is to ensure that the toe is on the true centreline of the pile. This is normally established by stretching a stringline down the pile from the centre of the head and judging the best line.

When round timber is used for stringers, the minimum seating dimensions specified for the decking and corbels must be obtained. Seating widths should be kept to a minimum however to retain maximum strength. Stringers should be orientated so that if they are oval-shaped, the major axis should be vertical. This is shown in Figure 20.2. In addition any sag is usually arranged downwards to give maximum depth at midspan although the sag may alternatively be arranged upwards to counter deadload deflections. It is also important that the top surface of all the stringers in a span are in the same plane so that the decking will be fully supported.

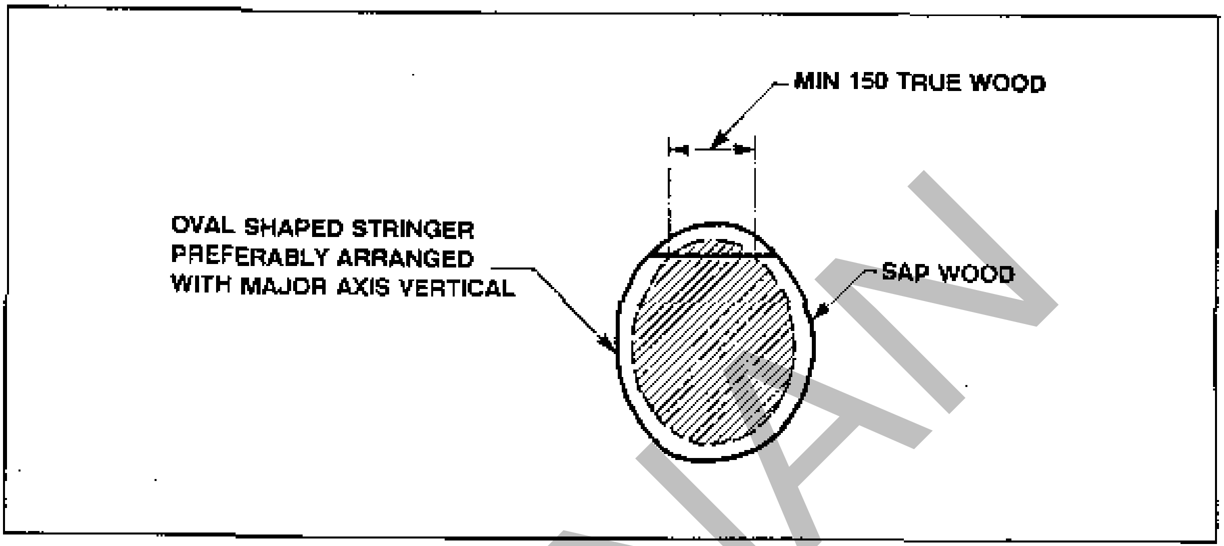


Figure 20.2 - Orientation of Round Timber Stringers

20.6.3 Sawn Timbers

Sawn timbers can be either backsawn or quartersawn depending on the position they are cut from the log as shown in Figure 20.3. The main difference this makes to the timbers is the distortion which accompanies drying out. Wood tends to exhibit an increasing rate of shrinkage the farther it is from the heart, so backsawn timber will bow in one plane, convex towards the heart, whereas quartersawn will bow in both planes, (Figure 20.4.).

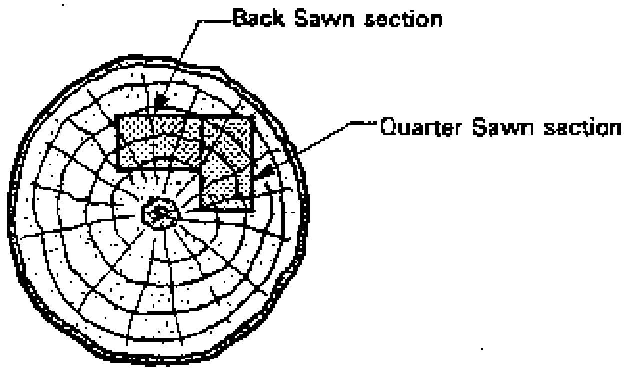


Figure 20.3 - Sawn Timber - Section

The results of this are most important especially for decking timbers which are difficult to hold down firmly under the effects of traffic and are more liable to deterioration from their greater exposure to the weather. For these reasons, decking is normally specified to be backsawn and is then laid sapwood up. This is because it is easier to pull down curled up ends rather than a bowed centre. It is also means that the more durable timber (the true wood closer to the heart) is in contact with other timber. All sawn timber is laid sapwood up where possible to enhance durability and make distortion easier to control.

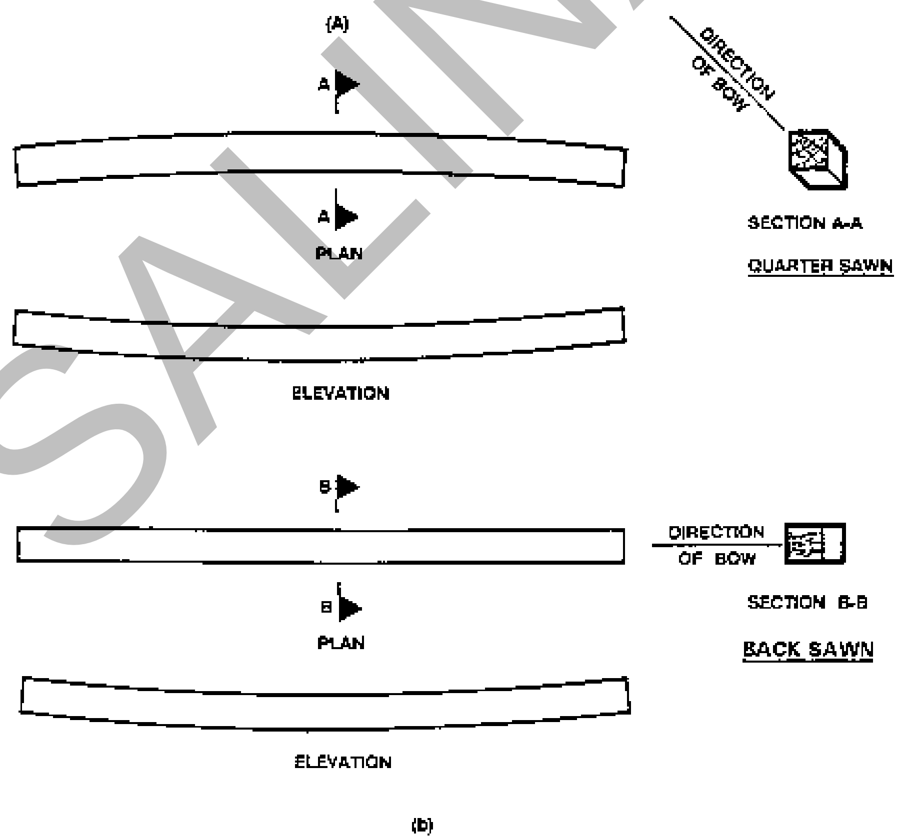


Figure 20.4 - Sawn Timber - Bowing

20.7 TIMBER CONNECTIONS AND SPLICES

The most common connectors used in timber bridge construction are spikes and bolts.

Spikes are used principally for fixing transverse decking directly to stringers. The normal size is 225 mm long by 10 mm diameter. They must be inserted in prebored holes 8 mm diameter to prevent splitting. The holes should be bored at an angle to prevent the spikes pulling out.

Bolts should be of mild steel and preferably galvanised, as black bolts tend to corrode in green wood with the consequent possibility of splitting the timber. If bolts are not galvanised, they should be cleaned and treated with a protective coating immediately on delivery. Red lead primer, hot linseed oil or tar may be used.

Bolts should be ordered with sufficient thread to allow for variation in the timbers and also to permit future tightening as the timbers dry out and shrink. Bolts may be square or hexagonally headed. Alternatively, round head and squared shank bolts may be used for *countersinking. After final tightening*, the ends of the bolt should be cut off close to the nut and the cut surface painted over. Where bolt heads are recessed into timber, the recess should be packed with a bituminous sand mixture to prevent entry of water which will cause decay.

The use of splices in load bearing members should be avoided wherever possible because of the reduced strength caused by the splice, but in some cases such as long piles and halfcaps (capwales), they may be unavoidable.

The normal types of splice used in timber piles are shown in Figure 20.5. The choice of splice depends on whether driving is to continue after splicing and the type of loading on the pile, ie. purely axial or axial plus moment. If there is doubt about the founding level of the piles, it is always preferable, if practicable, to order over-length piles rather than to plan on splicing, because of the associated high costs and delays.

20.8 TIMBER PILES

20.8.1 Preparation

Timber piles are prepared for driving as described in Section 20.6.2 and by marking the length at one metre intervals on the piles.

After driving, one permanent marking should be cut, located above ground or water level where it can be easily inspected, to indicate the length of the pile from the toe.

20.8.2 Handling and Pitching

Timber piles should be handled and pitched as described in Section 14.

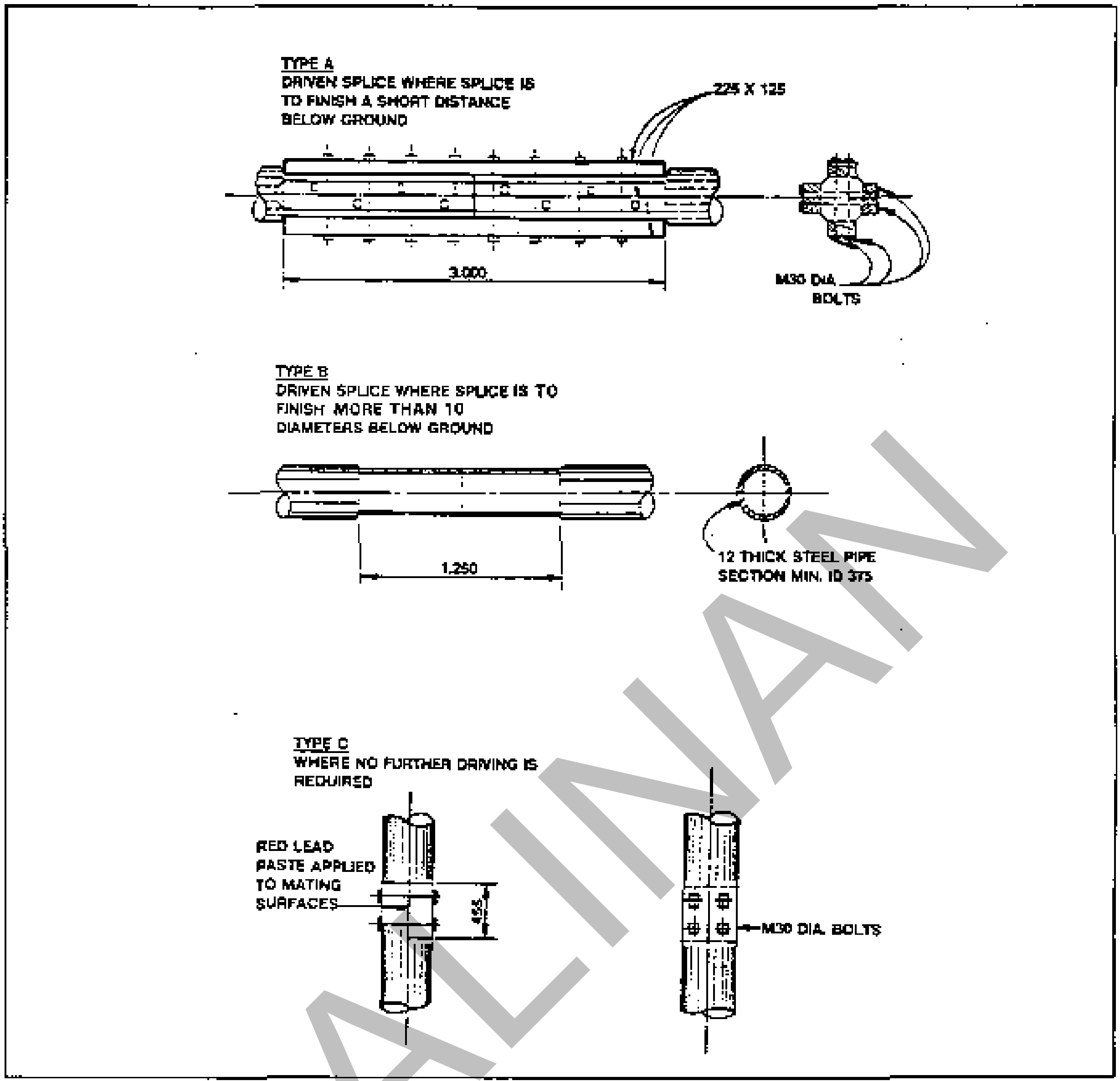


Figure 20.5 - Splices in Timber Piles

20.8.3 Driving

Driving of timber piles should commence using light blows of the hammer until the pile has penetrated sufficiently into the ground to ensure that it is proceeding in the correct direction. Blows should then be increased gradually until the specified rate of penetration is achieved. At no time should the intensity of driving be increased (in an endeavor to reach the specified toe level) to such an extent as to cause damage the pile. Unless instructed otherwise, driving should be continuous until the toe of the pile reaches the specified toe level, or the specified penetration per blow at full impact has been achieved.

As driving proceeds, the ropes holding the pile in position must be progressively lowered to avoid fouling, and ultimately removed. Should the pile tend to veer off course, the twitches may be used to correct its position to a limited extent, but if the pile veers off course to a marked extent it should be corrected if possible without damage to the pile.

If this cannot be done, it should be withdrawn if possible and re-driven near its correct position unless instructed otherwise.

Rock or other obstructions can be shattered in situ by explosive. The shattering should be done successively in not less than three explosions per pile. The first light shot should be fired at a depth 0.5 metres below the rock surface and the final shot should be fired at a depth 0.5 metres greater than the level of the pile toe as shown on the drawings.

During progress of the pile driving, measurements of penetration should be made on the pile.

Refer also to Section 14 for further details on driving piles.

20.8.4 Cutting Off

On completion of driving, the surplus length of pile should be cut off at the specified level shown on the Drawings, and the cut surface treated immediately with petroleum jelly (applied hot) to prevent splitting.

20.9 TIMBER SUBSTRUCTURE WORKS

20.9.1 General

Substructure refers to that portion of the structure from the firm foundation base up to bearing level of girders, and includes footings, columns, headstocks etc.

20.9.2 Scarfing of Piles

Where scarfing or 'cutting in' is necessary to join timbers together, it should be done in accordance with the diagrams shown in Figure 20.6. All timber surfaces in contact should be treated with a wood preserving compound before being finally bolted together.

20.9.3 Caps, Walings and Bracing

The piles should be marked off at the correct levels shown on the Drawings, surplus length cut off, the shoulders cut to receive the caps and the sides cut and trimmed at the positions shown on the Drawings to receive the braces.

Note: The distances shown on the Drawings between the inner faces of caps (and braces) at piles are minimum dimensions, and, in the case of oversize piles, care should be taken not to cut excessive timber away in an effort to reduce the distances between faces of caps (and braces) to these minimum dimensions. It is better practice to cut away only enough timber to provide a full bearing for the caps and an even series of faces across the pier for the braces).

The caps and braces should be cut to the correct length and then placed in position and bolted, care being taken to treat surfaces in contact with wood preserving compound. Holes for bolts should be drilled after the caps and braces have been temporarily clamped in position, and special attention given to ensure that holes are slotted where specified.

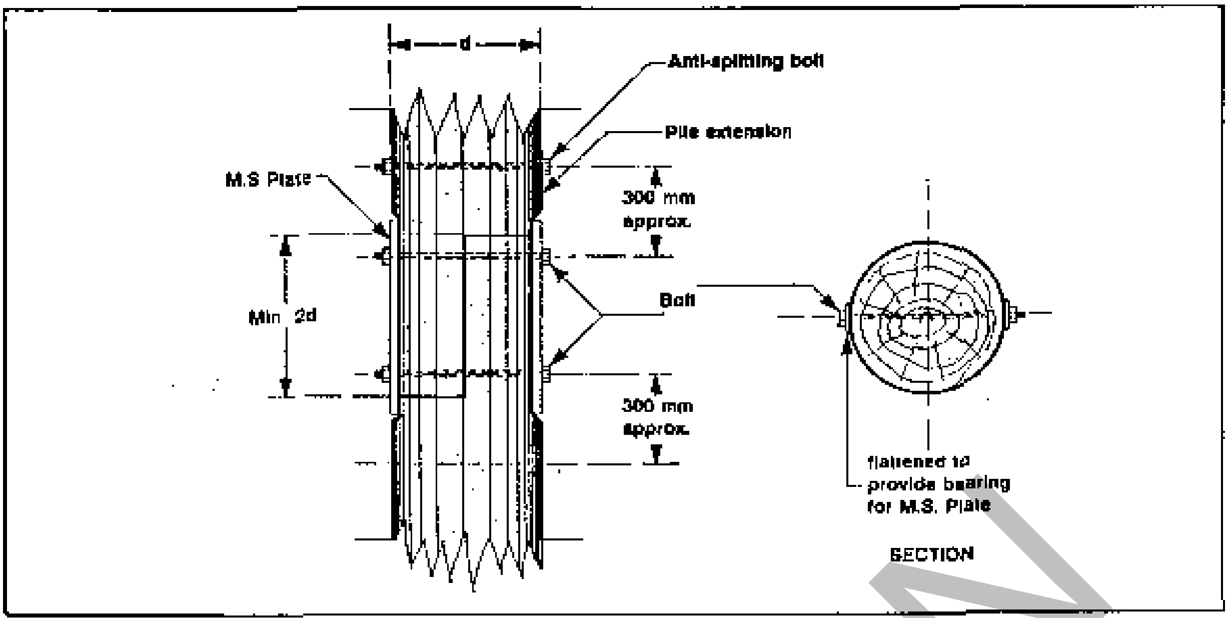


Figure 20.6 - Scarfing of Piles

20.9.4 Corbels

Corbels should be cut to length, corners trimmed, and surfaces dressed in accordance with the Drawings before being placed in position on the capwales or headstocks, surfaces in contact being treated with wood preserving compound. Holes should then be drilled, and the bolts fitted and tightened up.

20.9.5 Sheeting

Where sheeting behind piles at abutments or wingwalls is to be fitted, the backs of piles should be trimmed to a flat surface and treated with wood preserving compound before sheeting is placed. Only the minimum amount of timber necessary to ensure an even bearing surface for the sheeting should be cut from the piles.

20.9.6 Ironwork

Where bolts are required to connect timbers which may vary in thickness, for example capwales, braces, corbels, etc., the length of bolt required must be carefully measured and threads cut for a sufficient length along the bolt to enable the nut to be tightened fully with due allowance being made for re-tightening after shrinkage of the timber takes place.

20.10 TIMBER SUPERSTRUCTURE

20.10.1 General

Superstructure Work refers to that portion of the structure from the bearing bases upwards. The methods of erection of superstructures will depend on the following considerations:

(i) the nature of the crossing (bridge over road or rail, bridge over normally shallow water, bridge over deep water etc.);

(ii) the weights of individual members to be moved;

(iii) the maximum lengths of members and whether these are complete in themselves or require splicing;

(iv) the handling equipment available for the work.

20.10.2 Girders

Girders should be cut to length to fit the actual spaces between piers and/or abutments, their corners trimmed and surfaces dressed in accordance with the Drawings before being placed in position on the corbels. Surfaces in contact should be treated with wood preserving compound. Holes should then be drilled through girders and corbels and bolts fitted and tightened up.

20.10.3 Cross Girders or Cross Beams

Cross girders (or cross beams) should be cut to length in accordance with the Drawings, trimmed to fit the top surface of the girders, placed in position, drilled and bolted in place. All surfaces in contact should be treated with wood preserving compound.

20.10.4 Decking

Decking should be cut to length and fitted in accordance with the Drawings, ends of planks being retreated with wood preserving compound. Planks should be cramped tight, holes drilled and bolts fitted. After the deck is in position and fitted, the whole of the deck surface may be treated with bitumen and sand or other approved preservative. Joints in the decking should be staggered across the bridge.

20.10.5 Kerbs

Kerbs should be cut to length in accordance with the Drawings and fitted in position, the decking being trimmed if necessary to provide a neat fit. Any timber freshly exposed as a result of trimming must retreated with wood preserving compound. Kerbs should be drilled in position and bolted up.

20.10.6 Ironwork

Bolts, nuts and washers should be treated as described in Section 20.7 of this Manual.

20.10.7 Erection Methods and Equipment

Timber girders and smaller components may be lifted at the centre or at both ends, using mobile cranes, gin poles with winch accessories, flying fox equipment, etc. Wire rope slings may be used for hanging the girders from the hook of the lifting plant. Timber may be dragged or winched to the lifting point provided care is taken not to damage the trimmed faces. Maximum weights in timber superstructures will not usually exceed 2 tonnes per metre.

20.10.8 Concrete Deck

Concrete decks should be constructed in accordance with Section 15 of this Manual.

20.10.9 Handrailing

The kerbs and handrailing are portions of a bridge which are seen by the general public. It is therefore essential that the handrailing be erected to a good line and level throughout the full length of the bridge before being finally fixed.

The posts for timber handrailing are attached by bolting to the outer girders and kerbs. Notching of the outer girders to receive the posts should be carried out so that the handrailing when finally bolted is true to line and level. Bolting holes through the posts, with the exception of the lowest hole, should be slotted to permit subsequent adjustment to be made for the shrinkage of the girders, deck and kerbs.

TABLE OF CONTENTS

21. TEMPORARY BRIDGING

21. TEMPORARY BRIDGING

21.1 GENERAL

There are a number of different types of bridging used in Indonesia which are referred to as 'temporary or semi-permanent bridging'. These include various types of steel truss bridges, steel girder bridges, concrete girder bridges, timber bridges and panel bridges (of the Bailey, Mabey or Transpanel type).

This Section covers panel type temporary bridges.

Panel bridges are small, portable, prefabricated bridges suitable for rapid and easy assembly and installation by hand and light crane. They are especially useful when required to replace bridges damaged by fire, flood, accident, collision, timber decay etc. Temporary bridging is also used to provide for diversion of traffic during bridge construction or maintenance work.

Details of parts and components and the loading capacity for known types of bridges and their configuration are provided in the respective manufacturer's technical manuals.

21.2 TYPES OF PANEL BRIDGING

The original type of panel bridge was the "Bailey" type developed in the 1940's for military use. The following types of panel bridge are in use in Indonesia:

- Standard "Bailey"
- Super "Bailey"
- Acrow
- Mabey "Universal"
- Mabey "Compact"
- Transfield "TransPanel"

More details about Mabey 'Compact 200' and 'Transpanel' bridging are contained in the Bridge Construction Techniqes Manual.

21.3 DESCRIPTION OF PANEL BRIDGING

All the above types of panel bridge have the same design philosophy. The panels form a simple through-type bridge with the roadway carried between two main load-carrying girders. The main girders are composed of a number of identical panels pinned together, end to end, and connected where necessary side to side, to form continuous stiff girders from abutment to abutment.

The girder units may be stacked two or three high and/or additional chord reinforcement may be added for increased span and load carrying capacity. (Note that Transpanel bridging is not able to be stacked in this manner).

The main girders are connected and spaced apart by road bearers called transoms which also carry the subsidiary steelwork supporting the roadway. Decking systems of steel plate or timber can be used but normally timber is adopted for temporary construction.

Panel bridging can also be used vertically to form piers and towers.

The bridge configuration is described by reference to the number of truss units or rows and storeys or levels. These may range from single truss/single storey to triple/truss triple storey. Their designation follows this form with the first letter referring to the number of panels side by side and the second letter referring to the number of storeys. A structure of single panel width and single storey is S.S., three panels wide and one storey is T.S. and so on.

In some instances, the chords of the panels are strengthened by the bolting of reinforcing channel sections to the chord and in these instances the letter 'R' is added to the usual designation to indicate the use of chord reinforcement, eg. D.S.R. is double single reinforced. Reinforcement is usually an alternative to the use of an additional storey but is sometimes used in conjunction with multiple storeys. Some systems (for example Mabey) allow the use of regular or heavy reinforcement to the chords.

The bridge may be designed to be continuous over a support or simply supported. If it is a multiple span simply supported bridge it is often referred to as being a broken-span bridge.

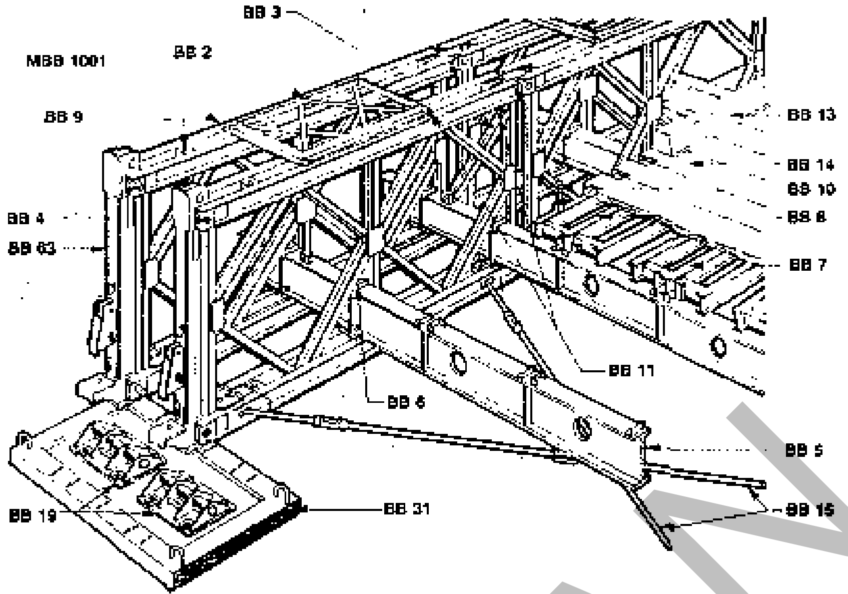
Panel sizes vary with the type of bridge. The original Bailey bridge panels were 3.048 m long and 1.448 m deep. The Mabey Compact 100 panels are 3.05 m x 1.45 m, the Compact 200 are 3.05 m x 2.13 m and the Mabey Universal are 4.5 m x 2.36 m. The Transfield Transpanel bridging panels are 5.000 m x 2.210 m (small chord reinforcing) or 2.390 m (large chord reinforcing).

The distance between opposite trusses can vary between 3.75 and 11.75 metres depending on the type and configuration. Some systems have footways which attach to the outside of the bridge.

In general the systems above are incompatible with each other. Components from one type of panel bridge cannot be used interchangeably with components from other types.

Figure 21.1 shows the components of a typical Bailey bridge.

Figure 21.2 shows the various span configurations of Bailey bridge. Note that the exact configuration and naming pattern may differ between the various proprietary types of panel bridging.



MBB 1001	Panel	BB 7	Plain Stringer	BB 13	Riband
BB 2	Bracing Frame	BB 8	Button Stringer	BB 14	Chess
BB 3	Raker	BB 9	Position for Chord Bolt	BB 15	Swaybrace
BB 4	Panel Pin	BB 10	Riband Bolt	BB 19	Bearing
BB 5	Transom	BB 11	Bracing Bolt	BB 31	Baseplate
BB 6	Transom Clamp			BB 63	Male End Post

Figure 21.1 - Components of a Bailey Bridge

21.4 SELECTION OF CONFIGURATION

Careful consideration of the configuration required must be made for each site.

Full details of various configurations are given in each manufacturer's manual but it is essential that the following aspects of performance be considered:

- span limitations
- permissible deflections
- shear, particularly with the use of trusses to support existing bridge decks
- frequency and intensity of traffic
- local and National standards for load requirements
- regular maintenance and in-service inspections

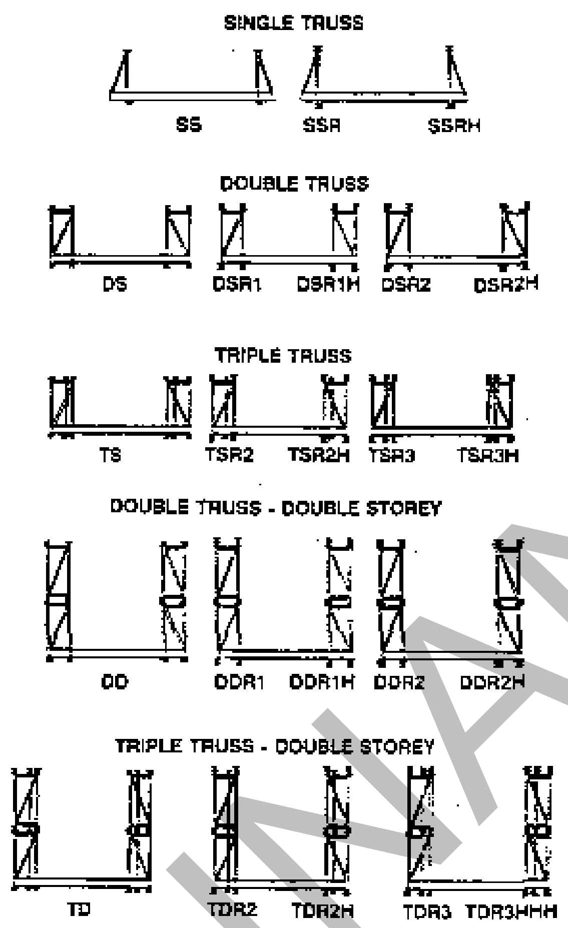


Figure 21.2 - Span Configurations

21.5 SUPERVISION

The Supervising Engineer's responsibilities include the following aspects of panel bridge construction:

- ensuring that the structure is built correctly according to the Erection Manual
- checking of dimensions and levels
- confirming that the bridge span and launching method are suited to the site
- ensuring that the launching is executed correctly
- ensuring that the jacking is carried out safely
- inspecting the finished bridge to ensure that all components have been correctly fitted and tightened before permitting traffic to cross.
- safety of all personnel

21.6 CONSTRUCTION

21.6.1 General

Panel bridging is designed to be assembled using only simple tools and equipment. A toolkit containing jack(s), spanners etc. often accompanies the components.

The normal method of erecting panel bridges is to build the bridge complete on rollers on one side of the gap with a launching nose (made from standard components) attached to the front end of the bridge. The bridge is then rolled forward over the gap until the point of balance of the bridge (with launching nose) is reached. The nose will then be over the landing rollers on the far side of the gap. When the nose has been lowered onto the landing rollers, the whole bridge is pushed forward until the ends of the bridge are over the prepared baseplate positions. The launching nose can then be dismantled and the bridge jacked down onto the bearings after removing the rollers. The bridge may be launched in its completed condition with the deck in place or more usually the timber deck is installed after erection.

After the bridge is jacked down, the ramps are fitted at each end of the bridge to complete *the construction.*

The normal method of construction described above is not always the most appropriate. Other methods of construction can be used where suitable heavy lifting equipment is available.

When panel bridging is used to support bridge spans under repair, special designs are adopted with or without transoms and decking.

21.6.2 Site Layout

The site layout will depend largely on the design of the bridge, the site conditions and the relevant levels on both sides of the gap.

Launching is simpler from the higher bank to the lower bank because of the need to build up roller levels on the lower side. On a flat site, the more convenient side can be selected.

An area 15 metres wide and extending back from the gap for a distance equal to the length of the longest span is required.

21.6.3 Assembly

Assembly of the bridge must be carried out as detailed in the appropriate Erection Manual for the type of bridge being constructed. Special attention should be given to the proper fitting of all pins and circlips.

The addition of second or third trusses and/or storeys may be carried out at the time of initial assembly or at some later time, even after the bridge is in operation. The weight of panels added prior to launching may require the use of more launching rollers.

The length of the launching nose must be determined to ensure that, with the bridge complete and the nose clear of the landing rollers, the weight of the bridge and nose over the gap will be balanced by the weight of the bridge on the 'home' side of the launching rollers. Generally the length of nose is equal to half the span length plus one panel length.

21.6.4 Launching

Mechanical aids to launching will only be necessary where the launching plane has a steep slope up or down. The bridge is pushed or pulled forward carefully while care is taken to ensure that the bridge remains on the rollers, the rollers do not jam or move and the nose is located over the landing rollers. Long bridges tend to wander off line easily if pushed and they should be pulled out into position. Launching continues until the end posts of the tail of the bridge are central on the baseplate. A method should be employed to ensure that the bridge will not overrun its final position eg. by the use of a tail rope anchored to a strong tree or connected to a bulldozer.

In some instances, there will not be sufficient room to permit assembly of the full span length prior to erection. A counterweight system and additional construction rollers may be needed to provide the additional balancing moment, although care is needed in planning the sequence of construction.

21.6.5 Jacking Down

Whilst the launching nose is being dismantled, jacking down can commence on the home bank. At no time should the bridge be supported on jacks at both ends. If the bridge is on a slope, it should be secured in position prior to jacking. The number and capacity of the jacks required may be calculated from the weight of the bridge. It is essential that packing with timbers accompanies the jacking process to minimise the risk of damage should any failure of the jacks occur.

Jacking is commenced by lifting the bridge clear of the rocking rollers which are then withdrawn. The bridge is then gradually lowered onto the bearings, care being taken to ensure that it is carried out evenly. Only the proper bearings should be used to support the bridge.

21.6.6 Ramps

The deck level of the bridge will usually be more than 0.5 metre above the ground and ramping will be necessary. A maximum slope of 1 in 10 can be adopted but a level approach or a maximum slope of 1 in 20 is preferable.

Each type of bridge will have its own individual requirements for ramp construction.

21.7 DISMANTLING

Dismantling and removal of panel type bridges is basically the reverse of the procedure used for assembly and launching.

TABLE OF CONTENTS

22. COFFERDAMS

22. COFFERDAMS

22.1 COFFERDAM CONSTRUCTION

A cofferdam is a temporary wall or structure intended to exclude water from construction work (usually foundations). It must therefore be designed for stability under maximum water level conditions, and should be safe against bursting, sliding, and overturning. Since cofferdams are temporary structures, economy is also major consideration. The selection of the type depends upon the area to be protected, the depth of water to be catered for, the possibility of overtopping by floods, and the nature of the material in which the cofferdam is founded (which must be reasonably impervious). In flowing streams, the possibility of scour due to the reduction of the waterway by the cofferdam, and the effect of pressure on the face of the dam, must not be overlooked.

22.1.1 Steel Sheet Piling

Steel sheet piling is a common material used for the construction of cofferdams. It has the advantage of great strength and is able to be salvaged relatively easily at the completion of the work. Except when the bottom is bare rock, a single wall of steel sheet-piling is *generally the most effective cofferdam for depths ranging from 5 to 20 metres. Even on* bare rock, if the surface is soft enough to permit a minimum of 300 mm penetration, steel sheeting may be used successfully.

There have been many shapes of section devised for steel sheet-piling, and all are usually provided with suitable interlocking 'clutches' along each edge.

One advantage of steel sheeting is that it may be driven below the bottom of the excavation to cut off water and to retain soft and unstable material. The depth of cut-off should be at least half the depth of water acting on the cofferdam.

A single wall of steel sheeting is driven by means of a guide frame. In water of up to 10 metres depth, this may take the form of timber piles with walings bolted into position to provide alignment for the sheeting. In deep water, it is usual to build a framework which will brace the piling after the cofferdam is pumped out. It is essential to keep the sheets vertical, and this is most easily achieved by standing up a long row of sheets and driving them down a short distance, the whole row being gradually driven to the required depth. Another important point is to place a very heavy grease in the interlocking clutches prior to assembly to prevent rusting and make extraction easier.

22.1.2 Concrete Sheet Piling

Concrete sheet piles are precast members constructed either with or without a jointing system (eg. tongue and groove) .

The points are often cast with a bevel, which tends to wedge each pile against the previously-driven pile. The piles are relatively bulky and they displace a relatively large volume of soil. This larger displacement of soil tends to increase the driving resistance.

By cleaning and grouting the joints after driving, a reasonably watertight seal may be achieved. Grouted walls may need expansion joints installed along the wall.

22.1.3 Braced Cofferdams

Braced cofferdams are designed so that loads on each set of horizontal walings are equal, in order to standardise the size of members.

Walings are installed by hanging them from the guide frame.

Allowance should be made in design for the possibility of struts being damaged by the digging bucket. It is usual to support them with braces and posts at reasonable intervals in order to reduce their unsupported length as columns. They must also be arranged to avoid fouling the permanent structure as much as possible.

22.1.4 Dikes

Dikes are embankments of earth fill or rock fill, and are designed as gravity dams. They are the simplest form of cofferdam but must be high enough to avoid any chance of overtopping unless suitably protected. Earth is used in quiet water and rock in more turbulent locations. Sealing the latter is often a difficult job, but may be achieved by sandbagging the face with clay. Dikes are usually employed for limited periods, particularly to enable installation of a more permanent cofferdam behind them. Sandbag dikes are useful for small heights, the individual bags of clay being laid in courses as with brickwork and the gaps between the bags packed with clay. In general, dikes should have a top width of at least one metre, with side slopes of the order of 2:1 to 3:1 for earth fill, and 1.5:1 for rock fill. Protection against wave erosion is essential on earth dikes.

22.1.5 Suspended Cofferdams

Suspended cofferdams are used when piles or caissons have to be capped below low water, and the depth to the river bed is large. A watertight box is constructed, generally of timber, with suitable holes in the floor to fit over the caisson or pile heads.

22.2 DEWATERING OF COFFERDAMS

Dewatering of cofferdams must be carried out with great care and attention. As soon as the cofferdam is closed, the water should be pumped down in stages, with accurate observations of inflow of water between pumping periods. Sealing of bad leakages and installation of bracing (as required) can proceed during these stages. Cofferdam pumps are usually of the centrifugal type with wide clearances since sand, silt and other foreign matter are generally contained in the water.

After the inside of the cofferdam is dry, it should be kept dry unless a blow-in occurs as a result of the floor being forced up by water pressure from outside. If this occurs, there is obviously not enough cut-off below the toe of the sheeting, and further driving to achieve a better seal may be necessary. The foundation area must be observed at all times for signs of weakness which may lead to a blow-in, and personnel should not be permitted to stay in the area if danger is suspected. At the first sign of severe leakage or weakening of the bottom, the area should be flooded and steps taken to obtain a better seal. On rock foundations, grouting may be effective in blocking leakage through fissures. If this is not possible, or if a cofferdam cannot be dewatered completely, excavation will have to proceed under water, and a concrete seal (designed against uplift) installed on the finished bottom, thus enabling the cofferdam to be pumped dry so that further construction work may proceed as planned.

Overtopping of cofferdams should be avoided if possible. Flood hazards should be soundly investigated, and the height of the cofferdam determined by judgement. The economical height is that at which the cost of additional protection will be more than the cost of delay and damage due to overtopping and flooding. If a cofferdam is in danger of overtopping, similar action must be taken as with a blow-in or serious leakage. Water should be pumped into the workings to prevent serious damage which may result from sudden ingress of large volumes of water. When the danger has passed, the area may again be dewatered.

Generally, it is expected that after a cofferdam is dewatered, work should proceed to its conclusion inside as fast as possible, with the inside of the cofferdam maintained as dry as practicable.

22.3 REMOVAL OF COFFERDAMS

The design of a cofferdam must take into account its removal on completion of the permanent works. There must not only be sufficient clearance inside the cofferdam to permit its removal without damage to the completed permanent structure, but also to enable work to proceed with reasonable access to all parts of the structure during the construction period. Bracing locations must be carefully chosen so that the braces may be removed without fouling.

Sheet piling is pulled with extractors, care being taken not to damage the sheeting. The greatest effort will be required at the start in loosening the piling both from the ground and the interlocks and difficult sheets may be left until neighbouring ones have been extracted.

TABLE OF CONTENTS

23. DESIGN OF TEMPORARY WORKS

23. DESIGN OF TEMPORARY WORKS

23.1 GENERAL

Temporary works for bridge construction include falsework, formwork, cofferdams and shoring. These works do not form part of the finished structure and they are usually removed prior to the completion of the permanent Works.

This Section covers only falsework and formwork. Section 22 describes of coffer dams and shoring of excavations.

23.2 FALSEWORK

23.2.1 General

Falsework is defined as any temporary support required for bridge construction. Falsework must be designed to withstand all the forces resulting from the specified loads and any additional loads that may be imposed during construction.

The design should take into account the magnitude, direction and duration of these forces individually and collectively.

The design of all falsework members and connections should comply with the relevant Standards referenced in the Specification and any statutory requirements.

Falsework members should be designed to limit deflections to 1/300 of the span and to prevent cracking of previously-cast sections by subsequent casts. Deflections of beams and dimensional changes in other members and connections must be limited to ensure that the finished concrete is within the specified tolerances.

23.2.2 Design Loads

a. Dead Load

For cast-in-place concrete construction, the design dead load includes the weight of forms, falsework, wet concrete, reinforcement and any other embedded material. The mass of wet concrete including reinforcement should be taken as 2700 kilograms per cubic metre.

For segmental work, the design dead load should include the mass of the segments and any other additional dead loads which may be applied before the structure becomes self-supporting.

Similarly, in steel construction, falsework may be required to temporarily support permanent girders or other steel members as well as any additional dead loads such as reinforced concrete decks.

b. Construction Loads

These loads include the weight of workmen, plant, equipment and runways, stacked material and an impact allowance equal to 25 percent of the total weight of mechanically operated equipment.

In no case should the design construction load be less than 2 kPa (0.02 kg/cm^2) (plus the weight of stacked material) on the plan area of the finished concrete or a single isolated load of 2.5kN applied at any point of the structure, whichever is the more severe.

c. Horizontal Loading

Horizontal loading includes wind loading, horizontal impact loading equal to 25 percent of the total weight of mechanically operated equipment, and all other horizontal loading occurring during construction.

In no case should the design horizontal loading in any direction be less than 1.5kN/m applied at the edge of the deck, or 2 percent of the total dead load, whichever is the greater.

d. Wind Load

The design wind load should be 2.5 kPa (0.025 kg/cm^2) acting on the exposed area of falsework, formwork and any object supported by the falsework or formwork.

e. Other Loads

Other design loads should include loads resulting from special conditions likely to occur during construction, the effect of prestressing, construction staging and removal of falsework.

23.2.3 Calculations and Drawings

The design calculations should state all design assumptions and should include an analysis of the forces, stresses, stability, deflections and other dimensional changes due to loading in all members of the falsework.

The drawings should be fully detailed including all member sizes and materials, dimensions, levels and erection procedures, bracing details, connections and foundations.

The falsework should be fully inspected by the Supervising Engineer before it is loaded to ensure that it complies with the design assumptions and the drawings.

23.2.4 Bracing

A large number of failures that have occurred during bridge construction have been attributed to inadequate bracing of falsework.

Adequate bracing must be provided in longitudinal and transverse directions to ensure that the falsework is stable and that significant horizontal movements resulting from the applied loads are prevented.

23.2.5 Provision for Adjustment

The falsework should have provision for vertical adjustment, to facilitate erection and stripping of forms and for realignment if excessive settlement takes place.

Screw jacks may be used at both the top and bottom of tubular shores and frame type shoring. The amount of extension of a screw jack may reduce the load capacity of the jack. The manufacturer's recommendations should be followed.

Wedges may be used to facilitate adjustment at the top or bottom of shores. Wedges are usually made of hardwood and driven in pairs to provide even bearing. When final adjustment of shore elevation is complete, wedges are nailed to the shore.

Where extensive movement of a heavy load is required, such as when a large section of shored structure is to be lowered or raised as a unit, hydraulic or pneumatic jacks are often used to provide adequate control of release.

For de-propping only, sand jacks can lower heavy loads and offer the advantage of little deflection under load and little danger of failure during placing and curing. The rate of lowering is easily controlled by the release of sand from the plug holes (see Figure 23.1).

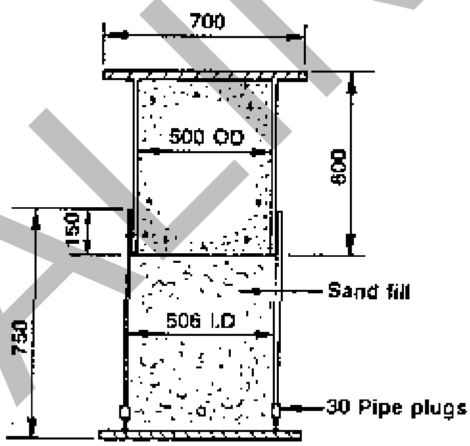


Figure 23.1 - Sand Jack details

23.2.6 Foundations

Foundations for falsework must be able to carry the load without excessive settlement of the falsework or relative settlement between adjacent supports.

Individual footings and groups of footings should also be designed to satisfy stability criteria.

Foundations for falsework must be drained wherever possible to prevent ponding of water. Where natural drainage cannot be provided, such as in open excavations where the foundations can become saturated, allowance should be made if appropriate for reduction in design bearing capacity, changes in stability and increased settlement or heave of the foundations. Nevertheless, it is good engineering practice to provide sumps in open excavations to assist in dewatering.

Bearing surfaces of footings should be horizontal. Foundation materials such as soil, fill or other materials which are soft and compressible or which may be subject to erosion by water, must be removed to expose a suitable foundation. Where such materials have been removed, the excavation may be back-filled to the required level by compacted stabilised crushed rock or equivalent.

Footings supported directly on the ground near surface level should bear on concrete bases, timber bed logs or other types of approved materials.

23.2.7 Alignment of Members

All falsework members must be straight without twists or bends and all damaged components should be removed from the site.

Vertical shores should be braced to prevent tilting. In multi-tier scaffolds, the vertical shores in the upper tier must be set vertically, directly above the shores in the lower tier to ensure that loads are applied vertically and without eccentricity.

Splices, couplings and joints in components must be secured against bending or buckling and they must be staggered with respect to other members.

Inclined members must be braced against possible movement.

23.2.8 Proprietary Falsework

Proprietary materials are now used extensively for falsework in concrete bridge construction. They have the advantage of safety, simplicity of design and ease of erection and dismantling.

Heavy duty shoring frames are designed for all formwork supports, with a maximum capacity of up to 45kN per leg when used with heavy duty accessories. They can also be used in conjunction with standard tubes and fittings.

Where falsework is required over deep crossings or where waterway or roadway clearances have to be maintained during construction, long span falsework has to be used. Long span falsework includes steel girders or frames and trusses (either steel or timber). Bailey bridging is a special form of steel truss which has been successfully used for long span falsework.

Although falsework is often supported off permanent parts of the structure such as piers, pier footings or abutments, it may be necessary to erect temporary support(s) at intermediate locations for longer spans.

For long spans, precambering of the falsework may be necessary to overcome the effects of deflection.

In prestressed, precast segmental construction, segments may be assembled on falsework. In such cases special provision has to be made in the segment support system to provide for the elastic shortening of the precast sections which occurs during prestressing and for possible rotations, especially in stage-by-stage construction.

23.2.9 *Inspection Checklist*

A check for a checklist for the final inspection of scaffold-type falsework is as follows :

(a) check to see that there is a sound footing, under every leg of every frame on the job and that the foundation is adequately drained.

(b) check that all base plates or adjustment screws are in firm contact with the footing or sill. All adjustment screws should be snug against the legs of the frame.

(c) obtain a copy of the falsework layout drawings. Make sure that the spacings between towers and the cross brace spacing of the towers do not exceed the spacings shown on the drawings. If variation is necessary because of a field requirement, consult with the Engineer who prepared the drawings for his approval of the amended layout.

(d) frames should be checked for alignment in both directions. The maximuum tolerance for a frame which is out of plumb is 1 in 300. If the frames exceed this tolerance, the base should be adjusted until the frames are within the tolerance.

(e) check that there are no gaps in the vertical joints or connections of frames. Gaps may indicate that frames are distorted or bases out of adjustment.

(f) all frames must be connected to at least one adjacent frame to form a tower. Check to make sure that the towers have all the cross braces in place.

(g) while checking the cross braces, also check the locking devices to ensure that they are in their closed position or that they are all tight.

23.3 SCAFFOLDING

23.3.1 Scaffolder's Responsibility

a. General

Scaffolding is used to support men, materials and equipment. It can be subjected to heavy loading and its safe design, erection and operation is of primary importance to job safety and the quality of workmanship.

The design of scaffolding should be carried out by an Engineer with a thorough knowledge of the requirements.

b. Responsibility of Scaffolders

It is the responsibility of the scaffolder to ensure that all scaffolding work is carried out in a safe and efficient manner according to the relevant regulations. In the absence of appropriate regulations, established customs and practice should be followed. At all times the first consideration must be directed to the safety of all persons using the scaffolding or in the surrounding work area. Where a new type of scaffolding is to be used, it is necessary for approval to be sought from the Engineer before it is erected.

23.3.2 Use of Scaffolding

a. Footings

The Supervising Engineer should that the foundation footing or structure from which a scaffold is to be erected or suspended is solid, substantial and of sufficient strength to support the scaffold. The bases of standards, or vertical members, should be set on planking at least 200mm wide and 40mm thick, and of sufficient length to distribute the load over a suitable bearing area. Where ground may become softened due to wet weather, suitable drainage must be provided. Asphalt pavements may be softened by heat, and surfaces which may appear sound may cover fragile or broken pipes. Where necessary, protection against the impact of heavy trucks or other heavy moving equipment should be provided.

b. Spacing of Vertical Members

For tubular scaffolding, it is advisable to set out the vertical members at centres to suit the lengths of the planking. For planking 4 m in length the verticals should be placed at 2 m centres.

c. Erection in Vicinity of Electricity Lines

Before erecting any scaffolding adjacent to or in the vicinity of electrical wires or apparatus, it is essential to ensure that suitable protection is provided for employees. All electrical wires which could create a dangerous condition should be de-energised, short circuited and earthed, or re-routed. Scaffolding should not be erected until the appropriate Authority has been contacted, and the high voltage wires have been made safe. Positive steps should be taken to prevent accidentally re-energising the wires when work is in progress. Where the de-energising of overhead wires is not practicable, the wires should be fully covered by the appropriate controlling Authority. The protection provided should safeguard employees against contact with live wires which may lead to severe electrical shock if touched. Care must be taken in wet and windy weather conditions.

d. Secure Planking

Scaffold planking and plywood sheeting should always be secured, regardless of height above ground.

e. Maximum Free Standing Height

Any free-standing scaffold, whether of timber, tubes or frames, should not exceed in height or length more than three times the least dimension or width at the base, unless it is adequately tied to a secure structure, or tied by steel wire rope guys to a secure anchorage. Alternatively, the base area of the scaffolding should be increased by additional bays or frames properly secured and braced so that the height does not exceed three times the least dimension of the extended base.

f. Tie Bracing

All forms of scaffolding should be strengthened by adequate tie-bracing in all directions. Ties of mild steel wire, twitched or twisted, are not permitted. Steel wire ropes of adequate diameter may be used instead of steel struts.

g. Movable Scaffolds

Movable scaffolds must have horizontal members close to each wheel to prevent bending *of the verticals, and care must be exercised when moving the scaffold that the wheels do* not strike obstructions. Horizontal diagonal bracing must also be fitted at the base of the scaffold in order to prevent distortion.

h. Handrails and Toe Boards

Handrails and toe boards should be fitted on all scaffolds from which a person or object can fall a distance of 1.8 m or more. Handrails fitted in an improper manner, of defective material, or of small dimensions give a false sense of security. Ropes are not acceptable as handrails.

i. Ladders

Accidents involving ladders should not occur if proper safety rules are observed. Accidents usually involve persons falling when a ladder slips away at its base or slides sideways at the top.

All ladders, temporary or permanent, should be firmly tied and secured to prevent movement. Regular checks should be carried out to ensure defective or broken ladders are not used.

Ladders must not be raked more than 1 in 4 and should project past the landing by 0.9m.

23.3.3 Types of Scaffolding

The most common types of scaffolding used in bridge construction works are independent pole scaffolds and cantilever scaffolds.

They can be constructed for heavy duty, medium and light duty. They are suitable for concreting, brick laying, demolition, masonry, rigging etc. Medium and light duty scaffolds are used for lighter trades such as painting, electrical, plastering etc.

Steel tube scaffolding, because of its high strength, should be used for independent pole scaffolding except where special circumstances may render the use of metal inadvisable.

A cantilever scaffold may be used as a working platform around the perimeter of a deck. In may cases, the cantilever brackets are prefabricated from timber and they should be firmly attached by bolts with full thread contact on the nuts. Screw connections into ferrules are not recommended because there is no clear method of inspecting the thread contact in the ferrule.

23.4 FORMWORK

23.4.1 General

Formwork is designed and built as a containment for fresh concrete in order to mould it to the required shape and dimensions. It has to support the weight of the fresh concrete until it hardens sufficiently to become self-supporting and has to support its own weight plus temporary construction loads.

There are a number of publications which provide sufficient reference material for the design and construction of formwork, such as the following:

- Hurd M. K. 'Formwork for Concrete' ACI - SP-4 (Fourth Edition), and
- 'Recommended Practice for Concrete Formwork' ACI 347-78

23.4.2 Typical Form Assemblies

In general, formwork consists of sheeting to shape and retain the concrete and supporting members to hold the sheeting firmly in place. Direct support of the sheeting is provided by members called *studs* in vertical formwork and *joists* in horizontal formwork for slabs. Studs are usually supported by cross members called *wales* (or walers), and the joists by *stringers*. The wales or stringers are held in place by tension members such as tie rods or bolts, or compression members such as shores or posts. The whole assembly may be braced by struts, guys or cables. Typical formwork assemblies are shown in Figures 23.3, 23.4 and 23.2.

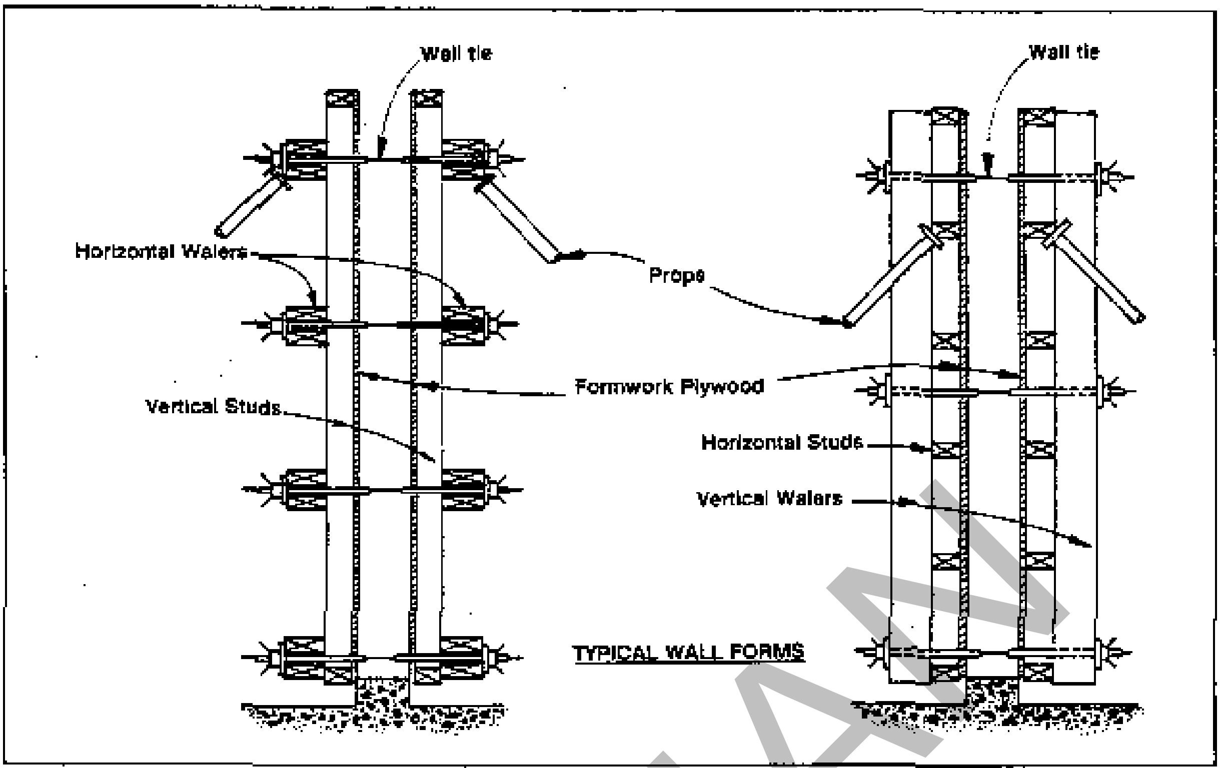


Figure 23.2 - Typical Wall Forms

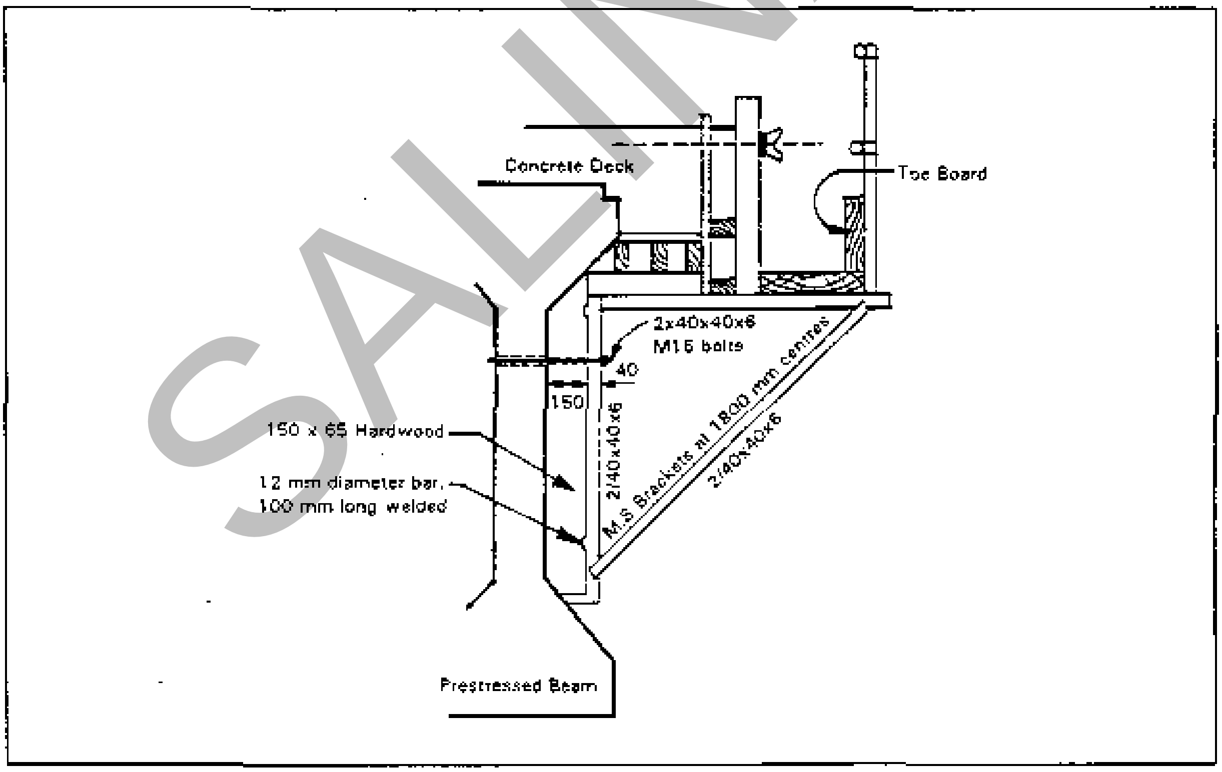


Figure 23.3 - Typical Deck Cantilever Formwork

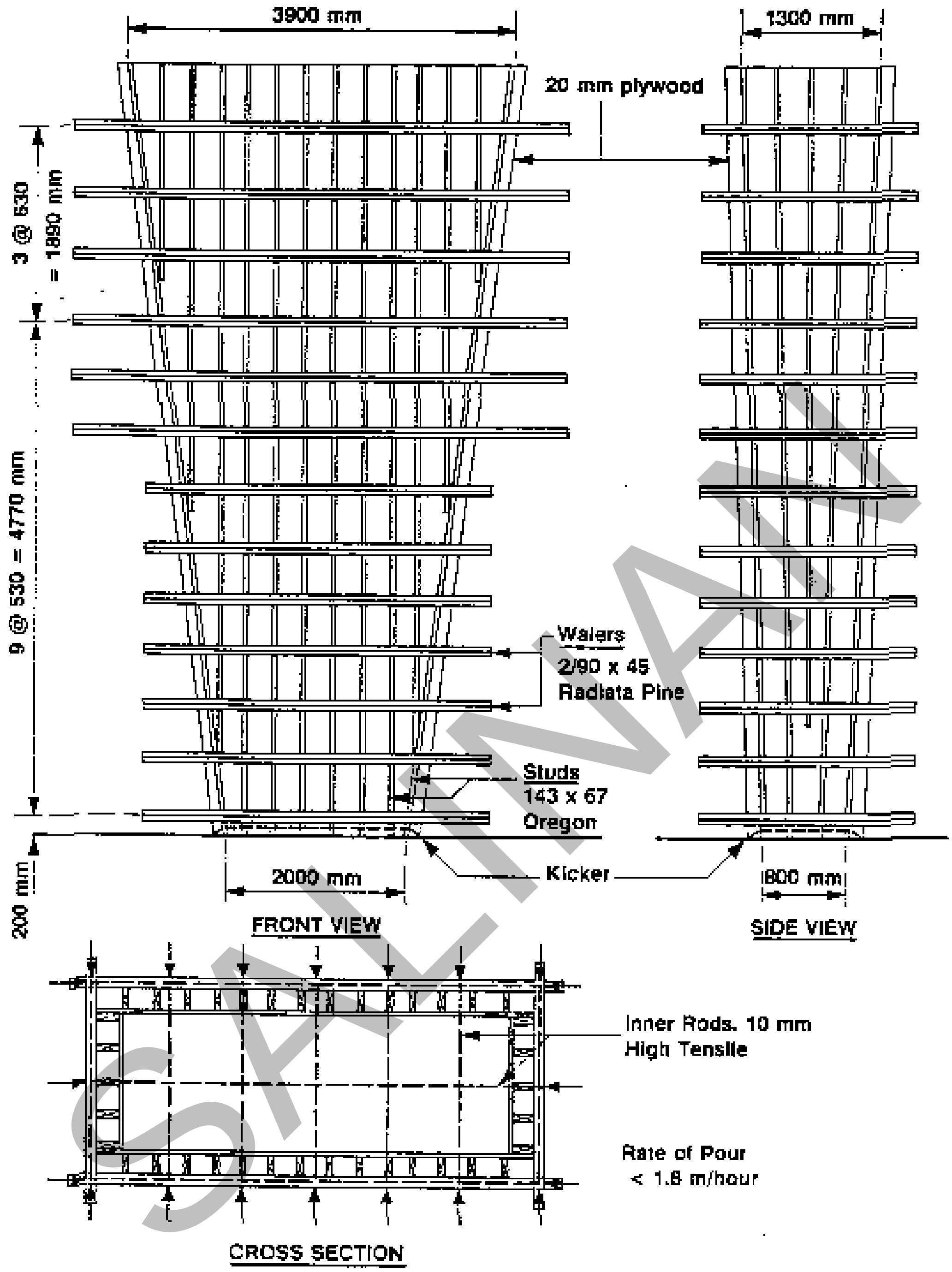


Figure 23.4 - Typical Pier Formwork

23.4.3 Design of Formwork

a. Design Objectives

There are four objectives in the design and manufacture of a form as follows:

- **Strength** - the forms should be designed so that they will safely support all loads without collapse or danger to the workmen or the structure.

- **Rigidity** - forms must be sufficiently rigid under construction loads to maintain the required shape and alignment. Formwork tolerances are generally tighter than the tolerances specified for the finished concrete due to the deflections caused by elastic shortening of braces, embedment of mating surfaces and flexure of beams.

- **Appearance** - the appearance, texture and colour of a concrete surface is a function of the quality of the forms. The appearance is determined by the degree of flatness, misalignment and surface roughness.

  Texture can vary from smooth to rough and can be accidental or intended. Colour may be uniform or variable. Where uniform colour is required, it is imperative that forms and joints are watertight and forms are of sufficient and uniform stiffness to avoid varying amplitudes during compaction caused by high frequency vibration.

  Dark areas will form on the concrete surface if the form is not watertight or the form lining varies in stiffness. Loss of grout will cause honeycombing.

  The use of plastic sheeting as a lining will prevent leaks but will be difficult to strip. Its use should be discouraged and the Contractor encouraged to use plywood, especially for deck slab pours.

- ***Economy*** *- in the building of formwork, the aim is for minimum cost* without sacrificing safety or quality. Experience and ingenuity in the use of formwork can have a large influence on cost. Forms must be adequately constructed so they will withstand handling and reuse without losing their shape.

b. Loadings on Formwork

Loads which the formwork has to withstand are :

- *Dead Loads* - weight of formwork, reinforcement, embedded materials, fresh concrete;

- *Superimposed Loads* - weight of workmen, equipment, runways, allowance for impact, and the weight of temporary loads caused by stacking of materials;

- *Lateral Pressure of Concrete* - which increase with the height of concrete poured. Vibration of concrete also increases lateral pressures;

- *Other Lateral Loads* - wind loads, forces from cable tensions, and inclined supports. These loads have to be considered mainly in the design of formwork;

- *Special Loads* - caused by any special conditions of construction.

For the design of formwork, the density of normal reinforced concrete should be taken as 2700 kg/m^3.

(a) Loads on Horizontal Forms

For horizontal forms (eg. for slabs), the loads on the forms are listed above.

The weight of the formwork itself can be taken as 0.5 kPa. The minimum value for superimposed loads providing only for the weight of workmen and an allowance for impact is 2.0 kPa. A loading of 3.6 kPa is recommended when concrete is placed with powered buggies. Where materials are to be stacked temporarily on the forms, allowance must be made for the loading caused by such materials.

(b) Loads on Vertical Forms

For vertical forms such as for walls and columns, the load is determined by the lateral pressure of the fresh concrete which is, in turn, a function of the ambient temperature, the height of the lift, the rate of casting and the method of compaction.

(i) Lateral Pressure of Fresh Concrete

Vertical forms are loaded by the lateral pressure of the wet concrete. The freshly placed concrete behaves temporarily like a fluid, producing a hydrostatic pressure which acts laterally on the vertical forms. This lateral pressure is comparable to a full liquid head when concrete is placed to the full height within the period required for its initial set.

With slower rates of placing, concrete at the bottom of the form begins to harden and the lateral pressure is reduced to less than full fluid pressure by the time concrete is completed in the upper parts of the form.

The effective lateral pressure - a modified hydrostatic pressure - has been found to be influenced by the mass, rate of placement and temperature of the concrete mix, use of retarders and the effect of vibration or other consolidation methods. How these factors effect lateral pressure will be discussed briefly before considering the magnitude of pressure to be used in form design. The factors affecting lateral pressure on forms are :

- *Mass of Concrete*. The mass of the concrete has a direct influence since hydrostatic pressure at any point in a fluid is created by the mass of a superimposed fluid. Liquid (hydrostatic) pressure is the same in all directions at given depth in a fluid. If concrete acted as a true liquid the pressure would increase proportionally with depth in the liquid. However, fresh concrete is a mixture of solids and water whose behaviour only approximates that of a liquid, and then for a limited time only until the concrete starts to set.

- *Rate of Placing*. The average rate of rise of the concrete in the form is referred to as the rate of placing.

As the concrete is being placed, lateral pressure at a given point increases as concrete depth above this point increases. Finally, by consolidation, stiffening, or a combination of the two, the concrete at this point tends to support itself, no longer causing lateral pressure on the forms. The rate of placing has a primary effect on the lateral pressure, and the maximum lateral pressure is proportional to the rate of placing, up to a limit equal to the full fluid pressure.

- *Vibration.* The purpose of internal vibration is to consolidate concrete. It results in increased temporary lateral pressures.

- *Temperature of Concrete* at the time of placing has an important influence on pressures because it affects the setting time of concrete. At low temperatures, the concrete takes longer to set and therefore, for a given a rate of casting, a greater depth will be placed before the lower portion sets sufficiently to become self-supporting. The greater liquid head thus developed results in higher lateral pressures on the formwork.

- *Slump.* The higher the water content of a mix, the longer it will take to set and therefore high slump concrete will cause greater lateral pressures than low slump concrete.

- *Retarders.* The use of retarders in concrete has the effect of delaying the setting time thereby increasing internal pressure on the formwork.

Bending, shear and axial stresses usually are the governing factors in the design of studs, joists and other formwork.

Another factor in the design of timber members is the bearing stresses set up where members bear against one another. Such members must have sufficient area for bearing to prevent crushing of the grain of the timbers.

(ii) Lateral Pressure Design Values

Forms, ties and bracing should be designed for maximum lateral pressure of plastic concrete as set out below.

The lateral pressure may be taken as the **minimum** of:

(a) Pressure due to hydrostatic head, $P = p \times h/100$ (kPa)

(b) Pressure limitation due to arching, $P = 15 + 3 \times R + d/10$ (kPa) where d is not to exceed 500 mm.

(c) Pressure limitation due to stiffening of concrete,
$P = (p \times R \times K)/100 \; + \; 5$ (kPa)

where:

P = maximum lateral pressure in kiloPascals
R = rate of placement in metres per hour
p = density of plastic concrete in kg per cubic metre
d = thickness of concrete in forms in millimetres
h = height of pour in metres
K = correction factor (see Table 23.1)

Table 23.1 Correction Factor K for use in formula (c) above

Workability (mean slump)	Value of correction factor K	
	Concrete temperature, degrees C	
millimetres	25	30
50	0.60	0.45
75	0.75	0.55
100	0.90	0.65

An impact allowance of $4 \times p \times 10^{-3}$ kPa should be added to the lateral pressure calculated above. It should be applied at all depths.

TABLE OF CONTENTS

24. EPOXY RESINS

24.1 GENERAL

An epoxy resin is a synthetic liquid resin containing the epoxide chemical grouping, which is changed to a strong, hard solid by the addition of a curing agent or hardener.

Epoxy resins are used as coatings, adhesives and for a variety of purposes in the construction, maintenance and repair of concrete structures.

They can be modified by the use of flexibilisers, fillers and pigments.

24.2 PROPERTIES OF EPOXY RESINS

Epoxy resins generally exhibit outstanding adhesive, tensile and compressive strengths and have high resistance to moisture and oxidation. Epoxy resins also have high chemical resistance, particularly to alkaline environments.

Types of epoxy resins are as follows :

- Hydrophilic - these readily absorb water when uncured resulting in significant loss of strength. These resins are suitable for use in dry conditions only.
- Hydrophobic - these do not absorb water in the uncured state and are described as water tolerant. They are suitable for use on both dry and moist surfaces.
- Flexibilised - these can accommodate significant distortion such as bending or elongation in the cured state.
- Heat Resistant - these resist high levels of applied heat without loss of mechanical properties. Most epoxy resins become "cheesy" and lose their mechanical properties when heated to their heat distortion temperature. This is generally in the range from 90°C to 180°C but can be as high as 300°C.

Formulations for use on vertical or overhead surfaces are usually available in all of these categories.

24.3 APPLICATION OF EPOXY RESINS

Some applications of epoxy resins include :

- bonding of materials including metals, concrete and neoprene rubber;
- bonding of wet to dry concrete;
- repairs to concrete using epoxy mortar or epoxy concrete;
- repair of cracks in concrete by injection of epoxy resins.

- splicing of concrete piles;
- provision of non-skid surfaces using epoxy resin and sand;
- protection of metal surfaces against corrosion with epoxy paints.

24.4 USE OF EPOXY RESINS

24.4.1 Selection

Some factors to be taken into account when selecting an epoxy resin for a given application include :

- anticipated service conditions and loadings, to determine required strength, impact resistance and whether a hard or flexible epoxy resin is required.
- the condition of surfaces to be coated, whether wet or dry.
- the ambient and surface temperatures.
- curing rate and time available for application.

24.4.2 Surface Preparation

The successful use of epoxy resins is dependent on correct surface preparation. This involves the removal of all dust, scale, oil, grease, dirt or any other foreign matter. Depending on the formulation, it may be necessary to have a dry surface.

Correct surface preparation depends on the nature and composition of materials to be bonded. For most concrete and metal surfaces, abrasive blast cleaning is the preferred method of surface preparation.

Manufacturer's recommendations should be sought for the surface preparation of other materials, particularly plastics and rubbers.

24.4.3 Mix Proportions

It is essential that mix proportions of epoxy resin and hardener be strictly in accordance with manufacturer's instructions in order to achieve the stated properties for any given product.

The mix proportions of resin and hardener specified by the manufacturer for a given product are designed to obtain a cured resin with particular properties. Adding less than the manufacturer's recommended quantity of hardener or curing agent to a given epoxy will produce a lower cross link density between epoxy molecules, hence better toughness and flexibility but poorer chemical resistance and lower heat distortion temperature. Adding more than the recommended quantity of hardener can give "over-cure" with increased brittleness in some cases but increased softness in others. In general, excessive hardener results in poorer chemical resistance and inferior properties.

The rate of curing of epoxy resins is independent of the proportions of epoxy resin to hardener. Thus increasing the proportion of hardener will not increase the rate of curing of an epoxy.

24.4.4 Mixing

Complete mixing of epoxy resin and hardener is necessary for optimum results. Use of an electric or air powered paddle stirrer is recommended.

24.4.5 Epoxy Mortars and Concretes

Aggregates for epoxy mortars and concretes must be oven dry and well graded to minimise voids. The maximum size of aggregate should not exceed 20% of the thickness of the section to be filled. Compaction by hand or mechanical tamping is essential because epoxy mortars and concretes do not compact themselves and require working into position.

24.4.6 Sealing Concrete Cracks

The recommended procedure for epoxy injection of cracks is as follows :

- remove all contaminants along crack such as dirt, laitance and grease.
- seal along cracks between nipple locations using epoxy paste.
- attach nipple to stock at lowest level and inject an epoxy having low viscosity and the required strength characteristics.
- attach subsequent nipples and pump epoxy at each successive stock where epoxy appears.
- following injection at all points and minimum curing of 12 hours, remove injection points.
- remove epoxy sealing along cracks by grinding or by softening by flame and peeling off.

Notes :

(i) *Flexibilised* epoxies are used where cracks are subject to movement.

(ii) Cutting Vee-grooves along cracks is not recommended because this can result in the crack filling with concrete powder which tends to inhibit the penetration of epoxy. In addition, the cutting of Vee-grooves results in a repair which is far more obvious and generally more unsightly than that produced by the recommended method.

(iii) Nipple stocks can also be installed in drilled holes along cracks rather than by attachment to the concrete surface by means of epoxy paste. This is usually successful for wide cracks but narrow cracks can be blocked by concrete powder produced by the drilling and the penetration of epoxy can be inhibited in a similar way to the cutting of Vee-joints.

(iv) Kits are available commercially which include all necessary epoxies and injection points for the epoxy injection of concrete cracks.

(v) One commercially available technique involves the use of equipment which employs two metering pumps to deliver epoxy resin and hardener components of a fast-setting epoxy to a mixing head. Mixed epoxy is injected directly into cracks through a special gasket.

24.4.7 Curing

The rate of curing is a function of the temperature of the epoxy resin.

Reactions of epoxy resins and hardeners are exothermic and yield considerable heat.

The greater the volume of a given mixed resin, the greater the build-up of heat and the faster the curing rate.

24.5 STORAGE

Components of epoxy resin should be stored at a temperature recommended by the manufacturer.

Components should not be kept for more than one year and should be checked before use for signs of gelling of the epoxy resin base and cystallisation or surface skinning of the hardener. For this reason, it is essential that epoxy products have a date of manufacture or a batch number (which can be used to determine a date of manufacture) clearly shown on the packaging or container.

24.6 SAFETY PRECAUTIONS

Personnel handling epoxy resins should be fully instructed on the potential hazards of the material, the correct use of equipment, the need for protective clothing, washing procedures and barrier creams. Particular care must be taken to prevent epoxy resins coming into contact with exposed skin.

Fumes from epoxy resin hardeners are often toxic and often have an irritating odour. These materials must therefore not be used in confined spaces which might give rise to a concentration of fumes, unless forced ventilation or respiratory apparatus for personnel is provided.

24.7 PRODUCT INFORMATION

Suppliers should provide the following product information :

- mixing directions for the base and hardener.
- surface preparation required for various materials.
- minimum and maximum air temperatures for application.
- pot or working times at various air temperatures say between 20°C and 35°C.
- time for curing at typical working temperatures.
- minimum and maximum temperatures for safe storage.
- shelf life.
- safety Precautions.
- details of Solvents.

TABLE OF CONTENTS

25. DEMOLITION AND REMOVAL OF STRUCTURES

25. DEMOLITION AND REMOVAL OF STRUCTURES

25.1 GENERAL

Planning for the demolition and removal of a bridge requires consideration of the following:

- type of plant available.
- size and weight of the sections into which the structure is to be cut for removal.
- whether the bridge is over dry land or over water.
- costs of alternative methods of demolition.
- whether piles require complete extraction or whether a cut-off, say 1 metre, below ground or stream bed level would be acceptable.
- the method of disposal.
- the construction material of the bridge.

Demolition work must proceed in an orderly and workmanlike manner. The method adopted should ensure that the standing portion of the structure is stable and secure at each stage of demolition. Consideration may have to be given to the use of temporary ties, guys or struts to eliminate potential dangers.

25.2 EXPLOSIVES

Explosive are often used in demolition work, especially in underwater situations. Factors to be considered before proceeding with their use include :

- proximity to existing structures;
- presence of services, both overhead and underground;
- type of explosive best suited to the work;
- availability of rope or other type of matting or heavy blankets to control flying debris.

Explosives must be transported, stored and handled only by experienced, qualified personnel. For contract demolition work, use of explosives requires the written permission of the Engineer.

25.3 CONCRETE STRUCTURES

Sections of thickness 300 mm or less can be cut using :

- hammers and manual labour.
- diamond circular saw.
- explosives as a line plaster charge. A line explosive is placed on the surface in a continuous line and covered with sand, clay or blasting mats. The effect is to remove concrete from around the reinforcement enabling the reinforcement to be cut and the section removed.
- explosives in drilled holes. A line of holes drilled closely together with every second hole charged produces a similar effect to (ii). Very thin slabs (150 mm) with this method show a tendency to blow out in the direction of the hole and not along the line of holes.
- hydraulic pick or 'breaker' mounted on an excavator to either completely demolish the structure or to remove concrete from around the reinforcement.
- metal ball or similar dropped from a crane.
- chemical expanding agents. The chemical is mixed and poured into drilled holes. The expansion causes the concrete to crack and assists subsequent removal by jack pick.

Sections greater than 300 mm thickness can be cut using :

- hammers and manual labour.
- explosives in drilled holes;
- thermic lance;
- a rock splitter. This is a hydraulically driven wedge which is placed in a drilled hole and expanded. When used along a line of holes near to a free edge, concrete can be cracked allowing easier removal by jack pick. It is common for rock splitters to be used in pairs.

25.4 TIMBER STRUCTURES

Timber structures can be removed cheaply by burning. Fire restrictions or proximity to built-up areas need consideration.

Removal in pieces or in larger sections (crane-handled) are other options. If some of the timber is in sound condition, it may be economical to cut it out with chain saws and stack it for future re-use.

25.5 STEEL STRUCTURES

Steel structures can be removed in sections by flame cutting in the reverse order of construction, or in large sections depending on the lifting capacity of available cranes. If steel trusses or girders are to be recovered for re-use elsewhere, careful attention has to be paid to the method of demolition to avoid damage to the steel members.

25.6 PRESTRESSED CONCRETE BRIDGES

Except for bridges with ungrouted tendons or external tendons, normal demolition methods as used for reinforced concrete bridges can be applied. The procedures and sequence of work proposed must first be approved by the Engineer. In the case of bridges with ungrouted or external tendons, the procedure for demolition will be as directed by the Engineer.

25.7 EXTRACTING PILES

Piles should be extracted by an extractor suspended from a crane. The extractor grips the pile and only the weight of the extractor itself is taken on the crane, allowing the hammering action of the extractor to raise the pile. Trying to jerk the load to extract a pile may impose critical loads which could overload or overturn the crane. Assistance can be provided in sandy ground by jetting around the pile whilst operating the extractor.

Directly pulling on a pile with a crane is not good practice. Horizontal loading on the crane boom can result and this can overload the boom.

Care should be taken when lifting piles which are submerged in water. There will be a sudden increase in the load once it is lifted free of the water and the allowable operating radius of the crane may be exceeded.

Piles in water have sometimes been strapped to heavy pontoons at low tide and an effective lift obtained with the incoming tide. If this fails to dislodge the pile, a pipe is driven or jetted down adjacent to the pile and a small explosive charge lowered inside the pipe. The percussion resulting from the firing of the charge, combined with the applied upward lift, is often sufficient to free the pile.

Over water, and where a firm bed is available, piles have been successfully extracted by a number of 50 tonne hydraulic rams contained in a steel frame which fits over the pile. The frame is seated on the river or sea bed. Powerful pivoted grips engage with the top of the pile whilst the thrust from the rams, on each side of the pile, is exerted.

25.8 UNDERWATER CUTTING OF STEEL

Gas cutting of steel is possible under water provided the appropriate mixture of gases is used, as follows :

- under 3 m deep - Oxy-acetylene or L.P.G. and Oxygen;
- over 3 m deep - Hydrogen and Oxygen.

TABLE OF CONTENTS

26. CLEANING UP

As construction work proceeds, the Works should be maintained in a tidy condition. Surplus materials should be regularly removed from the site.

After completion of the bridgeworks, all temporary works, buildings, workshops and equipment which have been constructed or brought on to the site must be removed, except for those items which are needed for the performance of the maintenance and remedial work.

Temporary concrete slabs placed in work areas during construction must be broken up and removed and areas disturbed by access roads must be restored. Excess soil should be spread evenly on the site and used to fill local depressions. Topsoil and turf should be replaced if specified.

Damaged fences must be reinstated to the condition at commencement of the Works.

Where temporary fill has been placed as an aid to construction, especially in waterways, the material must be recovered, disposed of, and the banks returned as close as possible to the condition existing at the time of commencement of the work. Likewise, temporary anchors placed in waterways for manoeuvering floating plant must be recovered and removed from site. Temporary piles must be withdrawn or cut off at an appropriate level and removed from the site.

All parts of the Work must be left in a neat and tidy condition.

LIST OF REFERENCES

I. *Bridge Construction Practice*
Austroads, Draft 1989

II. *Construction Planning, Equipment and Methods*
Peurifoy and Ledbetter, 1987

III. *Civil Engineering Construction*
Antill and Ryan, 1972

IV. *Training Manual for Bridge Foremen*
Department of Main Roads NSW, Australia, 1973

V. *Construction Manual for Highway Bridges and Incidental Structures*
AASHTO, 1973

VI. *Australian Concrete Inspection Manual*
Nagarajan and Antill, 1978

VII. *Basic Guide to Concrete Construction*
Cement and Concrete Association of Australia, 1975

VIII. *Prestressed Concrete Inspection Practice*
NAASRA, 1983

IX. *Manual of Concrete Inspection*
American Concrete Institute, SP-2, 1988

X. *Recommended Practice for Concrete Formwork*
ACI 347, 1978

XI. *Guide for Measuring, Mixing, Transporting and Placing Concrete*
ACI 304R, 1985

XII. *Guide for Use of Admixtures in Concrete*
ACI 212.2R, 1981

XIII. *Formwork for Concrete*
American Concrete Institute, SP-4, 1988

XIV. *Properties of Concrete*
Neville, 1981

XV. *Foundation Analysis and Design*
Bowles, 1989

XVI. *Pile Design, Construction and Practice*
Tomlinson, 1989

XVII. *Pile Foundations*
Chellis, 1961

XVIII. *Wika Piles*
PT Wijaya Karya, Brochure

XIX. *Construction and Geotechnical Methods in Foundation Engineering*
Koerner, 1988

XX. *Project Management Techniques*
SMEC, 1985

XXI. *Mabey Compact Bailey Manual*
Mabey Johnson, 1987

DIRECTORATE GENERAL OF HIGHWAYS
MINISTRY OF PUBLIC WORKS
REPUBLIC OF INDONESIA

BRIDGE CONSTRUCTION SUPERVISION MANUAL

APPENDICES

BRIDGE MANAGEMENT SYSTEM
BMS
A PROJECT JOINTLY FUNDED BY INDONESIA AND AUSTRALIA

JANUARY 1993

DOCUMENT No. BMS9-M.E

APPENDIX 1

STANDARD FORMS FOR BRIDGE CONSTRUCTION SUPERVISION (ADMINISTRATIVE)

STANDARD FORMS FOR *BRIDGE CONSTRUCTION SUPERVISION*

ADMINISTRATIVE:

- Inspectors Daily Diary - Bridge Works
- Supervisor's Weekly Report
- Daily Diary for Contract Bridge Works
- Site Memo
- Correspondence Register (Incoming and Outgoing)
- Drawing Register (To and From Contractor)
- Issue of Drawing to Contractor
- Request for Price
- Change Order (Instruction to Contractor)
- Change Order Register
- *Request for Dayworks*
- Dayworks Register
- Dayworks (Summary)
- Construction Project Input Data Sheet
- Progress Payment - Monthly Certificate
- Progress Payment - Summary
- Progress of Construction (S-Curve)
- Weather Chart

TECHNICAL:

- Setout Check Record
- Pile Driving Record
- Pile Group Driving Record-Summary
- Concrete Mix Design Checklist
- Weekly Report of Concrete Aggregate Tests
- Preplacement Checkout Card - Concrete
- Concrete Placing Record
- Concrete Field Testing Data Sheet
- Epoxy Joints and Repairs
- Record of Site Stressing
- Bolt Tightening Final Check Certificate

INSPECTOR'S DAILY DIARY - BRIDGEWORKS

Bridge No : .... Bridge Name : ....

Contract No : .... Contractor : ....

Province : ....

Date : .... Weather Conditions : ....

LABOUR ON JOB

Classification	Number	Overtime		Lost Time		
		Men	Hours	Men	Hours	Reason
Foremen						
Labourers						
Carpenters						
Plant Op.						
Others						

PLANT ON JOB

Item	Work Time	Standby	
		Hours	Reason

WORK DONE

Description	Labour, Plant and Hours	Remarks

MATERIALS SUPPLIED BY THE EMPLOYER

Description	Delivery Details	Checked	Remarks

GENERAL COMMENTS

(Delays and reasons, instructions from Engineer amendments to drawings or specifications, visitors, details of important conversations with Contractor including names and times)

Signature ....

Inspector

SUPERVISOR'S WEEKLY REPORT

LABOUR ON JOB (number)				Overtime	Lost Time	Reason	Week Ending
	Carpenters	Labourers		Brought Hours	forward Hours		
Mon.							Bridge No.
Tues.							Contractor
Wed.							Contract No.
Thurs.							Province
Fri.							Road
Sat.							Bridge or Stream Name
Sun.							Location: From km.

WORK DONE				Materials Used	Materials Received
Mon.					
Tues.					
Wed.					
Thurs.					
Fri.					
Sat.					
Sun.					

PROGRESS TO DATE

Substructure	Excavation Piles	Footing Pilecap	Columns Wall	Cross Head	Superstructure	Beams Slabs	Deck	Kerbs Handrails	
Abutment					Span No.				
Abutment									
Pier No.									

MATERIAL REQUIREMENTS (Employer Supplied)			MAJOR PLANT & CONDITION
Type	Quantity	Date	
Cement			
Reinforcement			

GENERAL COMMENTS (Include Quality, Future Work, etc.)

Estimated percent of total completion

.... %

Signature Supervisor

DAILY DIARY FOR CONTRACT BRIDGE WORKS

Contract No

Contract Title

Contractor ....

Date ....

Bridge No. ....

Inspector ....

Weather

Rainfall .... mm

No. of Hours .... hrs

Temp. Range .... °C

Wind ....

General ....

Time Worked

Labour

From .... to ....

Contractor Manpower

Engineers

Office

Foremen

Carpenters

Labourers

Plant Operators

Total

Sub Contractor

Total

Total Manpower on site

Major Plant on Site

Cranes

Concrete Pumps

Batch Plants

Excavators

Trucks

Dozers

Loaders

Rollers

WORK IN PROGRESS

Description	Location	Output	Remarks

CONCRETE PLACEMENTS

Location of Placement	Class / Mix	Quantity Poured	Remarks

OTHER COMMENTS

Contractor

Instructions or Warnings (confirm in writing)

Important matters discussed

Amendments to Drawings, Specification or Programme

Breakdown, Delays etc., affecting progress (detail)

Materials received on site

General

Traffic Arrangements and road conditions

Special or Unusual features of work

Visitors

Engineers Instructions

Engineer ....

SITE MEMO

Contract No. : ______________________ Date : / /

Contract : ______________________ Time :

Contractor : ______________________ Number : __________

To : ______________________

From : ______________________

______________________ ______________________

for Engineer's Representative *for Contractor's Superintendent*

Correspondence Register

(Incoming) Contract No. : ____________

Contract : ____________________

Contractor : ____________________

Date Received	Date of Letter	Contractor's Reference	Subject	File Number

Correspondence Register

(Outgoing) Contract No. : ____________

Contract : ____________________

Contractor : ____________________

Date	Number	To	Subject	File Number

Drawing Register

(to Contractor) Contract No. : ____________

Contract : ______________________

Contractor : ______________________

Date	Drawing Number	Rev	Title	File Number

Drawing Register

(from Contractor) Contract No. : ____________

Contract : ____________________

Contractor : ____________________

Date Received	Drawing Number	Rev	Title	File Number

Contract No. : ____________________ File :

Contract : ____________________ Reference :

Contractor : ____________________ Date : / /

Dear Sir,

Issue of Drawing

In accordance with the provisions of Article 7(1) of the General Conditions of Contract two copies of Drawings :

Drawing Number	Revision	Title

are hereby issued to the Contractor.

Please complete and return the acknowledgement slip on the attached copy of this letter.

Yours faithfully

____

Engineer's Representative

copies to :

Encl:

We hereby acknowledge receipt of the above drawings (and bar schedules).

____________________ ____________________

Date For Contractor

Contract No. : ______________________ File :

Contract : ______________________ Reference :

Contractor : ______________________ Date : / /

Dear Sir,

Request for Price

In accordance with the provisions of Article 51 of the General Conditions of Contract, the Contractor ...., is hereby requested to submit, for the Engineer's consideration, a price for the item(s) of work listed in the schedule below:

1. Schedule

Item No	Description	Unit	Quantity	Rate (Rp)	Amount (Rp)

2. Drawing

3. Specification

[In accordance with the relevant sections of the Specification for Contract No. ....

Date : ______________

Requested by:

____

Engineer's Representative

Date : ______________

Prices Submitted by:

____

for Contractor

copies to :

CONTRACT VARIATION/CHANGE ORDER

CHANGE ORDER NO. : C - / /8______ DATE ______________ ,19 ________

TO : (CONTRACTOR) ____

____

ATTENTION ____

FROM : (PIMBAGPRO/PROJECT MANAGER) ______________________________

____

____

GENTLEMEN :

IN ACCORDANCE WITH ARTICLE 42 OF THE GENERAL CONDITIONS OF CONTRACT, VOLUME 2, THE FOLLOWING WORK IS HEREBY CHANGED :

- DESCRIPTION : ____

____

____

____

REASON FOR CHANGE ORDER : ______________________________

____

____

____

- PAYMENT (DETAILS AS NOTED ON PAGE 2) :

____

____

____

- COST INCREASE/DECREASE : ( ) ______________________________
- INCREASE/DECREASE PERCENTAGE :

( ) ______________________________ % (OF CONTRACT SUM)

- TIME EXTENSION : ______________________________ (CALENDAR DAYS)

PREPARED BY : ______________________ (QUANTITY SURVEYOR) DATE __________

CHECKED BY : ______________________ (SITE ENGINEER) DATE __________

APPROVED BY : ______________________ (PIMBAGPRO) DATE __________

DISTRIBUTION - CONTRACTOR (2) SITE ENGINEER (1)
PIMBAGPRO (1)
CONTRACT FILE (2)

(I OR + REPRESENTS INCREASE/D OR - REPRESENTS DECREASE)

CONTRACT NO. ______________________ VARIATION/CHANGEORDERNO. ______________

DATE ______________________ PAGE 2

SCOPE OF CHANGE IN WORK ITEM (S)

ITEM NO.	DIVISION.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	ESTIMATED AMOUNT (Rp.)
INCREASE/DECREASE IN COST : Rp.						

* INCREASE/DECREASE IN COST
  - PAY ITEM NO. ( ) ______________________ Rp.
  - PAY ITEM NO. ( ) ______________________ Rp.
  - PAY ITEM NO. ( ) ______________________ Rp.
  - CONTRACT SUM ( ) ______________________ Rp.
* PERCENT INCREASE/DECREASE IN CONTRACT SUM ( ) ______________________ %

I : (INCREASE) OR (+); D : (DECREASE) OR (-)

PREPARED BY : ______________________
QUANTITY SURVEYOR

CHECKED BY : ______________________
SITE ENGINEER

APPROVED BY : ______________________
PIMBAGPRO

Change Order Register

Contract No. : ____________

Contract : ____________

Contractor : ____________

Date	Change Order Number	Description	Value	Date Approved

Contract No. : ____________________ File :

Contract : ____________________ Reference :

Contractor : ____________________ Date : / /

Dear Sir,

Request for Dayworks

In accordance with the provisions of Article 50 of the General Conditions of Contract you are hereby directed to carry out the following works on the basis of Dayworks:

This work is to be given the reference number DW - .....

You are required under Clause 1.1.42 of the Specifications to furnish daily a record of plant, labour and materials used in these Dayworks.

Payment will be made at the rates and lump sums previously agreed for Dayworks.

Yours faithfully

____

Engineer's Representative

copies to :

Dayworks Register

Contract No. : ____________

Contract : ____________

Contractor : ____________

Date	Dayworks Number	Description	Estimated Value	Total Value to date

CONTRACT NO : ____________________ DATE : ___/___/___

CONTRACT : ____________________

CONTRACTOR : ____________________

LOCATION : ____________ DATE WORK PERFORMED ___/___/___

ITEM OF WORK : ____________ SHT. NO. : ________ OF ________

DAY WORK

(SUMMARY)

MAN POWER						
NO.	DESCRIPTION	QTY	HOURS	UNIT PRICE	TOTAL AMOUNT	REMARK
1	FOREMAN			Rp.		
2	SKILLED LABOURER			Rp.		
3	GENERAL LABOURER			Rp.		

EQUIPMENT						
NO.	DESCRIPTION	QTY	HOURS	UNIT PRICE	TOTAL AMOUNT	REMARK

MATERIAL					
NO.	DESCRIPTION	QTY	UNIT PRICE	TOTAL AMOUNT	REMARK
		SUB - TOTAL			
		TOTAL			

Submitted by Contractor:

Checked by Inspection Engineer :

Reviewed by Site Engineer :

Calculated by Quantity Surveyor

Approved by PIMBAGPRO :

CONSTRUCTION PROJECT INPUT DATA SHEET All costs expressed in millions rupiah	
1. Project ID	
2. Project Code	
3. D a t e	
4. Reporting Unit	
5. Contractor	
6. Construction Contract	
7. Consultant	
8. Project limit, bridges	
9. Project limit, to	
10. Length	
11. Invite Bids	
12. Open Bids	
13. Award	
14. Noticed to proceed	
15. Begin Contract time	
16. Original Contract time	
17. Original Completion date	
18. Approved time extension	
19. Revised time extension	
20. Days Elapsed	
21. Estimate Completion date	
22. Actual Completion date	
23. Original Contract Amount	
24. Approved Change Order	
25. Certified Price Escalation	
26. Anticipated Price Escalation	
27. Material on Site	
28. Anticipated Change Order	
29. Value of Certified Work	
30. Value of Scheduled Work	
31. Advance paid	
32. Advanced Refunded	
33. Approved Claims	
34. Certified interest	
35. Net Retention Money	
36. Certified Currency Adjustments	
37. Other Approved Adjustments	
38. Other Anticipated Adjustments	
39. Revised Contract Amount	
40. Probable Final Cost	
41. Actual Percent Complete	
42. Scheduled Percent Complete	
43. Revised Contract Time	
44. Percent Time Elapsed	
45. Lender's share	

DEPARTEMEN PEKERJAAN UMUM DIREKTORAT JENDERAL BINA MARGA
DINAS PEKERJAAN UMUM
BRIDGE REPLACEMENT PROGRAMME PROVINCE

Contract Package No. :
Contractor :
Contract No. :

Monthly Certificate :
For the Month of :
Date of MC. :
Constitutions :

Summary of Works		Contract Sum					Cost of Works Performed			
		Bid		Revised		Total Rupiah Equiv.	Cost to Date			Percent to Date
Div	Description	Local (Rp)	Foreign (US$)	Local (Rp)	Foreign (US$)		Local (Rp)	Foreign (US$)	Rupiah Equiv.	
1.	General									
3.	Earth Works									
5.	Shoulders									
6.	Sub Base and Base									
7.	Surfacing and Pavement									
8.	Structure									
9.	Miscellaneous									
	Total Sums									
	Material on Site									
	Gross Sum of Monthly Certificate									

Deductions	Local (Rupiah)	Foreign (US$)
Previous Monthly Certificate ; Total Sums (cummulative net sums)		
Retention Money ; 10% of Total Sums (cummulative)		
Advance Payment Repayment 25% of Total Sums (cummulative)		
Other (specify)		
Total Sum of Deductions		
Net Sum of Monthly Certificate		
In words		
Local Currency Component		
Foreign Currency Component		

Fixed Exchange Rate
US $ = 1,650 Rupiahs
Yen =
Other =

Percentage Achieved
To Date :
To Previous Monthly :
For the Month :

Submitted by Contractor

Contractor's Representative

Checked by Engineer

Supervision Engineer
(Supervision Team)

Approved for Payment by Employer

Project Manager

DEPARTEMENT PEKERJAAN UMUM
DIREKTORAT JENDERAL BINA MARGA
DINAS PEKERJAAN UMUM
PROPINSI
BRIDGE REPLACEMENT PROGRAM

Contract No :
Contractor :
Local Consultant :
International Consultant :

Monthly
Certificate No :
For the month of :
Date

Distribution of charges

	Currency	Portion	Amount to be paid
GOI	Rp		
ADB	Rp		
Ppn	Rp		

Percentage achieved
To date
Previous month :
For the month :

Summary		Contract Sum Rp		Cost of Work Performed Rp	Percent to date
Div	Description	Bid	Revised		
1.	General				
3.	Earth Work & Demolition				
5.	Road Shoulder				
6.	Sub Base & Base				
7.	Surfacing & Pavement				
8.	Structure				
9.	Miscellaneous				
	Total Sum				

Material on site	
Gross sum of Monthly Certificate	
Less Deduction :	
1. Previous Monthly Certificate	
2. 10% Retention According to contract	
3. 25% Repayment of Advance	
Total sum of deductions	
Certified sum for Payment (in words)	

Submitted by :

Checked by Consultant :
Local :
International :

Approved by :

Contractor

Supervision Eng.

Bridge Expert

Project Manager

Example of S Curve

Contract No : ....
Contract : ....
Contractor : ....
Month : ....

PROJECTED AND ACTUAL PROGRESS OF CONSTRUCTION

Div	Item	Contract Price Rp.	Percent to Total	Percent Progress	Percent Total to Date		1989 Jul	Aug	Sep	Oct	Nov	Dec	1990 Jan	Feb	Mar	Apr	May	Jun
1	General					P												
						A												
3	Earth Work & Demolition					P												
						A												
5	Road Shoulder					P												
						A												
6	Sub Base & Base					P												
						A												
7	Surfacing & Pavement					P												
						A												
8	Structure					P												
						A												
9	Miscellaneous					P												
						A												
	Total																	
	Accumulation of Project Progress					%												
	Accumulative of Progress Reschedule					%												
	Accumulative of Actual Progress					%												
	Differences (+) ahead, (-) delayed					%												
	Accumulative of Projected Amount					x Rp. 1000												
	Accumulative of Actual Amount					x Rp. 1000												
	Material of Site					x Rp. 1000												

CONTRACTOR : ____________________

Contract No. : ____________

WEATHER CHART

Contract : ______________________

For Month of : ____________ 19 ___

Bridge No : ______________________

DAY / FEATURE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
General Weather (R/S/C)																															
Maximum Temperature																															
Minimum Temperature																															
Relative Humidity (%)																															
RAINFALL																															
Rain (mm)																															
Started at:																															
Stopped at:																															
River Level (m) at time																															
River Flow (cumecs)																															

NOTE : R : RAINING
S : SUNNY & DRY
C : CLOUDY

REPORTED BY : ______________________
Inspector

APPENDIX 1 (Continued)

STANDARD FORMS (TECHNICAL)

DEPARTEMEN PEKERJAAN UMUM
DIREKTORAT JENDERAL BINA MARGA
DINAS PEKERJAAN UMUM

PROPINSI : ....

SETOUT CHECK RECORD

CONTRACT NO: ______________________

CONTRACTOR : ______________________

BRIDGE NO. ______________________

ELEMENT ______________________

DESCRIPTION : ______________________

Feature	Design	Measured	Comment
Reduced Level			
Chainage			
Offset			

CHECKED BY : ______________________

DATE : ______________________

PILE DRIVING RECORD.

Province .... Contract No. .... Bridge No ....

A Pile Identification & Location About / Pier ....

Pile Mark ....

Casting Date ....

Cast Length ....

B Hammer Details Type .... Weight ....

C Helmet Details Type .... Weight ....

D Packing Details Type ....

Initial thickness .... Final thickness ....

E Driving Details Driving Date .... Start Time .... Stop Time ....

Ground R.L. .... Specified Toe R.L. ....

Actual Penetration .... Actual Toe R.L. ....

Final set .... blows for .... mms

F Driving Log

Penet^n (m)	Blows	Drop * or Energy	Penet^n (m)	Blows	Drop * or Energy	Penet^n (m)	Blows	Drop * or Energy
.25			7.25			14.25		
.5			7.5			14.5		
.75			7.75			14.75		
1.0			8.0			15.0		
1.25			8.25			15.25		
1.5			8.5			15.5		
1.75			8.75			15.75		
2.0			9.0			16.0		
2.25			9.25			16.25		
2.5			9.5			16.5		
2.75			9.75			16.75		
3.0			10.0			17.0		
3.25			10.25			17.25		
3.5			10.5			17.5		
3.75			10.75			17.75		
4.0			11.0			18.0		
4.25			11.25			18.25		
4.5			11.5			18.5		
4.75			11.75			18.75		
5.0			12.0			19.0		
5.25			12.25			19.25		
5.5			12.5			19.5		
5.75			12.75			19.75		
6.0			13.0			20.0		
6.25			13.25					
6.5			13.5					
6.75			13.75					
7.0			14.0					

* Record fall of drop hammer in metres or energy input of diesel, air or steam hammers in m tonne

PILE GROUP DRIVING RECORD - SUMMARY

CONTRACT NO	BRIDGE
CONTRACTOR	PILE GROUP LOCATION
TYPE OF PILE	PILE DIMENSIONS Length (L) .... (m) Cross Section .... m x .... m
TYPE OF PILE DRIVING RIG	
WEIGHT OF HAMMER (W,)/ENERGY RATING (E,)	
PILE DRIVING FORMULA	VALUES USED IN DANISH FORMULA 1)

$$R_u = \frac{e \times H \times W_r}{s + 0.5 \times s_0} \; ; \qquad R = \frac{R_u}{FS}$$

$$s_0 = \sqrt{\frac{2 \times e \times H}{A \times E}}$$

FS ....

e .... W_r .... (kN) W_p .... (kN)

A .... (mm²) E .... (MPa) E_r .... joules

SKETCH OF PILE GROUP (Piles to be numbered)

Pile No.	Date Driven	Drop of Hammer H (m)	Set per Blow s (mm)	Temp. Comp. (mm)	Safe Load R (kN)	Penetration (m)	Ref. R L 2)	R L Toe Actual (m)	R L Toe Plan (m)	Remarks

1) Refer Specification Clause 5.6.1
2) R L from which penetration is measured

General Comments :

Engineer :	Inspector :	Date

CONCRETE MIX DESIGN CHECKLIST (Weigh Batching)

Contract No : ____________________ Concrete Class : K________

Contractor : ____________________ Maximum Slump ________ mm

PART A - GENERAL

	Contractor's Design	Check Calculation		Comment
1. Target Strength (MPa)		Std Dev.	Control Factor 1.64	OK Y/N
2. Water/Cement Ratio		Estimated Strength		Y OK N
3. Water Cement Ratio for durability		Maximum Value (Specif. Table 8.3)		Y OK N
4. Maximum Cement Content		Maximum Value (Specif. Table 8.3)		Y OK N
5. Nominal size coarse aggregate		Maximum Size (Specif. 8.2.2.c iii)		Y OK N
6. Water (kg/m^3 of concrete)		ACI approximate figure		Y OK N

PART B - MIX PROPORTIONS

	Contractor Design (kg/m^3 concrete)	Calculated Figure	Comment
1. Water			
2. Cement			
3. Coarse aggregate			
4. Fine aggregate			

	Test Result Data		
	Cement	Coarse aggregate	Fine aggregate
Density (kg/m^3)	(3150)	(2600)	(2540)
Moisture Content (per cent)			
Fineness Modulus			

ACI Manual of Concrete Practice 211.1

TABLE A1.5.3.3 - APPROXIMATE MIXING WATER AND AIR CONTENT REQUIREMENTS FOR DIFFERENT SLUMPS AND NOMINAL MAXIMUM SIZES OF AGGREGATES

Slump, mm	Water, Kg/m³ of concrete for indicated nominal maximum sizes of aggregate							
	9.5*	12.5*	19*	25*	37.5*	50*	75	150
Non-air-entrained concrete								
25 to 50	207	199	190	179	166	154	130	113
75 to 100	228	216	205	193	181	169	145	124
150 to 175	243	228	216	202	190	178	160	-
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-entrained concrete								
25 to 50	181	175	168	160	150	142	122	107
75 to 100	202	193	184	175	165	157	133	119
150 to 175	216	205	197	184	174	166	154	-
Recommended average total air content, percent for level of exposure :								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0
Extreme exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5	4.0

* The quantities of mixing water given for air-entrained concrete are based on typical total air content requirements as shown for "moderate exposure" in the Table above. These quantities of mixing water are for use in computing cement contents for trial batches at 20 to 25 C. They are maximum for reasonably well-shaped angular aggregates graded within limits of accepted specifications. Rounded coarse aggregate will generally require 18 kg less water for non-air-entrained and 15 kg less for air-entrained concretes. The use of water-reducing chemical admixtures, ASTM C 494, may also reduce mixing water by 5 percent or more. The volume of the liquid admixtures is included as part of the total volume of the mixing water.

TABLE A1.5.3.4(a) - RELATIONSHIPS BETWEEN WATER-CEMENT RATIO AND COMPRESSIVE STRENGTH OF CONCRETE

Compressive strength at 28 days, MPa*	Water-cement ratio, by mass	
	Non-air-entrained concrete	Air-entrained concrete
40	0.42	
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

* Values are estimated strengths for concrete containing not more than 2 percent air for non-air-entrained concrete and 6 percent total air content for air-entrained concrete. For a constant water-cement ratio the strength of the concrete is reduced as the air content is increased.

Contract No. ....

WEEKLY REPORT
of
CONCRETE AGGREGATE TESTS

Bridge No. ....

Contractor : ....

Representing week of .... to ....

Fine Aggregate SOURCE: ....

Date Sampled: ....

Location: ....

Results (ARE) (ARE NOT) acceptable.

ORGANIC IMPURITIES - ASTM C-40

Test Value ....

SPEC: No. 3 Standard or Less*

* Greater than No. 3 standard is acceptable provided the discoloration is due mainly to small quantities of coal and lignite.

MONTHLY REPORT
of
CONCRETE AGGREGATE TESTS

Representing month of ....

COARSE AGGREGATE

COARSE AGG SOURCE: ....

Date Sampled: ....

Location: ....

FINE AGGREGATE

FINE AGG SOURCE: ....

Date Sampled: ....

Location: ....

Clay Lumps in Aggregates - AASHTO T112 (ASTM C 142): Clay Lumps and Friable Particles

AGGREGATE SIZE	FINE AGGREGATE				
% FRIABLE					
SPEC.	1.0 %				

REMARKS: Accepted / Rejected

Light Particles in Aggregates - ASTM C 123

AGGREGATE SIZE	FINE AGGREGATE				
% LIGHT PIECES					
SPEC.	1.0 %				

REMARKS: Accepted / Rejected

Soundness of Aggregates - AASHTO T104 (ASTM C 88)

AGGREGATE SIZE	FINE AGGREGATE				
% LOSS					
SPEC.	10.0 %				

REMARKS: Accepted / Rejected

REMARKS:

PREPLACEMENT CHECKOUT CARD

CONCRETE

CONTRACT NO. .... CONTRACTOR ....

BRIDGE NO. ....

PLACEMENT NO. .... PLACEMENT DATE ....

LOCATION ....

ELEVATION .... TO .... FINISH ....

CONCRETE CLASS ....

REFERENCE DRAWINGS ....

ITEM	CONTRACTOR		ENGINEER	
	SUPERVISOR	DATE	INSPECTOR	DATE
1. BASE PREPARATION				
2. REINFORCING STEEL				
3. FORMWORK				
4. FALSEWORK				
5. FITTINGS				
6. PLACEMENT : ACCESS/ VIBRATION/ SCABBLING ETC				
7. PRESTRESSING				
8. OTHER				
FINAL CLEARANCE	CONTRACTOR'S SUPERINTENDENT		ENGINEER'S REPRESENTATIVE	
	DATE : / /		DATE : / /	

CONCRETE PLACING RECORD

Contract No. ______________________ Bridge No. ______________________

Concrete Placing Started ______________ Hours. Concrete Placing Completed ______________ Hours.

Concrete placed and compacted in accordance with Specifications.

Comments: ____

____

____

____

____

____

____

____

____

____

____

____

____

____

Inspector ______________________

INSTRUCTIONS: Under "Comments" account for all unusual conditions and difficulties encountered affecting the placing and protection of concrete; also any special instructions to the Contractor and action taken.

CONCRETE FIELD TESTING DATA SHEET

CONTRACT No	CONTRACTOR	BRIDGE No
DATE		REPORT No

Location of Pour ____________________

Pour Card No ____________ Concrete Class: K ....

TIME	TRUCK NO.	TICKET NO.	SLUMP (mm)	AIR CONT. (%)	CONC. TEMP. (°)	AMB TEMP. (°)	UNIT WEIGHT (kg/m³)	CYL. NO'S.	NOTES

REMARKS. Test results meet indicated specification requirements ____________________

EQUIPMENT USED	SPEC. REQ'TS.	
Air Meter No	Air (%)	
Thermometer No.	Temp (°)	Max Min
U.W. Measure No	Slump (mm)	Max

________ ________
Inspector Date

________ ________
Supervisor Date

EPOXY JOINTS AND REPAIRS	
Bridge No : Contract No. : Contractor :	Date : / /
Location of Joint/Repair : Type of Joint/Repair : Type of Epoxy :	
Type of Surface Preparation :	
Materials added as Filler : Mix Proportions : Method of Mixing :	
Weather Conditions : Shade Temperature (C) Time after mixing before initial application :	
Method of Application :	
Volume of Epoxy Material used :	
Comments :	
	Inspector

RECORD OF SITE STRESSING

BRIDGE : .... CONTRACT NO. ....

MEMBER TYPE : ....

CONTRACTOR : .... DATE / /

CABLE No.	COIL No.	FORCE	PRESSURE READING	MEASURED ELONGATION				ANCHORAGE PULL-IN			NETT ELONGATION OBTAINED	NETT ELONGATION REQUIRED
				START	FINISH	DIFF	TOTAL			TOTAL		
		kN	MPa	mm	mm	mm	mm	mm	mm	mm	mm	mm
			Tendon length L =							metres		
			Tendon Cross-section area, A =							mm²		
			Modulus of Elasticity, E =							kN/mm²		

SUPERVISOR

FINAL CHECK CERTIFICATE FOR BOLT TIGHTNESS

CONTRACT NO. :

CONTRACT :

BRIDGE NO. :

BRIDGE NAME :

PROVINCE :

LOCATION :

SPAN : CLASS : DECK WIDTH :

TRUSS : GIRDER :

We declare that the bridge has been checked for bolt tightness.

PARTY	NAME	SIGNATURE	DATE
For Consultant (as Supervising Engineer)			
For Bina Marga (as Engineer)			
For Contractor			

COMMENTS :

APPENDIX 2

CHECKLISTS

GENERAL CONDITIONS OF CONTRACT

CHECKLIST FOR SUPERVISOR

CLAUSE NO.	HEADING OF CLAUSE
2(2)	**Authority and Duties of the Engineers Representative** The Engineer must notify the Contractor of the name of the Engineer's Representative and the powers and authorities which he intends to delegate to his Representative.
4(2)	**Award of Sub-Contracts** The Contractor is required to notify the Engineer of all sub-contracts he intends to enter into for material, equipment, or other components of the works. The Engineer must respond promptly to this submission from the Contractor.
7(1)	**Custody of Drawings** Two sets of Drawings (size not stated) are to be supplied to the Contractor.
10	**Performance Bond** The Contractor is required to submit a performance bond as follows: - within 15 days of the issue of the Notice of Award and before the signing of the Contract (this may be extended by Employer); - amount to be 10 percent of the local currency equivalent of the total Bid Sum; - validity period of Bond to be from the date of signing the Contract Agreement until 30 days after the date of Provisional Handover.

CLAUSE NO.	HEADING OF CLAUSE

11 **Advance Payment Bond**

The Employer makes available the Advance payment only after the Contractor furnishes an Advance Payment Bond.

The Contractor is required to submit an Advance Payment Bond as follows:

- within 15 days of the date of signing of the Contract;
- amount to be the value of the Advance Payment (20 per cent of each of the local and foreign currency amounts of the Contract Sum);
- bond is to be valid for the repayment period (normally from the third to the seventh Monthly Certificate) and is to be capable of adjustment in value (to reflect the repayments made).

13 **Programme to be furnished**

The Contractor is required to submit within 15 days of the Notice Award certain programmes and schedules.

These are:
- Mobilisation Programme
- Detailed Construction Programme
- Other as listed.

The requirements for each of these programmes should be set out in the Specifications. Any programming requested by the Engineer which falls outside the requirements of the Contract documents is ground for a valid claim by the Contractor.

20 **Insurance of Works**

(a) During the Contract Period

The Contractor is required to submit, before starting work, evidence that he has a valid policy in joint names (Employer and Contractor) for an amount equal to the full value of the works.

(b) During the Warranty Period

The Contractor is required to submit evidence that he has a valid policy in joint names covering the completed works for an amount equal to the full value of the completed works.

CLAUSE NO.	HEADING OF CLAUSE
22(1)/(2)	**Third Party Insurance** The Contractor is required to submit evidence of a valid third party insurance policy. This policy is to be obtained prior to the commencement of any works. The minimum amounts of third party insurance are as set out in Clause 22(2) of the General Conditions of Contract (GCC). *The Advance payment will not be made until evidence* of such policies is furnished to the Engineer. The renewal dates should be noted and the Contractor requested to furnish copies of the renewed policies by those dates.
23(2)	**Insurance Against Accident** The Contractor is to submit evidence of a valid accident insurance policy in accordance with the requirements of Clauses 23(1), 23(2) and 23(3) of the GCC. This evidence is to be submitted prior to the commencement of any work. The requirements of 23(3) are also to be noted and the Contractor's attention drawn to them (note that this is particularly relevant for foreign Contractors who may be not completely aware of these provisions).

CHECKLIST FOR INSPECTION OF CONCRETING WORKS

For convenient reference, this is a list of the various items which might be covered by inspection. The list is intended as a reference, not for daily use. For a particular job, the inspector will find it necessary to have at hand a similar list containing only those items that apply to the given specifications, organization, and job conditions.

Preliminary

Study of plans and specifications; construction codes

Division of duties between Supervising Engineer and Inspectors

Permissible tolerances of measurement

Provision for records and reports

Contractor's plant, calibrations, equipment, organization, and methods

Proportioning

Test of aggregates

Proportioning of mix

Mix computations

Grading of mixed aggregates; batch quantities; yield; air content

Materials

General (applies to all materials)

Identification; quantities (used, on hand); acceptability; uniformity; storage conditions; handling methods; waste; schedule of testing

Cement

Sampling for laboratory test
Protection from dampness

Aggregates

Acceptability tests

Gradation; organic matter; deleterious substances; soundness; resistance to abrasion; other tests

Control tests

Moisture; absorption; specific gravity; unit weights; voids

Admixtures

Reinforcing steel

Size; bending; surface condition

Accessories

Fixtures

Other materials

Before concreting

Lines and grades

Excavation; foundations

Location, dimensions, shape; drainage; preparation of surfaces

Forms

Specified type of form
Location
Alignment; provision for settlement
Stability (bearing; shores; ties and spacers)
Inspection openings
Preparation of surfaces
Final clean-up

Reinforcement in place

Size (diameter; length; bends; end anchorage)
Location (number of bars; minimum clear spacing; minimum coverage)
Splicing
Stability (wiring; chairs and spacers)
Cleanness (no loose rust; no oil, paint, dried mortar, etc.)

Fixtures (location; stability; cleanness)

Openings not shown on plans

Calibration of batching devices

Condition of mixer; speed of operation

Provision for continuous placement

Provision for curing

Provision for protection against sun, rain, hot or cold weather

Adequate tools and men for compaction, finishing, and curing

Concreting

Working conditions

Weather; preparations completed; specified interval since previous placement; lighting for night work; covering and protection

Batching

Cement; pozzolan; aggregates; water; admixtures
Check batching devices
Check yield of concrete

Mixing

Minimum time; batches delayed in mixer; maximum time; over-loading; number of revolutions of drum; water used; mixing capacity of drum; amount of concrete

Control of consistency

Observation of concrete being placed; tests; adjustments of water or admixtures in mix

Monitoring of air content

Concrete temperature check (if required)

Conveying

No segregation of materials; no excessive stiffening or drying out; time limits

Placing

Uniform and dense concrete; continuous operation; preparation of contact surfaces; mortar bedding; vertical drop, no dropping against forms or reinforcement; little or no flow after depositing; depth of layers; water gain; rock pockets; removal of temporary ties and spacers; disposition of rejected batches; placing concrete under water

Compacting

Thorough and uniform compaction; no overworking

Contraction joints

Location
Forming or tooling
Dowels or ties (if any) in place and aligned

Construction and hinge joints

Location; preparation of surface
Dowels or ties (if any) in place and aligned

Expansion and isolation joints

Joint filler material; location; alignment; stability; freedom from interference with subsequent movement

Finishing of unformed surfaces

Shallow surface layer of mortar; water gain; no overworking; first floating; alignment of surface; final hard troweling; plastic shrinkage cracks; rain

Finishing of formed surfaces

Condition of surfaces upon removal of forms (honeycomb, peeling, ragged ties holes, ragged form lines); repair of defects; surface treatment; no surface drying

Schedule of testing

After concreting

Protection from damage

Impact; overloading; marring of surfaces

Time of removal of forms

Curing

Surfaces continuously moist; time of beginning curing; length of curing period; see also concreting in cold and hot weather

Joints

Clean and seal
Timing and alignment of sawn joints

Test of concrete

Consistency tests

Tests for air content

Test for unit weight of fresh concrete

Analysis of proportions of fresh concrete

Strength tests

Molding specimens; curing specimens (standard conditions, field conditions); field test; shipping specimens to laboratory

Tests of hardened concrete

Cores
Impact hammer; probe
Pull-out

Other tests

Records and reports

Records: materials; mix computations; batching and mixing; placing and curing

Reports: daily; summary

Diary

Photographs

SPECIAL WORK

Hot weather concreting

Cooling materials, prewetting aggregates and contact surfaces; protecting concrete

Limiting combinations of wind, relative humidity, and ambient temperature

Filling under base plates

Preparation of base; proper mix; complete filling of voids

Pressure grouting

Holes (depth, spacing, freedom from clogging)

Materials (acceptability, quantities used)

Injection (sequence, pressure, times, completeness of penetration, no damage to structure)

Shotcrete

Materials (acceptability, quantities); condition of equipment; preliminary mixing; pressures (air, water); preparation of surfaces; application (thickness , no sagging, construction joints; surface finish; curing; tests-

Masonry

Units

Laboratory tests for strength and absorption

Field inspection for size, shape, and soundness

Construction

Moisture content of units; completeness of bedding in mortar; alignment; compliance with building code (mortar, minimum wall thickness, lateral support, bonding courses, supports for beams, openings in walls)

Cast stone

Laboratory tests for strengths and absorption

Field inspection for soundness and uniformity (match sample)

Architectural concrete

Location and neat joining of molds; surface coating to avoid sticking or staining; curing

Reinforcement near surface; support location and material

Vibrating to minimize bugholes

Color and texture; mock up

Protection against drip stains

Surface repair; hole filling

Colored concrete

Pigments; matching of colors; thorough and intimate mixing of color with cement' uniform application and troweling; curing

Painting

Cleaning surface; neutralizing surface (if needed); uniform application; curing portland cement paints

Lightweight concrete

Lightweight aggregates (acceptability, prewetting, preventing segregation)

Cellular concrete (admixture, timing of operations, mixing processes, foaming agents)

Test for unit weight

Mass concrete

Times and rates of placement; avoidance of high or non uniform temperatures; bonding of lifts; prevention of aggregate breakage

Preplaced-aggregate concrete

Gradation and placement of coarse aggregate; contamination prior to grouting; void content; composition and consistency of grout; sequence and pressures of grouting; completeness of filling of voids; condition of equipment.

Air-entrained concrete

Accurate measurement of air-entraining agent; tests for air content of concrete; regulation of air content; adjustment of mix to compensate for air content; avoidance of excessive mixing or vibration; avoidance of wet consistency; finishing

Tilt-up construction

Surface of casting platform; joints in sheet bond-breakers; timing and uniformity of liquid bond-breakers; alignment of edge forms; compaction of concrete at bottom corners; connections to columns; provision for expansion, if specified; strength of concrete at time of lifting; pick-up points; avoidance of excessive pulling, jerking, or jarring

Underwater construction

Avoidance of flowing water; temperatures; continuous placement; operation of tremie or bucket; minimizing of wash; protection from flowing water for several days

Vacuum concrete

Final thickness of slabs; timing and duration of application of vacuum; uniformity of processing; condition of mats

Prestressed concrete

Strength of concrete at time of prestressing; sheathing of reinforcement, if specified; accurate placing of reinforcement; avoidance of obstruction or excessive friction; measurement of tension by means of jack pressure and/or lengthening of steel; thoroughness of grouting, if specified.

CHECK LIST FOR PRECAST CONCRETE UNITS PRIOR TO CASTING

BRIDGE .... CONTRACT NO ....

CONTRACTOR .... *UNIT NO(S)* ....

Note : Insert a tick where the following items *conform to specification.*

Line of soffit	☐	....
Level of soffit	☐	....
Condition of soffit	☐	....
Condition of fillets	☐	....
Location of hold-downs	☐	....
Location of end plates	☐	....
Orientation of end plates	☐	....
Condition of end plates	☐	....
Position of holes in end plates	☐	....
Location of base plates :		
Longitudinally	☐	....
Vertically	☐	....
Angle of base plates :		
Longitudinally	☐	....
Transversely	☐	....
Condition of forms	☐	
Location of forms :		
With respect to soffit edges	☐	....
With respect to other forms	☐	....
Straightness of forms	☐	....
Location of cored holes		
Longitudinally	☐	....
Vertically	☐	....
Angle	☐	....
Position of stressing tendons	☐	....
Position of steel reinforcement	☐	....
Condition of tendons	☐	....
Condition of steel reinforcement	☐	....
Correlation of elongation & gauge pressure	☐	....

____
SUPERVISOR

______ / ______ / ______
DATE

CHECK LIST FOR PRECAST CONCRETE UNITS PRIOR TO DELIVERY

BRIDGE NO. .... CONTRACT NO. ....

CONTRACTOR .... UNIT NO(S) ....

Note : Insert a tick where the following items *conform to specification.*

Concrete mix and slump

Method of concrete placement

Adequacy of vibration

Finishing operations prior to curing

Steam curing

Normal curing

Concrete strength at release

Method of release

Lifting and removal of forms

Location of cored holes

Longitudinally

Vertically

Angle

Location of base plates

Longitudinally

Transversely

Angle of base plates

Longitudinally

Transversely

Overall length of unit

Other unit dimensions

Scabbling

Type of finish

Painting of ends

Cleaning out of cored holes

Stacking of units

SUPERVISOR

____ / ____ / ____
DATE

APPENDIX 3

Extract from :
'The Use of FIDIC Conditions of Contract for Works of Civil Engineering Construction'

SALINAN

Extract from : **'The use of FIDIC Conditions of Contract for works of civil engineering construction'**

TENDERING PROCEDURE

The FIDIC Conditions of Contract envisage that a contractor will be selected by the Employer following competitive tendering.

FIDIC has published a document entitled 'Tendering Procedure' which presents a systematic approach to the selection of tenderers and the obtaining and evaluating of tenders. It is intended to assist the Employer/Engineer to receive sound competitive tenders with a minimum of qualifications and formulated so that they can be quickly and efficiently assessed. At the same time, every effort has been made to provide the opportunity and incentive for contractors to respond easily to invitations to tender for projects they are well qualified to implement.

Experience has shown that, for major projects and those involving international tendering, prequalification of tenderers is desirable since it enables the Employer/Engineer to establish, *in advance, the competence of firms subsequently invited to tender. It also ensures that* invitations are addressed to leading companies who would not necessarily participate in open or unrestricted tendering. Such unrestricted tendering does not always facilitate appropriate competition because the number of tenderers may be so great as to make the odds against tendering successfully unacceptable. Additionally, prequalification has the advantage of reducing the inflationary effect which must arise where firms incur unproductive expense in submitting a large number of tenders in the knowledge that a high proportion of these must be unsuccessful.

A flowchart illustrating the recommended procedures for the prequalification of tenderers, for obtaining tenders and for opening and evaluation of tenders is reproduced on subsequent pages.

The documents issued to tenderers (the Tender documents) normally comprise conditions of Contract, Specification, Drawings, Bill of Quantities and form of Tender, together with Instructions to Tenderers. All except Instructions to Tenderers become Contract documents on award of Contract. It is usual to send the Tender documents to tenderers under cover of a letter which should be limited to identifying the documents and giving the recipient an invitation to tender.

Conditions of Contract

The Conditions of Contract will consist of Part I and Part II of the Red Book. The Conditions set out the legal/contractual arrangements that will apply to the Contract. The principles and the method to be followed in their preparation are described in a later chapter of this Guide.

Specification

The Specification will define the scope and the technical requirements of the Contract. the quality of materials and the standards of workmanship to be provided by the Contractor must be clearly described, together with the extent, if any, to which the Contractor will be responsible for the design of the permanent works. Details must be included of samples to be provided and test to be carried out by the Contractor during the course of the Contract. Any limitations on the Contractor's freedom of choice in the order, timing or methods of executing the work or sections of the works must be clearly set out and any restrictions in his use of the site of the works, such as the provision of access or space for other contractors, must be given.

Drawings

The Drawings must be in sufficient detail to enable tenderers to assess accurately, in conjunction with the Specification and the Bill of Quantities, the nature and scope of work included in the Contract. Only rarely is it possible to provide, at tender stage, a complete set of drawings so fully detailed that the work can be executed without any further drawings becoming necessary. On most contracts supplementary drawings will be issued after award as work proceeds.

Bill of Quantities

The Bill of Quantities is a list of items giving descriptions and estimated quantities of work to be executed under the Contract. The Red Book assumes a remeasurement form of contract, although that does not preclude the inclusion of a number of lump sum items in the Bill of Quantities provided that the scope of work to be covered by each lump sum item is adequately defined.

The Tender

It is highly desirable when inviting competitive offers from a number of tenderers, that the tenders received should be based as far as possible on equal terms and conditions and presented in a standardised manner. In this way evaluation and comparison between the tenders received can be made more simply and accurately with less risk of misunderstandings, errors and omissions.

The Tender is the most important single document submitted by the tenderer. It is here that each tenderer confirms that he has read and understood the requirements of the Tender documents and based on such requirements it is here that he states his tender sum for undertaking and fulfilling all his obligations under the Contract. It is therefore essential for the Employer that all Tenders received are stated in identical terms and thus it is necessary for the Employer, when inviting Tenders, to provide tenderers with a standard form of tender which each tenderer is required to complete and sign.

The form of Tender which is included at the end of the first volume of the Red Book following Part I of the Conditions of Contract is recommended for this purpose. It is short, it is clear and when signed and submitted creates a legally binding and valid offer.
It is common for Tenders to be identified by a tender reference or contract number which should be added to link the Tender to the project in question.

The organisation to which the Tender is being submitted must be stated in the appropriate space on the form.

The sum to be entered under paragraph 1 of the Tender is the tenderer's total Tender sum, which should be the same as the total from the summary page of the Bill of Quantities. The amount shall be entered in words and in figures and in the event of a discrepancy between the two it is common practice in most countries that the written amount shall prevail over the amount expressed in figures.

The sum agreed may very during the execution of the project depending on what circumstances occur, e.g. the instruction of variations, the occurrence of unforeseen events, which in accordance with the Conditions of Contract entitle the Contractor to additional (or reduced) payment.

Under paragraph 4 the Employer must state the time during which he requires the Tender to remain valid and open to acceptance. This time should be adequate to permit proper evaluation and award procedures to be completed.

In the event that the stated time proves to be insufficient, the Employer may ask tenderers to extend the period of validity of their Tenders for a further named period. At the same time tenderers should be asked to extend the validity of any tender bond accordingly. Tenderers are free to extend or not, if so requested, and in the event that they choose not to do so, the Employer has no right to cash or hold their tender bond.

The Employer must also fill in, before the issue of the Tender documents, the necessary details in the list given in the Appendix to Tender, in accordance with the Notes at the foot of the Appendix.

No reference is given to a covering letter in the form of Tender given in the Red Book. The completed Tender is, in many cases, sufficient in itself. If tenderers are invited or required to submit supplementary information, they should do so under a separate covering letter and in such a case it may be necessary for tenderers to add a reference to this letter in the Tender before submission.

THE PARTIES TO THE CONTRACT

The FIDIC Conditions of Contract are based on the assumption that the Employer, the first party, who has decided to have certain works carried out for the implementation of a project, and is sponsoring the Works, has decided to select a suitably qualified Contractor, the second party, to execute the Works.

It is also assumed that the selection of the Contractor will have been made through competitive tendering based on tender documents prepared for the project by a Consulting Engineer. This process has been dealt with in the preceding section.

The FIDIC Conditions of Contract cannot apply without an Engineer being appointed by the Employer to administer the Contract. Usually this would be the Consulting Engineer who has designed the project and prepared the tender documents. The Engineer is not a party to the Contract, but he plays an important role in the development process of the Works. The duties that the Engineer has to perform are defined under the Contract and he must have the necessary delegated authority from the Employer if he is to be able to perform them. The delegation of this authority is usually to be found in the Agreement between the Employer and the Consulting Engineer.

The Agreement will stipulate as the primary duty of the Engineer that he carefully observes the requirements of the Employer in the realisation of the project. It is important to note, however, that the Conditions of Contract between the Employer and the Engineer's duties are discretionary, the Engineer shall act fairly between the Employer and the Contractor and apply the Contract in an unbiased manner. The Conditions are based upon this fundamental principle and this requirement applies even if the Engineer is a member of the Employer's staff. The Contractor will, of course, have to assess whether or not he has confidence in the ability of an in-house Engineer to take independent decisions.

The Employer

As stated in the section dealing with the tendering process, the Employer notifies the successful tenderer that he has been awarded the Contract by issuing a Letter of Acceptance which records any changes to the Tender documents as submitted by the Contractor, resulting from agreement between the Employer and the Contractor, and the Contract Price.

The Employer consents to, or declines, requests by the Contractor to assign any portion of the Works, prepares the Contract Agreement (if any) for execution by both parties, approves the Performance Security and the insurers as well as the terms of the insurance policies submitted by the Contractor. The Employer will wish to ensure that the contract works insurance is in accordance with the laws and regulations of the country in which the Works are to be executed and that the policy adequately covers the Employer's Risks and the deductible limits are acceptable.

Provided it is acceptable to the Employer the Contractor will normally use his customary sources for the provision of securities and insurance.
The Employer makes the advance payment (if any) against a suitable guarantee from the Contractor and authorises the Contractor to move on to the Site. During the period of the certified by the Engineer to be due under the Contract.

The Employer takes over Sections of the Works as they reach substantial completion, if this is required under the Contract, and ultimately takes over the whole of the Works following the issue of Certificates by the Engineer. In the event of the Contractor becoming liable for liquidated damages, the Employer may deduct an amount in accordance with the Conditions of Contract.

The Employer may authorise work to be completed by others if the Contractor is in default. The Employer can terminate the Contract in the event of the Contractor failing to perform or in certain other circumstances defined in, and subject to, the law governing to the Contract. The Employer, if he defaults, can also be subject to cancellation of the Contract by the Contractor or to suspension of work by the Contractor.

The Employer and the Engineer should maintain such contact with each other as will facilitate smooth and unhindered progress of the Works. The Employer should respond, without delay, on all matters for which the Engineer is required by the Contract to consult the Employer before issuing an instruction, determining an amount to be added to or deducted from the Contract Price or granting an extension of time.

The Contractor

The obligation of the Contractor is to execute and complete the Works, for which he has submitted his Tender, within the time specified in the Contract. In addition he has an obligation to remedy any defects which appear during the Defects Liability Period.

As soon as is reasonably possible after receiving notification from the Engineer, the Contractor shall submit the securities, guarantees and insurance policies required by the Contract and shall commence the Works. He prepares the construction programme, provides all necessary materials, Contractor's Equipment, Temporary Works, management, superintendence and labour and selects the method of carrying out the Works. The Contractor is not responsible for the design and specification of the Permanent Works unless expressly provided for in the Contract nor for any Temporary Works not designed by him.

The Contractor receives and complies with instructions from the Engineer acting on behalf of the Employer and is responsible for the care of the Works throughout the construction period until the Works are officially taken over by the Employer or are deemed to be taken over by the Employer.

The Contractor is responsible for his own staff and work force and for taking out social and other insurances in respect of his personnel. He must comply with all applicable laws, by-laws and regulations and ensure that all those for whom he is responsible also comply.

Under normal circumstances the Contractor designs all Temporary Works and submits his proposals, with supporting calculations, to the Engineer for comment. If, during the construction period, he encounters unforeseen physical obstructions or conditions on the Site he notifies the Engineer who issues relevant instructions. The Engineer will review the circumstances and after consultation with both parties will determine to what extent, if any, the Contractor may be reimbursed for additional costs or granted an extension the Time for Completion.

In the event of default by the Employer the Contractor may suspend progress of the Works or reduce the rate of work and claim an appropriate extension of time and/or additional payment.

Normally there will be one main or principal contractor who signs the Contract and has overall responsibility for the execution and completion of the project. There will usually be a number of Subcontractors working on the Site undertaking specialist contracting activities. The Subcontractors are responsible to the Contractor for material, workmanship, performance and progress and the Contractor is responsible under the Contract for each Subcontractor's work and behaviour.

On occasions the Employer will wish to have a particular Subcontractor engaged because of his knowledge of that Subcontractor's skills or because of his knowledge of some process, materials or plant particularly required by the Employer. A Subcontractor selected in this way is known as a nominated Subcontractor. Once he has been accepted by the main Contractor the latter is responsible for the work of the nominated Subcontractor to the same extent as applies to the work of all other Subcontractors. For this reason it is important that nomination is not misused by the Employer. Failure to perform satisfactorily by a nominated Subcontractor can cause many difficulties on Site. The particular conditions applying to the appointment of nominated Subcontractors are dealt with in Clause 59 of the Conditions. The Contractor may object to the nomination for good and sufficient reasons (e.g. lack of experience or financial strength) and engagement against the wishes of the Contractor will probably disturb harmony on the Site. There would have to be very exceptional reasons for such a thing to happen.

In very large or complex projects a number of contractors may form a joint venture to act as the Contractor. In such cases the same principles apply as in the situation with only one Contractor. In the case of a joint venture the Employer would normally require that all the parties to the joint venture have joint and several liability.

In projects where several contractors are operating on a single site under individual contracts, each contractor must give the other contractors reasonable cooperation and opportunities for carrying out their work and this should be reflected in the terms of the contracts and in the respective programmes.

THE ENGINEER

The Engineer is not a party to the Contract between the Employer and the Contractor but his terms of engagement are set out in an agreement between the Employer (Client) and the Engineer (Consultant). This agreement is often in the form recommended by FIDIC which is entitled **International General Rules of Agreement Between Client and Consultant (IGRA)**. An updated version of this model form of agreement is scheduled for publication in early 1990. The new IGRA will stipulate what authority is delegated to the Engineer by the Employer and should specifically state if any of the authority given to the Engineer under the FIDIC Conditions is subject to restriction.

The duties under the FIDIC Conditions which are allocated to the Engineer include the issue of information and instructions to the Contractor as the work proceeds, commencing on the Contractor's proposals for carrying out the work, ensuring that materials and workmanship are as specified, agreeing measurements of work done and checking and issuing to the Employer interim and final payment certificates. In administration of the Contract all communications with the Contractor pass through the Engineer, thus avoiding possible confusion and misunderstanding although meetings between the Employer, the Contractor and the Engineer should be held regularly. The Engineer's duties will normally include instructions relating to management of the Contract and changes in the nature and extent of the work, the cost thereof and the time for completion. For example, the issue of instructions to proceed with or to suspend the progress of the Works is a matter of management. In order to maintain confidence between the parties it is important that the Contract properly discloses the procedures for the Engineer's action in such matters and that the Engineer duly observes such procedures.

Manu of the functions allocated to the Engineer involve financial matters. The certificates he issues for interim and final payments include all cost elements arising under the terms of the Contract other than those (if any) resulting rom arbitration proceedings and the application of the liquidated damages clause. Under normal circumstances the payments certified by the Engineer will ie within the Contract Price and will, therefore, have already been authorised by the Employer, but variations ordered under Clause 51, fluctuations in the price of labour, materials and freight under Clause 70, works done or materials and services supplied under Clause 58 and the settlement of the Contractor's request for additional payment under such Clauses as 12 and 53 could each result in an adjustment to the Contract Price.

The FIDIC Conditions are based upon the principle that the Engineer has the authority to determine additional payments. This is in the interests of efficient management and avoidance of duplication of effort. It also ensures that the Tender Price from efficient contractors will be lower than would be the case if the Contractor did not feel sure that when he was required to do additional work his remuneration for such work would be evaluated by a professional able to judge the value of such work. In the event the employer wishes to limit the authority of the Engineer this should be clearly stated in Part II so that the Contractor is aware in advance of tendering the conditions under which he is required to work. The degree to which the Employer leaves the Engineer to determine matters affecting the extent and cost of the *Works and the time for their completion will* depend to a large extent on the in-house capability of the Employer. Therefore, the Engineer should be selected having regard to his professional integrity and his ability to fulfil his obligations under the Contract and to administer the Contract fairly and impartially in the interests of both parties.

In the exercise of his duties the Engineer accepts the responsibilities attached to them. These responsibilities should be clearly defined in the Agreement between the Employer and the Engineer and should be made known to the Contractor.

As the Works progress the Engineer will be required by the Contract to give instructions, give or refuse approval or consent, approve work, authorise payments, issue certificates, etc. It should be understood by both parties to the Contract that in giving approval or consent and such other acts which are the duty of the Engineer his objective is to ensure that the Employer receives the Works at completion in accordance with the requirements of the Contract and that the Contractor is suitably rewarded for the work he carries out.

The Engineer's duty is to interpret the Contract as written. In doing so he should endeavour to determine what the Contractor could have reasonably foreseen would have been required of him when preparing his tender.

It is important to realise, however, that neither the Employer nor the Contractor is finally bound by the Engineer's interpretation or determination even if it is given in the form of a decision under Clause 67. This Clause defines the steps to be taken where the Engineer's decision thereunder is not acceptable to one or both parties. For further information see the commentary on Clause 67.