Queensland

IPWEA

INSTITUTE OF PUBLIC WORKS
ENGINEERING AUSTRALASIA

SUPERVISOR'S HANDBOOK FOR THE

CONSTRUCTION AND MAINTENANCE OF INFRASTRUCTURE

A MANUAL FOR THE TRAINING OF PRACTITIONERS AND A GUIDE TO WORK PRACTICES

SECOND EDITION 2016

SUPERVISOR'S HANDBOOK FOR THE CONSTRUCTION AND MAINTENANCE OF INFRASTRUCTURE A MANUAL FOR THE TRAINING OF PRACTITIONERS AND A GUIDE TO WORK PRACTICES

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FOREWORD

This handbook has been produced by the Institute of Public Works Engineering Australasia - Queensland Division Inc. (IPWEAQ), for use by Works Supervisors and works staff within the local government and public works industry.

The Institute is a professional organisation providing member services and advocacy for those involved in and delivering public works and engineering services to the community. Its members represent practitioners in state and local government and in private industry. It promotes professionalism, education and technical knowledge and holds strategic alliances with other relevant organisations.

The first edition of this Handbook was developed from a New South Wales prototype and was extensively modified to take into account the many changes in legislation, regulations, practices and procedures that have taken place over the past few years, and the State differences. The Handbook is Copyright and must not be duplicated in any form.

The Handbook is for use by field staff in city, urban and country environments, and it will be of value to younger engineers as they gain their experience in the field. It should be used by members of the workforce to find out what "works staff" do and to open up opportunities for workers seeking advancement in their careers. IPWEAQ can provide assistance to workers who seek recognition for the experience they have gained and also develop their skills – in a non-threatening environment, such as 'on the job'.

In covering such a broad range of activities in the Handbook it has been kept at a level that is not too technical, and assistance of a more qualified person should be sought where required.

IPWEAQ acknowledges the NSW Gangers Handbook, the Queensland Department of Main Roads 11AT document, documentation provided by Fitzroy and Sarina Shire Councils, and gratefully thanks Kevin Kerr AM, Murray Donald, Darren Shepherd, Steve Hughes and others who have given of their valuable time, experience and knowledge to the original edition.

I commend it for use by all public works practitioners in local and state governments and in private industry.

Joe Bannan
IPWEAQ President

Within this publication the following applies:

- Singular may mean plural
- Supervisor may mean Overseer, Foreman, Team Co-ordinator or other titles used.

PURPOSE OF HANDBOOK AND REFERENCES

The purpose of the Handbook is to provide some guidance for Supervisors and works staff in preparing, organising, managing, undertaking and completing works. It covers methodology in all aspects of the work, with reference to legislation and regulations applicable to the task.

It is meant as a practical reference book and can be used at all levels of the organisation.

Following is a list of some of the main Queensland legislation and associated regulations which empower local government or are otherwise of significant relevance to the administration of local government in Queensland. Other legislation not mentioned here may also affect local government and its operations and this should not be regarded as an exhaustive list.

- *Aboriginal Cultural Heritage Act 2003*
  Provides for the recognition, protection and conservation of Aboriginal cultural heritage.

- *Acquisition of Land Act 1967*
  Provides for the compulsory acquisition of land for public works and other public purposes.

- *Animal Care and Protection Act 2001*
  Promotes the responsible care and use of animals and protects animals from cruelty.

- *Anti-Discrimination Act 1991*
  Promotes equality of opportunity for everyone by protecting them from unfair discrimination in certain areas
  of activity and from sexual harassment and certain associated objectionable conduct.

- *Body Corporate and Community Management Act 1997*
  Provides for the establishment and administration of community titles schemes.
  Associated regulations include:
  - *Body Corporate and Community Management Regulation 2008*
  - *Body Corporate and Community Management (Accommodation Module) Regulation 2008*
  - *Body Corporate and Community Management (Commercial Module) Regulation 2008*
  - *Body Corporate and Community Management (Small Schemes Module) Regulation 2008*
  - *Body Corporate and Community Management (Specified Two-lot Schemes module) Regulation 2008*
  - *Body Corporate and Community Management (Standard Module) Regulation 2008*

- *Building Act 1975*
  Regulates building development approvals, building work, building classification and building certifiers.
  Associated regulation:
  - *Building Regulation 2006*

- *Building and Construction Industry Payments Act 2004*
  Implies terms in construction contracts, to provide for adjudication of payment disputes and establishes rights for progress payments.
  Associated regulation:
  - *Building and Construction Industry Payments Regulation 2004*

- *Building Units and Group Titles Act 1980*
  Provides for the horizontal subdivision and vertical subdivision of land into lots and the disposition of titles.
  Associated regulation:
  - *Building Units and Group Titles Regulation 2008*

- *Coastal Protection and Management Act 1995*
  Provides for the protection and management of the coast.
  Associated regulation:
  - *Coastal Protection and Management (Coastal Management Districts) Regulation 2003*

- *Disaster Management Act 2003*
  Provides for matters relating to disaster management in the State.

- *Environmental Protection Act 1994*
  Provides for the protection of the Queensland environment.
  Associated regulations and policies include:
  - *Environmental Protection (Air) Policy 2008*
  - *Environmental Protection (Noise) Policy 2008*
  - *Environmental Protection (Waste Management) Regulation 2000*
  - *Environmental Protection (Water) Policy 2009*
  - *Environmental Protection Regulation 2008*

- *Fair Work (Commonwealth Powers) and Other Provisions Act 2009*
  Provides the fundamental workplace relations principles for minimum employment standards; rights and responsibilities to ensure fairness, choice and representation at work, including the freedom to choose whether or not to join and be represented by a union or participate in collective activities.

- *Fire and Rescue Service Act 1990*
  Establishes the Queensland Fire and Rescue Service and provides for the prevention of and response to fires and certain other incidents endangering persons, property or the environment.

- *Fisheries Act 1994*
  Provides for the management, use, development and protection of fisheries resources and fish habitats, the management of aquaculture activities and helping to prevent shark attacks.
  Associated regulation:
  - *Fisheries Regulation 2008*

- *Food Act 2006*
  Provides for matters relating to handling and selling food, securing the safety and suitability of food and fixing standards for food.
  Associated regulation:
  - *Food Regulation 2006*

- *Food Production (Safety) Act 2000*
  Establishes Safe Food Production Queensland and provides for food safety matters relating to the production of primary produce.
  Associated regulation:
  - *Food Production (Safety) Regulation 2002*

- *Health Act 1937*
  Is concerned with matters relating to public health.
  Associated regulation:
  - *Health (Drugs and Poisons) Regulation 1996*
  - *Health Regulation 1996*

- *Heavy Vehicle National Law Act 2012*
  The object of this Law is to establish a national scheme for facilitating and regulating the use of heavy vehicles on roads in a way that promotes public safety; and manages the impact of heavy vehicles on the environment, road infrastructure and public amenity; and promotes industry productivity, efficiency and safe business practices.

- *Information Privacy Act 2009*
  Provides safeguards for the handling of personal information in the public sector environment, and to allow access to and amendment of personal information.
  Associated regulation:
  - *Information Privacy Regulation 2009*

- *Land Act 1994*
  Relates to the administration and management of non-freehold land, reserves, deeds of grant in trust, leases over non-freehold land, permits to occupy and the creation of freehold land.
  Associated regulation:
  - *Land Regulation 1995*

- *Land Protection (Pest and Stock Route Management) Act 2002*
  Is about the management of particular pests on land and the management of the stock route network.
  Associated regulation:
  - *Land Protection (Pest and Stock Route Management) Regulation 2003*

- *Local Government Act 2009*
  Provides for the way in which a local government is constituted and the nature and extent of its responsibilities and powers.
  Associated regulations:
  - *Local Government (De-amalgamation Implementation) Regulation 2013*
  - *Local Government (De-amalgamation Polls) Regulation 2013*
  - *Local Government Regulation 2012*

- *Native Title (Queensland) Act 1993*
  This Act applies the Commonwealth native title regime in Queensland.

- *Nature Conservation Act 1992*
  Provides for the conservation of nature in Queensland.

- *Peaceful Assembly Act 1992*
  Provides for the recognition, exercise and any necessary and reasonable restrictions of the right of peaceful assembly

- *Plumbing and Drainage Act 2002*
  Is about plumbing and drainage, the licensing of plumbers and drainers and on-site sewerage facilities.
  Associated regulations:
  - *Plumbing and Drainage Regulation 2003*
  - *Standard Plumbing and Drainage Regulation 2003*

- *Public Health Act 2005*
  Protects and promotes the health of the Queensland public.
  Associated regulation:
  - *Public Health Regulation 2005*

- *Prostitution Act 1999*
  Regulates prostitution in Queensland.

- *Queensland Competition Authority Act 1997*
  Establishes the Queensland Competition Authority, gives it powers and functions about pricing practices relating to Government monopoly business activities, competitive neutrality and access to services.
  Associated regulation:
  - *Queensland Competition Authority Regulation 2007*

- *Queensland Heritage Act 1992*
  Provides for the conservation of the Queensland cultural heritage.
  Associated regulation:
  - *Queensland Heritage Regulation 2003*

- *Queensland Industry participation Policy Act 2011*
  Provides for the development and implementation of a local industry participation policy about the participation by local industry in projects, developments, procurements and other initiatives undertaken or funded, whether wholly or partially, by the State Government, and to require reporting to Parliament on the policy's implementation and compliance with it.

- *Right to Information Act 2009*
  The primary object of this Act is to give a right of access to information in the government's possession or under the government's control unless, on balance, it is contrary to the public interest to give the access.
  Associated regulation:
  - *Right to Information Regulation 2009*

- *Residential Services (Accreditation) Act 2002*
  Regulates the conduct of residential services.

- *Sustainable Planning Act 2009*
  Sets a framework to integrate planning and development assessment so that development and its effects are managed in a way that is ecologically sustainable. The act requires coordination and integration of planning at the local, regional and State levels.
  Associated regulations:
  - *Planning and Environment Court Rules 2010*
  - *Sustainable Planning Regulation 2009*

- *Transport Infrastructure Act 1994*
  Provides a regime that allows for and encourages effective integrated planning and efficient management of a system of transport infrastructure.
  Associated regulation:
  - *Transport Infrastructure (State-controlled Roads) Regulation 2006*

- *Transport Operations (Road Use Management) Act 1995*
  Provide a regime that allows for and encourages effective and efficient management of a system of road use.
  Associated regulations:
  - *Traffic Regulation 1962*
  - *Transport Operations (Road Use Management—Dangerous Goods) Regulation 2008*

- *Torres Strait Islander Cultural Heritage Act 2003*
  Provides for the recognition, protection and conservation of Torres Strait Islander cultural heritage.

- *Tobacco and Other Smoking Products Act 1998*
  Restricts the supply of tobacco and other smoking products to children, restricts advertising and promotion of tobacco and other smoking products and prohibits smoking in certain places.
  Associated regulation:
  - *Tobacco and Other Smoking Products Regulation 2010*

- *Vegetation Management Act 1999*
  Regulate the clearing of vegetation in a way that conserves remnant vegetation that is an endangered or of concern regional ecosystem; and conserves vegetation in declared areas; and ensures the clearing does not cause land degradation; and prevents the loss of biodiversity; and maintains ecological processes; and manages the environmental effects of the clearing.
  Associated regulation:
  - *Vegetation Management Regulation 2012*

- *Waste Reduction and Recycling Act 2011*
  Promotes waste avoidance and reduction, and resource recovery and efficiency actions; to reduce the consumption of natural resources and minimise the disposal of waste by encouraging waste avoidance and the recovery, re-use and recycling of waste; to minimise the overall impact of waste generation and disposal.
  Associated regulation:
  - *Waste Reduction and Recycling Regulation 2011*

- *Water Act 2000*
  Provides for the sustainable management of water and other resources, a regulatory framework for providing water and sewerage services and the establishment and operation of water authorities.

- *Work Health and Safety Act 2011*
  Provides a framework to protect the health, safety and welfare of all workers at work. It also protects the health and safety of all other people who might be affected by the work. This includes employees, contractors, subcontractors, outworkers, apprentices and trainees, work experience students, volunteers and employers who perform work. The Act also provides protection for the general public so that their health and safety is not placed at risk by work activities. The Act places the primary health and safety duty on a person conducting a business or undertaking, who must ensure, so far as is reasonably practicable, the health and safety of workers at the workplace. Duties are also placed on officers, workers and others at a workplace. The Act also sets out the requirements for; incident notification; consultation with workers; issue resolution; inspector powers and functions; offences and penalties
  Associated regulations:
  - *Work Health and Safety (Codes of Practice) Notice 2011*
  - *Work Health and Safety Regulation 2011*

There are also Standards developed and sold by Standards Australia which are incorporated in job documents and must be followed. Your manager will advise you of these and your own staff should also be made aware. Australian Standards are referenced within this document.

Codes of Practice

Check Codes of Practice that are referenced in job documents.

Standard Drawings

Reference to Standard Drawings may mean:

- IPWEAQ
- Department of Transport & Main Roads
- Local Authority or relevant Australian Standards.

Websites

Institute of Public Works Engineering Australasia, Queensland (IPWEAQ)
www.ipweaq.com

The Queensland Government website (www.qld.gov.au) will take you to all applicable websites, or go directly to:

Department of Transport & Main Roads Technical Standards and publications
http://www.tmr.qld.gov.au/business-industry/Technical-standards-publications.aspx

Department of Natural Resources and Mines https://www.dnrm.qld.gov.au/

Local Government Association www.lgaq.asn.au

Department of Agriculture and Fisheries https://www.daf.qld.gov.au/home

Standards Australia (always check currency) www.standards.org.au

Department of Environment and Heritage Protectionwww.ehp.qld.gov.au

Workplace Health and Safety Queensland www.worksafe.qld.gov.au

Construction Works Procedures These are shown on the IPWEAQ website www.ipwea.org.au/qld

Capricorn Municipal Development Guidelines
Standard Drawings and Specifications.
www.cmdg.com.au

Acronyms

11AT: Department of Main Roads training series. Elements of this series are included within the Handbook, however the full document can be found on the IPWEAQ website.

ADAC: Asset Design As Constructed

AHD: Australian Height Datum

ALD: Average least dimension

AS: Australian Standard

ASS: Acid Sulphate Soils

BS: Back sight

CCA: Copper Chrome Arsenate

DBYD: Dial Before You Dig is a free national community service designed to prevent damage and disruption to the vast pipe and cable networks which provide Australia with the essential services we use every day – electricity, gas, communications and water. It acts as a single point of contact to receive information about underground networks at excavation sites so you don't have to contact the individual utility organisations. You tell them your dig location and they pass on the referral to the affected asset owners. They then send the information directly to you, generally within 2 working days.

FS: Forward sight

INT: Intermediate sight

MDD: Maximum Dry Density

MSDSs: Material Safety Data Sheets (MSDSs)

MUTCD: Manual of Uniform Traffic Control Devices

OMC: Optimum Moisture Content

QASSIT: Queensland Acid Sulphate Soils Investigating Team

QUDM: Queensland Urban Drainage Manual

R.L.: Reduced Level

RMPC: Road Maintenance Performance Contract

STD: Standard

TMR: Department of Transport & Main Roads

Symbol: capital L with a little c through it – Centreline

WH&S: Workplace Health & Safety

INTRODUCTION

Councils are very complex organisations and, although almost all have different structures, there are some elements common to all. These are:

"**The Council**" is controlled by a number of elected people who meet formally to set policy and interpret the community needs. As a Council they also carry out certain statutory functions such as setting the rates, approving the annual budget, accepting tenders, etc.

The **Chief Executive Officer** (CEO), who has general day-to-day responsibility for the administration of Council.

The CEO delegates some responsibility to other Senior Directors/Managers and other staff.

Some works and services are provided directly by Council staff and others are provided by outside contractors.

It does not matter which way they are provided, it is the Council staff responsibility to carry out the wishes of "The Council" which, in reality, are the wishes of the community.

Council has a responsibility to its community to provide various services of good quality at reasonable prices. Part of that responsibility rests with the Works staff, who are required to convert the plans or thoughts and desires of others in Council into the final products for the community. These products may be in the form of roads, drainage lines, water and sewerage systems, carparks, parks and many other works and services which must be constructed, maintained or delivered.

It is plain to see, therefore, that Works staff are a very important link in the chain which is required for Council to meet its obligations.

Additional information on the function and administration of Councils can be obtained from the Local Government Association, your local council or the relevant State Government department.

What skills are needed in a Works Department?

- Communication skills are necessary to deal with your employer and employees.
- literacy skills to comprehend the necessary paperwork.
- practical skills to do the work, and
- comprehensive awareness of the operations of the works being performed.

Role of Supervisor

To supervise and ensure all works are carried out to relevant standards efficiently and economically with reference to safety and quality and to encourage and motivate employees in their work and to deliver a valued service to the community.

What knowledge is required to perform the duties?

Knowledge of simple engineering calculations and an understanding of the basic properties of soils and road making materials, knowledge of the Work Health and Safety Act and associated publications, knowledge of the Department of Transport and Main Roads quality standards, knowledge of Council Quality Assurance System based on AS/NZS 9001-2000, local knowledge of materials, people etc.

Key responsibilities

The key responsibilities of the Works Super- visor are as follows:

- Organisation and administration of all council works activities in accordance with council safety procedures (refer to your Council's organisation chart).
- Efficient use of plant and workforce.
- Construction and plant safety.
- Servicing and maintenance of plant.
- Reporting of impending repairs.
- Team building.
- Human relationships and staff morale.
- Provision of traffic and public safety.
- Camp establishment, maintenance & cleanliness.
- Quality control on jobs.
- Ordering through the appropriate person for supplies and materials.
- Follow up on delivery.
- Reading and interpreting drawings and specifications.
- Levelling and setting out of works.
- Job cost control.
- Neat and accurate preparation of time sheets and dissection books where required.
- Safety training.
- Ensure appropriate staff are adequately trained in the areas for which they are employed.
- Induction of staff and others to particular sites.
- Customer Service.
- Liaison with Residents and Service Authorities.

Although works staff generally operate with relatively small gangs of from one up to eight or ten other staff, they still need to have a wide range of skills which include, but are not limited to:

Administration

There is a lot of paperwork required, such as completing and checking timesheets, leave forms, requisitions, plant sheets, daily diary, etc. Each organisation will have its own procedures and you should learn these and know where to find the appropriate paperwork.

People management

Managing people requires skills in being able to control, motivate, coach, counsel, work with in harmony, delegate, and of course obtain cooperation of all the staff in the team. Attend an appropriate skills development course to develop these skills (IPWEAQ provides).

Planning and organising

(see Chapter 1)

All of the work undertaken, whether it be construction or maintenance or some other form of service, needs to be properly organised and planned so that the various stages or activities occur efficiently and in the proper sequence. This avoids delays, re-work, frustration, and ensures smooth work flows.

Evaluation

One of the most forgotten functions in any role is looking back on what has just been done and seeing what lessons and improvements that can be made in future projects. What went wrong? What went right? … and why did it? Who should we tell and how?

Technical

In order to do any job, there is a basic requirement that a person must have the appropriate technical skills to understand and implement the work or service. Check with your manager as to the opportunities available through on-or-off the job competency training or other skills development programs available (IPWEAQ can assist).

Supervisors position in the Council's team and operation of gang

Council workforce has the most difficult job of working all day under the eyes of the public. Few workers outside council are in such a position and the Supervisor can do much in presenting his workforce as an efficient unit which will produce public praise rather than criticism.

Commencing work at the correct time, being gainfully employed on a well-planned, tidy job throughout the day and working up to knock off time is the best way to gain public approval and acceptance of Council staff as an efficient workforce, giving good value for rates paid. To achieve this aim, the Supervisor must have good leadership skills and good people in the gang and appropriately manage them. Not all workers are suited to outdoor work for a variety of reasons.

The Supervisor role is to develop a top team with willing workers. You should be firm but fair in moulding new members into the team and devote special time to any new- comer in the early weeks of their employment. New members in the team may need to be inducted for specific tasks.

The Supervisor should immediately address any problems directly with the person concerned, and perhaps the team, and complete the appropriate paperwork. Should there be ongoing concerns or if the employee is not fitting into the team then it will be necessary to discuss this with your manager, which may result in a transfer or other appropriate action.

Remember, it is your job to build a strong and reliable team and it is important, therefore, that you get to know your team and understand their strengths and weaknesses.

CHAPTER 1
PLANNING AND ORGANISING

Before work commences on any project you must have a pre-start meeting with your manager to discuss all aspects:

- What is the job?
- Budget
- Estimate
- Program
- Job documents
- Job Plans
- Job costing numbers

Each job should commence with a briefing by your manager, outlining the scope and requirements of the job such as the reason for it, location, timeline, budget and expectations. Documentation is discussed with job plans being reviewed. Job costing numbers are supplied and resources – people and plant and equipment – assessed. It is important at this meeting to discuss:

- *Underground and overhead services (DBYD)*
  What are they likely to be and how you find out where they are?
- *Cultural heritage* (see note in references and also Environmental Factors Chapter 2)

  Don't start the job until this has been checked: better to find out at the beginning than have the job shut down
- *Environmental Factors* (Chapter 2)
- *Work Health and Safety* (Chapter 3)
  Who does the site induction?
- *Traffic Control*
  Does Council have qualified Traffic Control personnel or do you need to contract these?

  Has the costing for these people been included?

  What signage do you need and do you have the appropriate signage?
- *Plant and Equipment, Materials*
  Has the plant and equipment been allocated?

  Make a list of the materials required – who orders them and how long will they take to be delivered?

  Have a check list drawn up to take with you to the site.
- *Staff – Human Resources*
  Do you have the appropriate and qualified staff available?
- *Contact Numbers*
  Check that you have all the contact numbers you need for while you are on the site.
- *Toolbox Meeting*
  Does your manager need to be there for the toolbox meeting?

You need to have a Job Diary and camera to record and photograph all activities on the site. You will need to have troubleshooting skills and contact numbers of appropriate people for queries or decision-making.

Where verbal instructions are given in place of job documents, ensure you have a clear understanding of the instruction and make a diary note of your understanding, and confirm this with your manager. It is important that new members of your team may need to be inducted for specific tasks.

When giving instructions to others ensure that your instructions are clearly understood and confirmed.

Make a list of essential items to be on your person or in your vehicle at all times, which could include:

- Supervisors Handbook
- Mobile telephone/Smart phone
- Laptop/tablet
- Job documents
- Job diary
- Tape
- Notebook and pen
- Calculator
- Spare PPE
- Spare batteries
- Marker pens
- Marker tape
- Pegs
- Keys

Always ensure you have a post project meeting to review the job. This is a method of improving work practices for future projects.

KEY MESSAGES
- **Plan first**
- **Ask questions**

CHAPTER 2
ENVIRONMENTAL FACTORS

Agencies:
Department of Environment and Heritage Protection www.ehp.qld.gov.au
Department of Transport and Main Roads – www.tmr.qld.gov.au
Department of Natural Resources and Mines www.dnrm.qld.gov.au

Local Government authorities have the task of managing more than 182,200 km of roads (80% of the road network, carrying 30% of the traffic) and associated reserved land in Queensland. This reserved land often contains remnant native vegetation that has an important role in regional flora conservation, as well as providing more general land and water conservation benefits. For many travellers, roadside vegetation is their link to the natural heritage of the State, and for the local community it provides their 'sense of place'. For some rare flora, it is their only habitat!

The sustainability of roadside remnants depends on the ability of the managing authority to maintain their road reserves in a manner that is sensitive to the roadside vegetation, especially with regards to clearing or drainage, and also to address an array of threatening processes or events, such as fire, weeds and disease, etc. The challenge is to maintain viable roadside vegetation, while still managing a safe and effective road transport network.

In the present climate of diminishing resources, it is tempting for road managers to take the simple option of managing the road in isolation, and disregard the roadside vegetation because it appears cheaper at the time to do so. In the longer term, this is not the case for the local community. The landcare movement has demonstrated the value of retaining regional vegetation for controlling water tables, providing protection from soil erosion and wind effects and habitat for local fauna. Roadside vegetation can be a significant regional contribution to this.

Consider the following issues:

- noise
- dust
- covering trucks
- cultural heritage
- weeds
- rainforest trees
- wash down bays
- flat wide floodway – contours
- scour control and prevention
- soil erosion
- erosion control
- wild life protection
- fish passage
- drought
- rock falls
- slope stability
- acid sulfate soils

Environmental checklist for construction workers

1. Check with Manager – look at the Council Environmental Plan
2. Clearly mark the limits of stripping and all other construction zones.
3. Always stay within the construction zone.
4. Obtain permission for vegetation removal.
5. Strip and stockpile topsoil from areas of good native vegetation. Re-use as soon as possible.
6. Control erosion in the following ways:
   a. minimise vegetation removal and encourage the growth of vegetation on batters;
   b. leave batters rough so as to hold the topsoil; limit access and earthworks to the area required for construction;
   c. establish adequate drainage systems and sediment control devices, e.g. silt sock; and
   d. avoid 'tidying up' cleared timber and roadside vegetation after construction.
7. Clean down machinery before moving to another site in weed sensitive areas.
8. Keep machinery and stockpiles on cleared land.
9. Only use the appropriate type and minimum size of machine for the job.
10. If there is no alternative to burning, do not burn under or near desirable vegetation.
11. Chip light material left over from tree removal into mulch to spread the local seed; large branches should be left for local fauna.
12. Check that permits have been granted before removing any trees.
13. Be aware of local water restrictions and ensure that water is only taken from a designated water source.
14. If sourcing water from a stream or waterway, ensure that the necessary approvals have been obtained from the relevant State Government Department.
15. Only use the quantities of water necessary for the job – do not waste water.

Environmental checklist for maintenance workers

1. Protect natural regeneration.
2. Avoid mowing in native vegetation.
3. Mow only up to the back of the table drain in most situations.
4. Avoid 'tidying up' vegetation. Retain stumps, dead trees and understorey wherever possible.
5. Remove drain spoil and dispose of in a designated dump site.
6. Locate stockpiles on already cleared land.
7. Only use the appropriate type and minimum size of machine for the job at hand.
8. Only use soil or gravel from a weed or dieback-free site.
9. Control erosion in the following ways:
   a. remove as little vegetation as possible and encourage the growth of vegetation on batters;
   b. maintain drainage systems;
   c. consider use of erosion control (commercial) structures, e.g. silt fence, silt sock, rock check dam;
   d. minimise disturbance to the soil; and
10. Clean down machinery before moving to another site particularly in weed sensitive areas.
11. Be aware of local water restrictions and ensure that water is only taken from a designated water source.
12. If sourcing water from a stream or waterway, ensure that the necessary approvals have been obtained from the relevant State Government Department.
13. Only use the quantities of water necessary for the job – do not waste water.

Walk the route

"Walking the route" involves inspecting the construction alignment before construction begins in order to confirm and mark the limits of all construction activities (the construction zone). This could involve the Construction Engineer and Supervisor and an offer may be made to any relevant agency that may have an interest in resources associated with the project. "Walking the route will also give you a much better understanding of the site, construction restrictions, safety issues and location of services. To minimise the impact of construction on vegetation, you should identify:

- the limits of stripping and where all vegetation removal should start. Use paint or tape to mark trees to be removed and to show the direction of felling;
- rare or priority flora or significant vegetation and sensitive areas which are to be protected from disturbance;
- the exact location of stockpiles, plant compounds and access roads;
- the presence of any cultural heritage sites; and
- locating existing services (Dial Before You Dig).

The value of roadside vegetation

Remnant roadside vegetation is often the only original native vegetation left in an area.

Native trees, shrubs and grasses on the roadside are valuable because they:

- are easier to maintain than introduced vegetation
- provide an important source of food and shelter for wildlife
- provide wildlife corridors linking other areas of native vegetation
- often contain rare and endangered plants and animals
- are a vital source of local seed for replanting.

Noxious and environmental weeds

Be aware of noxious and environmental weeds in your area. Noxious and environmental weeds can be spread during road construction and maintenance.

Noxious weeds are plants which are declared to be a serious threat to agriculture and the environment. For example, Burr, Parthenium, are noxious weeds and can be a maintenance problem. The provision of wash-down bays can assist in preventing the spread of noxious weeds. Quarantine areas may need to be created in some citrus fruit tree areas.

Environmental weeds are non-local plants that invade and replace the local native vegetation. They may be native plants which did not originally grow in the area, or non-Australian plants.

Quarantine areas – check whether there are any quarantine areas, particularly for citrus.

Notice should be taken particularly in wash down bays.

Ask your Manager for a list and photographs of the major noxious and environmental weeds in your area.

Cultural heritage

Queensland's diverse heritage contributes to our sense of place, reinforces our identity and helps define what it means to be a Queenslander. Our heritage sites have been shaped by our history, environment, resources and people. They comprise places of cultural and natural significance that we want to keep, respect and pass on to future generations. Heritage places include buildings, structures, cemeteries, archaeological sites, gardens, urban precincts and natural and landscape features.

Heritage places in Queensland are assessed and managed at four different levels:

International: World Heritage areas are natural and cultural places of 'outstanding universal value' selected by the United Nations Educational, Scientific and Cultural Organisation (UNESCO).

National: The National Heritage List comprises natural and cultural places with outstanding heritage value to the nation. The National Heritage List is administered by the Australian Government under the (EPBC) Environmental Protection and Biodiversity Conservations Act 1999. Also kept under the EPBC Act, is a list of natural, Indigenous and historic heritage places owned by the Australian Government. It includes places connected to defence, communications, customs and other government activities.

State: Non-indigenous places of cultural heritage significance to Queensland are protected by the Queensland Heritage Act 1992 and are entered in the Queensland Heritage Register. Aboriginal and Torres Strait Islander cultural heritage is protected under separate legislation.

Local: Places of local heritage significance may be listed by local government in a local heritage register or identified and protected in a local government planning scheme.

Cultural heritage (both Indigenous and European) issues must be identified and their impact must be considered in the planning and design process.

Aboriginal Cultural Heritage Act 2003 and the Torres Strait Islander Cultural Heritage Act 2003
These acts obligate all persons to fulfill a duty of care when undertaking actions that may impact on indigenous cultural heritage values; and requires anyone who carries out an activity to take all reasonable and practicable measures to ensure the activity does not harm indigenous cultural heritage.

All native title issues must be identified and appropriate actions taken in planning of a project.

Local Heritage Registers
Under the provisions of the Queensland Heritage Act 1992, each local government must keep and manage a local heritage register, or have a heritage overlay in its planning scheme. Local heritage registers identify places of local heritage significance. Some local governments also employ heritage advisors to provide conservation advice to owners of local heritage places. For more information about places that may be in a local heritage register, contact your local government.

Typical Job Environmental Management Plan templates can be found on the IPWEAQ website. You should modify these to suit your Council's and Client's requirements.

Environmental factors are included within other sections of this Handbook for specific application.

KEY MESSAGES
- **Walk the route**
- **Protect vegetation**
- **Locate services**
- **Be aware spreading of weeds**

CHAPTER 3
WHAT IS SOIL?

It is important to understand the types and properties of soils and their uses. Some soils are totally unsuitable for some works and Supervisors should consider this when planning the job. Discuss with your Manager. Some Councils have access to soil laboratories.

Soils are simply deposits of disintegrated rocks which have been slowly broken down into fine particles due to nature's physical and chemical processes. Physical processes may have included freezing and thawing, rolling, grinding, or blowing as dust in the air. The resulting gravels, sands, and silts are essentially miniature boulders.

Clay is formed by chemical processes due to the long term weathering action of warm and cold climates, plus rainfall. Clay consists of tiny flat particles with distinct crystal structure that evolve from a wide variety of rocks.

Plant growth also contributes to soil formation. When plants die, their residue becomes part of the soil. This organic matter is generally too spongy and weak to be used for structural purposes.

Soil groups

Although soils may vary widely in physical and chemical makeup, five fundamental groups are recognised.

Gravel
Individual grains vary in size from 2mm to 63 mm in diameter and have a rounded appearance.

Sand
Small rock or mineral fragments smaller than 2 mm in diameter and semi-sharp.

Silt
Fine grains appearing soft and floury when dry. When moist, silt pressed between thumb and forefinger will have broken appearance.

Clay
Very fine texture soil which forms hard lumps or clods when dried. When moist, clay is very sticky and can be rolled into a ribbon between thumb and forefinger.

Organic
This matter consists of either partially decomposed vegetation (peats) or finely divided vegetable matter (organic silts and clays).

Grain size limits

Most soils are made up of mixtures of the five basic soil types and are classified according to the types and amounts of each included such as sandy clay, clayey sand, sandy silt. The mineral portions of soils are divided in five types, each with a specific grain size as shown in Table 3.1.

Table 3.1: Grain Size Limits for Soils

Material	Size (mm)
Gravel	63 to 2.0
Sand	2.0 to 0.075
Silt	0.075 to
Clay	0.002 less
Colloids	than 0.002

Soil properties

A number of terms are used to express the properties and characteristics of various materials. A basic knowledge of these terms and their application to soil and compaction can provide a more thorough understanding of soil engineering. Also, it will provide useful background in the selection of the correct compaction equipment for a particular job.

Capillarity is a fine-grained soil's capacity to absorb water and transmit it in all directions (see Figure 3.1). Capillary action can damage embankments sealed by pavement since the water cannot escape. The trapped water softens and expands the subgrade resulting in an inadequately supported surface and pavement. By placing an insulating layer of sand, gravel or rock between the soil and water source, capillary action can be prevented (see Figure 3.2).

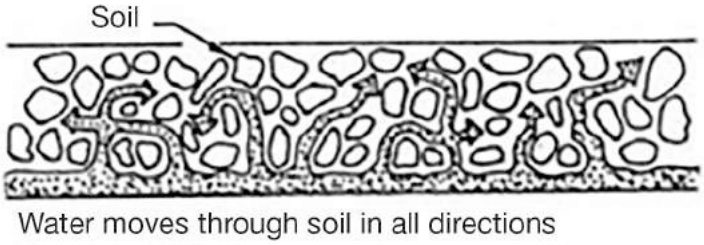


Figure 3.1

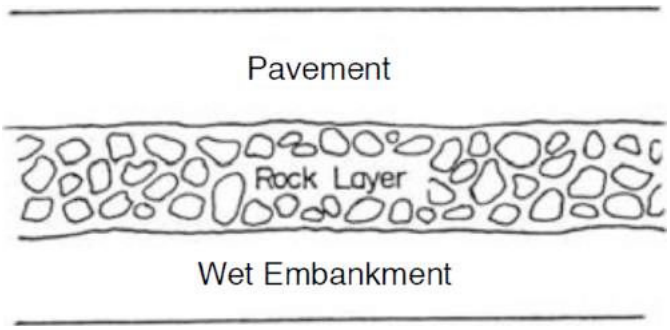


Figure 3.2

Compressibility refers to the reduction in soil volume that occurs when force is applied to it. Air between the particles has been compressed or has escaped, and any water that may have been present has been squeezed out. The result is that the soil particles are closer together and occupy less volume (see Figure 3.3).

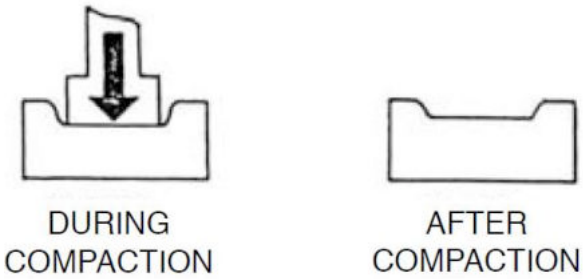


Figure 3.3

Consolidation refers to the increase in density of fill material under actual service conditions due to permanent loads or the passage of traffic. It usually takes place with the passing of time.

Elasticity is the ability of a soil to return, partially, to its original form after a compressive load is removed (see Figure 3.4). Road surfaces having elastic soils underneath will deteriorate due to constant flexing under loads.

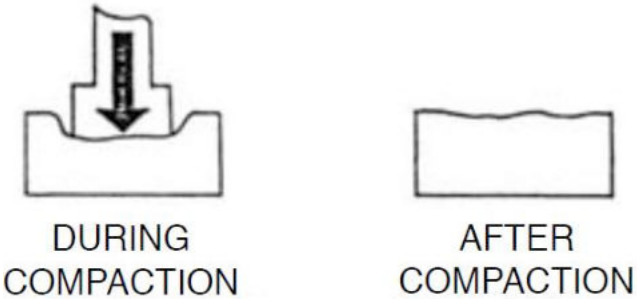


Figure 3.4

Permeability refers to that property of a soil which allows it to transmit water (see Figure 3.5). Sands and gravels are very permeable while fine-grained soils like clays, are least permeable.

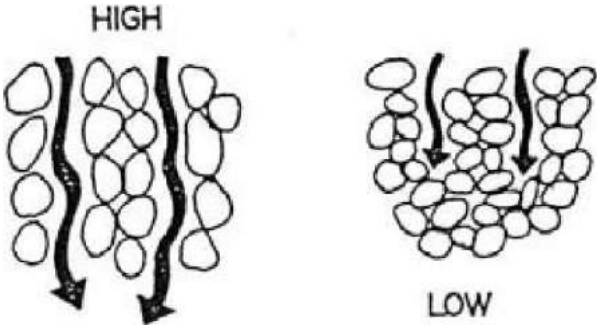


Figure 3.5

Settlement of embankment is a decrease in surface elevation due to consolidation of the fill material in the embankment (see Figure 3.6).

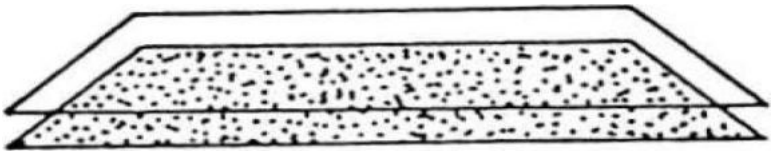


Figure 3.6

Shearing resistance is the ability of soil particles to resist sliding against one another when force is applied (see Figure 3.7). There are two mechanical properties of soil which determine its shearing resistance (see Figure 3.8).

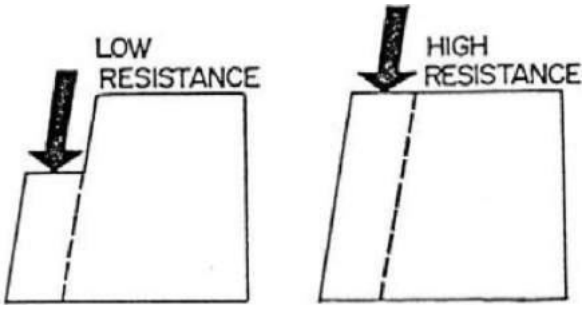


Figure 3.7

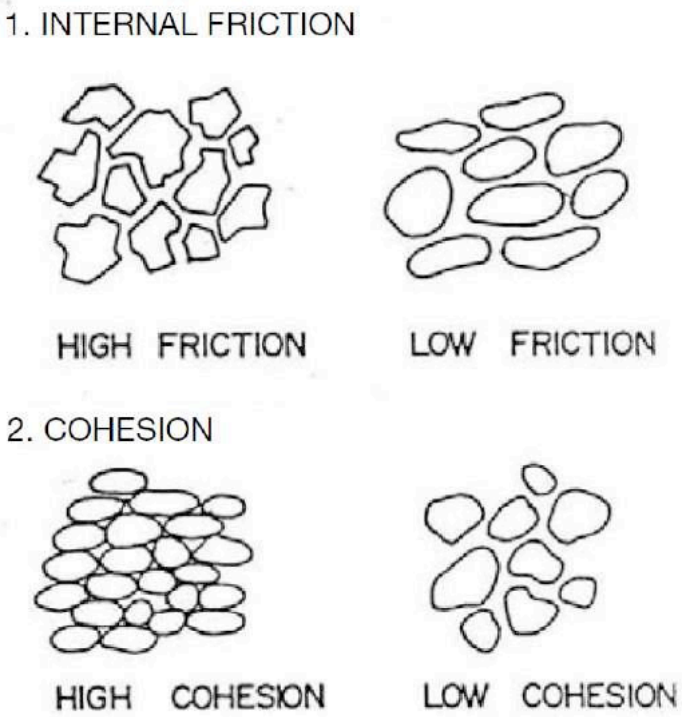


Figure 3.8

- Internal friction resulting from the soil particles resistance to sliding over each other - high in coarse sand and low in silt and clay.
- Cohesion resulting from the soil grains attraction to each other – low in coarse sand and high in smooth silt and clay.

Soil with a high bearing capacity may contain gravel and sand in sufficient amounts to contribute high internal friction, plus enough fine-grain soil (such as clay) to provide adequate cohesion.

Shrinkage occurs in fine-grain soils as water within the soil is reduced by evaporation (see Figure 3.9). Sand and gravel shrinkage is very slight, but clays shrink a great deal. Soil which shrinks when dried and expands when wet provides a poor foundation since the resulting movement can cause structural failures in pavement or buildings dependent on their support.

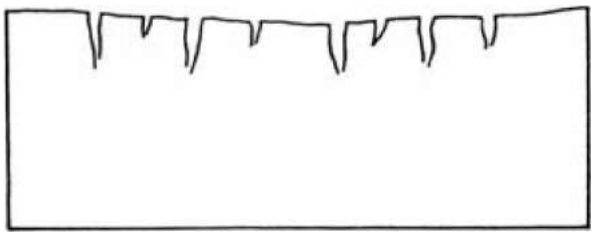


Figure 3.9

Water in soil

Water content in soil is all important as the liquid/solid relationship of soil controls such important physical properties as consolidation, compaction and stability. Water also acts as a solvent for salts present in soil.

Some of the more important physical properties of soils which are affected by the water content are as follows:

Cohesion

The mechanical cohesion between the individual particles of fine grained soils, such as silts and clays, is due to the fact that these particles are bound together by films of water. The cohesive forces are generally accepted as being due to:

(i) Surface tension at the air/water interfaces within the soil structure
(ii) Interaction between the soil particles or between the particles and water molecules.

It has been found experimentally that the cohesive forces increase with increasing surface tension and decreasing particle size. Cohesion is most marked in soils such as clays, which have a high proportion of very fine particles.

Swelling

The swelling of clay soils is a physical effect associated with particle hydration. Close to the surface of clay particles the absorbing forces acting on the water molecules are very strong, and the water is here believed to be in the solid rather than the liquid state (absorbed water).

As the absorbed layers grow during the wetting of clay, the effective solid volume associated with each particle increases, and if the layers are in contact with each other, the growth of the individual layers is reflected in an increase in the total volume of the soil structure.

Consolidation

The absorbed water films in clay grow in thickness until the suction pressure in the water becomes equal to the overburden pressure on the soil due either to self-loading or to externally applied loads. If at the point of equilibrium the loading is increased, the absorbed water films are reduced in thickness and then settlement occurs. This process is called consolidation.

If a structure is built on a clay soil which is liable to moisture changes it will normally rise and fall with the changing moisture conditions.

Plasticity

If a mass of soil is subjected to a stress above its elastic limit it will deform and rupture.

Should the soil be cohesive and have a sufficiently high moisture content, the soil will not break up but plastic flow takes place.

Plasticity is an important characteristic of all cohesive soils such as silts and clays.

Table 3.2: Description of properties and effect on stability

Basis of Description	Descriptive Term	Characteristic and Effect on Stability
Strength	Cohesive	Clay predominates; strength derives from cohesion and is strongly influenced by moisture content.
	Frictional non-cohesive	Sand predominates; strength derives from internal friction and is influenced by moisture content.
Grain Size	Coarse grained	Gravel and sand predominate - tend to be non-cohesive.
	Fine grained	Silt and clay predominate - tend to be cohesive.
Grading	Well-graded	Particle-size distribution extends evenly over a wide range of sizes, good stability.
	Poorly-graded	Particle-size distribution with an excess in some sizes and a deficiency in others adversely affects stability.
	Uniformly graded or Closely graded	Particle-size distribution extends over a limited range with one size predominating, low stability.
Plasticity	High Medium Low	A reflection normally of the clay content. Materials of high and medium plasticity would normally require stabilization.

Field identification

Soils fall essentially into two groups, coarse grained non-plastic soils, and fine grained plastic soils with intermediate groups. The characteristics used in field identification are different for each of the two groups. These characteristics (listed below) should be observed and noted, to facilitate identification. The soil can then be classified.

Coarse grained non-plastic soils

The majority of particles are visible to the naked eye and generally less than 50% would pass a 75 mm A.S. sieve. Identification is based on visual examination of particles and classification is as follows:

- *Particle size*

  Boulders – larger than 200 mm
  Cobbles – 63 mm to 200 mm
  Gravel – passing 75 mm A.S. Sieve
  Sand – 75 mm A.S. Sieve to 2.36 mm A.S. Sieve

- *Grading*

  Angular – sharp edges, unpolished flat surfaces
  Sub-angular – rounded edges
  Rounded – no edges, smoothly curved sides

- *Surface Texture*
  Polished, smooth or rough, clean or coated (usually with clay or salts).

Fine grained soils

The majority of particles are not visible to the naked eye and more than 50% pass a 75 µm A.S. Sieve. These soils are usually plastic and are subdivided on the basis of texture.

- *Particle size*
  Sand particles are visible to the naked eye and are easily identified as individual grains by touch.
  Silt particles are not visible to the naked eye and are difficult to identify as individual grains by touch. The grains may be identified by touching the tongue. A damp pat of silty soil will feel rough.
  Clay particles are not visible to the naked eye and cannot be detected by touch or taste. A damp clay pat has a smooth feel.

- *Texture*
  The texture of a fine grained soil may vary from clay (plastic) to silt (non- plastic) with intermediate combinations. The texture may be estimated by simple tests and may be accurately defined in accordance with a standard classification by laboratory tests of grading and plasticity.

  The simple tests used in field identification are:

(1) **Dry strength test**
This test involves using a pat of soil:
Low – pat can be powdered. This indicates low plasticity silty soil.
Medium – pat can be broken but not powdered. This indicates medium plasticity, clayey soil.
High – pat cannot be broken. This indicates a high plasticity heavy clay soil.

(2) **Wet strength test**
Uses a pat of wet soil.
Hard – Difficult to indent with thumb or pencil point (high clay content).
Stiff – Indented by thumb pressure. Difficult to remould.
Firm – Indented by moderate thumb pressure. Remoulded by firm pressure.
Soft – Easily indented and remoulded by light pressure.

(3) **Dilatancy** – shake test
Roll a wet pat of soil around in the palm of one hand and tap the back of it with the fingers of the other hand (see Figure 3.10). Observe whether or not the pat of soil gets shiny and wet on the surface. Then squeeze the pat of soil and note whether or not the wetness disappears, leaving a dull surface on the soil. Alternately shake and squeeze the soil and decide whether the surface water appears and disappears rapidly, slowly or not at all. Fine sands and silts have a rapid reaction while clays have little or no reaction and simply get messy.

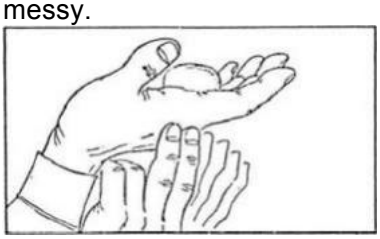


Figure 3.10

(4) **Shine test**

A moist pat of soil when stroked with the flat of a knife blade or the finger will show a smooth shiny surface if clay is present. A rough dull surface indicates silt.

(5) **Toughness test**

Roll a wet pat of soil between the thumb and fingers into a thread or "worm". It will be sticky at first but continued kneading will gradually dry it out. The object of the test is to gauge the "toughness" of the soil, when it gets so dry it begins to crack, when it is rolled into a worm 3.3 mm in diameter (see Figure 3.11). If a worm cannot be formed at all, the soils is definitely a silt or fine sand. Plastic silts and lean clays are weak and soft before they start cracking. Highly plastic solids take a long time to dry out, and they get hard and waxy so that considerable pressure is required to form a worm. A similar test is carried out in the laboratory to determine the plastic limit of a soil.

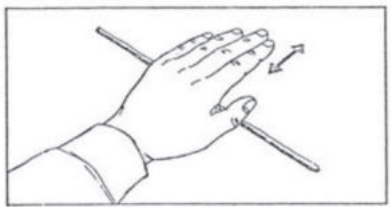


Figure 3.11

(6) **Hand washing**

Even when washing hands after tests, information can be gained which will help classify soil. After handling silts, the fingers will feel dusty and gritty and rubbing the fingers together will almost clean them. Water flowing gently from a tap will rinse off the soil. When clays are handled, a crust will form on the fingers that cannot be rubbed off when dry. Water will not rinse it off and the hands must be rubbed together under the water to cleanse them.

Laboratory classification

For detailed identification and classification of soils, the most commonly adopted procedures incorporate a measure of particle size, distribution and plasticity. Tests used for the determination of these properties are:

Particle size distribution

The methods of determining particles size distribution involve two stages viz.:

(1) Sieving for the coarse soils;
(2) Sedimentation analysis for finer fractions.

- *Sieve Analysis*

  A sieve analysis is carried out by passing a representative sample of the soil through a nest of sieves beginning with the sieve with the largest opening. Water is used to wash material through the finer sieves. The results are generally reported as the total percentage passing each sieve. Sieve sizes commonly used are:

  75 mm, 53 mm, 37.5 mm, 26.5 mm, 19.0 mm, 9.5 mm, 6.7 mm, 4.75 mm, 2.36 mm, 600 um, 425 um, 150 um, 75 um.

  To determine the particle size distribution below this, sedimentation analysis is carried out.

- *Sedimentation analysis*

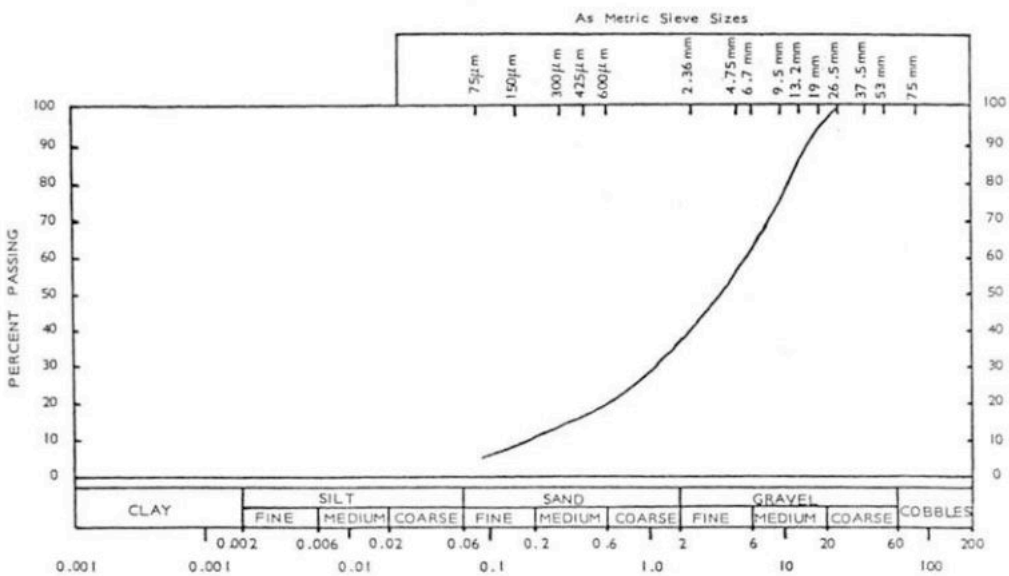
  If a soil is dispersed in water and then allowed to settle, the finer particles will take longer to settle than the coarse particles. This principle is used to determine the particle size distribution.

To carry out a sedimentation analysis, a sample of the material passing the 2.36 mm sieve is first treated with hydrogen peroxide to remove organic matter, and with hydrochloric acid to remove carbonates and gypsum, since these substances may give false results. The soil is then dispersed in a dilute aqueous solution of calgon which acts as a deflocculating agent. The particles are then allowed to settle. At given time intervals from the initial dispersion, samples are taken from a given depth below the surface. The sample of liquid will contain only those particles whose velocities have been insufficient to carry them further in time. The samples are dried and weighed and the percentages of different particle size are determined.

Table 3.3: Typical Sieve Analysis

A.S. Metric Sieve	Weight retained on	Weight passing sieve	% Passin
53 mm			
37.5 mm			
26.5 mm	0	431	100.0
19 mm	20	411	95.4
6.7 mm			
2.36 mm	121	164	38.1
425 µm	86	78	18.1
150 µm	37	41	9.5
75 µm	15	26	6.0

Table 3.4: Particle Size Distribution Curve Particle Size – mm



- *Hydrometer analysis*

  A simple and more convenient method of sedimentation analysis is the hydrometer method. This method gives results which are accurate enough for most purposes. A suspension of the soil in water containing sodium oxalate is prepared and washed through a 75 mm sieve as before. One litre of suspension is placed in a measuring cylinder.

  Readings are taken periodically with a hydrometer. The hydrometer is calibrated so that the equipment particle diameter corresponding to the elapse of time at each hydrometer reading can be obtained from a nomograph, and the percentage by mass of particles smaller than this particle's diameter, calculated.

Particle size distribution curve

On completion of the analysis, the results (see Table 3.3) are represented on a Particle Size Distribution Curve, the vertical scale representing percent-by-weight and the horizontal scale, grain sizes (see Table 3.4).

The steeper the slope of the curve, the more uniform all the grain sizes. Therefore, a vertical line would represent a perfectly uniform sample. Recording the particle size distribution of soil samples by this means enables simple, accurate classification.

Moisture content

Classification by particle size is satisfactory for granular soils, but the fine grain soils (silt and clay) can exhibit drastically different behaviours even though they have equal grain-size distribution. Moisture content influences the physical properties of any given soil, especially predominantly fine grain soils.

There are several physical relationships of soil and moisture content that have been established by laboratory tests. After performing certain tests and determining the moisture content, soils may be grouped by their physical characteristics.

The moisture content of a soil is the ratio of the weight of water within the soil, to the total weight of the dry soil sample. It is found by weighing the soil wet, then drying and weighing it again; the difference between the first and second weighing represents the weight of the water and the second weighing gives the weight of the dry soil.

Moisture content is usually expressed as a percentage, and is found by dividing the weight of the water by the weight of the dry sample. The relationship between air, water and soil can be expressed on both a volume and a weight basis. This relationship is shown in Figure 3.12 with a given loose m^3 of damp soil – imagine the air, water and soil particles to be neatly sorted out by weight and volume.

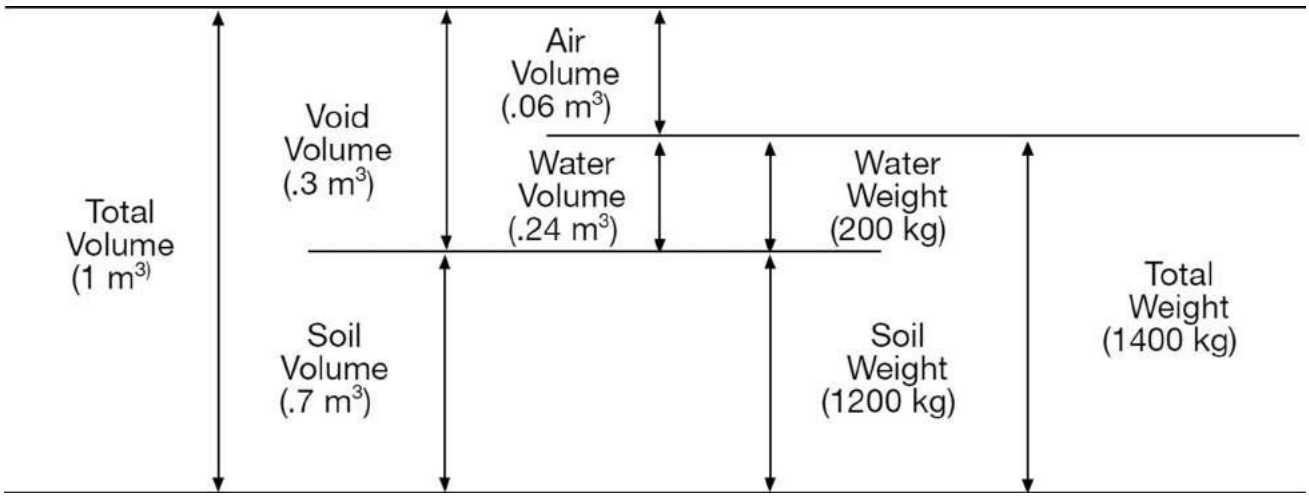


Figure 3.12

Generally, there are three types of water or moisture recognised by soils engineers. The type and amount of water occurring in a soil can have a great influence on its performance.

Gravitational water is free to move downward due to the force of gravity. It is water that can drain naturally from a soil.

Capillary water is held in a soil by small pores or voids. It is considered free water but can be removed only by lowering the water table or by evaporation.

Hygroscopic water is present in a soil after gravitational and capillary water are removed. This water is held by individual soil grains in the form of a very thin film having physical and chemical affinity for the soil grains. It is also spoken of as "air-dry" moisture content.

Certain limits of soil consistency – Liquid Limit, Plastic Limit, Plasticity Index, and Shrinking Limit - were developed by A. Atterburg, a Swedish Soils Scientist. They are discussed below and form the basis for differentiation between highly plastic, slightly plastic and non-plastic materials.

Plasticity of soils

The finest fraction of soils (silts and clays) have a most significant effect on behaviour. In particular, the proportions of these materials present and their nature must be determined as part of the classification process. In general, sedimentation analysis as described above is too time consuming and expensive for routine classification wash and simpler tests have been developed to provide information on the clay and silt fraction. These tests define what are commonly termed consistency limits.

As moisture content of a soil is decreased the soil passes from the liquid state to the plastic state to the solid state. The range of moisture contents over which the soil is plastic is used as a measure of the plasticity index.

The points at which soil changes from one state to another are arbitrarily defined by simple tests called Liquid Limit Test and Plastic Limit Test.

These tests are known as the **Atterburg Limits** and are the bases for differentiation between highly plastic, slightly plastic and non-plastic soils.

- *Liquid Limit (LL)*
  This is the moisture content at which a soil passes from a plastic to a liquid state. To illustrate this, take a wet sample of a plastic soil and knead it between the fingers slightly and then place it in a small bowl, flattening it out somewhat. Next, make a deep groove in the wet sample and then tap the bowl on its bottom 10-20 times, watching the groove. If the faces of the groove remain the same distance apart, pick up the sample, add some more water to it and repeat the process. When the faces of the groove move together, the sample has become somewhat liquid and it is said to have reached its Liquid Limit.
  Although the above process is a somewhat simplified version of the Liquid Limit test, it gives us a good illustration of a sample's LL. The value of this test is that it indicates at which moisture content a soil overcomes internal friction and cohesion by lubrication. High LL values, as determined by laboratory tests, are associated with soils of high compressibility. The LL of a soil is directly proportional to its compressibility.

- *Plastic Limit (PL)*
  This condition exists when a soil changes from a semi-solid to plastic state. It is said to prevail when the soil contains just enough moisture that a small amount of it can be rolled into a 3.3 mm diameter thread without breaking.
  The plastic limit of a soil is considered to have a number of significant meanings. It represents the moisture content at which the particles will slide over each other yet still possess appreciable cohesion. Also, the strength of a soil has been proved to decrease rapidly as the moisture content increases beyond the PL. It is also the point where the soil sticks more readily to steel surfaces and where best compaction is achieved with pure soils.

- *Plasticity Index (PI)*
  This is the numerical difference be- tween a soil's plastic and liquid limits. Soils having high PI values are quite compressible and have a high degree of cohesion. A soil with a zero PI is cohesionless, non-

plastic. Soil has little or no cohesion left when the moisture content is at the liquid limit, but it still has considerable cohesion when the moisture content is at the plastic limit. Therefore, the PI offers a means of measuring the compressibility and cohesion of a soil. The PI also indicates soil permeability. The higher the PI, the lower the permeability, and vice versa. On many jobs the specifications will call for material with a certain gradation, a maximum LL and a maximum PI.

- *Shrinking Limit (SL)*
  As the soil is dried below the Plastic Limit it shrinks and gets brittle until finally all the particles are in contact and the soil can shrink no further. This point is called the Shrinkage Limit. The soil still has moisture within it but if any of this moisture is lost on further drying, air has to enter the soil to replace it. The SL is the best moisture at which to compact many non-plastic soils. Soils containing enough clay to give them a low Plasticity Index are best compacted somewhere between the SL and the PL.

The relationship between liquid limit, plastic limit, shrinkage limit and soil consistency are shown in Figure 3.13.

Linear shrinkage

The linear shrinkage is the percentage decrease in length of a soil when it is dried after having been moulded in a wet condition, usually at liquid limit. The results give an indication of the volume change that may occur in a material with varying moistures.

Miniature abrasion loss

The test is a measure of the dry strength of non-cohesive and slightly cohesive mixture of sand and clay. Four dry pats of the soil are abraded together and the resultant loss in weight of the pats reported as a percent- age.

Clay materials give low values. Soil-aggregate for pavement construction should have a MAL of less than 15%.

California Bearing Ratio (CBR)

The CBR is a penetration test for evaluation of the mechanical strength of road subgrades and base courses. It was developed by the California Department of Transportation in the 1930's.

The test is performed by measuring the pressure required to penetrate a soil sample with a circular plunger of standard area for a specified distance, expressed as a percentage of a standard force. The standard forces used in this method are 13200 and 19800 newtons for penetrations of 2.5 and 5.0 mm respectively.

CBRs can be tested wet (soaked) or dry (unsoaked), although wet is the industry standard as it allows a road to be designed to better cope with stresses placed on the subgrade after it has been subject to significant amounts of moisture.

The CBR can also be used for measuring the load-bearing capacity of soils supporting similar structures such as airport runways. A higher CBR correlates to a stronger material i.e. high quality crushed rock has a CBR over 80.

Compaction

What is compaction?

Compaction is the art of artificially densifying material by pressing the particles together, expelling air from the mass and filling the voids. It is dependent on the lubrication of the soil particles by moisture. The object in compacting a soil is to improve its properties, in particular to increase its strength and bearing capacity, reduce its compressibility and decrease its ability to absorb water.

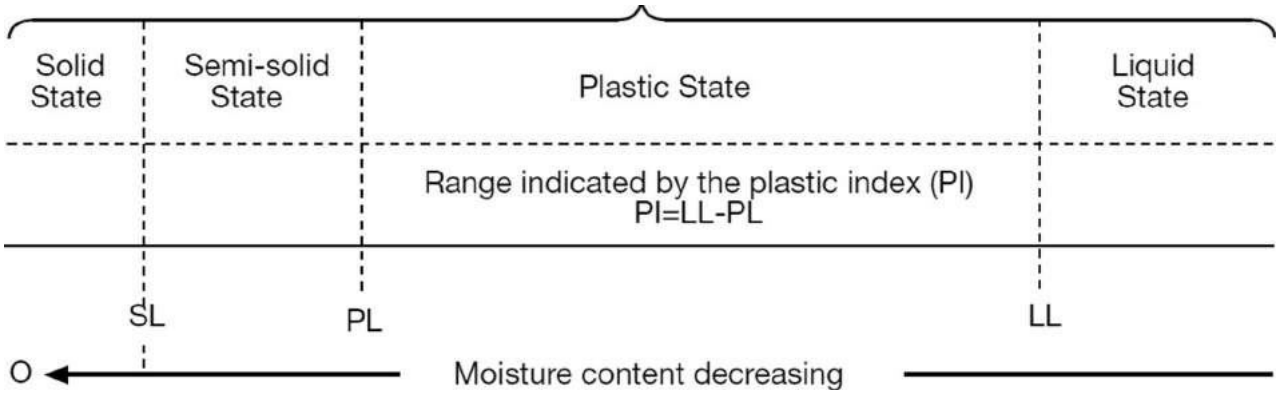


Figure 3.13

Moisture density relationship

By increasing the moisture content when a soil is being compacted, it has been found that the Dry Density will rise to a maximum and then decrease.

If the soil is dry, inter granular friction pre- vents the particles sliding over each other.

The addition of moisture lubricates the points of contact of the soil particles and allows the particles to be gradually forced into the dense state.

At the limit, the voids become filled with moisture and further addition of water displaces the soil particles and a lower dry density results.

A typical Moisture Density Relationship is shown in Figure 3.14.

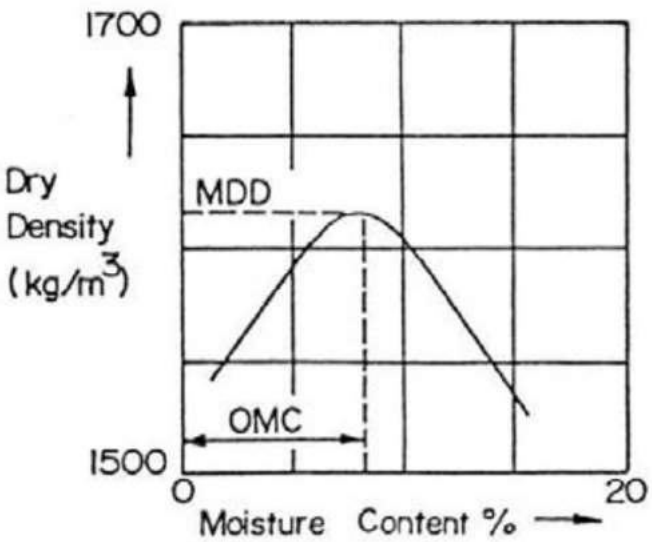


Figure 3.14

The **Optimum Moisture Content** (OMC) is the moisture content at which a specified amount of compaction will produce the Maximum Dry Density (MDD).

Laboratory testing

Several methods of compacting soils in the laboratory have been established to enable the determination of the Moisture Density Relationship and thus optimum moisture content and maximum dry density. The tamping method has been adopted as standard by the Department of Transport and Main Roads (MRD) as it is suitable for all soils. There are two tests used.

- *The Standard (or Proctor) Compaction Test*

  The compactive effort, used in compacting the soil in a 105.0 mm diameter, 1000 cc mould, is obtained with a 2.7 kg hammer falling through a height of 300 mm. The soil is compacted in 3 layers with 25 blows applied per layer (Figure 3.15). The test is repeated at a number of different moisture contents. Each time the mould is weighed and the bulk density determined. After the moisture has been measured, the dry density is determined and plotted against moisture content.

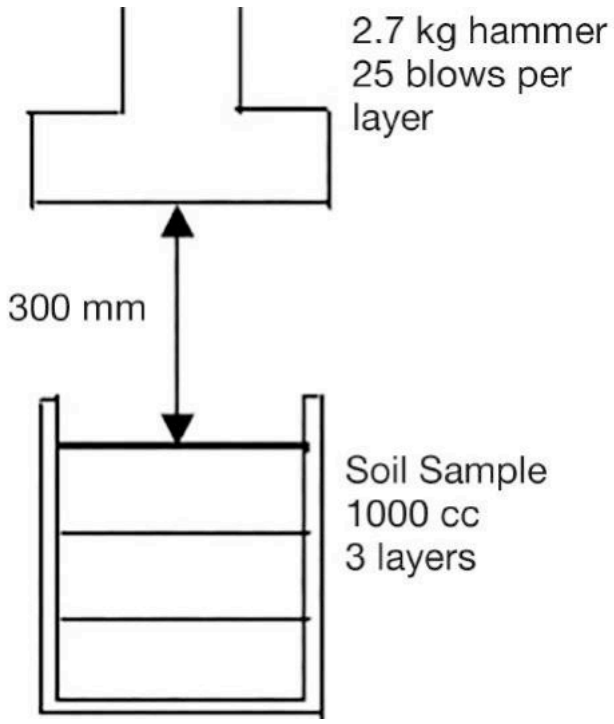


Figure 3.15

- *The Modified Compaction Test*

  As the use and efficiency of compacting equipment increased it was found that densities could be obtained in excess of the 'Standard' maximum. A test using more tamping effort has therefore been adopted. Basically the same as the Standard Test, the Modified Compaction Test uses the same mould but a heavier hammer (4.9 kg) falling through a greater distance (450 mm) is used to pack the soil into the mould. The soil is packed in 3 layers each receiving 42 blows of the hammer (see Figure 3.16). The compactive effort is thus increased by over 4 times.

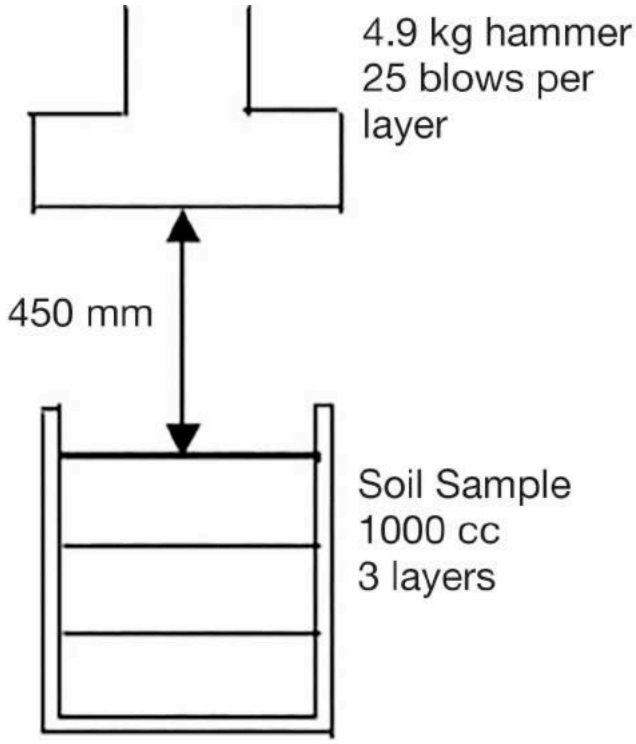


Figure 3.16

This increase in compactive effort causes an increase in the maximum density obtained and a reduction in the optimum moisture content. The density increase are most marked where the air voids are large, i.e. at lower moisture contents. This is shown clearly by Figure 3.17.

Figure 3.18 is a moisture density test result for a typical road making material and shows that the material has a Maximum Dry Density (MDD) of 1875 kilogram per cubic meter at an Optimum Moisture Content (OMC) of 13.1%.

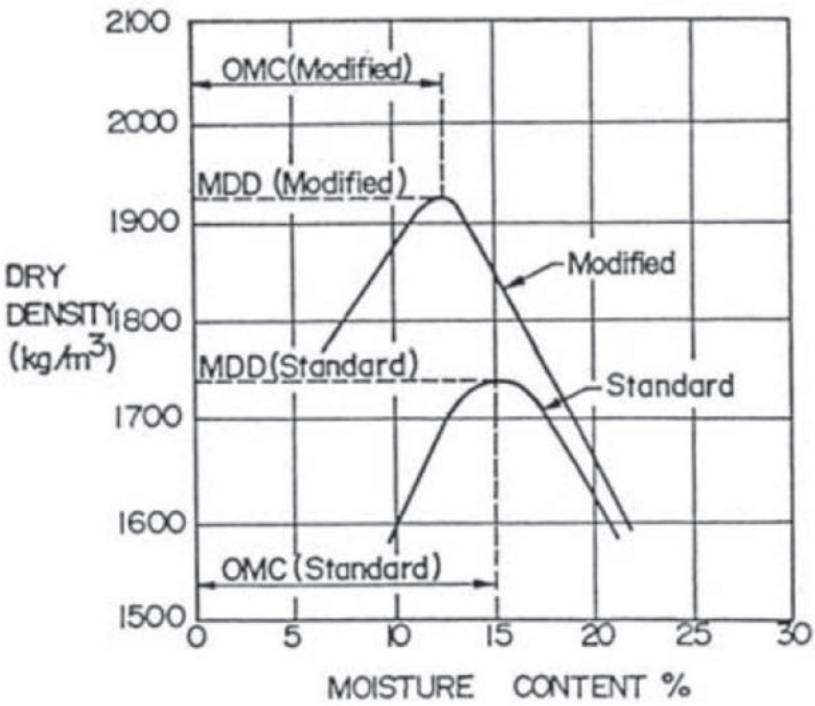


Figure 3.17

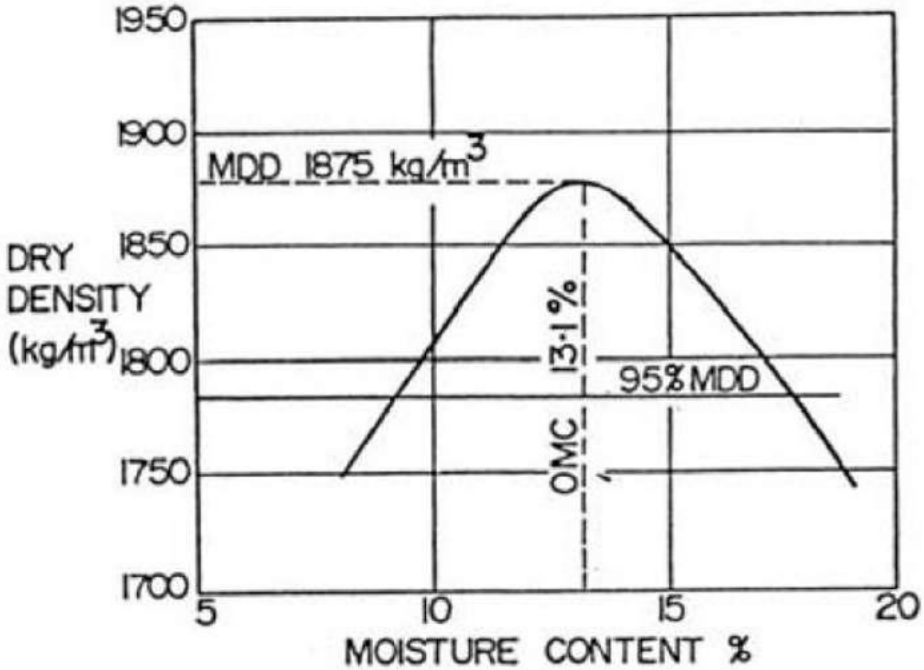


Figure 3.18

Field testing

Regular field testing is done in order to ensure that the declared compaction densities are being maintained throughout a particular construction job. These tests can also indicate the effectiveness of the compaction equipment and construction methods being used. The test used by TMR is the Sand Replacement method. Other methods commonly used are Water Balloon Method and Nuclear Method.

- *Sand Replacement Method*

  This method covers the determination of the in-situ dry density of natural soil as well as compacted soil. A density test is made by digging a 102 mm diameter hole 152 mm deep in the soil. All material from the hole is carefully salvaged. The gross weight, moisture content, and oven dry weight of this material is determined. The excavated hole is filled with sand of known density and the volume is calculated from the weight of sand used to fill the hole. The density of compacted soil is determined by dividing the dry weight of material removed from the hole by the volume of the hole.

- *Nuclear Guage*

  Nuclear moisture/density gauges are testing devices that use low level radiation to measure the wet density, dry density, and moisture content of soil and granular construction materials. These gauges work by measuring either the "backscatter" or the "direct transmission" of radiation directed at a material. "Backscatter" is the amount of radiation that is deflected by the material and is measured by placing the gauge on the surface of the material. "Direct transmission" is the amount of radiation that passes through the material and is measured by drilling a hole in the material and inserting the gauge. The radioactive sources in the gauge are surrounded by shielding. It is only when the gauge is mishandled or damaged that it becomes a significant radiological hazard to the operator. Extensive experience with these gauges over many years indicates that radiation exposure to workers is generally low and that accidents involving the gauges are infrequent. When these gauges are used properly, radiation exposure of the general public is not an issue.

Compaction standards

Compaction Standards are expressed as a percent (%) Relative Dry Density. The % Relative Dry Density is given by the following equation.

$$\%\,\text{Relative Dry Density} = \frac{\text{Field Dry Density}}{\text{Max Dry Density}} \times 100\%$$

Typical – use this information to determine the water required for the job.

MDD 1875 kg/m³
Maximum Dry Density

OMC 13.1%
Optimum Maximum Content

Thus:
Water required per cubic metre = 13.1% x 1875 = 246 kg of water
= 246 l of water

This typical job mix:
6m wide x 500m long x 0.2m deep
= 600m³ x 246l/m³ = 147600 l.

Note: actual quantity for job will depend on actual moisture content of material, ambient conditions and type of material.

Refer to Chapter 7 Calculations.

Additional information can be found in the 11AT series – www.ipwea.org.au/qld

KEY MESSAGES
- **Understand the types and properties of soils**
- **When and how to use**
- **Ask if not sure**

ACID SULFATE SOILS

Acid sulfate soils cover approximately 2.3 million hectares of land in Queensland and occur naturally along the coast, usually where land elevation is less than 5 metres AHD. These soils affect urban, transport, tourism, agricultural and industrial land uses. The exposure of ASS to oxygen (e.g. by drainage, excavation or filling) results in production of sulfuric acid and toxic quantities of aluminium and other heavy metals, informs that can be commonly released into waterways. The acid corrodes concrete and steel infrastructure and, together with the metal contaminants, can kill or damage fish, other aquatic organisms, native vegetation and crops. Queensland has an Acid Sulfate Soils Investigation Team situated at the Department of Natural Resources, Indooroopilly:

Phone 07 3896 9819 or
Fax 07 3896 9782
email: heyk@nrm.qld.gov.au

QASSIT carries out mapping, site investigation, laboratory testing, education and ASS research.

Be aware that ASS can be found in other parts of the State.

CHAPTER 4
WORK HEALTH AND SAFETY

When there is an incident on a work site, *someone* is held responsible and accountable.

Note: Ensure you know the latest legislation and regulations – go online every month or two and get updates – better still: sign up for them.

The WHSQ website at www.worksafe.qld.gov.au will help you comply with work health and safety laws. The website has information, safety alerts and films for free download to help you manage health and safety in your workplace.

You can also access legislation and codes of practice. Subscribe to the eNews service to receive regular eSafe newsletters, safety alerts and the latest work health and safety news.

A schedule should be set up as a structure to training staff. A copy of a simple schedule is available from the IPWEAQ website.

WH&S obligation and responsibility statements

Supervisors

Supervisors are responsible and accountable to their Department Manager for the health and safety of all employees, contractors, visitors and volunteers at workplaces that are under their control.

Responsibilities include:

1. Implementing and maintaining your Council's WH&S Management System – SAFE PLAN within their area of control.
2. Being aware of key performance indicators and targets that have been set by management.
3. Maintaining a safe working environment by ensuring that all employees under their control comply with legislative requirements and WH&S policies, procedures and work instructions.
4. Providing information to employees through team meetings, toolbox talks or information sessions in relation to SAFE PLAN, WH&S policies, procedures, work instructions and legal WH&S obligations and responsibilities.
5. Ensuring risk assessments are conducted and recorded for all identified hazards, or prior to the implementation of new work practices, hazardous substances, or plant. Also, as required, assisting or participating in the carrying out of risk assessments on identified hazards. All risk assessments are to be in accordance with your Council WH&S policies, procedures and work instructions.
6. Ensuring all incidents, serious bodily injuries, work-related illnesses or dangerous occurrences are reported to the WH&S Coordinator within the required timeframes.
7. Carrying out regular hazard/risk inspections of all areas and operations within their area of control, and monitoring records of the results of the inspections and corrective action taken.
8. Ensuring that Material Safety Data Sheets (MSDSs) are made available to all employees and ensure employees understand the importance of this information.

9. Ensuring contractors and suppliers comply with Council WH&S requirements, standards, and procedures. Any observed non-compliances must be brought to the attention of their Manager for action.
10. Ensuring that no employee under their control operates or uses any plant or equipment unless they are competent to do so. Further, ensuring that all relevant employees hold current and appropriate licences, permits or certificates, and their ability to operate and/ or use the plant or equipment has been determined prior to use.

Health and safety representatives (HSRs)

HSRs are elected by workers to monitor health and safety in the workplace. HSRs are entitled to undertake inspections and review the circumstances of workplace incidents. They are also entitled to participate in a work health and safety committee. HSRs can also issue provisional improvement notices to address work health and safety issues. The Work Health and Safety Act 2011 provides a legal entitlement for HSRs to request and receive training in work health and safety. This entitlement allows HSRs to attend training courses that are delivered by approved training providers.

Work Health and Safety responsibilities

The Supervisors of the work have a moral and legal obligation to be familiar with and ensure compliance with all statutory Acts and Regulations as well as all Council Policies and Procedures that have or will be introduced to protect the Health and Safety of Council employees, contractors and the general public.

Notwithstanding Industrial and Award Agreements and the obligations imposed by them, the Supervisor is responsible for his/her work sites for ensuring that:

1. All work and associated functions are performed in a safe manner that will not endanger yourself, other Council employees and contractors, or the general public;
2. All lawfully written and verbal Health and Safety instructions issued by Council, its officers or an Inspector of the Division of Workplace Health and Safety Queensland are carried out.
3. All personal protective clothing and equipment supplied by Council is maintained and used correctly.
4. Corrective actions are taken to man- age the risks of hazards within the workplace, or if the management of the risk is beyond the scope of this position report the hazard to your Supervisor.
5. Feedback is to be given to any employee that makes a suggestion to reduce the risk of a hazard.
6. A high standard of housekeeping and cleanliness is established and maintained within the job sites.
7. First aid and/or medical treatment is obtained for injuries requiring treatment and that all injuries are reported to your supervisor no matter how minor they appear to be.
8. A report on all accidents, non-injury incidents and hazards is forwarded to your supervisor together with your recommendations for corrective action to prevent a reoccurrence of the incident and that assistance is given with any further investigations of these occurrences as required.
9. All local area procedures that may be introduced or varied from time-to-time comply with.
10. All standard work procedures prescribed for particular equipment or tasks are strictly followed.
11. All employees and contractors at a jobsite are familiar with any site specific hazards, work procedures, first aid treatment facilities, fire protection facilities and evacuation procedures.
12. Regular work group discussions are held to discuss job safety issues, Council Work Health and Safety Policies, Procedures and Processes and each employee's responsibility for Workplace Health and Safety.
13. All changes to the Workplace including changes to work procedures and the use of new hazardous substances are referred to the Health and Safety Representative (HSR).
14. The use of any hazardous substance in the workplace is in accordance with its Material Safety Data Sheet (MSDS) and that the Material Safety Data Sheet is readily available to the user.

15. Regular Workplace Health and Safety inspections are carried out at each jobsite and that a record of the inspection and any corrective action required is kept.
16. Each employee is competent to perform any task required of him/her and that he/she holds the appropriate licences, permits or certificates that may be required for the task.

If any of the above requirements cannot be complied with for any reason report the problem to your manager immediately.

General construction induction training

The General Construction Induction card, formally known as a blue card, is intended to provide new and existing building and construction industry workers with the introductory understanding and knowledge needed to commence or continue work within the building and construction industry.

There is a duty to ensure general induction training is provided to a worker who is to carry out construction work, if the worker:

- has not successfully completed general induction training; or
- successfully completed general induction training more than 2 years previously and has not carried out construction work in the preceding 2 years.

Site-specific induction

Having measures in place at the workplace to ensure people are aware of the specific procedures and rules for the site will help minimise the risk of death, injury or illness.

A principal contractor must ensure a person has had a site-specific induction before that person starts construction work (other than housing construction work).

The principal contractor must ensure a person entering a part of the workplace where construction work is being done:

- has been given a site-specific induction, or
- is accompanied by the principal contractor or someone who has been given a site-specific induction.

The induction needs to address the contents of the WHS management plans.

The principal contractor must make a record of the people inducted and the date it was given. The record must be kept for the duration of the construction work.

It is the policy of all Councils that no employee will be required to perform any task that is reasonably considered to be unsafe.

KEY MESSAGES
- ***Someone* is responsible**
- **Staff are trained**
- **Regular inspections**
- **Report all incidents**

CHAPTER 5
SAFETY IN CONFINED SPACES AND TRENCHES, EMBANKMENT AND EXCAVATION STABILITY

This Chapter describes the hazards that can be encountered in confined spaces, and deals with potentially dangerous atmospheric conditions in confined spaces. Guidance is given on the procedures that should be adopted and the equipment provided. Other hazards such as physical dangers from structural failure or the use of tools, equipment and machinery in a dangerous manner are not handled in detail.

A template Work Method Statement for Confined Spaces is available from IPWEAQ.

What is a confined space?

A confined space is determined by the hazards associated with a set of specific circumstances and not just because work is performed in a small space.

A confined space means an enclosed or partially enclosed space that:

- is not designed or intended primarily to be occupied by a person; and
- is, or is designed or intended to be, at normal atmospheric pressure while any person is in the space; and
- is or is likely to be a risk to health and safety from:
    - an atmosphere that does not have a safe oxygen level, or
    - contaminants, including airborne gases, vapours and dusts, that may cause injury from fire or explosion, or
    - harmful concentrations of any airborne contaminants, or
    - engulfment.

Confined spaces are commonly found in Stormwater drains, sewers, trenches, tunnels, bridge voids, tanks, pits, pipes, ducts, flues, chimneys, silos, containers, pressure vessels, wet or dry wells, shafts, or other similar enclosed or partially enclosed structures.

Health hazards

Oxygen deficiency

When the level of oxygen is low life is threatened.

Toxic gases

These can cause poisoning or suffocation.

Explosion or fire

A build up of flammable gases or vapours can cause explosion.

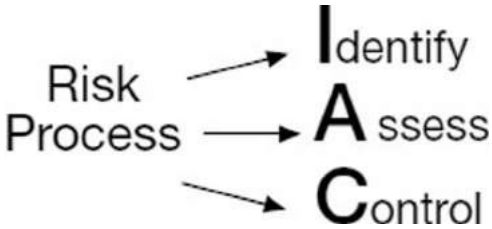
All of these can result in "DEATH"

Danger is always present during routine tasks such as maintenance, inspections, repairs, and cleaning.

Assessment

Before entering or working in a confined space, a risk assessment must be conducted to identify potential hazards and risks.

Always conduct a risk assessment before any controls are implemented and a risk assessment after the controls are implemented to ensure the risk has been eliminated or reduced.



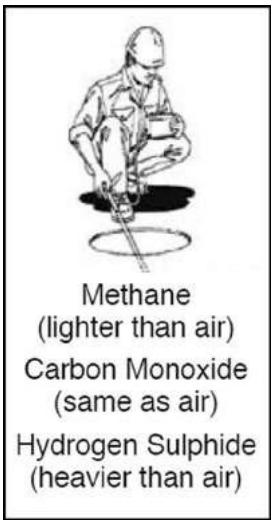
Where generic type work is carried out in confined spaces (maintenance) a generic risk assessment may be used for several confined spaces, however these risk assessments must be at the job site and discussed by staff before entry to a confined space.

Likelihood	Consequences				
	Insignificant No injury, 0 - Low $ Loss	Minor First Aid Injury, low - medium $ loss	Moderate Medical Treatment medium -high $ loss	Major Serious Injuries, major $ loss	Catastrophic Death, huge $ cost
Almost Certain is expected to occur at most times	H	H	E	E	E
Likely will probably occur at most times	M	H	H	E	E
Possible might occur at some time	L	M	H	E	E
Unlikely could occur at some time	L	L	M	H	E
Rare may occur in rare	L	L	M	H	E

Code: E – Extreme Risk, H – High Risk, M – Moderate Risk, L – Low Risk

Take into consideration:

- Oxygen levels
- Toxic gases
- Explosive gases
- Falling Objects
- Flooding
- Heat
- Isolation of electrical & mechanical services
- Emergency and rescue arrangement



Working safely in a confined space

- Never enter a confined space unless you are trained, have been deemed competent, and are authorised to do so;
- Ask your supervisor for an "Entry Permit" before entering a confined space;
- Conduct a risk assessment before entering the confined space;
- Test the atmosphere before you enter;
- Always monitor the atmosphere while working in the space;
- Always ensure adequate ventilation while working in the space;
- Make sure electrical and mechanical services are isolated. Whoever enters the confined space must check to see if it is isolated;
- Always wear a safety harness and lifeline while working in the space;

- Make sure another suitably qualified person is present in close proximity to the entrance of the space who is acting as an observer and stand-by rescue person;
- Sign the "Entry Permit";
- Never smoke in the space;
- If you are required to wear breathing apparatus, never remove it in the space;
- Always wear the provided Personal Protective Equipment;
- If an alarm is activated, get out immediately;
- Re-test the atmosphere before re-entering (refer to the 'Gas Action Chart');
- On completion of your work, always restore the space to normal; and
- Maintain all confined space equipment and record details in maintenance log book.

Never forget to complete the

"Entry Permit"

Emergency

- Call for help immediately;
- Attempt to retrieve person without entering the confined space;
- Never enter the confined space to rescue a collapsed worker without training and breathing apparatus;
- Once the person has been retrieved, commence resuscitation if necessary;
- Get medical assistance if possible;
- Isolate the area; and
- Notify your supervisor and WHSO immediately.

Note: Entry into a confined space requires specific training. Always check current regulations covering safety in confined spaces and trenches.

Obtain a Work Method Statement before commencement.

Most Important!

If you are working in a confined space and you feel dizzy, light headed, or the gas detector has gone into alarm mode,

LEAVE THE SPACE IMMEDIATELY!

Examples

1. New Manholes, Wells, Tanks and Pits under construction.
2. Sewage Treatment Works under construction.
3. New and old enclosed conduits, tunnels and dam outlets.
4. Work in old mine shafts or tunnels.
5. Confined Water Treatment Tanks and Filtration Equipment.
6. Deep pumping wells for water supply.
7. Inside steel tanks e.g. while descaling rust.
8. Marine craft bilges.
9. Document reproduction and plan printing rooms.
10. Work in cellars or excavations under or within old buildings.
11. Service tunnels and underfloor spaces.
12. Spaces between ceiling and roof, especially when insulated.
13. Excavation in wet sandy soils.
14. Graves
15. Inside Bridges

The regulation defines a confined space and the Code of practice provides practical guidance on how to meet the requirements under the WHS Regulation in relation to work carried out in a confined space. It applies to persons conducting a business or undertaking who have management or control of a confined space, and to designers, manufacturers or suppliers of plant or structures that include, or are intended to include, a confined space. The Code will help determine when a space is a 'confined space' for the purposes of the WHS Regulation, what the potential hazards are and how to eliminate or minimise the risks when carrying out work in a confined space.

The Code can also be used by workers and their health and safety representatives interested in understanding the hazards and risks associated with confined spaces.

In providing guidance, the word 'should' is used in the Code to indicate a recommended course of action, while 'may' is used to indicate an optional course of action.

The Code also includes various references to provisions of the WHS Act and Regulation which set out the legal requirements. These references are not exhaustive. The words 'must', 'requires' or 'mandatory' indicate that a legal requirement exists and must be complied with.

Workers and their supervisors must have the skills and knowledge to understand the hazards associated with working in the confined space, the contents of any confined space entry permit, and the control measures implemented for their protection.

Training should be provided to workers who:

- enter or work in confined spaces
- undertake hazard identification or risk assessment in relation to a confined space
- implement risk control measures
- issue entry permits
- act as a standby person or communicate with workers in a confined space
- monitor conditions while work is being carried out
- purchase equipment for confined space work
- design or lay out a work area that includes a confined space.

The training provided to relevant workers must cover:

- the nature of all hazards associated with a confined space
- the need for, and appropriate use of, risk control measures
- the selection, use, fit, testing and storage of any personal protective equipment
- the contents of any relevant confined space entry permit
- emergency procedures.

Re-training or refresher training should be provided as appropriate for a particular workplace. The frequency of this training should depend on how often workers are required to carry out tasks associated with entry to or work in confined spaces.

Records of all training provided to workers in relation to confined space work must be kept for 2 years.

The need for rescue from a confined space and the provision of first aid in an emergency should be in accordance with Section 6 of the Code of Practice. Rescue and first aid procedures should be planned, established and regularly rehearsed. The safety harness should be of an approved type, which will maintain an unconscious person in an upright position so that the person will not be stuck in the manhole opening, etc. as he is being lifted out.

Untrained, un-equipped and unprepared people must not enter a confined space to rescue a person because multiple fatalities may occur.

On each occasion of entry to a confined space the ventilation and the safety checks must first be carried out. It cannot be assumed when resuming work after a meal break or on the next day that the air inside a confined space has not been contaminated during or since the previous entry.

The Supervisor shall ensure that when persons are required to enter a confined space, all the equipment appropriate to the situation is available to ensure safety and to effect rescue in an emergency. The equipment that could be required includes:

- ventilation fan
- ducting and power source
- toxic gas detection meters
- breathing equipment
- safety harness and rope
- protective clothing
- first aid equipment.

Where a confined space is identified and will be in existence for some time, consideration is to be given to fixing a warning sign by the entrance in accordance with *Australian Standard 1319-1994*.

Requirements

Supervisors should be aware of the requirements of:

- **Legislation**
- **Regulations**
- **Standards**

and ensure the persons involved know the availability of help – there should be a list of which individuals to call.

General

- All confined spaces, particularly those that are not adequately ventilated, should be regarded as being potentially hazardous.
- Smoking and naked lights should be prohibited at all times in any confined space in a hazardous location and within six metres of any access opening to a confined space.
- When entry is first made to any confined space at the start of a shift or after a meal break, there must be at least one attendant located outside. The attendant must be able to call up rescuers immediately and effect a rescue in the event of a collapse of a worker.
- The safety of any would-be rescuer must be considered. Ensure that the rescuer can be pulled to safety.
- Ventilation of a confined space with fresh air, by natural, forced or mechanical means, may be necessary to establish and maintain a safe atmosphere and temperature for as long as anyone is in the confined space. If the confined space has sufficient openings then natural ventilation may be adequate, but in most cases mechanical ventilation is likely to be needed. Lift the lid of all pits before you assemble your gear to give extra time for fumes to dissipate.
- Where raw sewage is involved or where stagnant water containing organic matter is present or where forced ventilation is used, an attendant is to remain on the surface nearby while any person is present inside the confined space.
- Exhaust from internal combustion engines should be directed well away from confined spaces into which any persons may be required to enter.
- If the atmosphere within a confined space has been or could possibly become contaminated, suitable gas detectors are to be used before entry and continual monitoring is to be carried out while a person is inside.
- If entry into a hazardous location is unavoidable and the atmosphere within is suspect or could become contaminated, then appropriate respiratory protective equipment must be provided. The respiratory protective equipment should be provided and worn in situations where there is no exposure standard for a substance, or where the substance is present in an unknown concentration." In addition a safety harness fitted with a safety rope should be worn by each person entering and each rope should be controlled by two people near the entrance.

Trench and excavation safety

Be aware of public movement. Erect appropriate and approved barricades and signage.

Excavation means a hole in the earth, or a face of the earth, formed after rock, sand, soil, or other materials are removed. Examples are a trench, ditch, well, tunnel, pier hole, cutting, or a hole drilled in the earth.

Why is an excavation or trench a hazard?

An excavation or trench can be a hazard if proper precautions and planning are not established prior to work commencing. Excavation and trenching 'cave-in' is a significant cause of death and serious bodily injury.

Excavation collapse can result in:

- **Death**
- **Suffocation** – due to soil blocking the airways; and / or
- **Musculoskeletal injuries**, i.e. injuries to bones and muscles.

Trench support
Always make sure you conform to the *Workplace Health and Safety Act* before commencing works, particularly with regard to trenching requirements.

Trench shoring systems/shields are commercially available.

Templates for Work Method Statement for trenches less than 1.5 m deep and for trenches more than 1.5m deep are available from IPWEAQ.

Sizes of the shoring needed vary with trench size and details should be provided by the Engineering staff.

The above regulations are law and have been produced to avoid loss of life, mainly by suffocation when sides of trenches fall in as often happens in unstable material after heavy rain. Never take a risk of not adhering to the depth requirements specified in the WH&S Act as the consequences of any accident will stay with you.

For long runs of pipelines such as sewer lines, steel framework is often used instead of timber. The sides and cross supports are in one piece and due to their weight, use is usually restricted to small diameter pipeline.

A similar sketch should be given to you for each job with the sizes shown, and the type of shoring required.

In fact there are many specialised types of “shoring” devices available and approved by relevant authorities. Discuss the selection of appropriate devices with your Engineer, as although initial costs may seem substantial, savings are made in the longer period.

Site de-watering
Refer to Chapter 17 Water Supply and Sewerage

See also 11AT 25

Excavation safety
Refer to 11AT 25 Drainage

To ensure workers safety in an excavation site, it is essential that the following actions be followed:

1. An excavation site more than 1.5 m in depth must be assessed to determine whether shoring or benching is to be installed to hold back loose soil. The outcome should be documented in the Work Method Statement;
2. Ensure that heavy earth moving equipment is kept back from the edges (e.g. at least 1m) of any excavation or trench;
3. Equipment, soil or other material must **not** be placed closer than 600mm from the edge of an excavation or trench;
4. At least one other person should remain at ground level at all times, so that in the event of a collapse, the person at ground level will know where the trapped person is located;
5. Enter or exit into or out of an excavation should be by a ladder only. The ladder or set of steps must be located within 9m of either end of the excavation or trench at all times. Where the trench is more than 1.5m deep at least 1 ladder giving access to and from the trench must be installed in every 9m of the length of the trench in the part of the trench where a person will be;
6. No petrol driven vehicles are allowed in the excavation, due to the fumes created;
7. Ensure the excavation is barricaded if hazards are present or if it is accessible to those other than workers working at the site;

8. If the excavation is to be left open for an extended period of time, the excavation is to be checked daily for cracks, slides and scaling and inspection results must be documented;
9. During rain and other hazardous weather conditions, checks should be done more often; and
10. Check overhead power lines before excavation begins.

Gas leakage

Supervisors should always be on the alert for the smell of lethal gases, which are heavier than air and which easily flow into trenches. At the first trace of a gas smell, contact the authority in charge of the gas supply and find other work for the men to do until the leak is located and fixed.

Keep lights well away from gas as deaths have occurred where the mixture of air and gas has produced an explosive mixture.

Avoid using combustion-motored work implements in trenches (particularly deep trenches) unless adequate ventilation can be maintained, as carbon monoxide gas poisoning may occur.

Embankment and excavation stability

Be aware of embankment and batter stability when excavating. Sandy soils can be unstable and appropriate safety measures must be taken.

Be aware of:

1. Excavations close to or through old rubbish or refuse areas
2. Excavations through ground saturated by domestic waste water
3. Excavations through ground saturated by animal wastes
4. Tunnelling close to or through coal, peat or organic seams.

Hazards

The hazards commonly encountered in confined spaces are:

- Toxic gases
- Flammable gases with potential of fire or explosion
- Lack of oxygen causing asphyxiation
- Electric shock from portable lights, tools, or associated electrical equipment
- Injury from mechanical equipment such as inadvertently activated conveyors
- Bodily injury from direct contact with corrosives or dermatitis-producing chemicals
- Physical hazards such as slipping, falling and falling objects
- Burns and scalding.

Typical hazardous locations and situations

1. Operating Sewers, Manholes and Tunnels
2. Operating Sewage Pump Stations, wells and valve pits
3. Operating Sewage Treatment Works
4. Septic tanks
5. Digestor Tanks
6. Methane Gas Collector Stations
7. Town gas leaks
8. L.P. gas installation leaks at schools and industrial buildings and sites
9. Industrial Welding gas storage and use areas

10. Welding fume areas for close work or in confined spaces
11. Flammable liquid storage areas and service stations
12. Areas where chemicals are in use, e.g. epoxy paint, solvents, glues in confined space or for close work
13. UPVC solvent and cleaning fluid in confined space
14. Chlorine injection systems used in water treatment, sewage treatment and swimming pools
15. Close work with hot tip etching recorders
16. Ammonia gas installation leaks
17. Excavations close to or through old rubbish or refuse areas
18. Excavations through ground saturated by domestic waste water
19. Excavations through ground saturated by animal wastes
20. Tunnelling close to or through coal, peat or organic seams
21. Excavations exposing underground streams or caves
22. Confined spaces which hold or have held stagnant water containing organic matter
23. Confined spaces where carbon dioxide expired by workers inside could build up to an unsafe level
24. Exhaust from internal combustion engines leaking into any confined space, including into motor vehicles
25. Sumps and pits where vapour from fuel leakage may collect, especially petrol or L.P. gas
26. Old buried fuel tanks outside shops in remote and rural areas
27. High ambient temperatures in confined spaces in Queensland – can be 40+.

Trench shoring (also refer 11AT and commercial products for trench shoring)

Be aware of:
- Ground water
- Desert country
- Excavation in wet sandy soils.

KEY MESSAGES
- **Staff are trained**
- **Sites are assed prior to entry**
- **Sites are re-assessed during the job**
- **Know emergency procedures**

CHAPTER 6
TRANSFER OF DETAILS FROM PLANS TO "WORK ON THE GROUND"

Efficient transfer of details on drawings to produce a properly completed job should be every Supervisor's objective. A tidy, well planned job is the safest and most efficient way of achieving this aim.

Engineering staff will provide you with a variety of drawings, sketches, specifications and instructions, and the following points should assist you to convert their designs into something of value to the community.

Make sure you understand. If not, ask! Report back to the Engineer and/or Designer on any queries or issues relating to the site: if in doubt, say so!

Road details

Fully detailed drawings generally consist of the following types:

Plan (See Figure 6.1)
As shown, this is a view of the work from above and shows the layout of the road, distances of centre line pegs, details of curves if any, drainage layout and notes on the type of construction.

Longitudinal Section (See Figure 6.2)
This shows the side view of an imaginary slice cut down through the centre line of the road. The distances correspond to those shown on the plan.

Straight grades are shown as a percent- age, that is, so many metres vertical to 100 metres horizontal. For example, a 5 metre rise or fall in 100 metres is a 5% grade.

The straight grades are joined by vertical curves to provide a smooth ride when vehicles go from one grade to another.

Cross Section (See Figure 6.3)
These show imaginary vertical slices across the centre line from fence to fence. They show the cross fall or camber of the road as well as details of kerbing and guttering and footpaving if applicable.

Here again the distances correspond to those on the plan of the road viewed from above. See Figure 6.4.

Standard drawings
IPWEAQ produces Standard Drawings for use by councils. These Drawings include the most up-to-date specifications and standards for Roads and Streets, Drainage, Water Supply, Sewerage, Parks/Miscellaneous. Where a Department of Transport and Main Roads Drawing is applicable it has been called up in the Directory. Councils also have their own sets of drawings.

Summary
If you have any concerns or difficulties regarding the drawings, don't be afraid to ask questions!

Setting out work

The original centre line survey marks will have been placed before the drawings are drawn. In inner city and suburban work, greater accuracy is required in offsetting these marks, so the work will probably be done by registered surveyors, while in less populated areas offsets may need to be placed by the Supervisor clear of the area to be excavated or filled.

Offset pegs are set at right angles to the centre line on straight sections and along the radius on curves. Unless the centre peg of a curve is in existence and accessible (this will only be practicable for short radius curves) or the level of accuracy required for the particular job permits otherwise, curve offset pegs should be set out by the Engineering staff using a theodolite.

When designs have been based on co-ordinated systems, setting out of site reference points must be carried out by a cadastral surveyor in order to confirm cadastral and design alignment.

Be aware of limitations of setting out works by GPS and seek advice of surveyor.

Setting out techniques

Surveyors use various tools to do their work successfully and accurately; tools such as total stations, robotic total stations, GPS receivers, prisms,3D scanners, radio communicators, handheld tablets, digital levels, and surveying software.

As late as the 1990s, the basic tools used in surveying were a tape measure for determining shorter distances, a level to determine height or elevation differences, and a theodolite, set on a tripod, to measure angles (horizontal and vertical), combined with the process of triangulation. Starting from a position with known location and elevation, the distance and angles to the unknown point were measured.

A more modern instrument is a total station, which is a theodolite with an electronic distance measurement device (EDM). A total station can also be used for leveling when set to the horizontal plane. Since their introduction, total stations have made the technological shift from being optical-mechanical devices to being fully electronic. Modern top-of-the-line total stations no longer require a reflector or prism (used to return the light pulses used for distancing) to return distance measurements, are fully robotic, and can even e-mail point data to the office computer and connect to satellite positioning systems, such as a Global Positioning System.

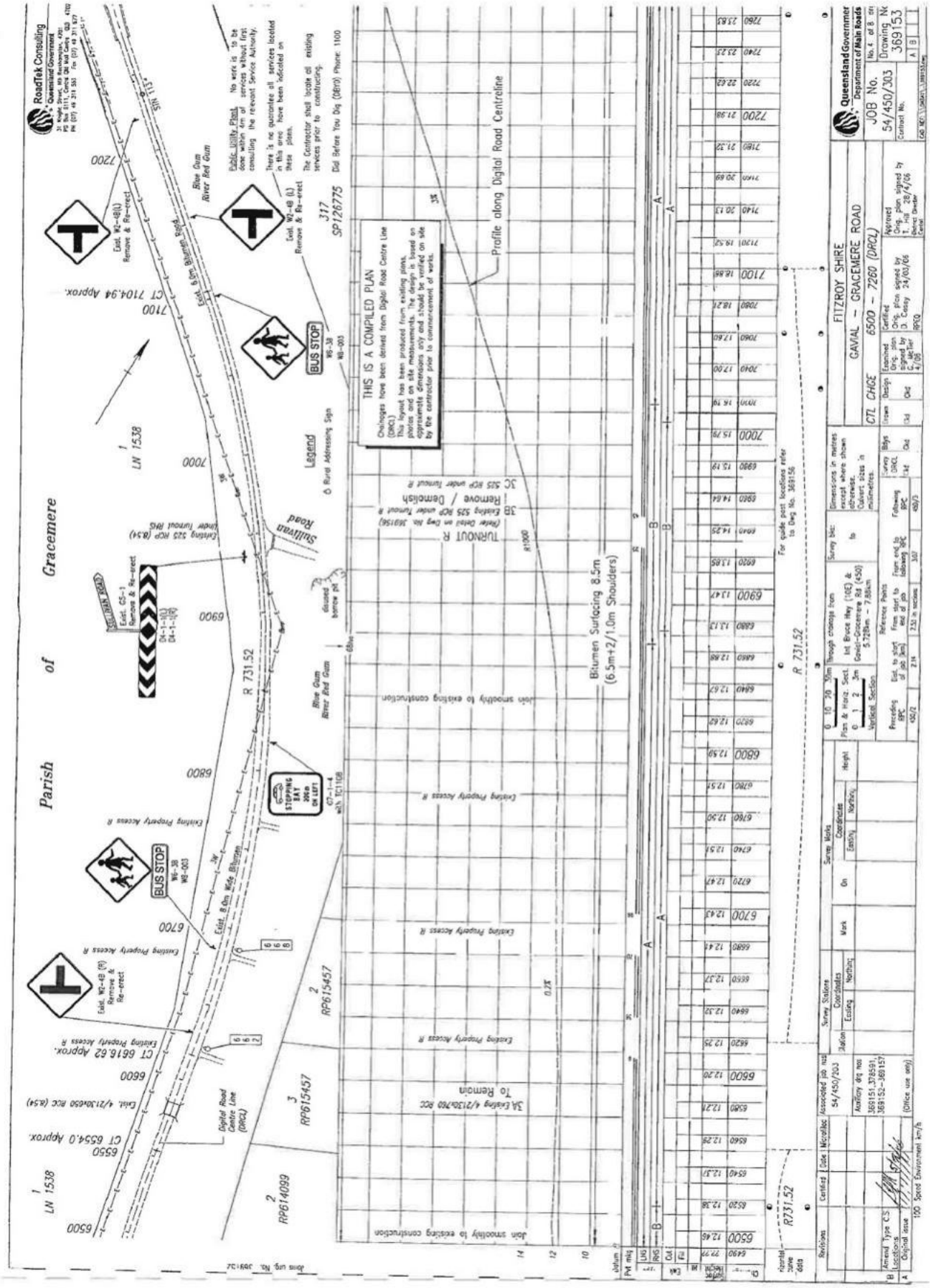


Figure 6.1 Plan and Longitudinal Section

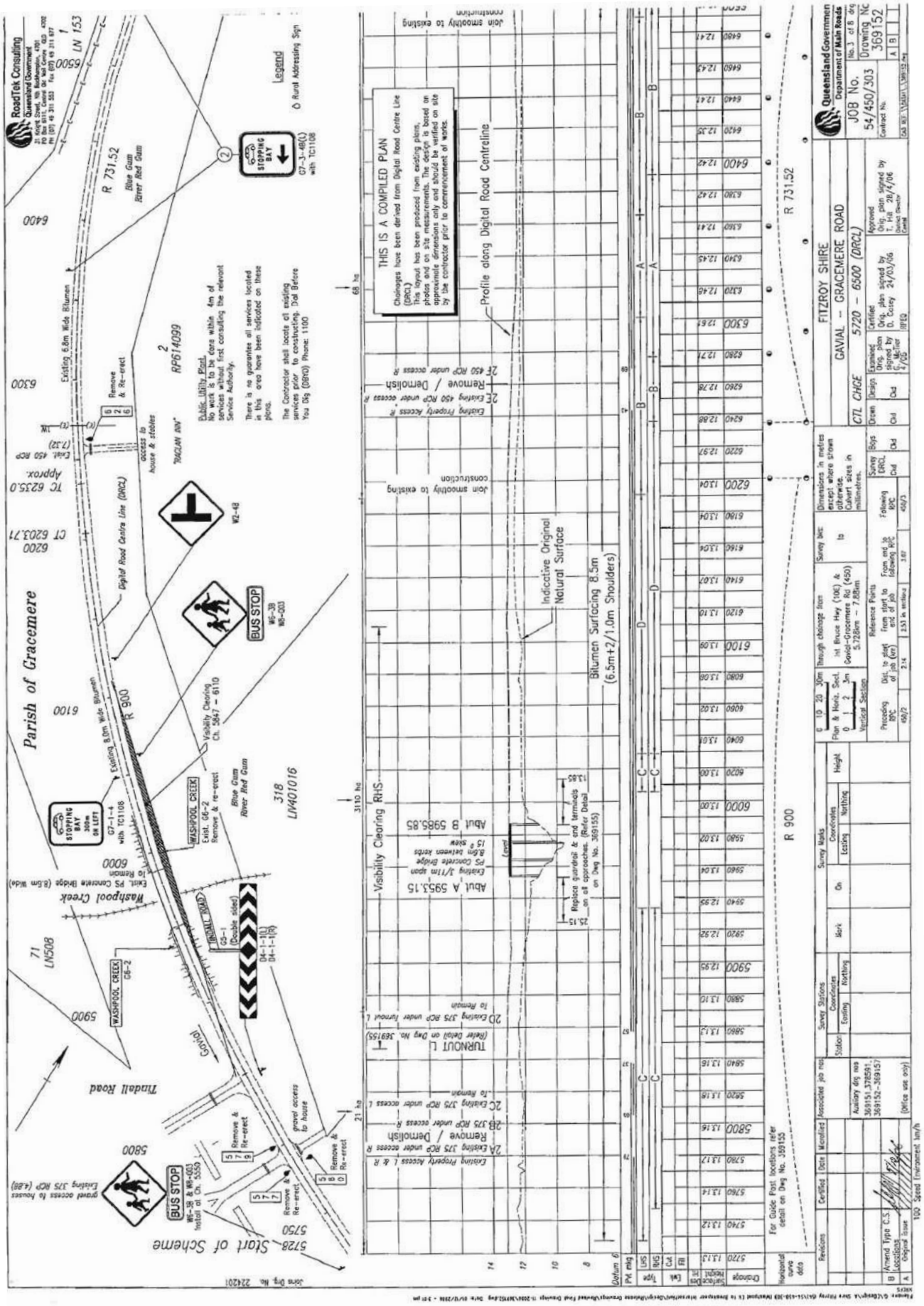


Figure 6.2 Plan and Longitudinal Section

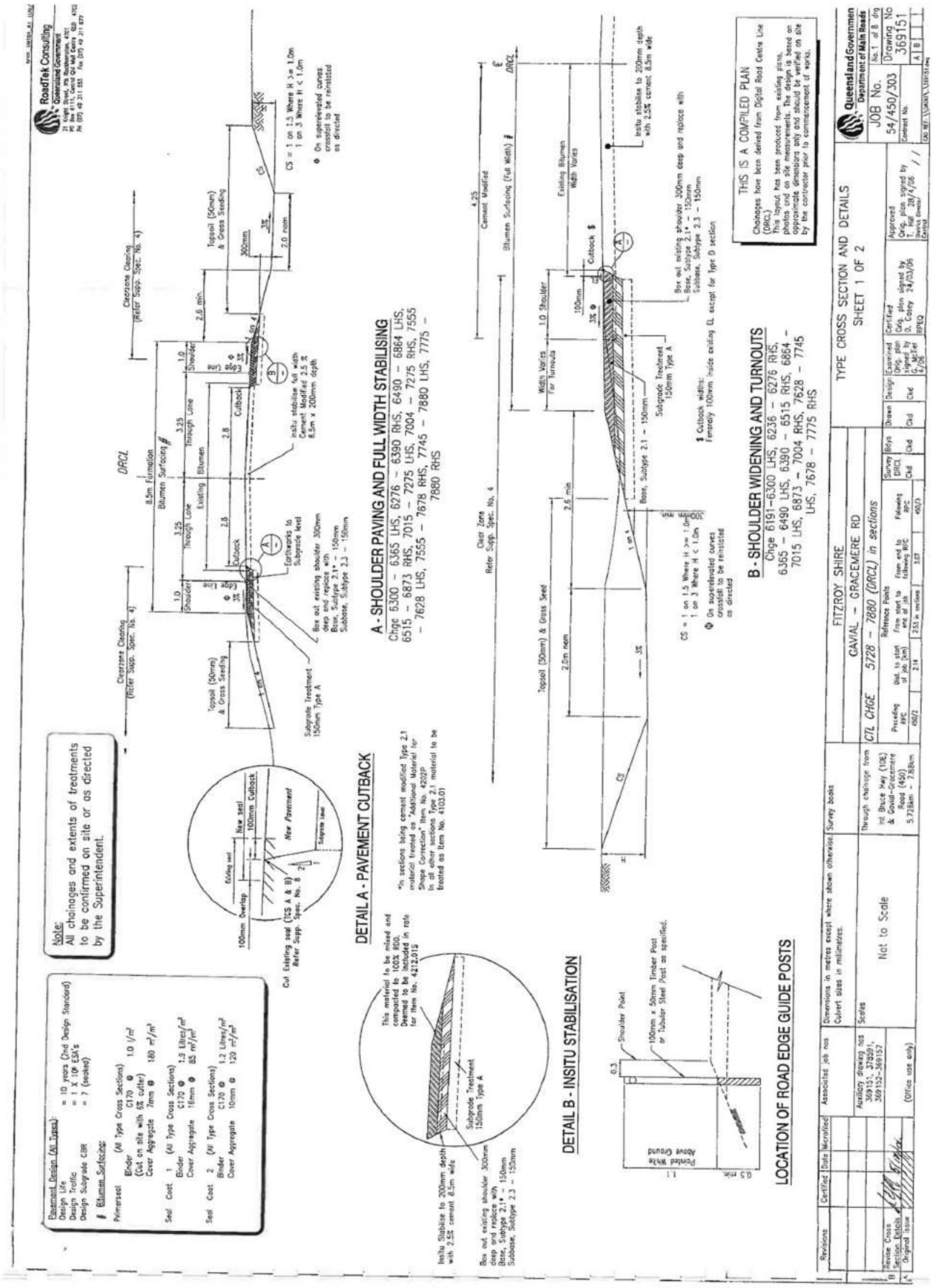


Figure 6.3 Typical Rural Cross Section

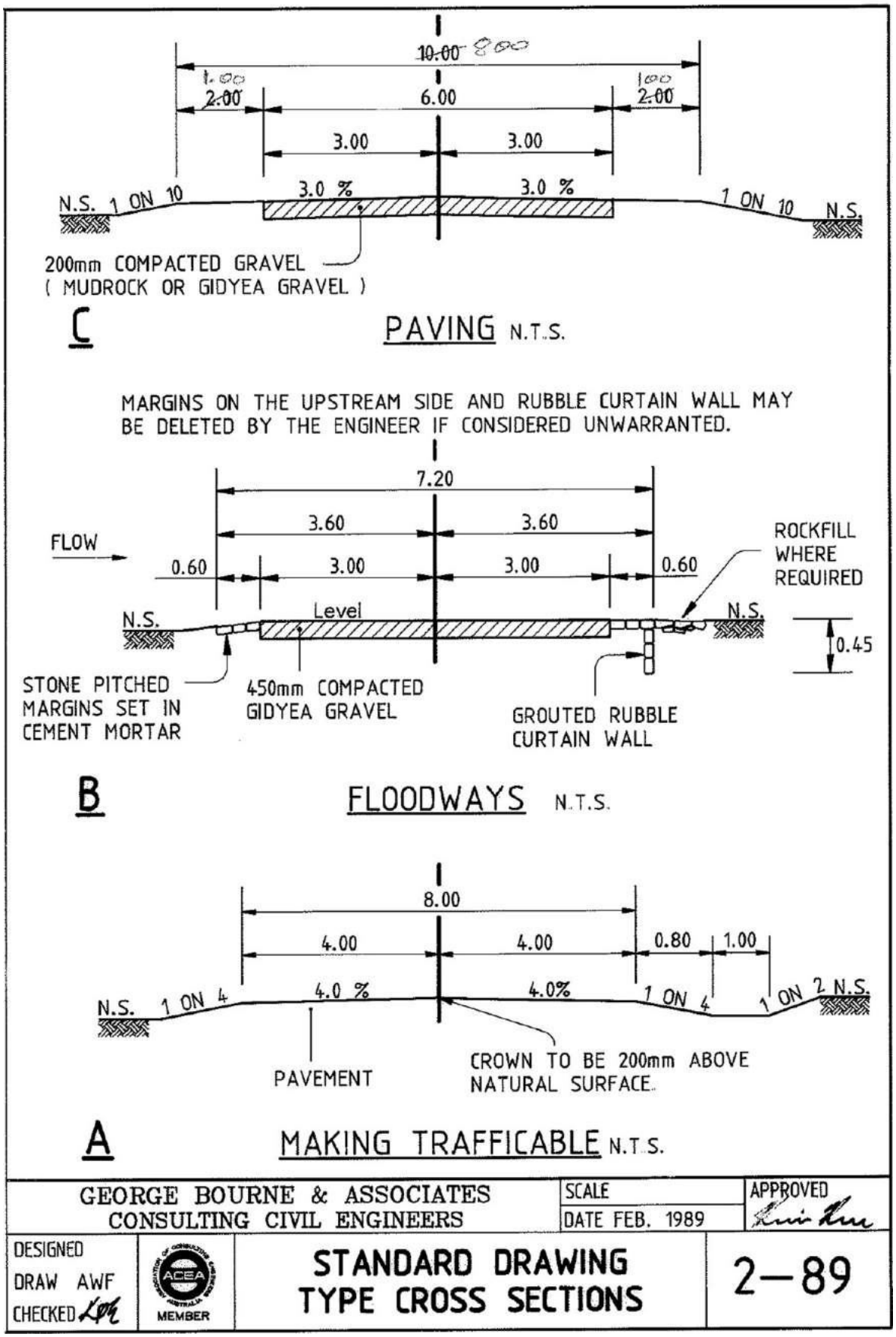


Figure 6.4 Typical Urban Cross Section

Total stations are still used widely, along with other types of surveying instruments, because GPS systems do not work well in areas with dense tree cover or constructions. One-person robotic-guided total stations allow surveyors to gather precise measurements without extra workers to look through and turn the telescope or record data.

On large construction sites, a great number of points at different heights need to be staked out or monitored, and it often makes sense to use a rotation laser. In this type of instrument, a rotating laser beam sweeps out a horizontal plane, which serves as the reference plane. A detector is slid down a levelling staff until it encounters the laser beam; the height can then be read directly from the staff.

A faster but more expensive way to measure large areas is with a helicopter, equipped with a laser scanner, combined with a GPS to determine the position and elevation of the helicopter. To increase precision, beacons are placed on the ground (about 20 km apart). This method reaches precisions between 5 and 40 cm (depending on flight height).

GPS surveys use the signals transmitted by satellites having trajectories such that any point on the Earth's surface can be determined around the clock and independently of weather conditions. The positioning accuracy depends on the type of GPS receiver and on the observation and post processing techniques used. Compared with the use of a total station, GPS surveying offers the advantage that the points to be measured do not have to be mutually visible. Provided that the sky is relatively unobstructed (by trees, buildings etc.) and therefore that adequate satellite signals can be received, GPS equipment can be applied to many survey tasks that until recently were carried out using electronic total stations.

Rules of setting out

The value of setting out depends upon accuracy. The cost of taking a little extra time to set out accurately (and to check) is well worthwhile in order to achieve a better job more economically. The following rules must be observed:

- All information collected in the task of setting out **must** be recorded in tables which must be held on the job for future reference, e.g. levels and locations of pegs, depth of cut, height of fill and rise or fall from recovery peg to finished surface.
- The plans, construction tables and specifications must be thoroughly studied and understood prior to setting out. All plan notes referring to setting out must be read carefully.
- When measuring distances by chain or tape, it is the **horizontal** distance, which is measured, not the slope distance.
- In measuring distances longer than the length of the tape, "range in" the intermediate points to be sure the measurements are being made on a straight line.
- Offset distances are measured out at **right angles** to the **centreline** on straights and **radially** on curves.
- To measure past an obstacle offset the line around the object.
- Never use a damaged or stretched tape.
- Instruments (e.g. dump level) need to be checked frequently for adjustment. (Refer Form 11AT16)
- Check level datum on places and any permanent marks used on the jobs. Note: AHD datum and Railway datum may be different for different locations.

- **Rectangular** pegs must be used for all engineering works. (The Survey Co-ordination Act (Queensland) states specifically that the use of square pegs is restricted to real property surveys).

- Pegs, rods, markers and finders must be neat, straight, clean, easily seen and easily recognised. They must, wherever possible, bear some identification mark, e.g. "offset 18.64 R 19280" (18.64 metres right of chainage 19280 metres) and colour coding. Costly errors have occurred because pegs have been incorrectly interpreted. Setting out pegs must be able to be quickly and easily interpreted by plant operators, job personnel and visiting supervisory staff.

- The task of setting out and control check levelling is facilitated by establishing good sound temporary and permanent bench marks as soon as possible. Culvert ends provide excellent locations for permanent references for chainages and levels. Additional information may be marked in the "green" concrete at culvert ends and may include job number, date of construction, chainage, etc. thus providing on-site reliable permanent information.

Stages in setting out

The following is a summary of the steps which should normally be carried out in setting out roadworks:

1. Locate the survey centreline pegs and offset pegs, replacing any missing pegs. (Book details of original pegs that are missing and show the Reduced Level (R.L.) of any new pegs.)

   Except where a shift is to be adopted, the construction centreline is marked on the ground by survey pegs. These are rectangular dumpy pegs driven to ground level at each chainage with a marker behind the dumpy. The first step is setting out is to locate these pegs and re-establish any which may be missing.

   The Surveyor will have provided offset pegs, at tangent points and at intervals elsewhere to assist in re-establishing the centreline. Details of these pegs are shown on the drawings. The Surveyors may use sections of star fence pickets for offsets. Such offsets are shown on working plans.

   Survey pegs must not be used for level control until the R.L.s have been checked with a dumpy level (from established BenchMarks) to ensure that they have not been disturbed. This check should be made by an Engineer or Surveyor.

   Where a shift centreline is to be adopted as the construction centreline. It is usually set out from the pegged centreline using the offset distances shown in the construction tables. These offset distances must be measured at right angles to the pegged line.

   In timbered areas the centreline is marked by “blazes” cut into tree trunks (150 mm or greater diameter) located up to 750 mm either side of the centreline. See Figure 6.5. When two blazes (one above the other) are cut into a tree, this indicates that the centreline passes through the tree.
2. Locate all benchmarks and check levels to ensure they have not been tampered with. This level check should also be made by the Engineer or Surveyor. Take particular care to ensure that bridge site benchmarks are not confused with those for roadwork jobs as they may be on a different datum.
3. Place marker stakes alongside all centreline, offset and road boundary pegs to protect them during clearing operations. (If no boundary pegs exist, mark fencing alignments in accordance with resumption plans.)
4. Mark out limits of clearing. The pegged centreline should be offset if it falls within the clearing limits.
5. After clearing re-establish any missing pegs and book the details.
6. Establish the construction centreline either by shifts or control line survey (as applicable).

7. Offset construction **centreline** clear of limits of work.
8. Mark out limits of earthworks. Erect batter boards.
9. Set out drainage lines and drainage structures. Check suitability of specified skew, and inlet and outlet levels.
10. When earthworks are completed re-establish the construction **centreline** on the new formation from offset pegs (where possible). Major earthworks jobs may require the services of a survey team.
11. Offset the construction **centreline** on each side of the formation and establish sub-grade and grade levels.
12. Control the various stages of paving with temporary crown and edge pegs as required.
13. Set out for bituminous surfacing.
14. Check all work frequently as it progresses.

Figure 6.5

Setting out job levels

THEORY OF LEVELLING

Staff readings and ground level differences

A level correctly set up, with a horizontal line of sight is used together with a staff to determine the differences in level between any number of points.

Provided the staff is held vertically, the staff readings at the various points, give the vertical distances from the horizontal line of sight readings between two points equals the difference in levels on the ground, e.g. Staff Readings are taken as follows:

A = 4.760; B = 2.120; C = 1.170 + D = 3.440

The difference in ground levels are as follows:

A to B 4.760 – 2.120 = +2.640
A to C 4.760 – 1.170 = +3.590
A to D 4.760 – 3.440 = +1.320

It should be noted that when the second reading is smaller than the first the ground level difference is positive and vice versa,

e.g. C to B 1.170 – 2.120 = -0.950.

This is evident from Figure 6.6.

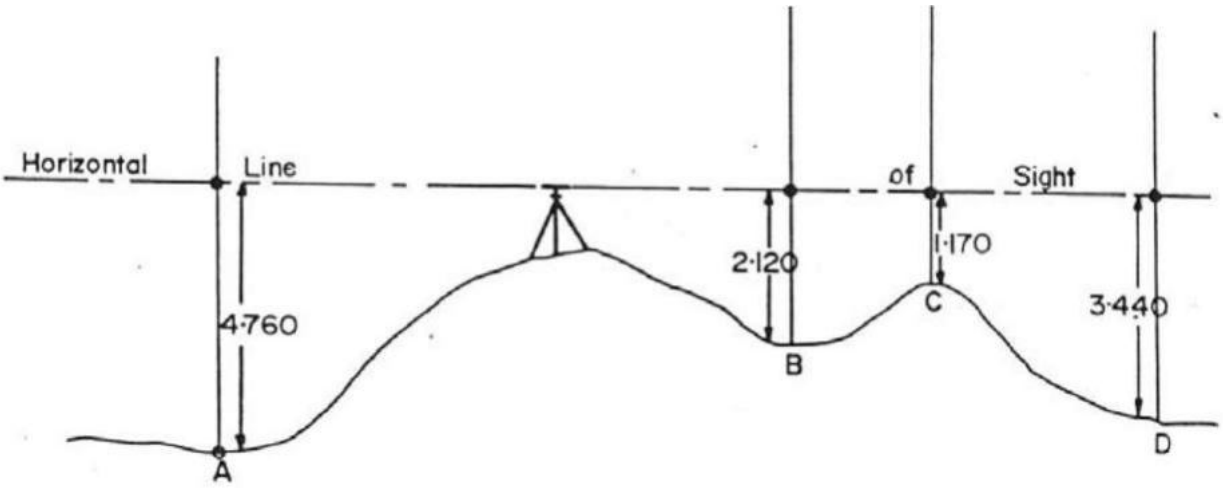


Figure 6.6

Level reductions

If the staff readings are compared in the order of reading then the difference in level of adjacent points are obtained.

e.g. A to B = 4.760 – 2.120 = + 2.640 Rise

B to C = 2.120 – 1.170 = + 0.950 Rise

C to D = 1.170 – 3.440 = – 2.270 Fall

Determining the rises and falls between consecutive points is the basis for the booking and reduction of levels in the most common method, called the rise and fall method.

For any set up of the instrument:

- The first points observed is always a point whose level value is known. At the commencement of a job it would be a Bench Mark (B.M.). This first point is commonly called the "Back Sight" (B.S.) because the observer is looking back to the point, when we consider the direction of the levelling.
- All other points observed, except the last are called “Intermediates” (Int)
- The last point observed is called the "Fore Sight" (F.S.)
- Back sight and fore sight are called **change points** and sound points should be selected for this purpose.

In a standard type level book the staff readings would be booked as shown in Table 6.1. For this particular case the point A in Figure 6.6 is a B.M., points B and C are intermediates and point D is the fore sight.

B.S.	INT	F.S.	Rise	Fall	Reduced Level	Chainage Remarks
		3.440		2.270	98 462	D 57600
	1.170		0.950		100 732	C 525
	2.120		2.640		99 782	B(57500)
4.760					97 142	A(Datum)

The following points are illustrated by the above table:

- Entries are made commencing from the bottom of the page and moving upwards. This is essential in official survey books but it is stressed that a supervisor may book from top to bottom if he finds this method simpler and less confusing. The calculations are still the same.
- Point "A", the first Back Sight, is the one from which all subsequent levels are derived and has the known level value from which level datum is established.
- Differences between adjacent levels are calculated and entered in the "Rise" or "Fall" columns.
- The reduced level of each point is obtained by applying the "Rise" or "Fall" to the reduced level of the previous point.
- The difference between RLs at the B.S. "A" and F.S. "D" (i.e. 98.462 – 97.142 = 1.320), equals the difference between the B.S. and F.S. readings. (i.e. 4.760 – 3.440 = 1.320)

  This quick check ensures that the individual levels have been correctly determined.

- The difference between the sum of rises – (2.640 + 0.950 = 3.590) and the sum of falls – (i.e. 3.590 – 2.270 = 1.320) also equals the difference in R.L.s of the first and last points.

Continuing levelling

Levels may be continued beyond the area of the first set up of the instrument by the procedure shown in Figure 6.7.

When all of the observations have been made for the first set up, a level for FSI can be determined. The instrument is now shifted to the position for the second set up after the line of sight is brought to horizontal, the staff is re-read on FSI, which now becomes the back sight for set up No. 2, i.e. BS2. When all other intermediate points and FS2 have been read a level for FS2 can be determined. The instrument is then transferred to the next set-up point, where a similar operation takes place. By extending this procedure, levels can be carried forward.

Booking and reduction is completed as shown in Figure 6.7. The following points should be noted:

FSI and BS2 (similarly FS2 and BS3 – and FS3 and BS4) are booked on the one line against the relevant remark or chainage.

- When determining Rises and Falls at BS's and FS's always work from left to right.
- The following differences must be determined and must be equal:
  (a) Difference between 1st and last R.L.
  (b) Difference between sum of Rises and sum of Falls.
  (c) Difference between sum of BS's and sum of FS's.

  If these difference are not all equal an error in reduction has occurred.

Alternative method of level reduction

The height of Collimation method (also known as "height of instrument" method) provides an alternative means of reducing levels, and is very useful when it is necessary to set pegs or form work to a required level. The line of collimation is actually the line of horizontal sight. The level of this line can easily be

determined by adding the staff reading on a Bench Mark or other known point to the level of that mark, e.g. Figure 6.8.

Let BM’ A’ have a value of 59.274m.By adding the staff reading 4.761 m we deduce that the Reduced Level (R.L.) of the line of collimation is 64.035 m.

If the peg at B is to be set at a R.L of 63.200 m then the staff reading must be –

64.035 – 63.200 = 0.835 m

If a staff at “C” reads 3.211 then the R.L. at ‘C’ = 64.035 – 3.211 = 60.824.

The observing and booking procedure for this method are identical to those of the rise and fall method. However, the reduction procedure is different in that each staff reading is compared with the reduced level of the line of sight (i.e. the height of instrument) instead of obtaining the differences with the preceding reading as in the rise and fall method.

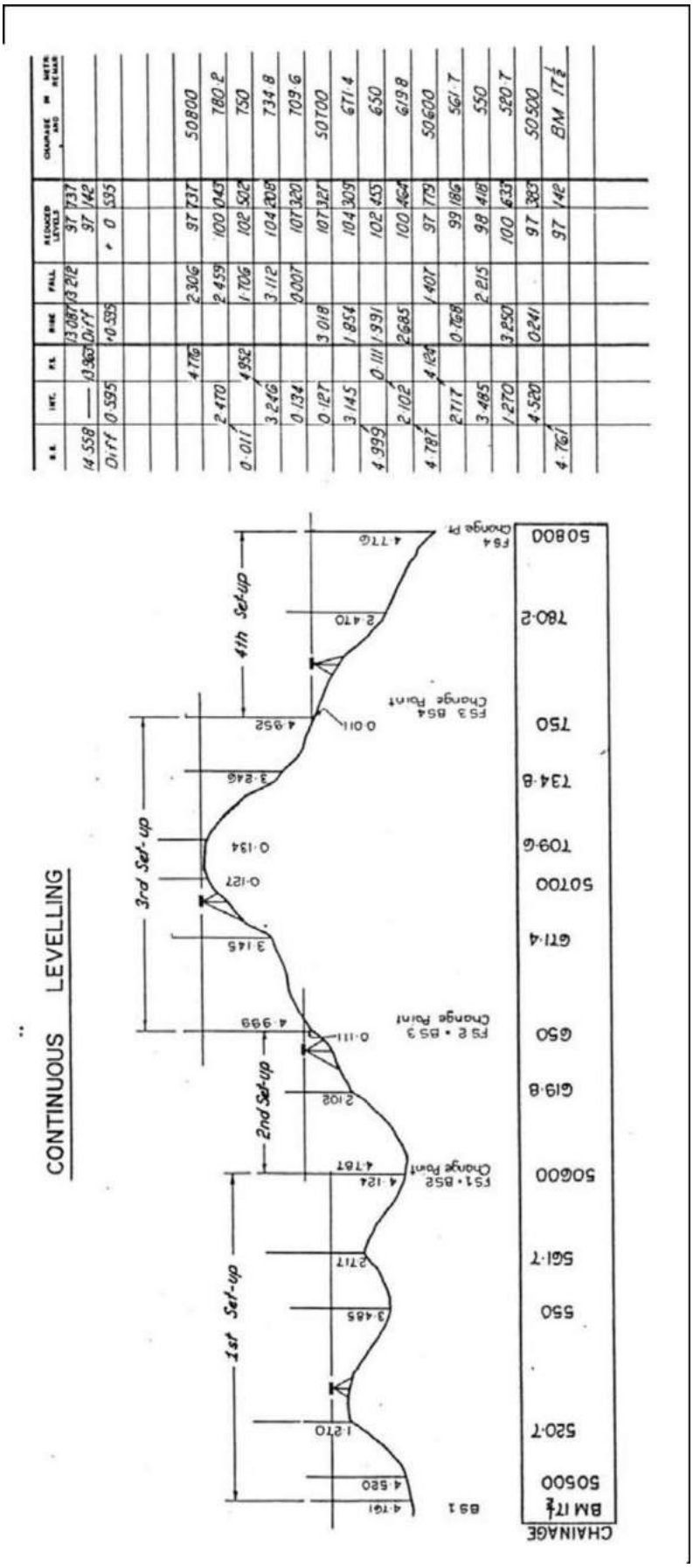

CONTINUOUS LEVELLING
1st Set-up
2nd Set-up
3rd Set-up
4th Set-up
BS 1
FS 1 • BS 2
Change Point
FS 2 • BS 3
Change Point
FS 3 BS 4
Change Point
FS 4
Change Pt
CHAINAGE
BM 17½
50500
520·7
550
561·7
50600
619·8
650
50700
671·4
709·6
734·8
750
780·2
50800

Figure 6.7

The same line of levels as used in the rise and fall method (Figure 6.8) can be used as follows.

To reduce the levels it is first necessary to determine the reduced level of the line of sight and enter same in the Height of Instrument column.

In the example the reduced level of BM 17½ is known to be 97.142 and the observed staff reading to that point is 4.761 (i.e. the line of sight of the level is 4.761 m above BM 17½). By adding the staff reading 4.761 to reduced level 97.142 we find the Height of Instrument for the first set up to be 101.903.

To obtain the reduced levels of the other points observed from the 1st set up it is necessary to subtract the staff readings at these points from the H. of I. Point 50 500 is 4.520 m below the line of sight, therefore it's R.L. = 101.903 – 4.520 = 97.383 and similarly at 50 520.7 the RL = 101.903 – 1.270 = 100.633.

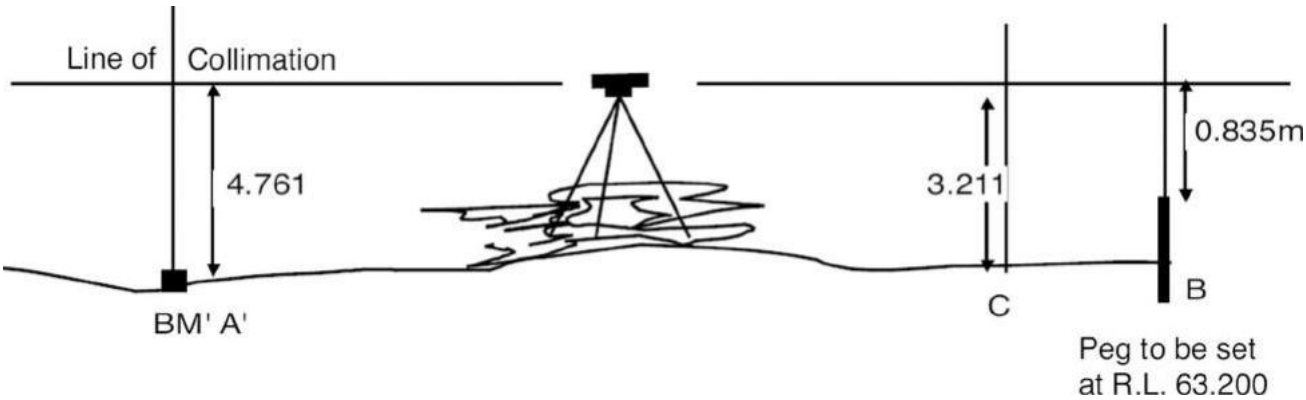


Figure 6.8 Height of Collimation

In this way all INT points are levelled and finally the reading onto F.S.I. is booked and the level (97.779) calculated.

The instrument is then moved and consequently a new H. of I. has to be determined. The R.L. at 50 600 has been calculated to be 97.779 and the staff reading to this point from the second set up is 4.787. Therefore the H. of I. for the 2nd set up is 97.779 + 4.787 = 102.566.

Reduced levels of other points observed from the 2nd set up are obtained as before by subtracting the staff readings at these points from the new H. of I. This procedure is repeated for each set up.

When the reductions are completed a check similar to the Rise and Fall check is applied by summing the B.S. and F.S. and deducing the difference. This difference must equal the difference between the first and last reduced level (0.595 in both cases).

In the Rise and Fall method this check proves the correctness of all reduced levels but in the case of the H. of I. method it serves as a check only on change point values (i.e. B.S. and F.S. readings). It does not prove the correctness of points which were observed at Intermediate sights.

Setting out of curves

Setting out horizontal circular curves

The following methods of setting out horizontal circular curves may be used:

(a) If the radius is small and the centre has been located, the curve may be set out by pegging one end of the tape at the centre of the curve and marking points on the curve by swinging the tape with the required radius. (See Figure 6.9)

(b) Accurate marking of short curves on formwork can be done by using a light piece of timber instead of the tape in method (a).

(c) Referring to Figure 6.9 if the radius is less than the tape's length and the two pegged lines (AC and BC) intersect to form a right angle at C (e.g. a turnout) set out is simple, as the tangent length equals the radius. Place pegs at A and B such that AC and BC equal the required radius of the curve. Place a peg at O using a tape (or 2 tapes) held so that AO and BO equal the radius. The peg O is at the centre of the curve.

Mark the curve with as many pegs as are needed.

Then fix the zero of the tape at point O, and holding the tape at the radius length swing through the curve from A to B marking with as many pegs as are required to satisfactorily build the job. (Points A and B are the "tangent points" of the curve, and lines AC and BC are the "tangents".)

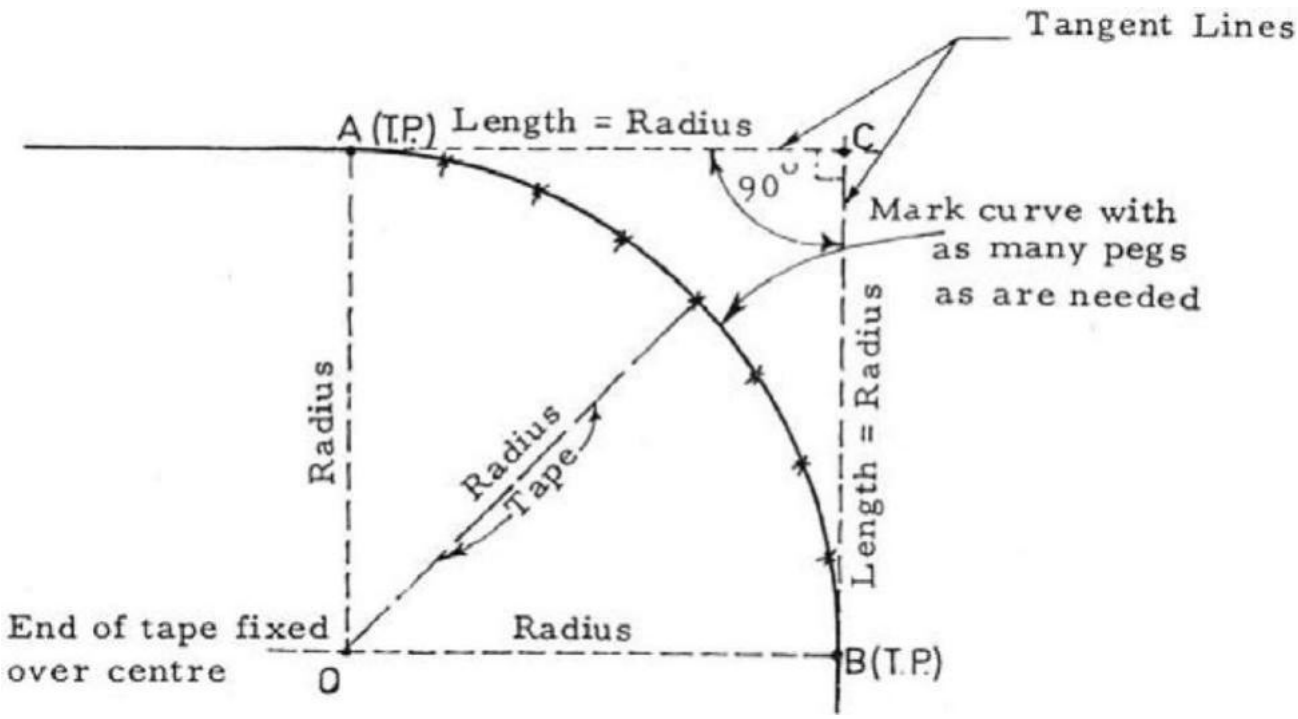


Figure 6.9

(d) Short Circular curves (Figure 6.10) may be set out by offsetting from the tangent lines using the formula offset

e.g. Offset

$$EB = \frac{l^2}{2R} = \frac{(AE)^2}{2 \times Radius\ of\ curve}$$

To minimise the chance of error, it is advisable to set out half the curve from each tangent point.

This method is most applicable in areas relatively clear of trees and obstructions.

Exercise caution as this method is not suitable for small radius curves.

(e) The properties of chords may be utilised to set out curves in heavily timbered country, and to reinstate missing ℄ pegs on a curve. (A chord is the straight line joining any two points on a curve.) See Figure 6.11.

To set out circular curves by chords, the line from which offsets are measured is taken over the 2 previous pegs and produced the chosen chord length.

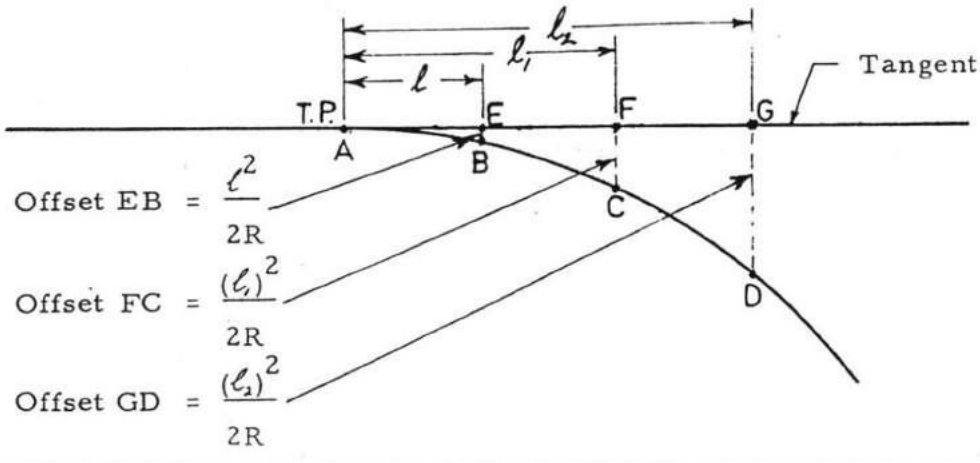


Figure 6.10: Setting Out Short Circular Curves

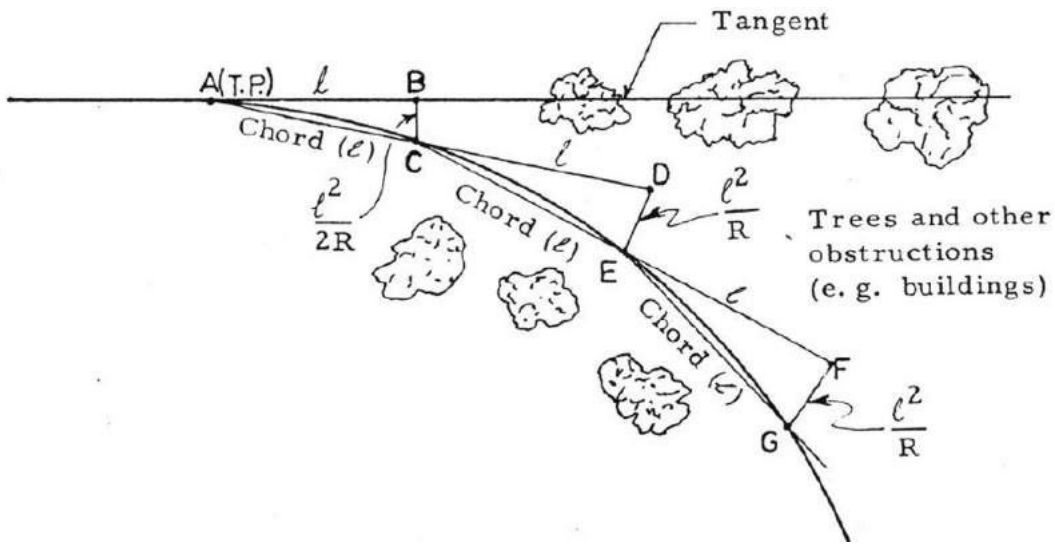


Figure 6.11

The first offset (from the tangent line)

$$= \frac{(Chord)^2}{2 \times Radius} = \frac{l^2}{2R}$$

Subsequent offsets (i.e. twice the first offset)
To minimise errors set out half the curve from each tangent point.

This method is approximate and should **not** be used for setting out very long curves. Its main use is in re-establishing missing sections. 11AT gives example of the use of this method.

Lengths over 100 m must be reinstated by the Engineer or Surveyor using a theodolite.

An alternative use of chords in reinstating sections of circular curves is illustrated in Figure 6.12. The method requires that the radius of the curve is known.

Range in the chord joining the existing pegs (A and B), setting out the three-quarter points (D, E and F) of the chord.

Set out the offsets DG, EH and FJ such that

$$EH = \frac{(Chord)^2}{8\,Radius} = \frac{1^2}{8R}$$

$$DG = FJ = \frac{3}{4}EH$$

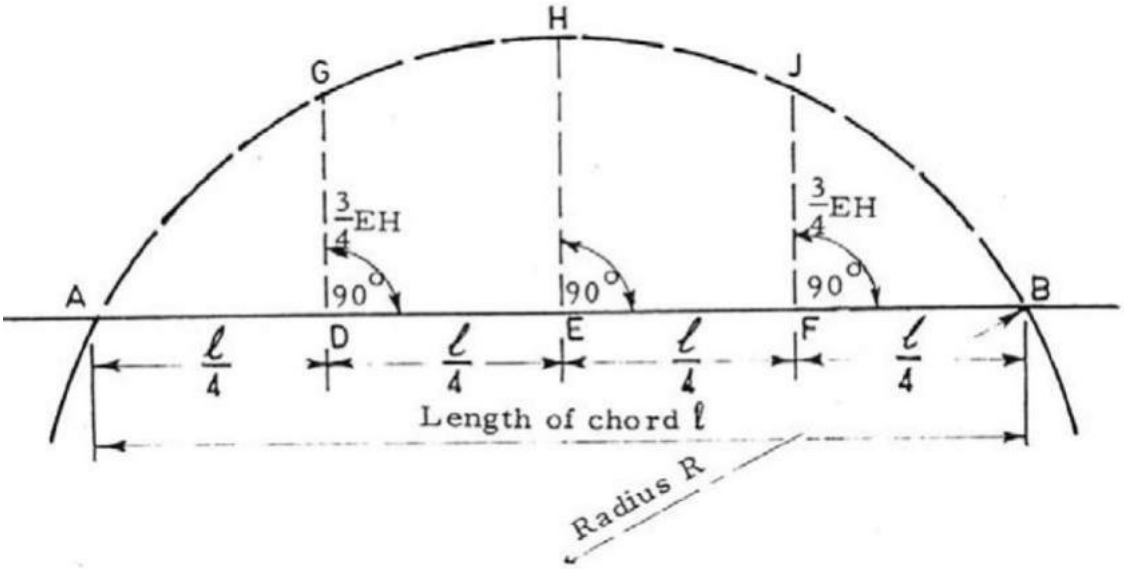
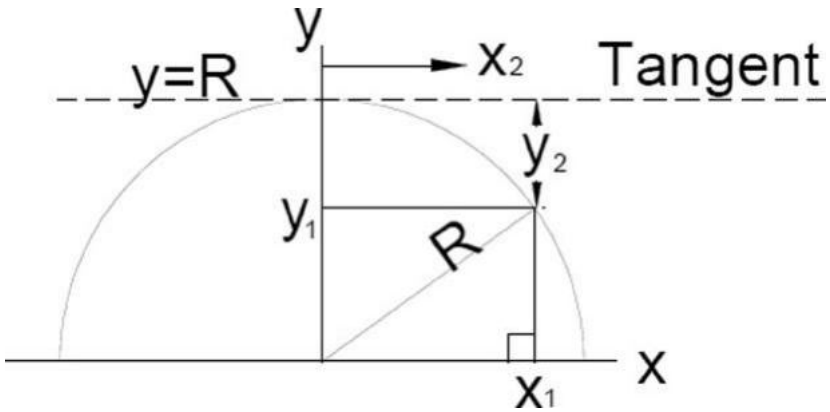


Figure 6.12: Reinstating Missing Sections of Circular Curves for Large Radius Curves

Accurate method for setting out curve from a tangent



Equation of Circle: $R^2 = x^2_1 + y^2_1$

Equation of Tangent Line: y = R

Offsets from Tangent Line:

$y_2 = R - \sqrt{[R^2 - x^2_1]}$

Thus for any Radius Curve offsets from tangent line can be calculated by the formula on a small standard calculator with a square root key “√”.

Example
Curve Radius 500m

Calculate offsets from tangent at 25m intervals for chord shown above.

$y_2 = R – \sqrt{[R^2 – x^2_1]}$

Set up table below:

Calculate offset from Chord A – B at a, b, c

Note:

$a = y_3$ at 75	therefore a = 5.675
$b = a - y_1$	therefore b = 5.675 – 0.625 = 5.050
$c = a – y_2$	therefore c = 5.675 – 2.506 = 3.069

Optical square – a simple survey instrument

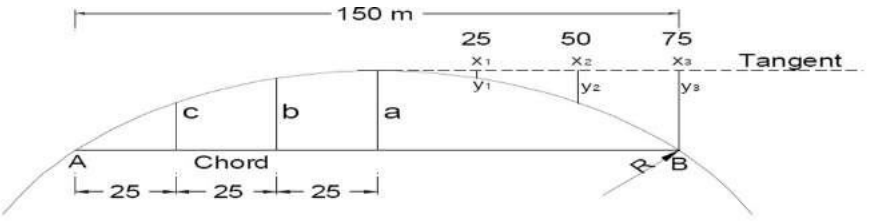
The optical square is a small hand-held instrument used for setting out approximate right angles. The accuracy attainable depends on the user’s experience and the care exercised in:

(a) Holding the optical square directly above the mark.

(b) Sighting along the reference line.

Any ray of light entering the optical square is turned, by mirrors or a prism through a right angle, so that the user looking into the eyepiece sees objects at right angles to the direction of his line of sight. See Figure 6.13.

Optical squares are lightly constructed and the mirrors or prisms are glued in position. They should be handled and transported with care.



1	2	3	4	5	6	7
x_1	R	R^2	x^2_1	$R^2 - x^2_1$	$\sqrt{[R^2 - x^2_1]}$	y_2 Col 7=2-6
25 x_1	500	250,000	625	249,375	499.375	0.625 y_1
50 x_2	500	250,000	2,500	247,500	497.494	2.506 y_2
75 x_3	500	250,000	5,625	244,375	494.343	5.675 y_3

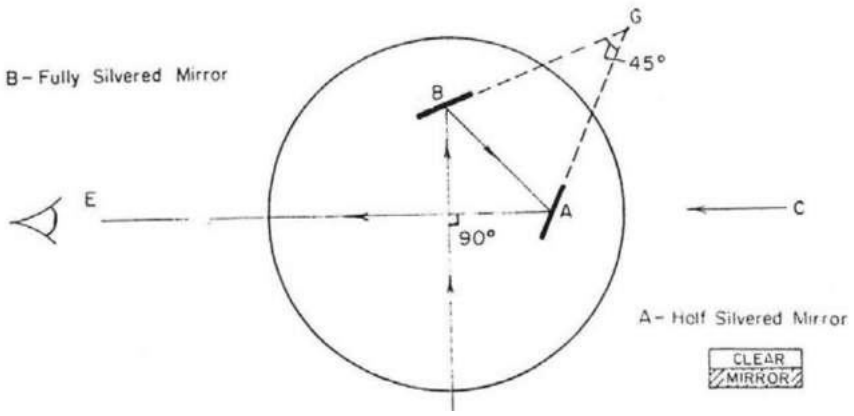


Figure 6.13

Because of its construction and possible user inaccuracy, the optical square should not be used when the right angles are required for important work such as structures. The accuracy attainable is in order of 0.01 m in 30 metres.

Using the optical square

The method of using the optical square is as follows:

- The operator stands on the reference line, just behind the mark from which a square off is required, and facing along the reference line. (In most cases the reference line is the road centre line.)
- The operator next brings the optical square up to their eye, so that the instrument is directly above the mark, with the eyepiece at the eye.
- The operator then looks through the eyepiece at a distant point on the reference line. Objects at right angles to this line can now be selected in the mirrors.

Whilst in this position, if the optical square is rotated slightly to the left and right and it will be noted that the selected objects at right angles remain in position, so that the line of the optical square is not critical.

The optical square can also be used to place the observer on line between two given marks in the following manner:

- Select any position on the ground approximately on line.
- Stand side on to the line looking ahead at approximate right angles to the line, (i.e. face one shoulder to mark 1 and the other to mark 2). (Figure 6.14)
- Bring the optical square to the eye and observe the right angle position as viewed. Walk slowly backwards or forwards until the Marks 1 and 2 both appear as being at right angles.
- Mark this point and then face in the opposite direction and repeat the operation, marking the second point at which the Marks 1 and 2 appear to be at right angles.

Half way between the two selected points is on the line between Mark 1 and 2.

Theoretically the selected points should coincide but slight differences are usually found.

A **steel square** is reasonably accurate.

Other methods of setting Right Angles

Place a string line along the marked centre line and place one edge of the square along the string line. Use a tape along the other edge and with the aid of a plumb bob, place the offset peg at the required distance, say 10 metres or whatever distance gives a minimum of a metre from the excavation.

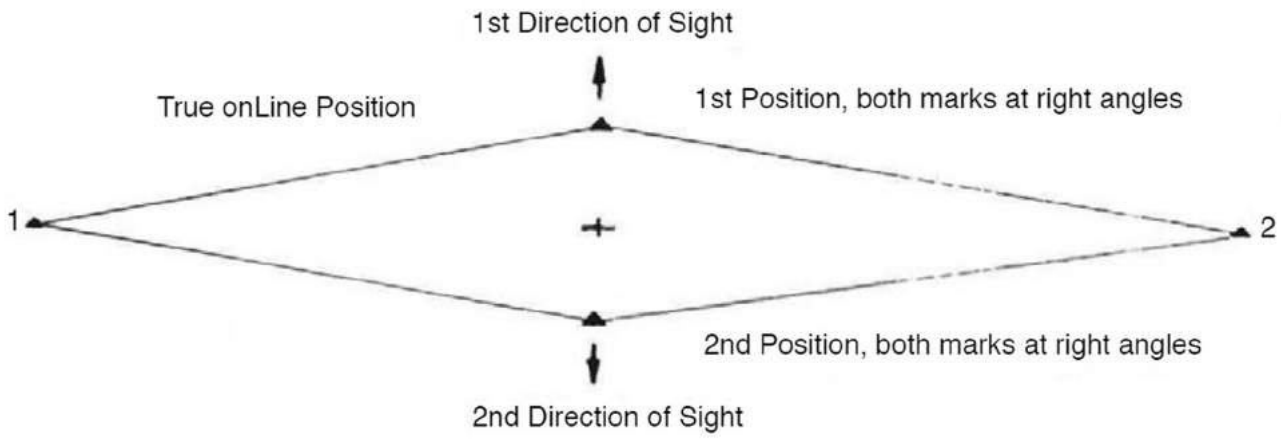


Figure 6.14

If a steel square is not available, a boning rod in good order is a suitable substitute.

An **alternative** to the above is to make one's own **right angle with timber** in the form of a triangle with sides in the proportion 3: 4: 5.

Measure 4 units along one piece of timber approximately 75mm x 25m, measure 3 units along another and place at an approximate right angle, measure 5 units on a 3rd piece of timber and adjust the first 2 pieces to fit the 5 unit piece.

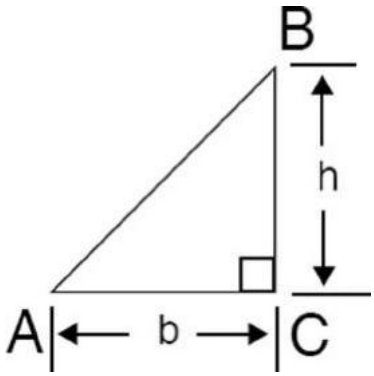
Nail all 3 together and trim off unwanted overhangs.

All measurements should be on the outside edges.

(c) **A pocket right angle** can be made with a string line, by measuring as above and knotting at each angle. By pulling the string tight at each knot a right angle is formed.

(d) Suitable measurements for the above are as follows:

Triangle



AB = 5 units say 500 or 1500 mm
BC = 4 units say 400 or 1200 mm
CA = 3 units say 300 or 900 mm

Boning rods

Offsetting in flat country

In flat country in the absence of a level, satisfactory results can, with care, be obtained by the use of boning rods and tape.

The centre line crown level is first established and then offsets are put in at right angles one on each side of the centre line. The two offset pegs must be in a straight line at and right angles to the road centre line and at the same distance away from the centre line.

The offset pegs can be of any height, provided that the line of sight across the tops of the rods is straight. (Refer Figure 6.15).

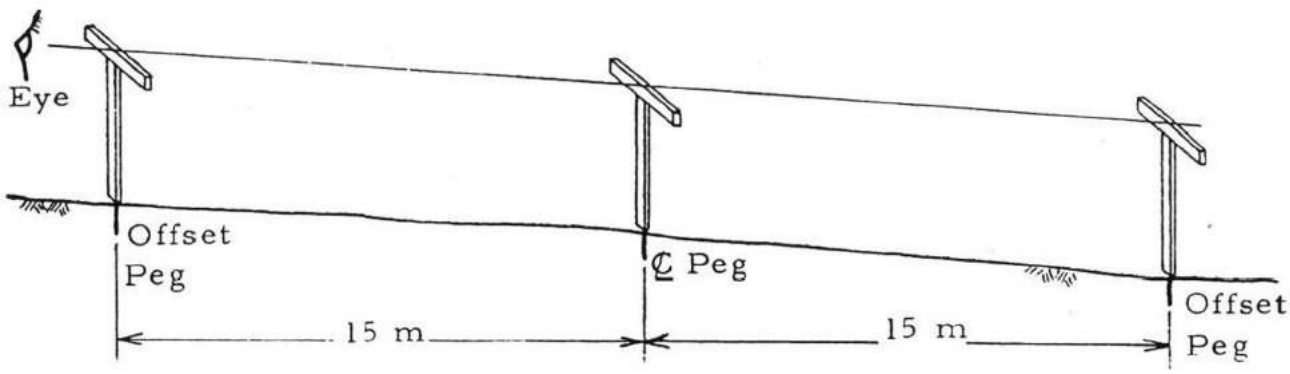
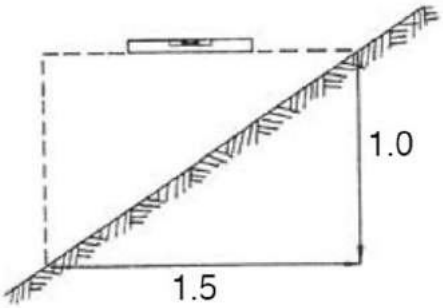


Figure 6.15

The practice of putting two pegs on one side of the centre line from which to bone back can give inaccurate results if the two pegs are placed closer than 8m apart. There are however, times when it is necessary to have both offset pegs on one side, e.g. in hilly country where side slopes are steep. (Refer Figures 6.16).

Batter profile
Slopes are shown as the horizontal distance in relation to 1 unit of vertical distance.

A common slope is 1 to 1.5 as below:



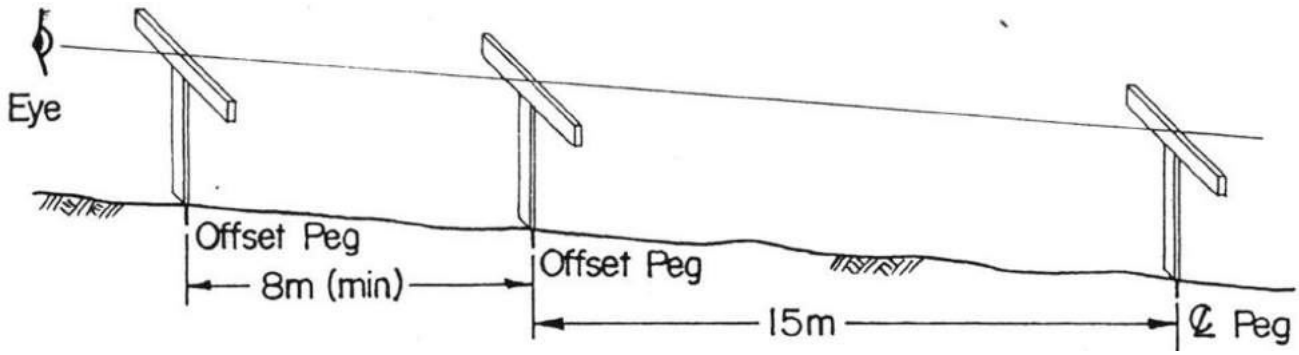


Figure 6.16

To check a batter, make a template out of timber with sides, say, 1 metre and 1.5 metres.

Use the template as shown dotted above and place a spirit level along the top edge to make it level, so determining whether the slope is correct.

Transfer of levels
When offset pegs are placed, their height in relation to the centre line peg must be determined before excavation or fill commences.

Whether for this or other purposes, using modern survey equipment is the most accurate method of transferring levels, however the following techniques are often adequate:

(a) Use of **spirit** or **smart levels** is restricted by the length of the straight timber avail- able. It is hard to store and retain long lengths of straight timber, so use is generally restricted to a few metres. Intermediate pegs may therefore need to be used.

Spirit levels should be regularly checked for accuracy by placing the level in the reverse direction once the first level position is set.

It is important to keep up with current technology.

KEY MESSAGES
- **Ask questions**
- **Understand the job**
- **Take the time to set out accurately**

CHAPTER 7
MEASUREMENT OF AREAS AND VOLUMES, AND PAVEMENT CONSTRUCTION CALCULATIONS

Common symbols:

Area	A	Greater than	>
Volume	v	Less than	<
Height	h	Greater than or equals	≥
Pi	π	Less than or equals	≤
Square root	√	Not equal to	≠
Percent	%	Sum	∑

To enable ordering of materials for future work, the Supervisor must be able to calculate required quantities. A simple rule of thumb is to break down sites into smaller sizes.

The area of a regular shape such as a square or rectangle is simply obtained by multiplying length by breadth, but make sure all the measurements are in the same units (for example, metres).

Triangles are a little more difficult, with their area always being half the base, times the height.

Formulae to calculate areas of various shapes

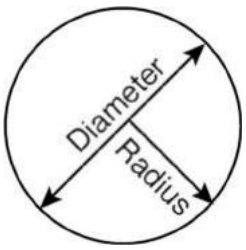
Circles involve a number called "pi" π, which is approximately 3.14 or 22/7.

$A = \pi r^2$
e.g. Radius 3m
$\pi \times 3 \times 3 = 28.27m^2$

Areas

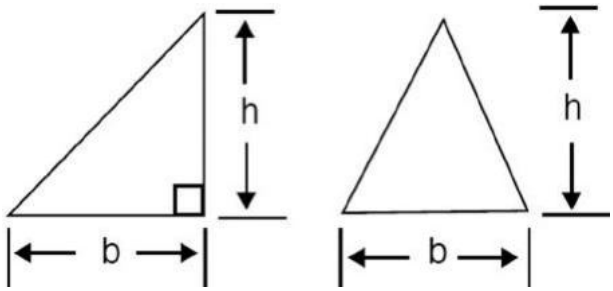
Circle

$$A = \frac{\pi d^2}{4} = \pi r^2 \text{ or } 0.784d^2$$



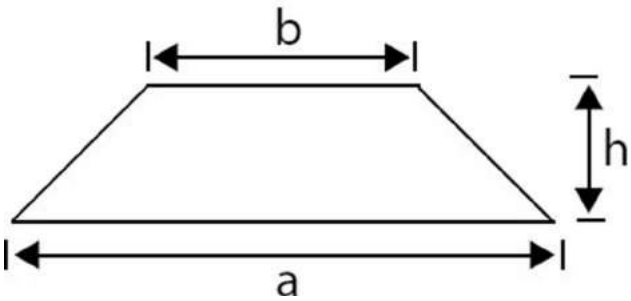
Triangle

$$A = \frac{bh}{2}$$



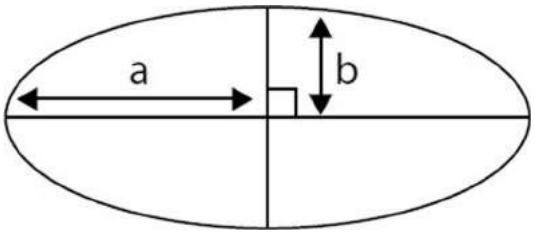
Trapezium

$$A = \frac{(a+b)h}{2}$$



Ellipse

A = πab
a = ½ Major Axis
b = ½ Minor Axis



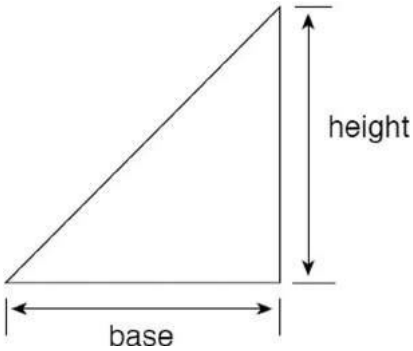
Right Angle Triangle

$a^2 = b^2 + c^2$

E.g. a = 3 a^2=9

b = 4 b^2=16

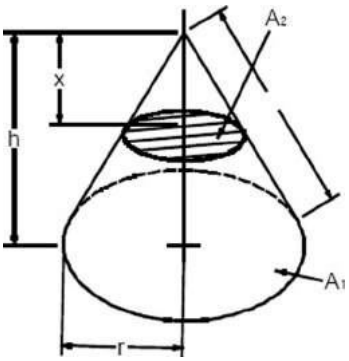
c = 5 c^2=25



Volumes

Cone

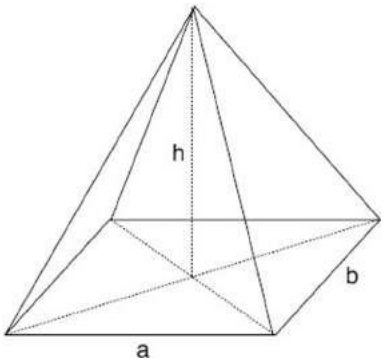
V = 1/3 π r 2h



Square Pyramid

V = 1/3 Bh

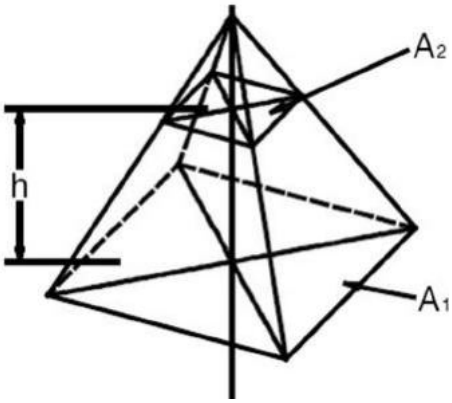
B = Area of base (a x b)
h = height of pyramid



Earth Tank

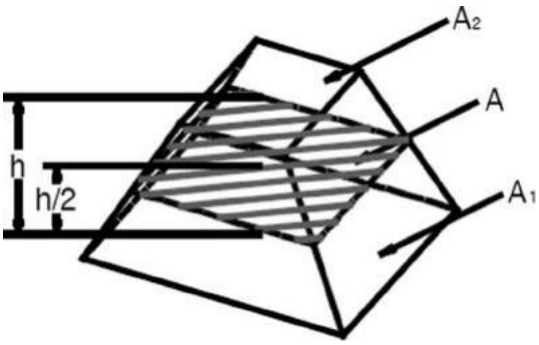
V = h/3 [A_1 + A_2 + √(A_1. A $_2$)]

(frustum of Pyramid)



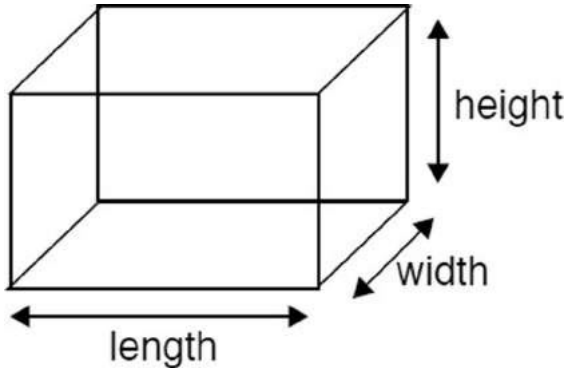
Prismoid

V = h/6 [A1 + A2 + 4A]



Cuboid

V = length x width x height



Occasions will arise when a shape is more complex than described above, such as with kerb and channel or mountable kerb. It is still easy to calculate volumes if you know the cross sectional area. For example, if kerb & channel, when viewed from the end, has a cross sectional area of 0.09 square metres, the volume of concrete needed to construct 100 metres is:

0.09 x 100 = 9 cubic metres

As the cross sections vary in different Councils, it will be necessary to ask for the local figure.

Once a few jobs have been measured, it will perhaps be easier to note how far 1 cubic metre of concrete goes.

Measuring volume on a truck

Determine volume of body with hoist well in body. Refer to drawing of truck body with hoist well (Figure 7.1).

Step 1: Calculate volume of truck body
Volume = Length x Width x Depth
= 5.96m x 2.31m x 0.91m
= 12.529m^3

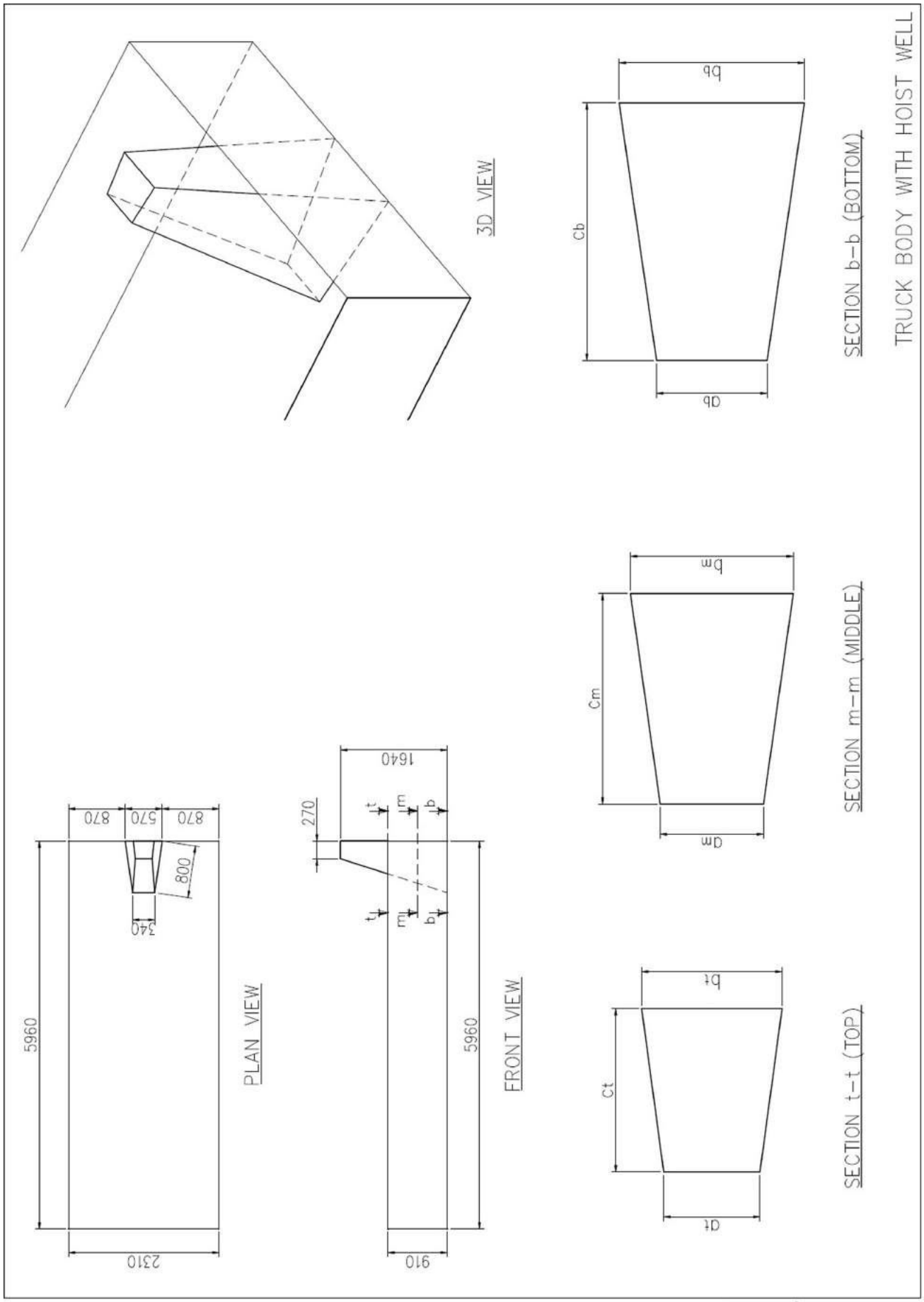

3D VIEW
SECTION b–b (BOTTOM)
TRUCK BODY WITH HOIST WELL
bb
Cb
Qb
SECTION m–m (MIDDLE)
bm
Cm
Qm
SECTION t–t (TOP)
bt
Ct
Qt
PLAN VIEW
5960
2310
870
570
870
800
340
FRONT VIEW
1640
270
910
5960
t
m
b

Figure 7.1

Step 2: Calculate volume of hoist well in truck body

Formula:

Volume of Prismoid

h = Height

Vol = $H/6\ [A_T + A_R + 4A_M]$

A_T = Area of Top

A_R = Area of Bottom

A_M = Area of Middle Section

For Hoist Well

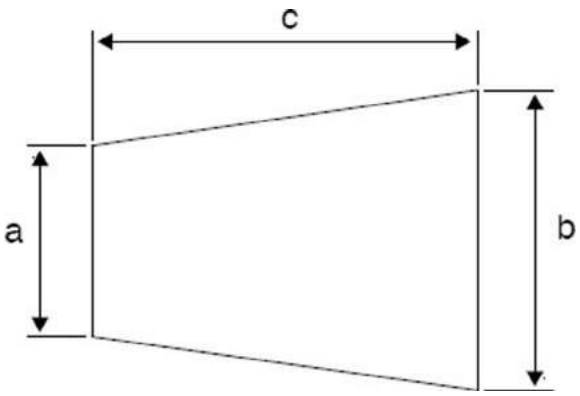
A_T = Area of Well Section at Top of Truck
(Refer to Section t-t (TOP)

A_B = Area of Well Section at Bottom of Truck
(Refer to Section b-b (BOTTOM)

A_M = Area of Well Section at Mid Height of body
(Refer to Section m-m (MIDDLE)

Area of trapezium

$$\text{Area} = \frac{(a+b)}{2} \times c$$



Hoist well measure dimensions:

At Sections t-t, m-m, b-b.

A_T *Top of body* a = 295mm b = 431mm c = 560mm

$$A_T = \frac{(0.295 + 0.431) \times 0.56}{2}$$

= 0.36 x 0.56

= 0.203 m²

A_B *Bottom of body* a = 340 b = 570 c = 800

$$A_B = \frac{(0.34 + 0.57) \times 0.800}{2}$$

= 0.455 x 0.800

= 0.364 m²

A_M *Middle Area* a = 318 b = 500 c = 676

$$A_M = \frac{(0.318 + 0.50) \times 0.676}{2}$$

= 0.41 x 0.676

= 0.277 m²

Volume of hoist well in truck body

Vol = $H/6\ [A_T + A_R + 4A_M]$

h = 0.910m = 0.91/ 6
[0.203 + 0.364 + (4 x 0.277)]

= 0.91/ 6 [0.567 + 1.11]

= 0.91/ 6 x 1.677

= 0.254 m^3

Therefore the net volume of truck body is:

= 12.529 – 0.254

= 12.275 m^3

= 12.30 m^3

Earthworks calculations

- Cuts and Fills
- Borrow Pits
- Stockpiles

Basic definitions

Reference 11AT 03 Engineering
Calculations

- *Cut*: the earth or rock that is removed to permit placing the road below the natural surface of the ground is called cut. The term cut is also used to designate the space originally occupied by the removed material (Figure 7.2a).
- *Side Cut*: A side cut is an excavation forming a bench or shelf in a transverse slope crossing the alignment (Figure 7.2b).

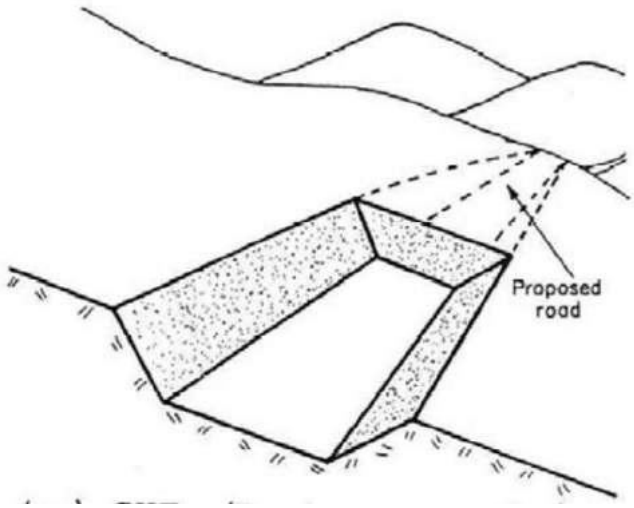


Figure 7.2a: Cut – Roadway Excavation

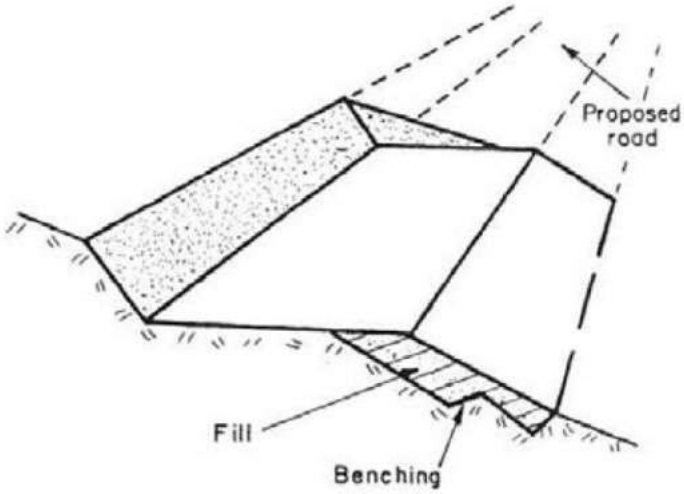


Figure 7.2b: Side Cut

- *Fill*: The bank of earth, rock or other material constructed above the natural surface of the ground for the support of the road, or the space occupied by such material is known as fill or embankment (Figure 7.2c).

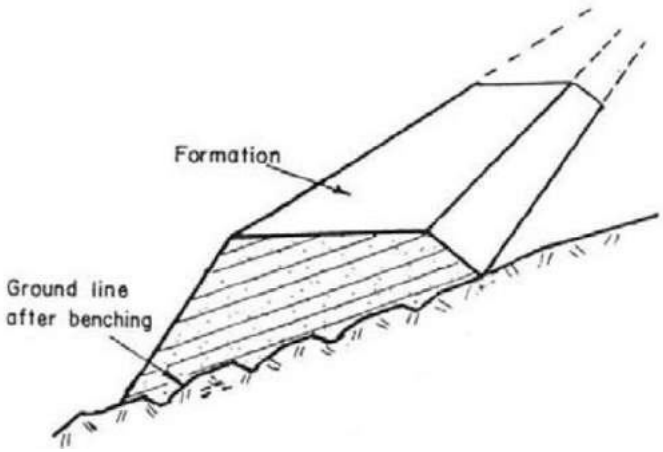


Figure 7.2c: Fill (Roadway Embankment)

- *Subgrade* – The surface to which the cut or fill extends in earthworks construction is the subgrade, which means lower grade. Usually the subgrade is below the selected fill section of the pavement (Figure 7.3).

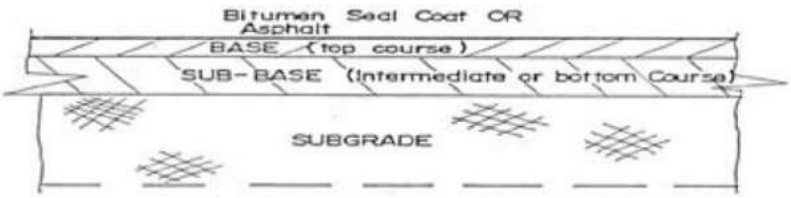


Fig. 1 Cross Section of Typical Pavement

Figure 7.3: Cross Section of Typical Pavement

Earthworks volume calculation

Although modern civil design software has the ability to calculate complex earthworks volumes, it is important to be able to compare the software outputs to the actual cross sections in case there are errors caused by minor discontinuities or clashes within the electronic model.

Volume is obtained by multiplying an **area** by **length**.

In the calculation of the volume of Earthworks we first calculate the area of a cross-section and then multiply by the distance between two cross-sections (i.e. the length) (Figure 7.4).

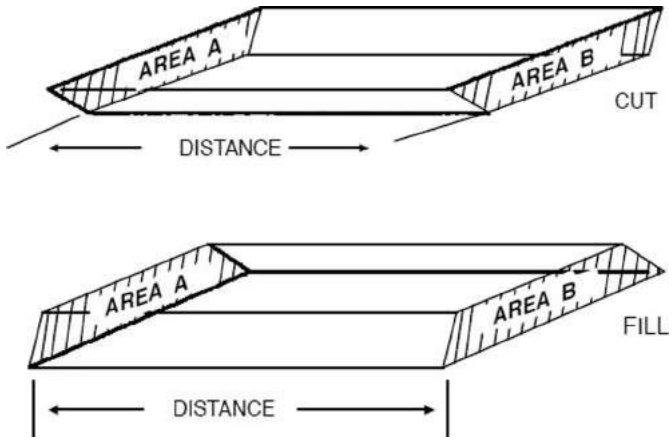


Figure 7.4

In the sketches above, if the end areas A and B of the cut (or fill) **are equal**, the correct volume would be obtained by multiplying either area by the distance D.

However, in practice the end areas are seldom equal – a good method is the **Average end area method** of calculating the volumes of cuts and fills.

Average end area method

In the following sketch showing a length of fill, let Area A and area B represent the areas of the two adjacent cross-sections in square metres, and D the distance in metres between the two cross-sections (Figure 7.5).

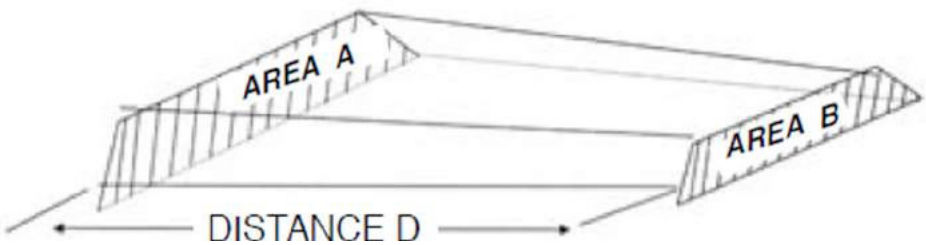


Figure 7.5

Then the approximate volume of the length of fill (in **cubic metres**) is obtained by taking the average of Areas A and B, and multiplying by the distance D, i.e.

$$\text{Volume} = \frac{\text{Area A} + \text{Area B}}{2} \lozenge \text{Distance D}$$

This **average end area method** of calculating volumes may be used to determine the volume of cuts, fills and side cuts as follows:

- Calculate Area A
- Calculate Area B
- Add A and B then divide by 2 to find the **average area**
- Multiply the **average area** by the distance D between the cross-sections.

In using the average end area method for volume calculations it is desirable to use at least every cross-section given in the job documents for the section of roadway under consideration. The omission of any intermediate sections over a length of road can lead to appreciable errors in the volume so calculated.

Example (one section only)
Calculate the volume of Earthworks in the Embankment section shown in Figure 7.6.

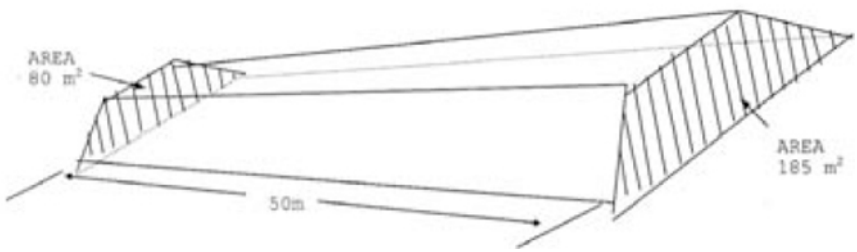


Figure 7.6

Using the Average End Area Formula

$$\text{Volume} = \frac{\text{Area A} + \text{Area B}}{2} \lozenge \text{Distance D}$$

In this example:

- Area A = 80 m²
- Area B = 185 m²
- Distance D = 50 m

Therefore Solid Volume of Earthworks

$$= \frac{(80 + 185) \times 50}{2}$$
$$= \frac{265}{2} \times 50$$
$$= 6\,625\text{m}^2$$

Example (multiple sections)
Details given:
- The embankment shown in Figure 7.7 is divided into segments by plan cross- sections at the chainages shown.
- The formation changes from cut to fill at chainage 220 m and this must be regarded as the first cross-section with an area of 0 m².
- The next cross-section is at chainage 250 m and its area is 45 m².
- Other chainage and area details are as shown.
- At chainage 390m there is a change back from fill to cut. Thus the area at chainage 390m is 0m²

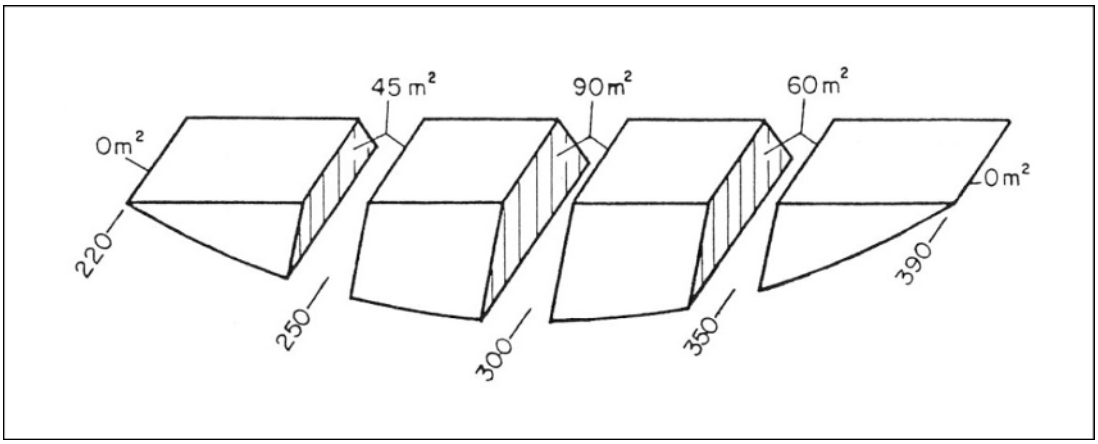


Figure 7.7

So volume of first segment is:

$$= \frac{\text{(sum of the 2 cross-section areas)}}{2} \times \text{distance between them}$$

$$= \frac{0+45}{2} \times (30\,m) = \frac{45}{2} \times 30 = 675 m^3$$

Volume of second segment is:

$$= \frac{45\,\text{(at chainage 250)} + 90\,\text{(at chainage 300)}}{2} \times (50\text{m})$$

$$= \frac{135}{2} \times 50 = 3\,375\,\text{m}^3$$

Volume of third segment is:

$$= \frac{(90+60)}{2} \times 50 = \frac{150}{2} \times 50 = 3\,750\,m^3$$

Volume of fourth (and last) segment is:

$$= \frac{(60+0)}{2} \times 40 = \frac{60}{2} \times 40 = 1\,200\,m^3$$

The total volume of earthworks in the embankment is obtained by adding together the volumes of the individual segments, i.e.

$$\text{Volume} = 675 + 3\,375 + 3\,750 + 1\,200$$
$$= 9\,000\,\text{m}^3$$

Cross section area

The most important calculation in the computation of earthwork volumes is the cross- section area of a cut or fill.

It is normal practice to breakdown the cross-section into rectangles and triangles and to calculate the area of each of them separately and then add them together to find the total area.

Let us now consider the computation of cross-sections in:

- Cuts
- Fills
- Side Cuts

The dimensions and levels normally given on cut and fill cross-sections are as shown in Figure 7.8.

All other dimensions required to calculate the cross-section area are found by computation or scaling off the drawing, if it is drawn to scale.

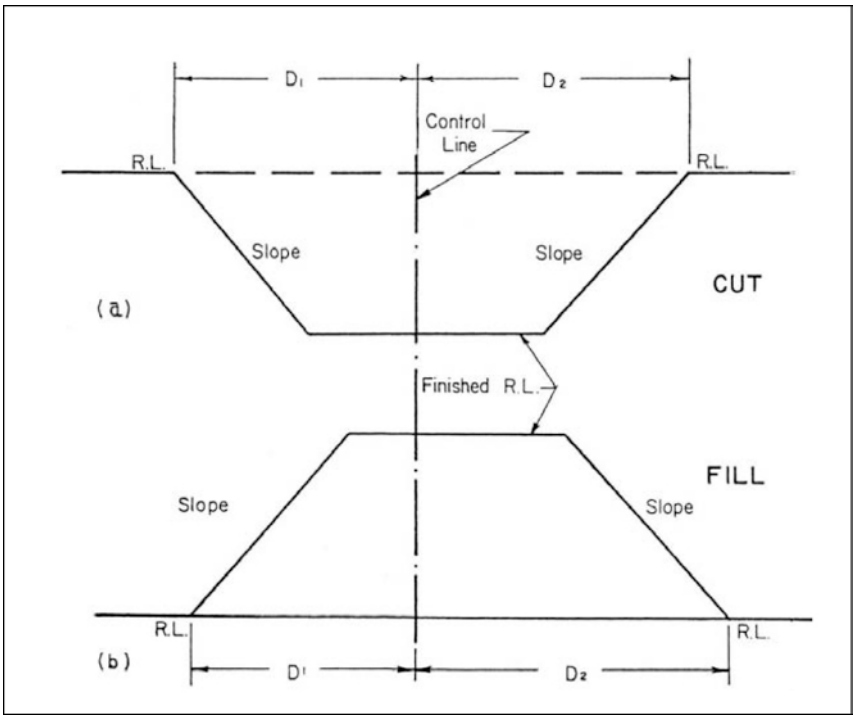


Figure 7.8

To illustrate how we can calculate the other dimensions let us find h, d_1 and d_2 in Figure 7.9.

To find height "h" of the embankment

Subtracting the natural surface (ground) RL from the finished RL of the embankment, we can determine the height bd (i.e. h)

So h = RL 8.00 – RL 0.00

= 8 m

To find width "d" of the embankment

- First find the length ab in the triangle, abd.

  From our basic maths we know that for a right angle triangle with a 1 to 1 hypotenuse slope the base length = height,

  i.e. ab = bd (= h, since bd = h)

  = 8 m

- Next find length bc, since bc = d_1

  We know that bc (i.e. d_1) = D_1 – ab, but distance D_1 is shown on the drawings as 15 m and ab from our calculations = 8 m.

  Therefore to find d_1 (= bc) we take 8 m from 15 m,

  i.e. d_1 = 15 – 8 = 7 m

- Then find d_2

  As the cross-section is equal on both sides of the control line we know that d_2 = d_1 = 7 m so that the formation width is:

  $d_1 + d_2 = d$

  7 + 7 = 14 m

We have now calculated all the dimensions required to find the cross-section area of the embankment.

Types of cross-sections

Let us now consider the various types of cross-sections in cuts, fills and side cuts. They can be divided into:

- *Regular sections*: where the ground is level and the control line is in the centre of the cross-section.

- *Irregular sections*:

  Case 1 – where the ground is level and the control line is not in the centre of the cross-section.

  Case 2 – where the ground is not level and the control line is in the centre of the cross-section.

  Case 3 – where the ground is not level and the control line is not in the centre of the cross-section.

- *Combination sections* where there is a double carriageway embankment that can be a combination of regular and irregular cross-sections.

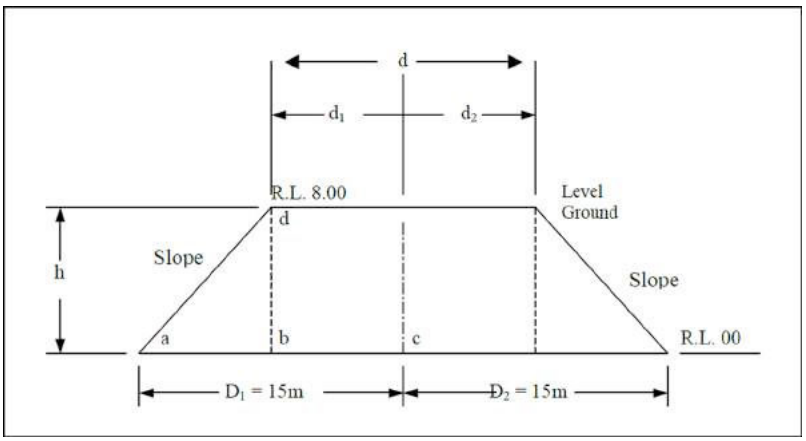


Figure 7.9

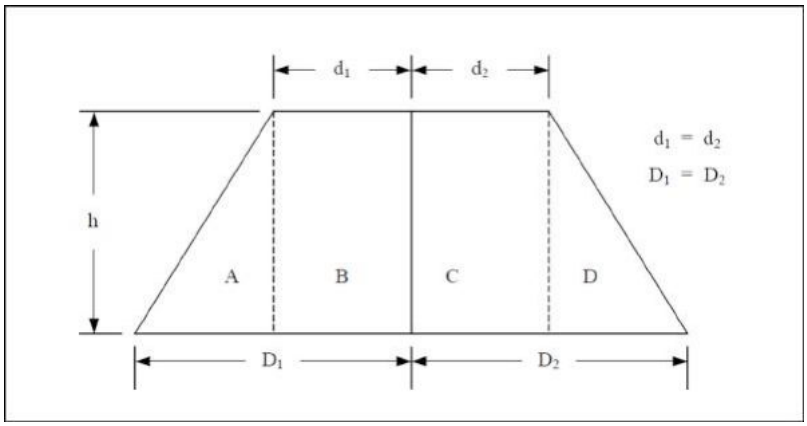


Figure 7.10

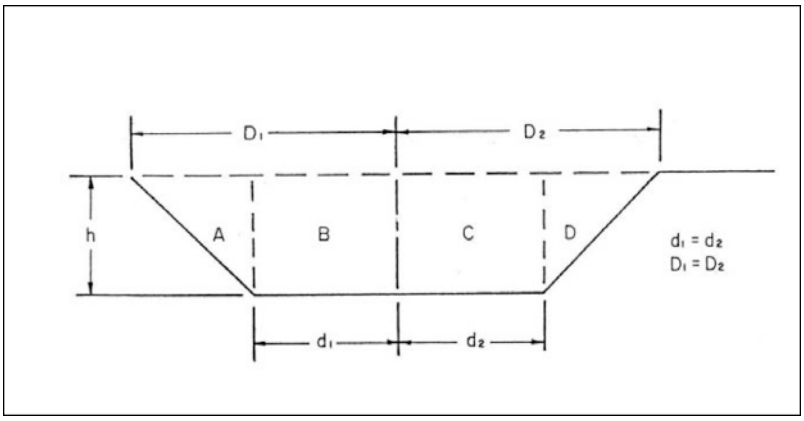


Figure 7.11

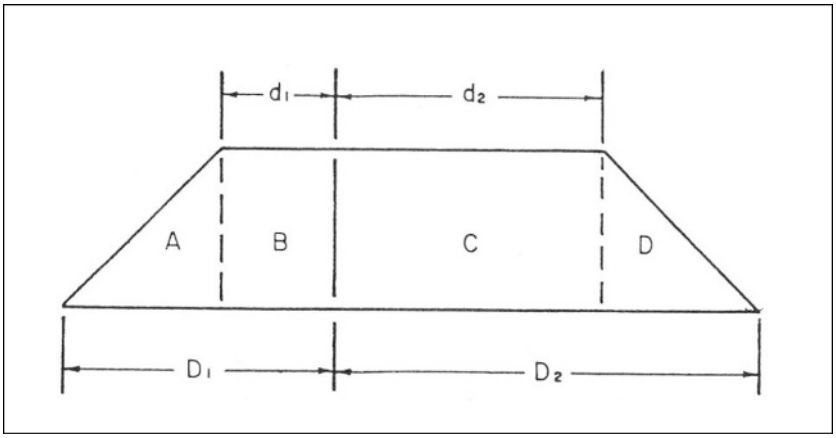


Figure 7.12

Regular cross-sections (fills) (Figure 7.10)

Area A = Area D = $\frac{D_1 - d_1}{2} \times h$

Area B = Area C = $d_1 \times h$

So Total Area of Cross-section

$$= 2\left[\frac{(D_1 - d_1)}{2} \times h - (d_1 \times h)\right]$$

Regular cross sections (cut)

The calculation of areas in cuts of regular cross section is done in the same way as fills of regular cross sections (Figure 7.11).

Irregular cross sections – Case 1

- Regular fill
- Control line offset

Calculate all the areas (A, B, C and D) separately and add to obtain the total cross- section area (Figure 7.12).

Irregular cross sections – Case 2

(Figure 7.13)

- Fill on sloping ground
- Control line central

The areas for A, B, C, D can be found as for a regular cross-section of depth h1.

Next find Area E:

- Step 1: Find h_3
  $h3 = h_2 - h_1$
- Step 2: Find length ab.
  For a slope of 1:1,
  $Ab = h_1 + d_1 + d_2 + h_1$
  But $h_1 + d_1 = D_1$ and $d_2 = d_1$
  Therefore $ab = 2D_1$

$$\text{Step 3: Area E} = \frac{ab}{2} \times h_3 = \frac{2D_1}{2} \times h_3$$

Then add all these areas (A, B, C, D and E) together to find the total cross-section area. The total area may be shown thus:

$$\text{Area} = 2\frac{(D_1 - d_2)}{2} \times h_1 + 2(d_1 \times h_1) + \frac{2D_1}{2} \times h_3$$

Irregular cross sections – Case 2 (contd.)

- Cut on Sloping Ground
- Control Line Central

This Cut Cross-Section area is calculated in the same manner as the fill on sloping ground with control line central.

Irregular cross sections – Case 2 (contd.)

- Side Cut
- Control Line Central

$$\text{Area A in } \underline{\text{Cut}} = \frac{D_1}{2} \times h_1$$

$$\text{Area A in } \underline{\text{Fill}} = \frac{D_2}{2} \times h_2$$

Irregular cross sections – Case 3
(Figure 7.15)
- Fill on sloping ground
- Control line offset

Calculate Area A, B, C, D in accordance with Irregular cross-section – Case 1, i.e. regular fill with control line offset.

Next find Area E

- Step 1: Find h_3

  $h_3 = h_2 - h_1$

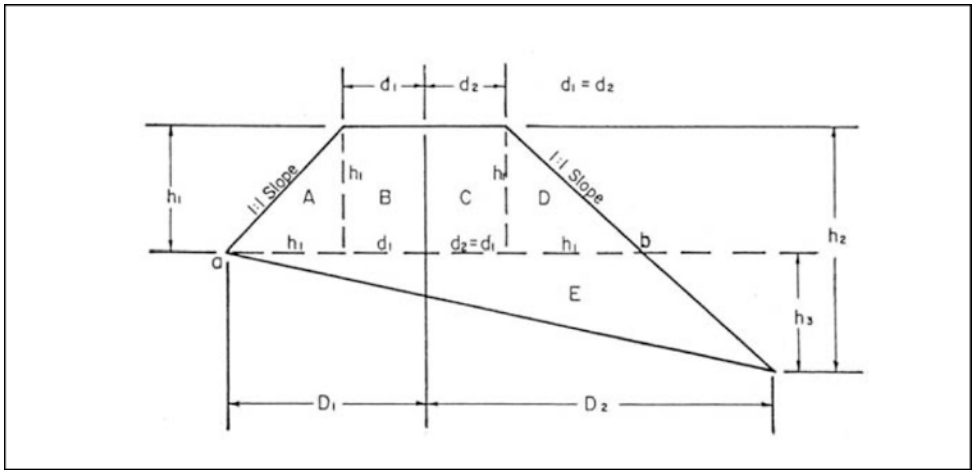


Figure 7.13

- Step 2: Find length ab

  For a slope of 1:1

  $ab = h_1 + d_1 + d_2 + h_1$

  $= 2h_1 + d_1 + d_2$

- $\text{Step 3: Area E} = \frac{2h_1 + d_1 + d_2}{2} x h_3$

Then add all these areas (A, B, C, D, and E) together to find the total cross-section area.

Irregular cross sections - Case 3 (contd.)
- Cut on sloping ground
- Control line offset

The cut cross-section area is calculated in the same way as for fill on sloping ground with control line offset (Figure 7.16)

Irregular cross sections - Case 3 (contd.)

(Figure 7.17)

- Side cut.
- Control line offset.

$$\text{Area A in Cut} = \frac{D_1 + D_3}{2} x h_1$$

$$\text{Area B in Fill} = \frac{D_2 - D_3}{2} x h_2$$

Combination sections

(Figures 7.18a and 7.18b)

The steps in calculating the total cross-section area of combined sections are as follows:

- Divide the area into segments as shown in Figure 7.18b.
- Calculate the area of each segment.
- Add together the areas of all segments.

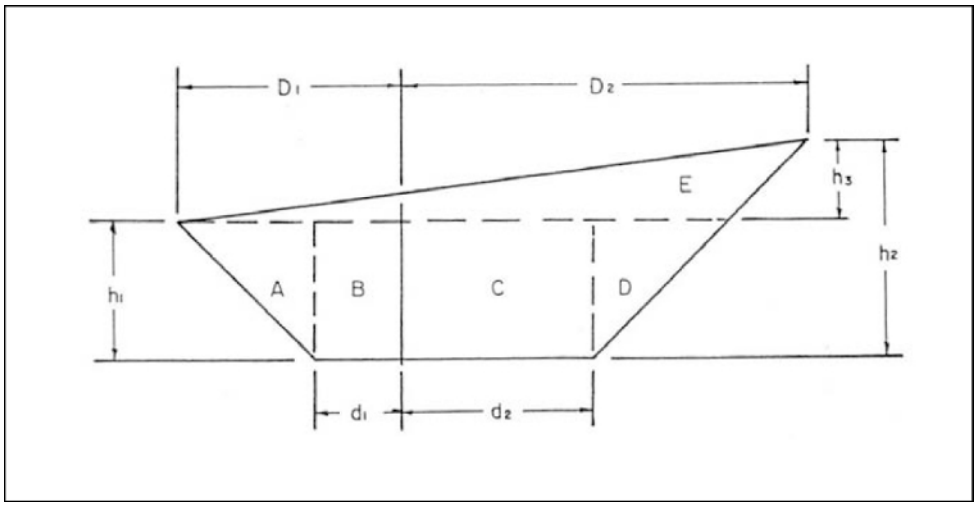


Figure 7.14

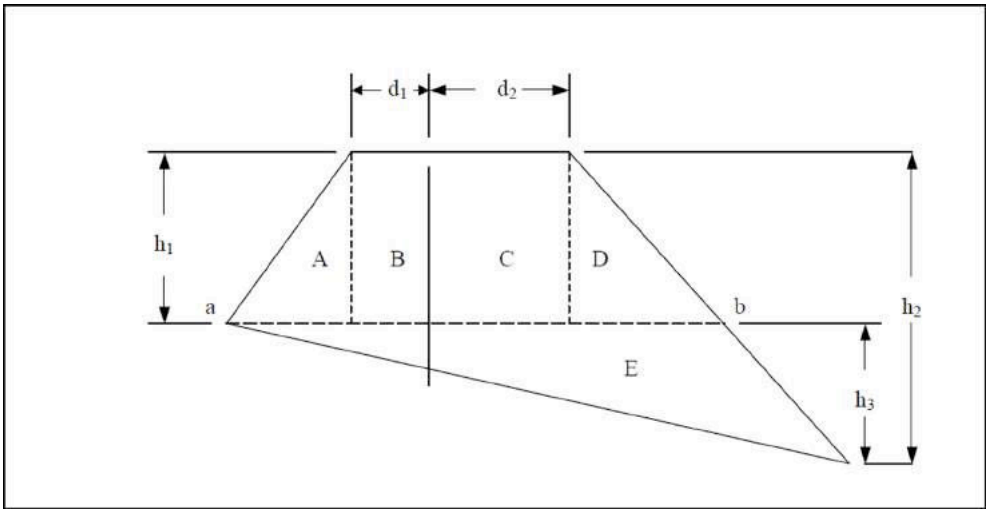


Figure 7.15

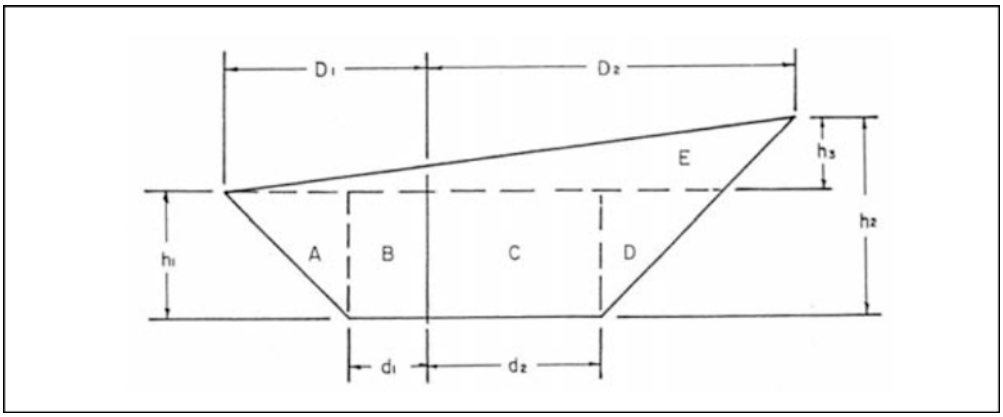


Figure 7.16

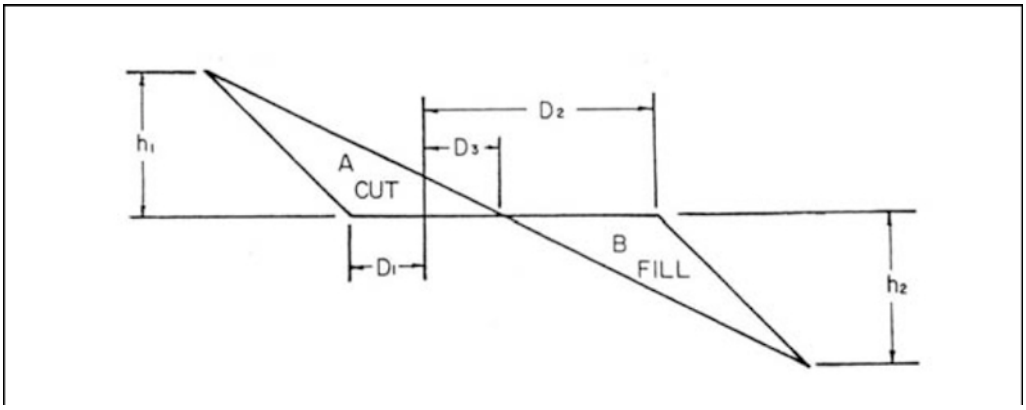


Figure 7.17

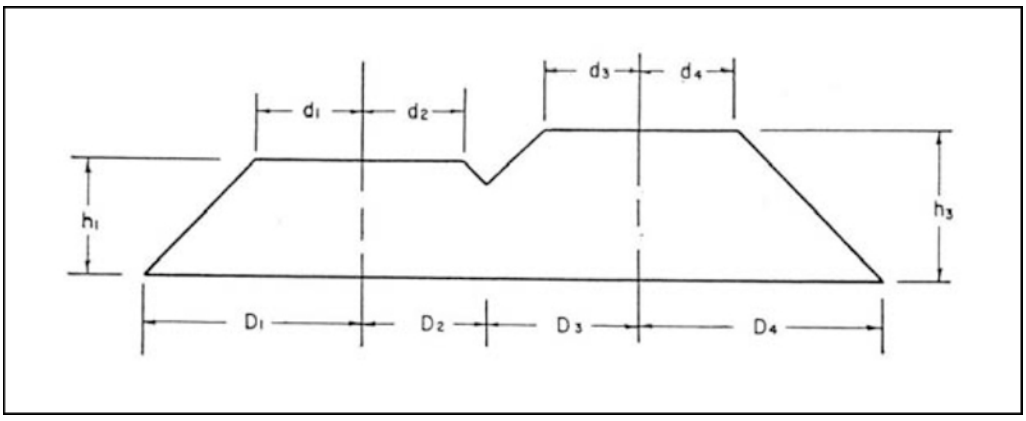


Figure 7.18a

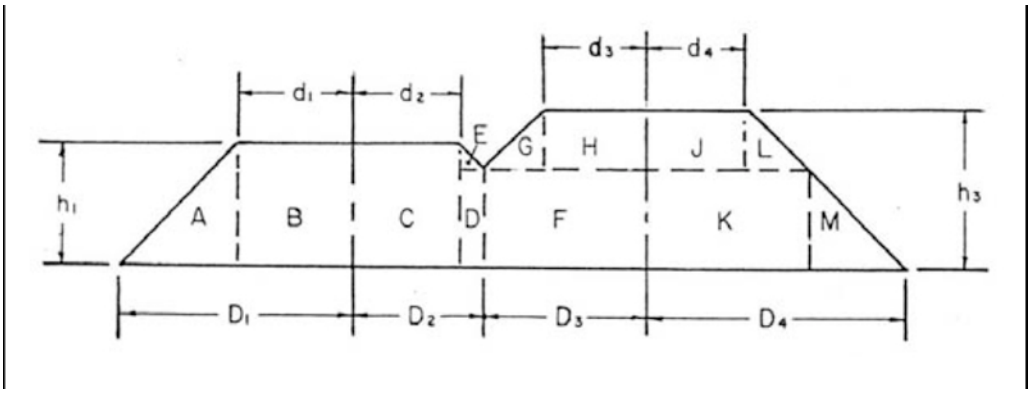


Figure 7.18b

Paving calculations

Introduction

The previous section on Earthworks Calculations covered the various methods used to calculate the volume of earthworks and the volumes of materials in borrow pits and stockpiles.

The calculations of the quantities involved in pavement construction will be illustrated by working through an example, and in doing so references will be made to various machine outputs.

Example

Calculate the quantities involved in constructing a road pavement specified as follows:

- Pavement to have compacted depth of not less than 250 mm and be constructed in 2 layers.
- Length of section – 4.8 km (i.e. 4800 m)
- Formation width – 7.4 m

Given also that:

(1) The soil aggregate paving material is a sandy gravel.
(2) The gravel pit is 5.6 km (5600 m) from one end of the job.
(3) The gravel is suitable for both top and bottom courses.
(4) The gravel only extends for a depth of 1.5 m (including 150 mm of overburden) and then runs into a clay band.
(5) Stripping overburden and stockpiling gravel will be carried out by a Caterpillar D7C dozer.
(6) The gravel is to be loaded with one Caterpillar 950 rubber tyred front-end loader with a rated bucket capacity of 1.9 m^3
(7) Gravel hauling is to be by trucks of 8 m^3 capacity.
(8) Grader – mould board length of 3.7m.
(9) Rollers –

(a) smooth drum (2.1 m wide), vibrating

(b) Pneumatic Tyred – cover width 1.8m.

Gravel requirement

Volume of compacted gravel required

= Length x breadth x depth

= 4800m x 7.4 m x 250 mm

= 4800 m x 7.4 m x (0.25 m)

= <u>8880 m^3</u>

This is the compacted volume so to determine the **loose** volume the conversion factor must be known. Normally this will already have been supplied by the soil tester but if it is not available the value shown in the following table may be used. See Table 7.1.

Loose volume of gravel required

= 8880 x 1.09 = <u>9680 m^3</u> (approx)

Wastage

Allow 10% additional volume for wastage in the various operations:

$$9680 \times \frac{10}{100} = \underline{968\,m^3}$$

Total volume of gravel required

= 9680 + 968 = 10,648 = $\underline{10650\ m^3}$ (approx)

Table 7.1

Material	State	Convert To		
		Bank	Loose	Compact
Gravel	Bank	1.00	1.00	0.92
	Loose	1.00	1.00	0.92
	Compact	1.09	1.09	1.00

Note: Have these values determined by a soil tester for materials used in your area or for your particular job. Always check the loose density of material being loaded onto the truck to ensure legal load limits are not exceeded.

Clearing the gravel pit

The minimum area of pit that must be cleared is found by dividing the volume of gravel required by the depth of the useable material.

Depth of useable material
= 1.5 m – 150 mm
= 1.5 m – 0.15 m
= 1.35 m

$$\text{Area} = \frac{\text{volume}}{\text{depth}} = \frac{10650\text{m}^3}{1.35\text{ m}}$$
$$= 7889\text{ m}^2$$

So clear and strip overburden from an area of $\underline{8000\ m^2}$ approx.

Stripping overburden and stockpiling gravel

From experience it is known that the Class 7 dozer outputs for these two operations are as follows:

- Stripping and pushing overburden into stockpiles: $40m^3$ (bank) per hour.
- Winning gravel and pushing into stockpile: $60m^3$ (bank) per hour.

The dozer will then take the following times assuming that the machine is working 8 hours per day:

(1) *Time taken to strip and stockpile overburden*

Bank Volume of Overburden = Cleared

Area x Overburden Depth

= 8000 m^2 x 150 mm

= 8000 m^2 x 0.15 m

= 1200 m^3

$$\text{Time Taken} = \frac{\text{Volume to be removed}}{\text{Output of machine per hour}}$$
$$= \frac{1200\ m^3}{40\ m^3/h}$$
$$= 30 \text{ hours}$$

(2) *Time Taken to Win and Stockpile Gravel*

$$\text{Time Taken} = \frac{10{,}650 m^3}{60\ m^3/h}$$
$$= 177.5 \text{ hours}$$

Thus the total time in days to complete both operations

$$= 30 + 177.5 \text{ hours}$$
$$= \frac{207.5}{8} \text{ days}$$
$$\approx 26 \text{ days}$$

This is assuming that the output times for the Class 7 dozer included, down time for maintenance and meal breaks and other factors as detailed in the course machine and therefore has a much lower output rating than the power shift machines. A power shift dozer normally has an output of 150 m^3 per hour. This would reduce the winning of the gravel and placing it in stockpile to 71 hours. The total time would then be 101 hours or 13 days.

Loading and hauling gravel

From experience it is known that the loader has an output of approximately 100 m loose per hour.

Also, from trials it is known that a single truck takes 25 minutes to cycle i.e. to load, travel to the middle of the job, tip and return to the pit.

The total number of trucks has not been determined, so first consider this operation and balance the number of trucks required against the output of the loader.

The Truck Output per hour can be found as follows:

$$\text{Output} = \frac{\text{Truck Capacity} \times \text{Efficiency hour}}{\text{Cycle Time}}$$
$$= \frac{(8m^3) \times (75\% \text{ of } 60 \text{ min})}{25 \text{ min}}$$
$$= \frac{(8) \times (0.75 \times 60)}{25}$$
$$= 14.4 m^3 \text{ per hour.}$$

This is a assuming an efficiency hour of 75%, i.e. the truck is operating for 45 minutes in every hour (record number of trucks per day to ensure accuracy).

The **Number of Trucks** required to balance the loader is theoretically the loader output divided by truck output i.e.

$$\text{Number of Trucks} = \frac{\text{Loader Output per hour}}{\text{Truck Output per hour}} = \frac{100}{14.4} = 6.94$$

Gravel quantity delivered per hour by 7 trucks = 14.4 x 7 = 100m^3

Total Output delivered to the job per 8 hour day

= (Truck output per hour x Number of trucks) x 8 hours

= (14.4 m^3 x 7) x 8

= 100 x 8

= 800 m^3 say 800 m^3

The Total Time for the trucking operation

$$= \frac{10500\ \text{m}^3}{(800\text{m}^3\ \text{per day})} = 13\ \text{days}$$

An example for determining the Tip Rates for a pavement with sloping edges and using trucks of varying capacities and a different type of paving material to that given above, is shown in Figure 7.19.

Step 1: Calculate Pavement Volume – in m^3/lineal metre

Note: If pavement edges are tapered an allowance for this material must be made.
Volume /m

= Pavement width x depth + pavement edge tapers

= (2 × 3.0 = 6) × 0.20 + (Area of Triangle) × 2

$$= 6 \times 0.2 + \frac{(0.2 \times 0.4)}{2} \times 2 \quad (d = 0.2)$$

= 1.2 + 0.08

= 1.28 m^3 / Lineal metre

Make allowance for the compaction factor of the gravel. Material as carted in loose volume.

Use previous experience as a guide to determine compaction factor. If this is not available measure loose density (from soil laboratory).

For Example Gravel say 1.68 tonne/m^3 loose and from Max dry density curve 2.1 tonne/m^3 compacted.

$$\text{Compaction Factor } \frac{2.1}{1.68} = 1.25$$

An allowance must be made for trimming, etc. allow 20mm for this exercise.

Trim volume = 6.0m x 0.02 = 0.12m^3 per lineal metre

Add to pavement volume 1.28m^3/m

1.28 + 0.12 = 1.4 m^3/m

Plan to construct trial length 200m long
Therefore Quantity of Compacted required
= 200 x 1.4
Quantity of Loose gravel

= 200 x 1.4 x 1.25

= 350 m^3 Loose gravel required

Typical truck volumes

Road Train 3 trailers @ 25m^3	
	= 75 m^3 loose
Body Trucks	= 10 m^3 loose
	14 m^3 loose
	12 m^3 loose
TOTAL	36 m^3 loose

Note: Always measure and calculate body capacities before carting as an incorrect calculation can result in:

(a) Carting too little – expensive to correct

(b) Carting Excess – waste over expenditure.

To determine number of loads divide loose quantity 350m^3 x capacity of the trucks.

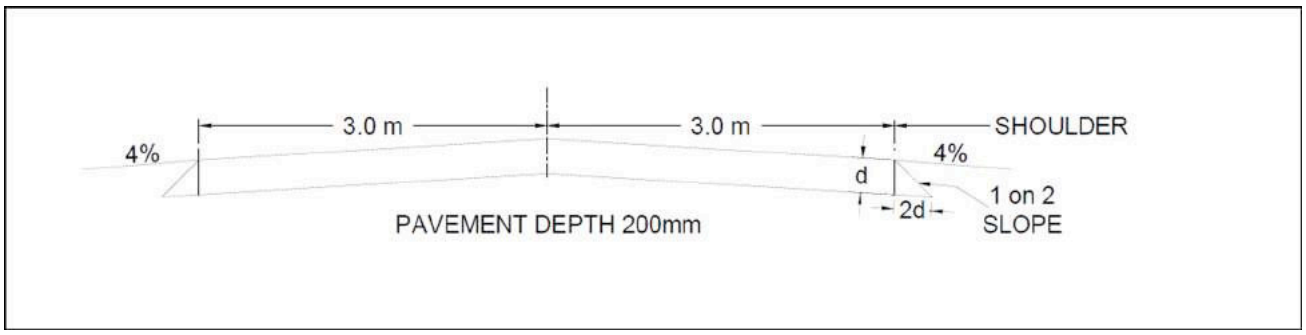


Figure 7.19

Therefore for body truck crew
36 m^3 9.7 loads
For Road trains
75 m^3 4.7 loads

Determine Tip Lengths for each truck
Pavement Volume loose

$= 1.4 \times 1.25$ (Comp Factor)

$= 1.75\ m^3$ loose/lineal m

Therefore trip length = $\frac{\text{Truck Volume}}{\text{Loose Vol/lineal m}}$

$10m^3$ truck $\frac{10}{1.75} = 5.71$m tip length

$12m^3$ truck $\frac{12}{1.75} = 6.86$m tip length

$14m^3$ truck $\frac{14}{1.75} = 8.0$m tip length

For Road trains

$25m^3$ trailer $\frac{25}{1.75} = 14.28$m

For 3 trailers $14.28 \times 3 = 42.8$m

Note: Compaction factors vary widely with variation in loose and compacted densities.

For example:

Mudrock Loose 1.17 tonne/m^3

Compacted 1.8 tonne/m^3

Compaction factor is $\frac{1.8}{1.17} = 1.54$

Note: Loose Mudrock may be delivered in bulk rock and requires crushing on site using a grid roller. The Compaction Factor for this operation is determined by controlled trials.

Note: When carting on public roads check that the load on the truck does not exceed legal load capacities. The manufacturer's gross vehicle weight must not be exceeded in any circumstances. This may mean reducing the volume for varying densities of materials carted.

Pavement construction

Machine outputs

The capacities of the available machines are as follows:

- *Grader (Figure 7.20)*

  For a width equal to the effective width of the grader blade the number of passes and operating speeds are:

  (a) Spreading – 3 passes – speed 10 km/h

  (b) Mixing – 3 passes – speed 16 km/h (Water)

  (c) Mixing – 6 passes – speed 12 km/h (Binder)

  (d) Finishing – 2 passes before compaction, final trim after Compaction 2 passes – speed 12 km/h

- *Compactors*

  Smooth Drum Roller – Vibrating – width of drum 2.1 m speed range 0-24 km/h

  Pneumatic Tyred Roller – width of coverage 1.8 m speed range 0-26 km/h

- *Water Truck* – Size determined by how much water is required, spray bar width 3.5 m

Moisture content

Tests show that the gravel arrives on the site with a moisture content of 5% and compaction trails show that 6 passes of the 15 tonne steel drum vibrating roller and 5 passes of the 15 tonne pneumatic tyred roller are required to achieve the required pavement density when the gravel has an optimum moisture content of 9%.

Thus **water to be added** = 4% (i.e. 9% – 5%)

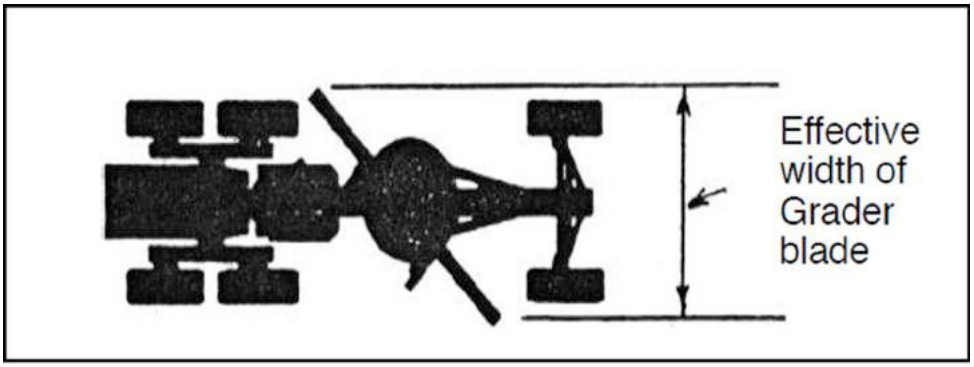


Figure 7.20

However an additional 2% may be required to balance the loss due to evaporation. Thus 6% of water is required to be added, and if the dry density of the gravel is 2000 kg per m^3, the added water

$$= \frac{6}{100} \times 2000 \text{ kg/m}^3$$
$$= 120 \text{ kg/m}^3$$
$$= 120 \text{ litres/m}^3 \text{ (since 1 kg of water has a volume of 1 litre)}$$

Grader operations

The trucks deliver to the site $100m^3$ of gravel per hour, i.e. $800m^3$ per 8 hour day. So next consider how much pavement this quantity will construct.

Compacted Volume (m^3)

= Length (m) x breath (m) x depth (m)

The volume delivered by the trucks is "loose volume", so this will have to be converted to "compacted volume" before calculating the length that can be constructed with $800m^3$ of loose gravel.

From Table 7.1 (page 59), the "loose volume" will have to be multiplied by 0.92 to give "compacted volume".

i.e. length × 7.4m × 125mm = 800 × 0.92

$$\text{length} = \frac{800 \times 0.92}{7.4 \times 0.125}$$

= 795.68 m say 796 m

The water required is

$800m^3 \times 120\ l/m^3 = 96000l$

∴ 12,000l water transfer, 8 loads are required.

On some jobs, production will be limited by the water available.

Grader operation times

The time taken to carry out one pass including the time for one turn for each of the operations of spreading, mixing in water and finishing is as shown below:

Time taken for one pass = travelling Time + Turning Time

$$= \frac{\text{Distance in m}}{\text{Speed in m/min}} + \text{Turning Time in min}$$

Spreading time

Firstly the Spreading Travelling Time given in km/h must be reduced to m/min.

i.e. Forward (production) speed = 10km/h

$= 10 \times 1000$ m/h

$= \frac{10 \times 1000}{60}$ m/min

Assume that the turning time, including gear change times, is the same for all operations and is 0.5 min.

Spreading Time (one pass)

$$= \frac{\text{Distance in m}}{\text{Speed in m/min}} + 0.5\text{min}$$

$$= 796 + \frac{(10 \times 1000)}{60} + 0.5 \text{ min}$$

$$= \frac{796 \times 60}{10 \times 1000} + 0.5$$

$$= 4.78 + 0.5$$

$$= 5.5 \text{ min.}$$

As 3 passes are required for each effective width of the grader blade, the total spreading time for this width is 16.5min (i.e. 3 x 5.5 min).

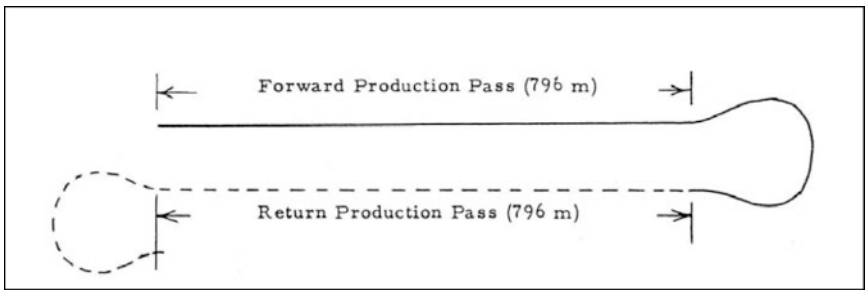


Figure 7.21

Mixing time for mixing in water only

$$\text{Mixing speed} = 16 \text{ km/h}$$
$$= 16 \times 1000 \text{ m/h}$$
$$= \frac{16 \times 1000}{60} \text{ m/min}$$
$$\text{Mixing time (one pass)} = \frac{796 \times 60}{16 \times 1000} + 0.5$$
$$= 3.00 + 0.5$$
$$= 3.5 \text{ min}$$

As 3 passes are required for each effective width of the grader blade the total mixing time for this width is 10.5 min (i.e. 3 x 3.5 min).

Mixing time for mixing in binder only

$$\text{Mixing speed} = 12 \text{ km/h}$$
$$= 12 \times 1000 \text{ m/h}$$
$$= \frac{12 \times 1000}{60} \text{ m/min}$$
$$\text{Mixing time (one pass)} = \frac{796 \times 60}{12 \times 1000} \times +0.5$$
$$= 4.5 \text{ min.}$$

As 6 passes are required for each effective width of the grader blade, the total mixing time for this width is 27 min (i.e. 6 x 4.5 min).

Finishing time

$$\text{Finishing speed} = 12 \text{ km/h}$$
$$= 12 \times 1000 \text{ m/h}$$
$$= \frac{12 \times 1000}{60} \text{ m/min}$$

$$\text{Finishing time (one pass)}$$
$$= \frac{796 \times 60}{12 \times 1000} + 0.5$$
$$= 4.00 + 0.5$$
$$= 4.5 \text{ min.}$$

As 2 passes are required (for each effective width of grader blade) before compaction, the finishing time before compaction is 9 min. (i.e. 2 x 4.5 min).

Similarly after compaction 2 passes are required for each effective width of grader blade giving a finishing time after compaction of 9 min.

Spreading + mixing + finishing time

The total time required by the grader to carry out the complete operation over a width equal to the effective width of the grader blade will be:

Operation	Minutes
Spreading	16.5
Mixing (water)	10.5
Mixing (Binder)	27
Finishing	
Stage 1	9
Stage 2	9
Total Minutes	72

Overall construction time

Number of operations

$$= \frac{\text{Width of Road}}{\text{Effective width of Grader blade}}$$

$$= \frac{7.4}{3}$$

$$= 3 \text{ for a pavement with a constant crossfall.}$$

However if the road is cambered from the centre to the outside 4 operations will be required.

Total time for laying one layer of

Constant Crossfall	Cambered Crossfall
72 x 3 = 216 say 3.60 hrs	72 x 4 = 288 say 5hrs

This is the time the operator would take if all conditions were perfect and the grader was working at **100% efficiency**. However this is not so in practice and site conditions, operator efficiency, management efficiency, weather etc. have to be taken into consideration. Refer to the example at the end of this section which uses the production factors which are discussed in “Plant Management” Form 11AT23.

Thus the grader will have only a portion of its time taken up with pavement preparation and will be available for use on other operations. The topic of balancing plant outputs will be dealt with in “Plant Management”, Form 11AT23.

Rolling

The compaction operation will be in a secondary role to the grader operation, and the output of the roller will be geared to the grader.

However the roller output should be checked against the number of passes required to achieve the correct compaction.

From compaction trials it has been found that to achieve the specified 95%, standard compaction, 6 passes of the smooth drum roller, and 5 passes of the rubber-tyred roller are required.

The area covered per hour is obtained using the following formula:

$$A = \frac{1000 \times S \times W \times E}{N} \text{ m}^2 \text{ per hour}$$

Where A = area covered
S = speed of machine in km/h
W = effective width of roll
N = number of passes
E = efficiency factor

This formula should simply be accepted at this stage as the topic is discussed fully in the "Plant Management" section of 11AT23.

The smooth drum roller will cover in one hour an area

$$= \frac{1000 \times 5 \times 2.1 \times 0.75}{6}$$
$$= 1312 \text{ m}^2/\text{h}$$

The rubber-tyred roller will cover in one hour an area

$$= \frac{1000 \times 10 \times 1.8 \times 0.75}{5}$$
$$= 2700 \text{ m}^2/\text{h}$$

The outputs for various types of equipment have been determined by calculation. In respect to the loader and bulldozer in the pit operation these outputs have been taken from past operations.

The outputs of the equipment used in the construction of the pavement have been calculated from first principles and factors such as the speed of the machines are those which would be achieved if the equipment was being operated at 100% efficiency. On a job site this is not possible and the outputs that have been calculated for the perfect situation have to be reduced to take into account site conditions, operator efficiency, etc. and the balancing with other equipment. This is discussed more fully in "Plant Management" 11AT23.

Some of the major factors requiring consideration when selecting the correct machine and estimating the output for a given set of conditions are:

- Nature of the material to be moved;
- Power required to move the machine over the ground for a given set of conditions (whether it is firm,
- Power available – this is determined by the machine selected;
- Power limitations – these are the restrictions imposed on the machine by the ground conditions;
- operator efficiency.

Applying these factors to the previous example and assuming the following conditions, the revised time for the job would be calculated as follows.

Operator efficiency

The period worked by the operator in any one hour assuming that his average operation is 45 minutes or 75% efficiency.

Management efficiency

If the job is being efficiently supervised and the grader operator does not have to continually stop his machine then it can be said that the management factor is 85%.

Task efficiency
The machine is working in a subsidiary role to the trucks bringing the material to the job, therefore the grader may have to stand down and wait for material. The length of pass is greater than 600+ metres so that task efficiency factor ranges between 80% to 100%, therefore assuming that there are no major hold- ups in the trucking operation the task efficiency factor is 90%.

Power availability
Normally graders are working at very low speeds, and assuming that the correct machine has been selected no reduction is necessary for changes in power output.

Total efficiency rating
Therefore the total efficiency rating for the job will be:

Operator efficiency x Management efficiency x Task efficiency

0.75 x 0.85 x 0.90 = 0.57 or 57%

Therefore the calculated production or output of the grader will be reduced by 43% and the time taken for the total operation increased.

Production Pass

$= 796 \text{ m} \times 0.57 = \underline{454 \text{ m}}$

Or Time Taken Constant Crossfall

$\frac{3.60}{.57} = \underline{6.32 \text{ hrs}}$

Cambered Crossfall

$\frac{5}{.57} = 8.77 \text{ hrs.}$

If it is proposed to match the trucks bringing the material to the job site the volume of material required per hour will be:

$$454 \times 7.4 \times \frac{1251}{1000} = \underline{420 \text{ m}^3}$$

Moisture content
The amount of water required at 120 litres/m^3 for 420m^3 will be:

120 x 420 = 50,400 litres

Therefore if we are using a 4500 litre water tanker it will require the tanker to be filled 12 times during the day or approx. 1½ times per hour.

Conclusion

This example shows how a construction job can be planned and the numbers and types of plant determined prior to the commencement of the job.

If the major role machine is the grader and it is proposed to haul pavement material to the job each day the number of trucks may be reduced from 8 to 5.

Therefore the loader would not be operating at its maximum output.

Refer 11AT 03 Part 2(b).

KEY MESSAGES
- **Take the time to understand the calculations**
- **Follow the examples**
- **Ask questions**

CHAPTER 8
STORMWATER DRAINAGE

The purpose of any drain or drainage system is to carry stormwater flow under a structure or through an area in such a manner as to minimise flood damage and inconvenience.

There are many factors which can seriously reduce the flow in a drainage system to well below its designed capacity, and thus result in much more frequent flooding. It is most important that these factors be eliminated.

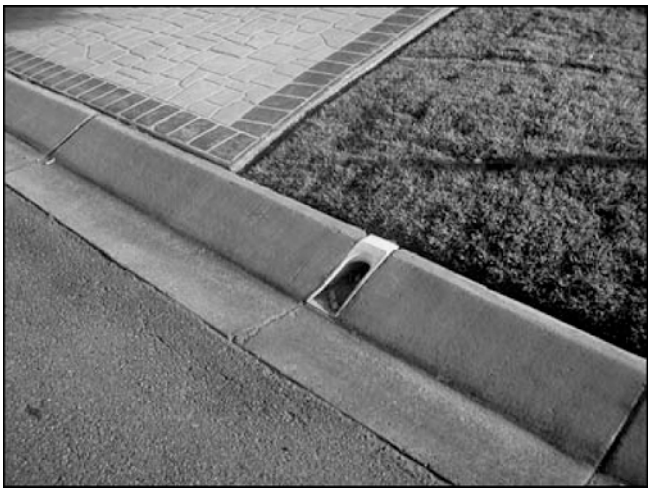
Some of the causes of reduced flow are the failure to provide an adequate number of inlets of proper capacity (keeping in mind the risk of partial blocking by debris); and the construction of inlets which can be easily blocked by light refuse such as papers or leaves. Other causes include: failure to provide entry head from pits or open drains to pipes; the construction of bad entrances to pipes or culverts from pits or open drains; and inadequate maintenance are other causes.

Maintenance

Maintenance should include the prevention or regular removal of vegetable growth near inlets, regular removal of silt and flotsam and the clearing of leaves, papers and debris, etc. in the catchment. It is necessary to ensure that the discharge end of a system is free, and to guard against erosion which can undermine the outlet. Stone filling may be sufficient to control erosion but in difficult cases a mattress of stone and wire mesh or gabions are useful.

In rural conditions, guide posts on head walls should be kept free of growth. They should be clearly visible from some distance, and kept painted. The use of red and white reflecting strips provides added security for night driving.

When concrete box culverts are of a size to permit internal inspection, they should be regularly checked to detect any deterioration. Where any discolouration indicates rusting of reinforcement close to the surface, advise the engineer immediately as structural damage may be imminent, and remedial action should be taken. Any cracking or flaking should be properly investigated. Where it is found that flaking and pocking is resulting from impurities in the aggregate, the area should be cut out and repaired.

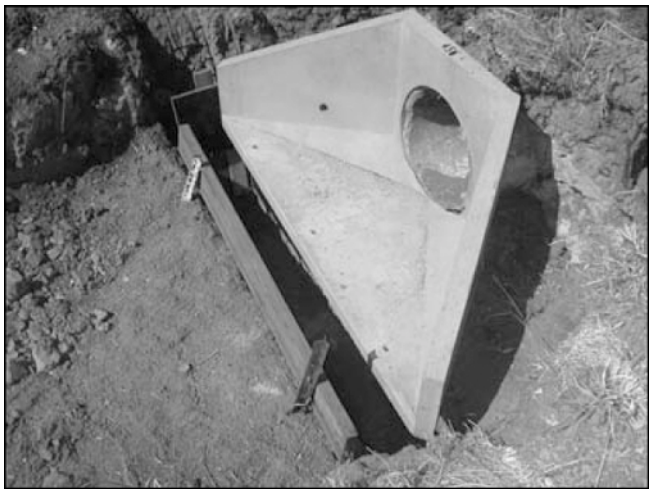


Tall slender wing walls should also be closely inspected. Where there is any sign of failure, steps should be taken to reduce earth pressures.

It is all too frequently assumed that concrete structures are completely durable, and once constructed, may be forgotten. This is not the case. Regular and careful inspections are needed to ensure the ongoing functionality and safety of the stormwater system, together with prompt remedial action when faults are found.

Pipe Culverts

Open joints in pipelines allow surrounding soil to be washed into the line producing a cavity, which may cause the collapse of the pipeline or of a road or other structure above or close to the pipeline. In sandy country rapid and severe damage may occur, and proprietary rubber sand bands should be installed on any new work in sandy type soils. Any subsidence over a pipeline or culvert should be suspect and be investigated.



Safety

Dangerous gas can enter pipelines. Risk to men working in lines must be minimised, by taking proper precautions, having regard to the Council's confined spaces entry procedures.

Most road design plans show details of drainage in the form of notes or actual drain-age plans which may include a site plan, a long section of the drainage line and detailed drawings of drainage structures. The level of the invert (bottom inside of the pipe) is shown as a level in relation to a bench mark. Pipe sizes are shown as the pipe diameter in millimetres. They are almost always laid on a straight grade between gully pits or junction boxes to allow better locking of joints, easier cleaning and ease of laying by use of laser level between profiles or templates. Pipe laying laser units are commonly used instead of boning rods and are particularly useful when laying to very flat grades or where accuracy of the levels is paramount.

Planning

(a) Setting out work

Setting out of the work is carried out in a similar manner as discussed in Chapter 6 – Transfer of Details. Supervisors should discuss with the Engineering staff the whole job and accurately locate all services in the vicinity of the works prior to any excavation taking place. This can be a difficult task and it is advisable to contact "Dial Before You Dig" and all utility providers to ensure all services have been located prior to construction works. Some Councils also have staff specifically trained in the operation of service location equipment.

(b) Setting of profiles

Most pipes are laid with the assistance of a pipe laser unit. These units are placed at the start of a trench and the pipe grade is set on the unit which sends out a beam of high intensity laser light, which describes the preset pipe grade. The laser beam is followed by the machine operator excavating the trench. Commonly a point on the bucket of the machine is used as a reference point, which is struck by the laser and can be easily seen. Care should be taken in handling and storage of pipe laser units as they can be easily damaged. It is not always apparent that a laser unit has become faulty or gone out of calibration, (causing incorrect grades). For this reason, it is important to always follow the manufacturer's directions for use and safety. Under no circumstances should any person look directly into the laser beam.

An alternative method for setting out pipes with boning rods is discussed below.

If for instance a pipeline is to be laid between two gully pits, a horizontal piece of timber is attached to a post each side of the trench. The level of the top edge of the horizontal timber should be placed in relation to the desired trench depth, which will allow for bedding material if required. A suitable figure for

small pipes is 2 metres. A 1 metre extension can be added to 1 metre boning rods (refer to Figure 6.16 Boning Rods).

As most excavation is done by backhoes and excavators it is often difficult to see past the machine to the top profile. If this is the case, place a third profile downhill from the bottom profile (say 5 metres) to allow for overboning as the excavation proceeds. This will save frequent movement of the backhoe to sight between profiles if only 2 are used.

Always excavate uphill to allow the trench to be self draining in the event of rain.

(c) Excavation

Before the job starts always decide what to do with the excavated material. Direct loading of excavated material into trucks by backhoe is uneconomical.

If the excavated material is suitable for backfill, it is better to place it to one side of the trench and load away the surplus after the pipeline is backfilled by front end loader.

When placing the excavated material to one side make sure there is room for delivery and laying of the pipes.

In most jobs there is room for the excavated material to be placed to one side of the trench leaving the other side available for pipe laying and placement of bedding material.

Bedding material

Accurate placement and compaction of the bedding material to specified depth allows the pipes to be laid rapidly with little adjustment to obtain the correct grade.

Pipe bedding material should not be compacted, but rather spread to allow the pipes to settle under their own weight. If timber support chocks have been used then it is essential they are removed before placement and compaction of the haunching (where bedding is placed around the barrel of the pipe) and backfill material. If left in place, the concentrated loads applied at the point of contact with the pipe will generally cause significant cracking to occur.

As the performance of the pipeline and its ability to support loads is dependent on the bedding and hauncing materials, it is important to use the specified material and to comply with the compaction requirements.

Jointing

Pipe jointing

All pipe joints should be such that they will prevent the washing of material into the pipe-line and will ensure that there is no lateral movement between pipes. Most concrete pipes are provided with either an internal or external interlocking joint.

Sand bands (consisting of a wide rubber band, which is fitted externally after laying) greatly enhance the effectiveness of inter-locking joints.

For some types of work the spigot and socket joints are used. Butt joints are seldom used except where short lengths or cut pipes are used for the construction of curves.

The interlocking and the spigot and socket joints are simply made and give good service if the dovetailed grooves or sockets are properly filled with mortar. A bandaged joint is usually used with butted pipes, especially in smaller sizes. This joint is made by using a 125 mm strip of 19 mm wire netting, a 150 mm strip of hessian or scrim, and cement mortar. The procedure is to scoop a hollow half under the

then the wire mesh, and then mortar to a height flush with the outside of the pipe. The butt ends of the pipe should be wetted and coated with a thin layer of mortar and the pipes butted closely together. A thin layer of mortar should then be placed around the top half of the joint and then the netting and hessian or scrim drawn tightly around the joint. A layer of mortar is placed over the hessian or scrim. The joint should be trimmed up so that a collar about 162 mm wide and 25 mm deep is formed around the full circumference of the pipe.

All mortar joints should be protected from the sun and wind, to prevent drying out of mortar for at least 48 hours after placing.

Care in jointing is essential as erosion of the bedding material and the backfill caused by leaking joints produces settlement and collapses. Often the erosion produces cavities near the pipe that do not show on the surface for years in some materials, due to the ability of those materials to arch over the cavity.

After years of use of the ground over a pipeline, particularly in private property, the fault can be difficult to reach due to development of gardens and nearby buildings. Cost of hand excavation can be extremely high, hence particular care should be taken during the initial works.

Direction of laying

Normal practice is to lay from the lower end of the job, up-grade. This method provides for more ready drainage of trenches and carrying away of stormwater.

Where spigot, socket or interlocking joints are used, the female end should be kept to the open end of the pipe, as this gives easier insertion of the male end.

Types of joints

There are many commercially available jointing systems including, for example, sand bands, rubber bands and geotextile fabric.

Butt and flush joints

These have in the past been the most common type and are easy to lay due to the outside of the pipe being even. Care must be taken in handling as both the spigot and the socket ends are easily chipped and loss of concrete in these areas make good jointing more difficult.

If damage to the ends is extensive, band-age joints should be used. These are made by using a length of brick or alternately a 125mm width of bird wire. A width of hessian 150mm wide is placed under the pipe in a hollow prepared in the bedding material at the joint. Mortar is then placed in the hollow and gradually added up the sides of the pipe as the hessian is pulled up to form the band-age, of wire and mortar.

It is good practice to cover the joints as soon as firm enough to prevent cracking and possible leakage.

If rubber rings are used for sealing within the joint, care should be taken to ensure the ring is correctly fitted and rolls fully into the groove allowed for the ring.

Spigot and socket

These type are used in both drainage and sewer construction as they provide a more positive joint.

They are more difficult to lay as the socket end unbalances the pipe.

Excavation is necessary under the joints to take the bulge of the spigot. Use of this type of pipe is more common in sandy or high soil movement terrain, and under buildings when leaking joints can be disastrous.

Rubber ring

Rubber rings are normally used to seal within the joint, and care should be taken to ensure the ring is correctly fitted and rolls fully into the groove allowed for the ring.

These are now specified in most drainage lines in subdivision construction as they seal water in/out and resist tree root intrusion.

Lengths

Pipes are typically manufactured in nominal 2.44m lengths to optimise transport and handling costs. Shorter or longer pipes can generally be manufactured on request and traditionally have nominal lengths of 1.22, 1.83, 3.66 and 4.88 metres according to diameter.

Other pipe types

Pipes made of other different materials (e.g. steel, PVC, fibre cement) are being more commonly used. The joints of these pipes should be put together in accordance with the manufacturer's direction and in discussion with the Engineering staff. These pipes vary in lengths, usually up to 6m, and can be an advantage due to their extra length and often lighter weight. However they are restricted to the smaller diameter range.

Backfill

Jointed pipelines will float if a trench is flooded before backfilling takes place. Even if the downstream section of the pipe has a clearance at the side of the pipe, cases have occurred where the sides of the trench have collapsed causing the water to pond and float the pipeline. Always promptly backfill.

The material used for backfilling should be approved by the Engineering staff and compacted in specified thickness layers (150-300mm) in the manner noted below.

If excavation can be kept to a minimum, stabilised sand or lean-mix concrete may be a more economical and timely method. Refer 11AT 25 Drainage.

Compaction of backfill

Loose backfill will always settle and cause continuous maintenance problems. Granular material should be used, where available, due to ease of compaction.

If specified, damp sand compacted with the aid of concrete immersion vibrators is the easiest material to pack around the shape of the pipe and over the top, depending on the depth of cover available. If cover is shallow other material may have to be used.

Compaction of other materials should be by mechanical rammers.

Multiple pipelines

Refer to Standard Drawings.

Where 2 or more pipelines are to be laid side by side, sufficient distance must be allowed between them to allow placement and compaction of backfill. A minimum distance of 300mm or one-half the diameter of the pipeline, whichever is the greater, is considered adequate.

Some safety points to remember

- Shoring or benching is required where excavated depths are over 1.5m below natural surface level or unstable ground.
- Hard hats must be worn by all personnel entering into a trench or working in the vicinity of excavating plant.

- The toe of the excavated material should be a minimum of a ratio of 1:1 away from the edge of the trench and graded back at a safe angle, e.g. 3m deep trench, 3m away.
- Ensure confined spaces safety requirements are followed at all times.
- Ensure any trench left open is securely fenced, sign posted and has warning lights so public safety can be maintained.

Strength of pipelines

Pipes without proper support cannot carry heavy loads. They depend for their strength on arching action and must be laid in such a manner that the surrounding earth sup-ports the pipe. Hard spots or weak areas in bedding will result in local overloading and fracture in the floor of the pipe. The lack of support of the sides of the pipe can result in the pipe being somewhat flattened or crushed. If larger stones in back-fill are placed too close to the top of a pipe, local areas can be crushed in.

When a pipe is laid in a trench in firm earth there is a tendency for the fill above the trench, as it settles, to arch across the trench. If the pipe is not in a trench, special care must be taken to compact the earth on each side of the pipe. If this is not done, and there is subsequent settlement of the earth on either side of the pipe, the weight of an increasing wedge of fill will bear on the pipe. Failure to guard against this condition, especially in uncompacted fills such as deep garbage pits and badly built embankments, has led to the collapse of many pipelines.

Standards Australia has issued specifications for pipe strengths and the fills and loads which they will safely carry in given bedding and trench conditions. The grade of pipe provided for in the design will not safely carry the loads unless the bedding, trench conditions, and back filling are in accordance with the specification.

It is most important that the Supervisor should have clear instructions on these matters. He must ensure that the trench is excavated to a clear depth below the bottom of the pipe equal to the bedding thickness, and that the bedding, which will usually be specified as sand or sandy material from the job, is uniformly firm and evenly shaped. It must be ensured that back fill or fill beside the pipe not in a trench is placed and compacted in layers. The specified clearance between the wall of a trench and pipe and between pipes in multiple lines, must be adhered to.

Buoyancy

It must always be remembered that an empty pipeline is buoyant and that it will float in a flooded trench. Where a pipeline is being laid in a meandering watercourse, it can occur that sections will be in trench and back-filled, and that intermediate sections will be in partial trench only, and awaiting the carting in of cover. In these conditions, special precautions must always be taken to prevent any possibility of ponding of stormwater near the exposed pipeline. Quite long lengths of large pipes have been lost by failure to take such precautions.

Construction of pipelines

The Supervisor should receive full details of the work in writing, and/or in plan form, prior to the commencement of the work. Pegs should be located and identified. The plant and work force to be used on the job and a work plan should be discussed with the Works Manager or Engineering staff.

A clear-cut plan of procedure should be worked out. It will include:

- methods of excavation
- provision for heaping or removal of excavated material
- location of pipe deliveries and storage to minimise handling
- provision of tracks and sites for cranes or other handling plant
- the locating and protection of utility services

- the provision and delivery of bedding material and, if necessary, imported back-fill
- the means of timbering trenches and supporting nearby structures, should such be necessary, etc.

A most important part of the plan will be the method of handling dry weather flow and storm flow. Where practicable, dry weather flow should be completely diverted. Small flows can be handled by pumps and temporary pipelines or earth channels. Another possibility is the laying of a small pipeline in one corner of the trench. In such a case, it is vital the pipe be properly jointed or enclosed in proper filter material to guard against sub-sequent removal of bedding along the line. It is safest to seal off the outlet of such a line upon completion of work.

A full list of gear which will be required should be prepared, and estimated dates when it will be needed should be set down.

Setting out

Where short culverts are to be constructed, centre line pegs and recovery pegs will usually be set clear of the work, both upstream and downstream. Level pegs should be placed at each end of the line. Ensure that the excavation is taken out to the required depth below invert to provide for the specified bedding. The bedding will then be prepared, the levels again being checked, prior to placing the pipe. If the bedding is properly placed and shaped, it should then be merely a matter of lowering the pipes into position with no further adjustment, but a check can be made as necessary.

Excavation of pipe trenches

All trenches should have vertical sides and be of a width sufficient to allow a minimum clearance of 150 mm on each side of the pipe. Check job specification.

The depth of the trench must allow for the specified bedding depth. In rock excavation, the bottom of the trench must never be less than 200 mm below the bottom of the pipe.

Pipe laying and jointing

Also refer to Chapter 17.

Any soft or yielding material should be removed from the bottom of the trench and replaced with sound material, and well compacted. All rock should be removed to the minimum depths specified and replaced with sound compacted material. Bedding should then be placed, compacted, and shaped so that the barrels of pipes bear evenly for their full length.

Where bandage joints or socketed pipes are to be used, proper recesses must be left under each joint.

It is most important that the bedding should be in accordance with the specification for the work. As previously mentioned, the bedding methods partially determine the strength of the pipeline and the loads which it can support.

The bedding for the job in hand will have been determined by reference to the Australian Standard, local authority or Transport and Main Roads Specifications. Any departure from the specification can seriously affect the strength of the job.

Where two or more lines of pipe are to be laid side by side, the space between the lines of pipe must be of a width not less than one third of the diameter of the pipe, or 300 mm whichever is the greater; e.g., a twin line of 1350 mm pipes should be laid with a space of 450 mm between the lines. Twin 600 mm diameter pipes would be laid 300 mm apart.

Where pipes 1200 mm in diameter or over are to be laid under embankments, having the top of fill more than 3 m above the invert of the pipe, they should be temporarily stiffened by the use of hardwood struts, placed as follows:

Hardwood struts of not less than 100 x 100 mm dimension shall be fixed vertically at each pipe joint and shall bear against a sill of 100 x 100 mm hardwood laid along the invert of the pipe and a cap of not less than 100 x 100 mm hardwood bearing against the crown of the pipe. The struts shall be wedged up tight, using hardwood wedges between the strut and the cap. The struts shall not be removed until so ordered by the engineer, but care must be taken that they are not forgotten. Do not overtighten the wedges or the pipe will crack from vertical internal pressure load.

Precast concrete pipes and culverts

Australian Standard AS4058 classifies precast concrete pipes as:

Reinforced – Class 2, 3, 4, etc.

The classes of pipes are determined by the load the pipe is required to carry. Most Council jobs would use Class 2 or 3.

Where an elliptical reinforcement cage has been incorporated in the pipe (generally in all pipes 450mm dia. and over), the word "TOP' is marked on the pipe. This indicates the direction of the vertical loading and the orientation of the reinforcement.

Placing of culverts generally follows the principles of pipe laying. They are placed on a compacted bed of sand approximately 75 mm thick or alternatively on a bed of mass concrete. The latter bedding facilitates the placing of the normally heavy sections, but it has the disadvantage where traffic problems exist, that at least 24 hours must elapse between the placing of the concrete and the laying of the culvert.

The upper sections of any box culvert should be jointed to the lower section with a thin mortar joint.

When placing box culvert crown units on a poured in situ reinforced concrete base slab, a recess or nib wall constructed to accommodate the legs, must be provided. This is necessary to prevent horizontal pressure from adjacent backfill squeezing and dam-aging the culvert precast sections.

Cast in place concrete box culverts

The construction of box culverts follow the same principles as the construction of concrete bridges. They are virtually small bridges but have a load bearing concrete floor.

Installing new box culverts

It is quite vital that steel reinforcement should be accurately placed, that good form-work is used, and that properly proportioned concrete made from good aggregates is provided.

Most Councils would use the IPWEAQ/ TMR Standard Drawings for box culverts.

Corrugated metal pipes

Corrugated metal pipes serve a very useful purpose in localities where the procurement and delivery of reinforced concrete pipes is difficult.

The flexible pipe should be laid with the same support as concrete pipes. Well compacted side support is essential, as the pipe develops its resistance to the load by flattening and thus transferring the load to the sides, as the horizontal diameter increases.

Subsoil drains

Subsoil drains are used for the collection and removal of ground water. The pipes used are normally perforated plastic pipes or geofabric drainage cells in rolls.

Whatever type of pipe is used, it is essential that it be surrounded by filter material so graded that the larger particles are larger than any of the openings into the pipe. Small particles must be small enough to produce a filter through which particles of the surrounding soil cannot pass.

If butt jointed 300 mm “agricultural” pipes are used, the openings will seldom exceed 3 mm. A filter material graded from 7 mm to medium size sand will generally be suitable. With perforated pipes, the maximum size stone should be one and a half to twice the size of the perforations, and the material graded again to medium size sand. Perforated plastic pipes require a coarse to medium sand filter.

Where practicable, subsoil drains should be so placed that they will intercept the flow of ground water before it reaches the road bed. This will not be possible where flow occurs in layers of material within the road bed.

Ground water flow will occur more frequently within cuttings.

The trench should be taken through the water bearing material into impervious material. The pipes should be laid in straight grades and have provision for access for cleaning at changes of grade or direction. They should always be provided with a well constructed outfall into stormwater drains.

Bedding conditions

Where a pipe is laid in a shallow excavation of a depth less than the external diameter of the pipe, it is said to have “projection bed-ding”, which means that the pipe is projecting above the natural surface. Where it is laid in a trench of depth greater than its diameter, it is said to have “trench bedding”.

The type of bedding is divided into three types, specified as

(a) Ordinary
(b) First Class
(c) Concrete cradle.

It will be seen that there can be six ways to bed a pipe, i.e., projection bedding, ordinary, projection bedding first class, projection bedding concrete cradle, trench bedding, ordinary, trench bedding first class, and trench bedding concrete cradle. The load the pipe can carry will depend upon the type and class of bedding.

Refer to Standard Drawings and/or pipeline manufacturer guidelines.

With projection bedding the minimum depth of the pipe below the natural surface should be 15% of its diameter, but where practicable this percentage should be in-creased. In trench bedding, the width of the trench is important, and an increase in the width beyond the specification could reduce the load bearing capacity of the pipe. The typical types of bedding are illustrated in Figures 8.1 and 8.2.

Structures

Structures, such as head walls, inlet and junction pits are required with most pipelines.

As far as practicable gully pits and junction pits should be constructed of standard prefabricated forms. Where these can be used in well trimmed, accurate excavations, no external formwork will be necessary. If the formwork has to be built up, it should be so built that it can be readily removed without injuring the concrete. Where external forms are necessary, they will usually be built up in similar sheeting material to the inside form-work. The formwork should be well braced so that it will not move or yield during the placing of the concrete. Forms should be well oiled or otherwise treated to prevent concrete sticking to their surface.

It is usual to cast the floor of the structure before erecting formwork. When it is firm enough to work on, the ends of the pipes should be trimmed so that they will be flush with the face of the forms or for better class work, will finish approximately 75 mm from the face of the forms so that a curved bell mouth of about 75 mm radius can be formed. Such a bell mouth considerably increases the carrying capacity of the pipeline.

Formwork will then be erected and braced in position. Concrete should be placed at even depths in the formwork and compacted in layers by tamping and spading. Uneven filling will tend to force the forms out of position. The top surface of the concrete will be struck off smooth with a wooden float. The forms must not be removed for at least 24 hours after the placing of concrete.

When forms have been removed, any faulty surface should be patched with mortar. Any rough surface should be rubbed over with a wooden float and clean water. It is usual practice to make all arises and corners clean and sharp and true to line. However, the provision of coves and fairings which will facilitate the passage of sticks and similar material is a more desirable practice.

Efficiency of inlets
It is a fact that a pipe with a bell mouth entry will carry substantially more water for a given head than a pipe having a flush square entry from a pit. A pipe projecting into a pit will have an extremely low efficiency and should never be constructed or permitted.

Standard designs
IPWEAQ, TMR and local authorities have available standard designs for box culverts, pipe head walls, inlet pits, double grating pits, double grating pits with extended kerb inlets, and junction pits.

Various firms produce precast lintel sections, which are extremely useful for constructing kerb inlets. Precast manhole rings and covers are available.

Each Council will no doubt have adopted standards for the structures mentioned, and the Supervisor should obtain a set of plans and study them closely.

Plant

Excavation in most cases will be done with some form of backhoe and/or excavators. Chain type trench machines will seldom be large enough for the laying of stormwater lines. Smaller backhoes are mounted on the rear of pneumatic tyred tractors and can comfortably handle trenches up to 900 mm in width. For larger trenches the crawler mounted excavator type machine is more suitable, but should one not be available the smaller hoe can make several cuts. This requires repeated movement of the machine and would probably involve some hand clearing of pillage.

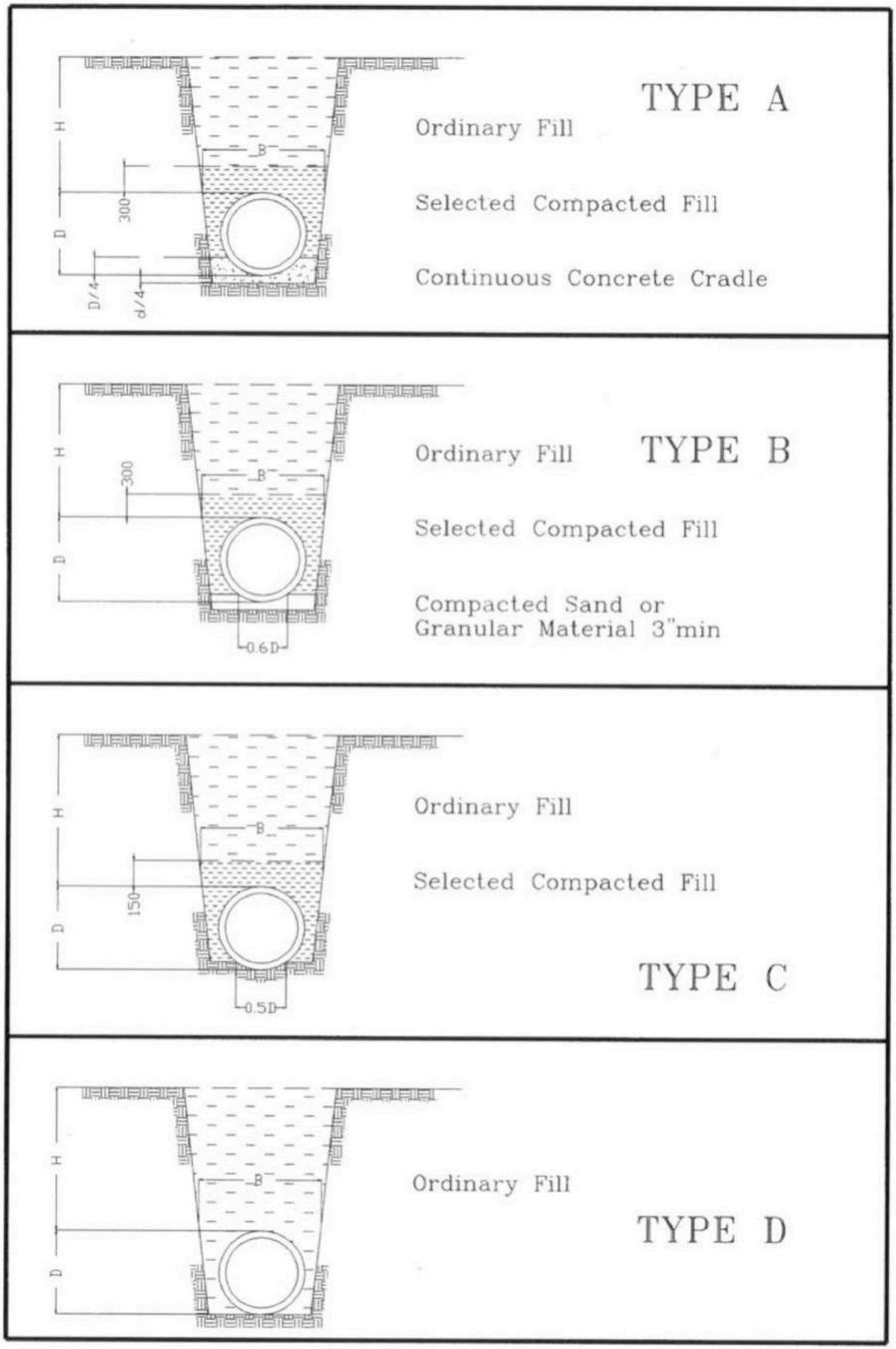


Figure 8.1: Concrete Pipes In Trench Types of bedding on earth

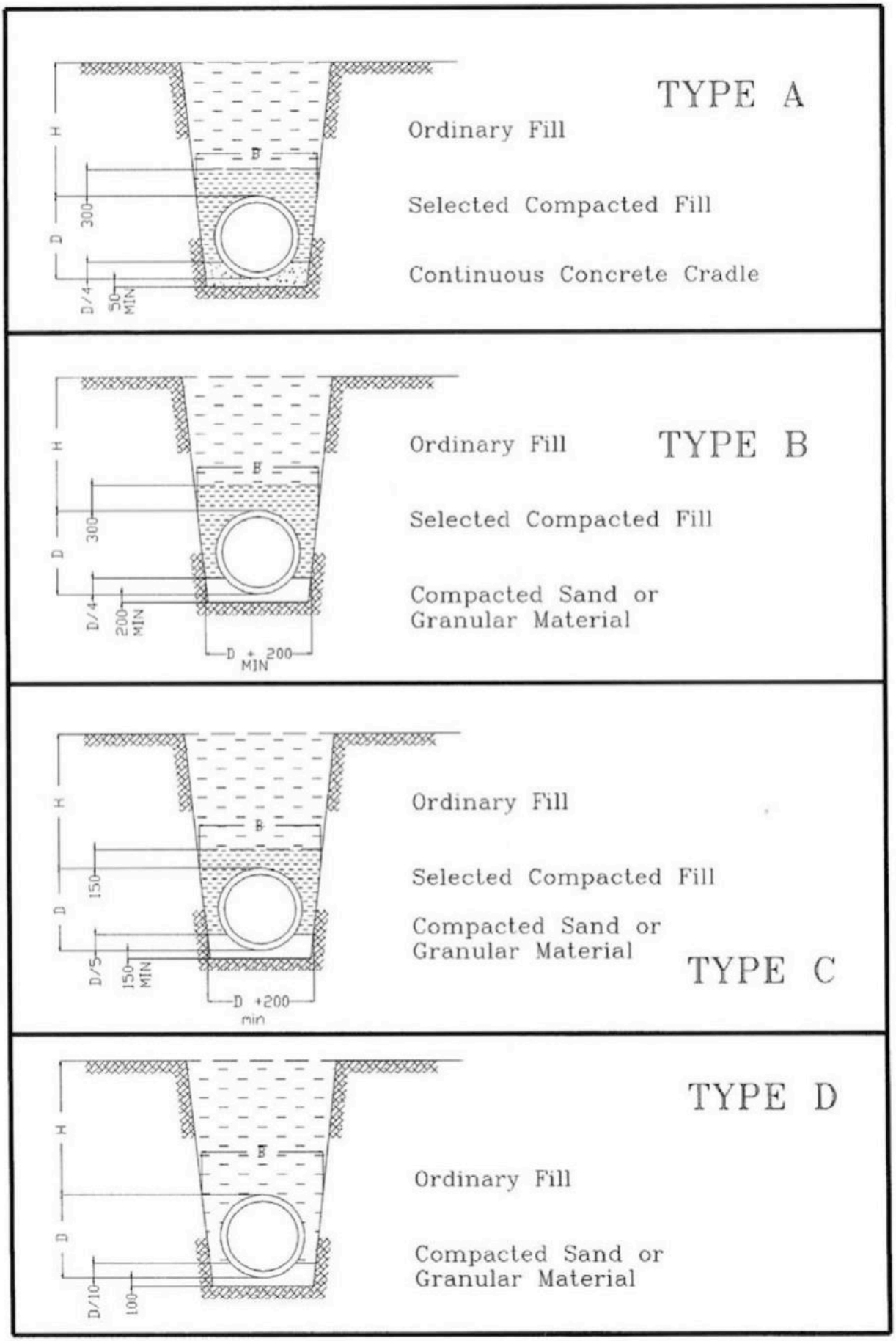


Figure 8.2: Concrete Pipes in Trench Types of bedding on rock

Pipes will be handled by approved equipment and competent personnel.

For smaller jobs, pipes up to about 750 mm diameter and 2.4 m long can be handled by the larger pneumatic tyred machines, either by attachment to the hoe or to the bucket of the frontend loader, which is normally part of the tractor equipment. Care must be taken that the capacity of the machine is not exceeded. Each machine should be marked with its authorised lifting capacity.

On larger jobs, crane handling will be normal. These machines vary from the non-slewing jib type, mounted on a truck, to the larger full slewing heavy lift cranes. The hiring charges for these larger cranes are high, but in well prepared and well organised work where good access has been prepared, they are very well worth using. This is especially the case where multiple lines are being laid, because their longer reach enables them to lay a number of pipes from the one set-up.

Back filling should be done with a bucket machine of some type, at least up to a level of 300mm above the crown of the pipe. Dozers should not be used to back fill. The front end loader operator should be carefully instructed as to the material which is to be used, and it should be explained that material must be placed in relatively small quantities and in such a way that compaction may proceed with a minimum of extra spreading.

Compacting equipment will consist of hand rammers, pneumatic tampers, petrol driven rammers and, where sand and flooding is in use, vibrators. There are trench type vibrating rollers available. They can provide a more rapid means of compaction in larger trenches once there is adequate cover above the crown of the pipe. Very heavy hydraulically operated rammers suspended from backhoe jibs are available for some classes of work. Their ramming action is severe. They must be used with caution to avoid pipe damage.

KEY MESSAGES

- **Keep drains clear**
- **Are there enough inlets?**
- **Check culverts and drains – be aware and WH&S conscious**
- **Be aware of options**

CHAPTER 9
ROAD CONSTRUCTION

For construction procedures refer to 11AT 23 Plant Management.

References
- Standard Drawings
- Local Authority Quality Systems and Procedures (QA)
- Local Authority Maintenance Management System (MMS)
- Department of Transport and Main Roads RMPC Manuals (RMPC)
- Department of Transport and Main Roads Road Technical Specifications (MRTS)
- Manual of Uniform Traffic Control Devices (MUTCD)
- TMR Bridge Inspection Manual
- TMR Timber Bridge Maintenance Manual
- Western Queensland Best Practice Guidelines. TMR Publication.
- Disabled Access and Disabilities Act. (Refer to AS 1428.1 -2009 Design for access and mobility)

Environmental Factors

Please refer to Chapters 2 and 13 before you commence any work on roads.

Refer Chapter 7 Measurements for calculations.

Topsoil

Topsoil should be stockpiled for restoring the worksite at the conclusion of the job.

Utility Services

Make sure you are given a plan of the electricity, water, gas and Telecommunications and overhead services in the area and go over it with the Engineer in charge of the project. Check with Dial Before You Dig.

Where levels of the services are not known excavate preferably by hand. Digging up electric cables can be dangerous and costly and can cause massive disruption.

Telecommunications cables are very expensive to repair and many people are inconvenienced if problems occur, particularly where computers are involved. Do not hesitate to seek the help of Telecommunications employees in locating their works.

Similarly, broken water mains and house services severely disrupt the job. Flooding can wreck a day's progress.

Gas has the added danger of being poisonous and explosive especially when it finds its way into underground pipelines.

Dial Before You Dig www.dbyd.com.au

Roadworks signage and traffic control

Traffic management is a high risk activity and deviation from safety standards can lead to death or serious injury to motorists or road workers, including the traffic controllers themselves. There are very significant costs to the community and public health arising out of road accidents and associated injuries.

In any situation, in which the motorist may be denied the safe usage of the full carriageway, provision for traffic is essential. This principle applies in both construction and maintenance.

Provision for traffic includes:

- the provision of traffic management around roadwork sites including the setting up of road signage and devices on roads
- operational traffic control (managing the flow of traffic around roadwork sites and other road sites)
- the design, auditing and provision of traffic management plans and traffic guidance schemes (this includes organisations that provide traffic management plans, designs or drawings to principal contractors; to third parties; or to traffic management companies).

Signs, barriers, other control devices and lights must be in accordance with the Manual of Uniform Traffic Control Devices.

Setting out of work

In this type of construction, offset pegs should have been placed accurately by Surveying staff. Locate these pegs or marks with the aid of the plan provided to you. Here again, do not hesitate to seek aid in locating or replacing pegs lost during construction.

Order of work

Check with DBYD or directly with Utilities before commencing work.

Utility alterations are usually done ahead of road excavation work and obviously should be at adequate depth.

Take care that during plant operations, particularly back hoes, graders and dozers using rippers are not over depth in this excavation or ripping.

Often additional utility services are laid as part of the new work to cater for future needs.

Co-operation with the utility authority is essential to avoid opening of new work not long after completion. Any opening of new work creates bad publicity.

Drainage

As mentioned in the section on drainage, work should always start at the lowest point so that the job is self draining.

Here again, be careful not to leave pipe-lines without compacted backfill overnight.

See Chapter 8.

Clearing, grubbing and compaction of natural ground

Modern dozers with rippers are powerful and fast enough to handle almost all tree and vegetation removal.

Regulations specify that the dozers must be fitted with guards to protect the operator from injury in a roll over or tree fall.

Heavy mesh infills are also needed to protect the operator from falling branches.

Never use a dozer without the above safety protection.

All vegetation in the actual cut and fill area including trees, old stumps, roots etc. must be removed from the site. They should never be used under fill as they will eventually rot and cause settlement type failures.

Large trees can generally be removed by firstly ripping the roots. The more stubborn trees may require a temporary earth ramp to allow the dozer to push at a higher level, thus providing greater leverage. Trees with root systems in rock may require explosives. This however, is somewhat of a hit-and-miss system and should only be done by expert shot firers.

Compaction of natural ground and back fill of stump holes will result in an increase of fill quantities.

Filling

Identify control points before proceeding.

After tree stump holes etc. have been filled and well compacted, filling must proceed in thin layers, each compacted as the work progresses. The object is to achieve an even density of compacted material. This is best achieved by spreading an even layer of loose material before compaction commences. 300mm of material is about the maximum depth that should be compacted at one time.

If the fill material is delivered in trucks, have it tailed out to an even depth. Do not dump in heaps as the impact of the heap dumped material is often sufficient to unevenly compact the base of the heap. If material is dumped in this fashion, as can occur in after hour deliveries, spread the whole load to an adjoining location before compaction begins the next day.

Geotextiles

Geotextiles are used in specialised situations.

Construction in flat country

Refer type cross sections.

Formation consists of the shaping of the road and is carried out by moving the soil from adjacent areas to the area to be occupied by the road. It is important that it be carried out to the correct shape and alignment of the finished road. Neat, accurate work will always be the cheapest and best.

In flat plain country, formation work is usually carried out using a heavy grader or, in some cases an scraper. The road formation is built up from material obtained from the table drains. These will be of such dimensions as to provide the necessary material and may be in fact larger than is necessary from a drainage point of view. The material is progressively moved across by grader and finally spread in layers to form either the earth road or the sub-grade for pavement material. The material should be compacted in thin layers, preferably between 75mm and 300 mm.

A typical rural road drawing is shown as Figure 9.1.

Urban roads

Urban roads are being asked to carry more traffic each year and it is essential that they be properly constructed to give their full design life.

By its very nature, this type of road is the slowest to construct due to traffic volumes, pedestrians and utility services. This type of job is the one more readily criticised or occasionally praised by rate payers as they regularly see the progress of the work. Aim for praise by pre-planning the work along the following lines:

Excavation

Accuracy in excavation is essential to ensure the pavement to follow is thick enough and thus will do the job without early failure.

It is also very important from a cost point of view not to over excavate. 25mm of over excavation in a 250mm pavement will add at least 10% to the cost of this section and often more, firstly as the over excavated material has to be disposed of and the extra filling placed and compacted.

Extra time needed can increase the 10% cost increase particularly if the pavement material has been ordered to fill the 250mm and not 275mm.

Regularly check the excavation as it proceeds, to ensure accuracy. Do not leave it to the eye of the plant operator. Although many operators are very skilful, nobody can do a perfect job by eye.

Be aware that excavation of natural ground will increase the quantity of the fill required for compaction.

Trimming of sub-grade

A small margin should be left in the bulk excavation for final trim by graders in jobs other than rock. Trimming and compaction of the sub-grade is a very important part of the job, as the success of the pavement depends on an even well-compacted sub-grade. Watch the rollers to see no soft spots appear as they proceed to evenly compact the sub-grade.

Natural material can vary, particularly where shale is less than a metre below the sub-grade. Report any movement in the sub-grade under the roller.

Flexible pavements

Refer to Chapter 3 What is soil? and be aware of specification and testing requirements.

Fine crushed rock

This will either be ordered (according to standards) or be available from the Council quarry.

Gravels

Many areas have to make use of local materials in the form of gravel. Variations are extreme, with the behaviour mainly dependent on the nature of the fines. Testing of gravels is beyond the scope of this manual, however the following variations are attributed to the fines.

Granular fines will allow ready penetration of water to the sub-grade, thus softening the material and weakening the pavement.

Clayey fines cause slippery conditions in unsealed conditions, and excessive wet conditions make the pavement material plastic with resultant ease of deformation and loss of support.

Clayey loams are the best binders and reduce both the above effects. Blended gravels may have to be used where natural supplies are either too granular or too clayey.

Maximum stone size should not exceed one-third pavement thickness.

In deep thickness pavements, stone maximum sizes should be reduced as surface level is approached to allow ease of working and tighter surface. Gravels should be regularly tested as the variation in the pits can be considerable.

Crushed sandstone

Crushed sandstone quality varies through-out the State. Local advice should be sought and standards should be checked.

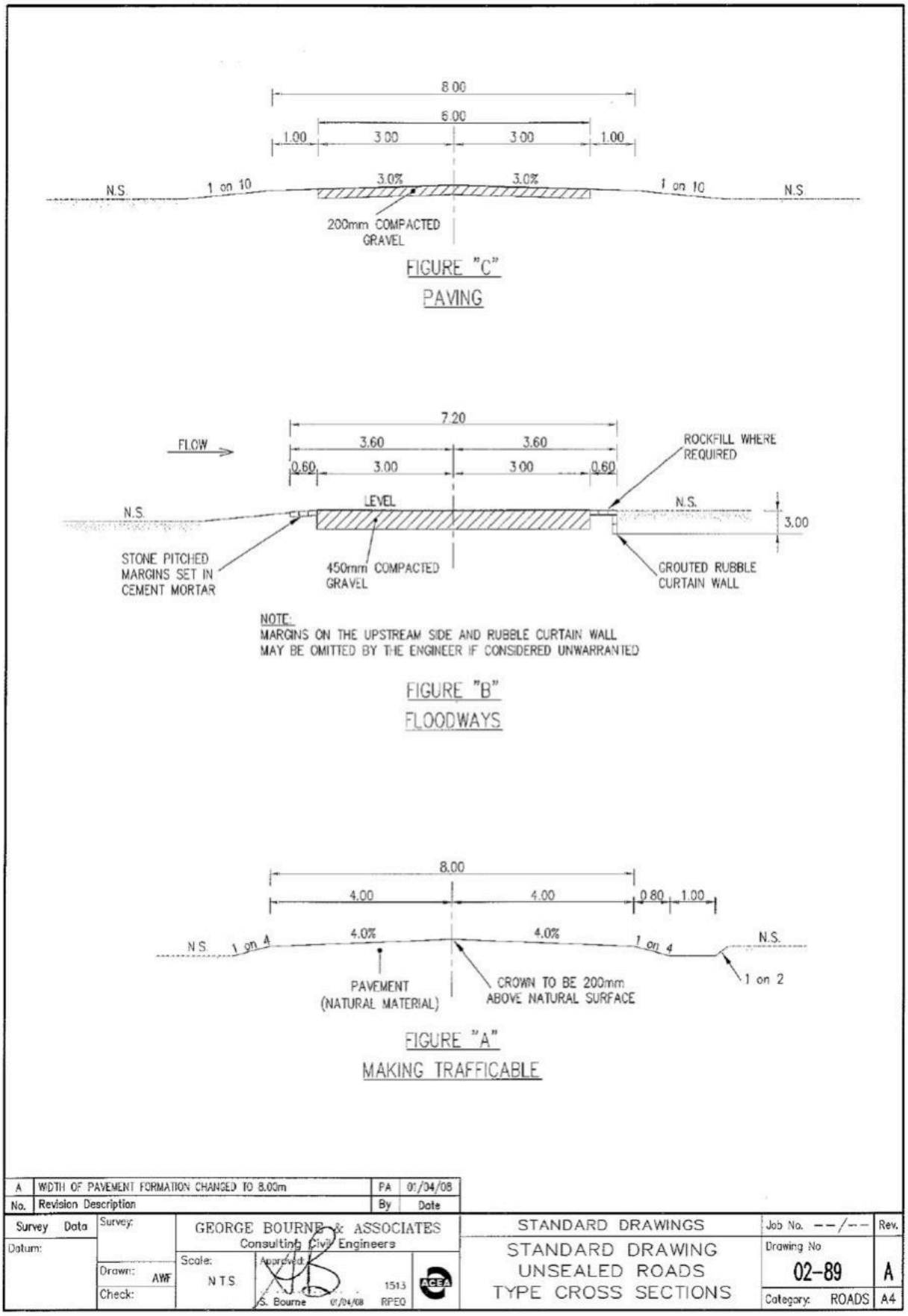


Figure 9.1: Rural Road Construction

Soil stabilising

Stabilising of soils refers to mechanical mixing of certain activities, i.e. lime, cement, emulsion into the sub-grade or pavement to improve its strength. The most common additives used to date are:

- sand and/or clay
- granular materials (selected grades)
- Portland cement
- lime (quicklime and hydrated lime)
- lime-flash
- bitumen
- foamed bitumen
- polymers.

Stabilising is used when the Engineer considers the existing material requires strengthening because of its weakness, moisture content, thickness or the economics involved.

This treatment can be carried out on the existing sub-grade, sub-base, base or even shoulders.

The method of carrying out stabilising is by either mixing-in-place or by a stationary plant away from the job.

(a) Mixing-in-place is generally done with a purpose built stabiliser, however it can also be done with a combination of graders, rotary hoes, mixing machines, cement/lime spreaders, water trucks and compaction equipment on existing pavements to a depth of 150 to 200mm.

Stabilisers are purpose built to break up pavements as well as incorporating a mixing chamber and teeth on legs which are at a designated length away from the rotor drum to allow for efficient and thorough mixing of the stabilised materials. The mixing chamber is designed to retain the material until the mixing of pavement material and binders is complete. The material is mixed across the full width of the drum evenly.

(b) Stationary plant mixes all the appropriate materials together off site and is then transported in trucks to the site to be laid through a spreader.

Cement stabilisation of pavement

Pavement drainage

Be aware of circumstances in your local area.

Water penetration of the pavement material is the greatest cause of road failures. Even sealed pavements are not 100% waterproof; for instance hydraulic pressure, produced by vehicle tyres pushing the water downwards. The seal also has the capacity to draw water from below and condense the moisture on the underside of the seal when it cools.

Other sources are side entry of water from road shoulders and or sub soil water seeping into the pavement from adjoining country. Shoulders should have adequate cross fall to reduce the possibility of side entry.

Sealed and gravel pavements should have a nominal crossfall of 3%.

Subsoil drains

Subsoil Drains are commonly constructed with corrugated, perforated plastic tubing. This product is very easy to lay as it is simply rolled into the trench thus eliminating the labour intensive job of laying the clay or the no fines concrete pipes.

Backfill around the pipes should be of a graded granular nature to allow easy access of water to the pipeline. Very small silt particles have a tendency to be washed into the pipelines and many blockages have resulted, particularly on flat grades.

Covering of the corrugated plastic pipe with a geofabric gives added insurance against silt penetration.

Products such as Geocomposite or panel drains comprising of a prefabricated drainage core with an outer geotextile filter are also frequently used. Geocomposites have a larger surface area than round pipes, so generally collect water more quickly. Geocomposite panel drains can also be more economical when installed in narrow trenches of approximately 100mm. Because of their relatively stiff structure and high flow velocity there is also less risk of siltation.

It is essential that backfill be capable of allowing the water to flow to the drain. Well graded granular material is the most efficient. Clay materials are obviously unsatisfactory.

Water from adjoining land should be caught in catch drains clear of the road shoulder and also above cuttings where cuttings exist. In open country the drains should be discharged into adjoining property at frequent intervals to prevent the volume of water building up to the point where it will cause erosion.

In urban areas, a 600mm deep drain is rarely acceptable due to danger to pedestrians and the problems it creates with vehicle entry to properties. Installation of subsoil drains or stormwater drains fed by kerbing and guttering is the acceptable alternative.

When backfilled with granular material, stormwater drainage trenches act as a good subsoil drainage item. If subsoil drainage flow is excessive, a subsoil line can be installed in the same trench. In either case, provision is made at gully pits for discharge of subsoil drainage water. If no subsoil pipe is used, care must be taken to ensure a filter material is used at the pits to allow water entry but not backfill material. The outlets of sub-soil drains not discharging into gully-pits, manholes etc. should be constructed together with a small area of stone pitching to prevent grass growth and blocking of the outlets. To aid finding the outlet a post marker should be provided.

KEY MESSAGES

- **Locate services**
- **Refer to environmental factors**
- **Read specification documents**

CHAPTER 10
KERB & CHANNEL AND CONCRETE FOOTPATH CONSTRUCTION

Refer to IPWEAQ Complete Streets publication.

Kerb & channel is mainly used in urban areas where traffic volumes are high and where houses are close enough to allow residences to maintain attractive lawns. Its use defines pedestrian areas from vehicle areas and defines the road pavement.

It is also used to dispose of surface water from the road pavement, properties and footpaths sloping towards the kerb, and also acts as a ready connection for house roof water lines. Its water carrying capacity without sealed shoulders is minimal.

The main use on rural roads is where scour problems occur on hills in long cuttings where it is not practical to discharge water into adjoining properties at frequent intervals. In cases where it is installed the shoulders are usually sealed.

Support for kerb & channel

Careful attention into design is required in poorly drained expansive clay subgrades.

The old practice of pouring kerb and channel on the natural ground has produced problems in recent years when traffic volumes have increased greatly. When the road is sealed to the gutter more traffic, particularly when parking, runs on the gutter.

To provide support for the comparatively thin gutter section, modern practice is to continue the road pavement under where the kerb and channel is to be poured.

See Figures 10.1 and 10.2 at end of the Chapter.

Level pegs

As the slope of the kerb and channel determines the look of the finished road, adequate level and line pegs should be provided. On straight grades pegs offset 1 metre behind the face of kerb and spaced every 15 metres, produce a good result. On vertical curves the spacing should preferably be half the above.

Access to properties

Most complaints made to Council during construction are made because people have not been notified of kerb and channel construction and arrive home either to find their car blocked in the garage or they can not gain access to their property. Some days advance warning should be given, preferably by doorknock, or as is often the case when husband and wife work and they have left for work earlier than the arrival of Council staff, letterbox notification should be used. This is good public relations and most people will cooperate for the few days needed to pour and cure the concrete.

Kerb & channel shapes

Refer to Local Authority drawings, IPWEAQ Standard Drawings or IPWEAQ Complete Streets and job documents.

Use of continuous dish crossing type or alternately a rolled edge kerb has been used by some Councils in new subdivisions. Advantages are that the vehicular crossings can be placed anywhere without breaking out the kerb.

Disadvantage is they do not adequately keep vehicles on the road pavement, which is a source of annoyance to people maintaining a neat lawn on the footpath.

Mountable kerbs are used in median strips or traffic islands.

A good example from Magnetic Island is shown at the end of the Chapter (courtesy of Townsville City Council) (Figure 10.3).

Kerb & channel formwork

Machine laid

When performed by experienced workers this method provides the best job. On a prepared base this method offers the advantage of a variety of shapes through different moulds in the machine as well as a very high daily output.

The concrete mix is critical as it must be dry enough to stand up unsupported behind the machine yet strong enough to do the job. Ready mixed concrete firms have all designed their mixes to suit local aggregate supplies so it is simply a matter of specifying the strength required. The product has reduced fines and the dry mix needed for the machine produces a boney mix unsuitable for use without topping with a sand cement mix.

This topping is comparatively thin and care must be exercised that it is not scraped by graders or loaders during trimming.

Machine-laid kerb and channel is not as durable as that produced by skilled formwork workers. Apart from speed of laying, the method has the advantage of not needing labour to compact or screed the concrete, finishing only being required.

Setting up is easy as all that is needed are steel pegs to support the steel wire set ahead of the machine to the line and level of the finished road.

Steel forms

Less use is made of steel formwork, mainly due to weight restricting its use to short length. Bending due to careless handling has also produced problems over the years.

Timber formwork

Use of a backboard, a gutter board nailed to wooden pegs and a face board positioned on steel templates held by stirrups has produced a very good kerb and channel.

The advantage is, the concrete used is durable and even, when adequately compacted by spading. Disadvantages are the labour content of the formwork and the skill needed to hand-level and finish the gutter and later to hand-finish the face when the face board is stripped. Cleaning and oiling forms presents some problem. The steel templates should be placed approximately 4.5 metres apart and the gaps left after they are carefully removed can be used as expansion contraction joints. In hot arid areas, provision should be made for expansion joints at a nominal 3m and should be dowelled (see photograph at end of this Chapter).

Drainage holes

Care should be taken to locate all roof water lines and allow holes in the kerb for later connection.

It is good practice to leave some additional holes for seepage water that will use the comparatively soft backfill of the footpath to flow behind the kerb. Wooden bungs or short lengths of plastic pipe or special galvanised steel as well as aluminium sleeve are available for use in kerb and channel construction with formwork to provide the necessary holes.

In machine laid kerb and channel, holes have to be cut behind the machine.

Do not neglect this important aspect as holes cut or kerb broken, later spoil a good job.

Curing

Best work is produced when concrete is cured for at least 7 days. The longer the better. Covering with waterproof paper or plastic is satisfactory if it can be kept in place. Material left to flop in the wind is virtually useless. Holding the sheeting down with sand if available is satisfactory.

The alternate is to use concrete curing compounds which are sprayed on and do not have the disadvantages of sheet covering.

Access to properties

To help public relations, concrete vehicular crossings should preferably be poured the following day to reduce time residents are denied vehicular access.

Three days curing time should preferably be allowed before light vehicles use the crossings.

Footpath paving

Dimensions

Most Councils adopt a width of 1.2 metres and 100 mm thick to allow pedestrians to pass in opposite directions without problems.

Jointing

Dummy joints are best placed at a maximum of 1.2 metres. If cut well into concrete, shrinkage cracks should not be a problem. Experience has also shown that these joints are adequate for expansion joints except on extra long runs. In hot arid areas adequate expansion joints must be used to prevent cracking.

Provision of expansion jointing is laborious and formation of a straight joint is difficult. In expansive soil areas it is advisable to dowel joints.

Durability

This is the most important requirement of concrete paving and cannot be achieved without adequate cement content, with careful attention given to the mix design.

Ready Mix Companies have found that compressive strength can be obtained by improved mix design, additives and using less cement. Durability however, requires the equivalent of 8 bags of cement per Cubic Metre (equivalent to 20 Mpa).

Finishing

A good finish is essential as poorly finished concrete footpath paving stands out more than any other Council works.

The art of finishing is knowing when to finally float the mix. Overworking the concrete by early and excessive floating brings excessive water to the surface. Excess water is a great weakness of concrete and a weak surface is not durable.

Just when to finish the concrete with the minimum of floating is a matter of judgement gained from experience. It depends on the slump of the mix, which should be as low as can be handled, as well as the temperature and humidity and wind conditions of the day. As the latter two vary greatly, no guide can be given as to time.

Wooden float finish or broom will give adequate roughness.

Finish with a soft broom finish to provide adequate slip resistance.

Width of the concrete so finished is not however sufficient to cause slipping problems.

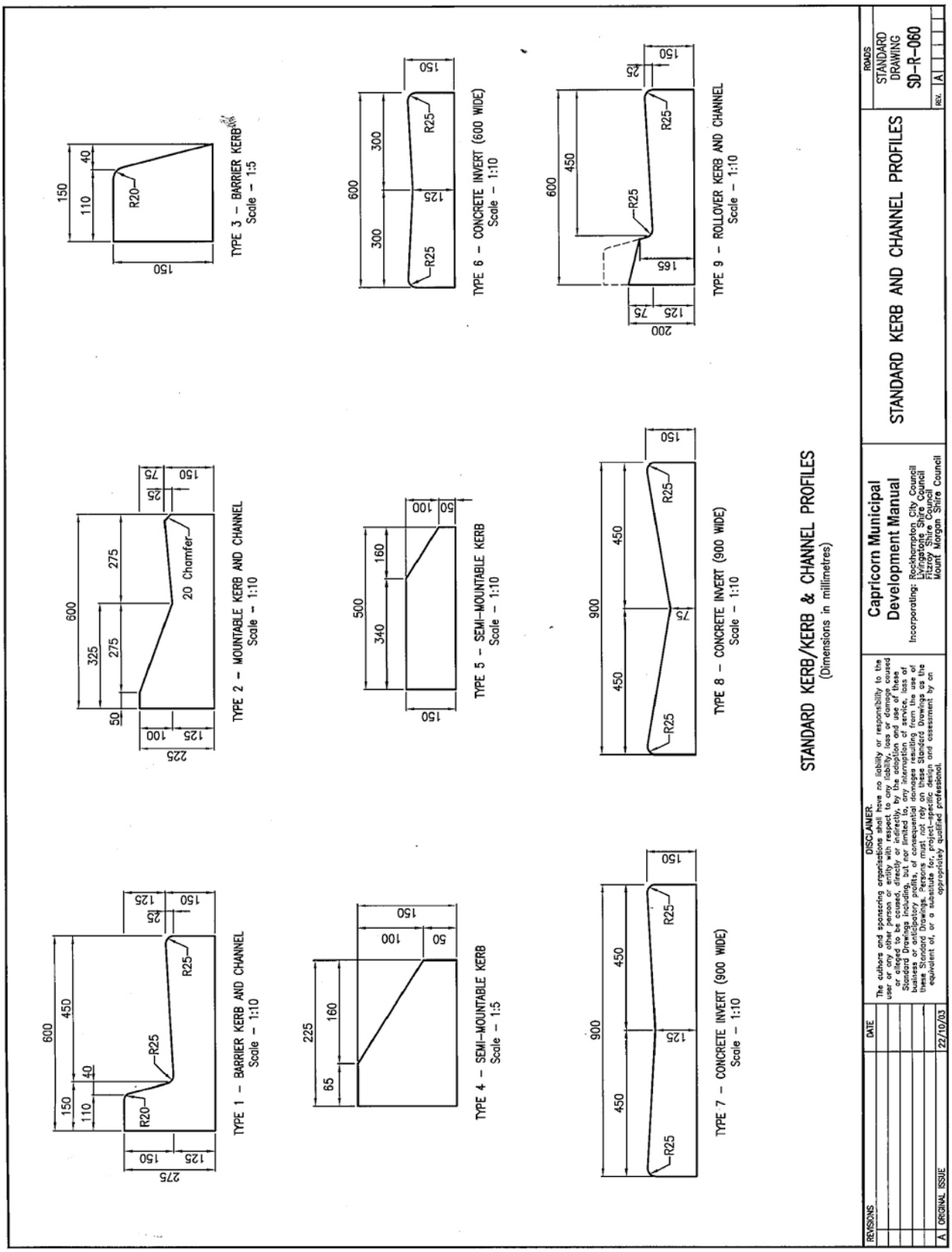
The most important aspects to good footpath paving are therefore:

1. Well aligned and levelled formwork
2. Adequate cement for durability
3. Finishing with minimum of floating
4. Accurate trimming of subgrade
5. Accurate placement of reinforcing where applicable
6. Water/Cement Ratio
7. Construction Joints

Refer to Chapter 14 Concrete.

KEY MESSAGES

- **Be aware of the types of soils**
- **Notify residents**
- **Create a good finish**


TYPE 1 – BARRIER KERB AND CHANNEL
Scale – 1:10
TYPE 2 – MOUNTABLE KERB AND CHANNEL
Scale – 1:10
20 Chamfer
TYPE 3 – BARRIER KERB
Scale – 1:5
TYPE 4 – SEMI-MOUNTABLE KERB
Scale – 1:5
TYPE 5 – SEMI-MOUNTABLE KERB
Scale – 1:10
TYPE 6 – CONCRETE INVERT (600 WIDE)
Scale – 1:10
TYPE 7 – CONCRETE INVERT (900 WIDE)
Scale – 1:10
TYPE 8 – CONCRETE INVERT (900 WIDE)
Scale – 1:10
TYPE 9 – ROLLOVER KERB AND CHANNEL
Scale – 1:10
STANDARD KERB/KERB & CHANNEL PROFILES
(Dimensions in millimetres)
DISCLAIMER.
The authors and sponsoring organisations shall have no liability or responsibility to the user or any other person or entity with respect to any liability, loss or damage caused or alleged to be caused, directly or indirectly, by the adoption and use of these Standard Drawings including, but not limited to, any interruption of service, loss of business or anticipatory profits, or for consequential damages resulting from the use of these Standard Drawings. Persons must not rely on these Standard Drawings as the equivalent of, or a substitute for, project-specific design and assessment by an appropriately qualified professional.
REVISIONS
DATE
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22/10/03
Capricorn Municipal Development Manual
Incorporating: Rockhampton City Council
Livingstone Shire Council
Fitzroy Shire Council
Mount Morgan Shire Council
STANDARD KERB AND CHANNEL PROFILES
ROADS
STANDARD DRAWING
SD-R-060
REV. A

Figure 10.1

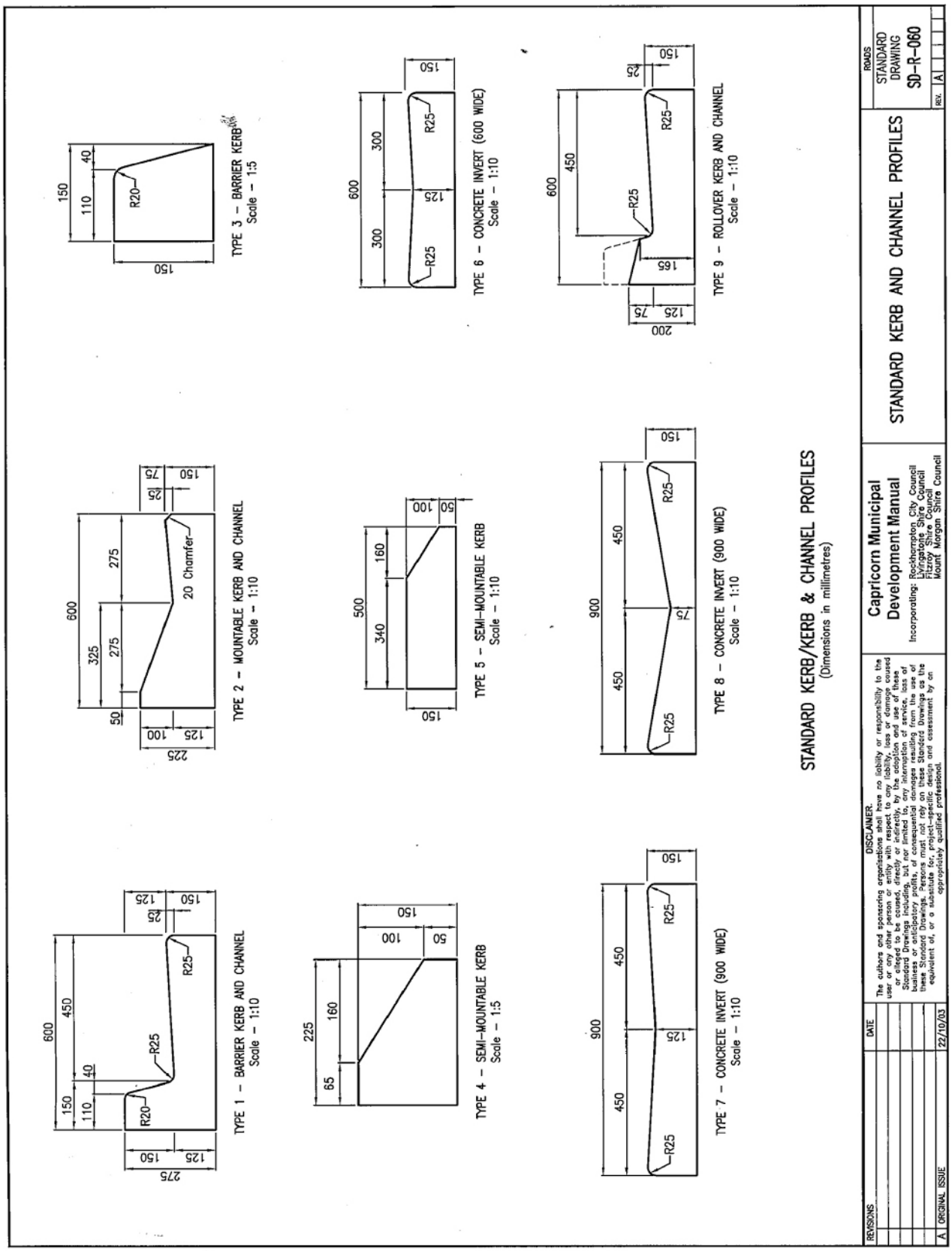


Figure 10.2 Reinforced Concrete Pavement with Rollover Kerb and Channel

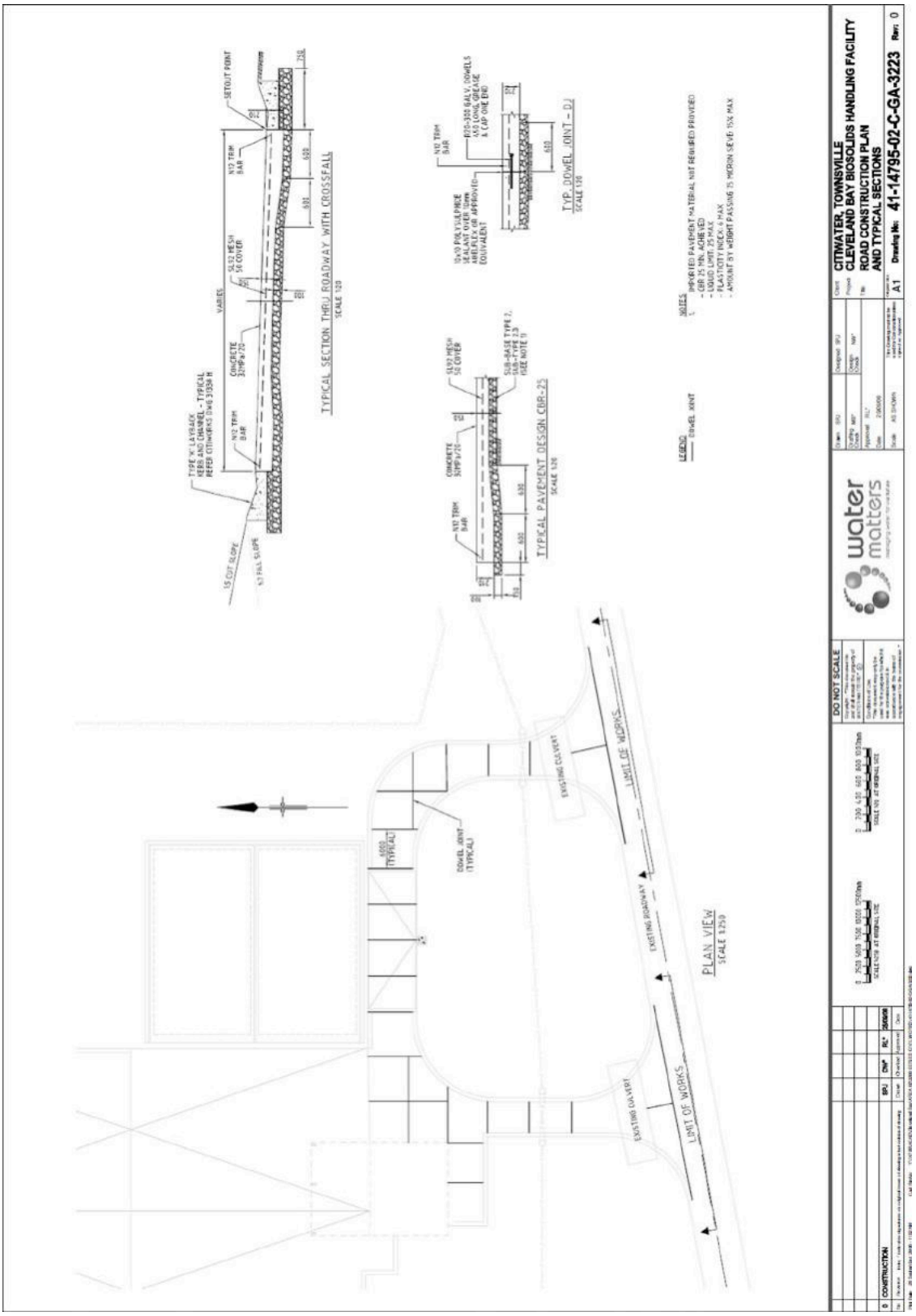


Figure 10.3 Kerb and Channel – Magnetic Island

Refer Figure 10.3.Concrete pavement, showing finished expansion joint details (Magnetic Island)

CHAPTER 11
SURFACE COURSES AND RE-SURFACING (BITUMINOUS SURFACE CONSTRUCTION)

All works in accordance with TMR and/or local authority specifications.
The basic term used in Australia for an application of bituminous binder and aggregate is sprayed seal, commonly shortened to seal. When placed as a retreatment of an existing bituminous surfaced pavement it is referred to as a reseal.

Initial treatments generally require the use of either a prime or primerseal. A prime is the application of a bituminous material of suitable viscosity to a prepared pavement prior to the application of the next bituminous surfacing. A primerseal is the application of a suitable primerbinder and fine cover aggregate to a prepared pavement. It is generally used as a temporary treatment prior to applying the next bituminous surfacing.

Preparation of pavement for sealing

This is the most important part of the job. While it may take a short period of time it is a significant part of the cost.

Physically and closely inspect all areas to be sealed in advance of priming and check again after sweeping.

As seals are comparatively thin, any irregularities in the pavement will show through. It is essential therefore that the pavement material be thoroughly and evenly compacted to an even surface, free of weak areas. Loose or dusty material should be swept off.

Actual area to be sealed should be clearly marked on the pavement.

Sprayed sealing of gravel roads

Priming coat

A priming coat is applied to the gravel to bind the fines and give some tie to the coarse stones, thus giving the bitumen something to adhere to, as hot bitumen will not penetrate the road material.

It is desirable to let the primer penetrate for as long as possible before applying the seal and to allow the Cutter oil to evaporate from the pavement. If the road is already a traffic carrier and not a new road, coarse sand or other granular material should be applied before allowing traffic onto the primed area. This is to avoid the danger of allowing traffic to use what is mostly a slippery surface.

No more than a few days should elapse before the seal proper is applied as primers are not very durable under traffic. Ideal weather conditions for the seal are hot and dry. Seals should not be attempted in damp, cold conditions. Ensure that all sand is removed from primers before sealing to prevent stripping.

Sprayed sealing of gravel roads

Stone preparation (precoat)

Reject dirty and dusty aggregate from suppliers: refer aggregate grading specifications. In this type of seal, problems of stripping have been experienced. Traffic volumes and high speed also contribute. Stones are therefore mostly pre-coated to help overcome the stripping problem. Obtain the pre-coat application rate from the Engineer and mix well.

Spreading cover aggregate

Use TMR approved proprietary materials and apply in accordance with job specifications.

Spraying technique

Once the primed surface has had any loose dusty material removed, a strip of paper is placed under the spray bars of the tanker at the start of the spray and another at the end of the area to be sprayed. The paper is usually held down with sand. This is because the full even spray is not obtained immediately valves are opened or cut off.

Adequate trucks of aggregate should be on hand as it is essential to apply the stone to the bitumen while hot and soft. Application of the stone should be accurate to the specification. Too little stone will produce a fatty slippery surface lacking durability. Too much stone if left after rolling, will produce windscreen damage when high speed traffic uses the road.

Constructing Joints Between Adjacent Sprayer Runs

Common practice is to overlap the binder between adjoining runs prior to spreading with aggregate with the intention of achieving a seamless joint. This requires the correct selection of spray nozzles and width of overlap Incorrect overlapping can result in areas where there is:

- insufficient binder to hold the aggregate and a potential for stripping; or,
- too much binder and a potential for flushing.

It is important to use the same type of nozzle on both overlapping edges. Overlap between binder sprayed with an intermediate nozzle and an end nozzle can result in a binder application rate with a variation of up to double the designed rate in the overlap area. Spray bars that are adjustable in width on the run require particular consideration.

Spraying Around Curves

Spraying around tight curves can result in a significant difference in binder application rate between the inside and the outside of the curve. Binder application rate will increase with reduced speed on the inside of the curve while the higher speed of the outside edge results in lower rates.

Sealing techniques

Primer seal

This eliminates the primer coat and is used mainly in urban areas. See Table 11.1 which shows the Cutback Bitumen Classifications and their applications for the various bitumen surfacing processes used in road construction. Refer also to relevant TMR standard specifications. As an alternative to cutback bitumen, bitumen emulsion binders may be suitable depending on the type and condition of the pavement, and weather.

Cutback bitumen primerseals should be cured for a minimum of 6 months, or possibly up to 12 months in cool conditions, to reduce the risk of cutters softening the following bituminous surfacing. Primerseals constructed with bitumen emulsion binder require a minimum curing period of three months before applying the further seal.

Single coat seal

This consists of one application of bitumen and one layer of aggregate, sprayed in accordance with engineering design.

Double coat seal

This involves one layer of bitumen with larger stone and a second layer of bitumen with smaller stone. Spray rates as per engineering design.

All design binder application rates and additive mixing rates are measured and expressed at 15ºC.

It is important that bitumen surfacing work has designed application rates as they vary due to temperature and other conditions. See your Engineer to design your application rates.

Table 11.1: Cutback Bitumen Classes

Class (AS 2157 designation)		Approx. parts Cutter Oil per 100 parts bitumen (vol. at 15ºC)	Equivalent percent of kerosene (vol. at 15ºC)	Viscosity at 60ºC (Pa.s)
Precoating and priming classes	AMC00	127	56	0.008–0.016
	AMC0	86	44	0.025–0.05
	AMC1	61	34	0.06–0.12
Primersealing classes	AMC2	38	27	0.22–0.44
	AMC3	28	21	0.55–1.10
	AMC4	18	16	2.0–4.0
Sealing classes	AMC5	12	11	5.5–11.0
	AMC6	7	7	13.0–26.0
	AMC7	3	3	43.0–86.0

Spreading

Rolling

Careful attention must be given to rolling in of aggregate particularly in low traffic rural remote areas. Only multi rubber roller or rubber pad rollers should be used. Constantly/ closely monitor performance following completion of works.

On roads with higher traffic volumes, the traffic provides a greater contribution to aggregate reorientation and embedment, and the rolling requirement is less. Rolling requirements for larger aggregates are greater than for small aggregates.

It is important that the aggregate is rolled before the binder sets up and becomes too viscous to achieve wetting and adhesion. Therefore, the first roller pass must follow as closely as practical behind the spreader(s). In cold conditions, or where polymer modified binders are used, there should be enough rollers to cover the full width of the spray run with one pass. Initial roller passes should be undertaken without overlapping in order to roll the aggregate as quickly as possible after spreading. After the surface has been covered once, rolling should proceed by overlapping each preceding pass by about one third of the effective roller width, starting at the edges and working towards the centre. The first two passes should be done at a low speed (5 – 10 km/h) to achieve the aim of pressing the aggregate into the binder, but after that, the rolling speed may be increased to between 15 and 25 km/h to move and re-orientate the aggregate particles to their correct position.

Rolling should be continuous and the full width of the seal should receive an equal number of roller passes. Rolling should be maintained throughout the day and rollers should not be left idle, e.g. between sprayer loads, but used at every opportunity. Rolling should be continued until the aggregate is well embedded in the binder and a uniform surface obtained. Adequate time must be allowed at the completion of the day's work to ensure that the last materials spread receive the same amount of rolling as that placed earlier in the day. Rollers must be stopped and started smoothly to avoid skidding the wheels which will tear out and damage the new work

Hot mix asphalt

Hot mix is a term loosely applied to a stone and bitumen mix applied to the pavement in a hot condition. In finer definition, is a mix with fine aggregate comparatively open in grading. Asphaltic concrete is a mix with a more dense fine aggregate content. Sheet asphalt is a dense mix with small maximum size aggregate. It is often used on footpaths.

Dense graded asphalt mixes are most commonly used for strength, durability and resistance to traffic stresses. They can provide substantial improvement in noise reduction of existing pavements through improvement in smoothness and ride quality. Other types of asphalt mixes have specialist application, providing particular texture characteristics in terms of noise or water spray alleviation, but may involve compromise in terms of cost, durability, or lack of contribution to structural stiffness. Open graded mixes have low resistance to surface shear and should not be used at heavily trafficked intersections. Stone Mastic Asphalt would be suitable at intersections. Open Graded mixes must also be placed on a sound waterproof base or used in conjunction with a waterproofing membrane seal.

By varying the aggregate combination to provide a range of different air voids, and using different grades of binder, asphalt properties can be adapted to suit applications from low traffic areas to freeways and heavy duty areas such as airports and container storage areas.

In light traffic areas, the asphalt may fail by ravelling due to oxidation of the binder. To minimise this, a soft grade of binder may be used and air voids reduced with a high binder content and/or fine aggregate grading. Fine gap graded mixes are a modified form of dense graded mix specifically developed to achieve durable asphalt mixes for use in light traffic areas.

On more heavily trafficked pavements it is important that the asphalt does not flush, deform, or fatigue under the action of traffic. Resistance to flushing and deformation is improved with coarser gradings and stiffer binders. Polymer modified binders can be used to enhance both rutting resistance and fatigue properties.

For most applications, asphalt is dumped directly from trucks into the front hopper of the paver. Where project circumstances are suitable, a materials transfer device may be used to improve control over feeding asphalt materials to the asphalt paver. In this case, delivery trucks dump asphalt into a materials transfer device, which then feeds it into the paver hopper by means of a conveyor belt. Materials transfer devices generally hold about 20 to 25 tonnes of asphalt.

Pavers operate on the floating screed principle, spreading material in a uniform layer to a desired thickness and longitudinal and transverse shape. The paver also provides primary compaction of the mix (which is completed by subsequent rolling). The principal components of a self-propelled paving machines are:

- tractor unit
- screed unit
- automatic sensing and levelling equipment.

Automatic level sensor equipment should be used, where appropriate, to control the operation of the screed. These controls are used to maintain levels, thickness and crossfall to a greater degree of regularity than that generally obtainable with manual control alone. Automatic controls use sensors to activate the hydraulic mechanisms that control the paver pivot points. Raising and lowering the pivot points changes the angle of attack and thickness of asphalt mat. Sensor probes may travel:

- on the finished surface of the mix in an adjacent run,
- on a moving level averaging device, or
- on a fixed reference line parallel to the desired finished surface.

In addition, level control can be achieved using laser or acoustic technology, or by on-board computer.

Proper compaction is essential for the performance of hot mix asphalt. Dense graded mixtures in particular, rely on high standards of compacted density for structural strength, fatigue life, resistance to deformation and durability. The basic roller most commonly used for the compaction of asphalt mixes is the tandem, steel-wheeled vibratory roller. Compacted density is achieved through a combination of contact pressure and amplitude and frequency of vibration. Roller manufacturers provide guidelines for selection of forward speed, vibration frequency and amplitude for different asphalt mix types, layer thickness and placing conditions.

Matching speed of rolling to frequency of vibration is an important factor in compaction effectiveness. Good practice requires the establishment of roller patterns and number of passes based on monitoring of density outcomes for the types of asphalt mix being placed.

Multi-tyred rollers are used to further increase the density of asphalt mixes compacted with steel-wheeled rollers. Care is required to avoid pick-up on rubber tyres. Preferably, tyres should be warmed on previously placed warm surfaces before rolling fresh hot materials. Use of tyre coating agents and cleaning of tyre surfaces, are also important practices. Steel-wheeled rollers in non-vibratory mode may be used to finish rolling and remove surface marks, etc. Vibrating plate compactors are used to supplement rolling in areas inaccessible to the larger machines.

Construction of longitudinal and transverse joints is a critical asphalt paving issue. Joints are a potential source of weakness and must be properly formed and compacted to ensure adequate density and possible increased permeability. Transverse joints are also a potential source of increased segregation, particularly if handwork is excessive.

Polymer modified binders

Check local practices. Polymer Modified Binders, known as PMBs are Class 170 bitumen to which a modifier is added to improve properties. This modifier is Polymer.

Common polymeric materials used in spray work include:

- Styrene Butatiene Styrene (SBS) block copolymer
- Granular Scrap Rubber
- Ethylene Vinyl Acetate (EVA) Copolymers

Some typical polymers and their uses: SBS
- Crack treatment
- Aggregate retention
- Low temperature crack resistance

EVA
- Crack treatment
- Aggregate retention
- High temperature crack resistance

PMBs are used as:

1. **Strain Alleviating Membrane** (SAM). A SAM consists of a PMB with aggregate typically 10mm to 14mm in single or multiple applications. A SAM is used for reducing reflection cracking and water-proofing pavements and bridge decks.
   A PMB is effective in reducing reflective cracking where the pavement has not deteriorated to the stage where pumping of fines to the pavement surface is a problem.
2. **Strain Alleviating Membrane Interlayer** (SAMI). A SAMI is an interlayer consisting of a PMB with aggregate, which is used prior to asphalt overlay. It is designed to relieve tensile strains developed in under-lying layers, and so lessen the likelihood of cracking in the overlay.
   SAMI are generally used on cracked pavements and to waterproof pavements and bridge decks.
3. **Highly Stressed Seals** (HSS). An HSS comprises a PMB with aggregate in single or multiple applications. These seals are used for improving aggregate retention under high traffic induced stresses.

Typical job: Bitumen surfacing

All seals must be designed by the Engineer and a number of factors are taken into consideration in the design.

Refer to ‘Austroads Design of Sprayed Seals’, TMR Region and Local Authority Policies.

A typical seal in a remote area may comprise:

- 16mm Cover Aggregate – spread rate $1m^3/80m^2$

Step 1: Determine the area to be sprayed

Total truck volumes - 14 + 12 + 10 = 36m^3

Multiply by aggregate spread rate - 36 **x** 80 = 2880m^2

Step 2: Determine length of sprayer run

Divide above area – 2880m^2/6.0m seal width = 480m run

Step 3: Mark out 480m length on the pavement

Step 4: Determine quantity of bitumen, cutting oil and additive to be loaded into the sprayer

Quantity of bitumen required for the 480m run;
= area x spray rate
= 2880m^2 x 1.8L/m^2
= 5184L

To this must be added the cutting oil 3% & additive 0.5%

3.5% of 5184L = 181L

Therefore Total Quantity @ 15º C =

5184L + 181L = 5365L

Now convert to volume at 165º C in the bitumen tanker.

Refer to 'Transport and Main Roads Specification. MRTS 11. Table 15B' – Heat factor for 165º C is 0.9089, Divide the quantity 5365L/Heat factor.

5365L/0.9089 = 5903L

Therefore for a sprayer of capacity 14000L there will be sufficient for two runs before a reload of the sprayer.

Resealing

The greatest enemy of bitumen is sunlight, which causes the surface layer to break down. Next worst offender is lack of traffic. Regular traffic flow kneads the surface and helps close up cracks that form. Refer Chapter 12 Road Maintenance.

Detailed instructions and specifications for resealing works are given in the Transport and Main Roads Standard Specifications and RMPC Manuals and the Local Authority Quality Assurance Systems and Procedures.

Funds can become available at short notice for long length of reseals and it is important that the ganger/supervisor is aware of the general requirement of the above documents and that the relevant sections are readily accessible. Keep in mind, location where such projects can be carried out.

The scope of works can vary from just a straight bitumen resurfacing job, to involving full profile correction, pavement repairs and crack patching in addition to the reseal.

Listed below are some essential items that must be undertaken for any seal or reseal.

- Compile a copy of all relevant sections of the standard specification and QA procedures applicable to the project, and have these available on site.
- Detailed inspection of site, identifying defects, scope of repairs and material required.

- Order all materials – Cover Aggregate
  – Bitumen and rate of delivery to site
  – Cutting Oil
  – Additive – check for approval of type or grade
  – Paper
  – Brooms
  – Shovels
  – Signs

- Prepare stockpile sites – Note location and wet weather access
  – Construct in accordance with specifications

- Following delivery of Aggregate
  – Collect samples
  – Test for compliance
  – Determine ALD
  – Design Seal – usually by a professional engineer
  – Measure stockpiles and confirm quality of aggregate

- Plan, programme and implement all pavement repairs, crack patching, edge patching and profile correction.

- Plan Traffic Control – Side Track/Under traffic
  – Signs and traffic control
  – Estimate delays to traffic
  – Notify the public via radio, newspapers and public notice board

- Organise Plant – Trucks
  – Aggregate spreaders
  – Loaders and Back up loader
  – Rollers and Back up loader
  – Job Truck and patch crew and tools
  – Additive, cutting oil, paper
  – Tapes
  – Confirm traffic control

- Sweep pavement and check that all loose material vegetation etc. is well clear of pavement edges.
- Sealing operation

  Refer to Typical job: Bitumen surfacing for a method to determine spray length with available trucks.
- Ensure additive, cutting oil, paper, pavement thermometer, spraysheets, tape, radio and specifications and QA procedures are on site.
- Check traffic control systems operations.
- Commence spraying and monitor spray rate and aggregate spread rates
- Commence Rolling. Note in low traffic areas allow for additional rolling for several days after seal, particularly on edges and section outside of wheel paths.
- Sweep off loose aggregate gently to ensure that embedded aggregate is not disturbed.
- Re-establish pavement markings.
- Follow up with inspections regularly to monitor performance of seal or reseal and report any defects in the surface.

Bearcat aggregate spreader

In the event of a serious underspray or commencement of aggregate stripping notify engineer follow up with a surface enrichment. This will eliminate loss of aggregate and pro-long life of any deficient works. Eventually the surface needs resealing due to cracking or ravelling. The latter is the loss of stone resulting from lack of grip due to ageing.

Slurry Seal

A further surfacing type is slurry surfacing, which provides a thin, uniform, fine textured surface, suitable as a maintenance retreatment on sound, stiff pavements with low to medium traffic levels. It is used when the old seal needs protection from raveling.

Reseals should occur in 10-12 year cycles depending on climatic conditions. In some areas this may be required earlier.

Asphalt paving and overlays

As mentioned, added depth of hot mix strengthens the pavement. In developed areas however, adding layers of hot mix over the years can produce level problems. There can also be problems of getting new layers of asphalt to adhere to the old, perished surface skin.

Thin layers of resheet are rarely successful due to this adhesion difficulty and the fact that the old pavement has hardened and the new surface being comparatively soft re-ally needs a yielding layer to transfer stress to the old seal. If the old pavement is sound and the surface not too hard and brittle, a simple tack coat of bituminous emulsion is applied before the machine lays the new mix. Paving can also be done in 2 layers, the first having the advantage of acting as a levelling coat. As with the original hot mix, the surface course can be a more dense mix.

Stress transfer layer

Where there is a problem of movement differentials between the old still pavement and the new softer mix, a layer of elastic material can be applied. The material is commercially available and is sprayed thicker than the normal tack coat. It has the added advantage of penetrating and sealing cracks in the old pavement thus producing better water proofing and reduction of the reflection of any old cracks in the old pavement through to the new.

Geotextile Reinforced Seal (GRS)

A seal incorporating a layer of geotextile fabric. The first application of binder (bond coat) is used to hold the geotextile fabric in place while the second (main) application holds the aggregate. A GRS is used to provide enhanced levels of performance in SAM and SAMI applications and can also incorporate polymer modified binders to further improve waterproofing membrane performance. Both single/single and double/double seals can be used in GRS but the latter is preferred due to improved aggregate retention and better performance under traffic. Geotextile Reinforced Seals can also be combined with polymer modified binders for even higher levels of performance.

Geotextile Reinforced Seals have been used as a surface treatment on road pavements constructed of low quality base materials. This has been found to be effective in remote areas where high quality roadbase materials are unavailable. By controlling moisture, using a combination of pavement drainage and the waterproofing effectiveness of a reinforced seal, clay soils and other low quality materials may provide adequate load carrying capacity.

Geotextiles

Geotextiles used in sprayed sealing work are generally non-woven, needle punched and manufactured from polyester or polypropylene. Polyester geotextiles are generally preferred for hot bitumen work due to their higher melting point. Polypropylene geotextiles should not be used where binder temperatures are likely to exceed 165°C. Important characteristics for sprayed work are the volume of binder retained and the strength of the geotextile. The only additional equipment required is a frame to facilitate the application of the geotextile. This may be attached to a loader, tractor, or roller and is designed to ensure that the geotextile is placed evenly without creases or wrinkles.

The geotextile must be applied promptly after spraying of tack coat to ensure adhesion and to avoid potential slippage. The geotextile is then rolled with a multi tyre roller to obtain embedment into the tack coat. Traffic and other construction vehicles are generally kept off the geotextile before spraying the remainder of the binder and spreading of aggregate.

Renewing all or part of old asphalt

If level build-up is a problem, removal of all or part of the old asphalt is appropriate.

(a) HEATING AND TYNEING

The top surface containing the perished skin can be removed by heating the old pavement with a large rectangular blow torch arrangement. While hot, the top 12mm or so can be tyned and removed. The rough surface left will readily accept a new sheet of hot mix.

(b) GRINDING

Machines with grinding heads are available to plane off any depth of hot mix required. If the depth is great, multiple passes may be required.

The loosened material is loaded away and makes excellent pavement material on new jobs. Any small particles left on the surface after grading, loading and sweeping can be readily removed by a suction-type street sweeper.

Paving is then carried out, often to the original levels if height is critical, such as in commercial areas.

KEY MESSAGES

- **Prepare well**
- **Use the appropriate technique**
- **Note the essential items lists**
- **Check Council procedures**

CHAPTER 12
ROAD MAINTENANCE

References
- Standard Drawings
- Local Authority Quality Systems and Procedures (QA)
- Local Authority Maintenance Management System (MMS)
- Department of Transport and Main Roads RMPC Manuals (RMPC)
- Department of Transport and Main Roads Road Specifications
- Manual of Uniform Traffic Control Devices (MUTCD)
- TMR Bridge Inspection Manual
- TMR Timber Bridge Maintenance Manual
- Western Queensland Best Practice Guidelines. TMR Publication.
- Disabled Access and Disabilities Act. (Refer to AS 1428.1 -2009 Design for access and mobility)

Detailed information for the efficient and effective methods of carrying out road maintenance are covered in the above documents and referred to in brief below.

Check with the Engineer whether a Road Safety Audit of the area has been undertaken and its findings. The results may change the type of maintenance required.

Funding

Road funds are limited and are subject to change at short notice.

Available funds can be significantly reduced and or may be significantly increased for a variety of reasons, e.g. change in Government policy, implementation of new programs.

Therefore you must be prepared to respond to these changes by either reprioritising of work or fast track projects from the defects list.

Purpose of maintenance

Safety is the first and foremost priority for all maintenance works.

When first appointed to the position of a supervisor responsible for maintenance on any road network familiarise yourself with all available records, road notes, existing recorded defects and current work programs.

Check if any Road Safety Audits have been carried out and note the contents and recommendations.

Refer to General Note 6: Disabled Access.

If a road or section of a road is unsafe it must be closed until it is made safe, or until funds and or resources are available to carry out the necessary work.

The second function is referred to in the RMPC documents as “Stewardship” and comprises the wise investment of available funds and management of resources to ensure that the asset is maintained in the best interest of the public.

The supervisor's role in stewardship is fundamental to the successful management of the road network. Put simply it is the "preservation" of the network. Understand the purpose, function, and performance of that portion of the road network under your control. Continually expand your general knowledge of the network and identify and implement processes that lead to the enhancement of the serviceability of the network.

Scope of maintenance

The scope of maintenance may be categorised under the following subheadings.

- Sealed Roads
- Unsealed Roads
- Drainage – Surface drains
  - Culverts
  - Floodways
  - Kerb Channel and Stormwater

Drainage Systems (Chapter 8)

- Road Side Work – Clearing and Mowing
  - Rest Areas
- Road Furniture – Guide Posts and Delineation
  - Barriers
  - Signs
  - Guard Rails
- Lighting and Traffic Signals
- Traffic Delineators – Line Marking Reflectors
- Structures

  Large Culverts – Corrugated Steel
  - Mass Concrete
  - Reinforced Concrete
  - Precast Concrete

  Detailed maintenance procedures are available in the references listed above.
- Bridges (Refer also to Chapter 15)
- Grids

Maintenance management system

Your employer may have in place a Maintenance Management System (MMS) and it is imperative that as a works supervisor that you are conversant with those elements of the MMS that are relevant to the work under your direct control.

You must be familiar with the MMS as a whole and the particular role of yourself and your gang in the successful implementation of the total maintenance works programme.

This process can be summarised under the following sub headings:

- Inspection

  Inspect and record all defects and identify where improvements can be made e.g. curve widening, widening of cuttings, improvements to surface drainage to control erosion.
- Plan Maintenance so that it is carried out in a systematic way.
  - Prioritise work: safety, first priority
  - Note and plan for protection of the environment
  - Work Safety – workplace and public safety

  – Traffic Control
  – Response to spillage of dangerous goods
  – Identify any minor works project which can be undertaken if funds become available.
- Schedule works and identify resources required: workers, methods, materials.
  – Risk management for work items.
  – Know your gang costs and production targets
- Record and feed back
  – Record the location of all works
  – Compare actual costs with estimated costs
  – Record actual productivity – look for methods of continuous improvement
- Be part of the process of continuous improvement, training, review, and application of new technology.

Maintenance of sealed roads

This section describes some of the common maintenance activities that are carried out on sealed roads to prolong their life and to provide a safe and comfortable driving surface for motorist. The following work instructions are general in nature and supervisors should check to see if their organisation has specific work instructions.

Pothole repairs

Potholes should be repaired as soon as possible after they appear. Small potholes (less than 150mm diameter) can be easily and economically repaired with premix asphalt that is readily available in convenient 20 kg buckets or bags. Supervisors who regularly inspect sealed roads should carry a small quantity in their vehicle and repair potholes when they are small. However larger potholes should be repaired conventionally as described below.

1. Determine work area and erect appropriate signage and traffic control.
2. Square up the hole edges and remove any loose material. Joint face should be at least 25 mm deep.
3. Apply light even tack coat of emulsion to hole an extension 100 mm around hole, try to avoid pooling of emulsion and then allow emulsion to break .
4. Place, spread and compact premix in uniform layers, no deeper than 75 mm. Loose depth will need to be approx 1.25 times compacted depth. Compact edges first and compact until no more impressions are made by compactor.
5. Ensure finished surface is smooth and matches surrounding surface and remove any loose material to leave area in a safe and tidy condition.
6. Pot holes in sealed roads in low traffic areas may be repaired using compacted gravel or cement treated gravel with a thin premix cover on a primed surface.

More recent techniques such as jet patching also provide a cost-effective way of maintaining the wearing surface. This technique uses a high volume, low pressure blower to blow all loose debris from the pot hole, cleaning it and preparing the hole for an effective patch. Once the pothole is clean, an application of emulsion is applied. Then the aggregate is mixed with the asphalt emulsion and blown into the pothole at high velocity. After the pothole has been effectively sealed and filled, a light layer of dry aggregate is applied to the patch, preventing the patch from adhering to car tires prior to the emulsion fully curing.

Edge repairs

The work instructions outlined below are generally for isolated short lengths of edge break that need to be repaired. Most organisations have access to mechanical devices such as sleds drawn behind trucks or attached to skid steer loaders to repair long lengths of edge break.

1. Determine work area and erect appropriate signage and traffic control.
2. Stringline the outside edge to ensure neat job and ties into adjoining edge of seal.
3. Square up the seal edge and remove any loose material. Joint face should be at least 25 mm.
4. Apply light even tack coat of emulsion, avoiding pooling and allow emulsion to break.
5. Place, spread and compact premix in uniform layers, no deeper than 75 mm. Make sure cross fall matches existing. Loose depth will need to be approx 1.25 times compacted depth. Compact edges first and compact until no more impressions are made by compactor.
6. Remove any loose material and leave area in safe and tidy condition. Consider re-establishing line marking and or use of Temporary Raised Pavement markers.

Surface correction

This activity is generally used to correct isolated bumps or rough sections of seal to match its profile into the surrounding surface. It is usually not successful correcting bumps or ruts caused by a failed pavement or sub grade which should be repaired / replaced before correcting the seal.

1. Determine work area and erect appropriate signage and traffic control
2. Estimate quantity required and arrange for delivery of premix
3. Sweep the work area and apply light even tack coat of emulsion, approx 0.6 litre/sq metre, and allow emulsion to break.
4. Spread premix in even smooth layers with sled, skid steer loader, grader etc. to approx 1.25 times the compacted depth
5. Compact the edges first with plate compactor or steel drum roller depending on quantity, and check that repaired section matches smoothly with surrounding area
6. Remove any loose material and leave area in safe and tidy condition. Consider re-establishing line marking and or use of Temporary Raised Pavement markers

Stabilising / profiling

This activity is used to repair failed pavements and subgrades that were previously repaired by digging out and replacing the failed material. In some areas where profiling machines are not available the dig out and replace method is still used. Stabilising machines vary from the small attachments on skid steer loaders (e.g. 600 mm wide by 200 mm deep) up to specialised stabilisers (e.g. 2400 mm wide by 500 mm deep).

1. Determine work area and erect appropriate signage
2. Spread make up gravel to correct any slumping or rutting of pavement and lightly compact. Spread stabilising agent, usually cement or lime, evenly over work area at required spread rate typically 1.5-3.0 % by weight.
3. Use stabilising machine to mix stabilising agent into pavement. Two passes may be required to ensure thorough mixing and correct moisture content is achieved.
4. Trim and compact pavement to correct profile. Trimming should be kept to a minimal number of passes as material is already mixed and segregation may occur if material is overworked. All trimming
5. Compacting should be completed within 2 hours of starting mixing and incorporation of water.
6. If asphalt is to be applied as seal, surface will need to be trimmed to -25 mm from surrounding seal.
7. Stabilised area should be kept moist until curing or seal layer is applied
8. Apply appropriate seal coat and consider re-establishment of line marking or Temporary Raised Pavement markers

Shoulder grading / resheeting

Bitumen roads without a sealed shoulder may need regular shoulder grading and or resheeting to keep the edges safe and correct cross fall drainage problems.

1. Determine work area and erect appropriate signage and traffic control
2. Remove guide posts and other road furniture if required
3. Carefully remove vegetation from the work area without damaging adjoining seal pavement
4. Add shoulder material if required.
5. Tyne with grader and thoroughly mix material and incorporate moisture. Edge against bitumen should be boxed out to a minimum of 100mm and re-compacted to avoid lamination to thin layers.
6. Trim and compact to correct profile. Restored surface should match existing seal cross fall.
7. Reinstate and clean out table drains and side drains.
8. Sweep any loose material off road and replace guide posts and other road furniture

Maintenance of unsealed roads

Some essential elements are discussed below.

Plant

Motor graders

The essential plant for any unsealed roads maintenance is, of course, the motor grader, with the most useful machine having a weight of about 130000kg and 56 kW to 90kW. Graders of less than 56 kW have limited application, and cannot efficiently cope with heave maintenance work, whilst kWs in excess of 90 cannot be **used** to their full capacity.

Trucks

Tipping trucks of up to and including road train side tippers are a very useful size for maintenance work. Where maintenance gravel is to be applied over long sections of road, larger trucks may be used to advantage, together with tractor-mounted loaders.

Water trucks

Tanks of 10,000 litre capacity mounted on suitable vehicles and fitted with a 50 to 75mm self priming pump and emptying through a spray bar are very useful plant items, They should be fitted with a driver-operated spray bar control in the cabin. With such a tank, 3000 to 6000 L can be applied to the road in about 10 minutes, and maintenance gravel can be set down at reasonable cost if water is available within a 4 to 6 km haul.

Loaders

Front-end loaders, working in ridge gravel can win and load about 450m^3 per day. In sandy loam, this quantity can be doubled. Rubber-tyred loaders have limitations in loose sandy materials unless they are of the 4-wheel drive type. The 2-wheel drive machines bog very easily in dry, loose materials. In hard digging, tyre wear can be excessive, but this must be balanced against the mobility of the machine and its ease of transfer from job to job.

Testing and suitability of materials

Materials

Material quality is critical in controlling the deterioration rate of a road after grading, and the amount of gravel loss over time.

Recently, some new gravel standards for unsealed roads have been developed which can help reduce these effects by testing materials before use and through improving or avoiding poorer material section.

The new gravel standard is recognized by ARRB of Australia and is now been used in many Queensland Councils.

To complete an assessment of the quality of gravel material a linear shrinkage and grading soil test on a uniform sample of the material, is required.

Once the test result is obtained, use the formula below to calculate the grading coefficient and shrinkage product that can be used. See Figure 12.1.

The horizontal axis, shown in Figure 12.1, is calculated by:

- Grading Coefficient = {(% Passing 26.5mm – % Passing 2.0mm) x (% Passing 4.75mm)/100}

The vertical axis, for the chart (figure 12.1 is calculated by:

- Shrinkage Product = (Linear Shrinkage x % passing 0.425mm Sieve)

It has been determined both on paper and in the field that if a council looks at achieving a "good" category material then in the long term these roads will require less grading and have less gravel loss over time. (It is not hard to prove that Council could spend another $3/m^3 on the material source and still be better off, than putting substandard materials on unsealed roads).

Grading frequency

No hard and fast rules can be laid down on the frequency of grading required on roads, as the combination of variable factors will influence the situation. The frequency will vary with the type of surface, the rainfall, amount of traffic, how soon traffic uses the road after rain, etc.

Gravel roads

Gravel roads require re-grading when corrugations develop and before these corrugations reach such proportions that they become potholes. Traffic will rapidly pothole a deeply corrugated road after a shower of rain, therefore re-grading should be carried out often enough to avoid the development of deep, heavy corrugations. Although it may appear to be wasted effort, it has been found to be profitable to regrade in dry weather, when corrugations quickly appear on a loose surface, with the hope that rain will fall after the job is completed. This often happens and a good surface results, which will stand for some weeks.

If regrading is delayed because of dry conditions, corrugations become worse and a potholed surface results when rain comes.

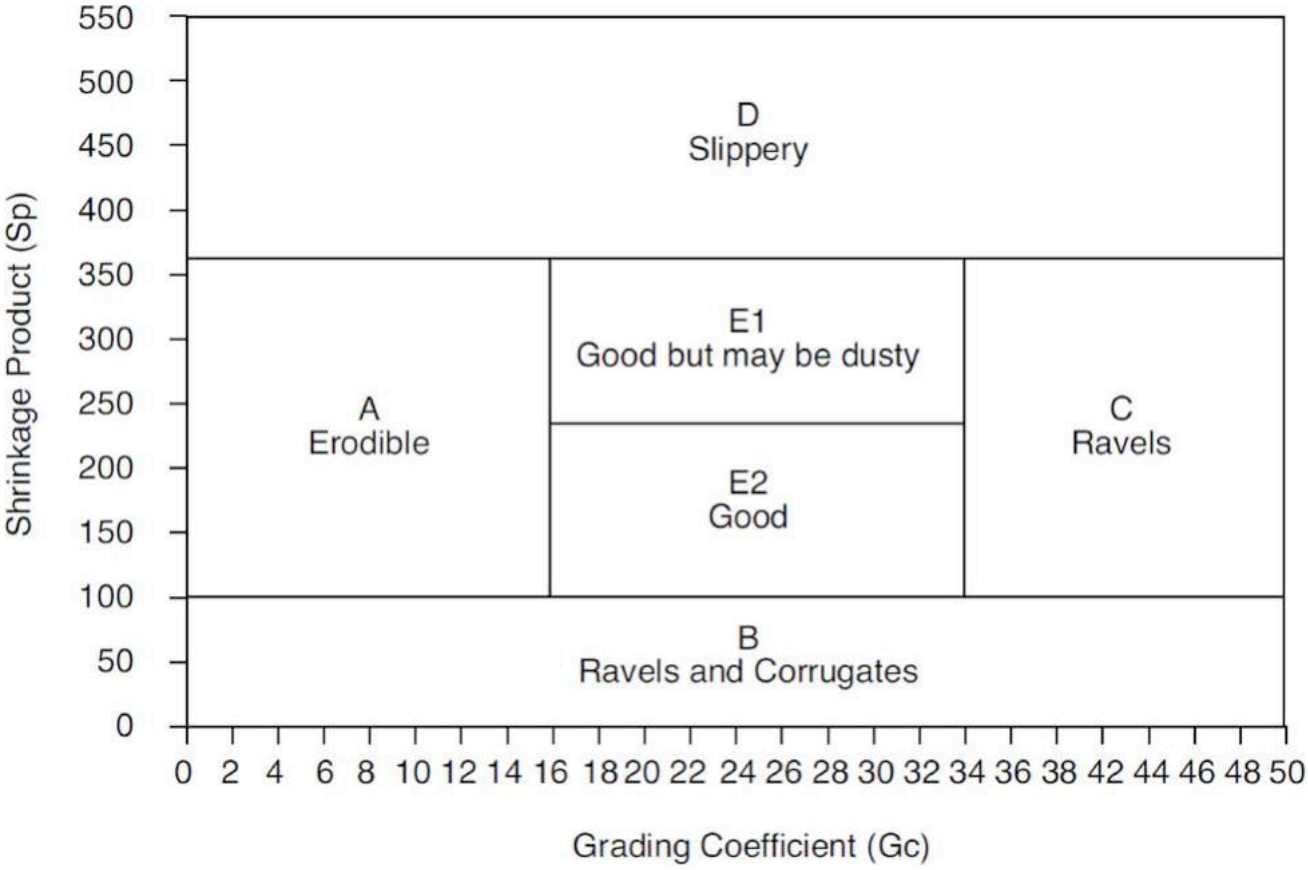
The ideal treatment would be, of course to have the re-graded surface watered immediately, but cost makes this impracticable even if water is available.

Surplus loose stone on a gravel pavement is a traffic hazard, as traffic soon causes it to be pushed into windows on each side of the road. These windows are dangerous, particularly for light cars and vehicles with direct steering. In natural gravel country the surplus loose stone should be graded right off the road. If it occurs on a section where gravel has been carted from some distance because of economic reasons, a suitable material should be added as a binder.

Loam pavements

Loam pavements often require less grading than gravel pavements, but they can pothole without first forming corrugations. For this reason more patching is usually required on a loam pavement than on a

gravel one. Watering is even more desirable after regrading loam than gravel as the surface of the loam is much finer and the loss of the material when loose, would be much greater, due to the action of traffic.



Source: "Neural networks for performance prediction on unsealed roads" by Lea, Paige-Green and Jones. RTR 1999.

Figure 12.1

Earth formations

A good, heavy shower of 12 to 25 mm will usually cause less bother on an earth formation than will 5 to 8 mm of light rain. In the first case, the surface is packed down by the heavy rain and most of it runs off. With light rain, most of it penetrates, and traffic cuts up the surface badly. This applies particularly to black soil. Re-grading cannot be successfully carried out on an earth formation that has deep tyre tracks containing water. The water must be allowed to soak away or evaporate until the material is only damp, otherwise a second grading will be required after a very short interval. Local circumstances may, at times, dictate immediate grading.

Gravelling

Gravel pavements to 5 to 6 m wide x 100 to 200 mm compacted depth are usually adequate. After the sub-grade has been shaped and thoroughly compacted, the pavement can be laid either in the boxing or spread first and the boxing brought up later. Gravel is dumped on the roadway in heaps at set distances, or run out of the truck over a measured length to obtain the required thickness. If dumped in heaps the gravel must be rilled, mixed and spread otherwise a heaped "bump" will appear where the gravel has been dumped.

The gravel is uniformly spread over the sub-grade, using a grader and making sure that every heap is disturbed to boxing level. It should then be watered and rolled, but in some cases it can be left to rain and traffic to complete the compaction. In the latter case, it is essential that the pavement should be re-shaped immediately after rain, otherwise traffic will badly cut the pavement about.

Routine grading

Material on unsealed roads will range from earth to gravel and fine crushed rock. The motor grader is the most effective item of plant for maintaining such roads, their shoulders and side drains. Light or medium motor graders are suitable for the routine grading of most unsealed pavements and shoulder materials but the heavy grader is necessary for scarifying and reshaping pavements and for cutting table drains, catch drains, etc. The heavier machine is also more suitable for the spreading of newly placed pavement material.

The main objectives of grading maintenance are:

a) To preserve the correct cross-section of the pavement, provide for proper run-off of rain water, and to minimise scouring and pot-holing of the surface;
b) To remove corrugations and other irregularities in the road surface and thus restore good riding qualities;
c) To eliminate seasonal vegetation growth from the roadside, to ensure good drainage in table drains, catch drains, etc., and to maintain good visibility;
d) To return displaced pavement material to the pavement surface from road shoulders and table drains.
e) Monitor and control erosion and scouring in all drains.

Routine grading work is completed on short sections of road pavement at any one time so that the surface can be left safe for traffic overnight. Under no circumstances should a windrow be left on a road formation after dark. The ideal time to carry out grading work is when the pavement is moist, as good compaction of the surface is then more readily obtained. It is good practice to take full advantage of suitable moisture conditions to concentrate on pavement grading and to leave the grading of shoulders and drains for attention in drier weather. During long periods of dry weather, excessive grading of the pavement should be avoided because it will results in a loose, possibly dangerous surface. Should the surface deteriorate to a stage where it is becoming uneven, minimum grading using a thin layer of gritty material would be a suitable treatment.

All drainage should be regularly and properly maintained. Drains should be cleared of excessive vegetation, silt and debris should be removed. Drains should always be kept in such a condition that scour and erosion are minimised.

Where conditions permit regular routine grading, it will usually be possible to produce a satisfactory result in three passes. The first and second passes bring the displaced material from the road shoulders to the centre, while the third pass spreads the resultant windrow with the grader blade set at right angles. The blade level should be such that windrows are not left as a result of the final traverse.

Where the crown of the pavement is excessive it will usually be necessary to make the initial cut close to the road centre, moving the loose material towards the edge. Subsequent passes would then work the windrow back towards the centre.

Patching

The routine grading of an unsealed pavement will, in many cases, fill shallow potholes and depressions with material graded from the edge of the pavement. This will be especially the case if grading work is carried out when the pavement is moist. Where any depression is too extensive to be eliminated by grading, it should be filled with material similar to that of the adjoining pavement. The work should preferably be carried out after rain. Compaction and smoothing may usually be left to traffic and normal patrol grading.

Where areas of weakness occur in the pavement or sub-grade, the full area of the failure should be excavated and the unsatisfactory material removed. Subsoil drains or deep side drains should be provided to intercept or to drain ground water in the sub-grade level with sound material which should be

placed and compacted in 100 mm layers and then filled to final surface level with compacted layers of material similar to the adjoining pavement.

Re-sheeting

All unsealed pavements are subject to wear due to the action of traffic and unfavourable weather conditions. The lost material must be replaced every few years by resheeting with suitable natural material. It is preferable to carry out re-sheeting work over the full width of the pavement and shoulders, which should be undertaken, as far as practicable, when moist conditions prevail. Re-sheeting material should be of good quality and taken only from approved deposits. Every care must be taken to ensure that the material won comes from the area and to the depth specified. The quality of the material should at least equal that of the original pavement, and where there is any prospect of future sealing, it should be properly tested to ensure that it is suitable for such work.

The road surface should be lightly tyned prior to the spreading of the resheeting material. If the original surface is badly worn and out of shape, it should be re-shaped and compacted so that there is a uniform thickness of resheeting material. Spreading of the material is performed either by running it as evenly as possible from the tipping truck which are delivering the material, or better still by using a drag spreader box. Dumping in heaps is to be avoided because of the risk that all of the material will not be re-worked, and because of the heavy strains that can be placed on graders. Where it is unavoidable, it is essential that all of the material in every heap should be turned over and moved, to minimise segregation and uneven compaction.

Final re-shaping by motor grader is carried out to obtain the required crossfall and longitudinal grading. It is usual for all drains to be cleaned as part of the re-sheeting operation. It is desirable that all re-sheeting should be compacted by rolling when the moisture content is suitable. If necessary, watering should be carried out. Where circumstances have not permitted rolling under proper moisture conditions, there should be follow-up grading immediately after any rain.

To ensure satisfactory compaction, new areas of pavement should be spread in layers not exceeding 100 mm in thickness and compaction should continue until no sign of movement is apparent. In general, rolling should commence at the edge of the work and proceed towards the centre, except on super-elevated curves where the rolling should commence at the inside edge and finish at the outer edge of the curve. Pneumatic tyred rollers are efficient in compacting fine grained, unsealed pavement materials.

Drainage (Refer to Chapter 8)

Surface drains

The provision of adequate drainage is a most important aspect in road construction and maintenance on the Western plains, as elsewhere. It is important to have

a) The crown of the road well above the water level in the table drains.
b) Adequate mitre drains to get the water out of the table drains to prevent them from scouring. The steeper the country, the closer the spacing of mitre drains.
c) Catch drains in siding ground to intercept water before it reaches the road formation.

Table drains and mitre drains are frequently forgotten during grading maintenance and allowed to become choked with grass and weeds. When rain falls, a choked drain can result in drainage crossing the roads and scouring the pavement and shoulders.

Many failures on roads are caused by drainage problems. Pipes and culverts and their associated inlets and outlets are important to drain water away from pavement materials. They should be checked regularly or at least annually to ensure they are working as designed.

Culvert maintenance

Timber culverts have mostly been replaced by concrete culverts.

There is very little maintenance required on concrete box culverts. Sometimes scouring occurs on the downstream end, requiring the placing of rubble or stone pitching. In hilly country this material may need grouting or wire mesh or stone gabions can be used.

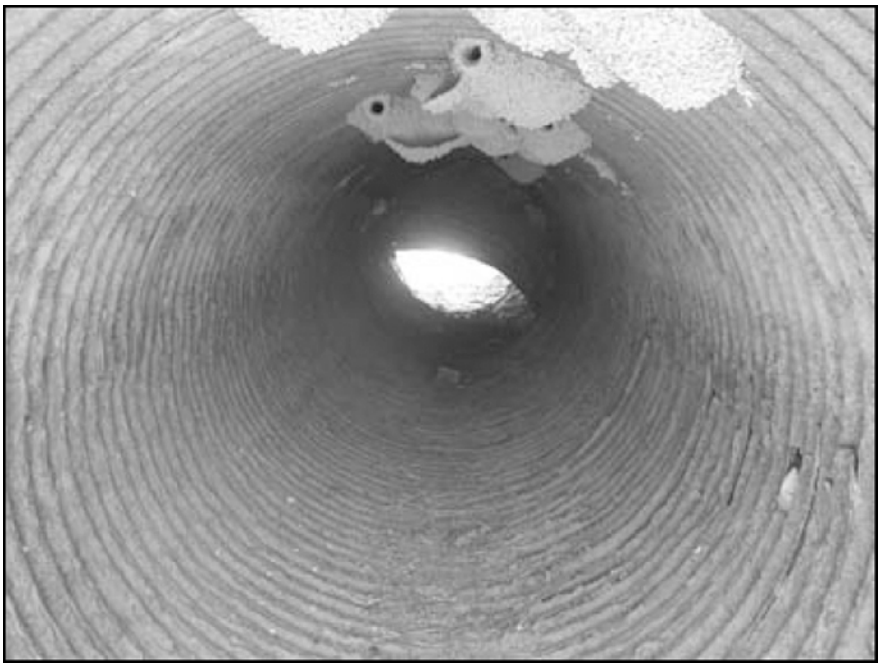
Pipe culverts require more maintenance because the inlets are readily blocked by sticks, leaves and debris accumulating against the head walls, particularly during storms. Flat country does not generally permit the use of larger than 450 mm pipes which very readily block. The problem can be overcome by the use of wider pre-cast concrete box sections in lieu of pipes. They permit the debris to pass through with few blockages.

At times of flooding, the upstream side of bridges and inlets to culverts should be inspected to ensure that there is not accumulation of logs, large stones or other debris and arrangements should be made where this does occur for their earliest removal.

The abutments of bridges, and the inlets and outlets of culverts should be kept free of undergrowth, rubbish, etc.

Vegetation can often be economically controlled by the use of suitable weedicides. Undergrowth should be kept clear of fender posts at culverts. Post and hand railings should be kept freshly painted.

Broken or defective deck planks in timber culverts require replacement. Nuts on bolts should be checked and tightened as necessary and any loose deck spikes should be given attention.



Collapsed steel culvert

When practicable, loose deck planks should be tightened by wedging under kerbs, and tightening kerb bolts. Refer to Chapter 15 Bridges.

After heavy rain, pipe culverts should be checked for blockages. Early removal of any silting or debris will reduce subsequent damage.

When routine inspections of a section of road are made, a careful watch should be kept for signs of broken or shattered deck planks, loose deck spikes, damaged hand railing, etc., on timber culverts.

Any subsidence or holes in the road surface near culverts should be checked as they may indicate pipes have been damaged. Suitable barricades should be carried and so placed to prevent traffic passing over any damaged section of culvert.

Where pipes have collapsed they should be replaced with pipes of the same size and class as the original culvert, and should be firmly bedded on sound material in such a way that they will not sink

below the original pipe on either side. The bedding should be accurately shaped to fit the outside of the pipe. Proper joining is essential.

The collapse of pipes is usually caused by there being insufficient cover. Arrangements should be made to increase the cover to a safe depth where damage is occurring.

Floodways

Unsealed gravel

Floodways are used in western Queensland in lieu of culverts because of cost savings. A concrete sill, 300 mm deep x 1500m wide x 80 m to 90 m long on the downstream side only, has proved satisfactory in retaining gravel. Floodways are provided with 150 to 225 mm gravel pavement and constructed to a level which will allow draining when flow ceases. Should scouring occur below the concrete sill, this can be remedied by the use of rubble which may be hand packed or, in some cases, grouted. The gravel pavement in floodways will need attention once or twice a year through the addition of maintenance gravel. Construction of these concrete sills will depend on the location, to be determined by the Engineer. One or two loads in the causeway before regrading is carried out keeps the causeway in very good shape.

Bitumen surfaced

Many floodways are constructed of sealed gravel or cement stabilised gravel. Regular inspections of pavement must be carried out, cracks sealed and repairs carried out as for any sealed pavement.

In some areas large areas of bitumen seal can be lifted up and floated off the floodway, without failure of the base.

Check all protection work for any undermining and fill with grout or lean mix concrete.

Concrete and reinforced concrete

Many floodways still in use have been constructed from unreinforced concrete. Monitor performance and carry out repairs.

Generally these floodways are on a replacement program. However, service life can be extended by covering with a geofabric and asphalt or premix.

Reinforced concrete to pavement, batters and apron must regularly be checked for cracking, undermining and cement spalling off reinforcement.

Any exposed reinforcement must be covered, the steels examined for structural stability and any undermining repaired.

Roadside work

Clearing and mowing

Because of the higher rainfall in coastal areas, clearance of growth must be regularly carried out. Undergrowth, brush and small trees will reduce visibility and create traffic hazards. They will reduce the effectiveness of the drainage system and detract seriously from the general appearance of the road. It is important to attend to growth in its early stages when carrying out routine grading work. If attention is left too long, it often becomes necessary to grub out and clear trees. Consideration should always be given to the use of suitable weedicides. In some areas regular mowing of grasses and soft weeds near the shoulders may be necessary. Shoulders and formations should be cleared where animal hazards are prevalent.

Rest areas

Rest areas are maintained in accordance with specific procedures in the Local Authority Quality Systems and Procedures.

Frequency of service will depend upon local conditions.

Regular check of all information signs and warning signs associated with the Rest Area and pavement condition at entry exit and parking areas. Check visibility clearances at entry and exits.

Road furniture

Signs, guard rails and guide posts need to be checked regularly and repaired/replaced if necessary. Sign maintenance may include cleaning, correct alignment, straightening, replacing if faded and it is good practice to carry out a night time inspection of roads annually as some defects may not be apparent during daylight hours.

Lighting and traffic signals
Refer to specialist gangs or contractors.

Traffic delineations
- usually by contract
- condition monitor and record all unserviceable delineation

Structures

- *General*
  All structures must be inspected regularly and any defects noted and if any doubt exists as to severity of a defect, report it to the Engineer, e.g.
  – Corroded Steel culverts
  – Exposed reinforcement
  – Large cracking in concrete components
  – Displaced structures, wing walls
  – Approach slab, protection works
  – Settlement of bridge abutments
  – Rotting and cracked timber components.

- *Loading and traffic conditions*

  Note that many structures are aging and often have had little maintenance for long periods of time and may be in advanced conditions of deterioration.

  Many were designed and built in a period of much lighter and infrequent loading and traffic conditions.

Be aware of all structures and the general appearance and condition on roads under your control and note any load restrictions, on any structure that appears unsound.

- *Large culverts*

  Detailed maintenance procedures are available in the reference listed above.

  Check and investigate
  – Road subsidence over culverts
  – Separated and displaced joints in any drainage structure
  – Exposed reinforcement
  – Spalled and broken concrete
  – Collapsed and subsiding protection works
  – Corroded and out of shape steel drainage structure, pipe arches, etc.

  Note that exposed corroded reinforcing steel can lead to catastrophic failure of a structure. Subsiding road formation can be a warning of an imminent collapse of a culvert.

  If in doubt declare it unsafe, close the section of road until further examination or repairs are carried out.

  Note that the repair of spalled concrete and exposed reinforcement is a specialist job and often involves the use of specialist crews and repair methods. The importance of such repair work to the integrity and stability of a structure cannot be understated.

Bridges (Refer also to Chapter 15)

- *Bridge inspections*

  Refer to TMR Technical Publication
  – *Bridge Inspection Manuals and Timber Bridge Maintenance Manual*.

  On first contact with any bridge note the general visual condition and record number of spans, span lengths desk width and construction type e.g. timber, steel, concrete etc. Check if any inspection program exists, and if so follow up last inspection and condition report, if no record exists of any inspection or load carrying data for the bridge it should be brought to the attention of your supervisor and a program of inspection implemented. Bridge works, from detailed inspections through to, assessment, and major repairs are generally carried out by specialists. However, you may be involved in carrying out part of these works under supervision and a knowledge of the contents of the bridge manuals referred to above will be essential.

  In some parts of Queensland there are numerous timber bridges and culverts.

Corroded steel piles

- *Bridge maintenance*

  As discussed above detailed inspection and maintenance is a specialist job however, as gangers and supervisors the following routine items should be carried out:

  – Regular visual inspections – report on irregularities

  – Check:

    * Bridge approach guard rails and barrier rail
    * Bridge hand rail
    * Cracked or broken concrete on the structure
    * Exposed steel reinforcing
    * Deck running surface
    * Deck expansion joints
    * Bridge warning sign – hazard marker, delineation
    * Visual inspect underside of deck and substructure
    * Check bearings, clear of debris
    * Approach road formation and guard rail
    * Abutments and approach protective work.

Grids

Grids have been with us for a long time and will continue to be installed throughout the state in the years ahead.

Before installing any new grid ensure that it has been designed to meet current TMR Standards and the design has been certified by a Registered Professional Engineer.

Existing grids need to be inspected regularly and checked for broken welds, distorted structure members, abutment and road approach grading.

In certain locations steel can corrode rapidly.

Railway line grid rails can be broken under road traffic conditions – see photo.

Check if your Local authority has a Grid Policy and refer to it for detailed instructions.

Grids need to be regularly serviced, cleaned and checked for safety and signage and grading of approaches.

General notes

Note 1: That the methods discussed above are given as a guide and that alternative successful and established practices, are carried out to suit the varying local conditions across the state.

Note 2: "Best use" is often of selected local materials in localities where standard materials are either unavailable or too costly, e.g. clay stabilising of loose sand, adding loam binders to unsealed "hungry" gravel and mudrock pavement, where fine graded material has been lost.

"Best Use" is gained by experience. As a supervisor monitor closely the field performance of all local nonstandard materials used.

Refer to TMR Publication "Western Queensland Best Practice Guidelines".

Note 3: Pot holes in sealed roads in low traffic areas may be repaired using compacted gravel or cement treated gravel with a thin premix cover over a primed surface.

Note 4: Constantly keep your eye out for naturally occurring materials that are part of an existing road formation and are performing well under traffic. Collect samples and have properties tested and noted. E.g. some natural materials performing well on shoulders of narrow seals can be used for widening and ultimately sealed.

Note 5: Maintenance of concrete footpaths kerb and channel and urban stormwater drainage system is carried out in accordance with Local Authority Quality Systems and Procedures.

Note 6: Disabled Access. Regularly check that paths and roads are safe for disabled persons, and that construction and maintenance work conform to the Local Authority Disabled Access Policy and Disabled Persons Act. Note that on any works resulting in changing of existing surface level. E.g. reseal, pavement overlay, footpath repair etc., that disabled access has not been disrupted.

Note 7: Never drill holes into any part of a bridge structure or any reinforced concrete structure without prior approval from the designer of the structure or a senior engineer with structural design experience.

KEY MESSAGES
- **Road safety**
- **Preserve the network by good maintenance**

Broken grid rails

CHAPTER 13
CLEAN UP AND RESTORATION

Conservation

Supervisors must endeavour to minimise the destruction and wastage of natural resources. Cleared and stripped materials must be used to best advantage in revegetating any distributed areas.

The natural resources most likely to be used or interfered with during road construction are timber, low growing vegetation, humus bearing topsoil, earth and rock, waterways and still water, wild life habitats, cultural heritage sites, historic places and land marks and natural scenery.

Conservation techniques

Keep areas of disturbance to a minimum. Refer also to Chapter 2.

Techniques commonly employed to conserve natural resources are as follows:

Timber

- Do not burn timber unless it is a last resource. (Some timbers have commercial use. Others may be capable of being chipped or transplanted).
- Do not allow felling and burning operations to destroy any desirable vegetation.

Low growing vegetation

- Remove large timber beforehand as a separate operation.
- Do not burn low growing vegetation if it is possible to turn it into mulch. Stack this vegetation separate from heavy timbers.

Conserving mulch and topsoil for revegetation

The Supervisor must plan his job so that humus bearing topsoil and natural grasses are removed to salvage stockpiles for subsequent use in revegetation work. The extent of this operation depends on the nature of the area to be cleared, e.g.

(a) In country with low scrub and few large trees, the trees and any dense hard scrub must be selectively removed and transported by rake dozer to selected areas for subsequent reuse or disposal.

Light brush can then be mulched with a heavy disc plough (Figure 13.1) and windrowed to edge of the cleared area where it can be mixed with salvaged topsoil for reuse as an erosion and revegetation cover. (Figure 13.2).

(b) In open woodland with a greater number of large trees, a similar operation to that used in (a) is applicable, but heavier equipment is required to dispose of the heavy timbers.

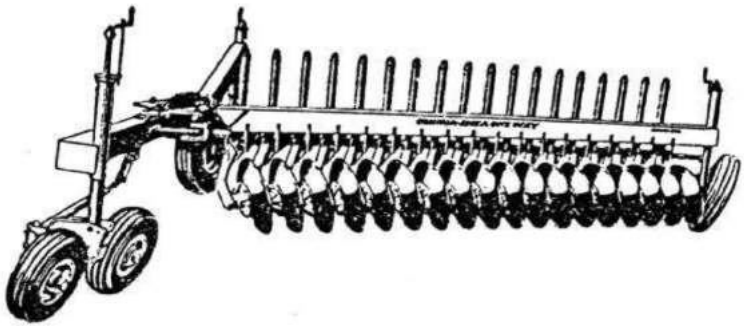


Figure 13.1 Disc plough

In dense forest areas it is normally impossible to salvage the lighter undergrowth. Because of this the clearing operations should not unduly waste the humus bearing topsoil by pushing soil and timber to stockpile in one operation. The timber should be stacked in the centre of the formation, and the topsoil windrowed to the edge (Figure 13.3).

Rake dozers are essential to ensure the stacked timber is relatively free of earth to allow efficient burning. Clearing must progress well in advance of the earthworks to allow burning to be carried out within the formation (Figure 13.3).

Spoil (earth and rock)

The disposal of spoil can be a major environmental problem, but one which can usually be resolved if preplanning is carried out. The estimated quantities of spoil are shown in the earthworks program, which allow the disposal of spoil to be planned in advance.

Earth spoil may be used to flatten batters or to improve other areas of the road reservation. However, under no circumstances should the spoil be dumped indiscriminately over batters, and form irregular shapes in the finished roadworks.

Large rocks may be buried in fills or placed on batter slopes as the work progresses. They must not be pushed into untidy heaps and simply left.

Waterways

- When constructing haul roads, do not allow waterways to become polluted with silt bearing materials. A gravelly or rocky material should be used for filling, especially over pipes in waterways.
- Do not dump soil on the upstream side of waterholes.
- Temporary erosion control measures and siltation blocks must be provided during earthworks operations.
- Do not leave areas which have been distributed by construction operations unprotected and therefore subject to erosion or siltation.

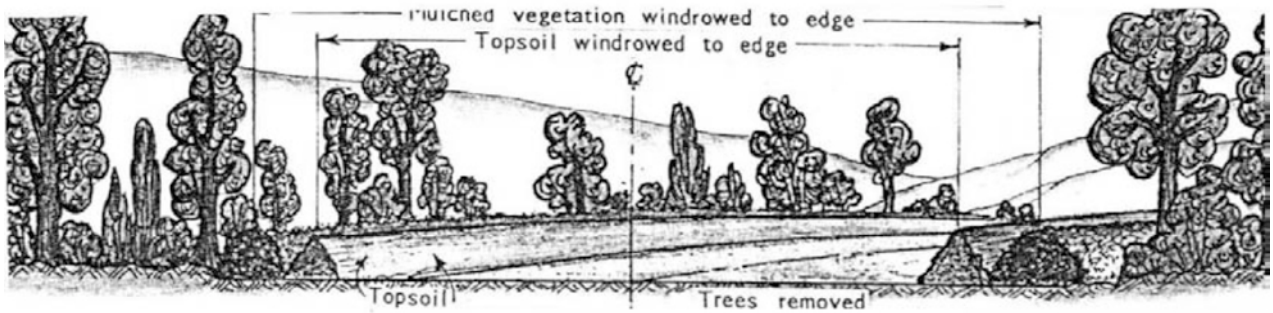


Figure 13.2

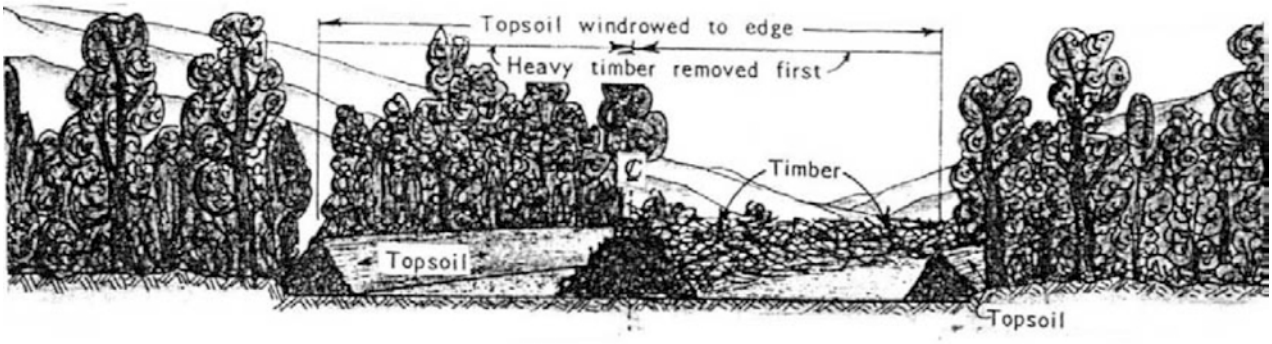


Figure 13.3

Wild life

- If the road reservation traverses a habitat for wild life, great care must be taken during construction to ensure minimum disturbance to the ecological requirements of the wild life results.
- Particular precautions in the case of certain species of wildlife and revegetation measures may be necessary.

Historic places and landmarks

All personnel associated with the project, from the planning stage on, must be made aware of the presence of historic places or areas of cultural heritage and native title, and important land marks which should be clearly identified for preservation.

Scenery and landscape

A road should fit in with the landscape. Where possible, provision is made in the design to achieve this, but there are many details which must be taken care of during construction.

For example, when roadmaking material is won from borrow pits within the road reservation the pits should, after use, be reshaped and revegetated. (Techniques for the treatment of shallow borrow pits are discussed in “Revegetation”).

General

The Supervisors should ensure that:

- All construction is finished in a neat and tidy manner (e.g. tops of cut batters rounded, no unsightly spoil heaps or borrow pits left).
- Construction operations are planned so any unsightly residual prisms of earth or rock on the downhill side of small cuttings are removed along with the flattening and rounding of batters at the beginning and end of cuttings.
- Re-establishment of natural vegetation is encouraged (see Revegetation).
- The construction does not create erosion problems. (Erosion control is a major topic for consideration and is dealt with in detail in Form 11AT25 – "Drainage").
- Irrespective of the methods employed in clearing, vegetation adjacent to the formation is preserved.

Revegetation

General

Revegetation of disturbed areas is a necessary requirement for the conservation of the environment and the prevention of erosion.

The shapes of batters and the characteristics of the soils laid bare are not necessarily conducive in helping nature to re-establish vegetation. Natural regeneration processes must therefore often be assisted by mechanical and horticultural methods.

Acceleration of revegetation around roadworks requires a knowledge of both engineering and horticultural practices. All plants are living organisms, and for proper growth they require the right conditions of temperature, light, moisture, and soil chemicals.

Condition of soil for revegetation

In order to achieve efficient revegetation, the soil must contain the necessary chemical elements for proper growth and have a suitable pore structure which allow the correct balance of water and air and permits penetration by young food collecting roots (i.e. the lateral and hair roots).

The most desirable soil texture possesses the proper combination of large pores and small pores. The large pores permit infiltration of water and air, resulting in good drainage and aeration. The small pores (and the surfaces of the soil particles themselves) retain water.

The ratio of air to water in the pores determines, in part, the suitability of a soil for good plant growth.

As good plant growth is the objective of accelerated revegetation, soil texture is very important. The following facts should therefore be remembered:

- Clay soils have very few large pores. In clay the movement of water and air is slow and root penetration is restricted. Compaction of the clay will further reduce the number and size of pores.
- Sandy soils have larger and more uniform pore spaces. As a result, these soils do not retain water for very long.
- The incorporation of organic material into clay soils and sandy soils improves the distribution of the various pore sizes.

The most suitable (and most readily available) soil for revegetation is the top layer of the existing surface - the "topsoil". This soil contains the organic matter necessary for plant life, as well as the seeds and roots of the vegetation growing on the site.

Topsoil can vary in thickness from 15 mm to 25 mm (sand dune country) to around 150 mm (old alluvial flats). The limit (in depth) of the topsoil layer can usually be determined as an abrupt change in the colour of the soil.

The thinner the topsoil layer the greater the care required in clearing and stockpiling operations to minimise loss and/or contamination of the topsoil.

Materials for revegetation

Materials used for revegetation can be divided into two categories:

(1) Those obtained from the job site.
(2) Those which are “imported” from other areas.

Materials obtained from the job site

This category includes topsoil, grass, grass roots, brush and other suitable material stripped from the site and stockpiled prior to carrying out the earthworks.

Imported materials

The category of imported materials includes:

- Topsoil from selected areas
- Seeds of selected plant species
- Live plants
- Grass sprigs and turf
- Erosion preventive mulches and soil stabilising agents
- Fertilisers
- Water

Machinery is required for the incorporation of some of the above materials.

When using imported seeds and plants, seek the advice of qualified persons (those trained in horticulture and agriculture) regarding the selection of species and how and where they should be planted. Plants are living organisms and need particular conditions for germination. A lot of care may be required to establish them under the conditions prevailing on site.

Procedures for establishing vegetation

Salvaging natural materials (within the limits of the job)

The method of clearing should ensure that light brush and topsoil are not lost.

If possible, the topsoil should be windrowed to outside the formation width, otherwise it should be removed and stockpiled in a position such that the material is readily accessible at a later stage.

If clearing and salvaging of topsoil is undertaken with care, using good construction methods and suitable equipment a depth of approximately 50 mm of topsoil may be all that is necessary to ensure adequate revegetation in the disturbed areas.

Preparing batters and using salvaged materials

(a) Cuttings

The batter slopes of most road cuttings are steeper than 1 on 3. Rock cuttings are usually 1 on 0.5. Revegetation should be undertaken on all cuttings other than full rock cuttings.

In order to obtain a dense coverage of vegetation on batter slopes of 1 on 3 or steeper, it is necessary to provide suitably stable steps in the batter in order to retain sufficient topsoil and moisture. Such steps should be in accordance with TMR standard drawing No. 1045 (Figure 13.4).

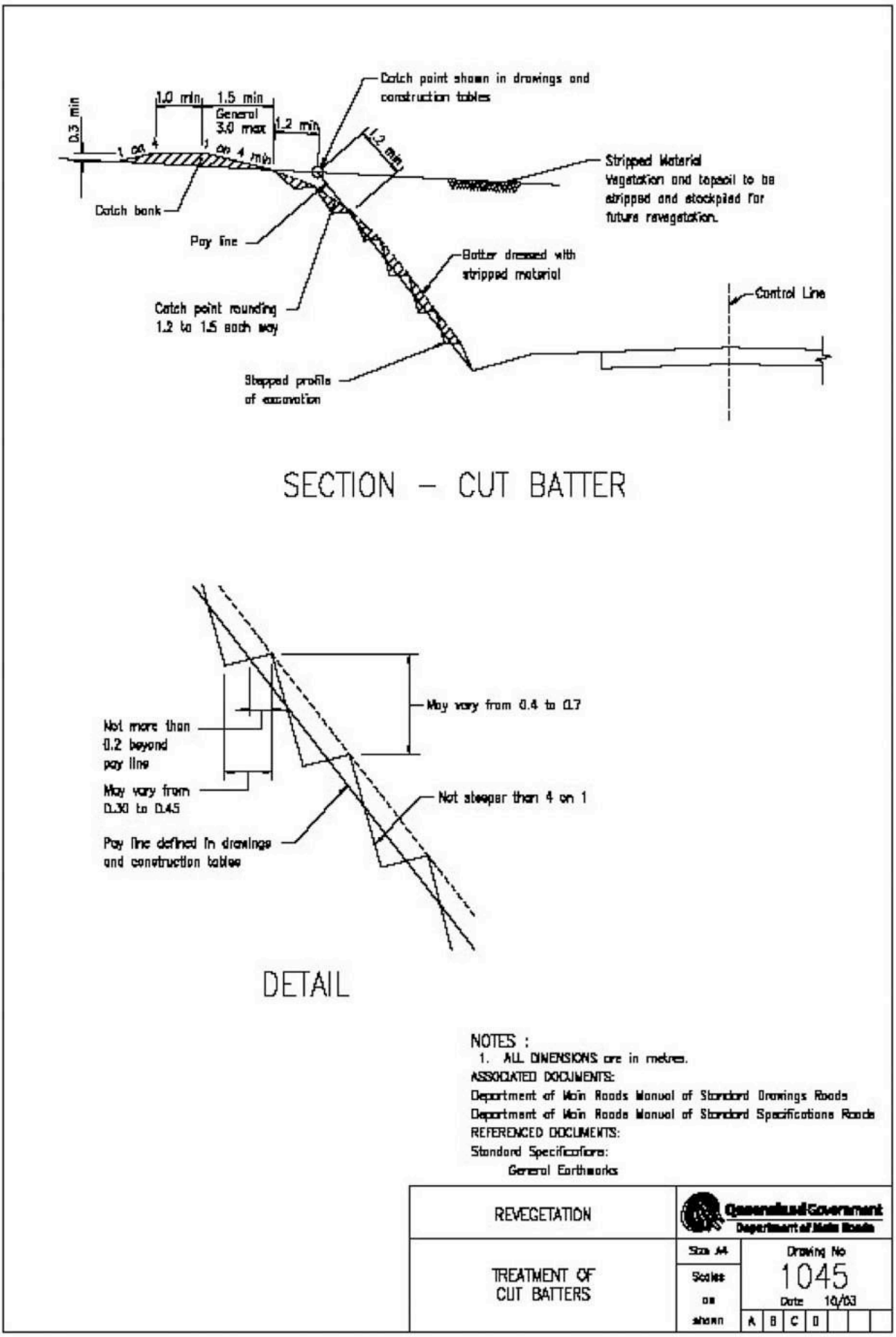

Catch point shown in drawings and construction tables
1.0 min
1.5 min
General 3.0 max
1.2 min
0.3 min
1 on 4
1 on 4 min
1.2 min
Stripped Material
Vegetation and topsoil to be stripped and stockpiled for future revegetation.
Catch bank
Pay line
Batter dressed with stripped material
Control Line
Catch point rounding 1.2 to 1.5 each way
Stepped profile of excavation
SECTION – CUT BATTER
May vary from 0.4 to 0.7
Not more than 0.2 beyond pay line
May vary from 0.30 to 0.45
Not steeper than 4 on 1
Pay line defined in drawings and construction tables
DETAIL
NOTES :
1. ALL DIMENSIONS are in metres.
ASSOCIATED DOCUMENTS:
Department of Main Roads Manual of Standard Drawings Roads
Department of Main Roads Manual of Standard Specifications Roads
REFERENCED DOCUMENTS:
Standard Specifications:
General Earthworks
REVEGETATION
Queensland Government
Department of Main Roads
TREATMENT OF CUT BATTERS
Size A4
Scales as shown
Drawing No
1045
Date 10/03
A B C D

Figure 13A

The stepping should be done progressively as excavation proceeds. The usual (and generally the most economical) method employed is to cut each step (using a dozer) as a profiling operation at the toe of each stage of cutting before excavating machinery moves in for the next stage.

Shaving of batters using a grader is both costly and unnecessary. Further, there is no need to cut steps in outcrops of hard rock. Such outcrops may be left exposed.

Salvaged topsoil and natural mulch should be progressively spread down the batter as excavation proceeds (e.g. each 2 m stage depth of cut). The early use of topsoil in this manner quickens revegetation and provides protection against erosion of the step.

“Overloading” of the steps with topsoil beyond the profile shown in Figure 13.4 is undesirable as surplus topsoil is subject to slumping when soaked. Surplus topsoil may be dressed off and spread longitudinally using heavy chains attached to dozers, loaders or graders working along the slope. Refer Figure 13.5.

On large areas of cut with steep batters it may be necessary to cut benches to provide stability and surface water control. Water from outside the formation must not be allowed to flow over the cut faces.

On batter slopes flatter than 1 on 3 the surface of the batter should be scarified and salvaged topsoil spread over the scarified surface. A 35-50mm depth of topsoil (dependent on the quality of the topsoil) should be sufficient for initial growth. If necessary, light rolling with sheepsfoot roller will provide added protection against erosion.

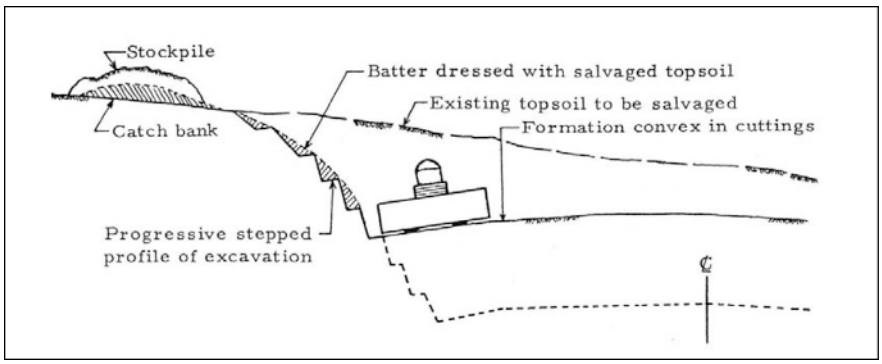


Figure 13.5

(b) Fills

Batters of fills are easier to revegetate than batters of cuttings since they are usually flatter and possess a rougher surface profile due to the methods of construction. Consequently natural revegetation will generally occur earlier on fills because soil structure is more suitable and moisture retention is far better for plant growth.

Under normal conditions the only pretreatment necessary for fills is to leave the surface rough so that topsoil, when spread, will lodge in the small pockets. On the steep fills, overloading with topsoil may result in surface slumps. On large fills, it may be necessary to provide berms to provide stability and surface water control (temporary water diversion blocks and/or permanent water diversion blocks may be necessary to direct water from road formation onto more stable areas outside the fill).

Situations which require more than the normal pretreatment sometimes occur. These situations are discussed further on under the heading “Use of Imported Materials”.

Borrow pits

Borrow pits should only be opened within the road reservation if such pits can be drained and reshaped to conform with or improve on the surrounding land form. All borrow pits should be revegetated. Figure 13.5 shows a method of operating a shallow borrow pit.

The borrow operations are phased progressively from section A to section D, each section being developed as follows:

1. Remove existing vegetation and stockpile
2. Remove topsoil and stockpile
3. Remove borrow material
4. Return topsoil to floor of pit and spread evenly
5. Rip floor of pit along contour, mix in topsoil and water the area
6. Spread the salvaged vegetation evenly over floor of pit.

If borrow pits are located within a reservation and the reservation is also a stock route, the sides of the pits must be flattened (slope not to exceed 1 on 4) in order to eliminate a potential hazard to stockmen, their horses and the stock.

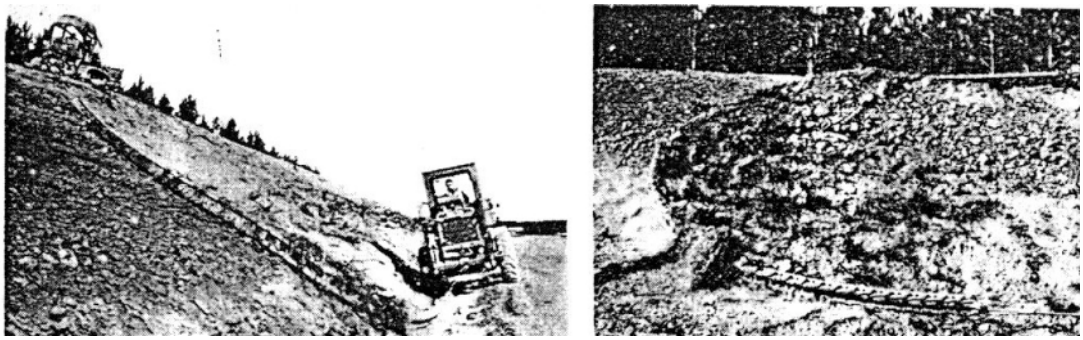


Figure 13.6: Chaining the Batters

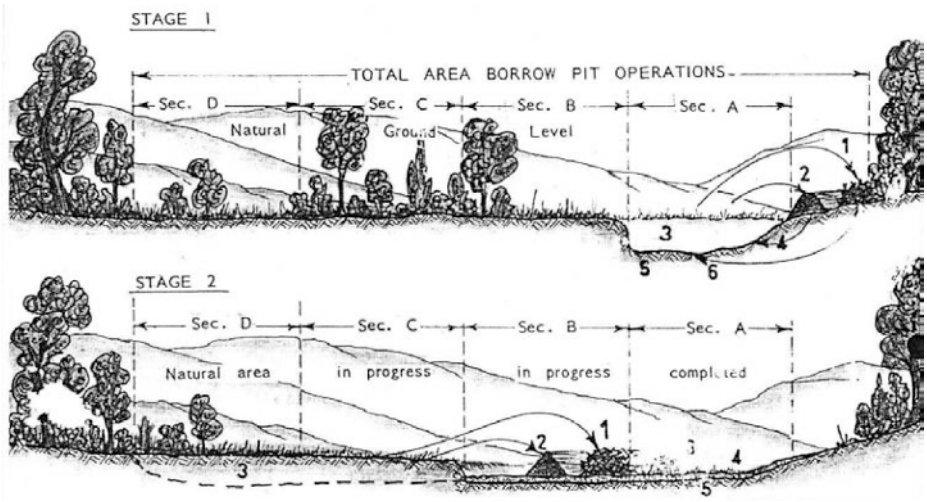


Figure 13.7

Haul roads to borrow pits must be so located as to cause minimum erosion. They too should be treated finally as disturbed areas and revegetated.

Restoration of gravel pits are to be similarly treated.

Use of imported materials

In order to minimise problems of erosion and siltation, or because of a need to provide a public amenity, it may be necessary to obtain a cover of vegetation within a very short time, i.e. at a faster than natural rate. This will necessitate importation of other materials.

Topsoil

The most commonly imported material is topsoil. Because of the often large quantities required and the high cost of imported topsoil, great care must be taken to salvage the maximum available amount of topsoil from within the formation width.

Imported topsoil must have the necessary components for accelerated revegetation. The main points to be considered when deciding on a particular soil are:

- Soil Texture – Is the soil sandy, loamy, silty or clayey?
- Soil Structure – Is the soil cloddy, stoney or friable? Does it contain organic matter produced from plant life? Does it exhibit a satisfactory pore structure?
- pH Value – Is the soil acid or alkaline?
- Existing – Is the soil suitable as a natural cover? Does it contain any noxious weeds?

Sprigging and turfing

Sprigs of grass planted at regular intervals will eventually spread to cover an area. With turfs however, a complete cover can be immediately provided.

Both methods require constant inspection of the materials at their source to ensure that undesirable plant species are not present. Care is needed in their transportation and storage because loss of moisture in the early stages is detrimental to live root systems.

Additional surface treatment may be necessary to protect the plantings. For example, turfs on slopes may need to be securely pegged to the surface, and placed with joints staggered. Top dressing of turfs is also necessary.

Sufficient watering must be carried out after planting to ensure that the soil in contact with the root systems retains sufficient moisture to balance transpiration. The amount of watering required is related to air temperature, relative humidity and air movements, but will generally vary from 20 to 30 l/m^2 per week. Watering should be carried out daily (and at times, twice daily) for a period of several weeks after planting.

Seeding

Revegetation of disturbed areas is best accomplished by seeding with selected species of grasses or woody plants.

Seeds may be broadcast by hand, incorporated in surface mulches, or placed in the soil using agricultural machinery.

The seeds of most plant species employed in revegetation are small and require a light covering of earth or mulch to provide sufficient warmth and allow adequate retention of water for germination.

To obtain adequate protection against erosion it is essential that vegetation cover be obtained quickly and that the cover is permanent. Plants which germinate rapidly and grow quickly are mainly annuals and usually have a short life.

Consequently, where early cover is required, a mixture of seeds of an early crop and of a permanent crop should each be used.

The selection of species should be made after consultation with local agriculturalists and horticulturalists. The rates of application will depend on the likely severity of the erosion and the agricultural procedures adopted.

Table 13.1 shows typical application rates for various species of cover. These rates are provided for guidance only.

Selection of species and specific application rates must be decided upon at the time of construction, since some of the grasses shown in the table are for winter planting and others for summer planting.

Revegetation with plants

The use of nursery-raised plants is normally restricted to the implementation of approved landscape designs. In this case the species are carefully selected. For example, large trees may be employed to stabilise an embankment by reducing the sub-soil moisture in areas prone to slip failure or slumping.

The establishment of live plants requires a knowledge of horticulture which is beyond the scope of this course. The Supervisor must therefore ensure that the specifications and instructions given regarding planting, and subsequent care of planted areas, are meticulously followed. If problems arise, advice should be sought from the person responsible for the preparation of the specification and instructions or, if necessary, from an experienced agriculturalist or horticulturalist.

Mulches and soil stabilising agents

Mulches and soil stabilising agents are used to provide protection against surface erosion until such time as vegetation becomes well established.

Mulches consists of surface covering of organic material. The cover breaks up the energy of raindrops, absorbs moisture, and effectively minimises quick runoff of water. The covering must be porous, to allow penetration of light and air. For this reason, heavy applications of dense mulching materials should be avoided.

Table 13.1

MATERIAL	RATE	REMARKS
White Panicum	28 kg /ha	Selection of species, fertilisers and stabilising agents to be determined, after consultations to determine those most suitable for planting at time of construction and under the prevailing conditions.
Oats	28 kg /ha	
Green Couch	22 – 28 kg/ha	
Rhodes Grass	2 – 6 kg/ha	
Molassus Grass	½ kg/ha	
Siratro	11 kg /ha	
Native Species (mixed)	3 – 7 kg /ha	
Fertiliser	500 – 750 kg /ha	To be used only where soil is too acid for plant species.
Lime	tonnes /ha	
Plastic Emulsion	300 – 1100 kg /ha	
Dilution Rate (in water)	20:1 to 60:1	Applied as a slurry.
Prepared Wood Fibre or Wood Pulp	250 kg /ha	
Bitumen Emulsion	See commercial application	
Dilution Rate (in water)	1:1	

Soil stabilising agents consists of a sprayed application of organic and/or inorganic material onto the ground surface. The agent provides a strengthening of the surface to resist erosion.

Satisfactory mulching and soil stabilising materials include:

- Leaf mould and brush
- Sawdust and other vegetable fibres
- Prepared wood fibre and wood pulp*

- Porous plastic emulsions*
- Bituminous emulsions*

(* Typical application rates are given in Table 13.1).

Mulches and soil stabilising agents may be applied by hand or by mechanical means. The materials used must be free of any additives which may prove injurious to germination and plant growth.

Fertilisers

Plants require a ready supply of nutrient elements such as carbon, hydrogen and oxygen (available from the air and water in the soil), nitrogen, phosphorous, sulphur, potassium, calcium and magnesium (available in varying quantities from the soil or supplied as additives).

A further group of nutrient "trace elements" (e.g. iron, copper and manganese) are essential for good growth. These may be available from the soil or be supplied as additives.

When nutrient elements are supplied as additives, they are called fertilisers. The elements are normally absorbed through the plant root system provided sufficient available moisture is present. No fertilisers should be added to a soil unless additional water is also applied.

Fertilisers may be either organic or inorganic in origin. The nutrient elements can be supplied in varying proportions. The type of fertiliser needed will depend on the relative deficiency of particular elements in the soil.

Commercial fertilisers are rated on the percentage of nitrogen (N), phosphorous (P), and potassium (K) present (with or without trace elements). These ratios are shown clearly on the labels.

The manufacture of commercial fertilisers is based on the economics of supplying the necessary elements in the cheapest way. Use of the correct fertiliser will make the nutrients available which are deficient in a particular soil without waste.

Before selecting a fertiliser, the particular deficiencies of the soil should be known. Where doubt exists, samples of the soil should be tested or advice from a qualified person sought.

Nearly all soils will respond to nitrogen fertilisers provided sufficient water is made available to support added plant growth.

Most soils will benefit from the addition of phosphorous provided the nitrogen content has been built up.

Some soils will require the addition of potassium. The addition of other elements will depend on known deficiencies. Fertilisers, used properly, are essential in any accelerated revegetation program. Use of quantities in excess of the recommended rates is dangerous, and will result in "plant burn". It is therefore desirable to apply lighter applications of fertiliser at more frequent intervals.

Finally – get the right advice

Because of climatic variations, failures in revegetation work must be expected (crop failures occur from time to time even on the best run agricultural properties).

To minimise such failures, advice must be sought from agriculturalists and horticulturalists experienced in the growing and care of plants under the harsh conditions usually associated with roadside revegetation. However caution must be exercised in accepting advice from nurserymen and other "experts" whose experience relates only to the proportion of plants in situations where conditions can readily be controlled to provide a favourable environment for plant growth.

KEY MESSAGES

- **Keep disturbance to a minimum**
- **Be aware of native flora and fauna**
- **Re-establish vegetation**

CHAPTER 14
CONCRETE

For centuries, concrete has been made from cement, coarse aggregate, fine aggregate and only sufficient water to hydrate the cement and make the mix workable. Sloppy concrete is bad concrete. Trial mix design and test result before proceeding.

Some people may need protective clothing including gloves, glasses etc. and be aware of handling techniques.

References:

- Cement and Concrete and Aggregates Australia.
- 11AT 20 Concrete

Cement

Most cement used is normal Portland cement.

If high early strength is required before the normal 28 days, High Early Strength Cement is used.

In setting, concrete generates heat and this can be a problem in large masses of concrete such as dam walls. Note that in areas of high ambient temperature, aggregates and water may need to be cooled.

Low heat cement is used in dam walls and in addition, pipes are often bedded in the mass and chilled water piped through to reduce the heat of hydration.

Most small Council jobs, however, use normal Portland cement in 40 kilogram bags of 25 to the tonne, of aggregate.

Coarse aggregate

The most common type of stones used are:

(a) Crushed blue metal (basalt or similar). (b) Crushed granite.
(c) Crushed river gravel
(d) locally produced screened gravel.

Good aggregate must be:

(a) dense
(b) hard
(c) durable
(d) chemically inert so it will not continue to react
(e) not brittle so it will not break down under normal loads
(f) clean to enable cement paste to adhere
(g) rough to provide better mechanical bonding with cement paste and fine aggregate.

Aggregate is sometimes referred to as metal or screenings.

Normal size is a maximum of 30 mm for concrete roads and 20 mm for concrete footpath channel and guttering and most reinforced concrete work. Sizes available are 30 mm, 20 mm and 10 mm, and should be used appropriately.

The minimum size particles are 5 mm size; less than this fall into the fine aggregate class.

Fine aggregate

Usually sand or fine stone screenings varying in size between 0.16 mm and 5 mm.

Fine aggregate should have the same properties as coarse aggregate and be free from clay or organic matter. If present in the natural state, they should be washed from the sand prior to its use.

River sand has a variable grading in particle size compared with many beach or dune sands. The latter tend to be more even and small in size as they have been deposited by winds, and most winds are not strong enough to blow large particles.

If the fine aggregate is too small and even in size, fine crushed rock is often added to provide a better grading for mechanical interlock and less surface area for the cement paste to cover, with a resultant saving in the quantity of cement needed, cement of course being the most expensive ingredient.

To illustrate the point, compare the surface area of a golf ball of 40 mm diameter. If a box of cubic shape and sides of 400 mm is filled with golf balls, the volume inside the box is more completely filled than if a single ball of 400 mm diameter is placed in the box.

The box will hold 1000 golf balls with a total surface area 10 times that of a single ball.

Water

The purpose of water in concrete making is partly to lubricate the mix for ease of placement but mainly to hydrate the cement.

Water should be clean and free from silt and vegetable matter. Be aware of using water with high visible silt content.

The amount of water needed to do the job is critical. Too much water ruins concrete for the following reasons:

Firstly, it dilutes the cement paste and, like anything diluted, it becomes weak.

Secondly, the excess water temporarily takes up space in the concrete.

When it dries out, a honeycomb effect in the concrete is left which is weaker than a dense cement filling in the voids of the aggregate.

This honeycomb effect allows water to penetrate the concrete more easily during wet weather with possible early effect on the reinforcing steel.

How much water?

Laboratory tests carried out on test cylinders of concrete, crushed 28 days after manufacture until they fail show how vital the water/ cement ratio is in concrete.

The water/cement ratio is the weight of water divided by the weight of cement in the mix.

Figure 14.1 shows how excess water, that is a higher water/cement ratio, causes concrete to fail.

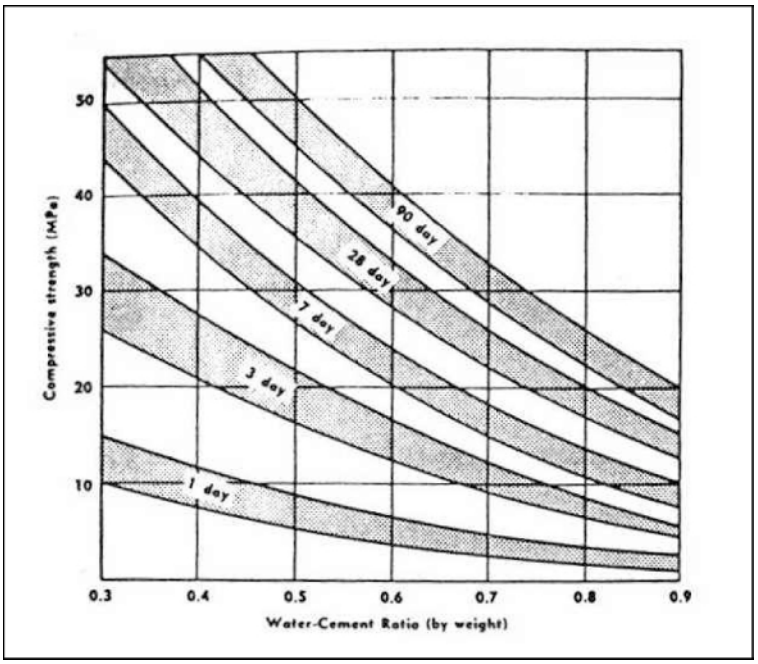


Figure 14.1

The compressive strength is shown in Megapascals (MPa) that is millions of pascals. A pascal is the pressure exerted by 1 kilogram force (called a Newton) acting over an area of 1 square metre.

Compressive strength

The strength of concrete is assessed by measuring its compressive strength (i.e. its resistance to crushing) when test cylinders are crushed to destruction in the laboratory.

The strength of concrete determines the loads it can carry and also affects its durability. Concrete is strong in **compression**, i.e. it can resist high crushing loads. (It is, however, comparatively weak in tension, i.e. it cracks fairly readily if stretched or flexed.)

The compressive strength of concrete is influenced by:

- Water-Cement Ratio (strength increases as W/C ratio is decreased)
- Concrete Density (strength increases as compaction is increased)
- Curing Conditions (strength increases with moist curing)
- Age (strength increases with age).

Water – cement ratio

This is the ratio of the amount of water present in freshly mixed concrete to the amount of cement present.

In TMR works the W/C ration is measured by mass.

Example

If 20 litres of water are used with one bag of cement, the W/C ratio by **mass** is calculated as follows:

$$\text{W/C Ratio} = \frac{\text{20 litres of water}}{\text{1 bag of cement}}$$

$$= \frac{20\text{ kg}}{40\text{ kg}}$$ (since 20 litres of water has a mass of 20 kg and 1 bag of cement has a mass of 40 kg)

$$= \frac{1}{2} \text{ or } 0.5$$

The lower the W/C ratio, the greater will be the strength (Refer Figure 14.1), e.g.

- 24 kg of water to a bag of cement (W/C Ratio = 0.6) may give a compressive strength of 20 Mpa).
- Whereas 16 kg of water to a cement (W/C Ratio = 0.4) may give a strength of 40 MPa).
- However, if the W/C ratio is too low, the mix will be stiff and unworkable, so a proper balance must be achieved.

In determining the W/C ratio, allowance must be made for the water already present in the sand and other fine aggregate since the amount of water present can be quite appreciable, can vary from day to day, from one side of the stockpile to another and from load to load.

A simple test to determine the amount of water in sand is described in Chapter 3. The road construction supervisor should carry out this test himself if a soil tester is not available.

Suppose tests show that the sand contains 5% mass of water (average for damp sand) then the amount of water in 1 tonne of damp sand would be:

$$= 5\% \left(\text{or } \frac{1}{20}\right) \text{ or 1 tonne}$$

$$= \frac{1}{20} \times 1000\text{ kg (as 1 tonne=1000 kg)}$$

$$= 50\text{ kg}$$

$$= 50 \text{ litres (as 1 litre of water has a mass of 1 kg)}$$

This means that for every tonne of sand used, the amount of water added to the mixer would be 50 litres less than the calculated quantity of water required.

Sand however, produces a problem as it bulks or swells when wet. The amount of moisture in the sand must be allowed for by reducing the water added to the mix. Sand can bulk up to about 10%. That is, a cubic metre of wet sand will fill a box 1.1 cu metres in volume.

Allowance must be made by adding more sand to the mix if the sand is wet.

A suitable field test is to use a glass cylinder filled say 3/4 full with the damp sand. The level of the damp sand placed in the cylinder (do not pack the sand tighter than it is in the pile) is measured, water added and the cylinder shaken until the sand settles to the bottom. The new measurement of the sand will approximate that of dry sand.

The difference in measurement will tell you how much the sand has bulked and therefore how much extra to use.

Concrete density

This is the mass of a cubic metre of concrete, and normally will be between 2.2 and 2.6 t/m^3.

Concrete must be properly compacted (by vibration) to minimise the amount of air trapped in the hardening concrete. Air pockets cause a reduction in density and hence a loss of strength. A 5% reduction in density could mean a 30% reduction in strength.

Age of concrete

Because hydration continues for a very long time, the concrete will continue to gain strength for a number of years, rapidly at first but more slowly as time progresses.

Therefore, the age at which the concrete is tested is important. Usually it is tested at 28 days, as it will then have gained a large proportion of its final (ultimate) strength.

Cement storage

It is vital to keep cement dry as any dampness starts to hydrate the cement with resultant part-setting evidenced by the formation of lumps. Later addition of water will not let the lumps form into a paste.

Cement should always be stored off the ground or on concrete floors.

To ensure good concreting, any cement bags with lumps in them should not be used.

Mixing of materials

Best concrete is produced by carefully weighing the materials, for example, in a central batching plant or in ready mixed depots.

On site mixing must be done by volume measure which has been calculated from the original weigh batches.

Cement when dry (as it must be when used) bulks or fluffs up when shaken or loosely turned over. Fluffing can be as much as 50%.

For this reason full or half bags should be used in any volume-batched concrete.

Quantities of materials required

Table 14.1 shows the volumes of metal, sand, cement and water needed to make good concrete for the various uses. The examples shown make 1 cubic metre of concrete.

Concrete placement

At the start of the day, mixer and barrows will take some of the sand-cement content out of the first batches. It is good practice to prime the mixer with a 2-sand 1-cement mix and transport it to the job, and use it on the bottom layer where it will be of adequate strength but will not affect the texture of the surface concrete.

Concrete **should not** be transported in tip trucks as the coarse aggregate will vibrate to the bottom of the pile and will not be distributed uniformly in the job.

Tipping concrete from a height has the same effect.

Any drop over a metre should be catered for by using chutes, which should not be steep. A speed of 1 or 2 metres per second along the chute should be the maximum, otherwise the coarse aggregate again tends to separate to the outside with the more fluid fine aggregate and cement paste flowing faster down the centre.

Concrete should be placed within 20 minutes of mixing to avoid initial set. Any time longer than 45 minutes should be rejected, particularly in hot weather.

Table 14.1: Concrete Quantities
A Practical Guide to Mixtures and Quantities of Materials Required for a Variety of Jobs

Class of Work	Materials required to make 1 cu.m of Mixture					
	Proportion of Nominal Mix (volumes)	Cement (40 kg paper bags)	Sand (cu.m)	Metal Gravel (cu.m)	Yield of mixture per paper bag of cement (cu.m)	Water in litres per bag of cement
Heavy duty floor surfacing for factories and dairies, very thin slabs and slender columns where heavily reinforced	1:1:2	11.9	0.37	0.74	1.084	20
High structural strength						
Concrete for thin reinforced walls, slender reinforced columns, fence posts, heavy duty floors	1:1$^1/_2$:3	9.0	0.42	0.85	0.111	23.6
High strength concrete for heavily trafficked roads and heavy-duty factory or mill floors	1:2:3/2	7.8	0.48	0.85	0.130	26
Commonly adopted mixture for reinforced concrete beams and floor slabs, roads, footpaths, silos etc.	1:2:4	7.1	0.44	0.89	0.140	27
For general structural purposes	1:2$^1/_2$:4	6.5	0.51	0.82	0.153	26
For strong foundations, lean mix roads	1:2$^1/_2$:5	5.8	0.45	0.91	0.172	30.6
Foundations for roads, machinery, buildings etc. and for concrete in mass walls	1:3:6	4.9	0.46	0.91	0.205	34.6
High strength grout mixture	1:1	23.2	0.72	–	0.043	17.6
Watertight plaster coats for cellars, tanks, dairy walls etc. Mortar for structural brickwork	1:2	15.2	0.95	–	0.066	21
Surface rendering for two course concrete paths. Grout for cement penetration roads etc.	1:2$^1/_2$	13.1	1.01	–	0.076	22.6
Mortar for wall plaster rough casting and stucco	1:3	11.4	1.06	–	0.088	24.6
Sand cement mixture for building blocks and bricks. Will not resist damp	1:5	7.5	1.17	–	0.133	31

Compaction

Best method is by internal vibrators placed to reach the bottom of the concrete and slowly withdrawn.

It is possible to over vibrate with the result again being the heavy stones sinking to the bottom. Keep the vibrator moving.

In road slabs, a combination of internal and surface-screed vibration is best.

For thinner slabs, surface screed vibration is adequate.

Footpath work is not thick enough for internal vibrators and surface vibrators are rarely used. Adequate spading followed by screeding and the use of a wire mesh roller produces a satisfactory job.

The latter pushes the coarse aggregate just below the surface to reduce the amount of floating necessary to produce a good finish.

Remember, over floating ruins a good surface.

Reinforcement

Concrete has little strength in tension, hence the need for steel. Positioning of the steel as per drawings is vital to produce the necessary strength in tension. Of equal importance is the cover of concrete on the steel.

If the cover is not as per design, the steel will rust and fail, thus causing collapse of the whole unit. Use bar chairs: do not lift mesh during pouring. There are many examples in recent years, particularly in high rise buildings, where inadequate steel cover has cost fortunes in repairs, if repair is at all possible.

The problem is more apparent at seasides where the salt air accelerates steel degradation.

Reinforced concrete slab floodways

The old method of placing individual slabs generally 15 metres long, 3 metres wide and 200mm thick with 20mm long dowels and 16mm transverse rods with deformed joints together with a reinforcing mat, have given excellent service in the past 60 years or so.

Cost of labour and the relatively slow output have led to the present method of placing a low strength concrete working platform approximately l00mm thick and later following it up with a continuous pour of 200mm high strength concrete.

The latter can be poured into forms and screeded off with a vibrating screed or as is becoming more popular, laid by machine. Reinforcement is sometimes used.

Machine-laid roads can be placed at a very high rate. The controlling factor is the ability to get the concrete to the machine.

Modern pavers can place 6 Cubic Metres of concrete in less than an hour. Joints are preferably cut at an angle to reduce the thump often associated with the older type slabs.

The traffic thump is the result of

(a) the gap between the concrete slabs and
(b) the slight hill of concrete produced as a wave by the vibrating screed working towards a fixed cross form.

Machine laid concrete is being used with a bag finish as a direct traffic surface, with good results.

Other concrete pavements are often given a surface course of 50mm of asphaltic concrete. This gives a very good riding surface.

With steady increases in bitumen prices and improvement in concrete laid by machine, fewer overlays will probably be used in the future.

Ready mixed concrete

Where these facilities exist, they have the advantage of producing large concrete quantities with reduced manual effort.

The Supervisor will have no control over the actual mix of aggregate, cement. He must, however, exert control over water added to the mix.

As stated, excess water ruins the mix. There have been cases where drivers have added water to speed up discharge time. This should never be tolerated.

Rejection of the mix that is too sloppy or one that has been on the road too long, due to some delay and has started its initial set and is too stiff to work, quickly puts a stop to these failings.

Water should never be added to a stale mix.

When is mix acceptable

Excess water can be detected by the slump test. This involves filling the cone in 4 layers, rodding each layer 25 times with a bullet nosed rod of 16 mm diameter.

The cone is filled to the top, struck off and slowly removed and placed alongside the test heap. The rod is placed across the top of the cone and the slump measured from the bottom of the rod to the top of the concrete, as shown below.

Slump should be specified by the Engineer for all concrete work and should normally be in the range of 50 to 75 mm. See Figure 14.2.

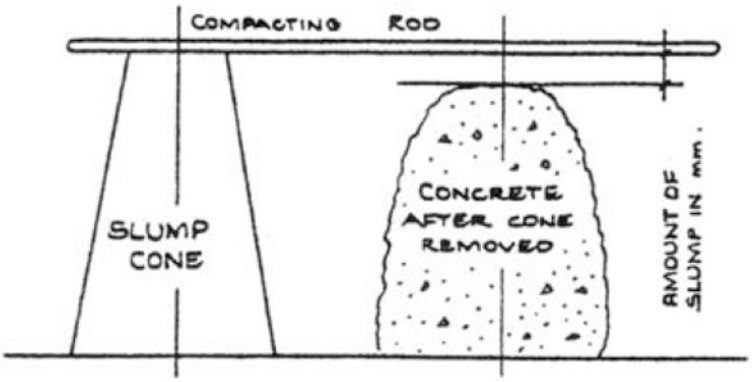


Figure 14.2

Specialist finishes

Proprietary retardants are available:

- Stencil
- Exposed aggregate
- Colour

Test cylinders

These are filled in three layers, and rodded as in the case of the slump cone. They should be made on a steel base and finished off smoothly and covered with a metal plate to avoid rapid drying, a problem that also produces weak concrete.

Concrete curing

The slower the drying of concrete, the better the strength. Methods generally adopted are along the lines of providing a moist layer of material over the concrete as soon as the surface is hard enough not to mark.

Wet sand, hessian, sisal paper, plastic sheeting, etc. are also used.

They all have a problem of being dislodged by wind causing the exposed concrete to rapidly dry out and losing strength.

Soaker hoses can keep sand damp but the quantity of water needed and the servicing of the above at weekends present a problem.

Placing sufficient sand over the plastic to hold it down in the wind presents a problem later in its removal.

The individual treatment must be selected as best suited to the location.

Special curing compounds overcome the above problems and are easy to apply as soon as the concrete has set sufficiently to avoid absorbing the compounds.

In hot areas, cooling of both water and aggregate may be necessary for good concrete.

Concrete retardants

Concrete retardants should not be used unless specified and controlled by the engineer.

Coloured concrete

Pigments are too expensive to add to the mix in sufficient quantity to colour the whole mix. Sprinkling into the surface prior to floating is an art that has to be achieved with experience. Obtaining even colour is difficult, due to uneven mixing of the pigment.

If colour is required, the following are the most common pigments used:

- Black: Black Iron oxide or manganese dioxide.
- Red: Iron oxide.
- Yellow: Yellow iron oxide.
- Brown: Brown iron oxide.
- Green: Chromium oxide.
- Blue: Cobalt oxide.

Reinforced concrete bridges and structures

Do not drill any holes into reinforced concrete structures without consulting the engineer or designer.

See Chapter 15 Bridges and Culverts.

KEY MESSAGES

- **Trial mix and test**
- **Be aware of handling techniques**
- **Use clean water**
- **Cure well**

CHAPTER 15
BRIDGES AND STRUCTURES

Part I: Timber bridges and culverts

Bridges
The structure integrity inspection, maintenance and repair of a bridge is a specialist job.

Limited road funds, changing priorities and turnover of staff often leads to bridges being low in the inspection priority until imminent failure or serious deterioration of deck surfaces becomes apparent.

Often in your role as supervisor or ganger you become the first point of contact. Particularly on bridges and drainage structures in isolated areas on rural roads.

Loading
Bridges have been designed for the load condition that existed at the time they were built, often local timber was used, in timber bridges.

Today, very heavy loads are transported over the rural road network and aging bridges are expected to carry loads far in excess of their original design loading with resulting catastrophic failures. It is not uncommon to find heavy rubber tyred earth moving plant travelling on isolated rural roads with the operator oblivious to either the structural capacity of bridges, or the high axle loads of their machine.

Bridge inspections
Refer to TMR Technical Publication – Bridge Inspection Manuals and Timber Bridge Maintenance Manual.

On first contact with any bridge note the general visual condition and record number of spans, span lengths deck width and construction type e.g. timber, steel, concrete etc.

Check if an inspection program exists, and if so follow up last inspection and condition report, if no record exists of any inspection or load carrying data for the bridge it should be brought to the attention of your supervisor and a program of inspection implemented.

Bridge works, from detailed inspections through to, assessment, and major repairs are generally carried out by specialists. However, you may be involved in carrying out part of these works under supervision and a knowledge of the contents of the bridge manuals referred to above will be advantageous.

Timber bridges and culverts
Timber bridges and culverts have largely been superseded by concrete or steel structures however many existing bridges will require maintenance for years to come.

Species of timber and use
At the end of this section is a list of timbers used for bridge work. The main characteristics are listed. Timber bridges are subject to damage by:

(a) weather,
(b) decay,
(c) borers,

(d) termites,
(e) burning, and
(f) poor maintenance technique.

Weathering

Hardwoods weather very well, apart from incidences of 'surface checking', which tends to detract from the appearance of the structure. For this reason, and to improve visibility, most bridge superstructures are painted.

"Surface checking" refers to small cracks (called checks) which form on the surface of unprotected timber following periods of wetting and rapid drying. These "checks" retain moisture and may lead to further decay.

Any unprotected wood exposed to alternate wetting and rapid drying will suffer deterioration at the affected surfaces, which swell and shrink in response to the moisture changes. Purely surface weathering is not particularly serious, except in comparatively light members. However, one of the consequences of the alternate shrinkage and swelling of the timber is the opening up of checks, which in time deepen and provide pockets for the lodgement of moisture and may provide sites for the development of decay (extract *Timber Engineering Design Handbook*, CSIRO, 1958, p.214, Pearson Kloot and Boyd).

As a minimum, components of timber bridge superstructure that are not painted should be treated with CCA or a similar product. CCA preservatives are regulated by the Australian Pesticides and Veterinary Medicines Authority (APVMA). The APVMA implemented a number of restrictions on CCA that became effective in March 2006. The main implementation affecting the public is that CCA is no longer used to treat timber for structures where there is frequent and intimate contact, such as playground equipment, picnic tables, handrails, decking boards, garden furniture and exterior seating. Treatment levels for CCA are set down by Australian Standards and by state legislation in Queensland and New South Wales.

The approved CCA loading depends on the 'hazard' to which the timber will be exposed, expressed in 'hazard classes' – H1 to H6. Timber used most commonly for domestic purposes is in classes H3 (outdoor above-ground timbers such as decking, fence palings and fascia) and H4 (outdoor in ground contact, for example, posts). Wood treated according to the standard should carry a stamp or brand, indicating the hazard level to which it was treated and stating 'Treated with copper chrome arsenate'.

Timber sale yards should have brochures available that set out safety precautions, which should always be followed. Standard safety equipment should be used whenever working with wood - treated or untreated. Particular caution is needed if fighting a fire in CCA-treated timber because of the arsine gas liberated. Breathing apparatus may be required. CCA-treated timber tends to smoulder longer than untreated timber, a feature called 'afterglow'.

Alternatives to CCA are available but are not yet widely used because wood treated with them is generally more expensive than CCA-treated timber. They combine copper and organic preservatives and are more environmentally friendly than CCA as they do not contain chromium or arsenic. One alternative, alkaline copper quat (ACQ), is currently registered for use in all hazard classes except H6 (marine use). Tanalith E (copper azole) covers hazard classes H1 to H4 and H5 in softwoods (for example, decking and posts). Both have been extensively tested and generally perform as well as CCA.

Remember to use hot-dip galvanised or stainless steel nails or screws when fixing these treated timbers.

Decay

Timber can be attacked by fungus where the moisture content exceeds 20%, but fully saturated timber is immune. It is said that timber will last for thousands of years if it remains in a fully seasoned state or if it is completely immersed in wet soil.

The truewood of the hardwood species listed at the end of the chapter is fortunately quite resistant to decay if it is protected from excessive moisture. The parts requiring special attention will be all joints and areas where two timbers come together, (for example, between deck planks, and girders, between girders and bank seats.) One of the more common areas for decay is water bleeding through scuppers where the internal part of the pipe in the scupper does not continue below the bottom of the girder.

Sapwood of most species contains sugars and starches, and is therefore very prone to fungus attack and decay than truewood. In most species the sapwood is a narrow band about 12 to 25 mm in width, although spotted gum may have sapwood up to 50 mm thick. Sapwood is generally paler in colour than truewood.

CCA or other similar chemicals can be used to prevent decay if properly impregnated into the wood. Vacuum and pressure plants are available at different centres, but the treatment is costly and will usually involve considerable transportation. As sapwood is easily impregnated, its retention in some usages, such as poles and piles, would be an advantage.

Borers

Two common types of borer which attack bridge timbers are the pin-hole borer, and the Lyctus or powder post borer.

The **pinhole borer** attacks the living tree or freshly felled log and makes a hole straight enough to allow a pin to be readily pushed into the hole. The hole of a pinhole borer is lined with a dark coloration. This borer makes holes in both sapwood and truewood, when timber is green. Attacks stop once the timber dries and reinfestation does not occur. Provided the holes are not so clustered as to adversely affect the strength of the timber, this borer attack can be ignored.

The **Lyctus borer** is a greater threat to timber bridges, it can destroy the sapwood of many species of eucalypt hardwoods. However, the following species are, not vulnerable to attack by Lyctus Borer: Blackbutt, Grey Box, Grey Gum, Grey Ironbark, Narrow Leafed Red Ironbark, White Mahogany, White and Yellow Stringy Bark and Turpentine. It is important to note that only sapwood is susceptible to attack if it has an appreciable quantity of starch in its composition.

Bridge timbers to be painted should be cut free of sapwood if of a susceptible species. Normally the extent of sapwood is not relevant from a loadbearing perspective. If destroyed by the Lyctus borer, the attack will normally result in an unsightly appearance rather than a compromise of bridge strength. Treating Sapwoods with CCA or similar chemicals will help extend the life of sapwoods.

Termites

The damage by termites is often difficult to detect in timbers in contact with the soil. Termites seek dark and badly ventilated environments preferring to work inside the timbers, eating out large galleries along the grain, leaving the outer layers of wood intact. They construct earth tunnels in the surface of concrete, stone or termite resistant timber to secure access to more palatable wood. This, of course, assists in detection of colonies.

Termites may be controlled by the use of termite shields, poisoning of earth in contact with timber, and the treatment of the timber by impregnation with CCA lanoline based products or other suitable chemicals.

Termites must have access to a continuous source of moisture. Metal shields, which would prevent the construction of continuous tunnels will protect the timbers beyond the shields.

Earth in contact with timber can be treated with suitable poisons such as Lindane to prevent the termite passing through the earth to the timber. Brushing or spraying of the timber with creosote is often practised but is ineffective over a period because of the lack of penetration of the creosote into the timber.

Sapwood will more readily take up creosote so that its presence on posts, poles and round timbers can be an advantage. Creosoting which is carried out in pressure cylinders under properly controlled conditions will give timbers excellent immunity against termites. Any exposed area of timber that is cut or shaped after impregnation should be retreated with suitable products.

It should be noted that creosote stains timber a dark brown colour and because it will bleed through subsequent paint coatings, it must not be splashed on any timber that is to be painted.

Pressure treatments using copper, chromium or arsenic compounds are also available for wood preservation. They produce resistance to decay, termite and borer attack. The timber will be slightly greenish or brownish in colour, but may be painted.

It is advisable that any new timber used on existing bridges be treated prior to installation.

Painting

Ready mixed paints will almost invariably be used. There is a wide variation of formulation. It is most important that the manufacturer's instructions, which will be printed on the tin, are carefully followed. This particularly applies to the addition of solvents to the paint. The use of a solvent not mentioned in the instructions could lead to the rapid failure of the paint film.

It is also necessary that succeeding coats should be compatible with the paint already applied. One brand of paint should be used for all coats, and the suitability of the particular paint for application over others, should be checked on the container.

Paint, properly applied, should give a service life of about five years on bridges.

If an initial priming coat was applied to timber in the early stages of construction to prevent surface checking and some months have elapsed between the application and the arrival of the painter to complete the job, it is well worth while to apply another coat of primer. The power of the initial coat to prevent the wood from drawing the liquid constituents out of the subsequent coats may well be impaired by a long period of exposure to the weather and handling by builders. The primer should be well worked into the wood and for this reason brush-in is preferable to spraying in applying this initial coating.

Unseasoned timber with a moisture content in the surface layers of above 20% is unsuitable for painting because poor adhesion will be obtained and there will be considerable danger of blistering. Even if the timber is seasoned, painting during damp weather, early in the morning or late in the evening is very inadvisable because of the film of moisture likely to be present on the surface. Excessive heat and cold is also undesirable. For long service life, paint should preferably not be applied in those times of the year when there is a drop of more than 11°C, between maximum and minimum daily temperatures.

In fine, warm weather, coats of paint can be applied within 24 hours of each other, but if possible, an allowance of several days should be made. However, it is bad practice to wait longer than a couple of weeks between coats.

Quality of timber

The Standards Association of Australia has issued visually stress-graded hardwood for structure purposes (AS2082-2007). The Supervisor taking delivery of timbers should be supplied with a copy of the relevant parts of the specification to enable him to properly check timber on delivery.

Timber piles

As 3818.3 provides grading rules for timber piles. The acceptable species includes Grey Box, Grey Gum, Grey Ironbark, Narrow Leafed Red Ironbark, Broad Leafed Red Ironbark, White Mahogany, Turpentine and Tallowwood. Turpentine piles are generally installed with the bark still intact because of the extra protection it gives, especially against marine organisms.

Piles have to be reasonably straight to allow accurate driving. Deviations are permissible, provided that a line joining the mid-point of the butt and the toe does not depart from the centre of the pile at any point by more than 100 mm for piles up to 13 m in length, and 150 mm-for longer piles.

Driving of timber piles

Timber piles can be driven more quickly and with lighter equipment than applies to concrete piles. They can be cut off at an appropriate level more readily than concrete piles. However, all piles are better driven with a heavy, rather than a light, monkey. The heavy monkey produces a pushing action with a comparatively small drop. A light monkey with a long drop would tend to shiver the pile rather than drive it.

Bush timber bridge

Note railway line beams – underside deck

The pile should be prepared for driving by cutting the head truly square, trimming it to a circular and tapered section, and fitting a steel band 50 to 75 mm wide and 12 to 25 mm thick. An alternative to the band is to use a metal hood that has a tapered recess on the underside and a container for hardwood blocks on the other side.

Piles should not be pointed when driven into soft material but in hard ground they should be chamfered at an angle of about 60° with 100 to 150 mm square end. If the ground is very hard, cast steel of wrought iron shoes in the form of a pyramid with attaching straps, can be used.

Timber suitable for bridgework

Timbers listed hereunder are suitable for bridgework. There will be others, of course, which will vary between localities.

Principal species

- Broad Leafed Ironbark CCA Treated
- Spotted Gum CCA Treated
- Tallawood CCA Treated

Other suitable species

See Table 1.

Because of their strength, durability, and availability in suitable sizes, the Ironbarks, Grey Gums and Boxes are usually specified. However, in districts where haulage distance is prohibitive, other local timbers are used.

Timber bridges and culverts are prone to rapid deterioration if not maintained properly.

Accumulation of debris around posts, against sheeting and wall logs and other parts of the structure should be regularly cleared away to reduce fire hazard and white ant attack.

Table 1: Other suitable species

Standard Trade Common name	Standard trade reference name	Other common names	Durability H-High F-Fair	Use remarks
Box, Yellow	Eucalyptus melliodora	Yellow Ironbox, Honey Box	F	Bridge decking
Gum, Grey	Eucalyptus punctata	Yellow Ironbox, Honey Box	H	Hews and sawn girders, piles
Gum, Red, Forest	Eucaluptus tereticornis	Glue Gum, Red Iron Gum	F	As for Ironbarks
Mahogany, White	Eucalyptus acmenoiodes	Yellow Stringybark	H	Girders, piles
Bloodwood, Red	Eucalyptus corymbosa	Booodwood, Pink Bloodwood	H	Round members including piles
Tallow Wood	Eucalyptus microcorys		H	Girders, decking, piles
Gum, Red, River	Eucalyptus rostata	River, Murray or White Gum	F	As for Ironbark
Turpentine	Syncarpia Laurelifolia	Turpentine	H	Piles
Box, Grey Coast	Eucalyptus cosistonia	Box, Red Box	H	As for Ironbark
Box, Grey Coast	Eucalyptus bosisstoana	South Coast River	H	Piles

Dirt should not be allowed to accumulate on the deck as it holds moisture, which can lead to decay or can encourage white ants.

Preventative action against white ants includes frequent inspections, yearly treatment and the regular filling with poison of plug holes when detected.

The type of poison used should be specified by the Engineer, as recent studies have disclosed that some poisons used in the past have side effects detrimental to the user if proper precautions are not taken.

Sapwood on timber will eventually decay and commence to shell off from the main member. This should be removed down to sound timber and the new surface coated with creosote. The availability of CCA or similar products has resulted in sap retention for the life of the hardwood.

KEY MESSAGES
- **Ensure qualified staff inspect timber bridges**
- **Check inspection program**
- **Check type of borer or termites**
- **Use correct timber species**

Part II: Steel and concrete bridges and structures

The construction and maintenance of steel and concrete bridges are specialized jobs.

Bridges can be built from a combination of steel, reinforced concrete and timber, e.g.

(i) Old timber bridges may have the deck replaced with steel components and reinforced concrete
(ii) Bridges may have steel piles, crossheads and precast concrete deck units, or prestressed concrete deck units
(iii) Also reinforced concrete piles, crosshead with steel girders and reinforced concrete decks are common.

Large concrete structures may comprise a combination of mass reinforced concrete abutment wings and piers with reinforced concrete decks or be constructed solely of reinforced concrete floor, walls, wing and deck.

Some notes follow on Planning, Foundations and Earth abutments, and are given as general information. *Detailed information on the construction of bridges and large structures is beyond the scope of this Handbook.*

Notes on construction of foundations

Planning

Due to the provision needed to set out and construct various phases, concrete structures must be well planned.

Standards structures are rare due to variations in span, foundations and abutment height.

It is therefore essential to carefully study the plans to ensure the right equipment such as adequate concrete mixes, cranes and skilled form workers are available to ensure smooth progress with no delays from one stage to the next.

Whether the structure is capable of being built by Council staff should be determined by the Engineering section.

This having been determined, the Supervisor should discuss in detail the planning of the job with Engineering staff.

Foundations

Test bores in larger structures should have determined the type of ground necessary to support the structure.

a) *Sand*. If the structure is to be constructed in sand country, the excavation should be damp before concrete is placed to void rapid moisture withdrawal from the concrete.
b) *Soil and Clay*. Excavation should be undisturbed ground and be of even texture.

No soft spots should be evident. If any unevenness is encountered, the matter must be discussed with the Engineer as complete structure safety is dependent on the foundations.

Rock

Hydraulic picks should be used when possible. Problems can be found in rock excavations such as inclined layers, clay seams and water bearing sand seams. These should be discussed with the Engineer.

Pile foundations

Pile Foundations are used where insufficient bearing capacity can be obtained on natural ground near the surface.

Piles are driven either to rock or to an adequate depth to develop frictional strength to support a concrete headstock.

Pile driving is an art and generally performed by a specialist team as the piles must not be damaged by way of cracking while driving.

To avoid such damage, the following procedure should be followed:

1) Pile Frame must be robust and well braced.
2) Hammer should be about the same weight as the pile, although this should be specified by the Engineer.
3) Hammer drop should be such that the pile is not driven more than 62mm per blow.
4) Maximum drop in any case should not exceed 1.2m.
5) Adequate head packing should be placed on top of the pile. The packing is placed inside the driving helmet and may be old rope, rubber belting or a bag of sawdust. Thickness should be about 75mm. Sometimes good quality hardwood or propriety products are used instead.
6) As the pile approaches its final position or whenever the driving is hard, frequent checks should be made of the "set" or penetration of the pile per blow. Driving should stop when the specified set is obtained.
7) Specified set should not be less than 3 mm.
8) If any time the hammer bounces then it is too light or the drop too great. The Engineer's advice should be sought in this case.
9) The hammer should always strike the top of the pile helmet square and centrally.
10) Concrete piles should be at least 28 days old, regardless of test strength obtained in cylinders.

Jetting

For driving piles in compact sand a water jet is most effective. Pump used should have a capacity of at least 450 litres per minute at a pressure of about 7 kg per sq cm. The flexible hose should have a diameter of about 37 to 50 mm with a 12 mm nozzle at the end.

Jetting is not suitable for heavy gravels or clays or in heavily water charged ground, or where material disturbed cannot readily escape. In these cases compressed air may be used.

Jetting should stop about a metre before the pile reaches final level and final placement then finished by driving.

If piles have to be driven inside timbered pier holes or coffer dams, the excavation should be taken down below the finished level to allow for ground swell during driving.

Jetting of piles within a coffer dam can be very dangerous as it may cause the strata to run underneath and thus destroy the lateral support at the toe of the coffer dam sheeting.

Order of driving

Piles should be driven from the centre outwards to minimise effect on adjoining piles, especially in clay ground. Spacing of piles greatly affects their bearing capacity. Minimum spacing for concrete piles in ordinary conditions and fairly hard ground should be 1 metre.

It is essential that piles be driven as accurately as possible. Any piles tending to run off position during driving should be restrained by guy ropes, slings and tackle.

After a pile is driven the Supervisor should report any deviation from the theoretical alignment.

It is customary to keep a permanent record of all piles driven including the following items:

Method of driving

- Type and weight of hammer
- Drop of hammer under last five blows
- Number of piles driven, and
- The length of the piles below cut off level.

Concrete foundations

Excavation to surfaces upon or against which concrete is to be placed should comply to the specified location, dimension and shape.

Excavation should be taken to original undisturbed ground and any soft spots, fissures, inclined layers, clay layers or water bearing sand layers should be reported to the Engineer.

In rock, the surface should be sound, even at right angles to the load.

As mentioned in the chapter on blasting, extreme care should be taken both from the safety angle and damage to the bed rock on which concrete foundations are to be poured.

Reinforced earth abutments

A relatively new construction type, this allows abutments to be built on stable soil by placing reinforced earth walls. These consist of vertical face panels held in place by straps extending horizontally into compacted soils. A header beam is then placed on top to take the weight of the pre-cast beams or girders.

Road Maintenance

Refer to Chapter 12.

CHAPTER 16
PARKS AND MAINTENANCE

Well maintained parks and gardens are essential features of any Local Government area which is developing in a balanced manner. In the more heavily built-up urban areas, they provide the lungs of the community and the necessary open space and playing fields for community sport.

To a large extent, the civic pride of an area is judged on its well-maintained parks, street trees and gardens. The nature of displays and type of development will, of course, depend upon the geographical and climatic conditions of any particular area.

Park maintenance in the past was mostly done by hand, but under modern conditions it is essential that mechanical equipment be used to the maximum and that the layout and development of parks should be geared to this end. This should not merely apply to such matters as mowing, but should include the elimination, where practicable, of hand watering, hand weeding and cultivation, hand trimming of borders and edges, and the like. Pruning of trees and hedge cutting can be mechanised. The use of well chosen plant species can produce first class displays whilst reducing the heavy costs of planting and maintaining annuals.

Parks and gardens personnel should be constantly on the alert to make improvements in layouts which will maintain or even increase the attractiveness of an area, but at the same time reduce labour costs.

Playing fields

In most areas, playing fields will be used for both summer and winter sports, and very often will be in use most days of the week and for night training. The maintenance of such grounds in really good condition calls for considerable ingenuity. There should be a well planned and regular fertilising programme; turf renovators should be used between sporting seasons and at times during a season to combat undue compaction; and periodic light top-dressing will be necessary to maintain a smooth surface.

There will be a limit, however, to the amount of use that any ground can carry, and Supervisors in charge of such grounds should discuss with the Engineering staff any practices by sporting bodies that unduly damage the ground. This can particularly apply to winter sports where undue training in small areas, say in the vicinity of goals, can be minimised by introducing practice goals. Where there is room, periodically re-locating the goals and field boundaries can be used to spread wear more evenly. It is a good plan to have areas where turf can be lifted to enable badly worn portions of a playing field to be re-turfed at the end of the winter season. Special care should be taken to protect turf wickets from unnecessary wear during the winter season so that they are in a condition which will permit preparation for cricket play at the commencement of the summer season.

The removal of litter left by crowds of spectators can be a very costly matter. Considerable thought and planning should go into the layout and furnishing of spectator areas, to facilitate the removal of litter by mechanical means. In many cases it is desirable that seating of a type which will involve lots of hand cleaning should be replaced by an easily cleaned type of seating. Smooth concrete surfaces are more readily cleaned but are not nearly as attractive as grassed areas. A careful balance between the two types of surface is desirable.

Grass cutting

In recent years large gang mowers with 5 or 7 gangs have proven their reliability. They are the best for well-developed lawns such as exist in parks and ovals.

The retractable gangs make their use a proposition by being able to travel by road from park to park.

For rougher grassed areas, flail type tractor mounted mowers are more appropriate although less area can be covered. Tractormounted spin-cut types are suitable for close mowing to obstructions. This type however can produce a debris throwing problem and guards should be carefully maintained. It is essential that the blades and discs are also carefully maintained as blades separated from the discs can become lethal.

Park layout should be revised so that the great proportion of the grassed areas can be cut a by large machine. Park furniture should be installed in such a manner that there are no inaccessible grassed areas, e.g., seats should have a concrete base which extends for a sufficient distance beyond the limits of the seat to enable a gang mower to mow right to the edge of the concrete.

Gardens can be bordered by a concrete edge, which will similarly allow gang mowers to operate without leaving a fringe of uncut grass.

Every effort should be made to minimise the areas which must be cut by hand-controlled mowers.

It is very important that gang mowing and any necessary hand mowing shall be well co-ordinated to avoid the very unattractive appearance which results when one operation is carried out without the other.

The volume of grass cutting varies considerably with the seasons. It will usually reach its peak in late December and continue through to mid March. During this period, all available equipment will be needed and should be in first class condition. This requires that all machinery should be thoroughly repaired and re-fitted during the slack periods. A further factor which can result in grass getting out of hand is the Christmas close-down period. Adequate staff should be rostered to keep the mowing work abreast of grass growth.

Nature strips

Any district with well kept nature strips has a neat and pleasant appearance. Where paths become overgrown with grass and weeds, they detract seriously from the amenity of the area.

Each Council will have its own policy for handling this problem; some undertake complete maintenance of the paths and strips, but this is very costly.

Others endeavour to encourage residents to do their own mowing. The latter policy can be successful if it is pointed out to the residents that self help results in a substantial saving in rates, and if the Council gives ready assistance in establishing reasonably smooth paths finished with suitable soil, and provides top-dressing on request.

There will always be the problem of the odd frontage being allowed to become overgrown. Such cases can be handled by spraying with poison or in special cases where residents are unable to cope with grass-cutting for some good reason, Council may agree to regularly carry out the mowing.

Tractor mowers can be used in many cases, but smaller plant having cutting widths of about 750 mm and self-propelling, are available. These machines are usually designed so that they can cut close to obstructions. There are machines available for edge cutting and tractor attachments which can trim behind kerbs and along paths at a fairly fast rate. Hand chipping is extremely wasteful of labour, and therefore very costly.

Obstructions to grass cutting should be minimised by paving areas beneath and around seats, litter bins, and other street furniture. Areas subject to heavy wear should be paved.

Disposal of grass cuttings requires careful consideration. If residents are encouraged to compost the material the cost is minimised. Residents should be discouraged from leaving cuttings in gutters because of the risk of chokage of stormwater drains. It may be necessary to organise regular pick-up of material. It is often desirable that residents be permitted to place a reasonable quantity of grass cuttings in garbage bins.

Grass growth retardents are now available. They provide one means of reducing the cost of cutting and disposal of cuttings, but to date they are fairly costly. This technique should be kept in mind, and used wherever a real saving in cost can be made. Application techniques should be carefully considered and undertaken in a way which will not pollute waterways or adversely affect desirable plant species.

Gardens

Well tended, colourful gardens are most attractive features in the district, and can have considerable effect in fostering civic pride. On the other hand they can be labour-intensive and costly. There should be balance between the area and the funds available for maintenance. It is usually better to reduce the total area of garden and maintain a high standard in planting and maintenance than to have a larger number of gardens maintained to a mediocre standard.

In central locations or when special events are to take place, it is sometimes desirable to grow plants to an advanced stage in containers and then to plant them out immediately after one display is finished. Automatic watering can be readily applied. Handling to the planting site becomes fairly simple, and the actual planting can be rapid.

Mulching of gardens with materials such as wood chips can reduce the maintenance problem by reducing the watering necessary and minimising weed growth.

There has been an increasing use of rockeries for garden display. The usual practice is to blanket an area with weedmat, to build up the rockery with weathered stone, plant a number of suitable species in slits made in the sheeting, and then to cover the sheeting with materials varying from crushed tile, stones, gravel, some boulders and the like. Such rockeries, well laid out and planted, can remain attractive with a minimum of maintenance.

There is an increasing usage of ground cover, using creeping plants and hardy shrubs having a prostrate form of growth.

Well laid out shrub and ornamental tree planting provides very attractive effects in parks. They also form a means of minimising labour costs and producing a maximum display at a reasonable cost. Good quality plants should be used, but there is a risk of theft if outstanding and uncommon varieties are planted.

Roses, either in separate plantations or used in conjunction with garden beds or shrubs, can produce delightful effects. Heavy bearing, hardy and approved types of roses should be used. The aim should not be to produce outstanding individual blooms. It should rather be to produce a more or less mass effect. Some care should be taken in selection to avoid types that will tempt thieves. When planting, labels should be removed.

Tree planting

Tree planting policy will vary considerably between Councils and localities. City streets require quite different treatment to suburban areas or country roads, but to some extent the selection of trees, methods of planting and care, will have common features.

When deciding the type of tree to be planted, consideration should be given to the prevailing conditions, such as soil, aspect, climate, watering facilities, exposure to wind, and the nature of obstructions, such as overhead wires, shading by buildings, and so on. Other factors to be taken into

account are the possibility of pipe damage by root systems, the freedom of the tree from diseases and pest attraction, tolerance to pruning, the nature of any fruit or berries, problems which may arise from leaf dropping, the desirability of having evergreens or deciduous trees, and whether the trees are poisonous to animals or likely to have adverse effects on people subject to allergies. The general pleasant appearance of the tree, is of course, the most important consideration.

Planting

The Supervisor will be most involved once the tree planting programme has been determined and he is given the task of carrying out the actual planting.

In the past it was the practice to dig fairly large holes, say 1 m x 1 m and 600 mm deep, and refill with selected soil. In conditions where the ground is particularly hard, there is sometimes an advantage in running a ripper through 3 or 4 m of ground at the tree location prior to commencement of planting. The simplest planting method is probably to dig holes, about 300 mm diameter and depth, with a tractor-mounted post hole borer. The sides of holes should be roughened prior to planting. The trees to be planted will usually be in plastic containers. The container is removed. If pot-bound, roots should be slightly disturbed and spread, and the hole filled and watered.

Deciduous trees will usually have been grown in open ground and the root system balled. When planting such trees, the hole should be large enough to allow the root system to be fully spread out. Firm staking should be part of the planting procedure only in areas of high wind exposure. 50 x 25 mm or 75 x 25 mm hardwood is preferable to garden stakes, being stronger and less liable to be stolen.

Trees should be watered at regular intervals until well established. In a residential street this can be most cheaply achieved by filling a container from garden taps in private property. Water tank watering can be quite costly.

Pruning

Most trees will require some pruning to establish a shape suitable for the location. The first pruning should be at the stage where the tree is 2 to 3 metres high, and will be carried out in such a way as to encourage suitable branching where the type of tree makes this desirable. At this stage the work can normally be carried out using secateurs or a pruning head mounted on a rod.

When a tree has grown to the stage where it requires heavy pruning, mechanical gear can considerably reduce the effort required. Chain saws provide a rapid means of making heavy cuts, but they can be very dangerous unless used by standing on the ground or on a firm platform. Chain saws should not be used from ladders or perched in the tree and shall only be operated by accredited staff. Air hydraulic operated pruning heads mounted on rods will handle cuts up to about 30 mm diameter. Air hydraulic42 operated circular saws mounted on rods up to about 2.5 m in length can be used to handle branches up to about 75 mm diameter. Reciprocating saws, again mounted on rods and air powered, are available for cutting even larger branches.

The pruning cuts should be made in such a manner as to minimise damage to the remaining part of the tree. If not properly done, a failing branch can strip away large sections of bark immediately below the cut. To prevent this, a first cut should always be made on the underside to a sufficient depth to ensure that when the branch drops, it breaks cleanly at the cut without any stripping below the cut. With larger branches, and in awkward positions, it is sometimes desirable to cut the branch off a foot or so out from the final cut and make a second cut to remove the stub. The final cut should always be as near vertical as is practicable.

The disposal of tree prunings is best handled by using a chipping machine. These machines rapidly convert branches usually up to about 150mm diameter into wood chips and discharge them directly into

a truck or trailer. Branches that would normally produce many lorry loads are readily reduced to a single load with a minimum of handling. The wood chips can be used for garden mulching, improvement of dirt tracks at garbage depots, etc. One disadvantage of the chipping machine is that it sets up a loud wail, which can disturb residents. Work should be arranged so that the machine is taken rapidly through any particular street to reduce the operating time to a minimum.

Good pruning requires skill and experience. The aim should be to treat the tree in such a manner that its immediate appearance is still attractive and that its future growth will give a balanced shape. Most trees will look best when they have a natural appearance. Pruning by trimming the tree to a smaller size is not good practice. It spoils the natural look of the tree and encourages multiple shoots, which will usually grow rapidly and soon produce scraggy, unattractive growth. Most pruning cuts should be made well inside the tree in such a way that multiple shooting will be discouraged.

No tree should be lopped or topped at any stage.

Pest control

When some trees are pruned, insects are attracted by the smell of the sap. Fungus is likely to attack some cuts.

Most Councils will have mechanical gear suitable for spraying trees to control fungus growths, disease, and insects. It is most desirable, of course, that trees which will not require such attention should have been selected, but when necessary it should be carried out thoroughly and properly. Some sprays are very toxic. They can act through skin contact, breathing, or swallowing. Every care must be taken in selecting poisonous sprays to ensure that neither workmen, residents nor passers-by are endangered. Sprays shall only be used in exceptional cases and full Workplace Health and Safety practices should be undertaken.

Planting stock

Planting stock may be advanced plants in containers of about 150 to 200 mm size or can be smaller plants grown in planting tubes. The former material is used because it gives much better immediate results, but where large numbers are to be planted and cost is a consideration, a 50 mm planting tube stock is cheap, easily handled, and will give much the same result after about three years, but the effect for the first year or so is not usually suitable for street planting.

Nurseries for growing of shrubs and trees require increased mechanisation. This usually means that they must be fairly big to warrant expenditure on plant. In the past, some Councils have established their own tree nurseries, but this has usually resulted in the restriction of types available for planting in any particular season, a surplus of some varieties, and an expenditure exceeding the cost of purchasing suitable stock from commercial growers. It would seem that only very large Local Government areas could readily support their own nurseries.

There are various nurseries throughout the State. Stock is usually cheap.

Note: Department of Transport and Main Roads Road Landscape Manual, is an excellent reference. It lists the characteristics of trees, and sets out in detail, procedures for selection, planting and care of trees.

KEY MESSAGES

- **Lay out for easy mechanical maintenance**
- **Use appropriate plants for local condition**

CHAPTER 17
WATER SUPPLY AND SEWERAGE

Section 1: Water supply and sewerage

General duties – general public
A Supervisor and their team should act with courtesy towards the public, their customers, and members of other work groups or public bodies. A service request or complaint that is received by the public and that is beyond the normal limitations of the work group should be referred to the Manager or Engineer that they report to.

Authorised employees required to enter upon private property in the course of their duties must attempt to notify the occupier of the premises before commencing works.

Employees should present their instrument of appointment, "Authority", if it is requested.

Temporary interruption in consumers' services
When the supply of water is to be shut off for any purpose (planned shut off) all consumers affected by the shut off should receive at least 24 hours prior notification. In the event of an emergency (unplanned shut off), such as a main break, where immediate action is required, advise your Manager, Engineer, or Office of the nature of the problem and if possible the expected time to restore water supply.

Whenever possible and before supply is discontinued or disconnected, the consumers are to be given an opportunity to fill utensils or vessels to tide them over for a reasonable period of time.

Where instructions have been issued to disconnect a consumer on account of nonpayment of rates, the Supervisor may not refrain from carrying out his duty because a promise to pay or "call at the office" is supplied to him by the occupier or owner.

It is the duty of the Supervisor to notify both the consumer and the Office of any leaking meters and/or leaking pipes, taps and fittings observed on any premises.

Co-operation with other authorities
During excavation work, and at any time, where damage or leaks are observed in the assets of any other Body such as the Gas or Telecommunications Authorities, information should be passed on as a matter of courtesy.

Protection of trenches and obstructions
Council is responsible to protect the public and its employees from any damage or injury arising from an excavation, obstruction etc. that may occur at a job site made or left by its employees. All employees have a responsibility to ensure that the public is fully protected and all such excavations, etc., are properly guarded, sign posted and illuminated.

Complaints of poor pressure or supply or of sewer blockages
These should be investigated urgently, and if possible, in the presence of the consumer who made the complaint. An investigation in to whether this is due to low mains supply pressure, the condition of the mains, the condition of the service to the consumer's boundary or to the state of the pipes on the consumer's premises.

For poor water pressure/supply an idea of where the fault may lie can be obtained by the use of a pressure gauge placed respectively at a fire hydrant in the street, on a tap at the nearest point to the street property boundary or on a tap at or near the furthermost point supplied, at the same time drawing supply as liberally as the pipes will allow from the furthermost point served. Due allowance must be made when observing pressures, for differences in level (metres head) between the various points where the gauge is employed.

The use of two gauges at different points simultaneously will often serve to pinpoint the trouble.

To assist in the maintenance of proper records, the Supervisor should report their findings in writing, setting out in detail the results and action taken.

Complaints regarding the quality of water

These should be investigated urgently, and steps put in place to improve the quality of water as quickly as possible. To assist with their investigations the employee should:

(a) Find out how long the condition has existed,
(b) Whether the poor quality is continuous or intermittent,
(c) Whether adjoining premises are similarly affected. These enquiries will establish the full extent of the problem.
(d) Where it is evident that the poor quality is due to internal pipe work on the consumer's property, the consumer is to be advised. In most cases it is the responsibility of the consumer to repair damage to any internal pipe work located on their property.
(e) If the poor quality is due to a dirty main, the main should be flushed and a sample of the water taken for testing. Results should then be reported.

Complaints regarding blocked sewers

The Council is normally responsible for manholes, mains and sewer connections to the boundary trap. When an overflow occurs the Supervisor should rod upstream from the downstream manhole and, if necessary, plunge the boundary trap to clear the blockage.

Clean up of any spillage may require a disinfectant – see appropriate policy of your organisation.

Equipment such as steel rods, rod turning motors, small "eels", plungers etc. should be available on a trailer. Large blockages may be better cleaned by water jet cleaners. Clean up overflow material after the pipes have been cleared and disinfect the general area.

Emergency work

In the event of fire the Supervisor may be called upon to assist the Fire Brigade, and if necessary take action to maintain the mains pressure supply at its highest level.

When any leak, break or blockage in a main is reported directly to the Supervisor or member of their staff outside normal working hours, and it is outside the limits of their responsibility it should be reported to their Manager or Engineer for a decision as to what remedial steps should be taken.

Where supply is to be temporarily shut off, **immediate** notice should be given to the local Fire Station.

Electrical equipment – power and/or telephone cables

All connections to the power supply shall be carried out by a licensed electrician authorised to perform the work. Workplace, health and safety issues must be addressed.

During excavation work all care must be taken to avoid damage to telephone and electric cables. Any protective cover used to protect cables should be removed with care and properly replaced before backfilling is undertaken.

Prior to the excavation commencing, “dial before you dig” or the service utility should be contacted to provide service locations. Should accidental damage occur to any cables it should be reported to the proper authority, even if slightly damaged they may interfere with telephonic communications or may be dangerous to workmen or the public.

Wet Weather

Supervisors will be expected to use discretion in the matter of stopping work on account of wet weather; however, all men employed at a weekly rate should be gainfully employed to the best advantage while work is possible.

Because of its nature, important mains may have to be repaired during inclement weather. Supervisors should see that all men for whom he is responsible are provided with suitable waterproof protection and that these are properly cared for.

SECTION 1: KEY MESSAGES
- **Check with DBYD**
- **Act with courtesy to general public**
- **Advise when service interruption**
- **Advise of leakages**
- **Investigate complaints urgently**

Section 2: Laying and maintaining pipelines

See also Chapter 8.

Types of pipes

It is now usual to use ductile iron pipes in roadways and either Oriented Polyvinyl Chloride (OPVC) or Modified Polyvinyl Chloride (MPVC) pipelines elsewhere for water supply and PVC, earthenware or concrete pipelines for sewers. It is usual that all pipes have rubber ring joints of various types and which provide excellent service. There are a wide range of fittings available for each pipe type and also special fittings so that various types of pipe can be joined together.

PVC pipes are colour coded in accordance with AS/NZS 1477, to readily distinguish between the different types of pipe applications. AS/NZS 1477 covers two size ranges of PVC-U pipes. Series 1 is a metric size range and Series 2 is compatible with the outside diameter of Australian cast and ductile iron pipes. The following is a summary of the colours used for common applications.

- White/Light Blue - drinking water applications. Series 1 pipes are generally coloured white and Series 2 pipes are generally coloured light blue.
- Lilac/purple - recycled water/treated effluent
- Creampressure/raw sewerage

Cast iron pipes and fittings are either flanged or socketed. Flange joints are rigid and the two flanges are jointed with a separating gasket of insertion rubber. Flanges are generally used above ground and around pump stations although many engineers like to fit flanged valves in pipelines and these are joined to the pipe barrels with flanged/plain or flange/socket fittings. Normally, the pipes are spigot/socket type joined by elastomeric gaskets in the well-known Tyton joint. Pipes and fittings should be concrete lined.

Carefully inspect the 5.5m lengths before placing. These pipes can be laid on curves provided the pipes are not offset by more than 87 mm for pipes to 300 mm dia, 70 mm for 375 mm dia pipes and 52 mm for larger pipes. The pipes are available in several pressure classes so make sure the specified pipe is laid. Most fittings are double socketed requiring the pipe to be cut to enable them to be fitted. Also available are spigot/spigot/ flange tees and various flanged fittings.

OPVC pressure pipe is either class PN12 or 16, comes in 6m lengths, up to 375mm in diameter and are rubber ring jointed. This pipe is compatible with cast or ductile iron fittings.

MPVC pressure pipe comes in classes PN9, 12, 16, and 20, normally in 6 m lengths, up to 450mm in diameter and are rubber ring jointed. This pipe is compatible with cast or ductile iron fittings.

Excavation of trenches

See Chapter 5 Safety in Confined Spaces.

Excavation in open cut

Great care must be taken by the Supervisor and their team, in retaining the sides of a trench or open cut to protect men and workings from collapsed earth. Adequate shoring must be employed particularly in sand or reclaimed material and must be secured against side slip or drop by adequate bracing. During wet weather all shoring should be regularly examined so that necessary action to forestall movement may be taken.

Excavation in water-charged ground

In all heavily water-charged ground the excavation must be undertaken at such a rate that the lowering of the water level will not cause a ground disturbance in the vicinity of the work. In this way the fine materials will not be disturbed and carried into the excavation. If the ground is "fluid" there is always the danger of a "wash" of sand from outside under the toe of any shoring. Where any doubt is present regarding the stability of soils or of the shoring, reference should be made to the Manager or Engineer for a decision.

Stormwater

Excavations should be protected against the ingress of storm water in the event of heavy rainfall. Divert water from broken mains or emptying reservoirs into streams or gutters by means of spoil banks, or by means of temporary fluming.

Water supply trenches

For water supply pipelines, the minimum trench depth shall be 750mm above the top of pipe in roadways and 600mm elsewhere, except where additional cover is specified by the construction plans or directed by your Manager or Engineer. The minimum depth of pipe bedding is 100 mm.

Backfilling under roadways

For backfilling under roadways:

- all unbound gravel and select fill is to be compacted to 95% STD compaction to AS 1289.5.2.1
- all cement treated material is to be compacted to 100% STD compaction to AS 1289.5.2.1
- all cement stabilised material to have a minimum 4% cement by dry weight
- all material to be compacted in 150mm layers
- Surface level tolerance, the deviation from a string laid parallel to the centre line of an existing road as shown on the drawing shall not exceed 10mm.

Bedding pipes in trenches

When cement pipes are used the Supervisor or person in charge is responsible for seeing that every pipe is accurately and evenly bedded for the full length of its barrel. UNDER NO CIRCUMSTANCES WHATSOEVER should any weight rest upon the sockets. When the pipes have been bedded on their barrels, the fingers should be freely passed between the bottom of the sockets and the small depression cut in the bottom of the trench. The careless bedding of pipes so that their weight is supported wholly or partly upon collars or sockets is the most common cause of transverse breakages.

For **all** pipes it is important that the material in contact with pipes should be free from large stones, as these may cause local loading and ultimate failure. Pipes should be bedded on sand or dry friable material, and completely covered to a depth of at least 150 mm with the same material and a further 150mm of approved filling.

Filling material should be well rammed round the pipes and brought up in layers of up to 150 mm with continued ramming and (in constructed streets or footpaths) rolling with a vibrating trench roller or other mechanical device.

Before backfilling, pipes should be straightened so as to be a uniform distance from the kerb or building line. Such work is particularly simple with flexible joints.

Foreign matter should be excluded from all pipes when laying; sockets should be clean, and as a precaution all open pipes should be sealed during meal breaks and at the end of the day's work to prevent contamination from water, soil or small animals and other such life.

Laying of mains

As sand does not naturally occur in the bottom of a trench, the trench should be taken about 100mm lower than grade, to permit the pipe to be laid upon a sand or dry friable material (crusher dust) of that thickness. All pipes should be tested for soundness. Cracked or suspected spigot ends should be sawn off or otherwise removed.

To cut pipes various tools are available.

(a) chisel, in which case a groove should be deeply indented the whole of the circumference by a "diamond" chisel before using an ordinary cold chisel to deepen the indentation;
(b) pipecutters, which consist of a string of hardened wheels rotated around the pipe, each wheel marching in the indentation caused by its fellow;
(c) abrasive wheel operating at high speed by either compressed air, electricity or petrol motor. Asbestos cement pipes may be cut by:
  (i) coarse toothed hack saw;
  (ii) abrasive wheel of a different composition than that used for cast iron cutting;
  (iii) special asbestos cement cutting tool by which a ring of wedge shaped points are simultaneously pressed into the circumference of the pipe, causing a sudden breaking off of that part of the pipe to be severed. Refer WH&S Officer for special handling of asbestos.

OPVC or MPVC pipes may be cut by a coarse toothed hack saw.

Crossing other pipelines etc.

When crossing a pipeline which is at a lower level than the pipe being laid, pour a concrete pad 100 mm thick under the sand bedding the same width as the trench and 1 metre either side of the other pipe and use 4 reo bars 12 mm dia in the pad. When crossing a water course encase the pipe in lean concrete (1:12) 100 mm min thick around the outside of the pipe at its thickest part.

Sockets and spigot pipe – location of sockets

It is customary to lay such pipes with the spigot pointing in the direction in which the water is flowing. There is no rational basis for this, as the pipe should be equally efficient in sustaining flow in either direction. However, when laying pipes on sloping ground it is better practice to lay the pipes with the sockets at a higher level than the spigots, because it is easier to force the spigot well home in the socket under these conditions.

Pipes laid up a steep slope may be subject to creep and should be immobilised by concrete anchor blocks. Blocks are recessed into the hard undisturbed walls of the pipe trench at intervals depending upon the steepness of the slope.

Surface friction between the exterior of the pipe and the filling material assists in the overcoming of creep, but generally it is safe practice to provide blocks as follows:

Spacing of concrete anchor blocks:

Slope 1 in 5 to 1 in 6 – every 4th pipe
Slope 1 in 4 to 1 in 5 – every 3rd pipe
Slope 1 in 3 to 1 in 4 – every 2nd pipe
Slope greater than 1 in 3 – every pipe

Thrust blocks

These must be provided to control movement of the pipeline where such movements are likely to occur, and to resist any unbalanced load.

Where water is deflected from a straight line a very considerable side thrust is exerted. Such side thrust may cause damage to the pipe bend joints with subsequent leaking, creeping or complete failure of the joint. Refer to the standard drawings for details on installation

Size of anchorages

When the amount of thrust has been determined the size of anchorages may be determined by assuming the safe bearing pressure to approximate the following:

firm soil-10 to 20 Tonne/sq m.
hard dry ciay-10 Tonne/sq m.
rock-40 T/sq m.

Table 17.1 gives typical thrust block sizes for normal situations.

However in wet locations and with clayey soils, particularly when anchorages are on or near the surface, reference should always be made to the Engineer. More particularly is this the case where upward bends in a pipeline call for anchorages to prevent uplift.

For normal pressures and soils, the block should bear on a face cut into the side of the trench at least as wide as the total outside diameter of the pipe and four (4) times as long as the outside diameter of the pipe.

Thrust due to closed valves and end caps or plugs

When a valve is closed or an end cap placed in position, the pressure of the water tends to blow off the end, cap or push the valve along the pipeline.

This movement is opposed either

(a) In the case of the end cap by a thrust block as a form of anchorage
(b) In the case of the valve in a pipeline 200 dia or more by thrust block with thrust area the same as for an end cap, or for smaller valves by the friction between the earth and the pipeline, the pipeline acting as a strut or prop. In the latter case it is recommended that thrust blocks be used also.

It is interesting to note that for a normal head of 60 metres the thrust on the end cap of a 1 00 mm dia pipe is a half tonne, on a 200 mm end cap is 2 tonnes and 300 mm end cap is 5 tonnes. As a rule of thumb then, it would appear that the anchor block should bear on a face squared into solid ground at the end of the trench three (3) times the diameter of the pipeline.

Proximity of other pipelines to water pipes

In general, water and sewer pipes should not be placed in the same trench but if unavoidable, the water pipe should be laid higher than the sewer and to one side of it.

Polyethylene or poly-vinyl-chloride pipes should not be laid in close proximity to gas mains, petrol tanks or petrol pipelines, because gas or petrol vapours may permeate the soil, and, as they possess the property of being able to pass through these plastic materials, they may taint the water.

Backfilling of trenches

Pipes are to be covered with sand or fine material to a height of at least 150 mm above the top of the pipes. As this filling is placed in position the sides of the pipe are to be well rammed. The ability of a pipe to sustain load is dependent to a large extent on the support given to the sides of the pipe during backfilling. That is why thorough ramming is necessary.

When the trench contains about 300 mm of backfill above the pipes water flooding may be used to compact the soil. This method has the problem of fill drying out and contracting which then may require the trench to be topped up at a later date. Dry or semi-dry fill compacted with a vibrating roller, excavator wheel roller or a power rammer will give the best long term results for backfilling a trench.

If the top of the pipe is under the required minimum depth, then it is necessary to backfill across roads with lean concrete or cement stabilised gravel. Ductile iron pipes should also be considered for the road crossing in this situation.

Surplus soil taken from trenches is the property of the Council and should be disposed of by arrangement with that body.

Road surface maintenance

Excavation of trenches in existing roadways to install pipes and fittings requires special care. Trench edges should be cut by concrete saw when there is an AC (asphalted concrete) seal on the road so that it is relatively easy to repair. Trench back fill should be of good quality and compacted well (stabilised sand is an alternative) up to the sub grade level of the road. It is important that the remaining pavement is at least equal to the depth and quality of that of the existing road. The finished road surface should be neat and level with the surface of the road or footpath.

The construction crew is responsible to maintain safety on the work site during the period of construction. Should existing road or footpath levels be altered, the matter should be reported to the Engineer so that corrective action may be taken.

Materials removed from trenches or holes in gravel, bitumen or concrete pavements can be reused and should be divided or sorted according to its nature. Road gravel should not be mixed with clay or sand. The road or footpath may be back-filled with the materials in the reverse order to their excavation. Trenches and excavations that are properly backfilled and consolidated will not unduly settle.

MINIMUM THRUST AREA FOR ANCHORAGE IN SQUARE METRES WITH TEST PRESSURE 1300 kPa (NOM. 130m – HEAD)

SAFE HORIZONTAL BEARING CAPACITY OF GROUND For horizontal thrusts, the safe bearing load values for soils in trenches, where the cover over pipes is 450mm or greater.	90°& 60° HORIZ. BENDS				45°& 30° HORIZ. BENDS				22 1/2° HORIZ. BENDS				11 1/4° HORIZ. BENDS				TEES & DEAD ENDS			
DIAMETER OF FITTING	50 kPa SOFT CLAY	100 kPa FIRM CLAY SANDY LOAM	150 kPa SAND & GRAVEL HARD CLAY	200 kPa SAND & GRAVEL CEMENTED WITH CLAY	50 kPa SOFT CLAY	100 kPa FIRM CLAY SANDY LOAM	150 kPa SAND & GRAVEL HARD CLAY	200 kPa SAND & GRAVEL CEMENTED WITH CLAY	50 kPa SOFT CLAY	100 kPa FIRM CLAY SANDY LOAM	150 kPa SAND & GRAVEL HARD CLAY	200 kPa SAND & GRAVEL CEMENTED WITH CLAY	50 kPa SOFT CLAY	100 kPa FIRM CLAY SANDY LOAM	150 kPa SAND & GRAVEL HARD CLAY	200 kPa SAND & GRAVEL CEMENTED WITH CLAY	50 kPa SOFT CLAY	100 kPa FIRM CLAY SANDY LOAM	150 kPa SAND & GRAVEL HARD CLAY	200 kPa SAND & GRAVEL CEMENTED WITH CLAY
100	0.44	0.22	0.15	0.11	0.23	0.12	N	N	0.13	N	N	N	N	N	N	N	0.31	0.16	0.11	N
150	0.91	0.46	0.30	0.23	0.49	0.25	0.16	0.12	0.26	0.13	0.09	N	0.13	N	N	N	0.65	0.33	0.22	0.16
200	1.56	0.78	0.52	0.39	0.83	0.42	0.28	0.21	0.44	0.22	0.15	0.11	0.21	0.10	N	N	1.09	0.55	0.36	0.27
250	2.37	1.18	0.79	0.59	1.27	0.64	0.42	0.32	0.65	0.33	0.22	0.16	0.34	0.17	0.11	N	1.66	0.83	0.55	0.42
300	3.46	1.73	1.15	0.86	1.87	0.94	0.62	0.47	0.96	0.48	0.32	0.24	0.47	0.23	0.16	0.12	2.44	1.22	0.81	0.61
375	5.25	2.63	1.75	1.31	2.83	1.42	0.94	0.71	1.46	0.73	0.49	0.36	0.73	0.36	0.24	0.18	3.72	1.86	1.24	0.93
450	7.44	3.72	2.48	1.86	4.03	2.02	1.34	1.01	2.05	1.03	0.68	0.51	1.04	0.52	0.35	0.26	5.25	2.63	1.75	1.31

'N' Denotes nominal thrust area

Figure 17.1

In opening a trench in a reinforced concrete path or roadway, the reinforcements should be cut along the middle line of the trench in one line and the ends turned back so that repairs can be done at a minimum expense.

Indicator posts

Timber posts should be termite resistant. Those considered the most resistant are:

1. Cypress (Murray) Pine
2. White Mahogany
3. Red Gum
4. All Ironbarks
5. Other Hardwoods
6. Steel or aluminium Sections
7. Plastic Sections (eg, Carsonite)
8. Impregnated timbers.

It will generally be found that 6 7 and 8 are easiest to obtain and most satisfactory.

All other types should ideally be brushed or sprayed with creosote.

All hydrants and stopvalves should be marked with indicator plates on posts or nearby solid structures marked as HP (Hydrant Point), HR (Hydrant Riser) or SV (Stop Valve Service) and indicating distance to the surface box.

Water mains standard symbols

1. Blank Flanged Hydrant Tee
2. Hydrant
3. Stop Valve (SV)
4. Air Valve (AV)
5. Cap
6. Plug
7. Pipe passing under main or over main with no connection
8. Reflux Valve, or
9. Scour Valve, or
10. To establish location of a dead end (measure from corners of allotment)
11. To establish a starting point for chaining
12. Downward or upward bends.

Pipelines under railway lines

The State Rail Authority usually insists upon pipes under lines being installed with at least 900 mm between the base of the rail and the top of the pipe. The Authority likewise calls for such pipes to be laid in reinforced concrete, which should extend a prescribed distance outside the railway tracks. Details of the Authority requirements should be obtained from a representative of the Authority.

Sterilisation of mains

Mains should be thoroughly scoured after construction or after repairs. New pipe work should be sterilised and this may be carried out by injecting a chlorine solution in water into the pipes. It is preferable that chlorinated solution should remain in the pipe work for at least 24 hours before being removed. Chlorine gas can also be used but calls for special equipment, special techniques and careful control.

Chloride powder is commonly used, the recommended quantity to use is 100g of pool grade chlorine powder for each litre of water in the length of pipe being sterilised. The powder should be placed in a clean container and mixed to a smooth thin cream. This may be introduced through a hydrant as near as possible to the charging valve and is flushed into the pipeline with clean water. It is better if the charging of the main is done uphill. The pipe should be allowed to stand at least two hours, preferably overnight. The main should then be drained and thoroughly flushed with fresh water.

Scraping and cleaning of mains

Water pipes acquire soft deposits, which settle out from the water; and in the case of unlined cast iron pipes, tubercles or incrustations, depending on the quality of the water passing through them.

They are cleaned by pushing or pulling some type of scraping implement which, depending on the type of cleaning or scraping desired can take a variety of shapes.

A common procedure is to insert the cleaning or scraping tool through a "Y" or "T" and to push the tool along the pipe by water pressure behind it. A cable may be attached to permit its recovery or to indicate its location if it sticks. The deposits of material displaced may be removed by way of a hydrant, or through a fitting or gap in the pipe from which the tool is recovered.

Unfortunately harsh scraping, although it temporarily may restore the pipe capacity, may injure the pipe lining, and so must not be repeated frequently. Scrapers travel underground at a speed of about 5 kph and can be heard as they travel along a shallow main. They require a pressure of about 400 kpa when cleaning a 300 mm dia main. If the tuberculation is only slight, lower pressures may be successful.

Slimes may be successfully removed by the passage of two tight fitting rubber discs rigidly joined by a short length of steel pipe of length about twice the diameter of the pipe to be cleaned.

The smaller the diameter of the pipe, the higher must be the pressure for the effective driving of a tool of this type. This type acts as a piston and is generally employed to force a tool of the cutting type through an encrusted main.

Tools may be also dragged through a pipe by means of a cable and winch.

Flushing of mains

Dead end mains should be flushed regularly. To facilitate these operations such dead ends should be terminated with a hydrant or scour valve. Flushing of a long pipe from the hydrant nearest the dead end is not sufficient.

The hydrant nearest the source of supply should be first flushed, and then all other hydrants treated in succession.

Cement lining of mains

To restore cast iron unlined mains to their approximate original efficiency, the pipes may be scraped, cleaned and lined with cement and sand in situ. This work is usually let by contract to firms specialising in the operations. These skills may be acquired and utilised by the employees of medium size water supply. A certain amount of experimentation is called for, and some failures must be expected.

Short working lengths of pipe are removed from the main, after dewatering, from 30 to 100 m apart. A string of tools is introduced into the pipe and pulled through by means of a winch. The string usually consists of:

(a) a scraper to crush the tubercles,
(b) a circular steel brush or set of brushes,
(c) a rubber squeegee.

It may be necessary to pass this string through the pipe several times before the necessary cleanliness of the pipe is attained.

A pulling cable is attached to the rear of the string of tools at the last pass, and is allowed to lie in the pipe as it is to be the pulling cable for the lining operation. A calculated amount of cement-sand mixture is then introduced into the pipe at one end, and a lining tool is attached to the pulling cable. The lining tool is then drawn through the pipe by the winch and the lining established. After this operation, the lining thus affected is examined by means of mirrors or by the transmission of sound and if satisfactory, it is left to harden and cure. The main may be restored to use after twenty-four hours.

Usually a mix of 1 part of cement to 2 of sand is satisfactory, but the grading of the sand, the thickness of the lining, the slump of the mixture, the speed of travel of the lining tool, and the shape of such tool are all factors which influence a satisfactory job.

The mixture may be introduced into the pipe by many methods which include hand pumping, sucking, or compressed air, all of which may involve much experimenting before a uniformly satisfactory result may be achieved.

Cement lining of mains calls for patience, experimentation and an organisation capable of effecting quick alteration or adaption of plant and equipment to meet the needs of the job.

Maintenance of mains records

As the keeping of accurate records is an important function of the Engineer, reports concerning breaks or leaks in mains should always show distance from a stop valve or hydrant so that they may readily be located for present or future reference.

De-watering of trenches

To enable repairs to water mains the use of trench de-watering pumps is sometimes necessary, particularly. When large quantities of water are to be dealt with, there are several types of pumps available.

A. Self-priming pumps

These may be driven by belt or directly coupled to electric motors, petrol engines or diesel engines. The directly coupled pumps may be coupled through a flexible coupling or “close” coupled. In the former type the pump or the motor may be removed from the base plate and another pump or motor substituted with or without appropriate adjustments or alterations. In the latter type no such changeover may be affected as the end shield of the motor is, in effect, part of the housing of the pump. In all cases the close-coupled pump may be considered to be the most compact and the lightest. These self-priming pumps are in the smaller sizes equipped with carrying handles, but in the larger sizes are mounted upon wheels. Several makes are available on the Australian market. Their capacities naturally will depend upon the head against which they may be called upon to work, but models capable of handling from 2 l/s to 30 l/s should be readily obtainable.

B. Air-operated pumps

These require the use of an air compressor of adequate capacity; which can be obtained in various sizes and require no priming. They are of the submersible type where the whole pump unit is placed in the trench or hole to be dewatered, the supply of air turned on, and so long as a reasonable amount of water is fed to the pump there is no fear of seizure.

C. Electrically operated pumps

There are portable submersible compact units electrically operated, which can be thrown or lowered into a trench. These pumps in the upright position, pump down to the last inch or so of water, and can run “on snore” without being damaged. They require no priming, and can work in water containing sand and

other suspended solids. As soon as water flows to them, they resume pumping. Indeed the manufacturers claim they can pump up to 30% of solids. The smaller sizes are equipped with either single-phase or 3phase motors, and the larger sizes with 3phase motors. Smaller sized pumps may handle up to 5 l/s and the larger sized pumps up to 35 l/s. Even these larger sized pumps may be carried by two men.

In all of the above types of pumps, the actual capacity will depend upon the total lift from the surface of the water to the point of discharge, and upon the total length and diameter of the discharge pipe and the suction pipe (if any).

Pump priming and air locks

A true self-priming pump of the non-submersible type, if in good condition, requires no foot valve on the suction pipe, as it contains a flap valve in the water chamber above the pump. This chamber must be full of water before the initial pumping is commenced, and provided the flap valve does not leak it should retain its priming for subsequent operations. However, the valve frequently does leak, and so it is advisable to use a foot valve in the suction pipe, just as an added precaution.

With an ordinary, non self-priming centrifugal pump the foot valve must always be used. It must be tight closing for satisfactory operation. In this type of pump, pockets of air in the suction pipe should be avoided; all connections on the suction side must be air tight and the suction hose should fall continuously from the pump suction to the water surface. Pump failures can almost invariably be traced to either inefficient foot valves or air in the suction line.

Air locks in pipelines

Loss of capacity of water pipes may result from an accumulation of air in a high point of a line or a network. It is difficult to extract the air from them. Such air locks may be prevented by lowering the pipe, or may be relieved by installing an air valve at the troublesome rise.

Broken or leaking pipes

Where a short length of pipe is required for repair work, cement lined pipe if available should be used to repair cement lined main. On no account should cement lined pipe be used to repair an unlined main as subsequent lining operations or cleaning operations would be thereby rendered much more difficult.

Location of buried pipes

Pipes laid underground can be lost if no records are kept.

Detectors or pipe finders can be used to locate pipes and are generally of two types.

(a) The first type works with the hidden pipe as part of an electric circuit. Two exposed points on the pipe (or connections with the pipe) are connected to two ends of an instrument generating an intermittent or alternating current, which thus passes along the buried pipe. The position of the pipe is disclosed by earphones attached to a "searching coil" carried by the operator. The magnitude of the sound will increase as the pipe is approached, and recede as the pipe is left behind. Some instruments rely for indication upon a needle which registers the proximity or otherwise of the pipe. Other types of this instrument are so arranged that earphones will become silent when the observer is directly over the pipe.

(b) The second type is of the mine detector type and responds to the presence of iron material in the ground beneath.

The use of non-metallic materials for pipes which are non-conducting has tended to make the finding of underground pipes more difficult. Underground contact between water pipes and gas pipes can also add to confusion, particularly if the earthing wires of electrical installations are clamped to both types of pipes.

Where non-metallic materials are used for water mains or sewer lines an indicator tape should be laid above the pipe that contains a metallic thread that pipe detectors can use to find the pipelines later.

Sewer manholes *in situ*

Some Councils still utilise cast in-situ manholes. These should be constructed to the IPWEA sewerage standard drawing S-0022. Ensure that very good quality concrete is used to resist sewer gas attack, that all air is excluded during pouring by the free use of a vibrator and that the manhole is watertight around the pipelines.

Sewer Manhole bottoms must be at least 200 mm thick below the pipe and set on a very good foundation. Pour the bottom up to top of pipe level leaving the required channels. When set, pat down 50 mm of cement compo and sit the first manhole pipe in place and to true vertical by spirit level, pour concrete around the outside of this pipe extending 200 mm up the pipe and ram well to seal the bottom joint. Apply pipe joining compound (compo) to all joints. Make sure the lid ring does not rock and is at the right level. Compo the hob and channel using 1:3 cement compo finished with a steel trowel.

Sewer house connections

House connections should be constructed to conform to the water Service Providers requirements. If no such standard is available than IPWEA standard drawing S-0030 may be a suitable alternative. House connections should extend at least 600mm into the land being served. The pipes are to be laid on a minimum grade of 1 in 60 or steeper and should be brought to a level no closer than 1 metre to the natural surface by means of a bend and vertical pipe encased in lean (1 in 12 mix) concrete or soil. Provide a special collar at the end of the tie to seal the pipe until the end cap is removed and pipe extensions are made.

Buried sewer main junctions which are available for connection should be marked by polyethylene sewer indicating tape or rope tied to the junction and brought to the surface as backfilling progresses and tied to an indicator post.

Testing of sewer mains

If required the Supervisor will test sewer mains with water pressurised to approx. 30 KPa for a period of 5 minutes prior to the placing of backfill.

SECTION 2: KEY MESSAGES

- **Be aware of confined spaces**
- **Shore open cut**
- **Correct bedding techniques**
- **Scour mains after bedding or repair**
- **Mark sewer main junctions**

Section 3: Jointing of water and sewer pipes

Jointing of cast iron pipes

Lead and yarn is no longer used in the jointing of cast iron pipes, although some existing reticulation systems still have lead jointed cast iron mains. Burning out of this type of joint is covered later in the section.

Rubber ring joints
This is the most popular form of jointing cast iron pipes. However, different suppliers have different types of rubber rings. It is most important that Supervisors carefully follow the manufacturer instructions.

Generally, the following steps should be taken in jointing cast iron pipe.

Insertion of gasket
The gasket should be wiped clean, flexed and then placed in the socket with the bulb leading. When inserting 750 mm size gaskets, flexing in two places is necessary. The groove in the gasket must be located on the retaining bead in the socket, and the retaining heel of the gasket firmly bedded in its seat so that the heel of the gasket is not proud of the mouth of the pipe.

Lubrication
A thin film of lubricant is applied to the inside surface of the gasket, which will be in contact with the entering spigot. In addition a thin film of lubricant should be applied to the outside surface of the entering spigot for a distance of 50 mm from the spigot end.

Use only lubricant supplied by the manufacturer.

Initial entry of spigot
The spigot of the pipe being jointed must be aligned and carefully entered into the adjacent socket until it makes contact with the gasket. Final assembly of the joint is completed from this position.

Completely assembled joint
Joint assembly is completed by forcing the spigot end of the entering pipe past the gasket, which is thus compressed, until the first painted stripe on the end of the pipe disappears and the second is approximately flush with the socket face.

If the joint is difficult to assemble, the spigot should be removed and rotated through 90 degrees before attempting to assemble a second time. If the joint is still difficult to assemble, the spigot should be removed and the position of the gasket examined.

Deflection
The joints can be deflected in any direction up to 5 degrees for pipes up to 300 mm nominal size, up to 4 degrees for 375 mm size; and up to 3 degrees for sizes 450 mm to 750 mm.

All spigots must be chamfered.

When making a joint, pipes should always be in line and if required, deflection made after making the joint.

Jointing of rigid pvc pipe (rubber ring)
Ensure that the ring groove in the socket is free from dirt so that the rubber ring will seat positively in the groove. Insert the rubber ring in the groove with the colour marking facing outwards.

Run the thumb around the lead in angle of the rubber ring, which will position the ring for easier acceptance of the spigot.

Clean the spigot end and apply a coating of the manufacturer's lubricant to the chamfer.

With an even thrust push the spigot straight into the socket until the reference mark is just visible.

Jointing of rigid PVC pipe (solvent weld)
Ensure that the joint is clean and that any burrs have been removed from cut pipe. It is desirable to use the manufacturer's cleaning fluid to obtain best results.

Make sure that the pipe will enter into the socket, and using a clean brush apply a coating of solvent cement to the socket first and then the pipe end.

Enter the pipe into the socket within one minute and wipe off excess cement. Do not handle for 5 minutes and allow at least 24 hours drying time before subjecting to pressure.

Burning out lead joints

As injurious effects may be sustained in the burning out of lead joints, particularly in closed in areas, the following safeguards against lead poisoning should be observed.

(a) The operator must use an appropriate gasmask, even if such work is of only short duration.
(b) Operators should be instructed to wash hands and face immediately at the conclusion of such work, and particularly before eating.

Flanged pipe joints

It is preferable to use insertion of 3 mm thickness, which should be of sufficient diameter to cover the whole of the flange. (Occasionally joints are made in error by the operator forgetfully omitting to cut out the centre part corresponding to the bore of the pipe.) The insertion may be cut to correct size if it is laid upon the flange, and held firm, while the bolt hole and bore are marked and almost cut through by lightly hammering with a ball faced hammer. The bolts should be tightened up evenly and firmly, going over them several times and completing the tightening with moderate hammer blows upon the spanner.

For underground work, galvanised bolts and nuts are preferred, black iron bolts and nuts to be used underground should be liberally brush coated with bitumastic or similar product. Special care is required where flanges are in close proximity with meters or Venturi tubes. Turbulence arising from insertion protruding into the stream flow may affect the accuracy of the measuring device.

Under no circumstances should nuts be tightened with footprint wrenches, as these tend to wear off the nut edges and may render them unfit for use with spanners with parallel faces.

Spanners should not be used having longer purchase than that shown below:

15 mm diameter-300 mm
20 mm diameter-450 mm
22 mm diameter-600 mm
25 mm diameter-750 mm

Other forms of pipe joints

The gibault joint requires more room than a socket and spigot joint because the use of spanners is necessary. One gibault flange and one rubber ring should be placed on the end of each pipe, making sure that the flanges are not so loose fitting that they will permit bulging of the ring when the joint is tightened up. The cast iron sleeve is then placed on one pipe, the pipes butted together with about 6 mm allowed for expansion. The sleeve is then adjusted centrally over the junction of the pipes, the flanges drawn up, the bolts inserted and the nuts evenly tightened up. In large size diameter pipes it may be advantageous to use longer sleeves than the standard ones. The longer sleeves are more easily adjusted and certainly make a more reliable joint. As in the case of all underground work, the bolts and nuts of gibault joints should be galvanised, and the bolt threads eased with graphite grease after which the bolts should be liberally painted with bitumastic.

Joints, expansion joints of various kinds, ball joints, and slip-ring joints are all necessary for particular cases. When in doubt about the type to be used it should be referred to the Engineer.

Sewer pipelines
Pipelines are laid exactly the same as for water pipelines although, because of there being no pressure in the pipes some additional fittings are allowed.

In AC piping a "supertite to unturned" joint can be made. Use such a coupling on the supertite end of the pipe. Place an O-ring on the cut end of the new pipe as close to the end as possible. Do not use lubricant on the ring. Line the pipe up with the "machined out" end of the coupling and push the pipe home by means of bar and wooden block.

AC pipes can be used on tight radius bends using short pipe lengths and this form of coupling. A slope junction can be cut into an existing AC main using double rollon couplings and two cut pipes can be so joined.

Both AC & UPVC pipelines can be provided with various end caps permitting jointing of Vitrified clay rubber ring or mortar joint spigots or to cast iron spigots etc.

Sewerage systems will be most effective for pipelayers and all contractors if a standard sewer tie, e.g. ending in a VC rubber ring joint collar with knock-off cover plate, is adopted and always used.

SECTION 3: KEY MESSAGES
- **Follow manufacturers' instructions**
- **Use appropriate jointing**

Section 4: Common pipeline fittings

Stop valves
Unless otherwise indicated these should be installed with the spindle perfectly vertical.

Some Authorities may insist upon the installation of valves at critical positions, such as where pipes pass under railway lines or critical infrastructure.

Second hand or exhumed stop valves should not be re-used until fettled, or reconditioned. Stop valves under heavy cover should be fitted with an extension spindle to enable them to be operated with a standard valve key.

Rotation of valve spindles
As some Valves operate in a clockwise direction to open, and some in an anti-clockwise direction, all valves should be marked accordingly, either on the valve indicator post, or on the inside of the valve cover (or both). Valves should be correctly marked accordingly at the time of placing in position or of servicing. The words "Right to open" or "Left to open" may be confusing. The better wording is "Clockwise to Open (CTO)" or "Anticlockwise to Open (ACTO)".

Half open valves
To avoid confusion and uncertainty all valves on a system should be either open or shut.

Valves should be partly open only if definitely instructed; and even then this method of maintaining pressures in certain parts of a reticulation system can only be regarded as a very temporary measure. Records should be carefully kept of any valves partly open – particularly if their direction of operation is not clearly marked.

Operation of valves

It is desirable to exercise all valves once every three months if at all possible. To prevent water hammer it is desirable to open and close valves gradually. This is the case when closing valves, and more particularly when the valve is nearly closed.

Where by-pass valves are provided on large mains, the procedure in operation should be:

(a) Opening open the by-pass valve first, then the main valve;
(b) Closing close the main valve first, then the by-pass.

Valve maintenance

Valve chambers should be kept clean, and undue collection of water should be investigated and remedied.

Accidents to valves or other fittings should be immediately reported, particularly if a valve spindle is broken. If a flanged joint made with lead wire is broken, the lead wire should not be reused, but replaced by insertion rubber 3 mm thick.

Packing of valves

Valves should be packed in the closed position with proprietary packing approved by the Engineer.

Scour valves

They should be installed as near as possible to the main, and any pipe work leading away from them should be carefully graded to discharge into a natural or artificial water course.

Air valves

These are provided to allow air to enter the main while it is being emptied, and to allow air to escape while being filled. They may or may not be fitted with side controlling stop valves, in which former case the controlling valve must be kept open except while servicing the air valve. Double air valves have a large opening to allow for the rapid passing of large volumes of air, and a small opening to deal with smaller quantities. Single air valves have one opening only.

Regular inspections should be made to ascertain whether the valve is functioning correctly and the ball/s are seating properly. Balls that are pitted or distorted should be replaced.

Hydrants

There are three types:
(a) Ball type-in which the hole is closed by a floating ball.
(b) Spring type-in which the hole is closed by a mushroom shaped bronze dome supported by a spring.
(c) Screw down type-generally used in pillar hydrants in city streets.

Whatever type is installed care should be taken to close the hydrant down slowly to prevent undue water hammer.

It may happen with types (a) and (b) when closing down, that the hydrant will leak. This defect, if not due to a scored ball of “mushroom”, may be remedied by gently opening and closing the hydrant till the flow ceases. If the rubber or leather washer is damaged it may call for replacement.

In some cases the ball type hydrant will not close because of the rush of water over the top of the ball, in which case it may be necessary to operate nearby valves to minimise the flow, and so allow the ball to rise.

Hydrant surface boxes-should be constantly patrolled to ensure they are not covered with earth, sand or gravel and so that they may be immediately available for fire-fighting purposes. Dirt should not be allowed to accumulate around the top of the hydrant or within the box.

Indicator plates preferably of the reflecting type should be regularly inspected and maintained for ease of location of the hydrant.

If plates are of the vitreous enamel type they should be affixed to posts or walls by screws in such a manner that the enamel surface is not damaged. For such plates nails should not be used, and if necessary the plates should be packed underneath to prevent cracking or spalling of the enamel due to uneven bedding.

Spacing of hydrants etc.

The desirable spacing of hydrants will depend upon the type of main and the locality.

Maximum spacing for hydrants should not exceed 80 metres apart, and will depend upon whether the area is closely or sparsely settled. If mains are laid on both sides of the street or road and hydrants are placed on both of them, diagonal spacing between hydrants should approximate the distance apart of hydrants if only one main were laid.

Hydrants should be located clear of kerbs and gutters, and if possible clear of existing or future vehicular entrances. The lugs of the hydrant should be approximately 100 mm below the finished road surface. If they are at a depth that a Fire Brigade pattern hydrant standpipe cannot be connected, an appropriate riser should be used. Under no circumstances should the hydrant cast iron cover ride upon the hydrant lugs.

Where screw down hydrants are located on footpaths they should be installed with the outlet pointing in the direction of the vehicular traffic.

Hydrant or Valve indicator plates should be affixed to a marker located on the footpath close to the property boundary. The indicator plates should indicate the distance from the plate rather than that the hydrant or valve is situated on the road or footpath.

Standard pattern hydrant stand pipes are opened by a clockwise rotation of the operating handle. They must be opened slowly and closed down more slowly. After removing the standpipe the hydrant should be examined for minor leakage which may be overcome by gently tapping the ball or mushroom with an iron bar. Force must not be used. Hydrants should never be left leaking, even to a minor extent.

Unattended standpipes should be clearly indicated in some way.

Hydrants on trunk mains

On trunk mains hydrants should be installed with a control valve to avoid closing down the main for servicing of the hydrant. Ball type hydrants may be placed on summits to act as air valves and spring type hydrants in depressions to act as scours when needed.

Valve chambers – hydrant brick pits, etc.

Structures supporting valve and hydrant surrounds should preferably be bedded upon the floor of the trench rather than upon the piping in the trench. The valve or hydrant pit should straddle the main, so that in the event of a very heavy concentrated load bearing directly upon the surround the weight will be conveyed to the ground under the piping rather than to the pipe and fittings. The necessity for this type of precaution increases in heavy industrial areas, and near wharves and railways.

It is desirable to build these boxes from dry brick or stone work 225 mm thick or a 300 or 450 dia. pipe. Ram the earth tight around the box. Make sure the 'Mushroom' does not rock or move and is at the right level and grade to suit the road crossfalls.

SECTION 4: KEY MESSAGES

- **Use the appropriate fittings**
- **Don't re-use fittings unless reconditioned**

Section 5: Maintenance of reservoirs and pump stations

Reservoir maintenance

Supervisors charged with the responsibility of maintaining reservoirs should immediately investigate reports concerning leaking or overflowing. Protective coatings of paint, bitumen, etc., should be kept in first class order. Minor jobs such as the repainting of gates, fences, sheds, pipes, etc., should be carried out as time permits. Attention to large structures should be referred to the Engineer.

Algae in reservoirs

Some types of algae, if allowed to dry out when the reservoir is emptied, peel off the walls with little trouble leaving a clean surface. Other types may require to be scrubbed off.

To discourage the growth of algae the walls and floor of the empty reservoir may be brushed or sprayed with a weak solution of copper sulphate (0.5 to 0.65 parts per million of copper sulphate). This concentration is not injurious to human beings or most industrial processes but may be injurious to certain fish, (trout, carp, catfish and goldfish).

The growth of algae is not necessarily to the detriment of a water supply. It reduces the carbon dioxide content, liberating oxygen which tends to sterilize the water at the same time giving piquancy to the taste. However, drying or rotting algae can give rise to tastes and odours and may cause obstruction to meters and malfunctioning of certain types of valves.

Cleaning and disinfecting reservoirs

This should be a routine maintenance duty. The frequency, duration, and methods adopted will depend upon local conditions, location, and ingenuity. Methods include draining, hosing, scrubbing, scraping and refilling. Disinfection may be carried out by dosing with chlorine powder or sodium hypochlorite so that the concentration of free chlorine may be between 0.5 and 1.0 parts per million.

Chlorine powder used for pools is the material most readily available and contains about one third of its weight of free chlorine available for sterilization. Therefore to sterilize 1 ML of water the addition of from 1½ to 3 kg of powder would be called for.

Chlorine powder should be mixed to a cream, diluted and then added to the reservoir water, used as soon after mixing as possible before it loses its potency.

Pumping stations

Each pump station should be equipped with an exercise book for recording all changes of status.

It should show the operating parameters such as normal voltage, amperage and operating head. In this way it is easy to discern changes of status i.e. drop in head, increase in amperage etc.

Several pages should be set aside for kilowatt hour readings against hour meter readings to gauge pump efficiency changes during the year. The balance of the book should be used to detail all repairs to each pump showing hour meter readings at which each repair was undertaken.

Daily inspection of each station should be carried out. Check for pump gland leaks and check the temperature of electric motor and pump bearings. Grease bearings as necessary. Daily sweeping of pump house floors is desirable. In sewage pump stations the wet well should be hosed daily and coarse screens cleared of debris. The floats of the switching system must be kept free of a build up of fats.

Half yearly electrical checks should be carried out. All wire connections should be screwed tight and all starter contactors checked for wear and replaced as necessary. Good electrical housekeeping reduces breakdown.

The pump station surrounds should be mown regularly. The pump house must be inspected annually and repairs and painting carried out. Signage giving the name of the station, emergency contact details when red light flashing should be situated in a prominent location.

Once per year minimum, each sewage pump should be dismantled and the wear rings inspected. Worn rings lead to worn shaft, impeller and bearings. If the sewage is normally gritty this operation is more frequently necessary.

Section 6: Services and meterings

Boring under roads

To prevent damage to road surfaces (such as reinforced concrete or Asphalt) it is desirable to lay water services under these pavements in conduits. Future maintenance can then be carried out with a minimum amount of interference with the surface.

If the pavement is already constructed it is possible to bore or jack the service pipe under the road. Not all boring or jacking machines can be depended upon to do an accurate job. They all depend upon precise setting up in the hole excavated on one side of the road. If the road bed is of sand or moist loam, the service pipe may be jacked through, but if a solid obstacle is encountered the pipe may be completely stopped or seriously deviated. Machines that bore a hole through which the service pipe is threaded also depend for their accuracy upon precise alignment. Serious deflection can result from an unexpected obstacle. For most medium sized undertakings it is sufficient to jet a hole under the pavement using equipment that is cheap to manufacture and easy to handle. This method has many variations. One is described below.

After the main has been tapped and fitted with a main cock, water under pressure should be taken from it by means of a hose, to the front end of which is attached a 1 m length of 20 mm galvanised pipe fitted with an ordinary adjustable garden hose nozzle fixed in the "jet" position. The nozzle is shrouded or protected by a projecting "coronet" of teeth which may be made from a piece of 25 or 30 mm galvanised pipe. The teeth should be about 25 mm in advance of the jet.

The jetting tube should be carefully levelled and positioned in a hole about 1.5 m long, at the required depth. By slowly rotating the jetting tube and retaining its direction with regard to level and line the hardest of clay subsoils may be "chewed" through. As the boring tube advances, extra lengths of galvanised tubing are screwed on till the penetration of the road is complete.

This method can fail if the advancing jet encounters a large stone, brickbat, or area of ashes. A hole about 40 to 50 mm in diameter remains under the roadway, through which the permanent service pipe may be threaded.

Tapping of mains

Recently, the "self-tapping" main cock has been introduced and is suitable for connection to either cast iron or asbestos cement mains. This device calls for a tapping saddle to be attached to the pipe. Between it and the outside of the pipe is squeezed a rubber ring through which a special cutting tool (which forms part of the main cock) operates to penetrate the barrel of the pipe, after the main cock has been screwed into the tapping saddle.

The self-tapping main cock is a boon with UPVC pipes, which call for the use of a tapping saddle anyway. There are some concerns with cast iron pipes because:

(a) It involves the use of the extra tapping saddle, bolts and rubber ring not required with the standard method.

(b) Occasionally cast iron pipes of chilled metal are encountered which the cutting tool in the main cock cannot penetrate.

Care of water meters

The use of water meters is common all over the state and the care of them is important from two points of view.

(a) The charging for water depends upon them.
(b) They are becoming increasingly costly to both buy and repair.

The most frequent single cause of damage is frost from the pressure build of expanding water under freezing conditions. The problem can be minimised by:

(a) Lagging all the exposed pipes and elbows with cow hair felt which is subsequently given a thick coat of bituminous paint to exclude water. The exposed pipe work is the first part to freeze and lets solid plugs of ice form in the pipes on each side of the meter. The expanding water in the meter body is thus confined and bursts the meter. If the pipe plugs of ice do not form the meter stands a good chance of escaping damage.
(b) Covering the meter with sacking and then with an outer waterproof box. The covering should include the rising and falling pipes.
(c) Burying the meter and the pipes leading to and from it, so that only the top of the meter is above the surface of the ground. In areas with low ground temperatures this is perhaps the most satisfactory method of avoiding frost damage, but can easily lead to the meter becoming completely covered and unreadable.

Queensland

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