Operating Procedures for Central Materials Laboratory

Ministry of Works and Transport
Roads Department
Private Bag 0026
Gaborone, Botswana
Phone + 267 - 3913511
Fax + 267 - 3914278

October 2003

ISBN 99912 - 0 - 451 - 2

ROADS DEPARTMENT

Under the policy direction of the Ministry of Works and Transport, Roads Department is responsible for providing an adequate, safe, cost-effective and efficient road infrastructure within the borders of Botswana as well as for facilitating cross-border road communications with neighbouring countries. Implied in these far ranging responsibilities is the obligation to:

1. Ensure that existing roads are adequately maintained in order to provide an appropriate level of service for road users;

2. Improve existing roads to required standards to enable them to carry prevailing levels of traffic with the required degree of safety;

3. Provide new roads to the required geometric, pavement design and safety standards.

The Department has been vested with the strategic responsibility for overall management of the Public Highway Network (PHN) of some 20 000 km of roads. This confers authority for setting of national specifications and standards and shared responsibility with the District Councils and Department of Wildlife and National Parks for the co-ordinated planning of the PHN.

Roads Department is also responsible for administering the relevant sections of the Public Roads Act, assisting local road authorities on technical matters and providing assistance in the national effort to promote citizen contractors in the road construction industry by giving technical advice wherever possible. This task is facilitated by the publication of a series of Technical Guidelines dealing with standards, general procedures and best practice on a variety of aspects of the planning, design, construction and maintenance of roads in Botswana that take full account of local conditions.

Guideline No. 1 The Design, Construction and Maintenance of Otta Seals (1999).
Addendum to Guideline No. 1 Seminar Proceedings (June, 2000).

Guideline No. 2 Pavement Testing, Analysis and Interpretation of Test Data (2000).
Addendum to Guideline No. 2 Seminar Proceedings (January, 2002).

Guideline No. 3 Methods and Procedures for Prospecting for Road Construction Materials (2000).
Addendum to Guideline No. 3 Seminar Proceedings (April, 2002).

Guideline No. 4 Axle Load Surveys (2000).
Addendum to Guideline No. 4 Seminar Proceedings (January, 2002).

Guideline No. 5 Planning and Environmental Impact Assessment of Road Infrastructure (2001).

Guideline No. 6 The Prevention and Repair of Salt Damage to Roads and Runways (2001).
Addendum to Guideline No. 6 Seminar Proceedings (April, 2002).

Guideline No. 7 Technical Auditing of Road Projects (2001).
Addendum to Guideline No. 7 Seminar Proceedings (February, 2004).

Guideline No. 8 The use of Silcrete and Other Marginal Materials for Road Surfacing (2002).
Addendum to Guideline No. 8 Seminar Proceedings (February, 2004).

FOREWORD

This document sets out quality management and operating procedures for the Government Central Materials Laboratory (CML) of the Materials and Research Division of the Roads Department.

This Guideline on the operating procedures for Central Materials Laboratory (CML) is a very useful document in that it captures the experiences gained, over a period of twenty years, both within CML and in commercial Laboratories in and outside Botswana. CML is the principal materials testing laboratory in Botswana. The quality of services provided by CML has important influence on the quality of Botswana's road infrastructure. The laboratory could also be a standard bearer for the nation's commercial laboratories.

This manual is intended for daily use of CML staff at all levels for management and operational functions including outline of test procedures. The primary aim is to maintain quality, consistency and appropriate standards in the testing of road construction materials.

It is my sincere hope that this guideline will be useful to the Technicians and Engineers especially those deployed to CML for the first time and will assist in ensuring that the testing procedures are standardised and the results are quality assured. I trust that this is an important step towards establishing an internationally accepted code of practice on quality assurance.

Gaborone, October 2003

Andrew Nkaro
Director of Roads
Roads Department
Ministry of Works and Transport

ACKNOWLEDGEMENTS

This Guideline is one of a series that is being produced under the Institutional Co-operation Agreement that exists between the Roads Department and the Norwegian Public Roads Administration (NPRA). This Agreement falls under a NORAD Technical Assistance Programme to Roads Department that is co-funded by the Kingdom of Norway and the Government of the Republic of Botswana.

The production of this Guideline has been a joint effort amongst Civil and Planning Partnership (CPP), Botswana, CSIR-Transportek, RSA, and Dr. B Obika. The Guideline was written by:

Mr. K.J. Motswagole, CPP Botswana
Mr. D. Ventura, CSIR
Dr. P. Paige-Green, CSIR
Dr. B. Obika, Consultant
Mr.P. A. P. Oosthuizen (peer review) - MTS.

The Working Group that guided the project and reviewed the Guideline comprised the following people:

Mrs. N. Mpotokwane, Roads Department
Mr. C. Overby, NPRA
Mr. M.E. Segokgo, Roads Department
Mr. B. M. Sharma, Roads Department
Mrs. M. D. Sarma, Roads Department
Mr. P.D. Monametsi, Roads Department
Mr. K. Bale, Roads Department
Mr. M. Rahman, Roads Department
Mr. M. Molefe, Roads Department
Mr. P. Tsiako, Roads Department
Mr. R. Nduna, Roads Department
Ms. D. U. Ndwapi, Roads Department
Mrs. G. Solomon, Roads Department
Mr. S. M. Seloka, Roads Department
Mrs. P. Gilika, Roads Department
Ms. E. Botshomanyane, Roads Department
Mr. E. T. Phang, Roads Department

Mr. C. Overby co-ordinated production of the Guideline including final editing and formatting.

Photographs were provided by:
C. Overby, NPRA
K. J. Motswagole, CPP Botswana
D. Ventura, CSIR

LIST OF ABBREVIATIONS

10% FACT	10 Percent Fines Aggregate Crushing Value
AASHTO	American Association of State Highway and Transportation Officials
ABCC	Aggregates, Bitumen, Concrete & Chemistry
ACV	Aggregate Crushing Value
AIV	Aggregate Impact Value
ALD	Average Least Dimension
ARRB	Australian Road Research Board
ASTM	American Society For Testing And Materials
BOTEC	Botswana Technology Centre
BS	British Standards
CBR	California Bearing Ratio
CML	Central Materials Laboratory
CO	Computer Officer
CPP	Civil and Planning Partnership
CSIR	Council for Scientific and Industrial Research
CTO	Chief Technical Officer
DCP	Dynamic Cone Penetrometer
DMI	Durability Mill Index
FET-UB	Faculty of Engineering and Technology within the University of Botswana
FI	Flakiness Index
FWD	Falling Weight Deflectometer
GM	Grading Modulus
HETC	Highway Engineering Technicians Diploma Course
HOD	Head of Division
HUM	Heads of Units Meeting
ICL	Initial Consumption of Lime
IRI	International Roughness Index
ISRM	International Society For Rock Mechanics
LA	Laboratory Assistant
LL	Liquid Limit
LM	Laboratory Manager
LMS	Laboratory Management System
LS	Linear Shrinkage
MDD	Maximum Dry Density
MRD	Materials and Research Division
MTS	Material Testing Services
NORAD	Norwegian Agency for International Development
NPRA	Norwegian Public Roads Administration
NRN	National Road Network
OMC	Optimum Moisture Content
OPM	Operating Procedures Manager
OPQA	Operating Procedures Quality Audit
PHN	Public Highway Network
PI	Plasticity Index
PO	Project Officer
PRE	Principal Roads Engineer
PSV	Polished-Stone Value
PTA	Principal Technical Assistant

PTO	Principal Technical Officer
QO	Quality Officer
RE	Roads Engineer
RTC	Roads Training Centre
RTCC	Roads Technician Certificate Course
RTFO	Rolling Thin Film Oven Test
SABS	South African Bureau of Standards
SATCC	Southern African Transport and Communications Commission
SO	Safety Officer
SRE	Senior Roads Engineer
SRP	Sample Receiving and Preparation
STA	Senior Technical Assistant
TA	Technical Assistant
TFO	Thin Film Oven Test
TMH	Technical Methods for Highways
TO	Technical Officer
TOR	Terms of Reference
TRH	Technical Recommendations for Highways
TRL	Transport Research Laboratory (Based in the UK)
UCS	Unconfined Compressive Strength
UH	Unit Head
UK	United Kindom
WS	Works Superintendent

PART C

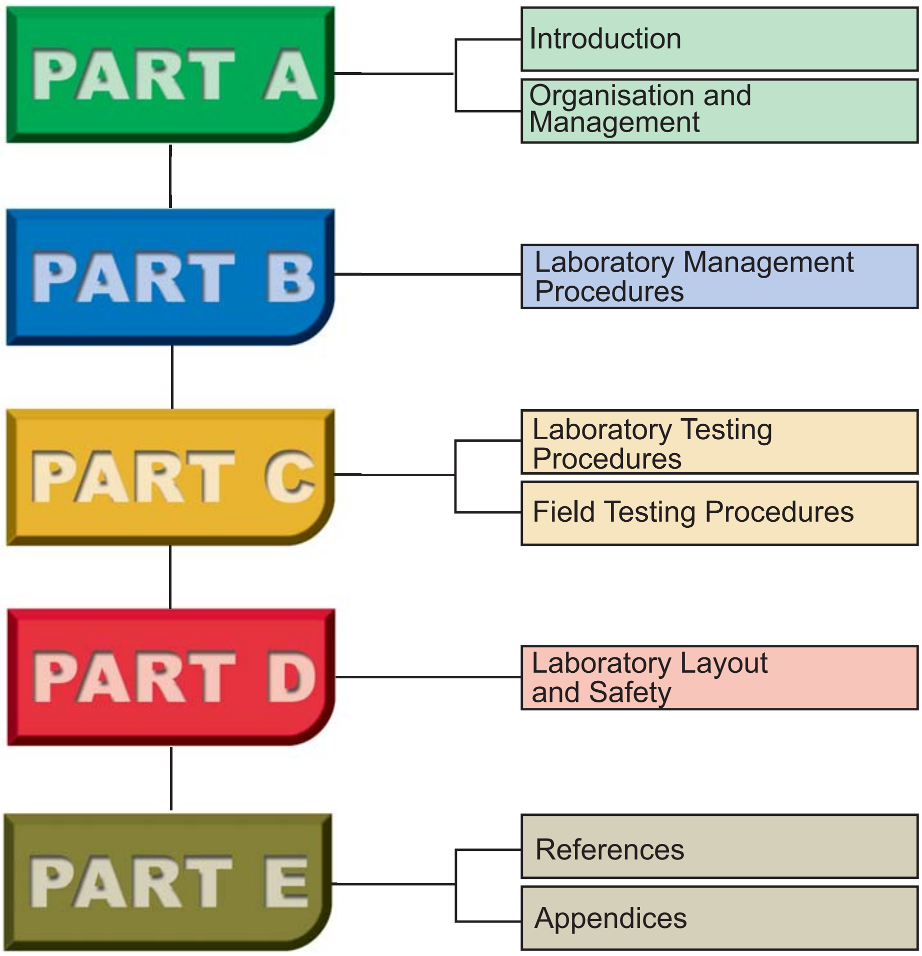
PART D

PART E

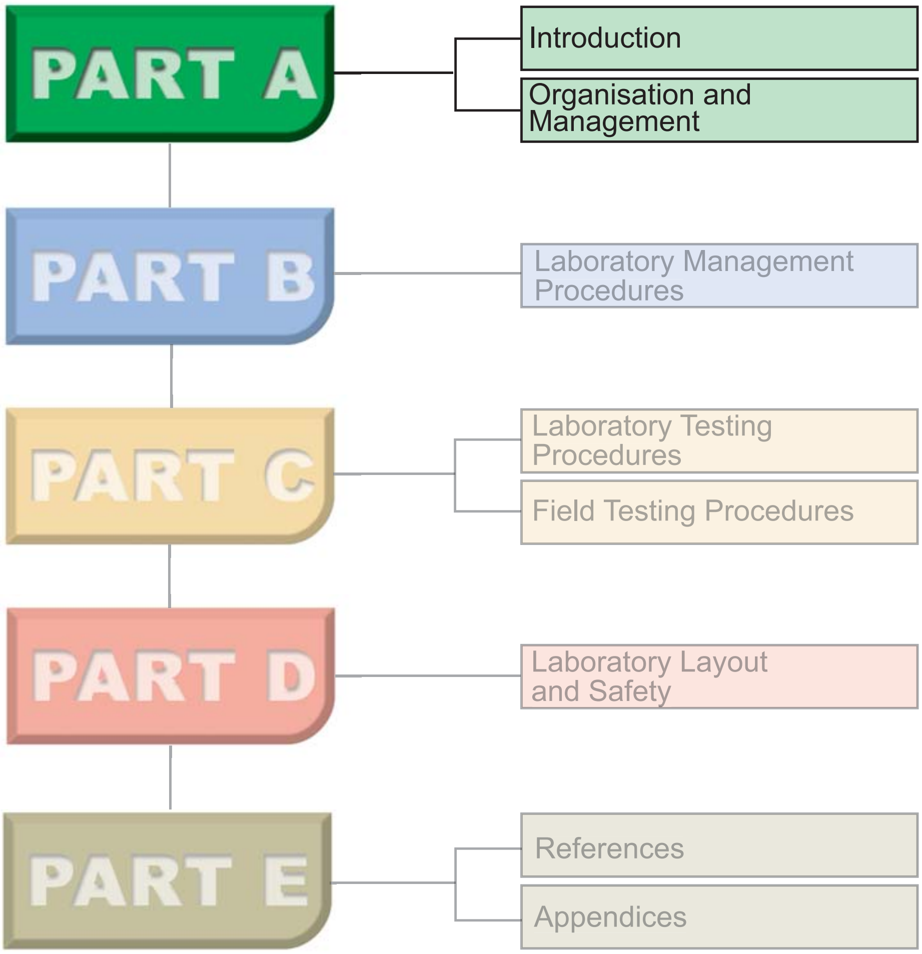
LIST OF FIGURES

LIST OF TABLES

LAYOUT OF THE GUIDELINE



PART A


PART A
Introduction
Organisation and Management
PART B
Laboratory Management Procedures
PART C
Laboratory Testing Procedures
Field Testing Procedures
PART D
Laboratory Layout and Safety
PART E
References
Appendices

1 INTRODUCTION

1.1 Background

This document sets out quality management and operating procedures for the Government Central Materials Laboratory (CML) of the Materials and Research Division of the Roads Department.

The Roads Department is responsible for the construction and maintenance of the primary and the secondary road network in Botswana. It also provides a demand led technical services to other Government Departments when permitted by available resources.

The Materials and Research Division (MRD) is responsible for quality control of road projects and for materials related research. An important part of MRD's work is the testing of materials and this is undertaken by CML.

CML is the principal construction materials testing laboratory for Government in Botswana. The quality of services provided by CML has an important influence on the quality of Botswana's road infrastructure. The laboratory could also be a standard bearer for the nation's commercial laboratories.

This Guideline is intended for daily use by CML staff at all levels for managerial and operational functions including outline of test procedures. The primary aim is to maintain quality, consistency and standards.

1.2 Scope and Layout of the Guideline

This Guideline is divided into five parts as follows:

PART A: Organisation and Management

Part A consists of two chapters. This part of the guideline will primarily be of use to laboratory management personnel whose responsibilities include the setting up of and monitoring quality assurance procedures.

Chapter 1: Introduction
This chapter provides a background and format of the guideline.

Chapter 2: Organisational Set-up
This chapter sets out the role and function of the laboratory, it's clients, management structure and quality standards.

PART B: Laboratory Management Procedures

The most important resource of the laboratory is its trained human resources. Chapter 3 describes the roles and responsibilities of each functional position in accordance with the schemes of service. The staff management and training procedures are outlined.

The necessary equipment and physical resources are also documented. The care for and calibration of testing equipment is emphasised. Accepted quality procedures, which are adopted by the laboratory for procurement, maintenance, calibration and disposal of equipment, are described.

This part of the guideline will be most useful to personnel responsible for equipment maintenance and staff development and management.

PART C: Testing Procedures

Part C forms the major part of the Guideline. The specific methodologies for type of tests undertaken in the laboratory and in the field are described to ensure consistency and common standards. Many tests are standards or variations of internationally accepted methodology and as such are not repeated but merely referred to.

Chapter 4 is concerned with laboratory testing and Chapter 5 with field tests and are intended as reference sources for all laboratory and field staff and those responsible for quality control.

Part D: Laboratory Layout and Safety

Part D of this Guideline deals with the layout of the laboratory and safety issues affecting workers within the work place and is intended to impress upon the management and the employees in general at CML the need for safety in the work place and good house keeping procedures. The chapter also highlights the need for adherence to good health practices such as no-smoking within the work places.

Chapter 6 is intended for all users of this Guideline.

Part E: References and Appendices

This part contains references and appendices.

1.3 Applicability and Status

The CML Guideline is subservient to Government General Orders, Circulars, Savingrams and Roads Department written policies as issued by Director of Roads. Where there is a conflict Government General Orders take precedence and is paramount.

1.4 Compliance with CML Guideline

All employees of Roads Department are required to comply with the CML Guideline except where there is conflict as defined in **Section 1.3**. The Head of Materials and Research Division (HOD) is the primary custodian of the Guideline and is responsible for ensuring compliance. The Operating Procedures Guideline shall be regarded as a ‘controlled document’. The HOD shall maintain a register of holders (**Form M1.1** in appendix B).

1.5 Build Up and Update of Guideline

This Guideline is dynamic and needs to be built up and refined over time. The Head of Materials and Research Division shall initiate a periodic review of parts of the Guideline with a more general review to be carried out every two years. **Form M1.2** (appendix B) is used by staff to suggest/recommend an update to specific clauses to the Operating Procedures Manager. Any member of staff of CML may suggest changes to the Operating procedures Guideline.

1.6 Operating Procedures Manager

The Head of Materials and Research Division shall be the Operating Procedures Manager (OPM) of the CML Operating Procedures. The HOD may, in turn, delegate this function to an appropriate senior officer who shall not be lower than a Senior Roads Engineer (SRE) or Chief Technical Officer (CTO) in rank.

The role and functions of the OPM is defined in Part B of this Guideline

1.7 Quality Officers

The OPM shall nominate Operating Procedures Officers (OPO) for each unit of the laboratory, who shall normally be the heads of the respective units. The OPO shall be responsible for ensuring compliance with the Guideline in their respective units.

1.8 Quality Review and Audits

The OPM shall initiate a periodic review and audit of compliance with the Guideline. The Audit shall be carried out by an independent person following the procedures set out in **Section 3.6.**

The auditor shall compile a report stating areas of compliance/non-compliance and recommended actions required to rectify any non-compliance.

Forms M1.3 and M1.4 (appendix B) shall be used for audit schedule, checklist and corrective action request respectively. Any changes to the guideline resulting from the audit shall be recorded in **Form M1.5** (appendix B). The findings of the audit shall be summarised in an audit report in a format presented in **Form M1.6** (appendix B).

1.9 Inter-Laboratory Quality Audit

The laboratory shall undertake an annual inter-laboratory testing to check quality, reproducibility and repeatability of results amongst at least three major commercial materials laboratories in Botswana. The procedure for carrying out such audits is described under **Section 3.7 of this Guideline.**

2 ORGANISATION AND MANAGEMENT

2.1 The Public Road Network

The administration of the Public Road Network (PRN) in Botswana is divided into two major areas of responsibility. The responsibility for constructing and maintaining the PRN is shared between Roads Department in the Ministry of Works and Transport, and Local Councils in the Ministry of Local Government.

The total length of the Public Road Network is more than 20 000 km of roads comprising paved, gravel, earth and sand wearing courses. The total length of the National Road Network (NRN) i.e. those under the responsibility of Roads Department, accounts for about 6350 kilometres of bituminous roads, about 2 610 kilometres of gravel roads and about 1 440 kilometres of earth / sand roads. The remaining roads fall under the management of Local Councils.

2.2 Roads Department

Roads Department is responsible for the forward planning, budgeting and implementation of projects pertaining to upgrading of gravel and sandy roads to bituminous and gravel roads respectively, construction of new roads, maintenance of existing roads and investigations of poor performance of newly constructed roads or old roads due for rehabilitation.

In the majority of cases, the Materials and Research Division (MRD), is involved right from the beginning in drafting of the Terms of References for various aspects such as pavement investigation and rehabilitation design, feasibility or detailed design and materials investigation for construction of new roads, and in the case of maintenance of gravel roads, the gravel and materials investigation required for spot improvement or gravelling/regravelling of sand or gravel roads respectively. Furthermore, where projects are undertaken by consultants, the MRD is responsible for supervising the former on issues pertaining to materials investigation, geotechnical investigation and searches for construction materials. The biggest task, however, is in proving sources of construction materials for maintenance projects.

Materials and Research Division is one of the six divisions comprising Roads Department. The other divisions are:

- Maintenance.
- Development.
- Forward Planning.
- Training.
- Administration.

Clear lines of communication between the Materials and Research Division and sister divisions are paramount for the efficient planning and execution of road projects. This is particularly so for the Maintenance and the Development divisions.

2.3 Maintenance Division

Maintenance Division is one of the most important clients for the MRD. Maintenance Division is charged with maintaining the National Road Network (NRN) in a sound and cost effective manner. The main activities of

Maintenance Division which require input from MRD are:

- Routine maintenance.
- Periodic maintenance.
- Evaluation of consultancy proposals and tenders.
- Control of overloading by heavy vehicles.

There are three sub-divisions within Maintenance Division namely Region North-with headquarter in Francistown, Region South with headquarter in Gaborone and Region West with headquarter in Maun. The Maintenance regions are tasked with maintaining all roads falling under the NRN within their region. This involves planning, budgeting and executing by force account or by private contractors, the maintenance of candidate roads.

All of these maintenance regions are required to send their construction materials and or pavements related requirements to Maintenance Headquarters in Gaborone from where they are collated, prioritised and sent to MRD for action.

It is quite common that the requests are brought in late leading to late delivery of the required services by MRD. In order to avoid these delays, the following communication schedule and time limits must be adhered to.

It is important to note that all Government projects, whether done in house or outsourced, need to have been budgeted for and the funds approved by 31 March of each year for the projects to commence during the financial year starting in April of the same year. In the case of MRD where pavement failure investigations and/or gravel survey need to be completed by the time the project is implemented the planning takes an even longer period.

For MRD to deliver services to Maintenance Division on time, requests for investigation/services should be submitted to the PRE - MRD two fiscal years before the intended start of the project. The request should be made preferably in April but not later than July two years before the construction stage of the project. This time is meant to give MRD time to include the project in the budget to be approved in April the following year. When the funds to carry out gravel survey or pavement evaluation have been approved then field work and testing or even outsourcing can commence after April. The investigation report should, therefore, be submitted to Maintenance division before March of the construction year. Figure 2.1 shows the life-cycle of a project involving MRD and Maintenance Division. A similar life-cycle could be used for projects involving MRD and other divisions.

In order to facilitate quality control and prevent delays during construction, a Technician from MRD should be seconded to maintenance contracts section for the duration of the project. Wherever feasible, routine and simple tests such as sieve analysis and Atterberg limits should be carried out on site. The upkeep, transport and related field expenses of the officer should be the responsibility of the client, i.e. Maintenance Division.

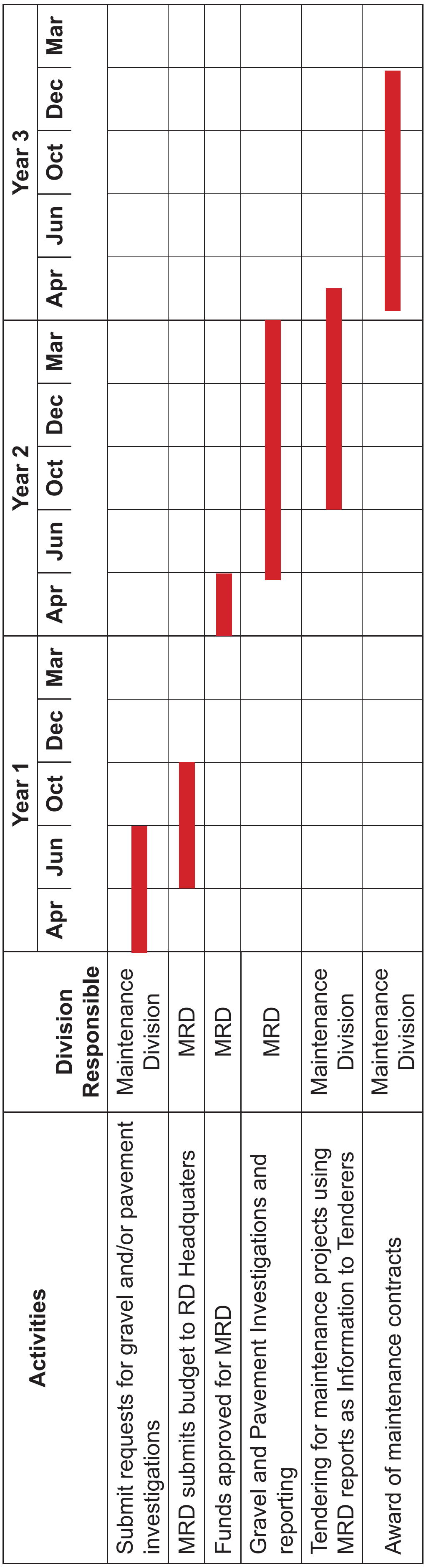


Figure 2.1: Recommended life-cycle of a project involving MRD and Maintenance Division.

2.4 Development Division

The Development Division is another main user of the services provided by the MRD. The Development Division is responsible for:

- Rehabilitation and construction of roads and bridges.
- Road and bridge design.
- Contract administration of road design and construction, through consultancy agreement and construction contracts.
- Traffic studies.
- Award of consultancies and construction contracts.

The MRD is critically required in most of the above functions specially supervision of consultants during the design stage, quality control on site during construction stage and technical input into the TOR services of consultants.

The lines of communication and target months are similar to those for maintenance. It is, however, much clearer in Development Division as to which projects are due for construction in the next two years or so as forward planning publishes these projects in advance. A list of projects that would require inputs from the MRD should be known at least 12 months prior to the start of the project. This would enable the MRD to budget in advance for the division's input in July of the year before commencement.

The project life-cycle suggested for Maintenance Division (figure 2.1) could also be adopted for other divisions depending on the nature of the project.

2.5 Forward Planning Division

The division is responsible for the overall planning of the department, which includes: Project appraisal, evaluations, cost estimates and implementation schedule; coordination of feasibility studies to determine projects viability for upgrading to bitumen standard and review of cost estimates; liaison with District Authorities in determining their road improvement requirements.

Forward Planning Division comprises Planning section, Information Technology section, Network Management section, and Traffic section.

2.6 Roads Training Centre

The Roads Training Centre (RTC) exists symbiotically with the MRD in that RTC train technicians who are later deployed at MRD. MRD, on the other hand, provides the necessary equipment and technical expertise required by the students during their training especially with regard to site investigations, construction quality control and testing of construction materials.

RTC exists in order to provide:

- Technical training in design, construction, supervision and maintenance of roads.
- Training with regard to the use of labour intensive methods of road construction.

The graduates of the RTC that are employed by MRD are those that have completed:

- Highway Engineering Technician Diploma Course (HETC).
- Road Technician Certificate Course (RTCC).

In order to avoid disruption to the works at MRD, it would be prudent that RTC submits their training requirements/schedule to HOD at MRD at the beginning of each year. The schedule shall include the objective of the visit or attachment, the number of students, if in groups the number of groups and the number of students per group, the dates and times of the visit, and state if the students are accompanied by their supervisors/lecturers or otherwise. MRD shall promptly inform RTC about the resources required from them during these visits.

2.7 Materials and Research Division

2.7.1 Composition

Entrance to Materials and Research Division.

Materials and Research Division (MRD) is headed by a Principal Roads Engineer (PRE) who reports directly to the Chief Roads Engineer – Materials and Maintenance and indirectly to the Director of Roads.

The Division comprises the following Sections:

- **Administration and Supplies:** – Facilitates the smooth running of the entire division by providing manpower and other resources necessary for MRD to discharge its responsibilities.
- **Central Materials Laboratory (CML):** – It is primarily responsible for carrying out various tests on construction materials and is the main focus of this guideline.
- **Materials Investigations:** – Primarily responsible for the location of road building materials throughout the country.
- **Research and Development including Pavement Monitoring:** – It is responsible for investigating properties of various pavement materials and facilitating their use for appropriate pavements. The section is also responsible for conducting research on road building materials, usually in association with other research organisations such as FET-UB, BOTEC, NPRA, TRL, CSIR, etc.
- **Design and Specifications:** – Undertakes in-house design and updates national standards and specifications for roads and bridges.

These sections interact very closely and their duties and responsibilities overlap. The Materials and Research Division organogram is shown as Figure 2.2. The organogram is based on the approved structures for the MRD.

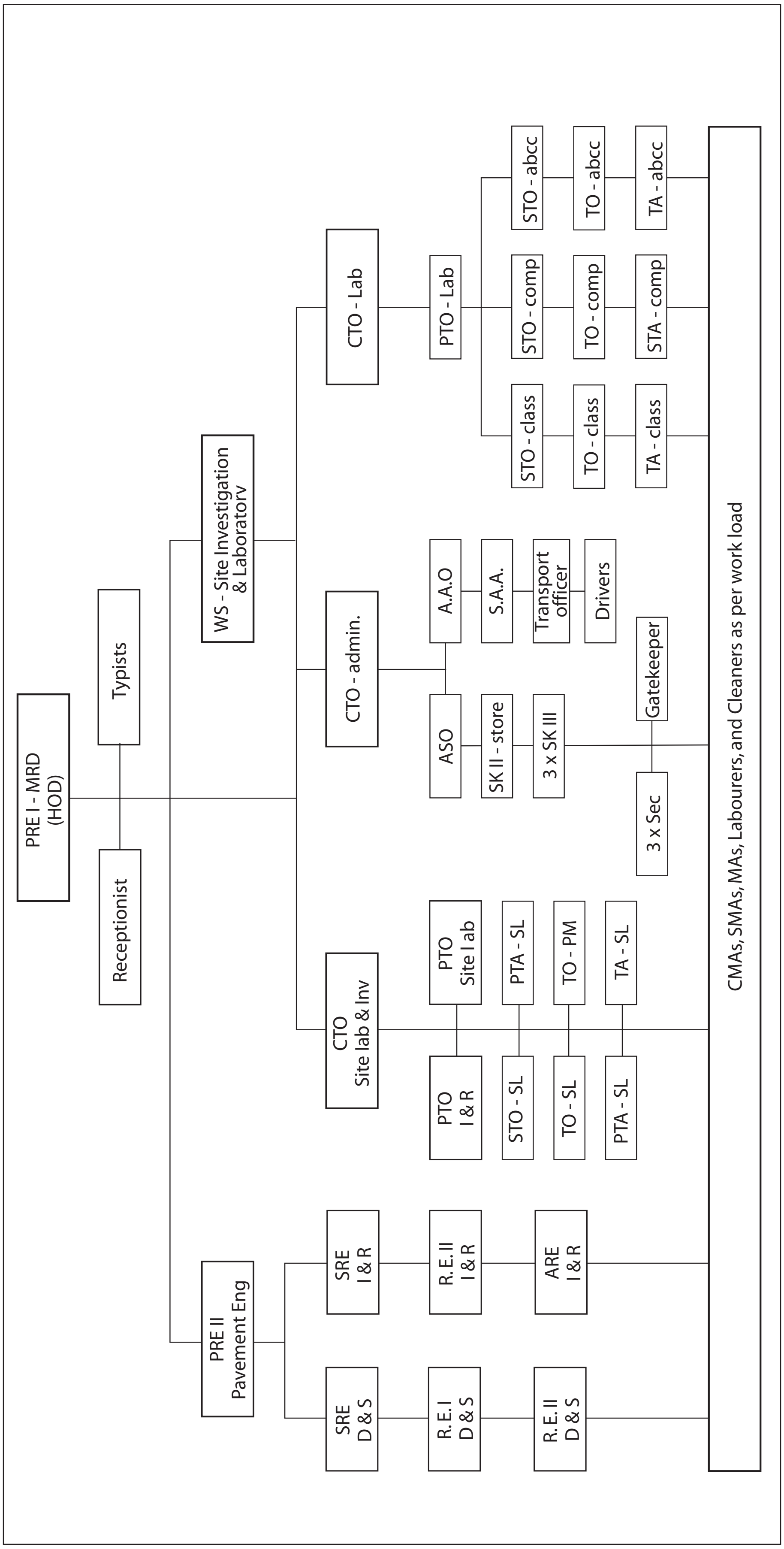


Figure 2.2: Materials and Research Division Organogram - based on the currently approved personnel establishment.

2.7.2 Responsibilities

The main responsibilities of the Materials and Research Division include:

- Reviewing and advising on materials aspects of feasibility study, design, construction and maintenance projects.
- Undertaking in-house pavement design.
- Prospecting, testing and approving sources of road construction materials.
- Assessing and evaluating consultancy proposals and contract documents to ensure adequacy of materials in-put and pavement design.
- Designing and undertaking appropriate research to increase efficiency and value for money within Roads Department, including bilateral co-operation with relevant research organisations in other countries.
- Conducting quality control monitoring and testing for all Roads Departments projects including in-house projects and projects undertaken by consultants and contractors on behalf of the Department.
- Designing and undertaking special investigations to establish causes of premature pavement failures/distress and assessing liability where relevant.
- Undertaking project level pavement investigation of projects identified by pavement management system for maintenance and rehabilitation purposes.
- Providing advice and assisting the Director of Roads on implementation of policy changes relating to pavement and materials technical standards, training and quality control of Roads Department projects.
- Providing advice on pavements, research and materials testing services to other Government departments and parastatals.
- Training of materials staff and assisting Roads Training Centre in materials aspects of its training programme.
- Support services to other divisions of Roads Department including:
  - teaching at Roads Training Centre
  - assistance to Maintenance and Development Divisions with the procurement of consultants by contributing to TOR preparation and evaluation of technical and financial proposal
- Development/preparation of technical guidelines and their dissemination to stakeholders.

2.8 Central Materials Laboratory (CML).

2.8.1 Roles and Functions

The main function of the Central Materials Laboratory (CML) is to test road building materials and to ensure that appropriate testing methods are followed.

The section is also responsible for:

- Periodic checking and calibration of all testing equipment.
- Continuous training of laboratory staff to enhance competence in carrying out most of the routine tests.
- Field and laboratory testing of various construction materials and preparation of factual reports.
- Provision of advice to other sections of the MRD, Roads Department and other Government Departments on materials testing and quality control.
- Management and operation of on-site laboratory testing facilities for nominated projects.

The day-to-day management and operation of the CML shall be in accordance with these operating procedures and the HOD shall ensure that CML has the resources to carry out the tests listed in Table 4.1.

2.8.2 Organisational Set up

The CML shall be headed by a Chief Technical Officer (CTO) who shall report directly to the Works Superintendent (WS) or Principal Roads Engineer (PRE). The head of CML shall be referred to as the Laboratory Manager (LM) for the purpose of this guideline. The LM shall get managerial and technical support from Engineers and technicians at MRD.

The LM shall be assisted by heads of various units, who shall be Senior Technical Officers (STO) or Principal Technical Officers (PTO) except for the sample preparation and receiving unit who shall be a Technical Officer (TO) or a Senior Technical Assistant (STA). There shall be four units within CML. The heads of the various units within the CML shall be referred to as Unit Head (UH) for purpose of this guideline. Each UH shall be assisted by Technical Officer (TO) and/or Technical Assistants (TA).

The UH shall also perform the role of Safety Officer (SO) and Quality Officer for their respective units. The UH shall be responsible for the overall quality, timely delivery, safety and general welfare of staff, quality of equipment, training of his/her staff, and accuracy of data produced and presented to the LM.

The actual qualification required for the various positions shall be determined by the Director of Roads Department from time to time as dictated by the dynamics of the service and ruling schemes of service. Provided however that the LM and UH are competent technicians who are qualified and well trained in the field of material testing.

It is not the duty of the Unit Head or the Lab Manager to interpret the data in terms of passing or failing any specification. Once the UH is satisfied that the results are in order he shall pass them on to the LM who shall in turn check and satisfy himself that the tests were performed in accordance with acceptable procedures and standards before passing them on to the Project Engineer for analysis and onward transmission to the client.

Depending on the availability of staff the HOD shall assign an Engineer of the level of Roads Engineer or higher, to the laboratory to assist with interpretation of results and assistance with specialized tests.

For major projects, such as road construction, road rehabilitation and road gravelling, it would be prudent to assign a specific officer to the project. An officer so appointed shall be referred to as the Project Officer (PO). The PO shall be responsible for determining the type and number of tests to be carried out on samples from the given project. It is, therefore, imperative that the officers are adequately trained in laboratory testing and handling of problems relating to construction materials for them to be able to handle the complexities of construction materials related problems. Such training is available at numerous reputable institutions such as Technicons in South Africa, TRL in UK, and universities. Table 2.1 summarises the primary and secondary responsibilities (task schedule) of engineers and technicians at CML.

2.8.3 Support Services

Data is stored in electronic media.

Administrative, Information Technology, Secretarial and Supplies Support services to the laboratory are provided by other sections of the Materials and Research Division. The effective functioning of the laboratory is dependent on the services provided by these support services. Primary support services are:

- **Administrative support:** Reception, typing and file management, clerical and routine accounting.
- **Supplies:** Purchase administration, storage, inventory, disposal and management of all supplies and equipment.
- **Information Technology Services:** Procurement, servicing, repair of hardware, network management, back up support, training on IT, virus management, software management and licensing, website support, maintenance of Laboratory Management System (LMS) and Database and others.

Table 2.1: CML Personnel Task Schedule.

TASK DESCRIPTION	HOD (PRE I)	PRE II	SRE's	RE 1	WS	LM (CTO)	CTO SL & Inv.	PTO SL & Inv.	ABCC Unit Head	Compa'n Unit Head	Classif'n Unit Head	Preparat'n Unit Head	IT Officer	AS0
Preparation of Annual and monthly Work Programmes		2			1	1								
Assessment and Approval of programmes	1													
Staffing Planning & Annual Training programme	2				1	2								
Preparation of testing schedule for samples	2	2	2	2	2	1	1	1	1	1	1			
Sample and sample book management						2			2	2	2	1		
Inter-laboratory testing			2		2	1			2	2	2			
Review of testing methodology		2	2		2	1			2	2	2			
Equipment Calibration - Compaction unit						2				1				
Equipment Calibration - ABCC Unit						2			1					
Equipment Calibration - Classification Unit						2					1			
Disposal of Obsolete equipment	2				2	1			1	1	1	1		1
Laboratory Health & Safety	2				2	1			1	1	1	1		
Review & Update of Quality Procedures Manual	2	1	1		1	1			2	2	2			
OP Management & Approval of Procedures	1	2	2											
Convening of laboratory Weekly and Monthly Meetings					2	1								
Preparation of lab. Testing factual reports			1			2	2	2	1	1	1	1		
Certification of laboratory factual reports			1			1								
Checking & Certification of laboratory reports	1	2	1			2								
Customer complaints Procedure	1	2			2	2								
Project Officer functions		1	1	1	2	1								
Annual Organisational Review	1	2	2		2	2								
Laboratory Computing									2	2	2	2	1	
Quality Audits	1	2	2	2	2	2								

1 - Primary responsibility. 2 - Secondary/supporting responsibility

2.8.4 Organisational Review

The Head of Division in consultation with Laboratory Senior Personnel shall undertake a biannual review of laboratory staffing status and shall delegate duties as appropriate to cover for any unfilled posts.

An annual organisational review shall be conducted by the Head of Division assisted by senior personnel including the Laboratory Manager. From this review the organisation plan for the year is developed including the requests for staff recruitment and transfers as appropriate to fulfil specific functions in the organogram. The annual review process shall be timed to complement the Roads Department Head quarter annual staff deployment review.

Staff development and training is described in Chapter 3 of this Guideline.

2.8.5 Laboratory Units

Due to the various and differing range of tests carried out by CML, the laboratory shall be subdivided into specialized units depending on the types of tests. The units are:

- Sample Receiving and Preparation (SRP) Unit.
- Classification unit.
- Compaction unit.
- Aggregates, Bitumen, Concrete and Chemistry (ABCC) unit.

Sample Receiving and Preparation (SRP) Unit

The Sample Receiving and Preparation (SRP) Unit shall be responsible for:

- Receiving of samples from field teams, other divisions and other stakeholders.
- Storage of samples in an orderly and neat manner until they are required for testing. Samples shall be received and stored in accordance with the sample receiving and storage procedure as detailed in Sections 3.3 and 4.3 of this Guideline.
- Preparation of the sample and making them ready for testing by the respective CML unit.
- Managing the sample shed and upkeep of the preparation area.
- Temporary storage of waste samples and the management of the disposal of the same to the dumping site. A tidy storage such as "Skip hire" is considered prudent.

The SRP unit shall be headed by a Technical Officer (TO) or Senior Technical Assistant (STA). The number of materials assistants assigned to the unit shall be dependent on workload.

One of the tests carried out by the classification unit is the PI.

Classification Unit

The classification unit is tasked with testing soil samples in order to determine their classification in terms of the AASHTO soil classification system or any other system as appropriate. The unit shall undertake the following tests:

- Sieve analysis of gravel, sand and soil samples.
- Liquid Limit of soils.
- Plastic Limit of soils.
- Linear Shrinkage of soils
- Hydrometer Analysis for samples finer than 0.075mm.

The PI test requires skill and diligence.

Compaction is an essential component of the CML.

AIV test is also carried out at CML.

Bitumen Adhesion Test at ABCC unit.

Currently CML does not carry out tests related to chemical stabilizations of materials such as Initial Consumption of Lime (ICL). It is recommended this test be conducted in CML because chemical stabilization is being performed on a number of projects.

The classification unit is also responsible for storage of unused fines from soil samples, which may be required for future use or repeat testing.

The Classification Unit shall be headed by a Senior Technical Officer (STO) who shall report to the Laboratory Manager (LM). The UH of Classification unit shall be assisted by Technical Officers and Technical Assistants. The number of Materials Assistants of various grades attached to the unit shall depend on the workload.

Compaction Unit

The compaction unit is responsible for testing soil samples in order to determine their density (compaction) characteristics. The compaction unit shall primarily undertake the following tests:

- Determining the Density–Moisture relationships in order to find the Optimum Moisture Content for achieving the desired Maximum Dry Density of materials.
- Determining the California Bearing Ratio (CBR).
- Determination of Unconfined Compressive Strength (UCS) of chemically stabilised materials.

The compaction unit shall be headed by a Senior Technical Officer (STO) who reports to the LM. The UH of Compaction unit shall be assisted by a TO and a Technical Assistant (TA). The number of Materials Assistants of various grades attached to the unit shall depend on the workload.

Aggregates, Bitumen, Concrete & Chemistry (ABCC) Unit

The ABCC unit is responsible for carrying out Aggregates, Bitumen, Concrete and Chemical tests. The following are some of the tests that shall be carried out within the unit:

Aggregates

- Aggregate Impact Value (AIV) test.
- Aggregate Crushing Value (ACV) test.
- 10% FACT.
- Average Least Dimension (ALD).
- Water Absorption.
- Bulk Densities.
- Adhesion test (Riedel and Weber).
- Flakiness Index.
- Dust Content.
- Particle size Distribution.
- Durability Mill Index.

Bitumen Tests

- Bitumen Penetration.
- Softening point (Ring and Ball test).
- Viscosity.
- Ductility.
- Asphalt Tests, mainly Marshall tests i.e. flow and stability.

Concrete Tests

- Cube Casting.
- Slump test.
- Cube Crushing.
- Brick Crushing.

Chemical Tests

- Electrical Conductivity.
- pH.

The ABCC Unit shall be headed by a Senior Technical Officer who shall report to the Laboratory Manager. The UH of ABCC shall be assisted by two TOs each of whom shall head a sub-unit being Bitumen and Chemistry, and Aggregate and Concrete. Each TO shall be assisted by a TA and a number of Materials Assistants whose number shall vary depending on workload.

2.9 Correspondence

All correspondence into and out of the laboratory to external individuals and organisations shall be addressed through the Head of Division (HOD). The HOD shall distribute all incoming mail by assigning action officer for specific query or request.

All requests for laboratory testing by external clients shall be addressed to the HOD while those from within the CML shall be addressed to the LM using a letter from the former or Form M2.1 (Appendix B) from the latter.

The content of telephone conversations with any client shall be recorded and discussed with the relevant Project Officer (PO).

All reports emanating from the laboratory shall be channelled through the LM to the PO or the HOD. The HOD will sign-off all reports from the LM and or PO to the respective clients. Where a project was not assigned a PO, the LM shall submit the factual reports directly to the HOD. Should the HOD require further work on the project or the report, he/she shall assign a PO to carry out the task.

2.10 Heads of Units Meeting (HUM)

The Laboratory manager shall convene a monthly meeting of Heads of Units to assess and discuss among other things:

- Current workloads.
- Resources (human & equipment).
- Plans and programme for the coming month.

At the monthly HUM, minutes shall be taken and action items noted for individual unit heads and their members.

Each UH may nominate a maximum of two additional officers from their respective units to attend the HUM.

2.11 Annual Work Plan

The Laboratory Manager, Works Superintendent, CTO Administration, the Principal and Senior Road Engineers, and the HOD shall carry out a review of CML's projects and activities, and produce an annual work plan prior to the beginning of each financial year. This shall normally be undertaken prior to budget preparation.

In order to facilitate this, it is critical to ensure that Maintenance Division and other outside clients submit their materials prospecting and testing requirements to MRD at least 8 months prior to the start of the financial year. The annual work plan will normally include all divisional activities. For the laboratory, these shall include:

- Testing workload/plan for the coming year.
- Resource requirements (human & equipment).

- Personnel development and training programme (see Table 2.2).
- Building and equipment maintenance.
- Developmental activities.

The LM shall maintain the annual work plan for the laboratory. The work plan shall be monitored monthly and progress reported at the monthly management meetings.

Table 2.2: Types of Training for Various Categories of Staff at CML.

TYPES OF COURSES / STAFF GRADE	Management/Organisational	Contracts & Quality Control	Materials & Pavement Eng	Courses leading to engineering degrees	Materials Testing-Basics	Laboroary Testing -Advanced	Technical Conferences-International	Conferences - Local & Regional	Customer Services & Supervisory	Admin. And Computing	On-the-job Laboratory Testing Trainning	RTC Diploma	RTC Certificate
Senior Engineers (REI and above)	1	1	1	2			1	1		2			
Junior Engineers		2	1	1		2		1					
Senior Technicians (STO and above)		2				1		1	2	2			
Junior Technicians					1	1		2	1	1			
Materials Assistants									2	2	1	1	1
Administrative and support staff									1	1			

1 - Primary relevance 2 - Secondary relevance

Note that TMH 1 is available on the Internet and includes periodic updates and improvements. Web-site: www.csir.co.za.

2.12 Technical Standards and Information

In order to ensure that most upto date technical standards are used for testing, frequently used documents such as TMH 1, ASTM, BS 812, BS 1377, etc. shall be registered as Controlled Documents.

The Laboratory Manager shall maintain a Register of Controlled Documents in the laboratory. The Laboratory Manager shall ensure that all Controlled Documents are updated with all revisions.

The controlled reference documents shall be held either in the library or issued to named individuals. The Designated Member of Staff shall record the names of individuals and their holdings of controlled publications in the Register.

The Laboratory manager shall clearly mark each controlled reference document as such.

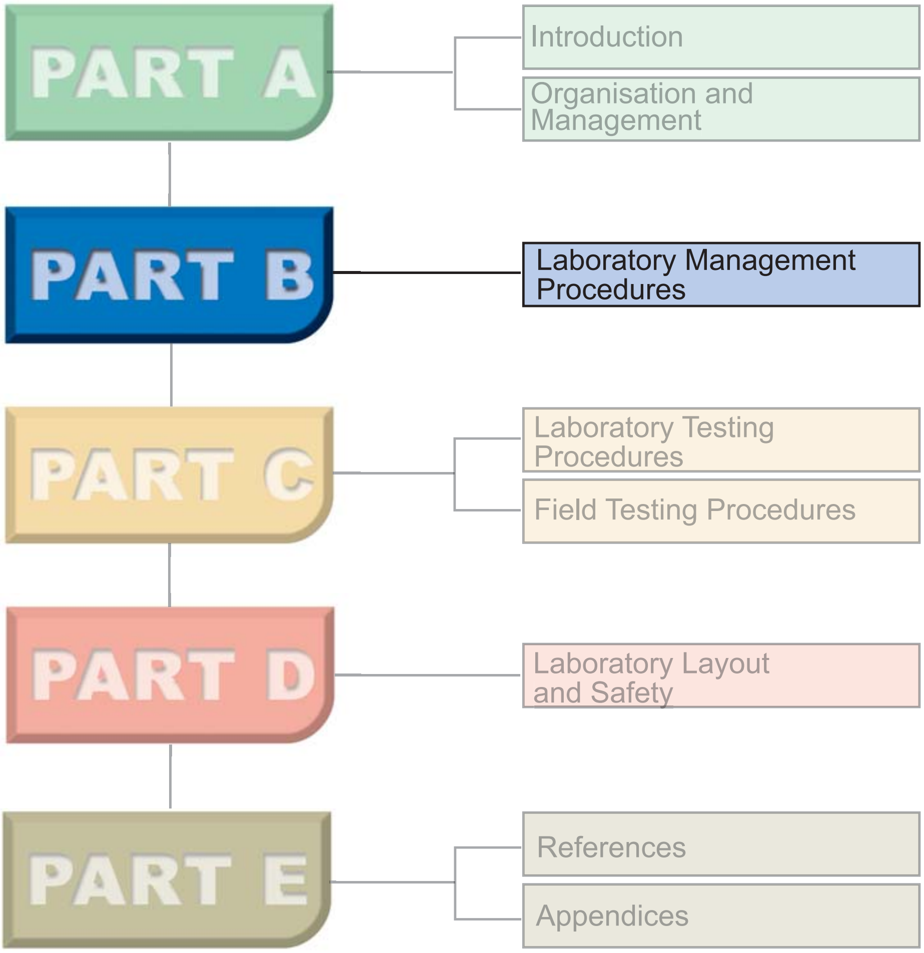
2.13 Client Satisfaction and Complaints

All complaints received from outside parties shall be recorded in Form M2.2 (Appendix B).

All complaints shall be brought to the attention of Head of Division who shall ensure that appropriate authority is delegated to deal with the complaint.

The Head of Division and Laboratory Manager shall counter-sign Form M2.2 signifying that the complaint has been dealt with. A copy of the signed form shall be filed both under the Divisional filing system and Laboratory filing system.

PART B


PART A
Introduction
Organisation and Management
PART B
Laboratory Management Procedures
PART C
Laboratory Testing Procedures
Field Testing Procedures
PART D
Laboratory Layout and Safety
PART E
References
Appendices

3 LABORATORY MANAGEMENT PROCEDURES

3.1 Introduction

The word 'management' has several meanings, depending on the context and purpose. There is no universally accepted standard definition of management. However, management may be simply defined as the process by which managers get things done through the efforts of others. To manage is primarily to direct people and organizations in such a way that certain objectives are accomplished.

With the adoption of stringent standards for materials testing, the importance of laboratory operation and the generation of credible data have increased. Competent management is essential to bring about reliable laboratory performance, thereby increasing the laboratory use as a tool for maintaining proper performance to ensure compliance with accepted standards.

In the various chapters of this report the following aspects of laboratory management and administration are discussed:

- Resources.
- Handling samples.
- Sample storage.
- Incoming work.
- Planning workload.
- Quality control of testing.
- Reporting results.
- Keeping records.
- Staff training.
- Calibration of equipment.
- Laboratory lay-out.
- Laboratory safety aspects.
- Laboratory housekeeping.

It is suggested that the Central Materials Laboratory (CML) supplement their existing operational procedures with those outlined in this Guideline.

3.2 Resources

3.2.1 General

The resources required both in terms of manpower and equipment is dependent on the amount of testing that is done by the laboratory on a regular basis. This has to be determined over a period of time, say one year, as the workload of laboratories is typically erratic. Sufficient resources should be available to handle the average workload. Too much equipment and staff will be expensive in terms of salaries, maintenance, capital costs etc., whereas too little resources will hamper laboratory operations and negatively affect production. An optimum level of resources is often difficult to achieve but should be strived for. Experience gained with time is the best indicator for determining resource requirements.

3.2.2 Manpower

Regardless of the amount of work, each unit should have at least one experienced (senior) Technician and one or two Technical Assistants as detailed in Section 2.8 of this Guideline.

A cleaner should also be available to clean and tidy up after testing and may be shared by the various units within the laboratory, however, where units handle large volumes of work more than one cleaner may be necessary.

At different times one unit, say the Classification unit, may have a greater workload than, for example, the ABCC unit. In such cases personnel from the ABCC unit should be temporarily used in the unit experiencing the high workload. It is thus important to train technicians to do various types of testing so that they are interchangeable amongst units.

Staffing the laboratory to deal with peak workloads is not recommended as this leads to people being idle for long periods when the workload is low. This normally results in personnel that are not used to working full days, which creates poor work habits in terms of efficiency.

The existing schemes of services and establishment register are considered to be adequate to meet the objectives of MRD. This is based on the past and present workload at MRD. The number of vacancies in engineering posts must however be filled to enhance the project monitoring and increase the number of Engineers assisting with specialised testing and data interpretation where required.

3.2.3 Equipment

CML has all the types of equipment, which are necessary to do the tests that are routinely carried out. When specialised testing is requested for which the laboratory does not have the equipment the work should be contracted out to a laboratory that does such testing.

The number of apparatus required for any particular test is dependent on the number of requests for that test in a given period. Where this is insufficient the productivity of the laboratory will be adversely affected. However, excessive amounts of equipment will have certain negative cost implications, in terms of purchasing, depreciation, maintenance etc. Also, space that could be used for other purposes will be occupied. It is the responsibility of the LM, in consultation with the HOD, to plan for the purchasing of new equipment and the boarding of disused equipment. The LM shall maintain an equipment control list **(Form M3.1,** Appendix B).

3.3 Sample Storage System

An efficient sample storage facility must allow for ease of sample storage and retrieval thus facilitating orderly storage of samples. There should be sufficient space in which to handle samples. Samples may be large (50 kg) or small (a few kg's) or anywhere in between and the system must cater for the various sample sizes.

A well-organised storage facility such as this one, facilitates easy identification and retrieval of samples as and when required.

Large samples should not be stored high above ground level (probably not more than 1,2 m above ground - chest height) as they are cumbersome to handle and incorrect handling may result in injury to the person storing/retrieving the samples. The storage height above ground may naturally be increased if some form of mechanical hoisting system is used to lift samples. In most laboratories, however, samples are handled manually as a mechanical hoist has the disadvantage of being expensive, slow, and cumbersome to move about. Also, a mechanical hoist requires more space, in which to manoeuvre, which means that less of the available floor space can be used for sample storage.

A storage facility must have provision for the temporary or short-term storage of samples and also storage for longer periods.

Samples that are to be tested soon after arrival, should preferably be stored at a location close to the sample preparation area. Samples that have been tested and are awaiting disposal should be stored in another location. Figure 3.1 shows the flow of samples between the various storage areas in the laboratory. Figure 3.2 depicts various types of storage that can be used to accommodate different types and sizes of samples.

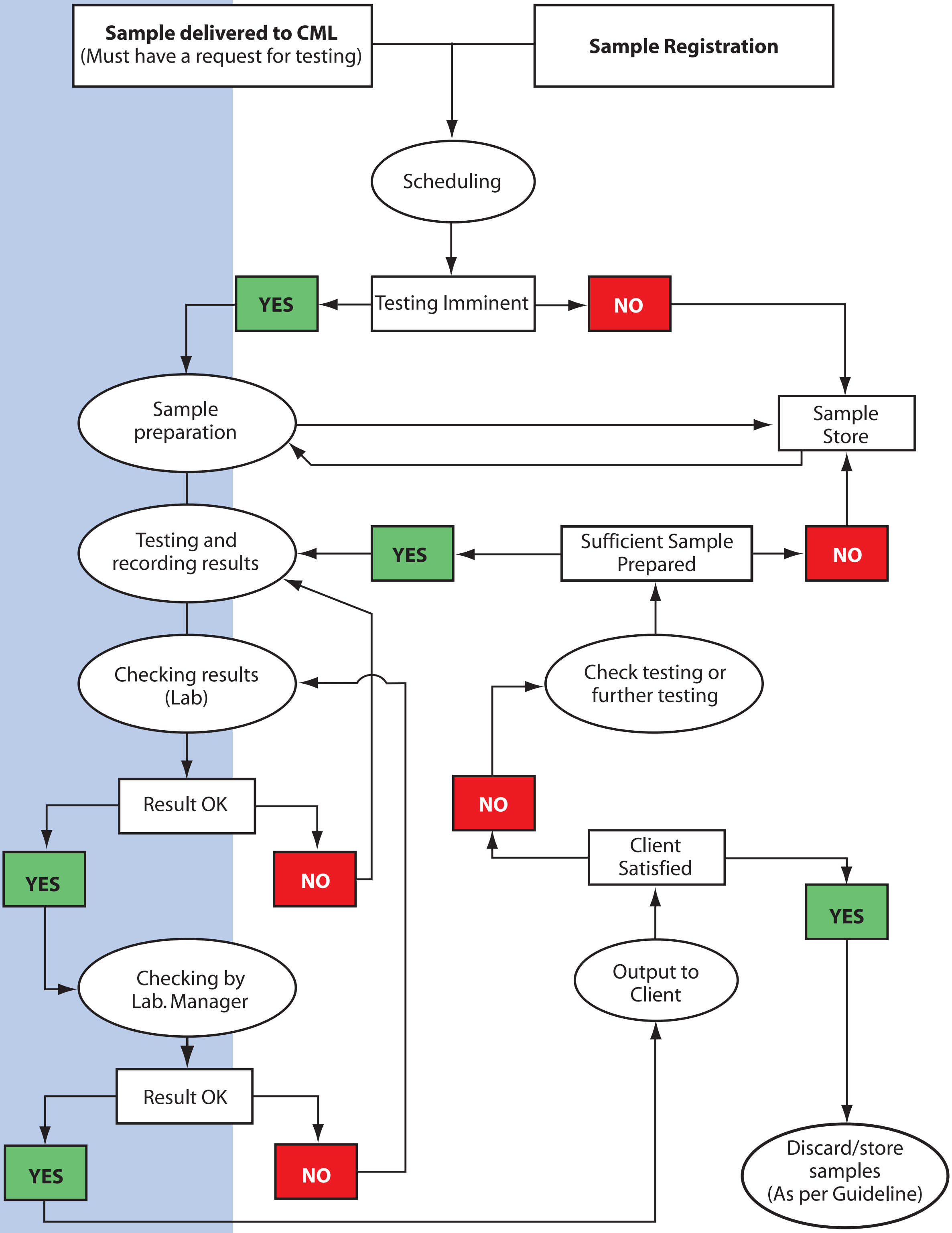
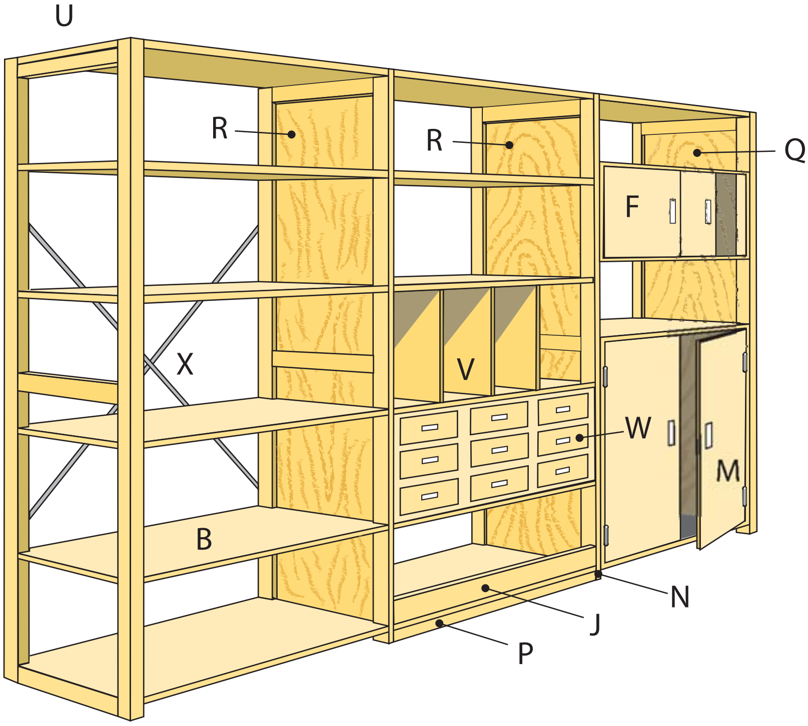


Figure 3.1: Flow Chart of Sample Movement and Associated Activities at CML.



B	Shelf	Q	Panelled end frame
F	Sliding door frame	R	Panelled intermediate
J	Bin fronts	V	Vertical division pieces
M	Hinged doors	U	Open end frame
N	Hanging strip for doors	W	Drawer units
P	Plinths	X	Cross brace

Figure 3.2: Various types of storage systems.

3.4 Recording Incoming Work (Jobs)

Requests for testing have to be recorded in order to keep track of the work details. This will normally be done in a job ledger. This may also be done electronically using a computer. The information required for the records is, however, the same whether it is done manually or electronically. It is desirable to have the following information concerning the work requested:

- Each work request is given a job number.
- The name of the person requesting the work.
- The date on which the job was received.
- Date on which job was started.
- The number and types of tests required.
- The numbers of the samples being tested.
- The estimated or required completion date.
- The estimated cost of doing the work.
- The person or persons that are going to be doing the testing.
- Date on which the job was completed.
- Amount invoiced for the job (if necessary).

A file should be opened on each job received. This file should contain all the information pertaining to the specific job, i.e. the work request form, all the working sheets, test results summary sheet and all the correspondence concerning the particular job. The LM shall maintain a register of project numbers using Form M3.2 (Appendix B).

3.5 Planning The Work Load (Scheduling Work)

3.5.1 General

For work to be done efficiently it has to be planned and scheduled. This is especially important when several job requests are received simultaneously or more work is received than the testing facility can comfortably cope with within a specified time limit. In any event jobs normally have to be done within a certain time and within specific cost constraints and this can only be achieved if the workload is adequately scheduled.

Work may be scheduled in various ways such as on a first come first serve basis or it may be prioritised according to the urgency of the situation. When scheduling work, factors such as use of equipment, optimal use of laboratory assistants, technical staff etc., shall be considered.

3.5.2 Use of equipment

It is often the case that various people request similar testing, which means that the same equipment needs to be used at the same time, which is obviously not possible. In this case it is advisable to stagger the start of the jobs so that optimal use of the equipment is made.

3.5.3 Programming work loads for testing staff

Work has to be set out in such a way that the technicians and technical assistants are as fully occupied as possible. This is cost effective and also prevents staff from developing bad work habits (staff used to being idle). Naturally at times when there is little or no work this is not possible. When this occurs staff should be employed to calibrate and service the equipment. It is, therefore, important that an adequate number of technical staff are trained in the service and calibration of most frequently used equipment. The training on these aspects could be arranged with equipment suppliers and testing institutions such as CSIR and equipment manufacturers etc.

3.6 Checking and Quality Control

3.6.1 General

CML shall maintain three levels of quality check and verification.

- First level checks shall be undertaken by the Unit Head supervising tests conducted within his/her unit of the Laboratory. The Unit Head shall check all the results submitted to him/her to ensure that tests were carried out in accordance with standards and that calculations and graphs, where applicable, were done correctly.
- Second level quality checks shall be carried out by the Laboratory Manager. The Laboratory Manager is required to check at least 20 percent of all results submitted to him/her. This would normally include visual inspection of the sample tested, checking of calculations and an interpretive assessment of whether the results make sense. The Laborator Manager shall signify his/her quality checks by signing the sample results summary sheet.
- Third Level verification shall be conducted by the Project Officer or SRE on receipt of the factual report from the Laboratory. Where an interpretive report is not required, the PO or SRE is required to check at least 10

percent of all results submitted to him/her. Where an interpretive report is required, the PO or SRE is required to check all results submitted to him/her. The PO or SRE shall sign the final certification prior to transmission of reports to external clients through the HOD.

3.6.2 Quality Control

It has to be ensured that the testing being done is of high quality. Test results have to be checked to ensure that they are correct and also that all the testing requested has been done. This could be achieved by ensuring that:

- Only persons who have been trained to do a given test should be allowed to carry out that particular test.
- An experienced technician should supervise testing so as to ensure that the correct procedures are being followed. This would normally be a senior technician such as the UH.
- Testing details and results should be recorded on a standard form and signed off by the technician doing the testing.
- The UH or his appointed unit supervisor shall check all calculations for accuracy and ascertain that the correct testing procedures were followed. This may be done by means of a calculator or, if available, with a computer. Presently a variety of computer programs are available to calculate test results. Computers have the advantage that they are fast, accurate and can immediately store the test data. Drawing a graph by hand (say of a MDD/OMC curve) can be time consuming and is also not very accurate. A computer, on the other hand, will do this quickly, accurately and consistently.
- The UH shall also ensure that all the client's requirements have been met (all the testing and procedures requested) before submitting the test results to the Laboratory Manager.
- Should there be, in the opinion of the UH, any discrepancies concerning test results or procedures then re-testing may be required before submitting the test results to the laboratory manager.
- Any anomalies concerning the tests or the sample/materials shall also be reported to the LM.
- The LM shall ensure that the test results are within acceptable limits for the materials being tested and that the client's requirements have been satisfied.
- The LM could only forward the final report to the PO or client (through HOD) once he is satisfied of the correctness of the test results. Repeat testing should be carried out in the case where he is uncertain of the results.
- Check samples shall be put through the testing production line on a regular basis to verify that the testing is being done correctly as suggested below in Section 3.6.3. The test results of these samples should be within previously determined acceptable limits (Within the standard deviation values previously obtained for the test results of the particular method). Should this not be the case then the testing procedures and equipment used for the test must be investigated to ascertain the reasons for the discrepancy.
- Inter-laboratory studies should also be carried out on the more important test methods on a yearly basis.

Checking and verification of test results is an essential component of quality control.

3.6.3 Check samples

Use of check samples is a useful method for determining whether testing is being done correctly. Check samples are obtained by repeat testing of a sample by various technicians who are familiar with the test method being done. An average test result is thus obtained for a particular sample for a particular test or several results for several tests. The most likely test result and the expected variability for that sample is thus known.

This check or control sample may occasionally be sent for testing together with other samples that are being tested at the time. The check sample's result is then compared with the average result obtained earlier to determine whether or not the testing is being carried out correctly. Should this result be close to the average then the test is in all likelihood being carried out correctly. If, however, this is not the case then the cause of the error has to be ascertained. It is possible that the technician conducting the test is not following the test method exactly as prescribed or that he/she may simply require more training. There may also be an equipment problem.

3.7 Inter-laboratory study

3.7.1 General

Inter-laboratory study is a useful exercise for determining the quality and accuracy of outputs emanating from participating laboratories. Inter-laboratory study is also used to establish acceptable limits for test results.

Tests performed on presumably identical materials under so-called identical conditions do not, generally, yield identical results. This is attributed to unavoidable random errors inherent in every test procedure, because factors that may influence the outcome of the test cannot always be completely controlled.

In the practical interpretation of test data, and especially where these data are used for quality control purposes, this inherent variability has to be taken into account. If this is not done it could happen that the difference between a test result and a value specified by the contract may be within the scope of unavoidable random errors.

Some factors that may contribute to the variability of a test procedure are:

- The operator's skill.
- The equipment used.
- The calibration of the equipment.
- The testing environment.

3.7.2 Procedure

Samples that are used in inter-laboratory investigations are normally prepared by one laboratory and distributed to the other laboratories for testing so that the test method is examined and not the method of sample preparation, unless the sample preparation method is being investigated.

This inherent variability in testing procedures is normally expressed in terms of the repeatability and reproducibility of the testing procedure. Repeatability (r) refers to tests performed at short intervals in one laboratory by one operator, using the same equipment on one sample. Reproducibility (R) refers to tests performed in different laboratories on supposedly identical samples, which implies different equipment, different operators and a different testing environment.

Multi-laboratory precision (reproducibility) and inter-laboratory precision (repeatability) testing are usually carried out using not less than 8 laboratories. This is not always possible as there may not be that number of laboratories in the region carrying out the test method under investigation. For purposes of this Guideline, therefore, inter-laboratory testing shall involve not less than 3 laboratories.

Samples shall be prepared by CML and then distributed to participating laboratories for testing. The test results received from all laboratories (including

CML) shall then be statistically analysed in order to determine the repeatability and reproducibility values for the test method.

These values shall be used to identify laboratories whose test results are not within acceptable limits. After further investigation steps could be taken to rectify errors within those laboratories, whether these be procedural or equipment related. In addition, appropriate action must be taken to improve quality, as necessary.

3.8 Reporting Test Results

3.8.1 General

Once the testing has been completed and the results checked the test results have to be reported to the person that requested the testing.

Normally Clients are only interested in the final test results. Sometimes, however, as in a research environment the researcher is interested in all the details pertaining to the test. In such cases he/she will wish to see the working sheets as completed by the technician doing the work as well as a summary of the test results. Summaries of various test results should be made on sheets such as those shown in Appendix A.

A computer may be used to process the test results and normally in such a case the computer is programmed to provide a summary sheet of the test results as well as store the test data. When using a computer program to store test data it is advisable to always make backup copies of the results. This data should be stored safely until required.

It is important to keep all working sheets safely as queries often arise concerning possible mistakes etc. and these can be traced on the working sheets in the job file. This file should be kept, whether or not a computer is used to process and store test data, as it is not only the test data that is important but also all the correspondence, working sheets etc., concerning the job. The file should be kept in the laboratory filing system. The original documentation must remain in the file and only copies given out, if required.

3.8.2 Types of reports

The CML generates the following types of reports:

- Test result sheets with calculations produced by Materials Assistants or individuals carrying out the tests in each unit of the Laboratory. These reports relate to specific samples and contain primary data or test information and are presented on pre-determined forms (see Appendix A).
- Sample results summary sheets produced by Unit Heads. These summarise all of the tests results.
- Factual reports produced for sets of samples or a project are compiled by UH and LM.
- Interpretive report where required are produced by the PO or SREs. These reports are usually required by clients from sister Divisions especially Maintenance division and Development division, and other Government Departments such as Civil Aviation and Botswana Defence Force.

3.8.3 Checking and verification

As indicated in the tests sheets, each test sheet shall be checked and countersigned by the Unit Head. The LM shall check at least 20 per cent of all test sheets and initial those checked.

The Results summary sheet report shall be checked and countersigned by the LM.

It is not the duty of the laboratory to produce interpretative reports. The laboratory, however, shall produce factual reports summarising the results including any remarks or problems arising from the testing. Such reports originating from the Laboratory shall be checked and signed by the LM. The PO or SRE shall be responsible for compiling the interpretative report as and when required. A senior engineer shall check the report before it is submitted to the Client through the PRE.

The MRD reporting system, is described in Report no. IC 001.

3.8.4 Numbering of reports and Archive

Each test sheet report shall contain the same number as the sample number to which the results relate. The sheet will also contain a description of the project.

Each results summary sheet shall be numbered in accordance with the sample number to which it relates.

All reports produced within the MRD shall be numbered in accordance with "The Materials and Research Division Report System – Report Number IC 001)".

All reports shall be entered in a central report register maintained in the divisional library and a copy of the report deposited in the same library. An electronic copy of all factual reports is also to be retained in the divisional central database.

Results summary sheets are to be retained in the electronic database only.

Test or work sheets are to be retained for only 24 months after the tests were conducted or 12 months after the completion of construction which ever is the longer. After this period, test sheets may be disposed off by the UH with the consent of the LM, PO and HOD.

Summarised results shall be stored electronically in the CML database. Hard copy summary sheets shall be kept in the MRD archive for at least 10 years. The archived factual report shall be recorded in Form M3.3 (Appendix B).

3.8.5 Invoicing (if required)

Once the job has been completed to the customer's satisfaction an invoice must be sent to the customer. The invoice should specify what testing or other work was carried out and the cost of such work. The amount of the invoice and the date on which it was sent to the client must be recorded in the job register.

Internal clients may require cost estimates instead of invoices so as to determine full analysis of project costs.

3.9 Training Laboratory Assistants

The quality of the test data generated depends, to a large extent, on the skills of the Laboratory Assistant (LA). It is imperative that the technician doing a specific test is fully conversant with the test method and does the test to the best of his/her ability. The laboratory shall have an on-going training program to train technicians and ensure that skills levels are maintained.

The training program must allow the Laboratory Assistant to progress through the various test methods. This allows the Technical Assistant to "grow" in his job. The LA experiences a sense of growth, which is good for his self-esteem, job satisfaction and is ultimately of benefit to the organization.

The Technical Assistant should be trained on only one test method at a time to avoid confusion. He/she must be trained to do the test strictly according to the test method described in an approved testing standard (specification). Laboratory test results should be repeatable (should the test be repeated by the same person a similar result should be obtained) and reproducible (similar results should be obtained by another person in another Laboratory doing the same test on the same material). Repeatability and reproducibility can only be achieved if the standard method is followed exactly. The use of shortcuts or “tricks of the trade” not in the test specification must be discouraged.

It is advisable that the technician first tests check samples (Section 3.6.3) to determine whether he is doing the test correctly before allowing him/her to test samples for specific jobs.

Training records of Laboratory Assistants shall be properly kept. The records shall show what testing the LAs are trained to do. The training history shall be recorded in the Form M3.4 while training consultation shall be recorded in Forms M3.5(a), M3.5(b) and M3.5(c) (Appendix B).

3.10 Calibration and Checking of Equipment

3.10.1 General

From time to time it is necessary to check and calibrate the equipment used for testing. This is important to ensure that the test results obtained are accurate and repeatable.

Equipment used for testing has to be used carefully and according to the instructions pertaining to the particular equipment. Nonetheless, use of equipment, no matter how careful, results in some wear and thus periodic maintenance and calibration is essential.

It sometimes happens that there is insufficient work to keep all the staff fully occupied. This is the ideal time to check and calibrate equipment. This pertains only to equipment where specialized knowledge is not required for the purposes of calibration and checking, for example mould dimensions, checking the condition of sieves, checking the condition of compaction hammers etc. Equipment checking and calibration is, however, very important and must be done whether free time is available or not.

Some of the equipment that will most likely require checking and calibration on a regular basis is discussed below. The equipment calibration requirements shall be recorded in Form M3.6 (appendix B).

3.10.2 Balances

Balances must be checked regularly to ensure that they are performing according to specifications. The easiest way to do this is to use several weights of different masses (for balances having different weighing capacities) to determine the accuracy of the balances

The masses of these weights must be determined very accurately preferably by an institution that specialises in the calibration of equipment such as the South African Bureau of Standards (SABS), or the Division of Metrology at the CSIR. The weights must only be used for the purpose of calibration of scales and nothing else. To avoid their use for other purposes it is best that the weights be safely locked away.

The older mechanical or electro-mechanical balances need to be serviced regularly as they have many moving parts. These balances need to be serviced, by an appropriately qualified technician, approximately once a year.

Presently, most balances used at CML are of the electronic type. This type of balance generally requires less maintnance than the older mechanical type.

Figure 3.3: Sensitive balance on thick slate base to minimize vibrations.

There should be a specific bench for very sensitive balances. The sides of this bench are usually made of thick wood, concrete or brick and the top is usually a concrete slab or perhaps thick slate. The idea is to minimize vibrations that may affect readings (see Fig. 3.3). This is especially important in Chemical laboratories where small quantities of chemicals are used.

3.10.3 Compacting equipment

Compaction moulds like other equipments in the laboratory must be taken care of. Appropriate storage is imperative.

Figure 3.4: Worn compaction hammer with rounded face.

Compacting equipment such as compaction hammers, moulds etc. is especially prone to wear due to the nature of its use

Compaction hammers need to be checked regularly to determine whether they conform to specifications. The weight must be determined, the length of fall of the hammer must be measured and it must be checked that the hammer falls freely. It is also important to check that the hammer face is flat as this sometimes becomes rounded with use (see Fig. 3.4). The hammer should be discarded when this occurs. Where an automatic compaction machine is used the hammer should also be checked regularly as is the case with hand held hammers (weight, fall, free movement and hammer face). Most automatic compaction machines have a mechanism that rotates the mould or the hammer or both and the operation of these mechanisms should also be checked.

In most laboratories compaction moulds are weighed and the volume determined and this data recorded in a book. Each time the mould is used these mould values are re-used. The moulds are, however, subject to rusting and also chipping from blows of the compaction hammer. It is thus imperative that the weight and volume of the moulds be determined from time to time depending on use but not less than twice a year.

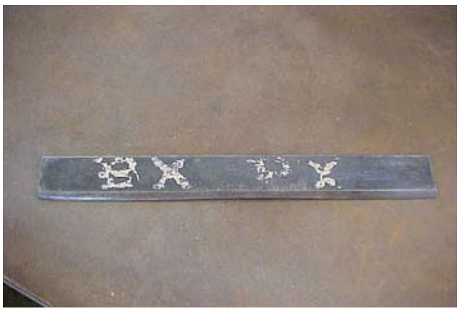


Figure 3.5: Straight edge that is no longer straight.

The steel straight edge that is used to cut off the excess material protruding from the mould after compaction must also be checked for wear. The straight edge tends to become rounded with use (see Fig. 3.5) and this results in the mould containing more material ie the mould volume effectively increases. When this happens the straight edge should be machined to a true straight edge.

Special care must be taken of moisture content tins to avoid rust.

The tins used for moisture content determinations are weighed and these values reused when the tins are used successively. The tins are especi-ally susceptible to rust and also accumulation of dirt and soil. Special care must be taken when cleaning the tins. They should also be weighed on a regular basis, depending on use, but not less than twice a year.

3.10.4 Sieves

Sieves have a limited life because of the wear that they are subjected to. The finer sieves (≤ 0.425mm) are especially vulnerable to the abrasive materials that pass through them. Sieves should be inspected regularly, at least once a month (depending on usage) to determine whether or not they need replacing. The 0.075 mm sieve is especially subjected to tearing and stretching of the sieve mesh and should be examined more regularly than other sieves. Once the sieve mesh has stretched (manifested as sagging in its frame) the sieve no longer conforms to specifications and must be replaced.

3.10.5 Atterberg Limit devices

The most important aspect is to calibrate the instrument so that the fall of the cup is exactly according to the specified 10 mm fall. This should be done before any sample is tested and is normally obtained by using the back of the grooving tool, which is usually designed for this purpose.

With use a groove usually develops inside the Cassagrande cup (bowl of apparatus), which is caused by cutting the sample in the cup with the grooving tool. When this groove is too large it may affect test results. When this occurs the cup should be machined to remove the groove or preferably replaced.

The cam that is part of the mechanism that lifts the cup also wears with time and this should be machined so that it has a sharp edge at the end of the cam.

The fall of the cup on the hard rubber base plate causes an indentation at the point of contact (see Fig. 3.6). When the indentation is too big it is no longer possible to set the cup height accurately and this, therefore, affects the result obtained. At this time the cup base should be machined or replaced. With some devices it is also possible to turn the base around so that the bottom faces upwards. It is also sometimes possible to move the cam/hinge mechanism forward or backward on the base so that the point of contact between the cup and base changes to a point where the base is flat.

Figure 3.6: Indentation on the rubber base of the Atterberg Liquid Limit device caused by the fall of the cup and a worn out spatula. Such deformed equipment should be removed from the laboratory.

The tool used to cut the groove in the material in the Cassagrande cup is also subject to wear with regular use. The cutting edge of the tool should be 2 mm wide. This tends to widen with use and at this point the tool is no longer suitable and should be discarded.

The linear shrinkage troughs used for linear shrinkage determinations are sometimes inadvertently damaged. These should be checked for dents, shape etc before being used.

It must be ensured that the correct Casagrande apparatus is used for the test. The hardness of the base materials differ, for example, the apparatus specified by ASTM uses a harder base than does the BS apparatus.

It must be ensured that the correct Casagrande apparatus is used for the test. The hardness of the base materials differs, for example, the apparatus specified by ASTM uses a harder base than does the BS apparatus.

3.10.6 Ovens

The ovens' thermostat should be checked periodically to ascertain whether or not it is working properly. This is best done by putting a thermometer in the oven and checking that the thermometer reading is similar to the thermostat reading. It is in any event good practice to keep a thermometer in the oven so that there is a constant check on the oven temperature. Most ovens have a hole in which a thermometer can be permanently kept (see Fig. 3.7). A fan is present in most ovens (especially larger ones) to provide air circulation and thus equalise the temperature throughout the oven. It should be checked that this is working properly. The door seal of the oven must also be inspected periodically to ensure that it is not broken or defective in any way.

3.10.7 pH electrodes

Figure 3.7: Thermometer positioned through hole on top of oven to check oven temperature directly.

The electrodes used in pH determinations have a limited life span, this being dependent on the solutions tested. Very high and very low pH solutions considerably shorten the life span of the electrodes. The electrodes have thus to be checked regularly using buffer solutions to ascertain whether or not they are still functioning properly. The calibration values of the electrodes change with usage and it is thus best to re-calibrate the electrode each day. Electrodes not in use must be placed in a solution suggested by the manufacturer and must never be allowed to dry out.

The manufacturer's instructions, which are usually supplied with the electrodes, should be followed to ensure that correct results are obtained and that the electrode has a relative long life. Replacement of electrodes is costly.

3.10.8 Thermometers

Thermometers have to be highly accurate for certain types of testing such as the bitumen tests discussed in Part C. It is best to have these thermometers calibrated by the institutions mentioned earlier (see section 3.10.2). New thermometers may then be checked against the calibrated thermometers to determine whether or not they are performing satisfactorily.

3.10.9 Distilled Water

Distilled water is often used in the laboratory. The quality of the distilled water being produced by the water still must be checked periodically. It may happen that some form of contamination has occurred. Also, vessels that are used to store distilled water must be thoroughly cleaned from time to time and should be used for no purpose other than keeping distilled water.

3.10.10 Presses

Presses such as those used for CBR and UCS testing must be calibrated regularly, preferably once a year. This should be done by reputable institutions such as the SABS, CSIR and others. Where this is not possible the presses should be checked with a proving ring that has been calibrated by one of the institutions mentioned. A calibrated load cell may also be used for this purpose.

Proving rings that are used regularly also need to be calibrated. This is a specialised job and can only be done by institutions such as those mentioned previously.

Many more equipment and tools than the items mentioned in this section need to be calibrated and checked. It is however, impractical to discuss them all. The important point to remember is that good test results are very dependent on equipment that is calibrated and in good working order. Calibration and checking of equipment is something that technicians and managers should always bear in mind.

Some of the equipment that should be calibrated and/or checked and the frequency with which this should be done are listed in Table 3.1.

Complete records of all calibrations must be kept.

Table 3.1: Laboratory Equipment that needs frequent calibration and/or checking.

EQUIPMENT	ACTION	FREQUENCY
Balances, Scales and weights	Calibrate	12 months
Test thermometers	Calibrate	6 months
Analytical balances and weights	Calibrate	24 months
Viscometers	Calibrate	36 months
Kneading compactor	Calibrate	36 months
Timers	Check accuracy	24 months
Ovens	Verify temperature settings	3 months
Penetrometer: Dial, needles, timer	Check condition	24 months
Ductility apparatus	Check speed of travel	24 months
TFO & RTFO oven shelf/carriage	Check rotation speed	24 months
Compression or loading device	Verify load indications	12 months
	Check squareness of setting platens	12 months
	Check that correct load ratings are applied for different sizes of specimen.	Daily
Mechanical compactor	Calibrate	6 months
Moulds	Check critical dimensions	12 months
Manual hammer	Check weight & critical dimensions	3 months
Sieves	Check condition	6 months for sieves larger than 0.425mm Monthly for ≤ 0.425mm sieves
Loss Angels Abrassion. machine	Check R.P.M, dimensions and weight of Steel balls	24 months
Vacuum system	Check pressure	24 months
Atterberg Limit device	Check fall and indentation	Daily
Conductivity Meter	Calibrate	6 months
Nuclear Gauges	Leak Test	6 months
	Check for conformity with sand replacement density test	Monthly
	Calibrate	When the above checks give erroneous results or 24 months whichever is less.

3.10.11 Equipment records

It is advisable to keep a register of all the laboratory equipment. This register should contain information such as; date of purchase of equipment, name and other details of the supplier, details of repairs, and maintenance and calibration of such equipment etc. It is also important to keep a file containing all the instruction manuals of the laboratory equipment.

3.11 Sample Storage and Disposal

Samples shall be stored in accordance with Section 3.3.

3.11.1 Soil Samples

The sample shed shall be maintained in a dry and clean state, free of water leakage. The floor of the shed shall be paved with concrete paving blocks.

Soil samples received by the laboratory shall be stored in the sample shed in clearly defined tidy rows. Each row shall be clearly identified by a board. The board shall contain the name of the project from which samples in that row originate and the name of the PO responsible for the project. The sample bag nomenclature currently used by the laboratory shall be used.

The Sample Receiving and Preparation Unit shall maintain the sample storage and preparation areas in a clean state at all times.

The remainder of tested soil samples shall be returned to and kept in their original sample bags. These samples shall be disposed off after 6 months of their testing unless instructed otherwise by the LM or the PO. The UH for the Sample Receiving and Preparation Unit shall be responsible for the disposal of tested soil samples.

Due to the limited storage space and the untidy nature of the waste soil samples it is prudent that a tidy disposal system such as "Skip hire" is engaged. Such a system has the advantage of regular collection and would therefore make more space available for sample preparation.

3.11.2 Aggregate samples

Stone and aggregate samples shall be stored and disposed off as per Section 3.11.1 of this guideline.

3.11.3 Water, Concrete, Bitumen, Brick and other samples

The Laboratory Manager shall, in liaison with the Project Officer, determine the sample storage and disposal requirements for sample other than soil and aggregate samples.

The Waste Disposal Act (1998) shall be fully adhered to especially with regard to the disposal of chemicals. No chemicals shall be disposed off without written authority of the LM. Where in doubt, the Department of Sanitation and Waste Management shall be consulted.

3.12 Computer Software

All requests for new software, whether produced in-house, "off the shelf" or written specifically for the CML, shall be referred to the Head of Division for approval.

New software shall be passed to the Computer Officer (CO) who is responsible for control of all software in the Laboratory.

- The CO shall be responsible for loading all new software onto the computers within the laboratory.
- The CO shall maintain a master list of all approved software held within the laboratory, which shall indicate the release or version reference of the software package.
- The master list shall indicate which software is loaded on which computer and shall be completed and signed by the CO each time a new software package is loaded onto or unloaded from any computer.
- Prior to approval by the CO for use, all technical software shall be validated by reference to hand calculated worked examples.
- Validation of technical software shall be the responsibility of the Head of Division who may delegate this authority to the Laboratory Manager or a Senior Engineer
- Problems encountered with a particular software package shall be referred to the CO who shall be responsible for ensuring that corrective action is taken either in-house or, where applicable, under a software maintenance contract.

The CO shall be responsible for maintaining the master disks for all approved software in storage and ensure that back ups of computer data are performed on regular basis. The computer backups shall be logged using Form M3.7 (Appendix B).

The Laboratory Manager shall be responsible for removing obsolete controlled reference documents from the library.

Where an obsolete document is required for reference purposes, the Laboratory Manager shall mark it as superseded and file it separately.

The Laboratory Manager, in consultation with Senior Engineers (SRE's and/or PRE's) and Head of Division, shall be responsible for maintaining subscriptions for technical standards for laboratory testing and ensuring that the Laboratory is updated with new, widely approved test methods.

3.13 Quality Audits

3.13.1 Scope

To ensure that the operating procedures guideline remains efficient and effective economic and complies with the requirements of the Laboratory and International Standards.

3.13.2 Procedure

Operating Procedures Quality Audit (OPQA) shall be scheduled by the Operating Procedures Manager (OPM) at maximum intervals of two years and shall be conducted by an Engineer of Principal Roads Engineer grade or higher.

Prior to the OPQA, a meeting comprising the LM, UHs and the OPM shall be held to enable the OPM to appreciate the concerns of implementers of the guideline.

The OPQA meeting shall address the effectiveness of the operating procedures guideline in meeting the requirements of CML particularly in terms of client complaints and satisfaction.

The register of client complaints shall be reviewed at each OPQA meeting and the close out of each complaint recorded on the register. The action taken since the last OPQA to address each complaint shall be recorded. (See Forms M1.4, M1.5, M1.6, M1.7 and M2.2 in Appendix B).

The OPQA meeting shall also address future quality strategy, which may be influenced by:

- New products or equipment.
- New Client requirements.
- Changes in the work place.
- Changes in testing standards and specifications.

Any actions adopted by the OPQA meeting resulting in changes to the operating procedures guideline shall be delegated to a senior member of staff and monitored until completion by the OPM.

The UH or LM shall prepare minutes of each OPQA meeting showing items discussed, corrective actions to be carried out and responsibilities for following up and closing out corrective actions.

PART C

4 LABORATORY TESTS

4.1 Introduction

This part of the guideline summarizes various laboratory tests, which are routinely carried out at CML. It is not the intention of this chapter to reproduce testing procedures/methods but rather to highlight pertinent points on the affected tests.

Sampling from large quantities of material shall be done by riffling or quartering according to Testing Methods for Highways 5 (TMH 5), to obtain manageable amounts of material required for testing. This shall be done on a clean hard dry surface, preferably a concrete slab, or on a large tarpaulin made of a thick durable material.

The specific quantities of material required for various tests shall be obtained by using a riffler having the correct size openings as specified by the test method.

Sample preparation should be done according to TMH 1 with the following exceptions:

- Where the person requesting the testing asks for a different method of preparation.
- Only the wet preparation method (TMH1: Method A1(a)) shall be followed except where otherwise requested.

4.2 Project Definitions, Name Convention and Internal Project Officer

Each sampling or testing work undertaken by CML shall be linked to a 'Project' and each project shall have a Project Officer, (PO) with MRD (Section 2.8.2). The primary reference number for all samples processed through the laboratory shall be the Project Reference and the primary responsibility for all action relating to the testing including determination of testing and reporting requirements shall rest with the PO. The PO is also the internal client to whom the Lab. Manager reports/discusses any issues pertaining to the sample.

A 'project' may be a major road project such as Artesia-Dibete rehabilitation involving the testing of many samples or it may be a small project comprising a single or a few sample(s).

The Project Name shall be the first three letters of the start and end of the project to which the material samples relate.

The sample number shall include project name as a prefix and the sample number as a suffix. Up to 10 Characters are allowed for any sample number in a given project. The letters shall comprise the first 3 characters of the project start, followed by a hyphen and the first 3 characters of the project end. The number shall start at 001 and increase sequentially to the last sample of the given project.

Example: The 173rd sample from Artesia – Dibete Road Rehabilitation project would be named; **Art-Dib 173.**

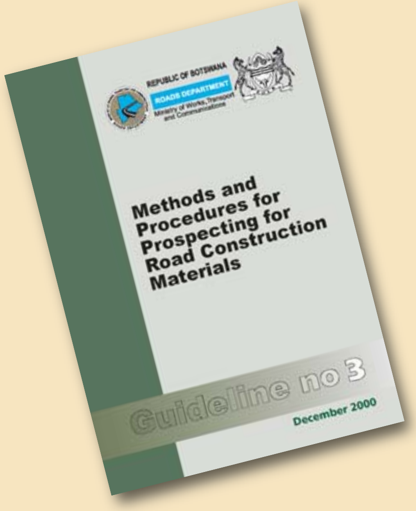
4.3 Sample Receipt and Logging

All samples delivered to the laboratory by external clients shall be accompanied by a covering letter or sample submission form for internal clients (Form M2.1 in Appendix B) addressed to PRE – Materials and Research Division with a minimum of the following information:

- Name, address and contact details of the sender.
- Description and number of samples sent and the project to which they relate.
- Purpose of sampling and required tests (if known).
- Date by which results are required and whether interpretation is required.

No sample shall be received without a letter or submission form. Where the sample is submitted without a submission form, the Sample Receiving Officer (SRO), shall store the sample in the shed and inform the LM immediately. The LM shall cause the error or omission to be corrected as appropriate. Where the error could not be corrected, the sample shall be kept for 4 calendar weeks and then disposed off.

All samples delivered to the Laboratory shall be received and logged by the sample-receiving officer (There may be more than one nominated sample receiving officer). The information required for logging (in accordance with Guideline Number 3-"Methods and Procedures for Prospecting for Road Construction Materials") shall be detailed in the Sample book.



More details regarding sample description can be found in Guideline number 3 "Methods and Procedures for Prospecting for Road Construction Materials".

4.4 Sample Numbering

The sample numbering convention, as detailed in section 4.2 above, shall be followed for all samples received into the laboratory.

4.5 List of Tests

Tests carried out by CML are listed in Table 4.1. The table also gives the standard specification that should be referred to for more details on the test. These tests are discussed further in some detail in Section 4.8 through section 4.12 and in Section 5, Field Tests.

4.6 Quantities of Materials Required

The approximate quantities of materials required to perform the various tests are given in Table 4.2.

4.7 Resources for Carrying out Tests and Expected Output

The time taken to do a specific test is very dependent on the material type and also the skill of the operator as well as the equipment available (number of pans, sieves, ovens etc.). Proper planning will also improve efficiency and therefore reduce testing time.

The resources indicated in Table 4.3 should be considered at best a rough guide of the number of tests that can be carried out in a given time period. Some activities such as sample preparation or tests such as Atterberg Limit determinations span over several days because of drying time in the oven.

Table 4.1: Tests carried out by the CML and the standard specifications followed.

CML TEST NUMBER	TEST DESCRIPTION	STANDARD	TEST NUMBER
	Soils Tests (S)		
S1	Sieve Analysis of Gravel, Sand and Soil Samples		
	Wet Preparation	TMH1	A1 (a)
	Dry Preparation	TMH1	A1 (b)
	Material Passing the 0.075 mm Sieve	TMH1	A5
	Hydrometer Analysis	TMH1	A6
S2	The Determination of the Liquid Limit of Soils	TMH1	A2
S3	The Determination of the Plastic Limit And Plasticity Index of Soils	TMH1	A3
S4	The Determination of the Bar Linear Shrinkage of Soils	TMH1	A4
S5	The Determination of the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of Soils	TMH1	A7
S6	The Determination of the California Bearing Ratio (CBR) of Untreated Soils	TMH1	A8
S7	The Determination of the Unconfined Compressive Strength (UCS) of Stabilized Soils, Gravels and Sands	TMH1	A14
S8	The Determination of One-Dimensional Consolidation Properties of Soils	ASTM	D2435
S9	The Identification of Dispersive Soils Using Crumb Test	BS 1377	1990
S10	The Determination of Durability for Cement-Treated Materials	TMH 1	A19
S11	The Electrometric Determination of the pH Value of a Soil Suspension	TMH 1	A20
S12	The Determination of the Electrical Conductivity of Saturated Soil Paste and Water	TMH 1	A21T
S13	The Determination of the Initial Consumption of Lime (ICL)	BS 1924	Part 2
S14	The Determination of the Sand Equivalent Value of Soils and Fine Aggregates	AASHTO	T176-00
S15	The Direct Shear Test of Soils	ASTM	D 3080-72
S16	The Determination of Shear Strength of Soils under Unconsolidated Undrained, Consolidated Drained and Consolidated Undrained conditions in Tri-Axial Compression	AASHTO	T 296-95
S17	The Determination of the Dry Density/Moisture Content Relationship of Granular Soil (Vibratory Hammer Method)	BS 1377	
	Aggregates Tests (AG)		
AG1	Sieve Analysis of Aggregates, including the Determination of Material Passing the 0.425 mm sieve and 0.075 mm Sieve	TMH1	B4
AG2	The Determination of the Aggregate Crushing Value (ACV)	TMH1	B1
AG3	The Determination of 10 Per Cent Fines Aggregate Crushing Test (10% FACT)	BS 812	Part 3
AG4	The Determination of Aggregate Impact Value (AIV)	BS 812	Part 3
AG5	Assessment of Aggregate Durability Using the Durability Mill Test	SATCC (1988)	
AG6	The Determination of the Flakiness Index of Coarse Aggregates	TMH1(1986) or BS 812	B3 Part 1
AG7	The Determination of the Adhesion of Bituminous Binder to Stone Aggregate by Means of the Chemical Immersion Test (Riedel And Weber)	TMH1	B11
AG8	The Determination of Dry Bulk Density, Apparent Relative Density and Water Absorption of Aggregates Retained on the 4.75 mm Sieve and Passing the 4.75 mm Sieve	TMH1	B14 and B 15
AG9	The Determination of the Accelerated Laboratory Polished Stone Value (PSV)	BS 812	Part 3
AG10	The Determination of the Aggregate Fingers Value and the Aggregate Pliers Value	CSIR	CB 22

Table 4.1: continued.

CML TEST NUMBER	TEST DESCRIPTION	STANDARD	TEST NUMBER
	Bitumen Tests (B)		
B1	The Determination of the Penetration Value of Bituminous Binders	ASTM	D5
B2	The Determination of the Ductility of Bitumen	ASTM	D113
B3	The Distillation of Cutback Bitumen	ASTM	D402
B4	The Determination of the Softening Point of Bituminous Binders by the Ring and Ball Method	ASTM	D36
B5	The Determination of the Kinematic Viscosity of Cutback Bitumen	ASTM	D2170
B6	The Performance of Bitumen When Subjected to the Thin Film Oven Test (TFO)	ASTM	D1754
B7	The Performance of Bitumen When Subjected to the Rolling Thin Film Oven Test (RTFO)	ASTM	D2872
B8	The Determination of the Percentage of Bitumen Soluble in Trichloro-Ethylene	ASTM	D2042
	Concrete Tests (C)		
C1	The Making Curing and Compressive Strength Determination of Concrete Test Cubes	TMH1	D1
C2	The Determination of the Slump of Freshly Mixed Concrete	TMH1	D3
	Asphalt Tests (AS)		
AS1	The Determination of a Suitable Binder Content for use in an Asphalt Mix	TMH1	C1
AS2	The Determination of the Binder Content of a Bituminous Mixture	TMH1 ASTM	C7 D1856
AS3	The Determination of the Bulk Relative Density of a Compacted Bituminous Mixture and the Calculation of the Voids Content	TMH1	C3
AS4	The Determination of the Resistance to Flow of a Cylindrical Briquette of a bituminous mixture by Means of the Marshall Apparatus	TMH1 ASTM	C2 D1559
AS5	The Determination of the Maximum Theoretical Relative Density of Asphalt Mixes (Rice's Method) and the Quantity of Bituminous Binder Absorbed by the Aggregates	TMH1 ASTM	C4 D2041
	Field Tests (F)		
F1	The Determination of In Situ Strength of Soils using the Dynamic Cone Penetrometer (DCP)	TMH6	ST6
F2	The Determination of the Radius of Curvature of a Road Pavement using Deflection Measurements	TMH6	ST9
F3	The Determination of In Situ Dry Density of Soils or Gravels using Sand Replacement Methods	TMH1	A10 (a)
F4	The Determination of the In-Situ Dry Density and Moisture Content of Soils or Gravels by Nuclear Methods	TMH1	A10 (b)
F5	Measurement of the Texture Depth of a Road Surface	TMH1	ST 1
F6	Measurement of Road Roughness Using The Merlin Apparatus	TRRL	
F7	Method for Determining the Point Load Strength Index	ISRM	
F8	Rapid Field Test For Determining The Carbonation of Lime or Cement Treated Materials	CSIR	RS/2/84
F9	Visual Assessment of Flexible Pavements	TMH 9	
F10	Visual Assessment of Unsealed Roads	TMH 12	
F11	Non-Repetitive Static Plate Load Test for Soils and Flexible Pavements	AASHTO	T222-81
F12	The In-Situ Evaluation of Base Course Materials by Means of the Clegg Hammer	ARRB (1996)	Vol. 8
F13	The Modified Tray Test for Chip Seals	TRH 3	Appendix L
F14	Determination of the Moisture in Soils By Means of a Calcium Carbide Gas Pressure Moisture Tester	TMH1	C1

Table 4.2 Approximate quantities of materials required for the various tests.

CML TEST NUMBER	TEST DESCRIPTION	Approximate Quantity (kg or g)
	Soil tests	
S1	Sieve analysis of Gravel, Sand and Soil Samples	5kg
	Wet preparation	
	Dry preparation	
	Material passing the 0.075 mm sieve	
	Hydrometer analysis	
S2	The Determination of the Liquid Limit of Soils	250g (-0.425 mm)
S3	The Determination of the Plastic Limit and Plasticity index of Soils	
S4	The Determination of the Bar Linear Shrinkage of Soils	
S5	The Determination of the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of Soils	35kg
S6	The Determination of the California Bearing Ratio (CBR) of Untreated Soils	22kg
S7	The Determination of the Unconfined Compressive Strength (UCS) of Stabilized Soils, Gravels and Sands	22kg
S8	The Determination of One-Dimensional Consolidation Properties of Soils	Undisturbed sample
S9	The Identification of Dispersive Soils Using Crumb Test	A few lumps
S10	The Determination of Durability for Cement-Treated Materials	50kg
S11	The Electrometric Determination of the pH Value of a Soil Suspension	50g (-0,425mm)
S12	The Determination of the Electrical Conductivity of Saturated Soil Paste and Water	250g (-6,7mm)
S13	The Determination of the Initial Consumption of Lime (ICL)	2kg
S14	The Determination of the Sand Equivalent Value of Soils and Fine Aggregates	1kg (-4,75mm)
S15	The Direct Shear Test of Soils	2kg
S16	The Determination of Shear Strength of Soils under Unconsolidated Undrained, Consolidated Drained and Consolidated Undrained conditions in Tri-Axial Compression	5kg
S17	The Determination of the Dry Density/Moisture Content Relationship of Granular Soil (Vibratory Hammer Method)	40kg
	Aggregates Tests (AG)	
AG1	Sieve Analysis of Aggregates, including The Determination of Material Passing the 0.425 mm sieve and the 0.075 mm Sieve	Depends on nominal size of aggregates
AG2	The Determination of the Aggregate Crushing Value (ACV)	Enough to fill the test cylinder
AG3	The Determination of 10 Per Cent Fines Aggregate Crushing Value (10% FACT)	
AG4	The Determination of Aggregate Impact Value (AIV)	1kg (-13.2,+9.5mm)
AG5	Assessment of Aggregate Durability Using the Durability Mill Test	20kg
AG6	The Determination of the Flakiness Index of Coarse Aggregates	5kg
AG7	The Determination of the Adhesion of Bituminous Binder to Stone Aggregate by Means of the Chemical Immersion Test (Riedel And Weber)	100g (-6.7,+4.75 mm)
AG8	The Determination of Dry Bulk Density, Apparent Relative Density and Water Absorption of Aggregates Retained on the 4.75 mm Sieve and Passing the 4.75 mm Sieve	5kg
AG9	The Determination of the Accelerated Laboratory Polished Stone Value (PSV)	1.5kg(-10+8mm)
AG10	The Determination of the Aggregate Fingers Value and the Aggregate Pliers Value	300 stones (-19 +13,2mm)

Table 4.2: continued.

CML TEST NUMBER	TEST DESCRIPTION	Approximate Quantity (kg or g)
	Bitumen Tests (B)	
B1	The Determination of the Penetration Value of Bituminous Binders	100g
B2	The Determination of the Ductility of Bitumen	100g
B3	The Distillation of Cutback Bitumen	200g
B4	The Determination of the Softening Point of Bituminous Binders using Ring and Ball Method	20g
B5	The Determination of the Kinematic Viscosity of Cutback Bitumen	10g
B6	The Performance of Bitumen When Subjected To The Thin Film Oven Test (TFO)	250g
B7	The Performance of Bitumen When Subjected to The Rolling Thin Film Oven Test (RTFO)	300g
B8	The Determination of the Percentage of Bitumen Soluble in Trichloro-Ethylene	10g
	Concrete Tests	
C1	The Making Curing and Compressive Strength Determination of Concrete Test Cubes	30kg
C2	The determination of the slump of freshly mixed concrete	10kg
	Asphalt Tests	
AS1	The Determination of a suitable Binder Content for use in an Asphalt Mix	25kg
AS2	The Determination of the Binder Content of a Bituminous Mixture	1.5 kg (briquette)
AS3	The Determination of the Bulk Relative Density of a Compacted Bituminous Mixture and the Calculation of the Voids Content	Briquette
AS4	The Determination of the Resistance to Flow of a Cylindrical Briquette of a bituminous mixture by Means of the Marshall Apparatus	5kg (3 briquettes)
AS5	The Determination of the Maximum Theoretical Relative Density of Asphalt Mixes (Rice's Method) and the Quantity of Bituminous Binder Absorbed by the Aggregates	1.5 kg (briquette)
	Field Tests (F)	
F13	The Modified Tray Test for Chip Seals	2 kg

Table 4.3: Approximate resources required to carry out tests and output per day or per week.

CML TEST NUMBER	TEST DESCRIPTION	Number of persons	Number of tests per time period
	Soil Tests		
	Riffling 50 kg bags	2	10 per day
S1	Sieve Analysis of Gravel, Sand and Soil Samples (prepared material)	1	12 per day
	Wet preparation	1	25 per week
	Dry preparation	1	35 per week
	Material passing the 0.075 mm Sieve	1	20 per day
	Hydrometer analysis	1	12 per day
S2	The Determination of the Liquid Limit of Soils	1	10 per day
S3	The Determination of the plastic Limit and Plasticity index of Soils		
S4	The Determination of the Bar Linear Shrinkage of Soils		
S5	The Determination of the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of Soils	2	5 per day
S6	The Determination of the California Bearing Ratio (CBR) of Untreated Soils	2	7 per day (compaction)
			7 per day (testing)
S7	The Determination of the Unconfined Compressive Strength (UCS) of Stabilized Soils, Gravels and Sands	2	8 per day (compaction)
			8 per day (testing)
S8	The Determination of One-Dimensional Consolidation Properties of Soils	1	1 Per apparatus per week
S9	The Identification of Dispersive Soils Using Crumb Test	1	50 per day
S10	The Determination of Durability for Cement-Treated Materials	2	Spec prep – 6 per day
		1	Testing – 10 per day
S11	The Electrometric Determination of the pH Value of a Soil Suspension	1	30 per day
S12	The Determination of the Electrical Conductivity of Saturated Soil Paste and Water	1	20 per day
S13	The Determination of the Initial Consumption of Lime (ICL)	1	12 per day
S14	The Determination of the Sand Equivalent Value of Soils and Fine Aggregates	1	6 per day
S15	The Direct Shear Test of Soils Under Consolidated Drained Conditions	1	1 Per apparatus per day
S16	The Determination of Shear Strength of Soils under Unconsolidated Undrained, Consolidated Drained and Consolidated Undrained conditions in Tri-Axial Compression	1	1 Per apparatus per week
S17	The Determination of the Dry Density/Moisture Content Relationship of Granular Soil (Vibratory Hammer Method)	2	5 per day
	Aggregates Tests (AG)		
AG1	Sieve Analysis of Aggregates, including The Determination of Material Passing the 0.425 mm Sieve and the 0.075 mm Sieve	1	12 per day
AG2	The Determination of the Aggregate Crushing Value (ACV)	2	12 per day
AG3	The Determination of 10 Per Cent Fines Aggregate Crushing Test (10% FACT)	2	4 per day
AG4	The Determination of Aggregate Impact Value (AIV)	1	8 per day
AG5	Assessment of Aggregate Durability Using the Durability Mill Test	1	6 per day
AG6	The Determination of the Flakiness Index of Coarse Aggregates	1	6 per day
AG7	The Determination of the Adhesion of Bituminous Binder to Stone Aggregate by Means of the Chemical Immersion Test (Riedel And Weber)	1	4 per day
AG8	The Determination of Dry Bulk Density, Apparent Relative Density and Water Absorption of Aggregates Retained on the 4.75 mm Sieve and Passing the 4.75 mm Sieve	1	24 per week
AG9	The Determination of the Accelerated Laboratory Polished Stone Value (PSV)	1	30 per day
AG10	The Determination of the Aggregate Fingers Value and the Aggregate Pliers Value	1	3 per week

Table 4.3: continued.

CML TEST NUMBER	TEST DESCRIPTION	Number of persons	Number of tests per time period
	Bitumen Tests		
B1	The Determination of the Penetration Value of Bituminous Binders	1	25 per day
B2	The Determination of the Ductility of Bitumen	1	15 per day
B3	The Distillation of Cutback Bitumen	1	3 per day
B4	The Determination of Softening Point of Bituminous Binders using Ring and Ball method	1	20 per day
B5	The Determination of the Kinematic Viscosity of Cutback Bitumen	1	6 per day
B6	The Performance of Bitumen when subjected to the Thin Film Oven Test (TFO)	1	2 per day
B7	The Performance of Bitumen when subjected to the Rolling Thin Film Oven Test (RTFO)	1	4 per day
B8	The Determination of the Percentage of Bitumen Soluble in Trichloro-Ethylene	1	5 per day
	Concrete Tests		
C1	The Making, Curing and Compressive Strength Determination of Concrete Test Cubes (3 replicates), (Prepared materials)	2	2 per day (compaction) 8 per day (testing)
C2	The Determination of the Slump of Freshly Mixed Concrete	1	10 per hour
	Asphalt Tests (AS)		
AS1	The Determination of a Suitable Binder Content for use in an Asphalt Mix	2	3 days
AS2	The Determination of the Binder Content of a Bituminous Mixture	1	5 per day
AS3	The Determination of the Bulk Relative Density of a Compacted Bituminous Mixture and the Calculation of the Voids Content	1	5 per day
AS4	The Determination of the Resistance to Flow of a Cylindrical Briquette of a bituminous mixture by means of the Marshall apparatus	1	30 per day
AS5	The Determination of Maximum Theoretical Relative Density of Asphalt Mixes (Rice's method) and Quantity of Bituminous Binder Absorbed by the Aggregates	1	6 per day
	Field Tests (F)		
F1	The Determination of In-Situ Strength of Soils using the Dynamic Cone Penetrometer (DCP)	3	½ hour per test
F2	The Determination of the Radius of Curvature of a Road Pavement using Deflection Measurements	3	½ hour per point
F3	The Determination of In-Situ Dry Density of Soils or Gravels using Sand Replacement Methods	1	1 hour per test
F4	The Determination of In-Situ Dry Density of Soils or Gravels using Nuclear Methods	1	½ hour per point
F5	Measurement of the Texture Depth of a Road Surface	2	1 hour per point
F6	Measurement of Road Roughness Using The Merlin Apparatus	1	2 km per hour
F7	Method for Determining the Point Load Strength Index	1	10 per day
F8	Rapid Field Test For Determining The Carbonation of Lime Or Cement Treated Materials	2	1 hour per test
F9	Visual Assessment of Flexible Pavements	1	1 km per hour (1 lane)
F10	Visual Assessment of Unsealed Roads	1	1 km per hour
F11	Non-Repetitive Static Plate Load Test for Soils and Flexible Pavements	2	3 hours per test
F12	The In-Situ Evaluation of Base Course Materials by Means of the Clegg Hammer	1	5 min's per point
F13	The Modified Tray Test for Chip Seals	1	8 tests per day
F14	Determination of the Moisture in Soils By Means of a Calcium Carbide Gas Pressure Moisture Tester	1	4 tests per hour

NB: The resources and time for processing the results is not included. Preparation of material for testing also not included in tests (e.g. Fines for Atterberg Limits - see sample preparation). Time taken to do many of the tests is dependent on material properties.

For the field tests, people required for traffiic safety reasons are NOT included.

4.8 Soils Tests

4.8.1 CML TEST NO. S1:

Sieve analysis of Gravel, Sand and Soil Samples

The Hydrometer test is necessary where it is important to know the distribution of particles smaller than 0.075 mm sieve, for instance where it is necessary to determine the heave potential of soil using Van der Merwe's curves. This test shall be carried out by a trained and skilled operator.

Scope:
The test involves the quantitative determination of particle size distribution in an essentially cohesionless soil down to fine sand size.

In the wet preparation procedure the sample is wet sieved to remove silt and clay sized particles followed by dry sieving of the remaining coarse material.

Definition:
Sieve analysis is an important classification test for soils, especially coarse soils, as it presents the relative portion of different sizes of particles. From this it is possible to determine whether the soil consists of predominantly gravel, sand, silt or clay sizes.

Procedure:
The following procedures shall be used as appropriate.

Wet preparation:	method **A1 (a): TMH 1:1986**
Dry preparation:	method **A1 (b): TMH 1:1986**
Material passing 0.075 mm sieve:	method **A5 TMH 1:1986**
Hydrometer analysis:	method **A6 TMH 1:1986.**

Notes:
- The decision of whether to use dry preparation or wet preparation shall be taken by the Laboratory Manager after consulting the Project Officer.
- The test sieves must be inspected for defects before use. A more detailed examination shall be made at regular intervals for signs of wear and tear, splits, holes, blockages etc.

4.8.2 CML TEST NO. S2:

The Determination of the Liquid Limit of Soils

Scope:
The liquid limit (LL) of a soil is determined from the liquid limit device by plotting a curve of the number of taps necessary to obtain a specific consistency of the soil fines against the moisture contents in three trials. The method also provides for the calculation of the liquid limit from a one-point determination if so required.

Definitions:
The liquid limit of a soil is the moisture content, expressed as a percentage of the mass of the oven-dried soil, at the boundary between the liquid and the plastic states. The moisture content at this boundary is arbitrarily defined as the liquid limit and is the moisture content at a consistency determined by means of the standard liquid limit apparatus.

Procedure:
Shall be carried out in accordance with method **A2: TMH1: 1986.**

Notes:
- It is very important to note that under the TMH1 procedure, liquid limit is carried out using the Casagrande device. The base of the device must be made of hard rubber with a Shore D value of 85 to 95 at 23±2ºC.
- The Unit Head shall ensure that only equipment that conforms to the specification is used.

- The Unit Head shall carry out general inspection of the apparatus at least once a month.
- The bowl and the hard rubber base of the liquid limit device shall be inspected by the Unit Head regularly, as they tend to wear readily.
- If the bowl is badly worn, it shall be replaced.
- If the base is badly worn, it shall be reversed or machined off level or replaced.
- Use of a BS Liquid Limit device will result in a Liquid Limit up to 4 percentage points higher than the TMH1 method.
- Pedocretes, particularly calcrete, often give lower Liquid Limits after oven drying than when air-dried. This aspect should be considered when testing these materials.
- When testing Kalahari sands the liquid Limit of the 0,075 mm fraction should also be determined.

4.8.3 CML TEST NO. S3:

The Determination of the Plastic Limit and Plasticity Index of Soils.

Definitions:
The Plastic Limit (PL) of a soil is the moisture content, expressed as a percentage of the mass of the oven-dried soil, at the boundary between the plastic and the semi-solid states.

The Plasticity Index (PI) of a soil is the numerical difference between the liquid limit and the plastic limit of the soil and indicates the moisture content range in which soil is in a plastic state.

Procedure:
Shall be carried out in accordance with method **A3: TMH1: 1986.**

Notes:
- The hands of the operator should be clean and dry when performing the test.
- When testing Kalahari sand it may be desirable to also perform the plastic limit test using fines passing the 0.075 mm sieve.

4.8.4 CML TEST NO. S4:

The Determination of the Bar Linear Shrinkage of Soils

Definition:
The Linear Shrinkage (LS) of a bar of a soil is the linear change in length of the fraction of a soil sample passing 0.425 mm sieve as it dries from the liquid limit moisture content.

Procedure:
This test shall be carried out in accordance with method **A4: TMH1: 1979.**

Notes:
- Do not allow the filled troughs to air dry before placing in the oven. Air-drying reduces the tendency for higher plastic materials to "bow" but reduces the measured linear shrinkage.
- Where the LL is carried out on non-standard fines i.e. P 0.075 mm sieve, the LS should also be carried out on the same.

The linear shrinkage test also serves as an approximate check on the plasticity Index results. Most types of soils exhibit a rough relationship between PI and LS which is commonly reported as PI = 2 x LS. For calcrete PI = 1.5 x LS. It is therefore recommended that the test be conducted, but that no decisions other than to check the Atterberg results should be based on this relationship.

Material retained on the 19.0 mm sieve can be handled in a number of ways. The suggested method is for all the material > 19 mm to be discarded and the OMC/MDD to be corrected according to ASTM D4718. Should 5 per cent or less be greater than 19 mm then there is no need for correction. Caution should be exercised when more than 30 per cent of the sample is retained on the 19 mm sieve.

In spite of the above it is recommended that method A7: TMH1 should be followed to avoid variations in the results from one Laboratory to the other.

4.8.5 CML TEST NO. S5:

The Determination of the Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) of Soils

Scope:
The maximum dry density and optimum moisture content are determined by establishing the moisture-density relationship of the material when compacted at the Modified AASHTO compaction effort at different moisture contents.

Definition:
The **Maximum Dry Density** (MDD) of a material for a particular compaction effort is the highest density obtainable when the compaction is carried out on the moist mass of the material and the moisture content is varied.

The **Optimum Moisture Content** (OMC) for a definite compaction effort is the moisture content at which the maximum density is obtained.

Procedure:
Shall be carried out in accordance with method **A7: TMH1: 1986**.

Notes:
- The test is only carried out on material passing the 19 mm sieve. The results are therefore not truly representative of the field conditions. This must be borne in mind when determining the in-situ compaction based on the laboratory MDD.
- The OMC determined is that of a specific compaction effort and may not represent that of light or very heavy field compaction equipment.

4.8.6 CML TEST NO. S6:

The Determination of the California Bearing Ratio (CBR) of Untreated Soils

Scope:
The California Bearing Ratio (CBR) of a material is determined by measuring the load required to allow a standard piston to penetrate the surface of a material compacted according to TMH 1, method A7. The determination of the CBR-density relationship is also part of the method.

Definition:
The California Bearing Ratio of a material is the load in kN, which is expressed as a percentage of California standard values at maximum dry density of a material for a particular compaction effort.

Procedure:
Shall be carried out in accordance with method **A8: TMH1: 1986.**

Notes:
- The same problems concerning the percentage of material greater than 19 mm discussed for MDD/OMC compaction, also occur with the CBR test.

4.8.7 CML TEST NO. S7:

The Determination of the Unconfined Compressive Strength (UCS) of Stabilized Soils, Gravels and Sands

Scope:
In this method, the unconfined compressive strength of stabilized materials is determined by subjecting prepared specimens to an increasing load until failure under unconfined conditions.

Definition:
The Unconfined Compressive Strength (UCS) of a stabilized material is the load in kilopascals (kPa) required to crush a cylindrical specimen 127.0 mm high and 152.4 mm in diameter to total failure at a loading rate of 140 kPa per second.

Procedure:
The test should be carried out according to method **A14: TMH 1, 1986.**

Notes:
- See notes given in test method **A14: TMH1, 1986.**

4.8.8 CML TEST NO. S8:
The Determination of One-Dimensional Consolidation Properties of Soils

Scope:
The test method covers a procedure for determining the rate and magnitude of consolidation of soil when it is restrained laterally and loaded and drained vertically.

Procedure:
The test should be carried out according to test method **D2435: ASTM, 1998**

4.8.9 CML TEST NO. S9:
The Identification of Dispersive Soils Using Crumb Test

Scope:
The test method covers a procedure for the identification of dispersive soils. The dispersive clays soils are identified by observing the behaviour of few crumbs of soil placed in distilled water. The dispersion is classified depending on the degree of muddiness of the water.

Dispersive soils are these containing high exchangable sodium percentage that cause the fine clay particle to go into suspension in fresh water.

General:
The Crump test is a simple test that is recommended for the initial identification of dispersive soils.

Procedure:
The test should be carried out according to test method **Part 5: BS 1377, 1990.**

Notes:
- For flocculated soils, a dilute solution of sodium hydroxide is required instead of distilled water. The Sodium hydroxide is prepared by dissolving 0.04g of anhydrous sodium hydroxide in distilled water to make 1 litre of the solution.
- The test report shall state the details of the reagent used.

4.8.10 CML TEST NO. S10:
The Determination of Durability for Cement-Treated Materials

Scope:
The test method covers the procedure for determining the soil-cement losses obtained by repeated wetting, drying and brushing of hardened soil-cement specimen.

The wet/dry brushing test was originally developed for cement treated materials but it can be used with equal success on material treated with other chemical stabilisers such as lime and blast-furnace slag. It must, however, be noted that with these stabilising agents, it may take more than seven days to produce strengths equivalent to that of cement.

Procedure:
The test shall be carried out according to test method **A19: TMH 1, 1986.**

Notes:

- Ensure that the brushing is performed vertically and that the applied force is approximately 1.36kg.
- Mass determinations of specimen shall be made at the end of each cycle.

4.8.11 CML TEST NO. S11:

The Electrometric Determination of the pH Value of a Soil Suspension

Scope:
The test method covers the determination of the pH value of a soil suspension by measuring the hydrogen ion concentration in the suspension with a pH meter.

Definition:
The pH expresses the degree of effective acidity or alkalinity of a solution and is defined as the negative logarithm of the hydrogen ion concentration of a solution i.e. $pH = -\log[H^+]$. The pH range for aqueous solutions extends from 0 to 14 with 0 to 7 indicating the acidic range and 7 to 14 the alkalinic range.

Procedure:
The test should be carried out according to test method **A20: TMH 1, 1986.**

Notes:

- The pH meter should be calibrated prior to the beginning of the testing and at frequent intervals between testing in accordance with the manufacturer's instructions.
- The tip of the combination electrode should be kept immersed in distilled water for at least one hour prior to starting the test to wet the salt bridge in the reference electrode, and should be kept immersed in distilled water between tests.
- pH probes are very sensitive to damage and should be treated carefully.
- pH is a function of dilution (quantity of water) and it should be ensured that the water content is consistent.
- The probes tend to have a short life span when used for testing high alkaline solutions (such as ICL determinations). When this type of testing is carried out it should be ensured that the probe is still fully functional.

4.8.12 CML TEST NO. S12:

The Determination of the Electrical Conductivity of Saturated Soil Paste and Water

Scope:
The test method covers the determination of the electrical conductivity of a saturated soil paste and of water using standard cup cell. The method also describes the procedure for estimating the soluble salt content of a soil or water from the conductivity.

Definitions:
The resistance of an electrolytic solution, as represented by the saturated soil paste or water, is that property of the solution that opposes the flow of an electric current through it.

Resistivity is the resistance in Ohms of $1m^3$ of an electrolytic solution at a specified temperature.

Conductance is the reciprocal of the resistance and is recorded in Siemens.

Procedure:
The test shall be carried out according to test method **A21T: TMH 1, 1986.**

Notes:

- If the material is dried at a temperature above 800 °C some salts may decompose resulting in a higher conductivity reading.
- Conductivity measurements may be used to estimate the soluble salt content of a sample.

4.8.13 CML TEST NO. S13:

The Determination of the Initial Consumption of Lime (ICL)

The ICL does not dispense of the need to establish the lime content required to achieve design strength or the required reduction in plasticity. It only gives a thresh-hold value to achieve a permanent stabilisation effect.

Scope:
The test method covers the procedure for the determination of Initial Consumption of Lime (ICL).

Definition:
The ICL is the amount of lime consumed in the initial ion exchange reaction in a material-lime mixture, and is the minimum lime content required to achieve a permanent gain in strength of the material.

Procedure:
The test shall be carried out according to test method **Part 2: BS 1924, 1990.**

Notes:

- The lime used in the test shall have a pH value ranging from 12.35 to 12.45 at 25 °C.
- The buffer solutions used in the test shall not be kept for more than 7 days.
- Electrodes used in the test must be suitable for highly alkaline solutions.

4.8.14 CML TEST NO. S14:

The Determination of the Sand Equivalent Value of Soils and Fine Aggregates

Scope:
This method is intended to serve as a rapid field test to show the relative fine dust or clay like material in soils or fine aggregates.

Procedure:
The test shall be carried out according to method **ASTM D2419 or AAHSTO T176-00.**

4.8.15 CML TEST NO. S15:

The Direct Shear Test of Soils

Scope:
This method describes the procedure for determining the consolidated drained shear strength of a soil material in direct shear mode. The test may be conducted in either a single shear or a double shear.

General:
The direct shear test is well suited to a consolidated drained test because the drainage paths through the specimens are short, thereby allowing excess pore pressure to dissipate fairly rapidly. The test can be made on all soil material, and on undisturbed or remoulded samples.

Procedure:
The test shall be carried out according to method **ASTM D 3080-72.**

4.8.16 CML TEST NO. S16:

The Determination of Shear Strength of Soils under Unconsolidated Undrained, Consolidated Drained and Consolidated Undrained conditions in Tri-Axial Compression.

Scope: A
This test method describes the determination of unconsolidated strength and stress-strain relationships for a cylindrical specimen of either an undisturbed or remoulded cohesive soil sheared un-drained in compression at a constant rate of axial deformation (strain controlled).

General:
The test method provides for the calculation of total stresses on, axial compression of the test specimen by measurement of the axial load and axial deformation.

The test provides data which is useful in determining strength and deformation properties of cohesive soils such as Mohr strength envelopes and Young's modulus.

Procedure:
The test should be carried out according to method **AASHTO T 296-95.**

Scope: B
This test method describes the determination of strength and stress-strain relationships for a cylindrical specimen of either an undisturbed or remoulded saturated cohesive soil when it is isotropically consolidated and sheared un-drained in compression at a constant rate of axial deformation (strain controlled).

General:
The test method provides for the calculation of total and effective stresses on, axial compression of the test specimen by measurement of the axial load and axial deformation and pore water pressure.

The test provides data which is useful in determining strength and deformation properties of cohesive soils such as Mohr strength envelopes and Young's modulus. Generally, three specimens are tested at different effective consolidation stresses to define a strength envelope.

Procedure:
The test shall be carried out according to method **ASTM D 4767-88** or **AASHTO T 297-94.**

Note:
Similar test is done in Tri-Axial Compression in Drained condition also where pore pressure gets dissipated and becomes equal to zero. The Mohr´s Strength Envelope in this case is expressed in terms of Effective stress where Total stress becomes equal to Effective Stress.

4.8.17 CML TEST NO. S17:

The Determination of the Dry Density/Moisture Content Relationship of Granular Soil (Vibratory Hammer Method)

Scope:
This test method covers the determination of the mass of dry soil per cubic metre when the soil is compacted in a specified manner over a range of moisture contents, including that giving the maximum mass of dry soil per cubic metre. The optimum moisture content and maximum dry density for a compacted material are thus determined.

General:
In this test which is suitable for fine-grained soils and for the fraction of medium and coarse grained granular soils passing the 37,5 mm sieve, the soil is compacted into a California Bearing Ratio mould of 152 mm diameter and 127 mm depth, using an electrically operated vibrating hammer.

Procedure:
The test shall be carried out according to method **BS 1377:** 1975.

Notes:
See notes given in the stated test method.

4.9 Aggregates Tests

4.9.1 CML TEST NO. AG1:

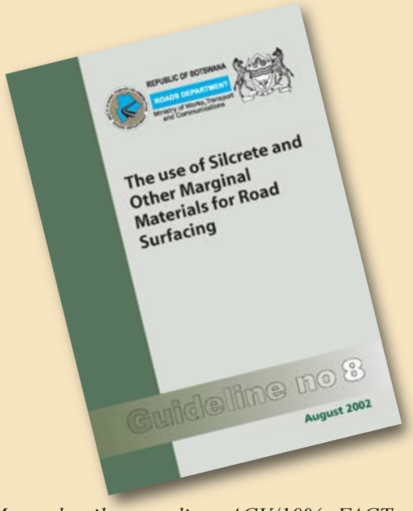
Sieve Analysis of Aggregates, Including the Determination of Material Passing 0.425 mm Sieve and 0.075 mm Sieve

Scope:
This method describes the sieve analysis of a dried aggregate sample, after it has been washed through a 0.075 mm sieve, and the subsequent determination of the percentages of material by mass passing the 0.425 mm and 0.075 mm sieves, also called the fines and dust content of aggregates respectively.

These determinations are done on aggregate for asphalt, surface treatments and concrete.

Procedure:
The test shall be carried out according to test method **B4: TMH 1:**1986.

Notes:
- The decision on whether to use dry preparation or wet preparation shall be taken by the Laboratory Manager after consulting the Project Officer/ SRE-Lab.
- The test sieves must be inspected for defects before their use. A more detailed examination shall be made at regular intervals for signs of wear, working, tear, splits, holes, blockages etc.



More detail regarding ACV/10% FACT and testing of weaker aggregates can be found in Guideline No. 8.

4.9.2 CML TEST NO. AG2:

The Determination of Aggregate Crushing Value (ACV)

Scope:
The Aggregate Crushing Value of an aggregate is determined by crushing a prepared confined aggregate sample under a specified, gradually applied compressive load and determining the percentage of the crushed material finer than a specified size.

Definition:
The **Aggregate Crushing Value** (ACV) of an aggregate is the mass of material, expressed as a percentage of the test sample, which is crushed finer than 2.36 mm when a sample of aggregate passing the 13.2 mm and retained on the 9.5 mm sieve is subjected to crushing under a gradually applied compressive load of 400 kN.

Procedure:
The test shall be carried out according to test method **B1: TMH 1:1986.**

Notes:
- For softer aggregates (say ACV higher than 30) it is recommended that the 10% FACT be done instead of the ACV in order to reduce the effect of compaction of the crushed material.
- Testing of material after water soaking and/or ethylene glycol soaking can provide useful additional information on the nature and durability of the material being tested.

4.9.3 CML TEST NO. AG3:
The Determination of 10 Per Cent Fines Aggregate Crushing Value (10 % FACT)

Scope:
The 10 per cent Fines Aggregate Crushing Value (10 % FACT) of an aggregate is determined by measuring the load required to crush a prepared aggregate sample to produce 10 per cent material passing a specified sieve after crushing.

Definition:
The **10 per cent Fines Aggregate Crushing Value** is the force in kN required to crush an aggregate sample passing 13.2 mm sieve and retained on the 9.5 mm so that 10 per cent of the total test sample will pass a 2.36 mm sieve.

Ethylene glycol soaking of aggregates can be carried out for 24 hours, 4 days or even 28 days before ACV, 10% FACT or AIV testing, particularly for basic crystalline rocks where the presence of smectite clays is suspected.

Procedure:
The test shall be carried out according to **BS 812: Part 3: 1983.**

Notes:
- Testing of material after water soaking and/or ethylene glycol soaking can provide useful additional information on the nature and durability of the material being tested.

4.9.4 CML TEST NO. AG4:
The Determination of Aggregate Impact Value (AIV)

Scope:
The aggregate impact value (AIV) of aggregates is a measure of the resistance of aggregate to impact. The aggregate is subjected to blows of a falling hammer and the resulting disintegration is measured in terms of the quantity of material passing the 2.36 mm sieve, which is then expressed as a percentage of the test sample. This is called the Aggregate Impact Value.

Procedure:
The test methods shall be carried out according to **BS 812: Part 3: 1983.**

Notes:
- The test is normally done on aggregates in their dry state but may also be carried out on aggregates that have been soaked in water or ethylene glycol for 24 hours.
- Water soaking is done to determine whether the aggregates are excessively susceptible to breakdown in wet conditions.

4.9.5 CML TEST NO. AG5:
Assessment of Aggregate Durability Using Durability Mill Test

Scope:
The test method provides a measure of the ability of an aggregate to withstand degradation both during construction and under various service conditions. It also furnishes additional data pertaining to the quality of the material and the

possible change in index properties likely to occur in the road and be detrimental to its performance. The test has the advantage of testing a full grading that is used in practice, unlike comparable tests such as the Los Angeles Abrasion test (LAA).

Definition:
The **Durability Mill values** are taken as the mass of dry material passing the 0.425 mm sieve after treatment, expressed as a percentage of the original dry mass of the sample. The Durability Mill Index (DMI) is the product of the highest percentage passing 0.425 mm for any of the treatments and the highest Plasticity Index (PI) for any treatment.

Procedure:
The test should be carried out according to test method **(d) in Standard Specifications for Road and Bridge Works (1998)** issued by SATCC.

Notes:
- Materials that contain high smectite contents within aggregate particles are clearly identified by the DM test as these are released during the treatments and manifested as high PI's in the wet test.
- Although no direct comparisons have been done in Southern Africa, it is thought that the dry treatment with balls in the DMI compares closely with the Los Angeles Abrasion (LAA) test, after consideration of the initial fines content.

4.9.6 CML TEST NO. AG6:
The Determination of the Flakiness Index of Coarse Aggregates

Scope:
The Flakiness Index of a coarse aggregate is determined by gauging screened-out fractions with the appropriate slot(s) given in a table in the test method. Aggregate retained on the 75 mm and passing the 4.75 mm sieve is not included in the test.

Definition:
The **Flakiness Index (FI)** of a coarse aggregate is the mass of particles in that aggregate, expressed as a percentage of the total mass of that aggregate, which will pass the slot or slots of specified width for the appropriate size fraction. The width of the slots is half that of the sieve openings through which each of the fractions passes.

Procedure:
The test should be carried out according to method **B3: TMH 1: 1986** or **BS 812: Part 1**.

Notes:
- Do not force the pieces of aggregate through the slots in the gauge. The aggregates that do not pass easily through the slots should be considered too large for the particular opening and recorded as such.
- The slots in the gauge tend to wear with time and should, therefore, be measured periodically to determine whether they comply with the specifications. Gauges with worn slots should be replaced.
- Flaky materials will often be manifested as a lower strength in the ACV or 10 % FACT tests, compared with cubical aggregate particles.

4.9.7 CML TEST NO. AG7:

The Determination of Adhesion of Bituminous Binder to Stone Aggregate by Means of Chemical Immersion Test (Riedel And Weber)

Scope:
This method covers the determination of the adhesion of bitumen to stone aggregate by boiling bitumen coated aggregate successively in distilled water and in increasing concentrations of sodium carbonate. These concentrations are numbered 0 to 9. The number of the concentration at which the bitumen strips to such an extent that it is no longer a film but only specks or droplets, is called the stripping value.

Definition:
The **Riedel and Weber value** is an expression of ability of an aggregate to bond to a standard bitumen (150/200 pen).

Procedure:
The test should be carried out according to method **B11: TMH 1: 1986**.

Notes:
- It is advisable to keep a stock of a reference stone of a known stripping value for reference purposes and to check new consignments of bitumen. The characteristics of bitumen may differ between consignments even though the penetration values are similar.

4.9.8 CML TEST NO. AG8:

The Determination of Dry Bulk Density, Apparent Relative Density and Water Absorption of Aggregates Retained on 4.75 mm Sieve and Passing 4.75 mm Sieve

Scope:
The dry bulk density and apparent relative density of both the plus and minus 4.75 mm fraction of the material, as defined below, are calculated from the loss in mass of saturated surface dry aggregate when it is submerged in water.

The water absorption is determined by calculating the mass of water absorbed after 24-hour immersion in water of the oven-dried material.

Definition:
Relative density is the ratio of the mass in air of a given volume of material at a stated temperature to the mass in air of an equal volume of distilled water at the same temperature.

Bulk Relative density is the ratio of the mass in air of a given volume of material (including the permeable and impermeable voids normal to the material) at a stated temperature to the mass in air of an equal volume of distilled water at the same temperature.

Apparent relative density is the ratio of the mass in air of a given volume of material (excluding permeable voids but including the impermeable voids normal to the material) at a stated temperature to the mass in air of an equal volume of distilled water at the same temperature.

Procedure:
The test shall be carried out according to the following procedures:
Material retained on the 4,75 mm sieve tested according to method **B14: TMH1: 1986.**
Material passing the 4,75 mm sieve tested according to method **B15: TMH1: 1986.**

Notes:
- The test results are very dependent on obtaining the correct value for the surface dry state of the aggregates and it is sometimes difficult to achieve this, particularly where the fine fraction is concerned. Every effort must be made to ensure that this condition is achieved.
- The loss of fine aggregates when drying must be guarded against.

4.9.9 CML TEST NO. AG9:
The Determination of Accelerated Laboratory Polished-Stone Value (PSV)

Scope:
The object of the test is to give a relative measure of the extent to which different types of road-stone in the wearing surface will polish under traffic.

General:
Where the surface of a road consists mainly of road-stone the state of polish of a sample will be one of the major factors affecting the resistance of the surface to skidding. The actual relationship between polished stone value and skidding resistance will however, vary with traffic conditions, type of surfacing and other factors.

Procedure:
The test methods shall be carried out according to **Part 3: BS 812, 1990.**

Notes:
- The use of a resin instead of cement is recommended for making the briquettes containing the surfacing aggregate as test results may be obtained much sooner. Briquettes made of cement have to be cured for a minimum period of 7 days.

4.9.10 CML TEST NO. AG10:
The Determination of the Aggregate Fingers Value and the Aggregate Pliers Value

Scope:
The test was developed for rapid field or laboratory strength-assessments of aggregates with particular reference to calcrete.

Definition:
The Aggregate fingers value is the percentage of aggregate pieces of a sample of a material that cannot be broken by finger pressure, whereas the aggregate pliers value is a measure of the number of aggregate pieces of the same sample that cannot be broken by a person using a standard pliers described in the test method.

Procedure:
The test methods shall be carried out according to method **C.B. 22: Manual of Testing Procedures for Highway Materials, CSIR. Transportek.**

Notes:
- Use only the type of pliers described in the method.
- Do not use these pliers for any other purpose other than testing.
- People doing the test should be of medium build (don’t use the biggest, strongest person in the lab because he or she can crush the most aggregate pieces).

4.10 Bitumen Tests

4.10.1 CML TEST NO. B1:

The Determination of the Penetration Value of Bituminous Binders

Scope:
Penetration is defined as the consistency of semi-solid and solid bituminous binders expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time and temperature. The units of penetration indicate tenths of a millimeter.

Definition:
Consistency is an engineering term defined as an empirical measure of resistance offered by a fluid to continuous deformation when it is subjected to a shearing stress.

Procedure:
The test shall be carried out according to method **D5: ASTM, 1998.**

Notes:
- Pre-soak penetration needles in a 1% solution of Oleic acid to remove any oils or dirt that may be present from handling, etc.
- Ensure that the needle being used complies with the test specifications.
- The performance of new needles should be compared with that of a certified needle, which is kept solely for this purpose and is not used for general testing.
- The penetration should always be done at the centre of the mould to avoid edge effects.
- Use only calibrated thermometers in Bitumen testing.

4.10.2 CML TEST NO. B2:

The Determination of the Ductility of Bitumen

Scope:
The ductility of bitumen is expressed as the distance in centimetres by which a standard briquette can be elongated before it breaks under specified conditions.

Procedure:
The test shall be carried out according to method **D113: ASTM, 1998.**

Notes:
- After filling the mould the excess bitumen must be carefully cut to the exact level of the mould. Too little or too much bitumen in the mould will obviously influence the test results.
- It should be ensured that there are no air bubbles in the specimens after moulding otherwise the test results may be erroneous.

4.10.3 CML TEST NO. B3:

The Distillation of Cutback Bitumen

Scope:
This method describes a procedure intended to give approximate information concerning volatile constituents in cutback bitumen and to provide a means for separating the bitumen from the more volatile constituents. The residue from the distillation is tested as required. Tests can also be carried out on the distillate.

Procedure:
The test shall be carried out according to method **D402: ASTM, 1998.**

Notes:
- Ensure that the correct mould is used to do the test, as other moulds with different dimensions are available for specifications other than ASTM.

4.10.4 CML TEST NO. B4:

The Determination of the Softening Point of Bituminous Binders using Ring and Ball Method

Scope:
This method provides a measure of the temperature susceptibility of a bituminous material. Bituminous materials do not change from a solid state to a liquid state at any definite temperature, but gradually become softer and less viscous as the temperature rises.

Definition:
The softening point is defined as the point at which the bitumen attains a particular degree of softness under specified conditions of test.

Procedure:
The test shall be carried out according to method **D36: ASTM, 1998.**

Notes:
- Use only freshly boiled distilled water.
- Use the correct mould size as specified by the method. Other sizes are available on the market.
- The container in which the specimens are heated must have the correct dimensions, as specified by the method.

4.10.5 CML TEST NO. B5:

The Determination of the Kinematic Viscosity of Cutback Bitumen

Scope:
The method covers the determination of the kinematic viscosity of opaque liquid petroleum products by measuring the time of flow of a fixed volume of liquid at a given temperature through calibrated glass capillary instruments using gravity flow. A procedure is given for the calculation of dynamic viscosities from measured kinematic viscosities.

Definition:
For the purposes of this method, **kinematic viscosity** is a measure of the time for a fixed volume of liquid to flow by gravity through a capillary tube. Dynamic viscosity can also be calculated from the kinematic viscosity.

Procedure:
The test shall be carried out according to method **D2170: ASTM, 1998.**

Notes:
- The capillary tubes must be spotlessly clean otherwise erroneous results may be obtained.

4.10.6 CML TEST NO. B6:

The Performance of Bitumen when Subjected to the Thin Film Oven Test (TFO)

Scope:
This method covers the determination of the effect of heat and air on bitumen by evaluating the degree of hardening that occurs after heating in an oven for a specified time at a specific temperature. The amount of hardening is evaluated from the reduction in penetration expressed as a percentage of the original value.

Procedure:
The test shall be carried out according to method **D1754: ASTM, 1998.**

Notes:
- The correct oven temperature is extremely important.

4.10.7 CML TEST NO. B7:
The Performance of Bitumen when Subjected to the Rolling Thin Film Oven Test (RTFO)

Scope:
This method is intended to measure the effect of heat and air on a moving film of semi-solid asphaltic material. The effects of this treatment are determined from measurements of the properties of the asphalt before and after the test.

Procedure:
The test shall be carried out according to method **D2872: ASTM, 1998**.

Notes:
- The correct oven temperature is imperative.

4.10.8 CML TEST NO. B8:
The Determination of the Percentage of Bitumen Soluble in Trichloro- Ethylene

Scope:
This method is applicable to bitumen and materials containing more than 95 per cent bitumen. This is intended for bitumen in which volatile constituents will not normally be present. If water is present, the amount will normally be small and can be removed and neglected in the calculation.

The bituminous binder is dissolved in the solvent and the bitumen content calculated as the percentage of material that is soluble in carbon disulphide.

Procedure:
The test shall be carried out according to method D2042: ASTM, 1998.

4.11 Concrete Tests

4.11.1 CML TEST NO. C1:
The Making, Curing and Compressive Strength Determination of Concrete Test Cubes

Scope:
This method describes the making, curing and testing of concrete test cubes for compressive strength.

Procedure:
The test shall be carried out according to method **D1: TMH1: 1986.**

4.11.2 CML TEST NO. C2:
The Determination of the Slump of Freshly Mixed Concrete

Scope:
The slump test is used to determine the workability of concrete mixes and is carried out by filling a specified mould with freshly mixed concrete and measuring the slump after removal of the mould.

Procedure:
The test shall be carried out according to method **D3: TMH1: 1986** or method **C143-74: ASTM**.

4.12 Asphalt Mixes

4.12.1 CML TEST NO. AS1:

The Determination of a Suitable Binder Content for use in an Asphalt Mix

Scope:
The method covers the procedure for determining the binder content(s) to be used for a particular aggregate to make a bituminous mixture, which will satisfy certain criteria.

Procedure:
The test shall be carried out according to method **C1: TMH1: 1986** or method **C143-74: ASTM, 1998**.

Notes:
- It must be ensured that the masses of the aggregates used for the various briquettes are identical.
- The Marshall hammer must be calibrated regularly (every 3-6 months depending on use).
- Segregation of the aggregate fractions must be prevented, by regular mixing, when placing the asphalt in the moulds for compaction. It is imperative that the temperatures of the aggregates, bitumen and compaction equipment must be at the required levels.

4.12.2 CML TEST NO. AS2:

The Determination of the Binder Content of a Bituminous Mixture

Scope:
The method deals with the quantitative determination of the binder content of a bituminous mixture by extracting the binder from the mixture using an organic solvent, and determining the binder in the solution by evaporation This method is not suitable for tar mixes. The binder so extracted may be tested, if required, according to standard binder tests.

Procedure:
The test shall be carried out according to method **C7 (a): TMH1: 1986** or method **D1856 ASTM, 1998**.

4.12.3 CML TEST NO. AS3:

The Determination of the Bulk Relative Density of a Compacted Bituminous Mixture and the Calculation of the Voids Content

Scope:
The bulk density of a compacted bituminous mixture is calculated from the mass and bulk volume of a briquette in a saturated surface dry condition. The voids content is calculated as the difference between the bulk volume of the compacted mix and the theoretical volume of its combined constituents and expressed as a percentage of the latter. The voids in the aggregate and voids filled with binder are also calculated.

Procedure:
The test shall be carried out according to method **C3: TMH1: 1986** or methods **D1188** and **D2726: ASTM, 1998.**

Notes:
- The water bath temperature must be measured accurately.

4.12.4 CML TEST NO. AS4:

The Determination of the Resistance to Flow of a Cylindrical Briquette of a Bituminous Mixture by Means of the Marshall Apparatus

Scope:
This method deals with the determination of the stability and flow (resistance to flow) of a cylindrical briquette loaded on the lateral surfaces by means of the Marshall apparatus.

Procedure:
The test shall be carried out according to method **C2: TMH1: 1986** or method **D1559: ASTM, 1998**.

Notes:
- The calibration of the Marshall apparatus should be checked on a regular basis (every 12 months is suggested).
- The water bath temperature must be measured accurately.

4.12.5 CML TEST NO. AS5:

The Determination of the Maximum Theoretical Relative Density of Asphalt Mixes (Rice's Method) and the Quantity of Bituminous Binder Absorbed by the Aggregates

Scope:
The maximum theoretical relative density of asphalt mixes is determined after filling all permeable voids in the material with water under reduced pressure.

Definitions:
The maximum theoretical relative density of asphalt is the relative density of the void-less mixture.

The absorption of bituminous binder of an aggregate is determined in terms of the mass of binder, expressed as a percentage of the mass of dry aggregate, which is absorbed by the aggregate without altering the bulk volume of the aggregate, and which does not contribute to inter-particle adhesion.

Procedure:
The test shall be carried out according to method **C4: TMH1: 1986** or method **D2041: ASTM, 1998.**

Notes:
- The calibration of the flasks should be done accurately and they should be inspected for defects such as cracks and chips at each use.
- The temperature of the water is very important. For consistent results keep the temperature at 25^{O}C.

5 FIELD TESTS

5.1 CML TEST NO. F1

The Determination of the In-Situ Strength of Soils by the Dynamic Cone Penetrometer

Scope:
This method describes the determination of the rate of penetration of the Dynamic Cone Penetrometer (DCP) into a natural or compacted material by virtue of the action of the built-in sliding hammer.

Definitions:
The DCP refers to the specific arrangement of an 8 kg hammer sliding along a 575mm long rod to push a cone with 60^{o}C into the ground. The penetration rate is inversely proportional to the resistance of the ground to the penetration of the DCP and may be related, *inter alia*, to the in situ CBR or soil density.

Procedure:
The test shall be carried out according to method **ST6: TMH6: 1984.**

Notes:
- The cone must be replaced when its diameter has been reduced by 5 per cent or it has been visibly damaged.
- Spare parts for the DCP apparatus should be available in the field, as the apparatus tends to break owing to the stress it is subjected to during testing (fall of the hammer).
- Disposable cones could be used. This ensure that the cones used are always sharp and reduces the damage to the DCP during removal of the equipment from the test hole after testing.
- DCP analysis computer programmes are available and their use is recommended.

5.2 CML TEST NO. F2:

The Determination of the Deflection and Radius of Curvature of a Road Pavement using Deflection Measurements

Scope:
This method covers the measurement of the deflection and radius of the longitudinal curvature of a road pavement under dual wheels of a loaded truck with a standardized axle load, tyre size, tyre spacing and tyre pressure. The deflection is measured by means of a deflection beam and the radius of curvature by either the deflection beam or the curvature meter.

Definitions:
Deflection - The amount of down ward vertical movement of a surface due to the application of a load, which is usually a loaded truck, to the surface of the pavement.

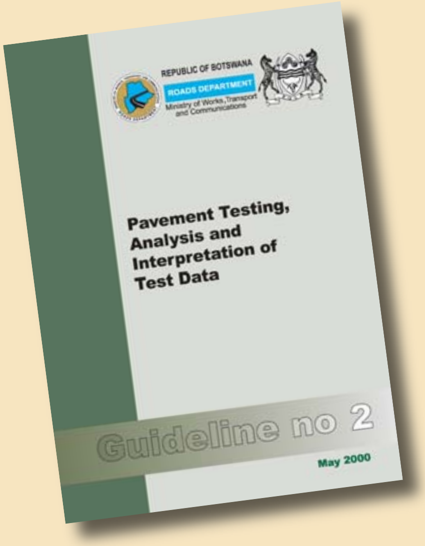
Transient deflection - The difference between original and final elevations of a surface resulting from the application and removal of one or more load to and from the surface of the pavement.

Rebound deflection - The amount of vertical rebound of a surface that occurs when a load is removed from the surface of the pavement.

Procedure:
The test shall be carried out according to method **ST9: TMH6: 1984**.

The DCP is used to assess the shear strength of a fairly uniform material by relating to penetration rate on the same material. In this way under compacted or "soft spots" can be identified, even though the DCP does not measure density directly.

DCP data is usually evaluated in terms of CBRs of the in situ layers derived from well-established DCP/CBR correlations.



More details on DCP and other field tests can be found in Guideline no. 2.

Experience in Botswana has shown that the deflection in the dry season can be as low as 65% of that taken in the wet season. Deflection measurement should therefore preferably be carried out in the wet season.

The strength of a road pavement is inversely related to its maximum vertical deflection under a known dynamic load. Deflection measured under a load can, therefore be a good indicator of the strength of a pavement.

It should be noted that there are other techniques of measuring deflections using automated equipment such as Deflectograph and Falling Weight Deflectometer (FWD).

Notes:

- It is important to ensure that the correct tyre pressures are applied on the truck used to load the pavement.
- It is imperative that the dial gauge on the beam moves freely. If this is not the case the gauge must be cleaned or replaced where cleaning does not resolve the problem.
- Also read notes given in test method **ST9: TMH6: 1984.**

5.3 CML TEST NO. F3:

The Determination of the In-Place Dry Density of Soils or Gravels by the Sand Replacement Method

Scope:
The method describes the determination of the in-place dry density of compacted soil or gravel. The dry density is determined by making a hole in a compacted layer and dividing the dry mass of the material removed from the hole by the volume of the hole. The volume is determined by filling the hole with a fine sand of known density.

Definitions:
The in-place dry density of a material is the dry mass per unit volume of the material and is expressed in kilograms per cubic metre.

Procedure:
The test shall be carried out according to method **A10 (a): TMH1**: **1986.**

Notes:
See notes given in the Test Method.

5.4 CML TEST NO. F4:

The Determination of the In-Place Dry Density and Moisture Content of Soils or Gravels by Nuclear Method

Scope:
The method describes the in-place determination of the density and moisture content of a compacted soil or gravel layer by nuclear methods.

Definitions:
The in-place dry density of a material is the dry mass per unit volume of the material and is expressed in kilograms per cubic metre.

The in-place moisture content is the mass of water per unit volume of the in-place material expressed in kilograms per cubic metre. (In this method moisture content will refer to this definition). This moisture can be converted and expressed as a percentage of dry material.

Procedure:
The test shall be carried out according to method **A10 (b): TMH1**: **1986.**

Notes:

- Always ensure that the batteries of the apparatus are fully charged before field use. Where disposable batteries are used a spare set should be taken to the field.
- It is advisable to check that the apparatus is fully operational before field use.

5.5 CML TEST NO. F5:

Measurement of the Texture Depth of a Road Surface

Scope:
This method describes the procedures for measuring the texture depth of a

road surface by spreading a known volume of sand on the surface and measuring the area covered. This is known as the sand patch method.

Definitions:
The texture depth is calculated in millimetres, which is determined by filling the surface voids of a given area of a road surface with a known quantity of graded sand and measuring the area covered by the sand.
Procedure:
The test shall be carried out according to method **ST1: TMH1: 1986.**

Notes:
- The sand used should be washed quartzitic sand, passing a 0.300 mm sieve and retained on a 0.075 mm sieve.
- Ensure that the sand used is completely dry.
- See notes given in the test method.

5.6 CML TEST NO. F6:
Measurement of Road Roughness Using the Merlin Apparatus

Scope:
The Merlin apparatus is an uncomplicated device for measuring road roughness.

Definitions:
The longitudinal unevenness of a road surface, commonly referred to as the road roughness, is measured in units of vertical movement of a wheel per unit length of the road, and expressed as meters (vertical) per kilometer (longitudinal). A fairly accurate estimation of International Roughness Index (IRI) can be obtained using the Merlin apparatus.

Procedure:The test shall be carried out according to **Transportation Research Record 1291, National Research Council, Washington D.C., pp 106-112.**

Notes:
- The Merlin apparatus should preferably be used for routine evaluations of short pavement sections, probably less than 10 km. The time and effort required for longer sections probably make vehicle mounted measurement devices more cost-effective and practical.
- The apparatus should routinely be checked for wear, as excessive play will have an effect on the accuracy of the readings.
- See notes given in Appendix C of Guideline number 2 (Pavement Testing, Analysis and Interpretation of Test Data) of Roads Department, Botswana.

5.7 CML TEST NO. F7:
Method for Determining the Point Load Strength Index

Scope:
This test is intended as a method for measuring the strength of rock specimens in the field for which portable equipment is used.

General:
Specimens used are in the form of either rock cores or irregular lumps broken by application of a concentrated load using a pair of conical platens. A point-load strength index is obtained and may be used for rock strength classification.

Procedure:
The test shall be carried out according to method given by the **International Society for Rock Mechanics (ISRM) - Committee on Laboratory Tests Document No. 1 (1973).**

Notes:

- The test is intended as a simple procedure for field classification of rock materials, and when necessary the recommended procedures can be modified to overcome practical limitations. Such modifications to procedure should however be clearly stated in the report.
- Point-load strength is closely correlated with the results of uniaxial compression and other strength tests.

5.8 CML TEST NO. F8:

Rapid Field Test For Determining The Carbonation Of Lime Or Cement Treated Materials

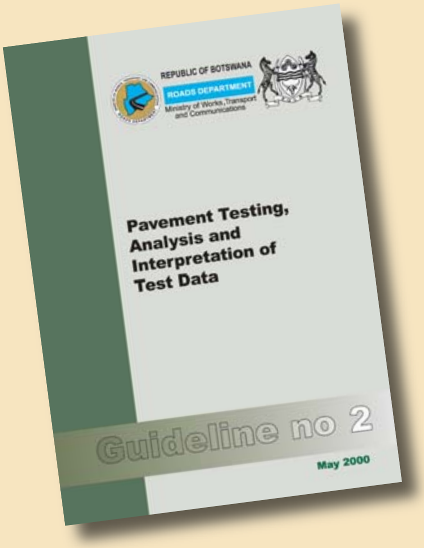
Scope:
This is a rapid indicator test for determining the carbonation of a layer, which has been treated with lime, lime-slag, lime-PFA, cement, cement-PFA and cement-slag.

Definitions:
Carbonation may be defined as the absorption of carbon dioxide (CO_2), which is present in the atmosphere by the calcium hydroxide ($Ca(OH)_2$) in lime or cement treated layers in order to form calcium carbonate ($CaCO_3$).

Procedure:
The test shall be carried out according to **Technical Report RS/2/84, Transportek, CSIR,1984.**

Notes:

- See notes given in the testing procedure .



Guideline no. 2 gives more details regarding Pavement Testing, Visual Condition Rating and Analysis.

5.9 CML TEST NO. F9:

Visual Assessment of Flexible Pavements

Scope:
The visual assessment or evaluation of a flexible pavement is done to determine the condition of the pavement surfacing and pavement structure. Aspects of distress such as cracking, ravelling, potholing, patching, pumping, deformation, bleeding, surfacing conditions, drainage and edge-break are evaluated visually.

Procedure:
The visual assessment shall be carried out according to **TMH 9.**

5.10 CML TEST NO. F10:

Visual Assessment of Unsealed Roads

Scope:
The visual assessment or evaluation of unsealed road is done to determine the condition of the gravel wearing course and factors, which may affect it. Aspects of distress such as, ravelling, rutting, corrugations, potholing, drainage, dust, gravel quality , gravel thickness, loose gravel etc. are evaluated visually.

Procedure:
The visual assessment shall be carried out according to **TMH 12.**

5.11 CML TEST NO. F11:

Non-Repetitive Static Plate Load Test for Soils and Flexible Pavements

Scope:
This method covers the carrying out of non-repetitive static plate load tests on

sub-grade soils and flexible pavement components, either in the compacted condition or in the natural state. It is intended to provide data for use in the evaluation and design of rigid and flexible type pavements.

Definitions:
Deflection - The amount of down ward vertical movement of a surface due to the application of a load to the surface.

Residual Deflection - The difference between original and final elevations of a surface resulting from the application and removal of one or more loads to and from the surface.

Rebound Deflection - The amount of vertical rebound of a surface that occurs when a load is removed from the surface.Procedure:

The test shall be carried out according to **AASHTO: T222-81.**

Notes:
- Keep a record of all conditions, which may affect the results such as weather conditions, list of testing personnel, any unusual conditions observed at the test site etc.
- Also see notes given in the testing procedure

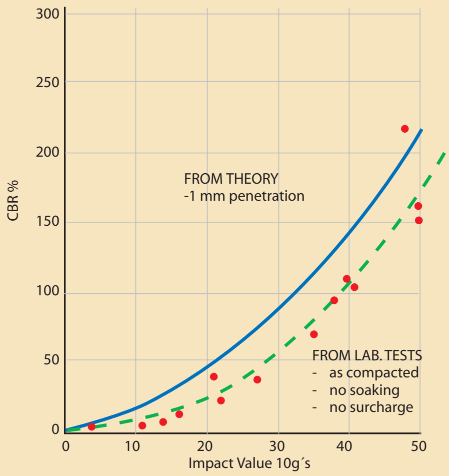
A minimum of four different plate sizes is recommended for pavement design of evaluation purposes.

A single plate of any selected size may however be used to give an indicative bearing index.

5.12 CML TEST NO. F12:
The in-situ Evaluation of Base Course Materials by Means of the Clegg Hammer

Scope:
This method describes the impact testing of compacted base course layers using the Clegg hammer apparatus, and is intended to provide data for acceptable compaction. The values obtained from the Clegg hammer may be compared to California Bearing Ratio (CBR) values.

General:
The device consists mainly of a laboratory compaction hammer to which an accelerometer has been attached. The peak output from the accelerometer, as generated by impact with the surface, is indicated on a specially designed hand-held meter. The procedure is to apply a series of impacts at one position on the surface until a constant value is recorded. Using a hammer weighing 500 grams, it is possible to extend the procedure for application to density control of fine sand.



Relationship Clegg Impact Value and CBR.

Procedure:

There is no specified test method. A description of the apparatus and details for its use are given in **ARRB proceedings, Volume 8, 1976.** Instructions for the use of the instrument are supplied with it.

Notes:
- Checking and calibration of the instrument is required before its use every time.
- It is advisable to carry a spare set of batteries when testing in remote areas.
- A sample of the material being tested should be taken for moisture content determination.

5.13 CML TEST NO. F13:
The Modified Tray Test for Chip Seals

Scope:
This method is used to determine the effective layer thickness of stone chippings, the void content in the stone layer, the void content in bulk aggregate and the practical and theoretical spread rates of aggregate.

Definitions:

Effective layer thickness: This is the average height of the layer of stone.
Void content: The air voids in the stone layer expressed as a percentage of the volume of the stones (voids between the stones).

Void content in bulk aggregate
The volume of the voids expressed as a percentage of the total volume of the un-compacted bulk density of the aggregate.

Aggregate spread rates: The volume of aggregate that covers a given surface area (m^3/m^2).

Procedure:
The test shall be carried out according to **TRH 3 1998,** appendix L.

5.14 CML TEST NO. F14:

Determination of the Moisture in Soils By Means of a Calcium Carbide Gas Pressure Moisture Tester

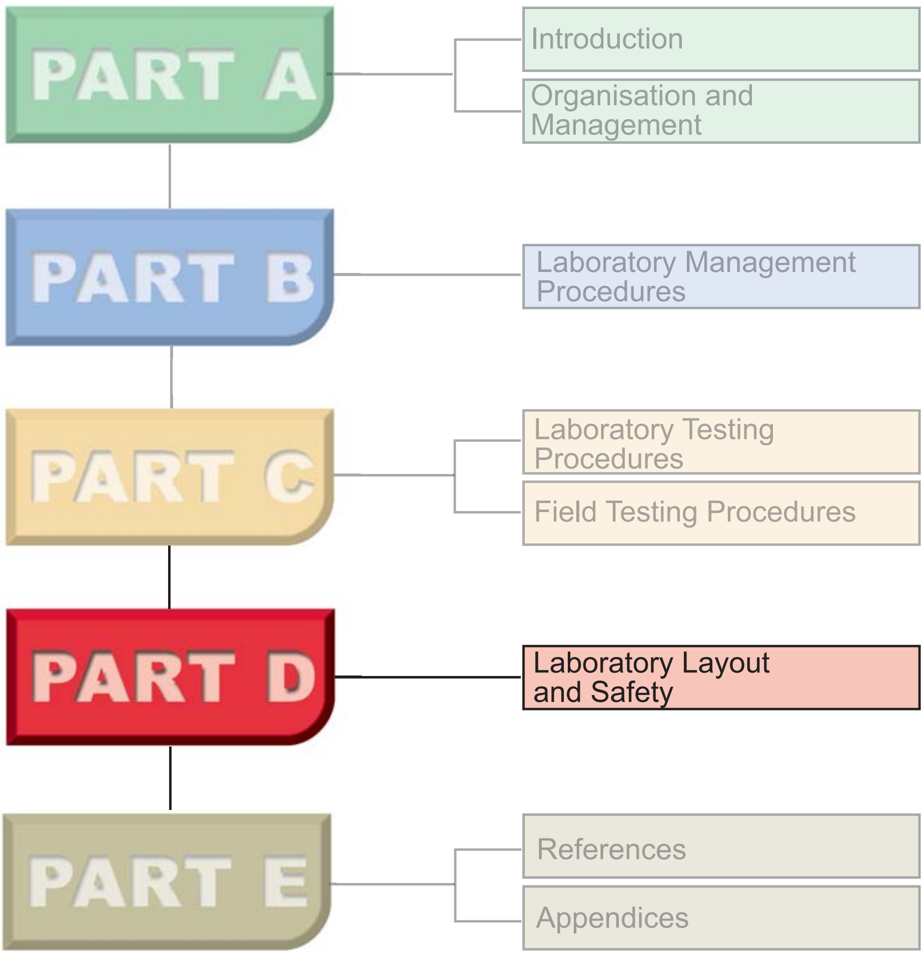
Scope:
This method describes the determination of the moisture content of soils by means of a calcium carbide gas pressure moisture tester. The manufacturer's instructions shall be followed for the proper use of the equipment.

Definitions:
The moisture content of a soil is defined as the amount of free water present in the soil expressed as a percentage of the dry mass of the material.

Procedure:
The test shall be carried out according to **AASHTO: T217-96.**

Notes:
- This method shall not be used for on granular materials having particles large enough to affect the accuracy of the test, in general any appreciable amount retained on the 4.75 mm.
- The super 200 D tester is intended to test aggregate.
- The shelf life of the calcium carbide reagent is limited, so it should be used according to the manufacturer's instructions.

PART D



PART A
Introduction
Organisation and Management
PART B
Laboratory Management Procedures
PART C
Laboratory Testing Procedures
Field Testing Procedures
PART D
Laboratory Layout and Safety
PART E
References
Appendices

6 LABORATORY LAYOUT AND SAFETY

Equipment and stationary shall be placed in an organised and orderly manner and must be clearly labelled for easy retrieval.

Samples shall be stored in a dry and clean environment in an orderly manner.

6.1 Laboratory Layout

6.1.1 General

The layout of the laboratory is very important for aspects such as productivity, safety, work flow, ergonomics etc.

The individual work areas or sections of a laboratory must all form a rational whole. The CML consist of the following areas:

- Sample reception area.
- Sample storage facility.
- Sample preparation area.
- Laboratory where "dirty" tests are carried out (dusty area).
- A section where "noisy" tests are done (such as compaction).
- An area where "cleaner" tests are carried out such as Atterberg Limits.
- A section for bitumen testing.
- A section for asphalt tests and a section for chemical tests.

6.1.2 Sample reception area

This area must be fairly large so that large samples may be easily handled and easily accessible to vehicles delivering samples. It should be close to where the samples are to be stored prior to testing and also close to the sample preparation area so that it is not necessary to manually transport samples long distances as this can be physically demanding especially where large samples are concerned. It is also a good idea to have some form of mechanical hoist so that large samples or samples in crates may be unloaded from delivery vehicles. This area should also not be situated close to offices as it is often noisy and dusty and the noise generated may be disturbing to office staff.

6.1.3 Sample preparation area

This area should be close to the sample reception area to facilitate sample movement. It should not be situated close to offices or areas that must be kept clean such as the laboratories where delicate testing is done as dust and noise tend to be generated when samples are being processed for testing. This area should also be well ventilated, as the dust created will be a nuisance to the people working there. It may be necessary for the workers to wear dust masks when handling very dusty material.

6.1.4 Testing that creates a lot of dust

There has to be a laboratory where tests such as grading, compaction etc. are carried out as such testing tends to be messy and create dust. It is best to use an area close to the soil preparation area for this purpose, which is also an area that requires seclusion from the rest of the laboratory. It must be easy to clean this area as it becomes very soiled due to the nature of the testing done there. The floor should preferably be of a hard concrete, which is also true of the sample preparation area. Also, only the minimum furniture and equipment should be kept in such a laboratory, as excess furniture and equipment will only gather dust and make cleaning up difficult.

6.1.5 Testing that creates a lot of noise

Some of the work or testing carried out in a laboratory generates a lot of noise (eg compactions, sieve shakers, ball mills etc.) Strong or repeated stimulation from noise can lead to loss of hearing to those working close to the noise source. This is only temporary at first, but after being “deafened” repeatedly some permanent damage may occur. This is called noise deafness, and is brought about by slow but progressive degeneration of a person’s hearing ability. The louder the noise, and the more often it is repeated, the greater the damage to hearing. It is also well known that noise consisting of predominantly high frequencies is more harmful than low frequency noise. Intermittent noise, such as hammering, is more harmful than continuous noise, and a single very loud noise such as a detonation or explosion can damage the ears immediately. Noise intensity (measured in dB) above 85 dB can be considered harmful to hearing.

A typical example of poor stacking.

Noise must be isolated either by placing the apparatus in a sound proof room or enclosing in sound proof container or the testing or work must be carried out in an area that is remote from other working areas. Some procedures are so noisy (eg. sawing asphalt slabs to obtain a sample suitable for testing) that the only practical way to curb the sound is to do the work in a sound proof room. Workers in noisy environments must wear personal ear protection (ear muffs or ear plugs) to protect them from the noise. Earplugs give sufficient protection where noise levels are not too high. In very noisy areas (noise levels above 100 dB) earmuffs should be worn.

Moving machinery, and motors in operation not only make noise, but also set the structure of the building in vibration. Such vibrations and resonance, and the secondary noises that they set up, can be disturbing throughout the building. For this reason these machines (eg compactor) should be mounted onto thick concrete slabs.

6.1.6 Lighting in laboratories

Laboratories should have good lighting; this is especially the case in laboratories where precision work is done. Where it is required to read meters, dials etc. good lighting is imperative. Laboratories should have sufficient natural light coming in through windows and also have electric lighting for occasions when natural light is insufficient (eg overcast conditions). Fluorescent lighting is recommended as shadows are reduced.

6.1.7 Handling loads in work areas

Lifting, handling and dragging loads, is often done in laboratories. It is part of the nature of the work in laboratories. These types of actions involve a good deal of physical effort. The main problem with this type of work, however, is not the heavy loads on the muscles, but much more the wear and tear on the vertebral discs of the back, with increased risk of back trouble. Back troubles are painful and reduce one’s mobility and vitality. They lead to long absences from work, and in modern times are among the main causes of early disability. They are comparatively common in the age group 20 - 40, with certain occupations being particularly vulnerable to back problems (occupations that are physically demanding).

Bad house keeping such as this may leads to accidents and fires.

It is thus imperative that handling of loads be considered when designing work areas. The following are a few practical hints:

- Workers should not have to rotate or twist when lifting a load.
- Workers should be able to lift loads close to their bodies as this position causes less strain on the back.
- It should not be necessary to lift a load with a bent back. Lifting with a bent back causes a lot strain on the spinal column.
- A person's hold on a load should not be lower than knee height.
- Whenever possible trolleys should be used to transport heavy loads (samples, equipment etc.).
- Under optimum conditions 40 kg should be the maximum load that is lifted (not continuously or repeatedly). This is, however, dependent on the person's size, strength, state of health etc.
- The use of trolleys is recommended to reduce physical strain.

Waste bins must be emptied on a regular basis.

6.1.8 Other considerations

Unpleasant or toxic fumes: Some tests cause unpleasant or toxic fumes (some bitumen tests, tests using mercury etc.). There should be fume cupboards with extractor fans available in these areas to extract the toxic fumes.

Chemical tests such as pH determination, titration, conductivity measurements etc. should be done in a laboratory that is not situated close to or is sealed off from dusty areas. Dust and soil may contaminate the workplace and produce erroneous test results.

All the laboratories should have running water, as this is necessary for most testing. Basins should all have soil traps to prevent soil from getting into the drainage system and causing blockages.

6.2 Safety In The Work Place

6.2.1 General

An aspect of laboratory management that is often neglected or overlooked is a safe working environment. Unsafe working conditions can lead to numerous accidents. Accidents result in loss of productivity and are costly to the organization. There is no doubt that safety in the work place is an important aspect of laboratory management.

Stack material away from aisles and exits.

The basic causes of accidents are:

- Personal factors; Lack of knowledge, Physical or mental defect, improper attitude or motivation.
- Job factors; Un-safe conditions or physical environment, inadequate work standards.

The latest report of the Workmen's Compensation Commissioner in South Africa reveals that more than 300 000 cases resulting in injury or disease are reported annually. There are some 30 000 permanent disablements and about 2 000 fatalities every year. The actual potential loss in man-days is more than 28 million which is equivalent to 100 000 workers lying idle each year. Apart from this each year millions of Pula are paid out in compensation to injured or disabled workers.

It is the responsibility of the management to provide a safe working environment for its employees. Some of the aspects that have to be considered by the employer to create such an environment are: good housekeeping practices; safe machinery; supply of protective equipment to staff; First Aid supplies and equipment; fire fighting and fire prevention equipment.

Form M5.1 (Appendix B) provides a safety checklist, which shall be referred to when performing safety inspections. Further more the safety rules and regulations written in both English and Setswana shall be displayed at strategic places around the laboratory.

For purposes of enforcing safety rules and regulations, each UH shall be the safety officer in-charge for his unit. The LM shall be responsible for the overall safety within the laboratory. The LM shall cause the statistics of accidents and injuries sustained in the work place and their extent, to be compiled every month. Such statistics shall be displayed on a board to be mounted in front of the laboratory.

6.2.2 Housekeeping

Basically good housekeeping means having a place for everything and keeping everything in its proper place. Typical examples of poor housekeeping are:

- Floors cluttered with objects that are in the way and over which people can trip.
- Too few and overflowing waste bins.
- Materials and objects poorly stacked on shelves.
- Aisles and exits cluttered or blocked with objects.
- Liquids spilt on floors not cleaned up.

Accidents in the workplace that are typical of poor housekeeping include: people tripping over loose objects on floors; articles falling on people; people slipping on greasy, wet or dirty floors; workers bumping against projecting, poorly stacked or badly placed materials. Fires can also result from poor housekeeping. Some of the reasons why good housekeeping is important and desirable are:

- It cuts down the time spent looking for articles, tools etc.
- Space is saved when everything is stacked away tidily.
- Injuries are avoided when gangways and working areas are kept clear of superfluous material.
- Fire hazards are reduced if combustible materials are kept in proper receptacles.

It is also true that good housekeeping improves the working environment. This means more pleasant working conditions, which arouses a desire in workers for greater efficiency. The end product is increased production.

6.2.3 Guards for machines

Machines that have moving parts (gears, pulleys, driving belts etc.) must have guards covering these to protect personnel from accidental injury. Injuries caused by machines are usually severe and permanent but the danger they pose is usually reduced or removed altogether by mechanical safeguards. Well-designed guards will not affect the efficient operation of the machine.

6.2.4 Personal protective equipment

Many types of personal protective equipment are available. The worker should be provided with protective equipment if the situation warrants it. The most commonly used types of protective equipment that are used are:

- Hard hats to protect the head from falling objects.
- Goggles for the protection of eyes. These should be used when the worker is doing any work that may pose a threat to his eyes (e.g. - sawing rock)
- Overalls (overcoats) to protect the workers clothing from damage.
- Different types of gloves to protect the hands (e.g. from hot bitumen or acids).
- Safety boots and shoes to protect feet from heavy objects falling on them.
- Dust masks for working in dusty environments.
- Earmuffs or earplugs to protect workers in noisy environments.

Clean up spilt oils and water to avoid accidents.

Compression machine shall not be operated while the safety cage is open.

The location of fire extinguishers must be clearly indicated by the use of red 'fire' arrows of by red painted strips. Reserve 'no parking' area immediately in front of the extinguisher.

6.2.5 Fire Prevention Equipment

Fire extinguishers shall be placed in clearly visible places with unrestricted access.

Fires in the work place are dangerous to lives and property. Fires, can to a large extent, be prevented by good housekeeping practices. Materials that are flammable (wood, paper, oily rags etc.) should not be left lying around. Most fires start in a small way and if they can be extinguished at this stage property and human lives can be saved. It is obviously much easier to extinguish a small fire than to allow it to spread and later have to extinguish a major blaze.

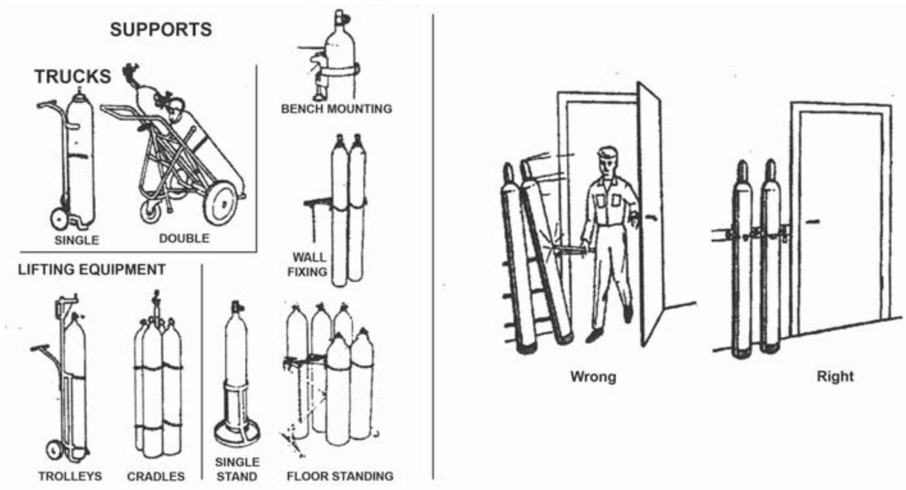
Laboratories should be equipped with some form of fire fighting equipment to deal with incipient fires immediately before they spread and become major fires. The most common fire fighting appliances are different types of fire extinguishers. Extinguishers should be placed close to likely fire hazards but not so close that they can be damaged or cut off from use by fires. They should be located outside entrances to danger areas, never inside where they might become inaccessible. At least one person per unit must be trained in the use of fire extinguishers. The Fire Brigades should be invited to give fire prevention workshops at least once a year. Extinguishers should be placed at conspicuous places.

6.2.6 Gas cylinders

Poor temporary disposal of waste soils. Waste soil samples must be managed in an organised and tidy manner to prevent wastage of space and contaminating the CML premises.

Special precautions must be taken when handling or storing gas cylinders. Because of their shape large gas cylinders are awkward to carry. They may be rolled but never dragged. It is best to have a purpose built trolley to move the cylinders. Cylinders should also be prevented from falling or bumping against each other.

Cylinders should be stored in a well-ventilated area away from heat or direct sunlight and on a level fireproof surface. Racks and/or chains should be provided for securing cylinders individually in an upright position.



Handling and storage of gas cylinders.

Interesting statistics were published a few years ago by the US National Institute for Occupational Safety and Health. Over-exertion was claimed to be the cause of lower back pain by over 60 % of the people suffering from it.

Another UK report presents the following data: 61 % of the over exertion injuries involve the back and 74 % of these back injuries were due to lifting loads.

In Western Germany it was also found that back problems cause 20 % of absenteeism and 50 % of premature retirements.

6.2.7 First Aid

Owing to the nature of the work done in laboratories it is more likely that accidents will occur than say in an office environment. It is thus desirable that each unit in the laboratory has at least one person who has been trained in First Aid techniques. A well-stocked First Aid box should also be kept in the laboratory.

6.2.8 Smoking

Smoking is a health hazard and it is against the law to smoke in offices and enclosed work places. No smoking signs must be placed at strategic places around the laboratory. In addition the worker shall be educated about the dangers of smoking. The Ministry of Health should be requested to conduct health workshops at MRD once a year.

6.2.9 Intoxicating substances

It is against the industrial rules and regulations for workers to work while under the influence of intoxicating substances. It is very hazardous for any worker to enter the laboratory while intoxicated. No worker shall be allowed to operate any equipment or machinery if they are suspected to be under the influence of intoxicating substances. Where a worker is suspected of being intoxicated, the UH shall inform the LM who shall immediately cause the person to be removed from the laboratory. Disciplinary measures as set out in the Regulations for Industrial Employees (RIE) and the General Orders shall then be applied as appropriate.

6.2.10 HIV and AIDS.

The HIV and AIDS epidemic continues to ravage the country through loss of the workforce. It is, therefore, in the interest of every organisation to join the fight against this disease. Currently the MRD has an AIDS committee, which operates on an ad-hoc basis. It is prudent that the operations of the AIDS committee are formalised. The LM shall chair the committee and committee members shall come from both the management and the laboratory assistants. The committee must be entrusted with planning and executing awareness campaigns, distribution of literature, sourcing and presentation of videos, distribution of condoms and any other strategies that may assist in the fight against the spread of HIV and AIDS.

Aids awareness messages shall be placed at strategic places around the CML premises.

Regular awareness campaigns shall be held. The Ministry of Health and Non Governmental Organisations such as Tebelopele Testing Centre and the Coping Centre for People Leaving with AIDS should be invited to make presentations at these workshops. It is imperative that during these workshops work is stopped and all workers are encouraged to attend.

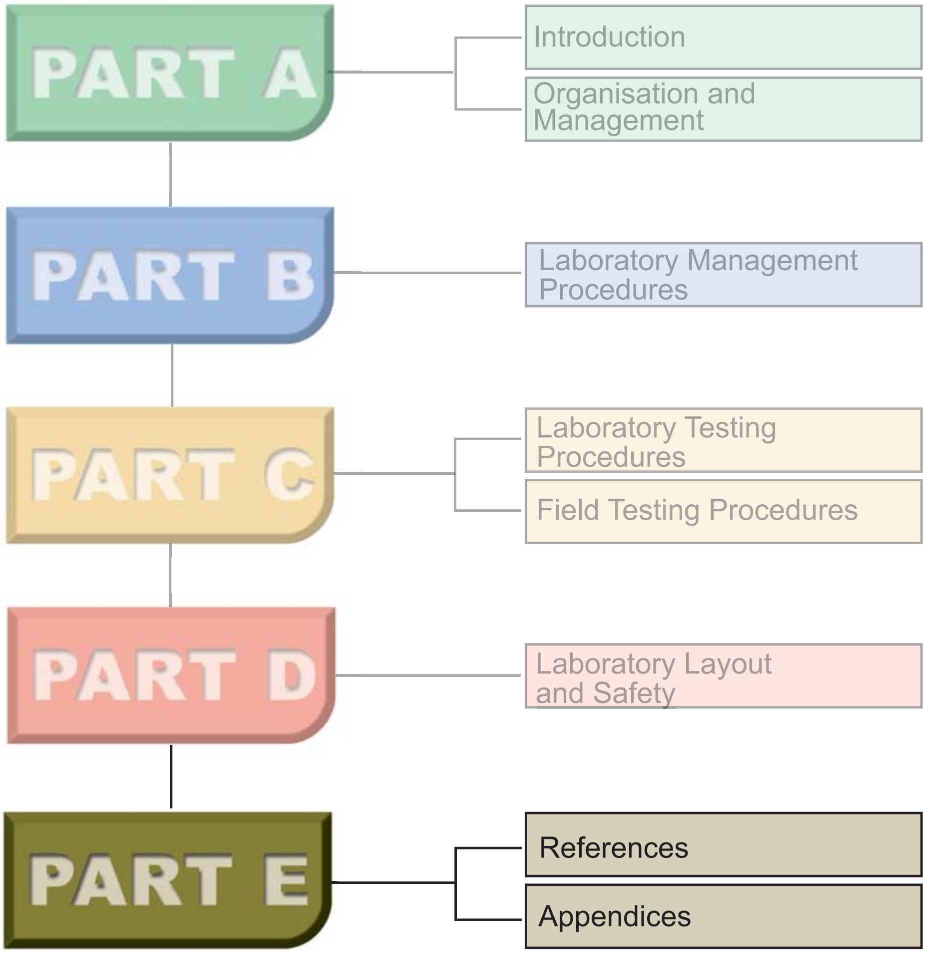
The MRD shall develop an AIDS policy, which shall be written in both English and Setswana. The policy shall be displayed at strategic places around the laboratory.

6.2.11 Safety Representative

There are many more safety issues that need to be considered than those discussed above. It is advisable that the LM appoints one of the lab staff to deal with safety matters. Apart from his normal duties in the laboratory it will also be this person's responsibility to ensure that safety standards are being adhered to. Apart from attending training courses this should not take more than a few hours of his/her time per month.

PART D

PART E


PART A
Introduction
Organisation and Management
PART B
Laboratory Management Procedures
PART C
Laboratory Testing Procedures
Field Testing Procedures
PART D
Laboratory Layout and Safety
PART E
References
Appendices

REFERENCES

A COMPENDIUM OF ROAD PAVEMENT IN BOTSWANA. 2000. Roads Department.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO). 1982. **Materials: Part 2: Tests**. 13th Edition, AASHTO, Washington, DC.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. 1978. **ASTM manual for conducting an inter-laboratory study of a test method.** ASTM Special Technical Publication, No. 335. ASTM, Philadelphia.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. 1998. **Annual book of ASTM standards**, Part 19: Soil and Rock; Building Stones. ASTM, Philadelphia.

BOTSWANA GOVERNMENT. 1996. General Orders Governing the Conditions of Service of the Public Service of the Republic of Botswana. Government Printers, Gaborone, Botswana.

BOTSWANA GOVERNMENT. 1996. Regulations for Industrial Class Employees. Government Printers, Gaborone, Botswana.

BOTSWANA ROAD DESIGN MANUAL. 1982. Botswana Roads Department.

BOTSWANA ROADS DEPARTMENT. 1992. ROADS IN BOTSWANA.

BOTSWANA ROADS DEPARTMENT. 2000. Methods and Procedures for Prospecting for Road Construction Materials. **Guideline No. 3**. Gaborone, Botswana.

BOTSWANA ROADS DEPARTMENT. 2000. Pavement Testing, Analysis and Interpretation of Test Data **Guideline No. 2**. Gaborone, Botswana.

BOTSWANA ROADS DEPARTMENT. 2002. The use of Silcrete and Other Marginal Materials for Road Surfacing. **Guideline No. 8**. Gaborone, Botswana.

BRITISH STANDARDS INSTITUTION. 1975. **Methods for sampling and testing of mineral aggregates, sands and fillers**. BS 812, Part 3. British Standards Institution, London.

BRITISH STANDARDS INSTITUTION. 1975. **Methods of Testing for Soils for Engineering Purposes**. BS 1377. British Standards Institution, London.

BRITISH STANDARDS INSTITUTION. 1990. **Methods for sampling and testing of mineral aggregates, sands and fillers**. BS 812. British Standards Institution, London.

BURROW BINNIE BOTSWANA. 1988. Institutional Study of the Botswana Roads Agencies, Final Report. Roads Department, Ministry of Works Transport and Communications. Gaborone, Botswana.

COMMITTEE OF STATE ROAD AUTHORITIES. 1979. **Standard methods of testing road construction materials.** Pretoria: Department of Transport. (Technical Methods for Highways, No.1).

COMMITTEE OF STATE ROAD AUTHORITIES. 1981 **Sampling Methods for Road Construction.** Pretoria: Department of Transport. (Technical Methods for Highways No. 5).

COMMITTEE OF STATE ROAD AUTHORITIES. 1986. **Standard methods of testing road construction materials.** CSRA Technical Methods for Highways, No 1, Pretoria.

CSIR, Transportek. 1984. Technical Report RS/2/84 Pretoria

CSIR, Transportek. 1984. Technical Report RS/2/84, Pretoria.

CSIR. 1968.. **Manual of testing procedures for highway materials**. NIRR, Pretoria.

CSIR. Transportek: Manual of Testing Procedures for Highway Materials,. C.B. 22. Pretoria.

DIRECTORATE OF PUBLIC SERVICE. 1994. Job Descriptions for Engineer and Technicians at Materials and Research Division. Form MSU 10B. Gaborone, Botswana. (These are numerous forms for each of the Positions at MRD).

DIRECTORATE OF PUBLIC SERVICE. 2001. Generic Schemes of service for Artisan and Technical Models in Government. Savingram, Ref. DP II.i.i.20(5). Gaborone, Botswana.

DIRECTORATE OF PUBLIC SERVICE. 2002. Establishment Register for the fiscal Year 2002 – 2003. Government Printers, Gaborone, Botswana.

EDWARDS, J A. 1960. **Laboratory management and techniques**. Butterworth & Co. limited, London.

GRANDJEAN, E. 1988. **Fitting the task to the man.** Taylor and Francis, London.
International Society for Rock Mechanics (ISRM).1973. Committee on Laboratory Tests Document No.1

INTERNATIONAL STANDARDS ORGANIZATION. 1981. Precision of test methods- Determination of repeatability and reproducibility by inter-laboratory tests. ISO 5725-1981 (E).

MATERIALS AND RESEARCH DIVISION. 1998. The Materials and Research Division Report System – Report Number IC 001. Roads Department.

NATIONAL OCCUPATIONAL SAFETY ASSOCIATION. 1991. **Questions and answers (on safety).** National Occupational Safety Association, Pretoria.

SATCC. 1998. Standard Specifications for Road and Bridge Works. Southern African Transport and Communications Commission. CSIR, Pretoria, RSA.

STANDARD SPECIFICATIONS FOR ROAD AND BRIDGES. 1983. Botswana Roads Department.

TRANSPORTATION RESEARCH RECORD 1291, National Research Council, Washington D.C., pp 106-112.

WASTE DISPOSAL ACT. 1998. Department of Sanitation and Waste Management. Government Printers. Gaborone Botswana.

WATER POLLUTION CONTROL FEDERATION. 1981. Laboratory management. Manual of Practice No. SM-1. Board of control Water Pollution Control Federation, Washington.

LABORATORY TESTING MANUAL 2000. Central Materials Laboratory (CML) Tanroads, Tanzania.

BRITISH STANDARDS INSTITUTIONS B S 1377 Part 7: 1990.

APPENDIX A – LABORATORY AND FIELD TESTING FORMS

- FORM S1(a) Mechanical Sieve Analysis for Soils and Gravels
- FORM S1(b) Moisture Content Determination
- FORM S1(c) Hydrometer Analysis
- FORM S1- S4 Soil Classification Test Results
- FORM S1- S6 Compaction, CBR and Classification Summary
- FORM S1- S6(b) Compaction, CBR and Classification
- FORM S2- S4(a) Atterberg Limits
- FORM S2- S4(b) Atterberg Limits
- FORM S5 (a) Maximum Dry Density Optimum Moisture Content
- FORM S5 (b) Maximum Dry Density Optimum Moisture Content Graph
- FORM S6 California Bearing Ratio
- FORM S7 Unconfined Compressive Strength – stabilised soils and Gravels
- FORM S8 (a) Consolidation Test Work Sheet
- FORM S8 (b) Consolidation Test
- FORM S9 Crump Test
- FORM S12 Conductivity and pH of Saturated Soil and Water
- FORM S13 Initial Consumption of Lime (ICL)
- FORM S15 (a) Direct Shear Tests
- FORM S15 (b) Direct Shear Tests
- FORM S16 (a) Unconsolidated Undrained Shear Strength of Cohesive Soils
- FORM S16 (b) Unconsolidated Undrained Shear Strength of Cohesive Soils Tests
- FORM S16 (c) Unconsolidated Undrained Shear Strength of Cohesive Soils Tests
- FORM AG1 Mechanical Sieve Analysis of Aggregates
- FORM AG2 Aggregate Crushing Value (ACV)
- FORM AG3(a) Dry 10% FACT Value
- FORM AG3(b) Soaked 10% FACT Value
- FORM AG4 Modified Aggregate Impact Value (AIV)
- FORM AG5 Durability Mill Index (DMI)
- FORM AG9 Accelerated Polished Stone Value
- FORM AG10 Aggregate Fingers and Pliers Value
- FORM B1 Penetration Test
- FORM B2 Ductility Test
- FORM B4 Softening Point
- FORM AS3 Bulk Relative Density of a Compacted Bituminous Mix
- FORM AS5 Maximum Theoretical Relative Density of Asphalt Mix
- FORM F1 Dynamic Cone Penetrometer (DCP)

Ministry of Works and Transport
Roads Department

FORM S1 (a)

Soil Tests: Work Sheet

Mechanical Sieve Analysis for Soils/Gravels

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………………………………………………………… Sample Location: ……………………….....

Client: ………………….. Date:…………….... Tested by: ……………………………………... Checked by: ………………………………...

Mass of Sample Taken: Mass of Sample Taken:

Sieve Size (mm)	Sample Number:				Sample Number:			
	Mass Retained	% Retained	Cumulative % Retained	Cumulative % passing	Mass Retained	% Retained	Cumulative % Retained	Cumulative % passing
75.0								
53.0								
37.5								
26.5								
19.0								
13.2								
9.50								
6.70								
4.75								
2.36								
2.00								
1.18								
0.600								
0.425								
0.300								
0.150								
0.075								
<0.075								
Total								

Ministry of Works and Transport
Roads Department

FORM S1 (b)
Soil Tests: Work Sheet
Moisture Content Determination

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ………………………………............... .... Sample Location: …………………….....

Client: …………………... Date:…………….... Tested by: ……………………….................. Checked by: ……………..................

Sample No.									
Pan number.									
Wt. pan + wet soil (g)									
Wt. pan + dry soil (g)									
Wt. pan only (g)									
Wt. moisture (g)									
Wt. dry soil (g)									
Moisture content (%)									
Sample No.									
Pan number.									
Wt. pan + wet soil (g)									
Wt. pan + dry soil (g)									
Wt. pan only (g)									
Wt. moisture (g)									
Wt. dry soil (g)									
Moisture content (%)									
Sample No.									
Pan number.									
Wt. pan + wet soil (g)									
Wt. pan + dry soil (g)									
Wt. pan only (g)									
Wt. moisture (g)									
Wt. dry soil (g)									
Moisture content (%)									

Ministry of Works and Transport
Roads Department

FORM S1 (c)
Soil Tests: Work Sheet
Hydrometer Analysis

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………………. Sample Location: ……………………………...

Client: …………………………… Date:………… Tested by: ……………………………. Checked by: ………………………………………….

Hydrometer Ref. No.: …………………….. R = Hydrometer Reading %passing N = % finer 0.425 x P/100 = ……………% R_C = Corrected Hydrometer Reading

Percentage soil in suspension P = R/W X 100% C_1 = Temperature Correction C_2 = Dispersing Agent Correction C_3 = Meniscus Correction f_1 = 1,130 f_2 = 1,205

Sample Number	Mass of Dispersed soil (mg)	Date	Time	Elapsed	R	Temp	Total Correction.	R_C	P	Estimated Diameter (mm)	N.	fN
				18 s						0.075		
				40s						0.050		
				60 min						0.005		
				7h						0.002		
				18 s						0.075		
				40s						0.050		
				60 min						0.005		
				7h						0.002		
				18 s						0.075		
				40s						0.050		
				60 min						0.005		
				7h						0.002		

Ministry of Works and Transport
Roads Department

FORM S1 - S6 (a)
Soil Tests: Summary Sheet

Compaction, CBR and Classification

CENTRAL MATERIALS LABORATORY
Materials and Research Division

SUMMARY OF COMPACTION, CBR AND CLASSIFICATION TEST RESULTS

Project:………………………..…… Sample Location………………… Sample number:………………… Tested:…..………………………..

Client:…………………………………………………..…… Date:………..…………………..… Checked:…………………………

Compaction Test Results (vibration / ……..kg x …….layers x …….blows)

Dry Density (kg/m3)									
Moisture Content (%)									

Maximum Dry Density = ……..….kg/m³ Optimum Moisture Content = …...%

California Bearing Ratio Test Results (Soaked or Unsoaked)

Campactive Effort	CBR 2.54mm	CBR 5.08mm	CBR 7.62mm	Moulding MC(%)	Dry Density kg/m³	Relative Density (%)	MC after soaking (%)	Swell %
Mod. AASHTO								
Intermediate								
Standard Proctor								

Particle Size Distribution

Percentage passing Seive Size (mm)														
75.0	53.0	37.5	26.5	19.0	13.2	9.5	6.7	4.7 5	2.36	1.18	0.425	0.250	0.150	0.075

Grading Modulus = ………………. Linear Shrinkage Product (LS x P0.425) = ……………

Sample Classification

AASHTO: …………………………….

TRH: ……………………..…………

Remarks

……………………………………………………………………….

……………………………………………………………………….

Interpolated CBR Results

CBR@ 100% Mod. AASHTO = ……………..

CBR@ 98% Mod. AASHTO = ……………..

CBR@ 95% Mod. AASHTO = ……………..

CBR@ 93% Mod. AASHTO = ……………..

CBR@ 90% Mod. AASHTO = ……………..

Index Tests

Liquid Limit: ………………....……%

Plasticity Index:...………..…......…...%

Linear Shrinkage: …………...….....…

Conductivity: …………….........mS/cm

pH: ....

Relative Density:………………...kg/m³

Ministry of Works and Transport
Roads Department

FORM S1- S6 (b)

Soil Tests: Work Sheet

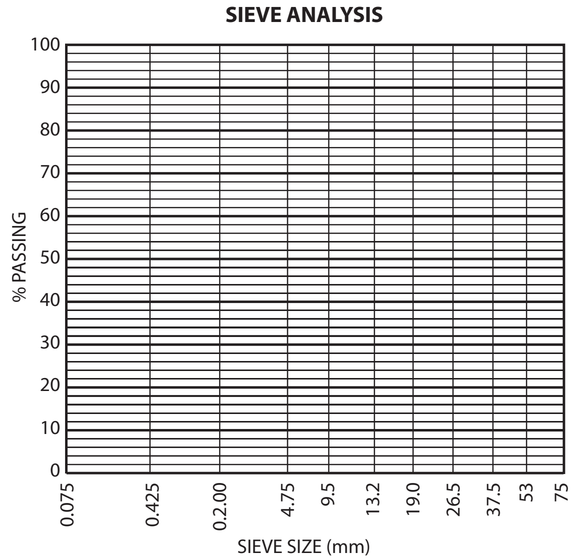
Compaction, CBR and Classification

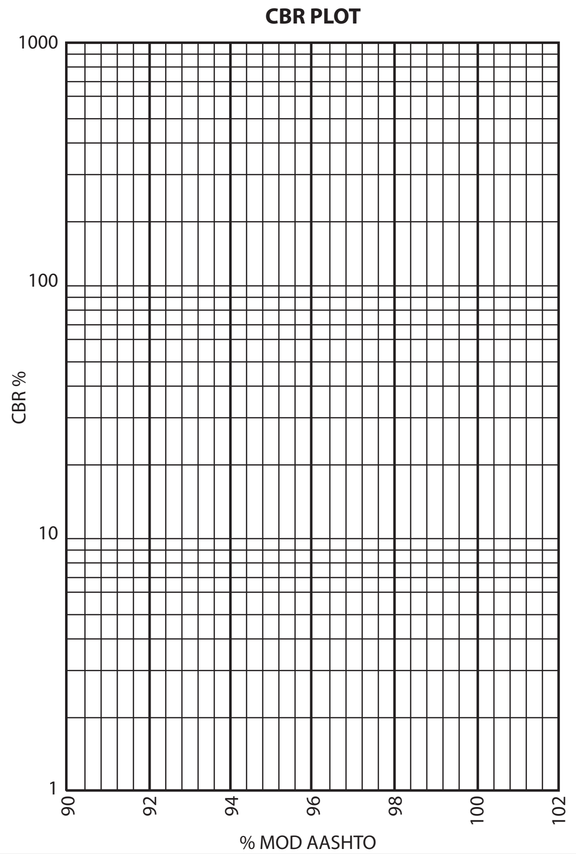
CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………………Sample Location: ……………………….... Sample Number...................................

Client: ………………….. Date:………….....Tested by: ………………………..................Checked by: ……………..................

MAX STONE SIZE						
SIEVE ANALYSIS (% PASSING)		+75.0				
		75.0				
		53.0				
		37.5				
		26.5				
		19.0				
		13.2				
		4.75				
		2.0				
		0.425				
		0.075				
GRADING MODULAS						
CON-STANTS		LIQUID LIMIT				
		PLASTICITY INDEX				
		LINEAR SHRINKAGE %				
PLOT CODE						
USPRA CLASSIFICATION						
TRH 14 CLASSIFICATION						
CBR / UCS CALCS	MOD AASHTO	MAX DRY DENSITY				
		O.M.C. %				
		HYGRO %				
		DRY DENSITY (Kg/m³)				
		% MOD AASHTO				
		MOD AASHTO VALUE				
		SWELL %				
	INTER	DRY DENSITY (Kg/m³)				
		% MOD AASHTO				
		INTERMEDIATE VALUE				
	PROCTOR	DRY DENSITY (Kg/m³)				
		% MOD AASHTO				
		PROCTOR VALUE				
98% AASHTO						
95% AASHTO						
93% AASHTO						
90% AASHTO						



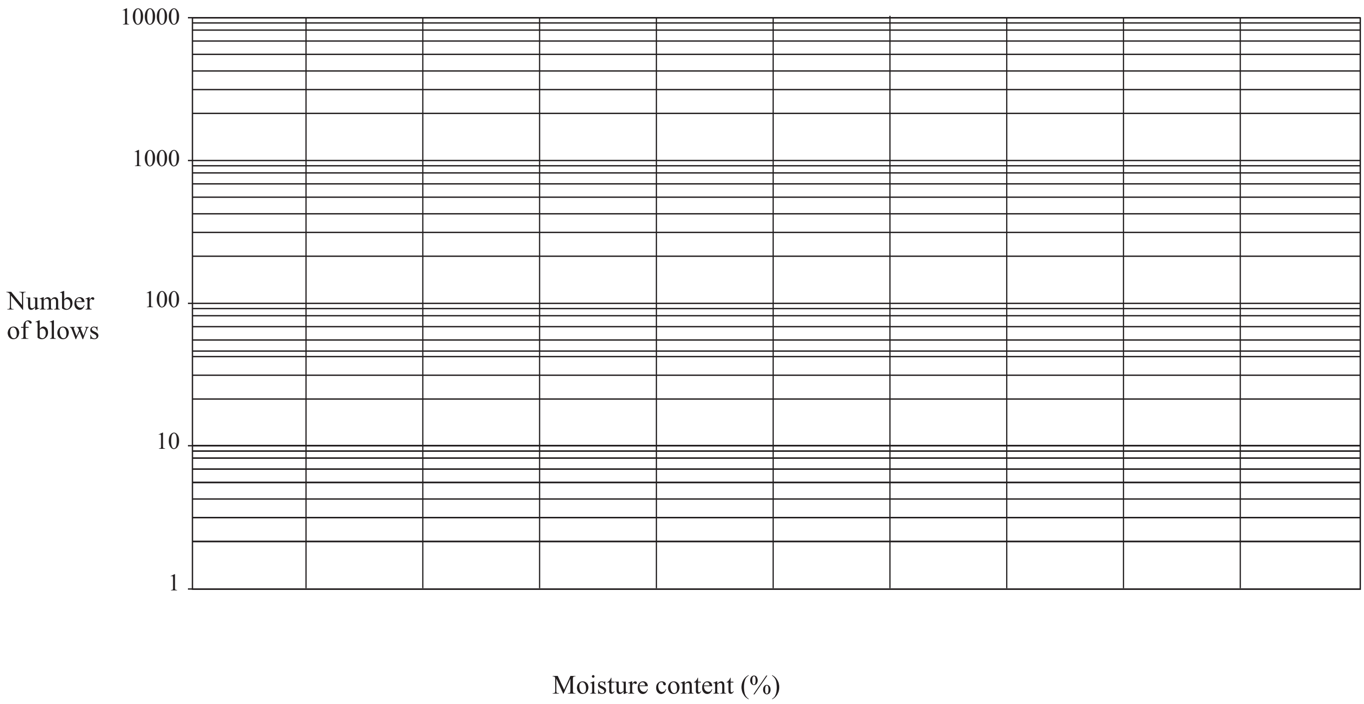


Ministry of Works and Transport Roads Department	**FORM S2 - S4 (a)** **Soil Tests: Work Sheet** **Atterberg Limits**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: …………………………................ .... Sample Location: …………………….....

Client: ………………….. Date:…………....Tested by: …………………….................... Checked by: …………….................

Test	**LL**	**LL**	**LL**	**LL**	**Av.**	**PL**	**PL**	**Av.**	**Field MC**
No. of blows									
Tin No.									
Wt. Tin + wet soil (g).									
Wt. Tin + dry soil (g).									
Wt. Tin (g).									
Wt. Water (g).									
Wt. Dry soil (g).									
Moisture Content (%)									
Fully shrunk length of linear shrinkage specimen 10 cm trough (No………)									



Liquid Limit	%		
Plastic Limit	%		
Plasticity Index	%		
Shrinkage	%		
Linear shrinkage	%		

LS = Sx (100/150) x 0´8/(1 - 0´00 8N)

Ministry of Works and Transport
Roads Department

FORM S1 - S4
Soil Tests: Summary Sheet

SOIL CLASSIFICATION TEST RESULTS

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………………   Sample Location: …………….............

Client: ………………………………….........   Date:…………..............   Tested by: …………………...........   Checked by: ………………………….....

Location	SN	Depth (m)	Sample Descrip-tion	Particle Size Distribution – Percentage passing														GM	LL	Ls (%}		PI (%)		PM (%)		AASHTO Classification
				Millimetres										Microns												
				75	53	37.5	26.5	19.0	13.2	9.5	4.75	2.0	1.18	425	250	150	075			a	b	a	b	a	b	

SN: Sample Number	**a:** 0.425mm sieve		**b:** 0.075mm sieve	
GM: Grading Modulus	**LL**: Liquid Limit.	**PI**: Plasticity Index.	**LS**: Linear Shrinkage.	**PM**: Plasticity Modulus (P0.425xPI)

Ministry of Works and Transport
Roads Department

FORM S2 - S4 (b)

Soil Tests: Work Sheet

Atterberg Limits

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: …………………………............... .... Sample Location: ……………………......

Client: ………………….. Date:…………….... Tested by: ……………………................... Checked by: ……………..................

Sample Number……………..	MOISTURE CONTENT			PLASTIC LIMIT		RESULTS
Trough No.						**LL**
Wt. tin. + wet soil (g)						**PL**
Wt. tin. + dry soil (g)						**PI**
Wt. tin (g)						**LS**
Wt. of moisture (g)						
Wt. of dry soil (g)						
Percentage Moisture (g)						
Number of taps (N)						

N= number of taps at Liquid Limit (TMH 1: 1986)

Trough Number ………….. Shrinkage (S) (mm): …………… Linear Shrinkage: …….%

LS = S x (100/150) x 0.8/(1-0.008N)

Sample Number……………..	MOISTURE CONTENT			PLASTIC LIMIT		RESULTS
Trough No.						**LL**
Wt. tin. + wet soil (g)						**PL**
Wt. tin. + dry soil (g)						**PI**
Wt. tin (g)						**LS**
Wt. of moisture (g)						
Wt. of dry soil (g)						
Percentage Moisture (g)						
Number of taps (N)						

N= number of taps at Liquid Limit (TMH 1: 1986)

Trough Number ………….. Shrinkage (S) (mm): …………… Linear Shrinkage: ….….%

LS = S x (100/150) x 0.8/(1-0.008N)

Ministry of Works and Transport Roads Department	**FORM S5 (a)** **Soil Tests: Work Sheet** **Maximum Dry Density & Optimum Moisture Content**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………….................Sample Location: ………………………........Sample Number.................................

Client: …………………..Date:…………....Tested by: ……………….…....................Checked by: …………….................

Container Number						
Mass of container + wet material (g)						
Mass of container + dry material (g)						
Mass of container (g)						
Mass of moisture (g)						
Dry Mass of Material (g)						
Moisture Content (%)						

Water required...................................... **Mould Factor........................**

% Moisture added						
Mass of Mould (g)						
Mass of Mould + wet material (g)						
Wet Mass of Material (g)						
Wet Density (kg/cm^3)						

MOISTURE CONTENT DETERMINATION AFTER COMPACTION

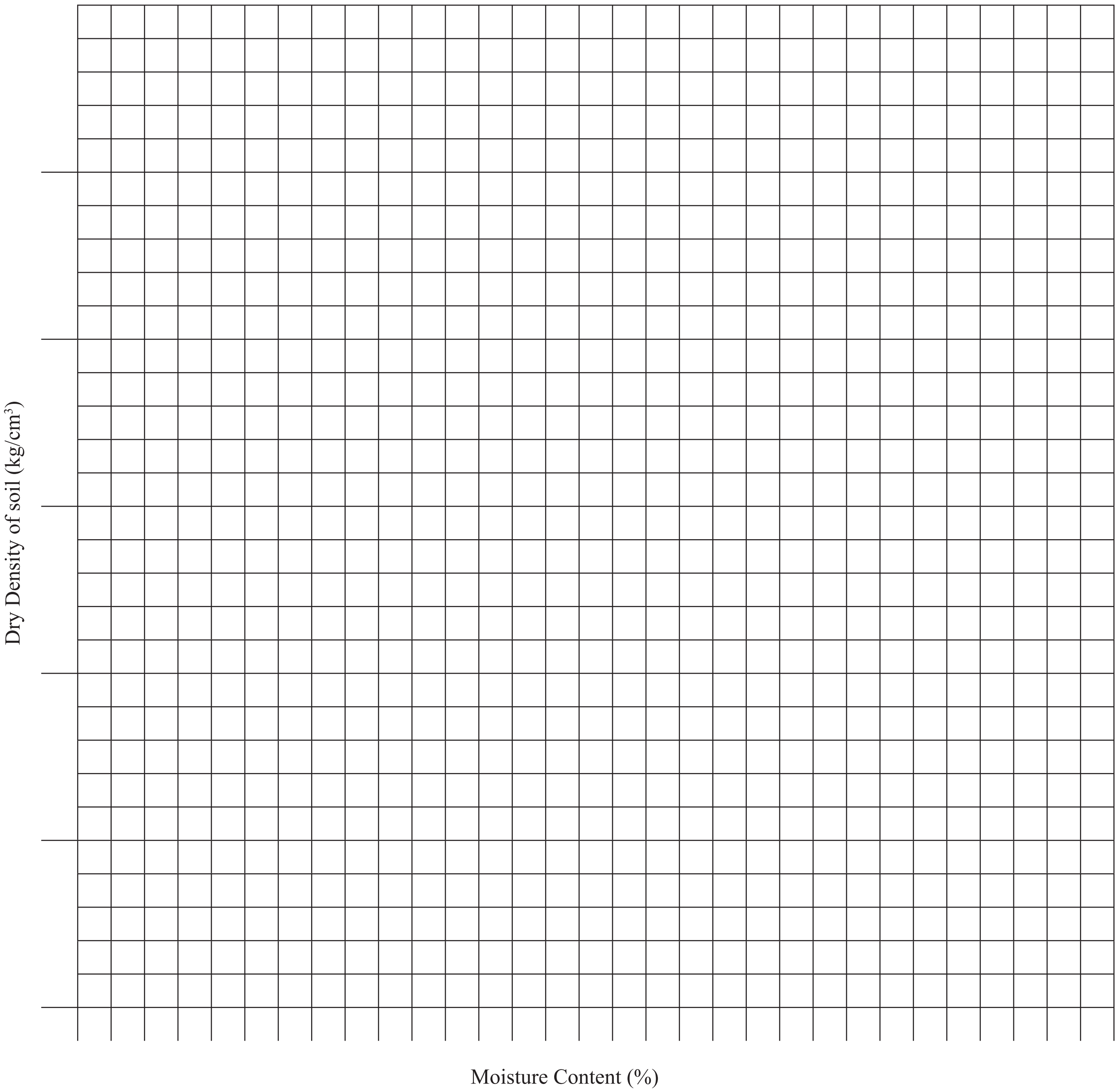
Conrainer Number						
Mass of container + wet material (g)						
Mass of container + dry material (g)						
Mass of container (g)						
Mass of moisture (g)						
Moisture Content (%)						
Dry Density (kg/cm^3)						

Maximum Dry Density........................kg/cm^3 Optimum Moisture Content..........................%

Ministry of Works and Transport Roads Department	**FORM S5 (b)** **Soil Tests: Work Sheet** **Maximum Dry Density & Optimum Moisture Content**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ………………………............... .. Sample Location.. .... Sample Number: ……………………....

Client: ………………….. Date:…………....Tested by: ……………….…................... Checked by: ……………..................



Ministry of Works and Transport
Roads Department

FORM S6
Soil Tests: Work Sheet
California Bearing Ratio (CBR)

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: …………….…………................ .. Sample Location.. .... Sample Number: ……………………....

Client: …………………. Date:…………....Tested by: ………………….................... Checked by: …………….................

Maximum Dry Density.……………...kg/m^3 at OMC …..….... Stabilization ……….…% Days Cured…..……..... Days Soaked……….…..

	MOISTURE CONTENT DATA					
	Hygro Moisture Content	Molding Moisture	Moisture After Soaking			
Pan Number		Water Required ……..% ………ml	Mould Number (kg)			
Wt. of wet sample (g)			Mould +wet weight (kg)			
Wt. of dry sample (g)			Mould weight (kg)			
Weight of pan (g)			Wet weight (kg)			
Weight of moisture (g)			Dry weight (g)			
Weight of dry Soil (g)			Moisture (g)			
% Moisture (g)			% Moisture			
Average			Average			

COMPACTION DATA

Effort	Modified	Intermediate	Proctor
Mould Number.			
Factor			
Weight of mould (Kg)			
Weight of mould+ wet sample (kg)			
Weight of wet Sample (kg)			
Weight of dry Sample (kg)			
Wet Density (kg) m^3			
Dry Density (kg) m^2			
% Compaction			
% Swell			

PENETRATION DATA

DEPTH (mm)	Reading	Correct Reading	CBR	Reading	Correct Reading	CBR	Reading	Correct Reading	CBR
0									
0.5									
1.0									
1.5									
2.0									
(0.1^{II})* 2.5									
3.0									
3.5									
4.0									
4.5									
(0.2^{II})* 5.0									
5.5									
6.0									
6.5									
7.0									
(0.3II)* 7.5									

Ministry of Works and Transport Roads Department	**FORM S7** **Soil Tests: Work Sheet** **Unconfined Compressive Strength - stabilised soils**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: …………….…………................. .. Sample Location.. .... Sample Number …………………….....

Client: ………………….. Date:…………....Tested by: …………………….................... Checked by: ……………..................

Type of Stabilizer	Stabilizer Content (%)	Modified AASHTO data		Specimen Data				
		Max Dry Density (Kg/m^3)	Optimum Moisture Content (%)	Dry Density. (Kg/m^3)	Moisture (%)	7 day compressive strength		
						Individual applied load		Average UCS (kPa)
						Applied Load	UCS (kPa)	

Compressive Strength

Ministry of Works and Transport
Roads Department

FORM S8 (a)
Soil Tests: Work Sheet

Consolidation Test Results

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Specimen Measurements:
Interior Diameater of ring =......................... cm
Specimen Area = ...cm^2 = A
Initial thickness of soil sample = ...cm
Specific Gravity of soil = ...G1
Equivalent height of solids, $2H_o \frac{W_S}{G1\ \gamma_W\ X\ A}$ = m

Consolidation ring weight = ...gm
ring+wet soil weight = ...m
Ring+dry soil weight = ...m
Dry soil weight = ...gm = W_S
Moisture content = ...%

Applied Pressure in (kg/cm^2)	Final dial reading d_f (mm)	Change in dial reading (mm)	Thickness of soil sample 2H (mm)	Equivqlent hight of voids $2H-2H_o$ (mm)	Void ratio $e = \frac{2H}{2H_o} - 1$	Change in void ratio Δe	Coefficient of com-pressibilty $a_V = \frac{\Delta e}{\Delta p}$ (cm^2/Kg)	$1+e_0$	Coefficient of volume change $m_V = \frac{av}{1+e_2}$ (cm^2/Kg)	Fitting time in minutes t_{90}	Coefficient of con-solidation $C_v = \frac{0,848\ d^2}{t_{90}}$ (cm^2/sec)	Compression index C_e	Coefficient of perme-ablity $K = C_v\ m_v\ \gamma_w$ (cm/sec)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.00													
0,10													
0,20													
0,50													
1.00													
2.00													
4.00													
8.00													
16.00													
8.00													
4.00													

Ministry of Works and Transport Roads Department	**FORM S8(b)** **Soil Tests: Work Sheet** **Consolidation Test**	CENTRAL MATERIALS LABORATORY Materials and Research Division

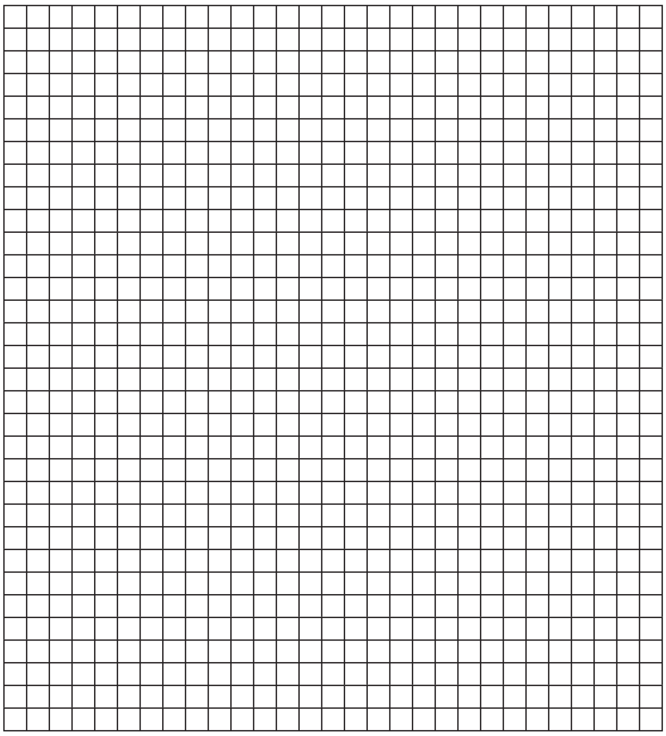
Project: ………………………………………………………………………………… Sample Location: ………………………….

Client: ……………………. Date:……………....Tested by: ……………………………………… Checked by: ………………………………

Load given = ………kg/cm²

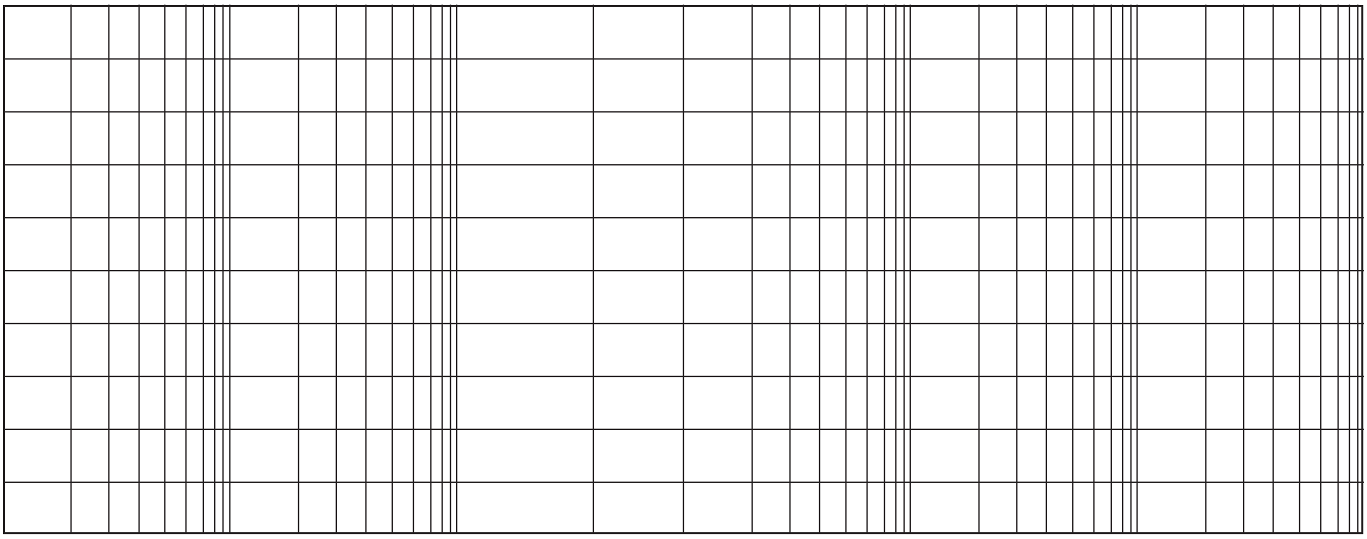
$\sqrt{t}_{90}$ = ………….

Dial Reading in mm



$\sqrt{t}$ in minutes

Void Ratio e



Consolidation Pressure log p in kg/cm²

Ministry of Works and Transport Roads Department	**FORM S9** **Soil Tests: Work Sheet** **Crumb Test**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ………………………................ .... Sample Location: ……………………....

Client: ………………….. Date:…………....Tested by: ………………….....................Checked by: …………….................

Sample Number	Soil Description	Reagent Used	Classification (Grade 1 – 4)	Classification (Non-Dispersive/Dispersive)

- Grade 1 and 2 represent a non-dispersive reaction
- Grade 3 and 4 represent a dispersive reaction

Ministry of Works and Transport
Roads Department

FORM S12

Soil Tests: Work Sheet

Conductivity and pH of Soil and Water

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………................ .... Sample Location: …………………….....

Client: …………………... Date:…………......Tested by: ……………………...................Checked by: ……………....................

Sample Number											
Container Number											
Size Fraction											
EC Reading											
Temperature (^{0}C)											
Temp. Conversion Factor											
Cell Number											
Cell Constant											
Conductivity (S/m)											
Percentage Soluble Salts											
PH											
Percentage Sat. Moisture Content											

NB: Electrical Conductivity (EC) is measured in Siemens per meter (S/m) at 25 ^{0}C

Ministry of Works and Transport
Roads Department

FORM S13

Soil Tests: Work Sheet

Initial Consumption of Lime (ICL)

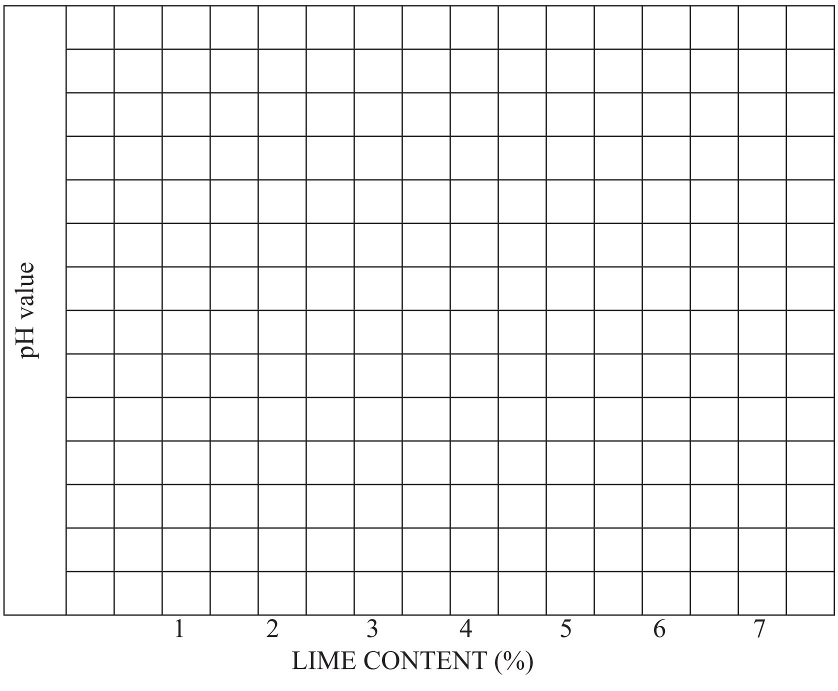
CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………………………..Sample Location.. ……………………………… Sample Number ……………………………

Client: …………………… Date:………………Tested by: ……………………………………Checked by: ……………………………

	Calcium hydroxide	Lime used in the test
pH of Saturated Solution		
Temperature (°C)		
pH corrected to 25 °C		

Lime Content (%)									
pH value of suspension									
Temperature (°C)									
pH corrected to 25 °C									



Proportion of material < 0.425 mm	%
Initial Consumption of Lime (ICL)	%

Ministry of Works and Transport Roads Department	**FORM S15 (a)** **Soil Tests: Work Sheet** **Direct Shear Tests**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………….. Sample Location.. .... Sample Number ………………….....

Client: ………………….. Date:…………....Tested by: ……………………................... Checked by: …………….................

Maximum Dry Density..……………....kg/m³ at OMC

Length of Sample L_0 =…………………………..... mm, Width of Sample B_0 = …………………………..mm

Area of Sample $A_0 = L_0 \times B_0$ = …………………………..cm² , Sample Thickness = ……………………...mm

Elapsed Time in min.	Shear Dial in mm δL_0	Shear strain in % $\varrho = \frac{\delta L}{L_0}$	Normal Dial in mm	Normal Displacement in mm	Proving Ring Dial in KN (P)	Corrected Contact Area A $= A_0\left(1 - \frac{\delta L}{L_0}\right)$	Shear Stress $\tau = \frac{\rho}{A}$

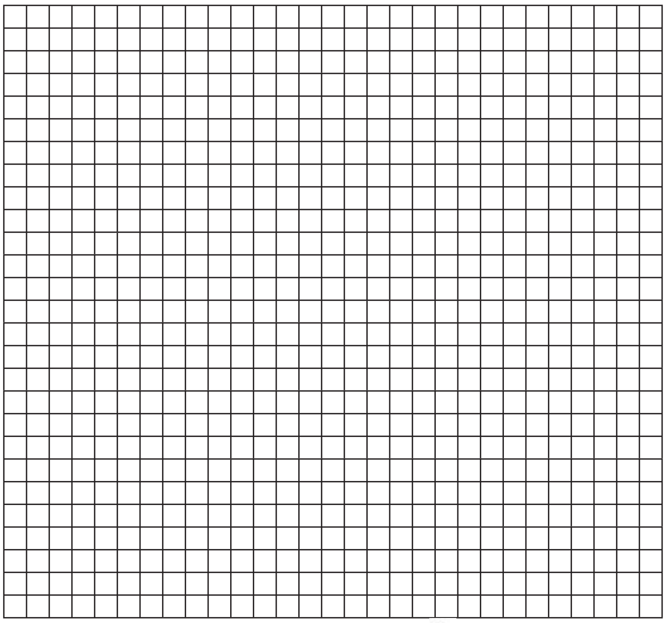
PULA Ministry of Works and Transport Roads Department	**FORM S15 (b)** **Soil Tests: Work Sheet** **Direct Shear Tests**	CML CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………………… Sample Location.. ……………………… Sample Number ……………………

Client: ………………….. Date:…………….. Tested by: ……………………………… Checked by: ………………………

Maximum Dry Density..……………..kg/m^3 at OMC

Shear Stress τ



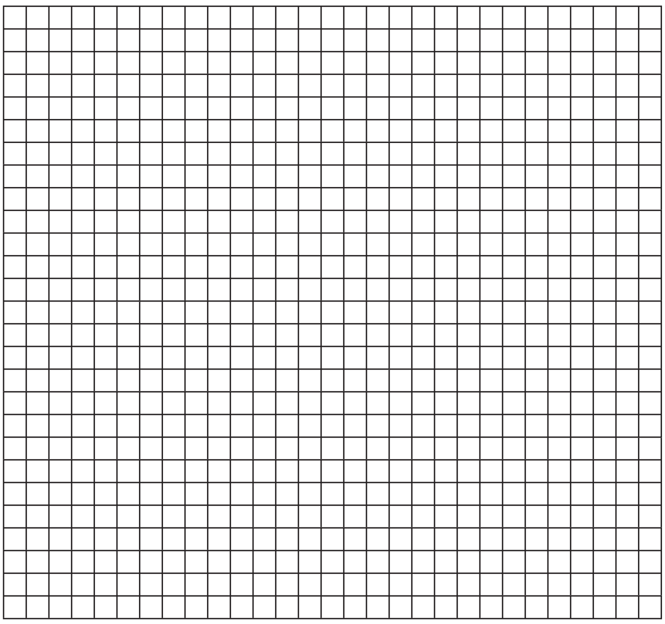
Strain / Displacement δL

Maximum Shear Stress

τ_{f} = ……………………………… KN/cm^2

Normal Stress = ……………… KN/cm^2

Shear Stress at failure τ_f



Normal Stress δ_n

Cohesion (c) = ……………… KN/cm^2

Angle of Shearing Resistance

(ϕ) in degrees = ………………………^{o}

Ministry of Works and Transport Roads Department	**FORM S16 (a)** **Soil Tests: Work Sheet** **Triaxial Tests** Consolidated Drained Consolidated Undrained Unconsolidated Undrained	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………….............. .. Sample Location.. .... Sample Number: …………………......

Client: ………………….. Date:…………....Tested by: ……………………..................... Checked by: …………….................

Confining stress (σ_3) = …………………………..kPa,

Consolidation Pressure = ………………………….kPa

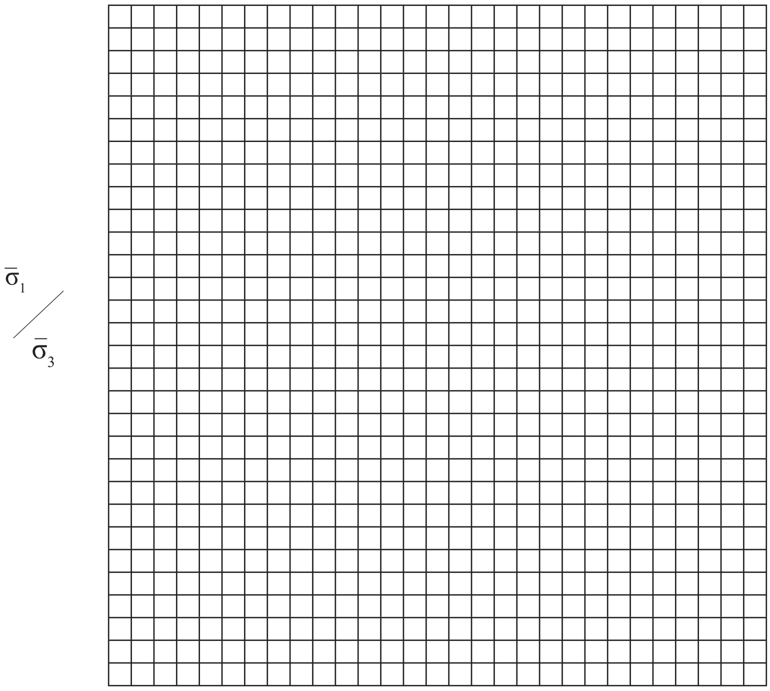
Sample Diameter (D_0) = ... mm
Sample Height (H_0) = ... mm
Sample Area (A_0) = ... mm^2

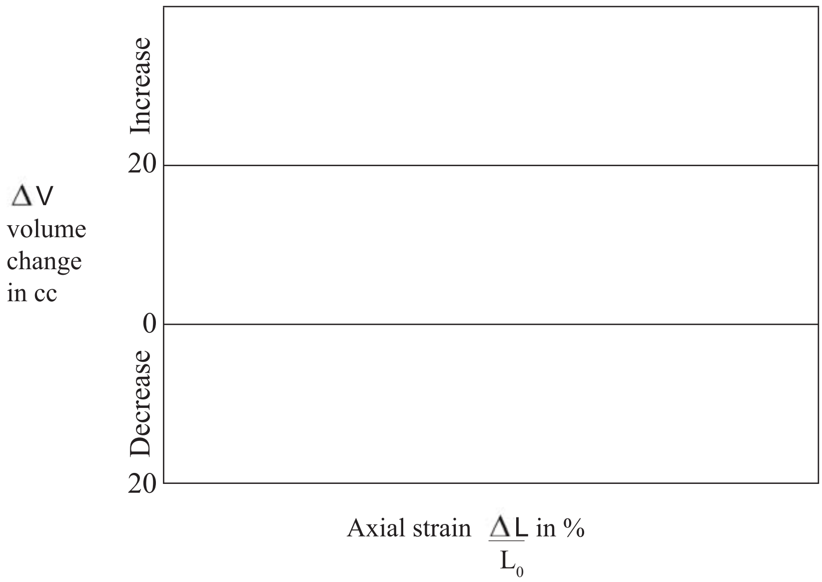
Dial Change Reading	Compression of sample ΔL (mm)	Strain $\phi = \frac{\Delta L}{L_0}$ in %	Proving Ring Reading	Axial Load ρ (N)	Corrected Area $A = \frac{A_0}{(1-\phi)}$ (mm^2)	Burette in cc	Deviator Stress $\sigma_1 - \sigma_3 = 1000\ ^P/_A$ kPa	σ_1 kPa	$\bar{\sigma}_1 / \bar{\sigma}_3$	Volume Change Δv, in (cc)

Ministry of Works and Transport Roads Department	**FORM S16 (b)** **Soil Tests: Work Sheet** **Triaxial Tests** Consolidated Drained Test Consolidated Undrained Test Unconsolidated Undrained Test	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………………... Sample Location.. .... Sample Number ……………………......

Client: ………………….. Date:…………….... Tested by: ……………………………………... Checked by: …………………………...

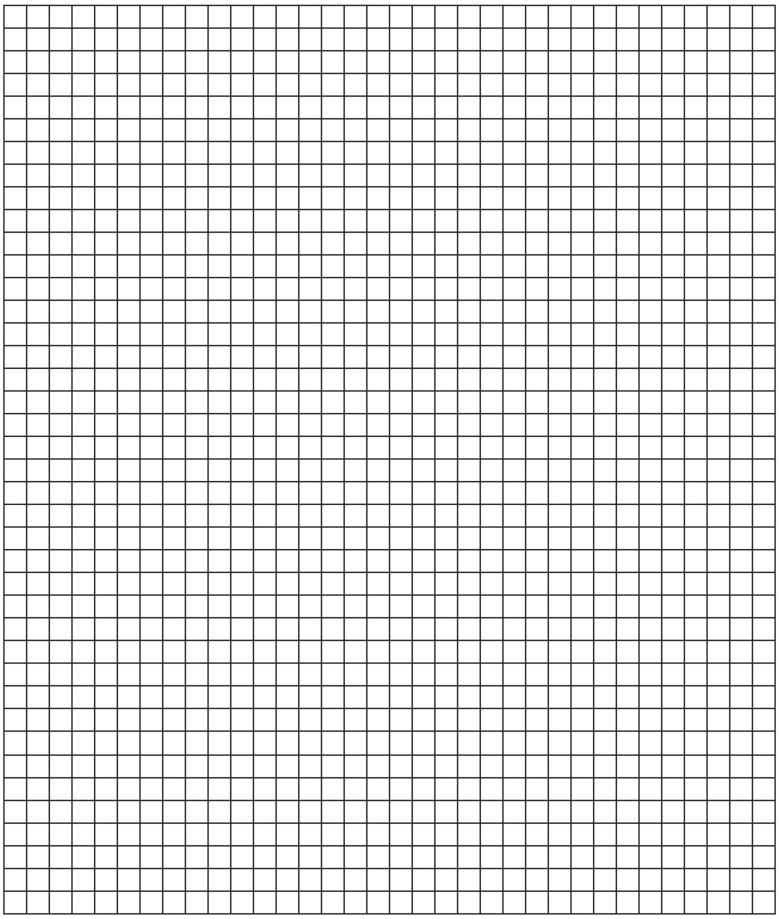




Ministry of Works and Transport Roads Department	**FORM S16 (c)** **Soil Tests: Work Sheet** **Triaxial Tests** Consolidated Drained Test Consolidated Undrained Test Unconsolidated Undrained Test	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………................. .. Sample Location.. .... Sample Number……………………....

Client: ………………….. Date:…………....Tested by: ………………….................... Checked by: …………….................



Cohesion (c)
=
Angle of Sharing Resistance (ϕ) in Degrees = …………............

Plotting of Mohr´s Circle

Ministry of Works and Transport
Roads Department

FORM AG1

Aggregates Tests: Work Sheet

Mechanical Sieve Analysis

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………..................Sample Location.. ....Sample Number …………………......

Client: …………………..Date:…………....Tested by: …………………..................Checked by: ……………...................

Mass of Sample Taken: Mass of Sample Taken:

Sieve Size (mm)	Sample Number:				Sample Number:			
	Mass Retained	% Retained	% passing	Cumulative % passing	Mass Retained	% Retained	% passing	Cumulative % passing
75.0								
53.0								
37.5								
26.5								
19.0								
13.2								
9.50								
6.70								
4.75								
2.36								
1.18								
0.600								
0.300								
0.150								
0.075								
<0.075								
Total								

Ministry of Works and Transport Roads Department	<u>**FORM AG2**</u> **Aggregates Tests: Work Sheet** **Aggregate Crushing Value (ACV)**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ………….…………................ .. Sample Location.. .... Sample Number …………………....

Client: ………………….. Date:…………....Tested by: ………………….................. Checked by: ……………..................
.

Weight of dried aggregate (A) g.			
Weight of fines after crushing (B) g.			
Dry ACV. = (B/A x 100%)			
Mean ACV			

Weight of dried aggregate (A) g.			
Weight of fines after crushing (B) g.			
Wet ACV. = (B/A x 100%)			
Mean ACV			

Remarks: Specify the aggregate size if non-standard aggregate sizes are used.

Ministry of Works and Transport Roads Department	FORM AG3 (a) **Aggregates Tests: Work Sheet** **Dry 10% FACT Value**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ………….………................ .. Sample Location.. .... Sample Number …………………......

Client: ………………….. Date:………….....Tested by: …………………...................Checked by: …………….................

TRIAL TESTS FOR LOAD (X)		
Weight of dried aggregate (A) in grams.		
Load applied (W) Tons		
Weight of fines (B) in grams.		
Percent fines (P) = 100B/A		
Load required for 7.5 – 12.5 % Fines (X) = 14W/(P+4) (kN)		

TEST AT LOAD (X) TONS		
Weight dried aggregate (C) in grams.		
Load applied (X) in Tons		
Weight fines (D) in grams.		
Per cent Fines (E) = 100D/C		
Mean percent fines (Y)		
10% FACT = 14X/(Y+4) (kN)		

Remarks: Specify the aggregate size if non-standard aggregates sizes are used.

Ministry of Works and Transport
Roads Department

FORM AG3 (b)

Aggregates Tests: Work Sheet

10% FACT Value

☐ **Dry** ☐ **Soaked**

CENTRAL MATERIALS LABORATORY

Materials and Research Division

Project: ………………………................. Sample Location.. .... Sample Number: …………………….....

Client: ………………….. Date:…………....Tested by: …………………...................Checked by: ……………..................

TRIAL TESTS FOR LOAD (X)		
Weight of dried aggregate (A) in grams.		
Load applied (W) in kN		
Weight of fines (B) in grams		
Percent fines (P) = 100B/A		
Load required for 7.5 – 12.5 % Fines (x) = 14W/(P+4) (kN)		

TEST AT LOAD (X) kN		
Weight dried aggregate (C) in grams.		
Weight soaked aggregate (F) in grams		
Load applied (X) kN		
Weight fines (D) in grams.		
Per cent Fines (E) = 100D/C		
Water Absorption = 100[(F-C)/C]%		
Mean percent Fines (Y)		
10% FACT = 14X/(Y+4) (kN)		
Mean Water Absorption %		

Remarks:

- *Specify the aggregate size if non-standard aggregate sizes are used.*
- *This method is similar to the Dry 10% FACT except that aggregates are soaked in water for 24 hours, allowed to drain briefly until surface dry and weighted. After crushing all material is oven-dried before screening.*

  The ratio of soaked 10% FACT / Dry 10% FACT gives an indications of potential durabiliy of the aggregates in service. Currently a minimum ratio of 0.75 is considered necessary for the aggregatesto be durable- Low ratios have however been advocated for N-values > 5, low volume roads and graded (Otta) seal (Guideline no. 8 - The use of silcrete and other marginal materials for road surfacing.

SUMMARY OF 10% FACT	
DRY 10% FACT	
SOAKED 10% FACT	
RATIO OF SOAKED 10% FACT / DRY 10% FACT	

Ministry of Works and Transport Roads Department	**FORM AG4** **Aggregates Tests: Work Sheet** **Aggregate Impact Value (AIV)**	CML CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………............... .... Sample Location: ……………………......

Client: ………………….. Date:…………....Tested by: ………………….................... Checked by: ……………...................

Dry AIV Sub-sample No:……………….. Aggregate Fraction used……………

No of blows (normally 15), *n*				
Mass of dry aggregates, M_1 (g)				
Mass of fines (passing 2.36 mm sieve for standard test), M_2 (g)				
Dry A.I.V. = (M_2/M_1 x (15/*n*) x 100%				
Mean Dry A.I.V				
Median Dry A.I.V				

Soaked AIV Sub-sample No:……………….. Aggregate Fraction used…………

No of blows (normally 15), *n*				
Mass of surface dry soaked aggregates, M_1 (g)				
Mass of fines (passing 2.36 mm sieve for standard test), M_2 (g)				
Soaked A.I.V = (M_2/M_1) x (15/*n*) x 100%				
Mean Dry A.I.V				
Median Soaked A.I.V				

Ratio of dry AIV to Soaked AIV (Dry AIV / Soaked AIV)	

Ministry of Works and Transport Roads Department	**FORM AG5** **Aggregates Tests: Work Sheet** **Durability Mill Index (DMI)**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………………………………………………………………………… Sample Location: ………………………

Client: ………………….. Date:………….... Tested by: …………………………………… Checked by: ………………………………

Sample No.								
Sub-sample no.	A	B	C	D	A	B	C	D
Sample Mass								
Sieve Size (mm)	Percentage Passing				Percentage Passing			
37.5								
26.5								
19.0								
13.2								
9.50								
6.70								
4.75								
2.00								
0.850								
0.425								
0.250								
0.150								
0.075								
<0.075								

ATTERBERG LIMITS

Liquid Limit								
Plastic Limit								
Plasticity Index								
DMI								

Durability Mill Index (DMI) = $PI_{(max)} \times P0.425_{(max)}$

Ministry of Works and Transport
Roads Department

FORM AG9

Aggregates Tests: Work Sheet

Aggregate Polished Stone Value

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………............... .... Sample Location: …………………….....

Client: ………………….. Date:…………....Tested by: ………………….....................Checked by: …………….................

Control Specimen	Mould Number	Stone Polishing Coefficient					Mean

PSV:…………………………………………………………….

PSV = S + 52.5 – C Where S = mean of control stone

C = mean of tested specimen

Ministry of Works and Transport Roads Department	FORM AG10 **Aggregates Tests: Work Sheet** **Aggregate Fingers & Pliers Value**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………………….. Sample Location and Depth ………………………………………………

Client: ………………….. Date:…………….Tested by: ……………………………………Checked by: ………………………….

Sample Number	Container Number	Details of Aggregate				Test	
		Size (mm)	Sieved	Visually Selected	Crushed or Natural	Soaked	Unsoaked

Test	Sample Number	Container Number	Number of pieces not broken (= B or C)	Total number of pieces	Percentage (AFV or APV)
Not broken by Fingers (AFV Test)					
Not broken by Pliers (APV Test)					

Ministry of Works and Transport
Roads Department

FORM B1

Bitumen Tests: Work Sheet

Penetration Test

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ……………………………................ .... Sample Location: ……………………....

Client: ………………….. Date:…………....Tested by: ………………….....................Checked by: ……………...................

Sample Number.	TIME			Penetration Value (0.1mm)	Mean
	Poured	Placed in Water at 25^0C	Tested		

Ministry of Works and Transport
Roads Department

FORM B2
Bitumen Tests: Work Sheet
Ductiliy Test

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project: ………………………................ .... Sample Location: ……………………....

Client: ………………….. Date:…………....Tested by: …………………….................Checked by: ……………..................

Sample No.							
Mould No.							
Time poured							
Time placed in water bath							
Distance elongated in mm.							

Sample No.							
Mould No.							
Time poured							
Time placed in water bath							
Distance elongated in mm.							

Sample No.							
Mould No.							
Time poured							
Time placed in water bath							
Distance elongated in mm.							

Sample No.							
Mould No.							
Time poured							
Time placed in water bath							
Distance elongated in mm.							

Ministry of Works and Transport Roads Department	**FORM B4** **Bitumen Tests: Work Sheet** **Softening Point**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………................ .... Sample Location: ……………………......

Client: ………………….. Date:…………....Tested by: ………………….....................Checked by: ……………...................

Time Poured: ………………………………………………………………………...……
……………………………………...

Water at 5 ^{o}C

Sample Number	
Time(minutes)	Temperature (^{o}C)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

Sample Number	
Time(minutes)	Temperature (^{o}C)
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	

	Ring 1	Ring 2	Average
Softening Point (^{0}C)			

Ministry of Works and Transport Roads Department	**FORM AS 3** **Asphalt Mixes Tests: Work Sheet** **Bulk Relative Density of Compacted Bituminous Mix**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: …………….………….................. .. Sample Location .... Depth ……………............................

Client: ………………….. Date:…………....Tested by: ……………….…...................Checked by: …………….................

Specimen Number							
Mass of briquettes in air, A. (g)							
Mass of briquettes in water, C. (g)							
Mass of saturated Surface-dry briquette in air, B. (g)							
Bulk Relative Density, A/(B – C)							

Ministry of Works and Transport Roads Department	**FORM AS 3** **Asphalt Mixes Tests: Work Sheet** **Bulk Relative Density of Compacted Bituminous Mix**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: …………….…………….................. .. Sample Location .... Depth ……………............................

Client: ………………….. Date:…………....Tested by: ……………….…...................Checked by: …………….................

Predetermined input data:

Bulk relative density of aggregate (Ga)				
Apparent relative density of binder (Gb)				
Percentage of binder in mix (P)				%

Test Data

Mass of flask (a)				grams
Mass of flask + sample (b)				grams
Mass of flask + sample filled water after removal of air (c)				grams
Mass of flask filled with water (d)				grams

Calculations

Maximum theoretical density of mixture (RDm) = (b-a) / [(d-a) – (c-b)]				G/cm^3
Percentage of binder in mix (P)				%
Mass of binder in sample (B) = P(b – a) / 100				grams
Mass of aggregates in sample (A) = [(100 – P)(b – a)] / 100				grams
Volume of aggregates in sample (Vb) = B/Gb				cm^3
Volume of binder in sample (Vb) = A/Ga				cm^3
Volume of voidless mix (Vm) = (d – a) – (c – b)				cm^3
Percentage of binder absorbed by the aggregate (Pb) = {[(Vb + Va – Vm)Gb] / A} x 100				%

Ministry of Works and Transport Roads Department	**FORM F1** **Field Tests: Work Sheet** **Dynamic Cone Penetrometer (DCP)**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project: ……………………………………….. Sample Location.. ………………………… Sample Location: ……………………….....

Client: ……………………. Date:…………….... Tested by: ……………………………………. Checked by: ………………………………

Km ______________ Offset ______________ Remarks ________________________________						Km ______________ Offset ____________ Remarks ______________________________					
No. of Blows	Reading mm	Depth mm	D.N. mm/blow	CBR %		No. of Blows	Reading mm	Depth mm	DN mm/blow	CBR %	

DCP/CBR Relationship: $\text{Log}_{10}\ \text{CBR} = -1.30\ (\text{Log}_{10}\ \text{D.N.}) + 2.65$

APPENDIX B – GENERAL AND MANAGERIAL FORMS

- FORM M1.1 Controlled Distribution List
- FORM M1.2 Guideline Changes Request Sheet
- FORM M1.3 Guideline Audit Check List
- FORM M1.4 Guideline Corrective Action Request
- FORM M1.5 Summary of Operating Procedures Guideline Changes
- FORM M1.6 Guideline Audit Report
- FORM M2.1 Internal Test Schedule/Requisition
- FORM M2.2 Client Complaint Record
- FORM M3.1 Equipment Control and Calibration
- FORM M3.2 Register of Project Numbers
- FORM M3.3 Factual Report Archive
- FORM M3.4 Record of Education and Training
- FORM M3.5(a) Training Consultation
- FORM M3.5(b) Training Consultation
- FORM M3.5(c) Training Consultation
- FORM M3.6 Equipment Calibration Requirements
- FORM 3.7 Computer Data Backup Log
- FORM 5.1 Safety Checklist

Ministry of Works and Transport Roads Department	**FORM M1.1** **GENERAL** **Controlled Distribution List**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Name of Holder	Office	Date Issued	Date Returned

Approved: Quality Manager	Date

Ministry of Works and Transport Roads Department	**FORM M1.2** **GENERAL** **Guideline Changes Request Sheet**	CENTRAL MATERIALS LABORATORY Materials and Research Division

To: Operating Procedure Manager	
From:	Office:
Signed:	Date:
Unit Head or Higher	

The following changes are suggested to the procedure, form or document:	
Procedure/Form/Document	
Section No(s).	
Proposed Changes	
Reasons for Changes	

Changes agreed / not agreed at Operating Procedures Review Meeting:	CR No.
Signed: Operating Procedures Manager/PRE-Mat.	Date:

Ministry of Works and Transport Roads Department	FORM M1.3 **GENERAL** **Guideline Audit Check List**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Audit Reference	Page No.	Auditor	Date
Project No.			

	COMPLIANCE			
PROCEDURE / SECTION	YES	NO	Unclear	COMMENTS

Ministry of Works and Transport Roads Department	**FORM M1.4** **GENERAL** **Guideline Corrective Action Request**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Audit Reference	Auditor	Date
Form No.	Contact	Unit
Guideline Document	Project No.	

Non-compliance	
Agreed Preventive and Corrective Action	
Date for Completion	
Signed (Auditor)	
Acceptance Signature	

	Action Complete (LM)	Action Verified (HOD)	No Further Action Required (HOD)
Signature			
Date			

Ministry of Works and Transport Roads Department	**<u>FORM M1.5</u>** **GENERAL**	CENTRAL MATERIALS LABORATORY
	Summary of Operating Procedures Guideline Changes	Materials and Research Division

Summary of changes/revisions made to the Operating Procedures Guideline			
Document Reference	Page No.	Section No.	Revision
Signed: Operating Procedures Manager			Date:

Ministry of Works and Transport Roads Department	**FORM M1.6** **GENERAL** **Guideline Audit Report**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Audit Reference	Auditor	Audit Date
Office		

Procedures Audited	
Persons Contacted	

Summary:

Signed: Auditor	Date:

Ministry of Works and Transport Roads Department	**FORM M2.1** **MANAGERIAL** **Internal Test Schedule/Requisition**	CENTRAL MATERIALS LABORATORY Materials and Research Division

To: Laboratory Manager	
For the attention of:	
From:	Date:
Sample Numbers:	
Brief Description of Samples, Origin and Purpose of Testing:	
Tests Required:	
Review, Checking and Approvals Required *(by PO or SRE-Laboratory):*	
Programme:	
Start Date: Completion Date:	
Comments:	
Signed: Internal Client Officer/Requestor	
Acceptance (Sign below and return copy to originator): Signed: Laboratory Manager Date:	

Ministry of Works and Transport Roads Department	**FORM M2.2** **MANAGERIAL** **Client Complaint Record**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Complaint ID	Project Number	Date of Complaint	Date Complaint Registered
Project Name			
Client			
Nature of Complaint			
Result of Complaint Investigation			
Action Taken			
Preventive Action Recommended			

	Head of Division	Laboratory Manager	Preventive Action Implemented
Signature			
Date			

Ministry of Works and Transport Roads Department	**FORM M3.1** **MANAGERIAL**	CENTRAL MATERIALS LABORATORY Materials and Research Division
	Equipment Control and Calibration	

Laboratory Unit (where equipment is located)	Sheet No.
	of

Item	Manufacturer	Serial No. or ID Mark	Date Purchased	Date when the next calibration or in-house check is due. *(Following calibration/check, initial along with date and add next date to adjacent column.)*							

Ministry of Works and Transport
Roads Department

FORM M3.2

MANAGERIAL

Register of Project Numbers

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Project Number	Project Name	Date of report	Date Archived

Ministry of Works and Transport Roads Department	**FORM M3.3** **MANAGERIAL** **Factual Report Archive**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Project Number	Project Title and Report Contents	Report Number	Date Archived	Earliest Date of Destruction	Location
Signed:				Date:	

Hand entries since this date shall be individually initialed.

Ministry of Works and Transport Roads Department	FORM M3.4 **MANAGERIAL** Record of Education and Training	CENTRAL MATERIALS LABORATORY Materials and Research Division

Name	Position	Date of Joining Roads Dept.

Education

Date		Name of School/College/University/RTC	Qualification Obtained
From	To		

Previous Employment (Including other Roads Dept. Divisions and other organisations)

Date		Employer	Position
From	To		

Record of In-House and External Training Attended

Date		Name of Institution e.g RTC/CML	Qualification Obtained /
From	To		Training Received

Professional Qualifications/Membership

Date	Organisation	Qualification/Membership (e.g. BSc./ MBIE)

Ministry of Works and Transport Roads Department	**FORM M3.5 (a)** **MANAGERIAL**	CENTRAL MATERIALS LABORATORY Materials and Research Division
	Training Consultation	

Personal Details

Name	Position	Date of Appointment
Laboratory Unit	Supervisor	

Section A

Aim: To help the staff member develop his or her capabilities and performance at work for the benefit of both the staff member and Roads Department.	
Objectives agreed at appraisal interview for the coming year:	
Comments by interviewer based on sections B and C attached:	
Signed: Unit Head/ Laboratory Manager	Date
Signed: Staff Member, having seen Sections B and C	Date

Ministry of Works and Transport
Roads Department

FORM M3.5 (b)

MANAGERIAL

Training Consultation

CENTRAL MATERIALS LABORATORY
Materials and Research Division

Section B Self Assessment

Name:	
Training undertaken and qualifications obtained since the last consultation (attach copies of certificates) eg courses at RTC and others.	
Please indicate how effective the above training/courses were in improving your performance.	
What training do you consider would improve your performance on tasks similar to those undertaken in the last year?	
What training do you consider would enable you to undertake additional tasks that would benefit the Laboratory?	
Signed: Staff Member	Date

Ministry of Works and Transport Roads Department	**FORM M3.5 (c)** **MANAGERIAL** **Training Consultation**	CENTRAL MATERIALS LABORATORY Materials and Research Division

Section C Training

Name		Position	

Training since last interview: (Attach copies of certificates where applicable)

Date		Description comprising
From	To	Institution, Type of training received and qualification attained

Future training requirements

Ministry of Works and Transport Roads Department	FORM M3.6 MANAGERIAL Equipment Calibration Requirements	CENTRAL MATERIALS LABORATORY Materials and Research Division

Name of Laboratory Unit	Sheet No.
	of

Item	Year of Manufacture	Manufacturer	Serial No. or ID Mark	Details of calibration, service and/or in-house checks	*Next Calibration*

Ministry of Works and Transport
Roads Department

FORM M3.7

MANAGERIAL

Computer Data Backup Log

CENTRAL MATERIALS LABORATORY
Materials and Research Division

DATE	TYPE OF BACK-UP	MEDIA TYPE	BACKED UP BY	SIGNED

Ministry of Works and Transport
Roads Department

FORM 5.1

MANAGERIAL

Safety Checklist

CENTRAL MATERIALS LABORATORY
Materials and Research Division

No	Potential Hazard
1	Outside structures safe? e.g sample shed
2	Eye goggles and other protective clothing during testing
3	Hazardous materials left outside the laboratory (e.g biological hazards, used condoms etc).
4	Electrical and other mains crossing the laboratory.
5	Hazard information signs used.
6	Essential fire precautions.
7	Emergency alarms and escape routes.
8	Toxic Chemicals in the ABCC unit properly stored.
9	Processes producing dust such as in the compaction unit, dust extractor
10	Structural instability in any of the buildings.
11	Traffic/pedestrian conflict at Entrance to Laboratory.
12	Water (work over, flooding etc.). Is shower area kept clean
13	Personnel (security).
14	Pollutants / confined spaces etc. e.g. fume cupboard in ABCC unit working?
15	Sample storage area run-off affecting neighbouring properties
16	Noise / vibration in the laboratory.
17	Slippery floors during cleaning
18	Adverse conditions e.g. hot weather/cold weather affect on staff.
19	Lifting of heavy equipment, samples and apparatus by staff.
Maintenance/Repairs	
20	Ladders (Hooped/Fenced)
21	Roofs (Fragile and Edges)
22	Windows opening/closing obstructing
23	Doors opening/closing obstructing/operating: Do they obstruct passageways or lead into hazardous situations.
24	Safety Controls for test machine operation: Stop/start/emergency stop. Dibble visual warning of operation.
25	Pressure systems such as water boiler-checked regularly.
26	Fire Alarms, Escape Routes etc. Is Extinguisher checked and filled?
27	Resistant bench surfaces - Electrical/Chemical.
28	Safety warning/information in the equipment.
29	Operating and maintenance manuals available at or before hand over.
30	Maintenance: Are there adequate maintenance arrangements for:- • Internal/external building fabric. • Window cleaning, Lighting, Movement of useable. • Ventilation/extraction, Gutter cleaning, Drains, sewers.