REPUBLIC OF BOTSWANA

ROADS DEPARTMENT

Ministry of Works, Transport and Communications

Technical Auditing of Road Projects

Guideline no 7

December 2001

Technical Auditing of Road Projects

Ministry of Works, Transport & Communications,
Roads Department
Private Bag 0026
Gaborone, Botswana
Phone + 267 - 313511
Fax + 267 - 314278

DECEMBER 2001

ISBN 99912 - 0 - 317 - 6

ROADS DEPARTMENT

Under the policy direction of the Ministry of Works, Transport & Communications, 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 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 18, 300 km of roads. This confers authority for setting of national specifications and standards and sheared 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)

Workshop Proceedings, September 2000, Addendum with reference to
Guideline No. 1 The Design, Construction and Maintenance of Otta Seals (1999)

Guideline No. 2 Pavement Testing, Analysis and Interpretation of Test Data (2000)

Guideline No. 3 Methods and Procedures for Prospecting for Road Construction Materials (2000)

Guideline No. 4 Axle Load Surveys (2000)

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)

Guideline No. 7 Technical Auditing of Road Projects (2001)

FOREWORD

This guideline document on technical auditing of road projects is a step in the right direction towards ensuring that the road projects undertaken in Botswana are appropriately designed and constructed.

Financial auditing of public funded projects are done but it is the technical audit which had not received any attention in the past. The need for producing a guideline on such an important aspect arose from the fact that very recently, some of the road projects implemented in the country have either failed pre - maturely and/or are in the process of showing distress ultimately leading to failure in the near future. The irony is that it has not been possible to portion accountability to parties involved in the contract. It is my hope that Roads authorities, administrators and organizations will start thinking about carrying out Technical Audit of road projects in order to ensure that the government and public in general get value for investment incurred.

The guideline describes step by step procedures involved in a technical audit process and details the methodology required to conduct a technical audit. This guideline will certainly go a long way in implementing road projects in the right manner and introduce accountability on the part of all Stakeholders, the Client, Consultant or the Contractor.

Gaborone
December 2001

Andrew Nkaro
Director of Roads

Roads Department
Ministry of Works, Transport and Communications

ACKNOWLEDGEMENTS

This Guideline is one of a series that is being published under the Institutional Cooperation 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, which is co-funded by the Kingdom of Norway and the Government of the Republic of Botswana. Roads Department also acknowledge the Department for International Development (DFID), UK. for their support.

The production of the Guideline has been a joint effort between the Roads Department and a joint venture of CSIR -Transportek, Pretoria and Civil and Planning Partnership (CPP), Botswana who acted as the Consultant for the Working Group. The Consultants staff were:

Dr. Phil Paige Green, CSIR
Dr. S. Kekwick, CSIR
Mr. R. Burrell, CSIR
Mr. K. Motswagole, CPP

The Working Group that guided the project and made significant contributions and comments on various drafts of the guideline consisted of the following people:

Mr. Barry Kemsley, Roads Department
Mr. P. Ododah, Roads Department
Mr. B. M. Mokgethi, Roads Department
Mr. B. M. Sharma, Roads Department
Mr. M. E. Segokgo, Roads Department
Mr. J. Sello, Roads Department
Mr. P. Alpajora, Roads Department
Mr. C. Overby, NPRA
Mr. R. A. Izzett, Newton McDonald & Associates
Mr. G. Vlug, Gerrit Vlug & Associates
Dr. B. Obika, Roughton International

The following people are also credited for their inputs to this guideline:

Mr. M. Kono, Roads Department
Mrs. J. Nwako, Roads Department
Mr. S. K. Agarwal, Roads Department
Mr. A. Kumar, Roads Department
Mr. A. Kgosi, CPP
Mr. D. Weston, TRL, UK

Photographs were provided by:
Ms. M. T. Keganne, Diwi Consult
Mr. C. Overby, NPRA

TABLE OF CONTENTS

PART C ANALYTICAL ASPECTS

PART D REFERENCES AND APPENDICES

LIST OF TABLES

LIST OF FIGURES

LAYOUT OF THE GUIDELINE

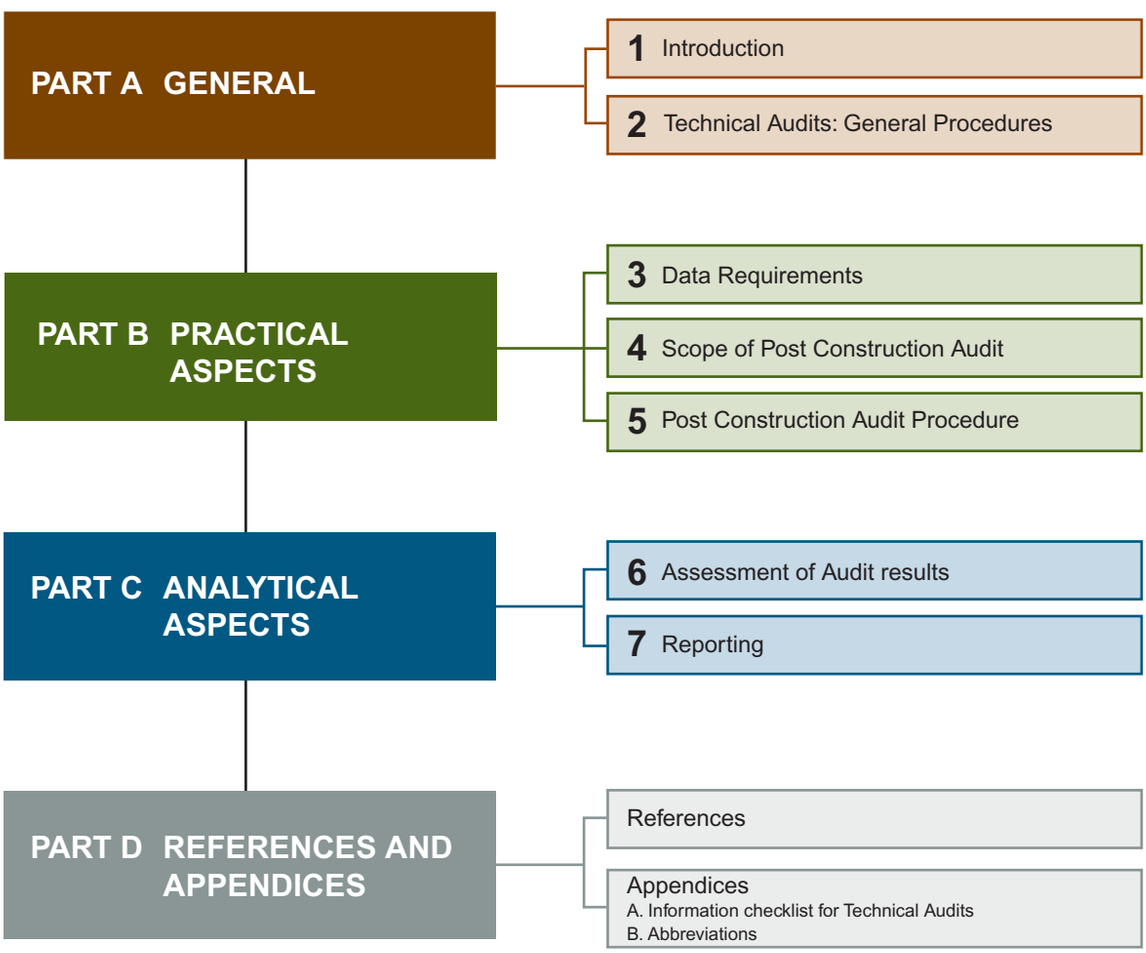
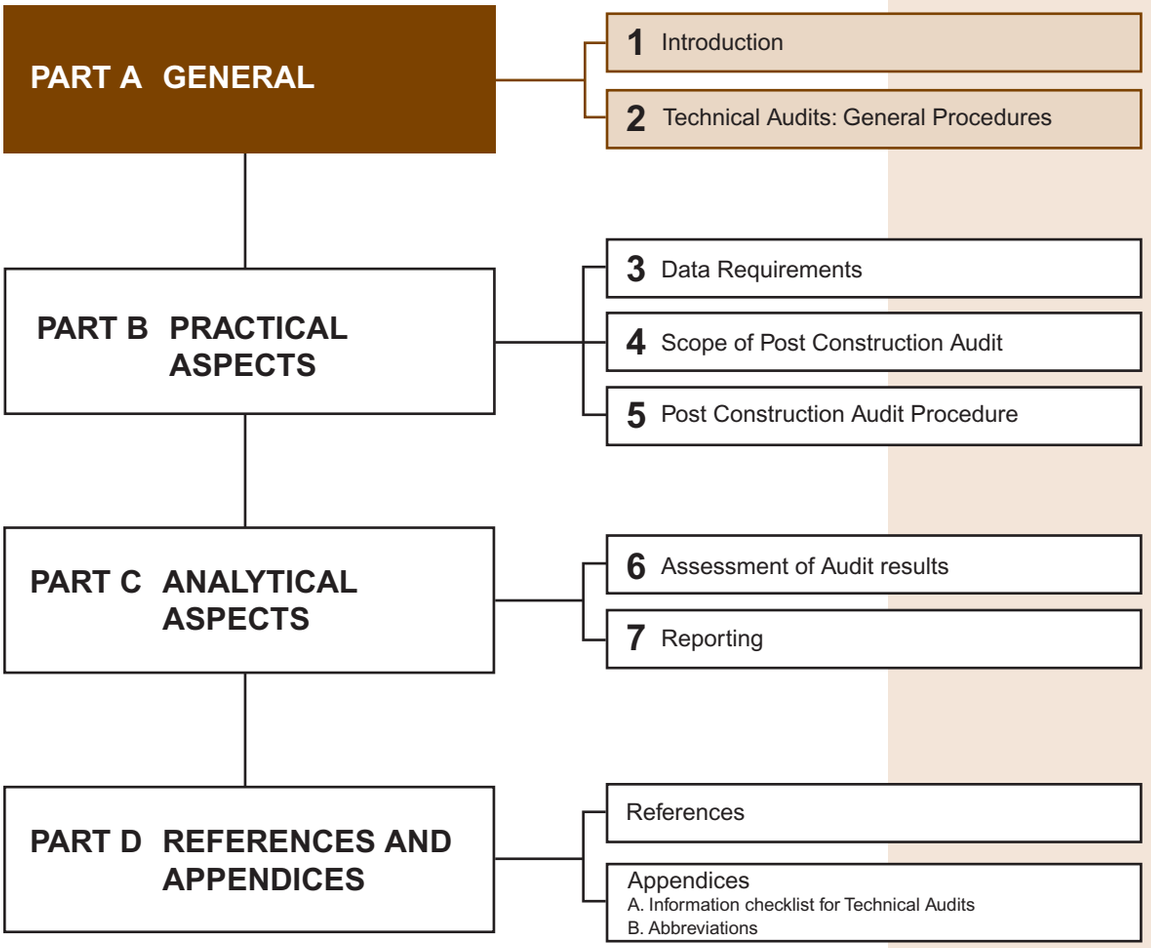


Figure 1.1 Layout of the Guideline.

PART A

PART A GENERAL



PART A

Kasane-Ngoma road at dawn.

1. INTRODUCTION

1.1. Background

The majority of roads in Botswana are constructed or rehabilitated through a process of design by an appointed consultant and construction by a contractor, both selected through a formal tender process. The appointed consultant could then be responsible for:

- Only the design phase, in which case a different consultant would be appointed to review the design and supervise construction; or
- Both the design and construction supervision.

During construction, a team from the Roads Department attends monthly site progress meetings in order to keep track of progress of the works and encourage adherence to the project specification. This arrangement has in the past had both success and failure in influencing the way the project progresses. On completion of construction, the Government's Auditor General may carry out a financial audit, but no technical audit of whether the Roads Department has obtained what it paid for, is carried out. On completion of construction, a Roads Department team consisting of project officer, design engineer, materials engineer, maintenance engineer/technician and other relevant staff inspects the road and structures, together with the consultant, identifying deficiencies and defects, which the contractor has to correct before demobilising and within the defects liability period.

This post-construction inspection currently carried out is essentially a visual evaluation and does not usually identify whether the specified materials have been used during construction or if the quality of the construction complies with the design specification. Technical or contractual weaknesses and construction defects that are not identified at this time frequently result in premature distress, which may occur after the stipulated defects liability period, making it difficult for the Roads Department to have adequate recourse to claim from the Contractor.

The use of a formal technical audit initiated during construction allows the Roads Department to identify whether the parties involved in the contract (including the Client) have given the Client what it paid for. This involves a more detailed assessment than the post-construction inspection in terms of compliance of the materials and construction with the design specification.

The primary objective of this Guideline is to assist the Department and Consultants appointed to carry out Technical Audits with assessing the required scope of the audit and identification of the appropriate requirements and techniques to be employed for such audits. The primary aim of these audits is to ensure that the road is constructed to the design specifications and that the Contractor is paid as per the contract conditions.

.

PART A

1.2. Structure of the Guideline

This guideline document is structured in seven sections described below and shown in Figure 1.1. Although not differentiated in the document, the sections can be grouped into four parts namely, General, Practical Aspects, Analytical Aspects and References and Appendices.

PART A GENERAL

Section 1 introduces the background and structure of the document.
Section 2 of the guideline highlights the purpose, scope and obligations of Technical Auditors.

PART B PRACTICAL ASPECTS

Section 3 summarises the initial data that is required to determine the scope and extent of the Post Construction Audit.

Sections 4 and 5 elaborate on the use of the initial data to identify the scope of the audit and discuss the requirements for the different complexities of the audit. It is not necessary to carry out complex Technical Audits that may include, destructive testing for all projects. It is essential that the correct degree of audit (neither too much nor too little) be carried out to minimise time and cost. The extent of the Post Construction Audit depends directly on the results of the Initial, Intermediate and Final Audits.

PART C ANALYTICAL ASPECTS

Section 6 discusses methods of assessment of the audit results.
Section 7 contains brief guidelines on reporting of the results of the Technical Audit.

PART D REFERENCES AND APPENDICES

Appendix A contains a guideline checklist for technical audits and
Appendix B, Abbreviations

PART A

2. TECHNICAL AUDITS: GENERAL PROCEDURES

2.1. Introduction and General

The purpose of technical audits is to enhance the quality of road construction in Botswana. The Technical Auditor will be a team of typically 2 to 3 engineers with substantial experience in the region, comprising:

- The Auditor - should be an appropriately qualified professional engineer with at least 20 years of experience covering among other things, highway design and construction and contract management.

- A Materials and/or Pavement Engineer - should be an appropriately qualified professional engineer with at least 15 years of experience in pavement engineering/materials. If only one of these engineers is preferred, then they should have an in-depth knowledge of the other field. For instance the Pavement Engineer would be required to have an in-depth knowledge of materials and the Materials Engineer would be required to have a sound knowledge of Pavement Engineering.

- Engineers with experience in drainage, structures/bridges and geometric design could form part of the team where necessary, depending on the complexity of the project. They should be appropriately qualified professional engineers with at least 15 years of experience in their respective fields.

All Technical Audits shall be carried out in a professional and objective manner.

2.2. Role and Responsibilities of the Technical Auditor

The Technical Auditor will be appointed as early as possible after appointment of the Supervising Consultant and immediately (preferably) before the start of the tender process and appointment of the Contractor. This will allow the Auditor the opportunity to assess the evolution of the project to its current stage.

Gross deficiencies in design, Bills of Quantities or tender documents identified by the Auditor and reported to the Client, may necessitate revisions. The Technical Auditor may, in addition to his specified duties, be called on to act as an advisor to the Client on matters pertaining to the project.

The Technical Audit for a typical road construction project should be carried out in four stages as presented in flowchart in Figure 2.1 These stages are spaced through the duration of construction of a road project in order to build in an early warning system.

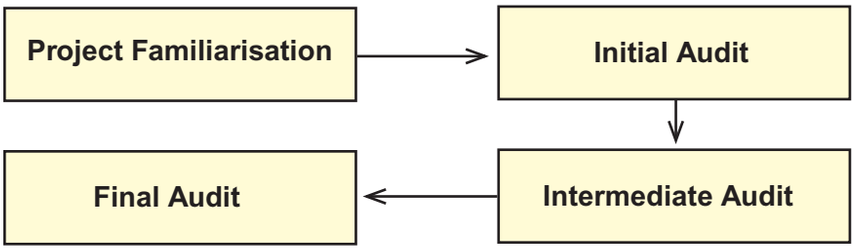


Figure 2.1 Auditing stages, flowchart

At the conclusion of each phase of an audit, the Auditor should present his findings in a report to the Client who may deem it necessary to hold a conference with the Engineer, to advise him of the major conclusions in the Auditor's report. It should be noted that obvious problems identified during the Audit process (e.g., the use of inappropriate materials) should have been brought to the notice of the Client for early intervention. Should there be any doubt as to construction requirements being fulfilled during the project and no remedial action having been taken, the Final Audit should recommend that a Post Construction Technical Audit be carried out. After the Final Audit, an exit conference to discuss the conclusions of the Technical Audit may be requested by the Client. This should involve the Client and Auditor and other relevant parties invited by the Client.

The Technical Auditor must be accountable for his duties to the Client, and must fullfil all the obligations specified in the Terms of Reference for his appointment.

The procedure and inputs for a Technical Audit are summarised in a flow-chart, see Figure 2.2.

2.3. Relationship of the Auditor with the Client, Consultant and Contractor

The Technical Auditor is appointed by the Client, to whom he reports directly. Under no circumstances will the Technical Auditor advise or issue instructions to the Contractor or Supervising Consultant. Communication should be focussed on seeking clarification or information regarding the project, and should avoid any interference with smooth implementation of the project. The Consultant, Contractor and Client must make available to the Auditor any document, as and when required by him and relevant clauses in the tender documentation and/or letters of appointment will make provision for this.

The relationship between the Auditor and the Client must be documented in his agreement with the Client. The Auditor can review actions of the Client during the project and any deficiencies or lack of performance should be noted in his report. This should make the process transparent, improve on internal practices and avoid problematic projects.

2.4. Project Familiarisation

The Auditor should clearly understand the scope and complexities of the project by reviewing all contract documentation including drawings, specifications, materials reports and conditions of contract. The tender documents

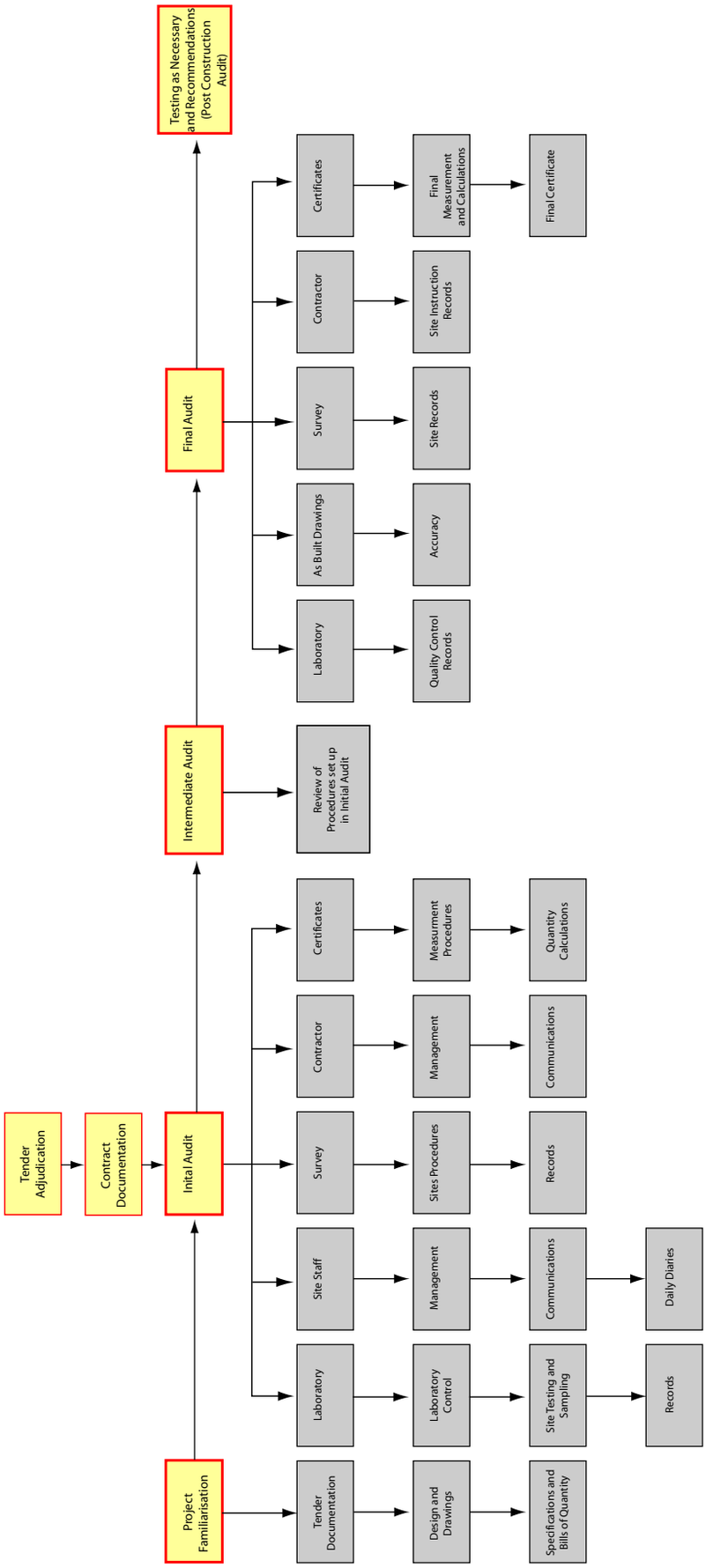


Figure 2.2 Technical Audit Flowchart.

and price submitted by the Contractor and the tender evaluation report should also be carefully studied and related to the Contractors proposed programme as well as his resources. This will probably require consultation between the Auditor and the Client.

This stage should be carried out immediately after the Auditor has been appointed and within two weeks of award of the construction contract. The Auditor must visit the project site during this phase to acquaint himself with the ground conditions. A report should be submitted to the Client highlighting the outcome of this phase in order to clarify details before the works proceed.

2.5. Initial Audit

This phase should be carried out as soon as the contractor is properly established but within the first three months or 20 per cent of the contract period, whichever is less. This phase should be carried out after construction has commenced so that all of the correct procedures can be established from the beginning of the project. In the first on-site audit attention should focus on project management issues and construction methodologies. This will incorporate:

- A review of the Resident Engineer's proactivity, control and approval procedures;
- Adequacy of the materials laboratory;
- Qualifications of staff;
- Site communications;
- Knowledge of the contract;
- Construction quality of work completed;
- General attitude towards the project.

The Auditor would also ensure/verify that the assessment of the Contractor has been done satisfactorily by the Engineer, regarding the following issues and aspects:

- Quality and appropriateness of the plant and equipment;
- Operator skills;
- Methods of working;
- Materials and water supply;
- Site organization and site management;
- Quality and detail of the construction programme;
- Site safety;
- Quality assurance procedures, and
- The Contractors project management processes and procedures.

The format and content of Monthly Progress Reports and Monthly Meeting Minutes should be reviewed to ensure that all the important matters are raised and reported. Proceedings of informal "technical" meetings should be assessed to ensure that no serious issues are being suppressed from public scrutiny.

This is a general guideline and does not preclude a review of other issues. However, this phase should culminate with the submission of a factual report to the client on critical issues. It should also include the auditor's opinion on the construction supervision and the ability of the contractor to deliver on time and to meet all of his obligations. The report should include recommendations to the client on any actions that are considered necessary and should include all issues assessed and not only the critical ones.

The surface sealing work may indicate that the project is close to completion.

2.6. Intermediate Audit

The Auditor should carry out an Intermediate Audit that concentrates on conformance with the specification and matters of effectiveness and ensures that the procedures set up initially are running correctly. This Audit will be carried out at a time approximately halfway through the project but not more than six months after completion of an Initial Audit. On large projects it may be necessary to carry out more than one Intermediate Audit and the timing and frequency of these should be specified in the Terms of Reference for appointment of the Technical Auditor.

The following should be addressed during the Intermediate Audit/Audits.

Initial Audit

- Review the Initial Audit and the subsequent actions by the Resident Engineer and Contractor resulting from the Initial Audit.

Specification

- Review of as-built records, relevant correspondence and minutes of meetings;
- Inspect and check both the completed work and work in progress. Completed work should conform to the typical plans;
- Assess the Consultant's quality assurance procedures, in particular the laboratory equipment, test methods and general procedures;
- Ascertain the quality and distribution of borrow pits and water points for the contract by undertaking visual inspections and studying laboratory test results;
- The construction methods and the care and diligence employed by the contractor should be carefully assessed.

Progress

- Review progress against the programme and review the history of programme changes (reasons and responsibility for delays should also be assessed).

Financial

- Check the current estimate against the tendered price using both the Engineers and the Contractors management systems;

- Check measurement records and the latest payment certificates and ascertain whether disputes and claims are being dealt with in terms of the contract;
- Check materials on site by sampling and testing and inspection of materials and records;
- Check that all payments to the Contractor are as per the contract conditions.

The above assessments/informations should be presented to the Client as a Summary Report highlighting any actions necessary to ensure successful completion of the project. If there are clear indications from the Initial and Intermediate Audits that there are likely to be problems, the issuance of the Taking Over Certificate should be held at the Client's sole discretion (without contravening the contract), until the Post Construction Audit is completed, bearing in mind the consequences of this action. It is suggested that provision for this be made in the Contract Conditions and should be reviewed in terms of the Standard Conditions of Contract.

2.7. Final Audit

This should commence at least four weeks before issuance of the substantial completion certificate and should be completed before the site staff is completely demobilised from site. If an earlier starting time for the Final Audit is possible without causing disruptions to the project, then it should be encouraged.

The purpose of the Final Audit is to determine conformance with all aspects of the Contract. The principal sources of information will be the as-built plans, test records, measurement and payment data, site correspondence and minutes. Both the actions of the Engineer and the Contractor should be assessed.

A principal output of the Final Audit should be a recommendation for any further testing that is required to assess the quality of the works (Post Construction Audit). The required field and laboratory investigation identified in Section 6 would follow this immediately and should be concluded within 6 to 8 months of issuing the substantial completion certificate. This is necessary so that deficiencies identified by the Post-construction Audit can be taken up with the Contractor prior to expiry of the defects liability period.

A full report on the project would be presented to the Client summarising any further testing considered necessary and indicating any contractual obligations that have not been fulfilled by either the Engineer or the Contractor or any other outstanding matters.

Finalisation of the side drains.
Lephephe - Shoshong Road.

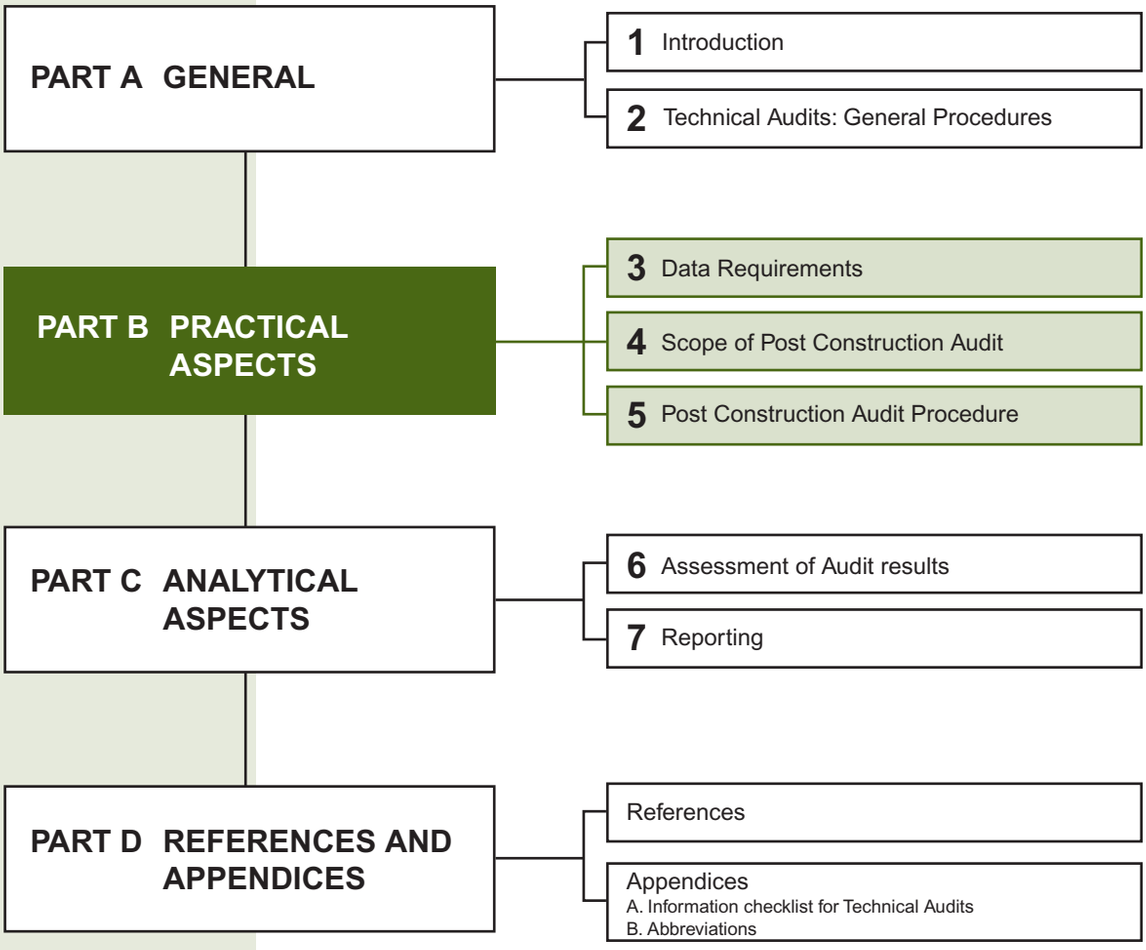
A newly constructed road.
Lephephe - Shoshong Road.

PART B PRACTICAL ASPECTS

3 Data Requirements

4 Scope of Post Construction Audit

5 Post Construction Audit Procedure



PART B

3. DATA REQUIREMENTS

3.1. General

During any Technical Audit, all available information must be collected for evaluation. The four phases of a Technical Audit summarised in Section 2 and discussed more fully below lead up to defining the extent of any possible Post-Construction Technical Audit, following the Final Audit.

A full Technical Audit, after construction has been completed (Post Construction), is the only phase that would require extensive laboratory and fieldwork. The input in the four phases (Familiarisation, Initial, Intermediate and Final) comprises predominantly a performance review and discussions with limited time spent on site. This would include visits to the site offices and a brief visual evaluation of the project in progress.

3.2. Project Familiarisation

During the project familiarisation phase of a technical audit, as much of the existing information as possible regarding the design and progress of the project should be obtained. This will include:

- Consultant's design and drawings;
- Materials reports;
- Tender documentation including Tender Evaluation report;
- Bills of quantities;
- Ownership of plant;
- Contractors resources, program and cash flow;
- Visit to site by the Auditor before the Contractor has mobilised/ commenced actual works on site.

All of the necessary data should be made available to the Auditor by the Roads Department and the Consultant. Discussion with the designers and client's engineers may also be necessary.

3.2.1 Consultant's Design and Drawings

All of the drawings and design documents pertaining to the project should be assessed.

It is not the duty of the Technical Auditor, however, to determine whether the design is appropriate for the specific situation.

The appropriateness of the project includes diverse considerations such as:

- Planning;
- Political;
- Social;
- Environmental;
- Cost-benefit prioritisation issues.

These would normally have been assessed in-house by the Roads Department prior to tender and it can be assumed that they were considered to be appropriate. This applies equally to issues such as hydrology, drainage, geometric design and safety.

The Technical Auditor must, however, familiarise himself fully with the background to the project, the pavement design, material types, qualities and quantities (from materials reports) and specific issues relevant to the project. Special cognisance should be taken of any unusual characteristics such as extreme subgrade conditions, unusual pavement designs or layer thicknesses, perched water tables, saline areas, etc.

3.2.2 Tender Documentation

The tender documentation should be carefully assessed and unusually high or low unit rates noted. Specific note should be made of any alternatives proposed and whether these were accepted. Special conditions of contract should be noted, particularly as they apply to quality control/assurance testing.

It is not within the scope of work of the Technical Auditor to evaluate the Tender prices or process, but aspects that might influence project management or quality of construction need to be highlighted during assessment of the tender documentation. Any examples of apparent negligence should also be noted.

Proposals to use unconventional construction plant or techniques should be noted. Special conditions such as the use of proof rolling should also be identified to ensure that the results of compaction trials are obtained, assessed and properly recorded.

3.2.3 Bills of Quantities

The Bills of Quantities should be assessed by the Auditor to identify unusual quantities, spurious prices and to generally familiarise himself with the pricing of the project. Aspects likely to result in claims (usually based on past experience) should be noted.

3.3. Initial Audit

The initial audit will require a visit to the site where establishment and methodology issues are generally audited. During this visit the following aspects should be assessed through observation and discussions with site staff:

- Management issues (e.g., work schedule, documentation, construction programme, etc);
- Construction methodologies;
- Site laboratories;
- Plant;
- Staff;
- Safety;
- Quality assurance;
- Site instructions.

The availability and quality of documentation (e.g., work programme, laboratory methods, control and approval procedures, etc) and communication among the respective parties should be evaluated.

Problems or deficiencies identified should be brought to the notice of the Client as soon as possible in order to rectify methods that could affect the final product. Assessment of the above information should provide the Auditor with a good indication of the expected quality of the final project.

3.4. Intermediate Audit

The intermediate audit is probably the most important phase in terms of identifying inconsistencies and deviations from conformance with the specifications. It is essential that the following data be obtained, through the Client. It shall be specified in the Tender documentation that all information will be made available to the Auditor for Auditing purposes.

- Laboratory test results;
- Daily/weekly/monthly construction records;
- Quality assurance data;
- Site correspondence, site instructions and minutes of meetings, engineers orders, etc.;
- Variation orders and contractors claims;
- Measurement and payment certificates;
- Project management issues;
- Efficiency of contractor's plant and machinery.

In addition, any other documentation originating from the project should be reviewed. This may include ad hoc reports emanating from the Roads Department, particularly relating to in-house material testing, quality assurance records, etc.

3.4.1 Laboratory Test Results

Routine laboratory test results should be inspected to ensure that the correct materials are being utilised, the materials are generally within specification and the laboratory testing is of the expected frequency and quality. The Auditor should inspect the laboratory equipment for calibration and check test procedures methodology for compliance with the project specifications.

3.4.2 Construction Records

Daily/weekly/monthly construction progress records should be inspected to identify problems resulting in slow progress as well as periods with greater than expected progress. Unless additional resources were employed, very rapid progress may be indicative of short cuts being taken.

Material quantities, stabiliser application rates, bituminous spray rates and quantities and water usage should all be assessed in terms of the completed works.

3.4.3 Quality Assurance Data

Routine density/compaction, thickness and quality control/assurance measurements should be inspected to ensure that the correct quality was achieved. Calibration and control records of nuclear density testing equipment should be inspected. The Auditor may take samples or carry out testing to check construction quality if so dictated by his assessment.

3.4.4 Site Correspondence

All relevant site correspondence and minutes of monthly meetings should be carefully assessed. Construction problems will usually be identified at these meetings, and disputes between the Client, Consultant and the Contractor can often be indicative of potential problems. Delays due to water or material shortages, compaction problems or other construction issues could all lead to potential "shortcuts" that are not easily identified when construction is complete.

All correspondence associated with progress of the project should be reviewed to identify how smoothly the project is progressing. A full set of site instructions must be obtained.

A high degree of rejection of work by the consultant could indicate that the Contractor experienced difficulties meeting the specification giving warning of potential problems.

3.4.5 Variation Orders and Contractors Claims

Variation orders should be assessed against the original design, the effect on cost and whether they were implemented correctly. Variation orders are almost always associated with claims.

3.4.6 Measurement and Payment Certificates

- Measurement and payment certificates should be compared with the tendered bills of quantities for confirmation of work done;
- It is essential to ensure that all of the specified layers are properly accounted for, especially when stabilisation of materials is involved;
- Sample payment certificates should be checked and related to the supporting documentation;
- Calculations for rain delays and contract price adjustment should be in accordance with the conditions of contract. The rates used to calculate amounts must be either the tendered rates or agreed rates with supporting documentation;
- Payments for extensions of time and unforeseen conditions must agree with the Approval given by the Engineer;
- Payments for day works should be according to the certificates signed by the Contractor and the Resident Engineer. The need for day-works can also be evaluated;
- All quantities should be measured in accordance with the pay items. Each certificate should be cross-referenced with the Engineer's and the Contractor's measurements;
- Dimensions from typical plans should be checked;

- Measurements based on the Engineer's judgement, such as for excavation of hard, intermediate or soft material and other ground conditions should be carefully assessed to establish the parameters used;
- Where a current certificate is evaluated, the materials on site should be verified. Spot measurement checks may also be required.

3.4.7 Project Management Problems and Issues

The application of good project management principles can be assessed in a number of areas.

The Contractor's programme is a key project management tool. The quality and detail of the programme, and progress according to the programme should be assessed. Consistency between planned activities and those actually undertaken should be noted as well as resources and time spent. The on-site labour force and plant resources should be pertinent to current activities and adequate for meeting project deadlines. Any excessive delays due to adverse weather should be noted and queried.

Conformance with the requirements of the General Conditions of Contract as to submission and response dates, certificates of insurance, compliance with statutory submissions for labour, etc. should be reviewed and compliance verified.

Both the Contractor and the Engineer should have suitably qualified site personnel to ensure that the project is properly managed.

3.5. Final Audit

The final audit carried out when construction is nearing completion makes use of all the information collected during the earlier phases to justify and identify the need for additional investigations. Problems identified and rectified during the Initial and Intermediate Audits should minimise problems likely to be revealed in the Final Audit.

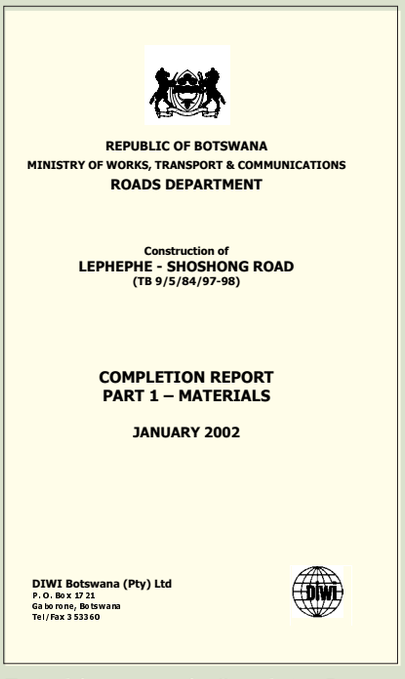
In addition to the information already available from the earlier Audits, it is necessary that the following also be evaluated:

- Consultant's construction/completion report;
- Performance of the road to date;
- Deflection and riding quality.

The completion report is usually not available immediately after completion of construction. Attempts should, however, be made to have it submitted as soon as possible.

3.5.1 Construction/Completion Report

It is essential that the Engineer submits a full completion report as soon as possible after construction has been completed, certainly within 6 months. This should contain all the relevant information regarding progress of the project including all quality control records and test results. This document must be very carefully evaluated. There should be a particular focus on the frequency of testing and completeness of test results, i.e. no areas with missing data.


REPUBLIC OF BOTSWANA
MINISTRY OF WORKS, TRANSPORT & COMMUNICATIONS
ROADS DEPARTMENT

Construction of
LEPHEPHE - SHOSHONG ROAD
(TB 9/5/84/97-98)

COMPLETION REPORT
PART 1 – MATERIALS

JANUARY 2002

DIWI Botswana (Pty) Ltd
P. O. Box 17 21
Gaborone, Botswana
Tel / Fax 3 53360

Typical front page of a Completion Report.

3.5.2 Performance of the Road to Date

The performance of the road in the first few months following its opening to traffic can be a crucial indicator of the quality of construction. Usually, parts of the project will have been opened some time prior to completion and the performance of these sections should be assessed. However, good early performance may not necessarily indicate continuing good performance. The road could perform well, for instance, if it is opened to traffic during the dry season but problems resulting from poor materials or construction could manifest as soon as the wet season starts or later during periods of higher than average rainfall.

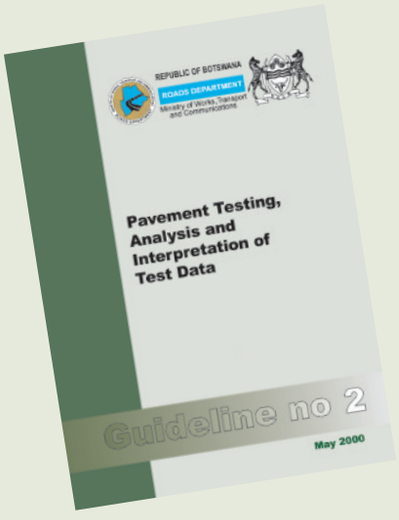
Aspects to be considered during assessment of the initial performance of the road include:

- The number of areas requiring patching or reconstruction;
- The overall riding quality of the road and evidence of functional distress, e.g. bleeding, ravelling;
- Early evidence of structural distress, e.g. deterioration of riding quality, rutting, fatigue cracking, shear failures, potholes, etc.;
- The overall finish of the road - a neat, well-finished project is usually, but not always, indicative of a well-executed project;
- Erosion of side slopes and drainage works.

Similar inspection of concrete structures should be carried out to ensure that the concrete quality is (at least visually) acceptable.

3.5.3 Deflection and Riding Quality Surveys

It is standard practice in Botswana, to carry out deflection and riding quality surveys on all roads as part of the Road Management System. These are generally carried out at about three year intervals. It is recommended that these surveys be conducted on all new projects within 6 months of construction (subject to the season as discussed below) by an independent party, in order to assist with the Technical Audit. The deflection and riding quality surveys shall be carried out as directed by the Client.



Deflection surveys should always be carried out at or towards the end of the wet season when the pavement is at its weakest, at intervals of about 100 metres as discussed in Roads Department Guideline No 2.[2] Aspects pertaining to Riding Quality measurements are also discussed in this document.

Although it is not recommended that the information obtained be used to analyse the structural or functional capacity of the project, it can be cost-effectively used in identifying those areas of the project with high variability or that differ significantly from the norm for the road, and may require more detailed investigation.

The deflection and riding quality information would also form the baseline data for most performance service index parameters.

PART B

3.5.4 Information Required

A checklist of the information required to ensure a successful Technical Audit is provided in Appendix A. Both the availability and quality of the documentation and information should be evaluated in terms of poor, medium or high for later use during the Audit. The quality and quantity of information available has a direct bearing on the extent of the Post Construction Audit. This is covered in detail in Section 4 and Table 4.1.

4. SCOPE OF POST CONSTRUCTION AUDIT

4.1. Assessment of Data and Compliance with Contractual Requirements

The data obtained during all the phases of the audit should be assessed to ensure that the project has been constructed according to the contractual requirements. These requirements include:

- All the layers to be to the specified thicknesses;
- All materials to meet specification requirements;
- All specified construction standards to have been met.

As most of the Initial, Intermediate and Final Audits will have been based on measurements, laboratory and field-testing and quality control/ assurance data pertaining to the road, the reliability of this information needs to be carefully assessed. The Technical Auditor must make use of all the relevant information available to determine whether this information is reliable enough to be used as the basis for the Post Construction Audit. Aspects to be considered during this assessment are:

- Are the results typical and realistic?
- Are the results highly variable or unusually consistent?
- Are the results consistently close to the specified limits?
- Were the prescribed sample preparation and test methods adequately followed?
- Were testing equipment and instruments (e.g. nuclear density meters) properly calibrated?

When laboratory and construction records indicate that the majority of the results (particularly grading, plasticity and CBR strength) are very close to the specified limits, the results are often unreliable. Experience has shown that reporting of marginal results is not always complete - unacceptably high results are frequently disregarded or omitted from the final reports.

The following discussion will assist in deciding on the extent of the Post Construction Audit based on the inputs of the Initial, Intermediate and Final Audits.

4.1.1 Variability

Before discussing specific aspects of material and construction quality, it is important to consider the implications of variability. Variability in construction quality can be attributed to the actual processes as well as the measurement or quantification of the relevant parameters.

Variability in materials can be attributed to:

- the natural spatial variation of the material properties;
- variations in the material placed on the road caused by processing and transport, and

- variations in the sampling and test methods used.

Too few tests, insufficient to average out random errors, can also lead to systematic errors.

The control of construction thicknesses, stabiliser content and compaction utilising the construction tolerances and statistical quality assurance methods included in the Botswana Standard Specifications for Roads and Bridges[1] allows certain test results to lie outside the specification, but the mean and absolute minima must conform to the specifications. This type of specification has the advantage that the Contractor's risk of properties being wrongly assessed is low without the Client's risk of accepting unsatisfactory work being excessively high. This type of judgement scheme assumes that the test results are normally distributed.

4.1.2 Pavement Structure

Although most deflection measurement methods allow a variety of parameters to be calculated, only the peak deflection values along the length of the road need be plotted for Technical Auditing purposes. These should be inspected for sections with significant variation from the mean. This will indicate that either the pavement structure differs in these areas or the foundation conditions have changed. Use of the Cumulative Sum Technique can assist with analysis of variations in deflection. This method has been fully described in Roads Department Guideline No 2, "Pavement testing, analysis and interpretation of test data".[2]

Where areas showing markedly different deflections are recorded, the possibility that the variation is a result of natural conditions should be investigated. Only if no explainable reasons for the differences are found can the cause be attributed to construction or material variations. Possible reasons for differences include changes in:

- Subgrade conditions (e.g. fill, cut, marshy areas, change in geology, presence of shallow pedocrete layers, etc.);
- Pavement design/structure;
- Pavement materials;
- Degree of compaction;
- Construction methodology.

Construction of the specified pavement structure can only truly be confirmed by excavating observation holes through the pavement. As this is not economically feasible for the majority of projects, evaluation of the measurement payment certificates and the records of levels and thickness control testing are the most convenient and cost-effective way of obtaining an indication of the pavement structure. The information should be assessed in terms of the results, their coefficient of variation and the number of data points per job lot.

Where doubt exists, quick and non-destructive testing using a Dynamic Cone Penetrometer (DCP) can give a good indication of the presence of specific layers as well as both the pavement strength and the pavement thickness. Spot checks using the DCP can improve the confidence of construction data.

DCP testing.

4.1.3 Materials Compliance

The evaluation of material compliance will in the first instance be based on the test results available from the Consultant and Contractor. The most important parameter to be evaluated is usually the California Bearing Ratio (CBR) or the Unconfined Compressive Strength (UCS) for stabilised materials. High quality crushed stone bases are not specified by strength but are usually specified by compaction density, grading and plasticity. The results of ongoing testing of these properties should be carefully compared with the specifications. Concrete cube test results should also be scrutinised for compliance.

Significant changes in deflection that cannot be attributed to other causes may be the result of changes in material quality and this aspect should not be neglected.

4.1.4 Construction Quality

Density control, using the sand replacement method.

Construction quality should first be assessed from the site records, monthly progress reports, quality assurance testing, and final test results presented with the completion report. The primary aspects to be considered are the final layer thicknesses and the degree of compaction achieved. These cannot be evaluated after construction without carrying out a programme of destructive testing, although carefully conducted DCP testing can give a good indication of layer thicknesses and compaction, particularly where the layers are very different, natural versus stabilised materials or crushed stone versus stabilised or natural materials.

During assessment of construction quality records, it is suggested that the data regarding density/compaction, thicknesses, stabiliser content and concrete strengths are closely examined. It is not possible to specify typical coefficients of variation for these parameters as they vary considerably depending on the Contractor, plant utilised, material type, experience of the staff, etc. Absolute standard deviations are generally high, primarily as a result of material variation, and are of little use as a measure of Contractor performance. Comparison of the relative standard deviations or preferably coefficient of variation (i.e. standard deviation divided by the mean) on different portions of the project or on similar projects in the area or by the same Contractor can assist with evaluating the quality of the Contractor's work.

A quick and convenient means of evaluating construction quality on pavements with bituminous surface dressing is to determine the riding quality of the road. (Asphalt surfacings often mask any deficiencies in the finish of the layerworks). Examination of a plot of the riding quality (measured roughness) against distance for the project will indicate areas with poor riding quality, which may be related to areas where construction problems occurred. Projects with general poor riding quality are usually indicative of poor construction practices. The "cumulative sum" technique can be used as a more precise method of identifying significant changes in the riding quality.

PART B

4.1.5 Drainage Provision

The drawings and specification will usually indicate the designed drainage needs. These should be easily evaluated during a visual inspection to verify compliance with drawings and adequacy of drainage protection.

4.2. Scope and Complexity of Post Construction Audit

Technical Audits with destructive testing are expensive and cause considerable disruption. It is thus necessary to identify the scope and complexity of each specific Post Construction Audit based on an evaluation of the available information.

From the information assessed, it should be possible to define the scope of the Post Construction Audit, such that the nature and cost of the Audit and need for destructive testing is directly related to the potential problems identified.

The type of Post Construction Audit is classified on a five point scale in this guideline with only assessment of the available records being necessary for a Type 1 Audit and a full field investigation with extensive non-destructive and destructive testing being necessary for a Type 5 Audit. Type 5 Audits should only be necessary when there have been major problems (e.g. incorrect materials, insufficient or dry compaction, non-addition of stabilisers, etc) during construction and the potential for premature failure and/or significant claims by or against the Contractor are likely.

The definition of the type of Audit will be based on the available information indicated in Column 1 of Table 4.1. Column 2 shows the type of Audit, Column 3 gives the Scope of the Audit and Column 4 nominates Further Requirements.

Table 4.1: Type and Scope of Post Construction Audit

(1) Indicators	(2) Audit Type	(3) Scope of Audit	(4) Further Requirements
Complete and reliable construction and quality records. Comprehensive and verifiable quality control. Only minor variations during the project. No problems during construction. No unusual claims*. Good track record of Contractor.	**1**	Assessment and verification of records	None
Reliable construction and quality records. Only minor problems during construction. No significant variations or claims*.	**2**	Assessment of records, deflection and roughness	Consistency of deflection and riding quality
Sufficient quality records but of doubtful reliability. Unusual construction methodologies. Unusual claim and variation history affecting contract duration*.	**3**	As for 2, but includes limited DCP testing	As for 2, plus evaluation of layer strengths and depths
Poor construction and quality records. Unreasonable claims and variations during construction*. Specific aspects brought to the attention of Client during construction.	**4**	As for 3, but includes more DCPs and some observation trial pits	As for 3, plus profiling of small trial pits
Poor appearance of final product. Minimal and unreliable construction and quality records. Many variations during construction. Numerous disputes during construction requiring intervention of the Client. Excessive claims related to materials and construction processes*.	**5**	As for 3, but includes DCP survey and test pits	As for 3, plus in situ testing and observation
* The use of claims as indicators of poor workmanship depends on the nature of the claim - only those relating to poor workmanship, or materials, should be considered.			

Note: This is only a guide and the Auditor is free to recommend his own Audit type.

5. POST CONSTRUCTION AUDIT PROCEDURE

5.1. General

When Type 4 or 5 Post Construction Audits are found to be necessary, a full range of non-destructive and destructive testing will usually be required. This should be carried out within the maintenance period and prior to settlement of all claims and release of retention monies.

Good Initial, Intermediate and Final Audits will result in few occasions when Type 3 and possibly even Type 4 Post Construction Audits are necessary. It should be noted that condemnation of poor sections of road result-

ing from the recommended testing procedures would need to be related to the contractual requirements and such actions will need to be defended in relation to the Conditions of Contract.

5.2. Uniform Sections

To carry out the Audit cost-effectively the road should be subdivided into uniform sections. These can vary in length and number, but each should have similar structural designs or pavement responses. The structural responses can only be determined for new roads using deflection surveys or DCP testing as visual characterisation seldom reveals significant differences soon after construction.

5.3. Pavement Response Assessment

Modern methods of deflection testing produce a number of pavement response parameters at each test point. These all have particular uses in the structural evaluation of pavements but for the delineation of uniform sections, the peak deflection usually provides sufficient information. Both the mean of the results and the variation within the section are indicative of the quality of the pavement.

For specific applications such as investigating whether sufficient stabilisation has been provided in the upper layers, parameters such as surface curvature index or radius of curvature may be more appropriate.

Analysis is most effectively carried out as discussed previously using the cumulative sum technique. This immediately highlights differences between sections and areas of high variability.

5.4. In Situ Strength

Although the DCP test is rapid and cheap, the results can be particularly useful. It should be remembered, however, that the test was originally devised for soft materials and results obtained in crushed stone and stabilised materials must be interpreted with caution. Results are also highly sensitive to variations in moisture and density.
A properly planned and executed DCP survey can, however, yield very useful information at low cost with minimal disruption to traffic flow. The frequency of testing should follow the recommendations given in Botswana Roads Department Guideline No 2.[2] Using customised software, the DCP can indicate in situ strength conditions, approximate thicknesses of the different layers, overall pavement balance and the structure to a depth of 800 mm in terms of the DSN_{800} or DCP structural number.

It is often useful to evaluate the DCP data for separate layers, e.g., the strength of the base, or as various ratios, e.g., the ratio of the number of blows to penetrate the upper 300 mm to the number required to penetrate 800 mm, the strength of the supporting layers (300 to 800 mm) only, etc. The results should be compared with the design strengths, taking cognisance of the fact that the moisture content is likely to be significantly lower than the soaked laboratory equivalent used for design. The in situ CBR estimated from the DCP data is also affected by the in situ density. It is often useful to carry out DCP determinations on the specimens compacted

in the laboratory for calibration purposes as both the moisture content and density can be accurately determined.

5.5. Observation Holes

Observation holes are small excavations in the road, mostly used to check the nature and quality of the material and thicknesses of the upper layers. The size of the hole will necessarily increase as the required depth of the excavation increases but should be kept to a practical minimum. Generally, they should not be used to investigate deeper than about 250 or 300 millimetres, in which case test pits are recommended.

Observation holes require significant resources and time to excavate and backfill but are particularly useful for inspecting the materials and thicknesses of the surfacing, prime and base and even the top of the subbase.

The information obtained from observation holes can be compared directly with the design, to confirm compliance in terms of thickness, type of material and presence of stabilisers. It is possible to obtain an indication of the degree of compaction during excavation of observation holes and by inspecting the exposed materials.

5.6. Test Pits

Test pit to check the pavement layers and their characteristics.

Test pitting is one of the most costly components of Technical Audits and should be carefully designed to minimise the cost, disruption to traffic and political unacceptability. The latter aspect is of major concern to the Roads Department where the need to avoid major investigations of new roads is of prime concern. It is of utmost importance to have all the necessary safety measures in place during test pitting, including flagmen, appropriate traffic control and adequate coning.

Test pitting is necessary when serious doubts arise as to the quality and treatment of materials in the road or where the construction quality is being questioned. Test pits allow a close examination of the pavement materials and structure, detailed in situ testing such as density, moisture and stabilisation reactions and allow access for sampling.

It is usual to excavate test pits adjacent to or around the point that a DCP test was done. The area should be fully characterised using a standard visual classification and the surfacing removed. Density testing and collection of a moisture sample should be done on top of the base and a representative sample of the base course material collected. It is essential to ensure that proper sampling techniques are used, contamination of the sample is avoided and a full depth sample with vertical sides is collected. If the grading is to be analysed (as is usually the case), as little breakage of aggregate as possible should be achieved. This process is then repeated for each layer down to the in situ material, unless the road is on significant fill.

Once the in situ testing and sampling is complete the thickness of each layer should be measured and the test pit profiled. This involves a full description of each layer according to the standard procedure included in Roads Department Guideline No 2.[2] Where chemically stabilised layers are

specified in the design, their reactivity with Phenolphthalein and Hydrochloric acid should be investigated to determine the presence and condition of the stabilising agent and/or the resulting cementitious products. A red reaction with Phenolphthalein indicates that lime or cement was added and is still present. If the material does not turn red with Phenolphthalein, pozzolanic stabiliser was either not added or has become carbonated or neutralised by the material. For non-calcareous materials, effervescence on the addition of Hydrochloric acid indicates that pozzolanic stabiliser was added but has subsequently been lost through carbonation.

Prior to backfilling the test pits, a photographic record of the condition, profile and thicknesses of the layers and any other aspects that could have bearing on future performance, claims or legal issues related to the road, should be made. The pit can then be filled in layers with material similar to that removed and surfaced with a cold-mix patch.

The samples removed should be subjected to the necessary testing to determine the suspect properties. These would normally include one or all of the following:

Base course

Grading and maximum size, Atterberg limits, Compaction characteristics, California Bearing Ratio (CBR), Apparent and bulk relative density, 10%FACT (wet and dry), Durability Mill Index, Initial consumption of lime/cement (ICL/ICC), pH, Electrical conductivity.

Subbase and upper selected layers

Grading and maximum size, Atterberg limits, Compaction characteristics, California Bearing Ratio (CBR), Initial consumption of lime/cement, pH, Electrical conductivity.

Selected layers and subgrade

Grading, Atterberg limits, Compaction characteristics, California Bearing Ratio (CBR).

Grading, strength and durability properties of stabilised materials that are extracted from a road and tested in a laboratory are not always representative of the condition of the material in the road. The plasticity properties and ICL/ICC are, however, of major importance during the evaluation of stabilised pavement materials.

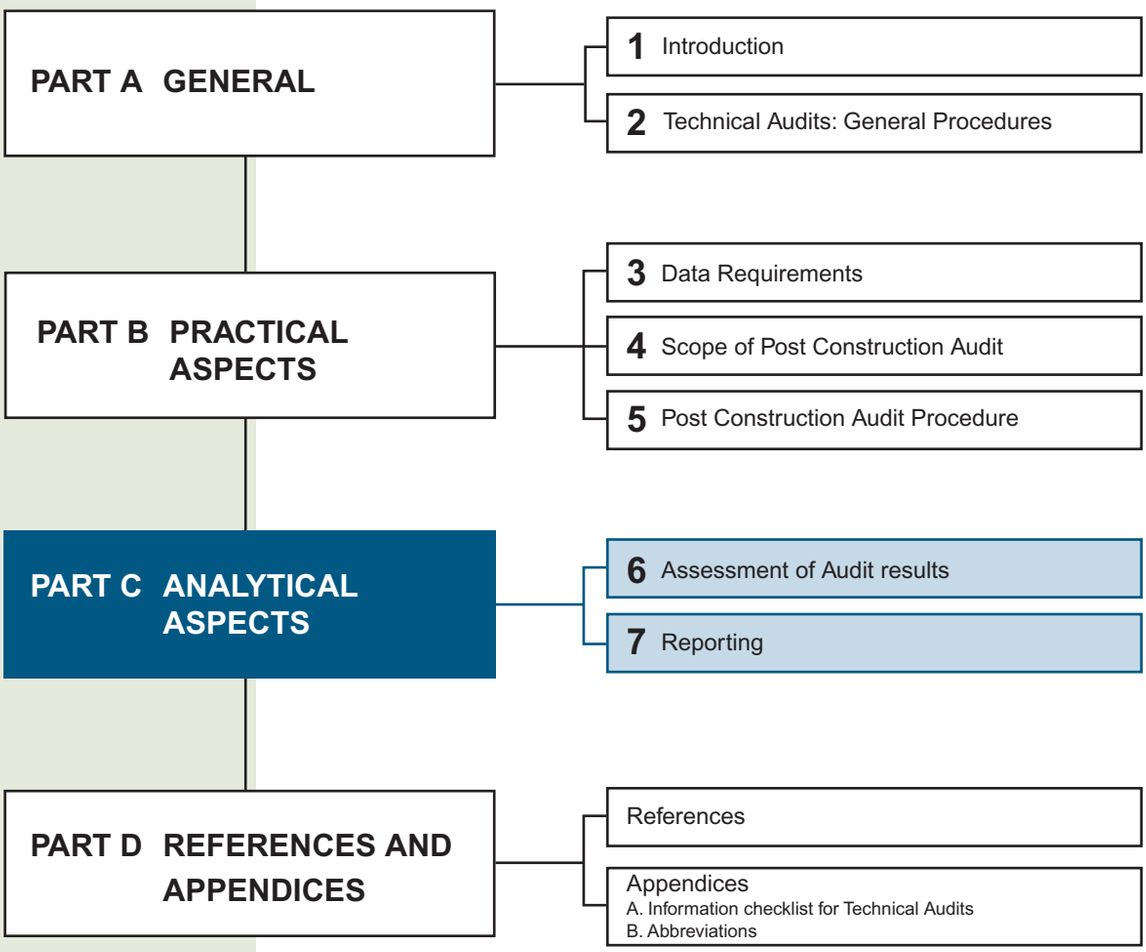
Test results on very weak or friable materials should be assessed taking consideration of possible changes in the properties that may have occurred during construction and sampling.

The results of this test programme will be compared with the material specifications for each layer of the project.

PART C ANALYTICAL ASPECTS

6 Assessment of Audit results

7 Reporting



PART C

6. ASSESSMENT OF AUDIT RESULTS

6.1. Contractual Implications

In assessing a project the Auditor will be working within the framework of two contracts - one between the Client and the Engineer and another between the Client and the Contractor. Both Contracts should be in the possession of the Auditor. The Contract between the Client and the Engineer for professional services requires the Contract Administration to be done with due care and diligence. The Contract between the Client and the Contractor is more clearly defined in the General and Special Conditions of Contract.

Where the Audit leads to the conclusion that either the Engineer or the Contractor has been in breach of their respective contracts and that this will lead to under performance of the final product then the Audit report should refer to the contracts and where possible the specific terms and clauses. The Client will then be guided by the result of the Audit in his decision as to whether or not to take appropriate action in terms of the contracts.

6.2. Design Compliances

The Engineer's intentions for the construction of the project are conveyed to the Contractor by way of the design drawings. It is important to confirm that all amendments to the design have been approved by the Client and that a complete set of signed drawings is or was available to the Contractor at all times.

Assessment of compliance by the Contractor should, in the first instance, come from a review of the Engineer's inspection and measurement records including dimension measurements of the roadway, drainage, services, layers and structures. The degree of verification checks that are deemed necessary will depend on the completeness and reliability of the records.

6.3. Material Compliances

Material compliance will be evaluated using a statistical technique. Although the strength/stiffness and durability are the primary requirements for pavement materials, a number of other properties are typically specified in the Standard Specifications and Contract Documentation. Some of these, e.g. Plasticity index, have been developed over time as proxies for other parameters such as strength. Despite this, they are still specified and the Contractor undertakes to comply with those specification.

Statistical acceptance schemes have been developed to take into account the natural variability of construction materials in such a way that the Contractor's risk of material being wrongly rejected is maintained at a low

value, whilst at the same time ensuring that the Client's risk of accepting poor quality workmanship is maintained at a similarly low level. These schemes have not yet been generally used for material control during construction and absolute limits are still applicable. This is probably the result of the large degree of natural and testing variability generally associated with rock and soil materials. The Technical Auditor should bear this in mind during the Audit but use some discretion with occasional results that are slightly out of specification for the project.

Graphic plotting of test results is a useful technique for identifying trends along the road. Simple spreadsheets should be used and statistical parameters such as mean, median, standard deviation and coefficient of variation should be determined. Changes in material source or uniform sections can be used to develop subsets of the data and allow more detailed assessment of trends.

6.4. Construction Compliances

Statistical methods of quality control are in use for construction and standards for construction tolerances are in the Standard Specifications. The Contractor has thus a definite target to work towards and this should be considered during any Technical Audit.

Properties such as density, layer thickness and percentage compaction should be plotted and analysed statistically, as discussed above, for material properties to assess trends and variations.

6.5. Consequences and Implications

The consequences of construction tolerances or material specifications not being met can be severe. Instead of the road carrying the traffic it was designed for, a poorly constructed road will require premature maintenance or rehabilitation/strengthening.

The most appropriate method of evaluating the consequences of poor construction or materials is to estimate the remaining structural capacity of the road using deflection measurements and to compare this with the design traffic. If the total cumulative traffic (that already carried plus the remaining structural capacity) is less than the design traffic loading the contractual implications will require careful assessment.

PART C

7. REPORTING

7.1. General

All aspects of the Technical Audit should be carefully and fully reported. In many cases the results of the Technical Audit could be the most important document affecting the outcome of arbitration or legal proceedings.

In general, Technical Audit Reports tend to contain large quantities of information but should not repeat contract data. To ensure that they are optimally utilised, they should be carefully structured. It is suggested that as much background and supporting information as possible is included in Appendices or referred as separate documentation and that the Audit Reports themselves concentrate only on the critical issues and their implications.

All reports should be comprehensive without being excessively lengthy. It is important that well considered, to-the-point executive summaries are included with all reports.

It is essential that Audit reports are submitted as soon as possible in order for the Client to institute corrective action. All Audit reports should be submitted within 3 weeks of completion of the respective Audits.

7.2. Familiarisation Phase

A written report is required from the Familiarisation phase of the project bringing out clearly deficiencies in design, tendering or other documentation. It is also recommended that the Technical Auditor prepares notes to assist him with assessment and Audits as the project progresses.

7.3. Initial Audit

The report at the end of the Initial Audit should include details of any critical issue that the Auditor considers could have a possible influence on the successful completion of the project. The suggested actions of the Roads Department must be clearly highlighted and prioritised, with summaries of the possible implications of the issue not being rectified. It should be noted that many of the concerns identified at this stage would have a serious impact on successful completion of the project.

7.4. Intermediate Audit

The report presented after the Intermediate Audit should be handled in the same manner as the previous report. In this case, however, emphasis should be placed on the material and construction techniques and whether all the issues identified in the earlier phases of the project have been addressed.

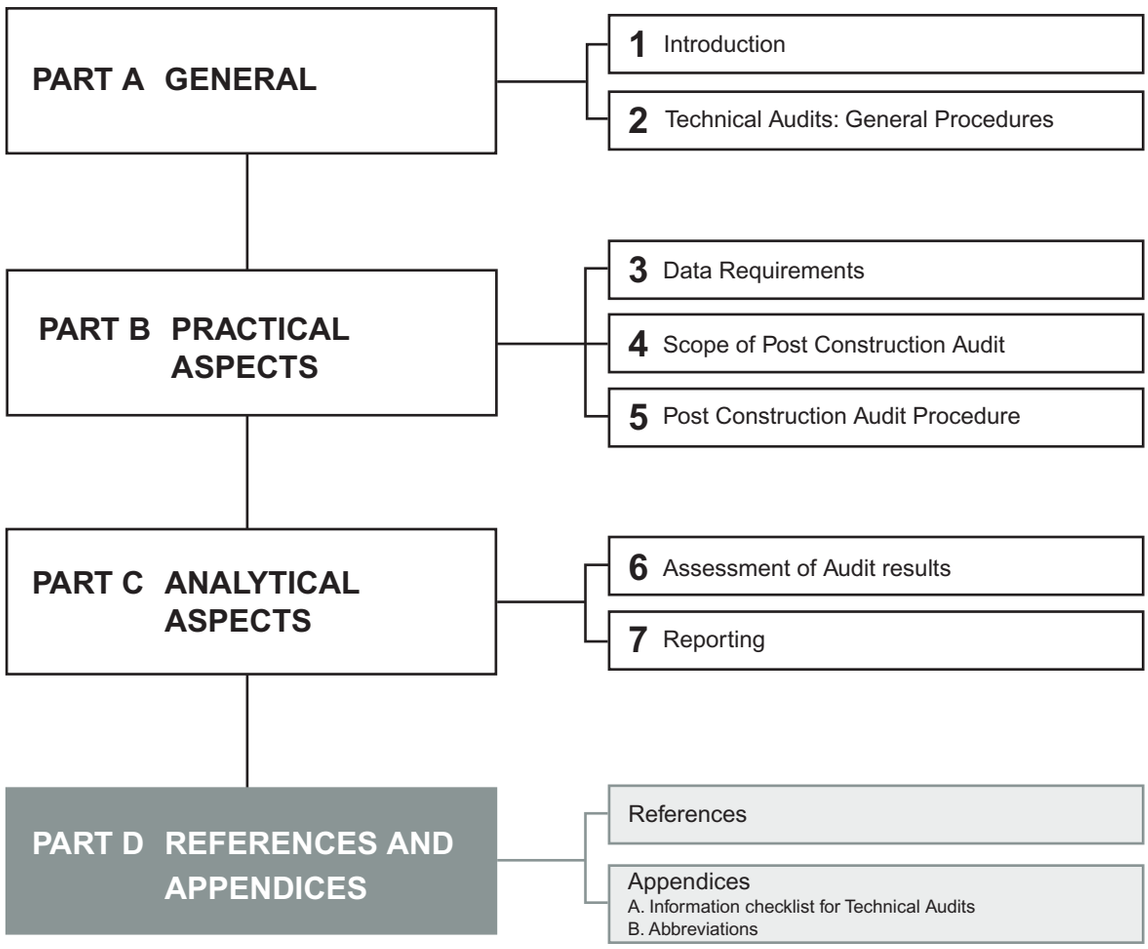
7.5. Final Audit

The report on the Final Audit will summarise the total project and make recommendations on any further investigation (Post Construction Audit) deemed necessary by the Auditors.

PART D REFERENCES AND APPENDICES

References

A. Information checklist for Technical Audits



PART D

REFERENCES

1. Standard specifications for Road and Bridge Works. 1983. Gaborone, Botswana: Ministry of Works, Transport and Communications.

2. Pavement testing, analysis and interpretation of test data. (2000). Guideline no. 2, Roads Department Gaborone, Botswana.

APPENDICES

APPENDIX A

INFORMATION CHECKLIST FOR TECHNICAL AUDITS

Information	Availability			Quality		
	Poor	Medium	High	Poor	Medium	High
Consultants design and drawings						
Tender documentation						
Bills of quantities						
Project management details/Gantt chart						
Monthly progress reports						
Construction reports						
Laboratory test results						
Measurement records						
Payment records						
Correspondence						
As built records						
Completion report						
Payment certificates						
Deflection and riding quality data						
Relationships between Consultant's and Contractor's staff (particularly the Resident Engineer and Site Agent)						
Contractor's and Engineer's attitude during the contract - Were there many disputes? - Were they declared?						
Was a time extension required? Valid reasons?						
Comparison of final account with budget						
Comparison of completion date with program						
Adherence to the program during the works						
Foreman's ability to read drawings						
Any other aspects can be added by the Auditor if required.						
Poor - Nothing or poor quality records Medium - Incomplete records Good - Quantity and quality of records to be expected from a well executed project						

APPENDIX B

ABBREVIATIONS

CBR	- California Bearing Ratio
CPP	- Civil and Planning Partnership
CSIR	- Council for Scientific and Industrial Research
DCP	- Dynamic Cone Penetrometer
DFID	- Department for International Development
DSN800	- DCP Structural Number over a depth of 800 mm
10% FACT	- Ten Percent Fines Value
ICC	- Initial Consumption of Cement
ICL	- Initial Consumption of Lime
NORAD	- Norwegian Agency for Development Cooperation
NPRA	- Norwegian Public Roads Administration
pH	- Hydrogen ion Concentration
PHN	- Public Highway Network
TRL	- Transport Research Laboratory, UK
UCS	- Unconfined Compressive Strength