

SOUTH AFRICAN PAVEMENT ENGINEERING MANUAL

Chapter 13

Quality Management



**AN INITIATIVE OF THE SOUTH
AFRICAN NATIONAL ROADS AGENCY SOC LTD**

Date of Issue: October 2014

Second Edition

**South African Pavement Engineering Manual
Chapter 13: Quality Management**

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BACKGROUND

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SCOPE

The South African Pavement Engineering Manual (SAPEM) is a reference manual for all aspects of pavement engineering. SAPEM is a best practice guide. There are many relevant manuals and guidelines available for pavement engineering, which SAPEM does not replace. Rather, SAPEM provides details on these references, and where necessary, provides guidelines on their appropriate use. Where a topic is adequately covered in another guideline, the reference is provided. SAPEM strives to provide explanations of the basic concepts and terminology used in pavement engineering, and provides background information to the concepts and theories commonly used. SAPEM is appropriate for use at National, Provincial and Municipal level, as well as in the Metros. SAPEM is a valuable education and training tool, and is recommended reading for all entry level engineers, technologists and technicians involved in the pavement engineering industry. SAPEM is also useful for practising engineers who would like to access the latest appropriate reference guideline.

SAPEM consists of 14 chapters covering all aspects of pavement engineering. A brief description of each chapter is given below to provide the context for this chapter, Chapter 13.

Chapter 1: Introduction discusses the application of this SAPEM manual, and the institutional responsibilities, statutory requirements, basic principles of roads, the road design life cycle, and planning and time scheduling for pavement engineering projects. A glossary of terms and abbreviations used in all the SAPEM chapters is included in Appendix A. A list of the major references and guidelines for pavement engineering is given in Appendix B.

Chapter 2: Pavement Composition and Behaviour includes typical pavement structures, material characteristics and pavement types, including both flexible and rigid pavements, and surfacings. Typical materials and pavement behaviour are explained. The development of pavement distress, and the functional performance of pavements are discussed. As an introduction, and background for reference with other chapters, the basic principles of mechanics of materials and material science are outlined.

Chapter 3: Materials Testing presents the tests used for all material types used in pavement structures. The tests are briefly described, and reference is made to the test number and where to obtain the full test method. Where possible and applicable, interesting observations or experiences with the tests are mentioned. Chapters 3 and 4 are complementary.

Chapter 4: Standards follows the same format as Chapter 3, but discusses the standards used for the various tests. This includes applicable limits (minimum and maximum values) for test results. Material classification systems are given, as are guidelines on mix and materials composition.

Chapter 5: Laboratory Management covers laboratory quality management, testing personnel, test methods, and the testing environment and equipment. Quality assurance issues, and health, safety and the environment are also discussed.

Chapter 6: Road Prism and Pavement Investigation discusses all aspects of the road prism and pavement investigations, including legal and environmental requirements, materials testing, and reporting on the investigations. The road pavement investigations include discussions on the investigation stages, and field testing and sampling (both intrusively and non-intrusively), and the interpretation of the pavement investigations. Chapters 6 and 7 are complementary.

Chapter 7: Geotechnical Investigations and Design Considerations covers the investigations into fills, cuts, structures and tunnels, and includes discussion on geophysical methods, drilling and probing, and stability assessments. Guidelines for the reporting of the investigations are provided.

Chapter 8: Material Sources provides information for sourcing materials from project quarries and borrow pits, commercial materials sources and alternative sources. The legal and environmental requirements for sourcing materials are given. Alternative sources of potential pavement materials are discussed, including recycled pavement materials, construction and demolition waste, slag, fly ash and mine waste.

Chapter 9: Materials Utilisation and Design discusses materials in the roadbed, earthworks (including cuts and fills) and all the pavement layers, including soils and gravels, crushed stones, cementitious materials, primes, stone precoat fluids and tack coats, bituminous binders, bitumen stabilized materials, asphalt, spray seals and micro surfacings, concrete, proprietary and certified products and block paving. The mix designs of all materials are discussed.

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Chapter 10: Pavement Design presents the philosophy of pavement design, methods of estimating design traffic and the pavement design process. Methods of structural capacity estimation for flexible, rigid and concrete block pavements are discussed.

Chapter 11: Documentation and Tendering covers the different forms of contracts typical for road pavement projects; the design, contract and tender documentation; the tender process; and the contract documentation from the tender award to the close-out of the Works.

Chapter 12: Construction Equipment and Method Guidelines presents the nature and requirements of construction equipment and different methods of construction. The construction of trial sections is also discussed. Chapters 12 and 13 are complementary, with Chapter 12 covering the proactive components of road construction, i.e., the method of construction. Chapter 13 covers the reactive components, i.e., checking the construction is done correctly.

Chapter 13: Quality Management discusses all aspects of quality assurance and acceptance control for the road prism and all pavement layers: gravel, cemented, bitumen stabilized, asphalt, seals, concrete and proprietary and certified products. Acceptance control processes are also included. Quality plans, responsibilities, training, sampling and testing, and interpretation are discussed. The documentation involved in quality management, including the Completion Report, is also discussed, and where applicable, provided. The appendices contains example Acceptance Control Worksheets for most elements of road pavement construction, completion times for acceptance control testing and testing frequencies for most materials.

Chapter 14: Post-Construction incorporates the monitoring of pavements during the service life, the causes and mechanisms of distress, and the concepts of maintenance, rehabilitation and reconstruction.

FEEDBACK

SAPeM is a "living document". The first edition was made available in electronic format in January 2013, and a second edition in October 2014. Feedback from all interested parties in industry is appreciated, as this will keep SAPeM relevant.

To provide feedback on SAPeM, please email sapem@nra.co.za.

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1. INTRODUCTION

It is often said that one of the reasons why the relatively thin pavements constructed in South African perform so well, is as a result of the high level of quality control exercised during the material selection and construction process. While the relatively high level of material testing, as generally prescribed, does play a significant part, reliance on test results only, without accompanying visual monitoring and inspection of construction processes and uniformity, significantly increases the risk of not realising optimal performance.

Quality control during the construction phase is generally based on a dual control system where both the contractor, and the supervising consulting engineer, have specific responsibilities and contractual obligations. Some of the basic differences between Quality Management (contractor's responsibility) and Quality Control (engineer's responsibility) are summarized in Table 1.

Table 1. Quality Management versus Quality Control

Quality Management (Contractor)	Quality Control (Engineer)
Prevents problems	Reacts to problems
Does the right thing	Does the right thing
Controls activity	Provides end inspection
Involves all people in the organization	Places reliance on quality control specialist
Places responsibility for quality with the people who do the work	Client supervision

The various phases of quality control may be summarised as follows:

- **Component materials**
 - Conformance to standards
- **Materials design: Laboratory**
 - Material quality
 - Design parameters
- **Design verification: Trial section**
 - Construction processes
 - Material quality
 - Design parameters
- **Constructed layer control**
 - Construction process
 - Material quality
 - Design parameters



Quality Assurance

Quality assurance is defined as planned and systematic actions necessary to provide adequate confidence that a product or service satisfies given requirements for quality. It is a proactive activity.

Quality control is an essential part of any construction project, regardless of the type of contract. Chapter 11: 2 discusses several contract types. Much of the discussion in this chapter focuses on conventional contracts, where the contractor is appointed by the client to construct the works as designed by the designer, typically a consulting engineer. The consulting engineer also administers the contract and monitors that the contractor constructs the works as designed, complies with the specified requirements, and follows good practice. The principles discussed in this chapter are, however, relevant to all contract types.

Figure 1 shows a flow chart indicating the basic steps in quality management.



Standard Specifications

Note that when this chapter was written and updated, the 1998 version of the COLTO Standard Specifications was being used. However, these specifications are currently being reviewed. A revised version of the Standard Specifications is likely to be published in 2015 and is likely to be issued either by SANS or COTO.

In this chapter, reference is only made to the Standard Specifications, which currently refers to the 1998 COLTO version.

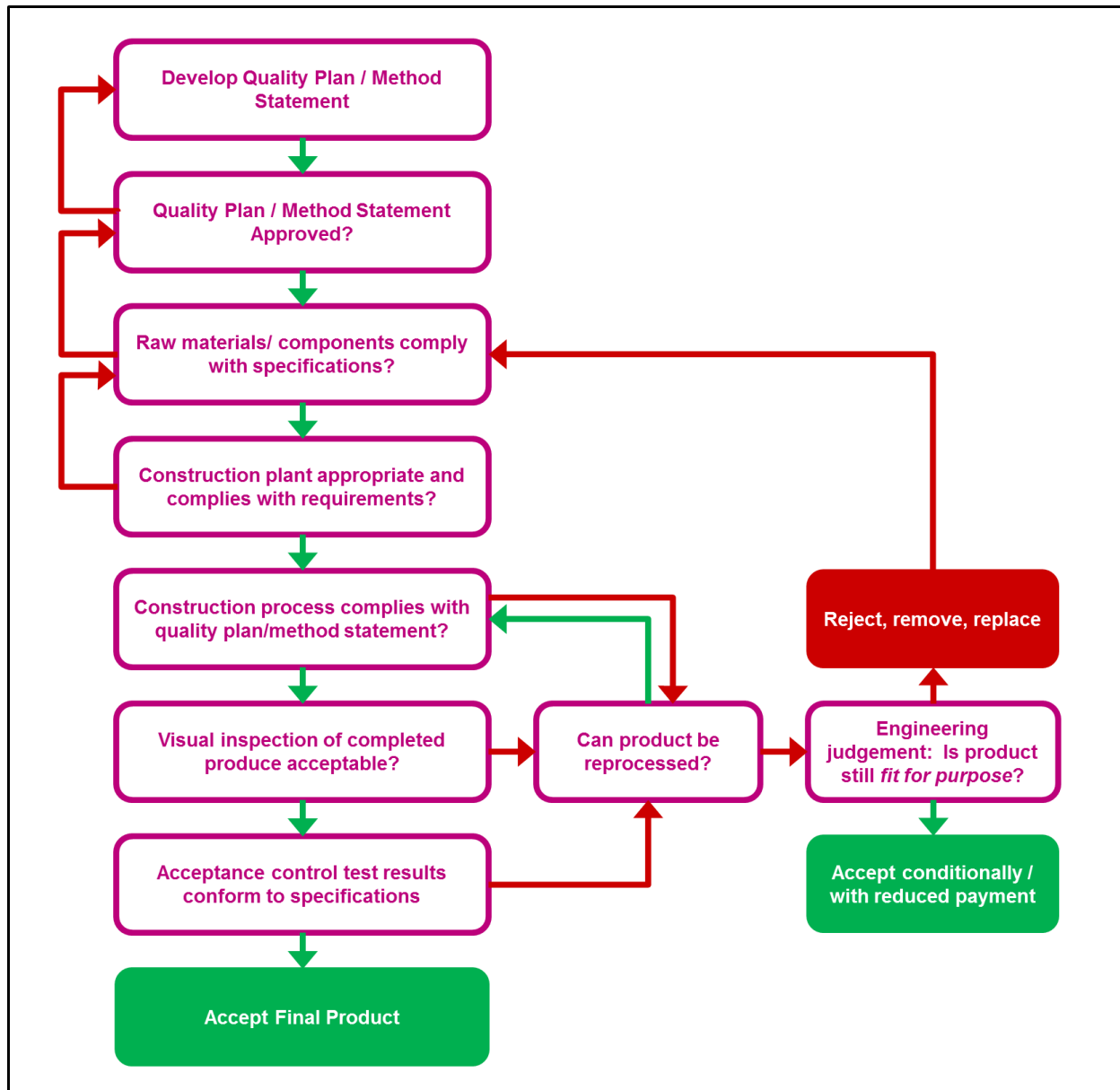


Figure 1. Basic Quality Management Flow Diagram

1.1 Quality Plan

Quality assurance is defined as *"planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality."* It is a proactive activity, aimed at significantly reducing, or eliminating, non-conformance before it occurs. Some of the processes and activities relating to quality assurance are:

- Quality system:** A documented system in which the organizational structure, responsibilities, procedures, processes and resources for implementing quality management are defined. ISO 9000 and SANS 17025 provide an excellent framework and point of departure for the development and implementation of an organizational quality system. A quality system is implemented in a project by the preparation and use of a quality plan.
- Quality plan:** A document setting out the specific quality practices, resources and sequence of activities relevant to a particular project or service. Such a plan should be appropriate to the scope, complexity, and/or risk profile of the works.



Quality Plan

For every project, a project specific Quality Plan should be compiled by the supervising team, temporary (site) laboratory and the contractor. The plan should set out the specific quality practices, resources and sequence of activities relevant to the project.

For every project, a project specific quality plan should be compiled by the supervising team, temporary (site) laboratory and the contractor.

1.2 Supervising Team

Quality control carried out by the supervisory engineering staff is defined in the Standard Specifications as Acceptance Control. It is the supervisory engineers' responsibility to institute a quality control system that conforms strictly to the contractual requirements, as prescribed in the appointment, as well as the Standard Specifications and relevant project specifications. Procedures not prescribed in the above documentation are carried according to the requirements contained in the quality manual, this guideline, or any other systems relating to current best practise.



Acceptance Control

Quality control carried out by the supervisory engineering staff is defined in the Standard Specifications as Acceptance Control.

To meet the above responsibilities, it is a requirement that a quality plan be compiled and implemented by the supervising engineer. Such a plan should clearly establish the contract administration activities required, particularly in relation to the contractors management and technical capability, and maturity of his quality system. Such a plan should cover the following issues:

- Client's policy on **contract administration**
- Project **organisation**
- **Responsibility and authority** of contract administration personnel, particularly relating to:
 - Release of hold points
 - Waiver of hold points
 - Surveillance and audits
 - Non-conformance
- **Procedures relating to:**
 - Contract management
 - Disputes
 - Variations to contract
 - Identified non-conformance and requested corrective action
 - Surveillance, including audits
 - Site meetings
 - Purchasing and leasing
 - Hold points and witness points
 - Records
 - Training
- **Schedule of procedures** requiring agreement by all parties
- **Audit schedule** for the contract



Hold and Witness Points

A **hold point** is one where work cannot continue until additional information has been obtained. For example, construction of a base on a stabilized subbase cannot continue until the laboratory results on the subbase are completed and verified.

A **witness point** is similar to a hold point, but the observation is just a visual observation, rather than a laboratory test.

The engineer is defined as the client's representative for the project. In conventional contracts, the engineer is a consulting engineer. The interpretation of test data, results and test reports produced by an external laboratory and/or the site quality assurance laboratory is the responsibility of the engineer. In the case of accredited laboratories, only the test and its data may be accredited. The interpretation of the results is, therefore, not covered in the accreditation of the test.

It is the combined responsibility of the laboratory and the engineer to ensure that the quality systems implemented for the quality and acceptance control, and the requirements set for the accreditation of the laboratory, are successfully integrated.

Whilst the engineer for the project is entitled to delegate a number of functions to the resident engineer, there are specific responsibilities and/or duties that may not be delegated. The scope of allowable delegations is prescribed by the client, and it is essential that all supervisory staff are fully aware of this.

1.3 Site Staff and Responsibilities

The duties of the materials supervisory staff extend beyond the mere testing of materials and associated reporting. Much of the quality of the work involved in road construction is directly related to techniques and plant utilised during construction.

To perform adequately throughout the road's design life, it is vitally important that the quality of the completed works be as uniform as possible. In the majority of instances, acceptance of completed elements is based on end result specifications. However, it is essential that a suitable construction process or technique be determined and agreed upon between the contractor and the supervisory personnel, for each relevant operation. The agreed process should thereafter be continuously monitored for compliance throughout the project. Every end result specification thus includes an element of method specification, to reduce the risk of non-conformance or non-uniformity of final product quality, or delays, which may result in extra costs.

The responsibilities of the materials supervisory staff cover a wide range of activities, including aspects such as:

- **Knowledge** of project requirements and specifications
- **Evaluate** of raw materials properties
- **Materials selection** and utilisation
- **Assess of materials** design properties and sensitivity to changes and variations
- **Suitability** of construction plant
- **Appropriateness and consistency** of construction processes and techniques
- **Adhere** to prescribed environmental limitations, e.g., weather and temperature
- **Visually inspect** completed elements
- **Test** materials properties in place
- Level, width and layer **thickness control**
- **Smoothness** and surface finish
- **Report** results and final assessment of completed work
- Knowledge of **SANS 17025**
- Knowledge of **laboratory quality** and auditing procedures
- **Record** as-built data

It is incumbent on the materials staff to keep the resident engineer fully informed on all the above issues at all times. The Resident engineer is in turn responsible for timeously informing the engineer and, if necessary, the client, of any contractual and or technical problems experienced or expected. The sometimes adopted practice of not formally commenting in writing on works, which are being carried out by the contractor in such a manner that it will obviously be rejected, is unacceptable.

Continuous communication and teamwork between the site supervisory staff and the contractor is essential, not only to ensure proper programming, but also to ensure that the common objectives are met in the most cost effective manner. Due care, however, should be exercised to not be prescriptive to the extent of removing contractual responsibilities from the contractor.

1.4 Visual Inspection

Relying solely on a relatively few test results in no way guarantees that a good quality product has been delivered. Visual inspections and assessments throughout the construction process, as well as any completed layer, form an integral part of quality control. Visible signs of poor workmanship, excessively variable properties, segregation, and/or any other visual defects constitute sufficient grounds for rejecting the work without testing.

It is considered good practice, and is in fact a general requirement in most quality assurance schemes, that visual inspections be carried out in a formal and structured manner. Accountability must be dedicated to specific persons. As a prompt to the inspector, and to limit any oversights, a



Conventional Contract

Chapter 11, "Documentation and Tendering", Section 2 discusses the types of contracts used for construction. The most common type of contract in South Africa is a conventional contract. This is where the client appoints a consultant to design the project, and supervise the contractor on behalf of the clients.

Much of the discussion in this chapter assumes the construction is administered through a conventional contract.



Formal Notification of Issues

The practice of not formally commenting in writing on works, which are being carried out by the contractor in such a manner that it will obviously be rejected, is unacceptable.



Importance of Visual Inspection

Relying solely on a relatively few test results in no way guarantees that a good quality product is delivered. Visual inspections and assessments throughout the construction process, as well as any completed layer, form an integral part of quality control. Visible signs of poor workmanship, excessively variable properties, segregation, and/or any other visual defects constitute sufficient grounds for rejecting the work without testing.

checklist for visual inspections should be included with the test result analysis sheet, and completed and "signed off" for each assessed lot.

1.5 Checklists and Reporting

Examples of checklists for most elements of road construction are given in Chapter 12, and also in the Chapter 12 Appendix in an easy to print format. Acceptance control forms are given in Appendix B of this Chapter 13. Section 11 discusses the reporting required for construction projects.

1.6 Training

Under certain conditions, the client may, on submission of a formal application, approve the deployment of trainee technicians and engineers on a project. To maximise the benefits, it is a requirement that all training is carried out in a formal and structured manner, as prescribed by the relevant Engineering Council, as well as any guidelines and conditions as may be imposed by the client. This implies that the trainee should not only be given duties of a mundane nature, but should be exposed to as many facets of construction as possible, with, where ever possible, some level of responsibility. A logbook detailing these facets and levels of responsibility should be kept to assist the trainee with professional registration.

1.7 Interpretation and Assessments of Results

Only the engineer has the delegated authority to accept or reject any work. Support staff must thus carefully avoid exceeding their levels of authority, and should channel any views, opinions or decisions to the contractor via the engineer. The final interpretation of the results thus remains the responsibility of the engineer.



Accepting or Rejecting Work

Only the engineer has the delegated authority to accept or reject any work.

The engineer is required to "sign off" each completed element, once satisfied that all the specified criteria and obligations have been met.

When the laboratory testing is complete, the senior materials staff, e.g., the SANAS approved signatory (see Chapter 5: 1.1), should record the results on the appropriate assessment forms, carry out the required statistical assessment and submit the forms to the resident engineer, together with any necessary interpretations and comments. Where the contractor and consultants do not share a combined laboratory, it is desirable that the contractor's process control results are also attached. On receipt of the visual assessment report (if not already included in the test result forms), as well as the surveyor's results of layer thickness, level and grade measurements, the engineer is required to assess the lot for full compliance, and inform the contractor accordingly.

The whole acceptance control procedure should be carried out as soon as is reasonably possible. Lengthy delays only result in frustration to the contractor, especially if working to a tight program. Delays attributed to a lack of attention to administrative detail, are not acceptable.

While the contractor is obliged to afford the supervisory staff reasonable notice and adequate access to the works for quality control purposes, the supervisory staff are also under an obligation to assess and accept, or reject, any completed elements as soon as is reasonably possible. Appendix C indicates a time schedule guideline for the more common types of acceptance control testing. A reduction in these time periods can generally only be achieved by testing outside of normal working hours, which has a cost implication, or by deviating from the standard test methods applicable, which should not even be considered.

Where the contractor requests test results rapidly to accelerate his work programme, and this can be achieved by overtime, it is SANRAL policy that the contractor be liable for all overtime costs of the laboratory testing staff required. Similar policies may exist with other agencies, the contractor and consulting engineer should be familiar with relevant policies for the particular project.

The assessment or interpretation of laboratory test results is a complex procedure that requires skill and experience. It is thus



Visual Inspection under a Water Cart

Traditionally, a fully loaded water cart has been utilised to visually identify any weak or unstable areas of completed roadbed treatment or selected subgrade layers, prior to requisitioning any testing. By driving the loaded water cart over the areas, any heaving or deformation can be identified.



part of the primary duties of the site personnel. The final interpretation of the results remains, however, the responsibility of the engineer.

All test results are assessed in terms of the material standards outlined in Chapter 4 and further enhanced by the applicable standard and/or project specifications. A summary of the testing requirements and frequencies for most construction processes are given in the chapter and summarized in Appendix D.

To assess whether certain requirements specified for material properties and workmanship are complied with, judgement plans are implemented. This minimizes the risk of accepting a non-compliant product that will not yield the anticipated long term performance. Thus, each material property requires either a minimum number of stratified random samples per lot, or per volume/area produced, to ensure that judgement based on test results is within acceptable risk levels for all involved parties. A statistical judgement scheme offers the least subjective outcome to all involved parties, even though it is not always called for in the project specifications. Such a scheme may be implemented if a minimum of four test results are available, but ideally not less than six. The higher the category road, the higher the required design reliability of the road, i.e., the less risk tolerated, and the greater the importance of statistical control. The uppermost structural layers are more at risk, and thus require a judgement scheme to limit the risk within an acceptable level.

COLTO (1998) offers Quality Control Schemes 1 and 2 in Sections 8200 and 8300, respectively. One of these schemes must be selected in the project specifications for a specific project. Statistical judgement plans are applied in Scheme 1. Table 8206/3, for example, reflects the values of constants for various constructed layer properties:

- **n:** sample size
- **L_s and L'_s :** lower and upper specification limits
- **Φ :** permissible percentage defectives

The specific judgement scheme selected is contractually binding to all parties, and must thus be strictly followed in all respects. Testing frequencies for the various properties to be assessed are prescribed in the specifications. It must, however, be stressed that these frequencies are the minimum allowable, and should always be increased if there is any doubt on the quality or non-uniformity of the product, or, larger volumes of materials or products are involved.



COLTO Quality Control Schemes

There are currently two methods of statistical acceptance control permitted in the COLTO Standard Specifications (1998). The difference focuses on the standard deviation:

- **Method 8200:** The **standard deviation is determined from all the results** in a specific "lot" which then determines the "Acceptance limits".
- **Method 8300:** In Section 8300 a "default" **standard deviation is applied based on historically derived values.**

The whole concept statistical acceptance control is currently under review and it is likely that the principles currently followed could change in the near future!

1.8 Non-Conformance

The identification of non-conforming work, and especially the frequent occurrence thereof, often leads to frustration, or even conflict, between the site supervisory staff and the contractor. A proactive approach to ascertain the reasons or causes for non-conformance, as well as positive inputs with respect to possible solutions, is encouraged. However, in no circumstances should any superintendence of the contractors operations be assumed.

Due to the relatively lower costs involved for corrections to completed elements assessed on a non- statistical basis, e.g., rip and re-compaction of granular layers, they are often not as contentious as rejections of "bound" products, e.g., concrete and asphalt. It is important to remember that products or elements falling into the "conditional acceptance" range do not automatically have to be accepted by the engineer, but should be assessed on their individual merits or risks. Continuous or frequent delivery of work within the conditional acceptance range requires punitive action, as such situations can be interpreted as the contractor having no intention of improving the workmanship or processes to comply fully with the specified requirements.

Under no circumstances are site personnel permitted to accept any work not complying fully with the requirements of the project. While the acceptance of work falling within the conditional acceptance range is the prerogative of the engineer for the project, no work in the rejected range should be accepted without the approval of the applicable road authority.

Non-conformance does not, however, always automatically imply that the element shall be reconstructed by removal and replacement. Each case should be judged on the principles of "fit for purpose". Such judgements require a high level of engineering knowledge and experience, based on known and acceptable levels of risk and cost implications.

Where it is intended that non-conforming work is permitted to remain in place, with or without remedial work, the standard process followed commences with the submission by the contractor of a formal request supported by technical data, performance history, proposed price discount, and any other mitigating factors relevant to the situation. The next stage in this process is for the engineer to assess the risk, proposed remedial measures and any cost implications, and forward the recommendation for the client's approval. As a general principle, any extended guarantee periods that may be offered should be viewed with caution as administration of such guarantees is administratively difficult. In addition, with time, the apportionment of liability as a result of initial non-conformance can be very difficult to prove as there are any number of "external" influences that can come into play.

1.9 Combined Site Laboratory

Combined laboratories are a joint venture between the employer/consultant and the contractor. Both parties contribute financially, normally 50/50 or as agreed, for the provision of personnel, laboratory equipment and transport. Both parties accept joint responsibility for all process and acceptance control results done by this laboratory. Some advantages of such a joint facility are:

- Improved **control**
- **Time savings** for the contractor
- **Cost savings** for the client and contractor

Due to the general shortage of qualified and experienced testing personnel currently experienced, the use of combined laboratories has become popular. Some road authorities, such as SANRAL, have made the use of combined laboratories obligatory, thus ensuring that all testing is undertaken correctly and in the most cost effective manner possible.

The following conditions for a successful combined laboratory are required from the contractor:

- An undertaking that the **contractor will accept the test results** of the combined laboratory. Should there be any doubt with regard to the validity of certain test results, the issue shall be resolved through the use of an independent laboratory mutually agreed upon. The costs involved in such instances will be to the account of the party at fault.
- An undertaking that the **engineer is in charge of the combined site laboratory**, and that staff and equipment supplied by the contractor are under the sole control of the engineer.
- The recent move by most Road Authorities to prescribe that all testing on site be undertaken under the "umbrella" of a **SANAS accredited laboratory** implies that a contractor generally cannot contribute staff or testing equipment towards a combined site laboratory. For example, SANRAL limits the contribution of the contractor to a financial one, i.e., they are required to tender a fixed monthly sum, which is then deducted from the payment certificates.

1.10 Control Laboratory

A base or control laboratory is an accredited laboratory, with fixed premises, that commits to taking responsibility for the control of a temporary laboratory under its own quality management system, including all technical competency aspects. This was previously known as a consultant's main laboratory. A temporary laboratory is expected to have a limited lifetime. The quality management system is administered from, and is common to, the base laboratory. The schedule of accreditation of the temporary laboratory shall be a sub-set, but no greater than, the base laboratory. The temporary laboratory was previously known as a site laboratory.

The base (or main) laboratory remains responsible for the quality of the testing, test data, results and test reports carried out and prepared by their site or temporary laboratories.

Until SANAS finalises the requirements for temporary (site) laboratories, the base laboratory is responsible for ensuring that the requirements and philosophy of SANS 17025 are carried out in the temporary (site) laboratory. These responsibilities and requirements include:

- Base laboratory has the **technical control** of the temporary laboratory. Where the temporary laboratory is not part of the same organisation as the accredited base laboratory, there must be a formal contract between the two laboratories. The documentation shall state how the level of technical control of the base laboratory for each temporary laboratory is assessed and allocated.
- Temporary laboratory's participation in regular **inter-laboratory comparisons** with their base laboratory, other temporary laboratories in the area, as well as the national proficiency testing scheme (if available).
- '**Setting up**' and '**closing down**' procedures for the temporary laboratory.

- Selection of staff, i.e., number of staff, experience levels, allocation of SANAS approved signatories from the base laboratory.
- Issuing and control of **reports**.
- **On-site auditing** of the temporary laboratory, typically at least every 6 weeks.
- **Storage** of equipment and records of equipment not currently in use.
- **Verification** of equipment performance and calibrations.
- **Records of specialised requirements**, e.g., set up of balances and compaction blocks, which require rigid footings.
- **Development of quality plans**, pertinent system and technical documentation for each site.
- Any other aspects pertinent to the **accuracy of testing** and the **compliance** to SANAS requirements.
- **Details of any variations** from the base laboratory's quality system, that are different, or not applicable to, the temporary laboratory.
- **Contract review arrangements**, both prior to acceptance of the work and during the life of the project.

It is the combined responsibility of the laboratory and the engineer to ensure that the quality systems implemented for the quality and acceptance control, and the requirements set for the accreditation of the laboratory are successfully integrated.

1.11 Accreditation

Certain client bodies, for example SANRAL, have implemented a policy to exclusively utilize laboratories that are accredited by SANAS to SANS 17025 for a wide range of testing. It is, therefore, a requirement that the base laboratories for the duration of the project, both at design and supervision stage, are SANAS accredited.

SANAS is the sole accreditation body recognized by government to assess, against internationally recognized standards, laboratories that provide test and calibration services. SANAS combines a depth of technical knowledge and laboratory management expertise built up over many years, with scientific and technical specialists operating across the test and calibration spectrum.

The internationally recognized standard for the competence of laboratories is SANS/ISO/IEC 17025 and is the standard against which SANAS accredits laboratories. Temporary (or site) laboratories are regulated to SANS 17025 through a SANAS regulation.



SANAS and Accreditation

SANAS is the South African National Accreditation System.

www.sanas.co.za

Chapter 5: 1.1 discusses SANAS and accreditation.

Laboratories that are certified to ISO 9000:2000 are not accredited. ISO 9000 relates only to quality management systems, and there is no specific requirement to evaluate the technical competence of a laboratory.

SANS 17025 requires that beyond the requirements of ISO 9000, these further areas of competency are met by the laboratory:

- **Competence** of personnel
- Availability and use of **suitable methods**
- **Internal quality control** mechanisms to support required schedule of accreditation, i.e., quality management aspects
- Suitable **standards and equipment** within the laboratory
- Suitable **testing environment**

Table 2. Primary Differences Between ISO 9000 and SANS/ISO/IEC 17025

	ISO 9001	ISO 17025
Quality system assessment	✓	✓
Technical assessment	✗	✓
Proficiency testing	✗	✓
Surveillance	✓	✓

Accreditation to SANS 17025 is test specific, whereas ISO 9000 is system specific. In other words, an accredited laboratory is accredited for a list or 'schedule' of tests, for which it has been assessed. All other tests carried out by that laboratory are not accredited.

A laboratory that has been accredited by SANAS to SANS 17025 is required to display the SANAS accredited laboratory logo and schedule of accreditation visibly in the laboratory, and to state which tests are accredited on the test reports.



The Standard

SANS/ISO/IEC 17025:2005 is known as the Standard, and is referred to as such in this chapter.

The Standard is available for purchase from The South African National Standards (SANS). Tel: (012) 428 6833.

Pro forma SANS/ISO/IEC 17025 procedural documentation is available on the internet, an example of which is <http://www.17025.homestead.com/index.html>



ISO 9000:2000

Laboratories that are certified to ISO 9000:2000 are not accredited. ISO 9000 relates only to quality management systems, and there is no specific requirement to evaluate the technical competence of a laboratory.

1.12 Sampling and Testing

1.12.1 Sampling

It is common perception that sampling is a relatively simple operation, and is thus often entrusted to very junior and/or unskilled personnel. In numerous instances, disputes with respect to validity of test results on non-conforming work are as a result of questionable sampling techniques.

For the results of any testing to be meaningful and representative of the product or lot, it is essential that all sampling is carried out in a consistent and correct manner. It is therefore required that all sampling is carried out strictly according to the methods and procedures as contained in TMH5: Sampling for Road Construction Materials. Where more than one sampling technique is allowable for a specific product, it is advisable that a method be selected and agreed to by all parties, prior to commencement of the actual work.

When a lot is tested, whether a normal sized lot or an isolated section, that clearly exhibits an abnormal variation of the property under consideration, all samples shall be taken in a random pattern. To ensure that the total length of a lot is covered, the random sampling is required to be carried out in a stratified manner, i.e., the lot is subdivided into a number of sub lots dependent on its length, after which a random number is selected from the tables as contained in TMH5, Appendix A or any other random number generating scheme. An example of how to implement stratified testing is given in the Standard Specifications. Notwithstanding requirements for random sampling, samples for testing should also always be taken from areas exhibiting different characteristics from that evident over the major portion of the assessed lot.



Stratified Testing

Stratified testing involves the random determination of testing positions. The aim is to eliminate bias when selecting test positions.

With stratified testing, the lot is subdivided into a number of sub lots, depending on the lot length, to ensure that the total area of the lot is tested.

1.12.2 Testing

SANS 17025 requires that test reports for all accredited tests include:

- **Client requirements**, i.e., test methods, time periods, test forms or any specific requirements.
- **All observations, data and calculations** are identifiable and traceable to the specific test or test report.
- Statement of **compliance and non-compliance** with requirements and or specifications.
- **Opinions and interpretations** are clearly marked.
- All **accredited tests**, as per the temporary laboratory schedule of accreditation, must be clearly identified as such. No ambiguity may exist between accredited and non-accredited tests in the test report.



Sampling References

TMH5: **Sampling for Road Construction Materials** is a good reference for sampling.

SANS 17025 further requires that the laboratory:

- Has a system to **systematically check calculations** and data transfers in a systematic manner.
- Has a **risk plan** identifying potential sources of non-conformance.
- Has a system in place to **identify and correct non-conforming work**, for example, control charts or trend sheets for test results of individual borrow pits and layers.
- **Inform clients** of any incorrect test results or reports that may have been issued for non-conforming work.



Construction Lot

A construction lot is a section that is constructed at the same time, of the same materials, and using the same method. It is considered to be the same for testing purposes. A lot is generally about a day's work or an element of a structure.

1.13 Interpretation

The assessment or interpretation of test results is a complex procedure that requires skill and experience, and is thus part of the primary duties of the senior materials personnel on site, i.e., the engineer or SANAS approved signatory. The final interpretation of the results remains the responsibility of the engineer.

All the results should be checked for correctness, prior to the formal reporting thereof. It is also imperative that the person assessing the test results is aware of the inherent variability of material properties and familiar with the acceptable standard deviations pertaining to the repeatability, and the reproducibility of the specific tests. It is also essential that test results are interpreted holistically, and not in isolation. For example, a single out of specification result is not sufficient ground to reject the product. Where, however, consistent borderline results are obtained, or other properties also indicate a move towards non-conformance, construction should be temporarily suspended and the issue investigated.

In addition, the early identification of any "strange" results is essential. Such instances should be immediately investigated as the reporting of any such results, especially those which are virtually unachievable, casts doubt as to the credibility of the testing facility. The resultant lack of faith often leads to unnecessary conflict situations.

1.13.1 Statistical Assessment

A statistical assessment involves the use of random numbers to determine where, and how many, samples to obtain and test. The advantage of a statistical judgement scheme is that it, to a large extent, removes subjectivity from the overall assessment procedure. As significant variations in product properties results in "stricter" acceptance limits imposed, it also assists in ensuring an acceptable degree of uniformity of the final product.

Experience has proven that the use of formal statistical judgement scheme assessment forms is useful to minimise errors. It is a requirement that all statistical values be calculated and reported to three decimal places.

While the relevant judgement schemes do make allowances for the identification of outliers within a population of results, the discarding of any such results should be viewed with extreme caution. Wherever possible, the test should be repeated on a retained sample or, where this is not possible, consideration should be given to extracting a sample from the representative area in the completed element for further evaluation. Where the result of the outlier has been confirmed, it should be included in the total population of results assessed. Where such a proven result deviates significantly from the remainder of the population, the total area represented by that result should be identified, investigated and evaluated according to "fit for purpose" criteria.

1.13.2 Non-Statistical Assessment

The Standard Specifications require that, for non-statistical assessment, the completed elements conform in all respects to the specified requirements. In most instances therefore, any non-conforming work is required to be reprocessed. Where it is believed that non-conforming work should be allowed to remain in place, it should always be referred to the client for a ruling, prior to a decision being forwarded to the contractor.

1.14 Trend Sheets

The implementation of trend sheets, displaying the key product properties during continuous asphalt or concrete production, has long been the norm for process control. They provide an assessment of the "job at a glance". A conceptual trend sheet is illustrated in Figure 2. It is, however, considered good practice to implement a similar trend sheet for acceptance control of other pavement layers, so that results in individual lots are assessed holistically and not in isolation. Trend sheets greatly contribute towards the principle of a proactive approach by identifying

undesirable trends timeously, thus allowing for corrective actions to be suggested or instructed before the product falls into a rejection zone.

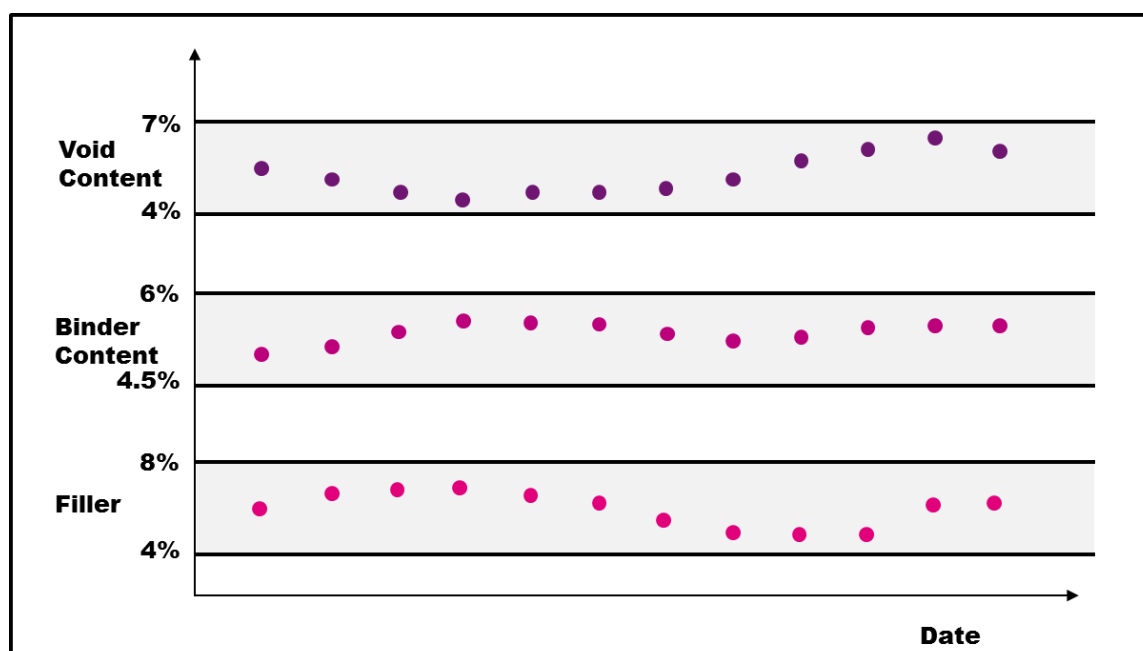


Figure 2. Conceptual Trend Sheet for Asphalt Production

1.15 Contractor Obligations

Quality control (management), as carried out by the contractor, is defined in the Standard Specifications as Process Control. The onus rests with the contractor to produce work which conforms in quality and accuracy of detail, to all the requirements of the specification and drawings. The contractor must, at their own expense, institute a quality control system and provide sufficient experienced personnel and equipment to ensure adequate supervision and positive control of the works at all times. On completion of each element of the construction work, the contractor is required to test and check such materials, products and/or elements for compliance with the specified requirements, and submit the results to the engineer for approval.

The intensity of control and frequency of tests to be conducted by the contractor in terms of these obligations is not prescribed in the Standard Specification. Some contractors tend to carry out very little, or no process control testing, but rely solely on the supervisory engineer's results. To promote the requirement that the contractor assumes responsibility for the work quality, it is recommended that a minimum process control testing frequency be prescribed in the project specifications. Such an approach also assists the contractor at the tender stage to estimate the potential costs associated with the testing. Combined laboratories have also become popular, where the client/consultant and contractor accept joint responsibility for all process and acceptance control results done by this laboratory. See more in Section 1.9.

Taking all the above into account, a quality plan should be prepared by the contractor describing the specific practices, resources and sequence of activities to be carried out relative to the execution of the project. Such a plan should include the following information:

- (a) **Quality objectives**
 - Quality policy
- (b) **Project organisation**
 - Project organisation
 - Responsibility and authority of personnel in relation to:
 - Execution of the contract
 - Hold points and witness points
 - Quality assurance and quality control
 - Sub-contractors



Contractor Obligations

To encourage the contractor to assume responsibility for the work quality, it is recommended that a minimum process control testing frequency is prescribed in the project specifications. Such an approach also assists the contractor at the tender stage to estimate the potential costs associated with testing.

- Communication channels
- Qualification and training
- (c) Process**
 - Flow charts (including hold and witness points)
 - Identification and trace-ability
 - Planning
- (d) Inspection and audit**
 - Quality control plan
 - Quality registration
 - Quality audit
 - Surveillance
 - OHS
 - Traffic accommodation
 - Environmental compliance
- (e) Procedures**
 - Evaluation of schedule of quantities and quality plan
 - Acceptance, issue and modification of documents
 - Purchasing
 - Evaluation of sub-contractors and suppliers
 - Handover of works
 - Management of non-conformance and corrective actions
 - Maintenance of equipment
 - Site meetings
- (f) Appendices**
 - A: Procedures for Quality Control
 - B: Quality Control Tolls
 - C: Work Instructions
 - D: Standard Report Forms

An overall content guide and framework for quality assurance is contained in the SABITA/CSIR Report: "Draft Framework for Quality Assurance Contracting in the South African Asphalt Industry" (Verhaeghe, 1998). Although the framework has been compiled specifically for the asphalt industry, its contents can easily be adapted for any construction process.

Should the contractor wish to include the process control tests as part of the acceptance control testing, the contractor's laboratory must be accredited for the tests performed.

1.16 Health, Safety and the Environment (HSE)

Health, safety and the environment must be considered at all times during a construction project. On most construction sites, safety audits are done regularly.

(i) Personal Protective Equipment (PPE)

The supervisor must ensure that all the members of the work team wear safety jackets and safety boots at all times. When working with dusty materials, dust masks must be worn.

A First Aid kit must be available at all times in case of an emergency.

The operator of a binder distributor and the assistant must at all times wear safety jackets, safety boots, heat resistant hand gloves, and safety goggles when working, or adjusting, the distributor. SANAS regulation R52-01 (www.sanas.co.za) covers the handling of dangerous and corrosive substances, and should be adhered too.

2. ROAD PRISM

Quality management for the road prism is discussed in this section, and covers fills, the roadbed and cuts.

2.1 Fills

This section gives the background required to adequately apply acceptance control processes for fill layers, as well as identifying and addressing potential problems.

2.1.1 Source

Fill material is normally obtained from cuttings along the road route. Where it is not possible to balance the earthworks mass haul, fill is obtained from borrow pits adjacent to the route. See Chapter 9: Section 3.2.5 for discussion on balancing the mass haul diagram.

Prior to excavating a cut or proposed source, it should be adequately explored, as outlined in Chapter 8.

The proposed site and rehabilitation plan for borrow pits should be approved by the Regional Director: Department of Mineral and Energy in accordance with the procedures outlined in Chapter 8, Section 2.4.

The component conformance control requirements should be in accordance with the contents of this section.

2.1.1.1 Sampling Plan

Should additional information be required or alternative sources contemplated, guidelines are provided in Chapters 7 and 8.

2.1.1.2 Tests

The properties measured in this phase of acceptance control are normally:

- Durability (mudrocks)
- CBR strength and swell
- Atterberg Limits
- Grading

Refer to Chapter 3, Materials Testing, Section 2, for a complete list of tests.

2.1.1.3 Time Schedule to Obtain Acceptance

The time schedule to obtain acceptance for the potential product is governed by the time to obtain the required samples and the duration of specific tests. A schedule of times is outlined in Appendix C.

2.1.1.4 Assessment

Quality assessment procedures may require the selection of cut material, the redirection of mining operations and processing techniques, or point towards stockpiling in the cut or borrow pit to improve the uniformity, prior to hauling to the road.

2.1.2 Trial Section

Once the source has been approved, a trial section is recommended to enable timeous assessment and verification of the construction procedures and processes. These include appropriate stockpiling procedures and compaction techniques, applied to satisfy the criteria outlined in Chapter 4, Standards before proceeding with full production. The first section constructed is usually the trial section.



Fills

Various aspects of fills are discussed in:

- Chapter 7: **Geotechnical Investigations and Design Considerations**
 - Section 4
- Chapter 8: **Material Sources**
 - Section 2.2.1
- Chapter 9: **Materials Utilisation and Design**
 - Section 3.2
- Chapter 12: **Construction Equipment and Method Guidelines**
 - Section 3.2



Drainage

Drainage is an extremely important consideration for pavements! Water is the primary cause of premature failure, accelerated distress and reduced structural capacity.

All aspects of drainage are comprehensively covered in SANRAL's Drainage Manual and not repeated in SAPEM. Download the Drainage Manual from www.nra.co.za.

Unless adequate historical data is available to verify all relevant parameters, a length of fill shall be constructed as a trial section:

- At the **start** of any fill construction
- On the introduction of fill from a **new source**
- When **compaction problems** are experienced

The trial section allows for the following:

- **Timeous implementation of modifications** to the processes used to achieve the compacted grading requirements, and to remove or reduce oversize material.
- **Assessment and reduction of variability**, especially regarding to the grading attainable with particular excavation techniques, stockpiling methods, grid rolling and the mined source.
- **Assessment of the suitability of compaction equipment** and/or settings of vibratory equipment.
- Verification of the **quality of the proposed source**, including any special treatment required.

2.1.2.1 Sampling Plan

The sampling requirements for a trial section are given in Chapter 6, "Road Prism and Pavement Investigation": 7.4 and/or project specifications, and cover the following issues:

- **Location** of trial section
- **Size** of trial section
- **Number** of test points
- **Position** of test points for in situ tests and for samples for laboratory tests, including length and width of test blocks, to ensure a stratified, random sampling approach

2.1.2.2 Tests

For each test point the following in situ tests are carried out:

- Layer **density**
- Layer **thickness**

Samples shall be taken at test points for the following laboratory tests:

- **Indicator** tests
 - Grading
 - Atterberg limits
- **CBR**, bearing strength and swell
- **Compaction** determination

Refer to Chapter 3: 2 and Chapter 4: 2 for details on these tests and standards.

2.1.2.3 Time Schedule to Obtain Acceptance

The time schedule to obtain acceptance depends on the length of time to complete each test. Duplicate samples may be required by the Control Laboratory, which could delay the final approval of the various parameters or criteria proposed for construction control.

The duration of the relevant tests are detailed in Appendix C. Also note the time constraints listed in the Standard Specifications.

2.1.2.4 Assessment

Assessment of the following results must be undertaken.

(i) **Grading**

The grading is not assessed using a statistical procedure. However, the individual test results obtained for each sample taken, and the calculation of the mean and standard deviation give an indication of the variability and expected quality of the fill material. The grading requirements given in Chapter 4: Section 2 are applicable, and depend on the material class.



Materials Depth

The materials depth describes the thickness or depth below the final road level of the road pavement where the soil characteristics have a significant effect on the road pavement behaviour. Below this depth, the strength of the materials are assumed to have a negligible effect on the road pavement's performance.

The material depth is discussed in:

- Chapter 9: **Materials Utilisation and Design**, Section 2 including figures

(ii) Atterberg Limits

There are no specific PI limits, but high PI values account for many premature pavement failures. They should, therefore, be avoided where possible, without incurring significant extra cost.

(iii) Bearing Strength and Swell

Material with a CBR of less than three percent at a specified density is not permitted in the upper region of the roadbed, known as the material depth. This requirement ensures that adequate total cover is maintained over poor material in the lower region of the roadbed, i.e., below the "material depth".

Material within the upper region must have a CBR equal to at least the value of the design CBR at 90% of MDD density and a maximum swell of 1.5% at 100% MDD. In the case of sand, the CBR must be evaluated at 100% MDD.

(iv) Compaction

The minimum compaction should be as listed in Chapter 4: 2.8, or as given in the project specification. The test is performed between 12 and 24 hours after compaction.

To calculate the degree of compaction, six maximum dry density (MDD) values are determined. The mean MDD is used for both the nuclear gauge and sand replacement methods. This means the MDD is used as the basis for commencing the MDDs for subsequent construction lots, for properly processed and/or stockpiled material. If this is not done, then at least three MDDs must be determined for each construction lot.

In some cases, the compaction cannot be satisfactorily controlled by testing the density, because of the nature of the material, such as rockfill. The engineer may then instruct that the layer is compacted by a number of passes of one, or a combination of various types of compaction equipment. See Chapter 12: 2.10 for a discussion on different types of rollers.

2.1.2.5 Comment on Rockfill

The ultimate performance of rockfill, in terms of long-term settlement, is an important consideration, especially where placed in approach fills to structures, or where an existing roadway is widened.

The requirements for rockfill are an attempt to minimize settlement, by providing sufficient fine material to fill the void space between larger rock particles. To evaluate all aspects influencing the required characteristics of a rockfill for large construction projects, large-scale field density tests need to be conducted in trial sections, to establish or verify a procedural specification. Matheson (1986) recommends that 1.0 m diameter test holes, 450 to 600 mm deep are excavated. The suggested hole volume, for the calculation of overall bulk density, is obtained by lining the hole with plastic sheeting and filling with water using a calibrated container.

Tarry (1994) also reported on compaction control for earth-rock mixtures. This method permits the calculation of the maximum dry unit weight and optimum water content of the total material, from corresponding values obtained on either the –20 mm or –5 mm fraction. A density interference coefficient and optimum water content factor are used, which are related to the gravel content.

The trial section offers the opportunity for a compaction study, to assess the effectiveness of the various compactors, and to assess the break-down of material.

2.1.3 Construction Lots

The quality of the fill is judged using construction lots. The construction lots shall satisfy the criteria outlined in Chapter 4: 2, or the appropriate project specifications. The project specifications may include more recent research findings and/or project specific requirements based on special investigations carried out during the planning and detailed design phase of the project. Any deviations from the materials standards, as given in Chapter 4: 2 should be



High PI's in Wet Areas

Be careful of materials with high PI's in wet areas. While they may be theoretically acceptable and meet the relevant requirements, construction in the rainy season is problematic.



Nuclear Testing

Nuclear testing is covered in the following chapters:

- Chapter 3: **Materials Testing**, Section 2.7.1
- Chapter 5: **Laboratory Management**, Section 6.3

A checklist for nuclear testing is included in Chapter 12, and in the appendices to both Chapter 12 and 13.



Compaction Tests

Tests of the compaction are carried out between 12 and 24 hours after compaction.

well researched, with special cognizance of the impact of such deviations on life cycle costing.

The test section must be visually homogeneous regarding grading, density and moisture content. Any isolated non-homogeneous areas, e.g., wet patches, must be excluded from the test section and treated separately.

2.1.3.1 Sampling Plan

The requirements for a sampling plan include:

- **Number** of test points
- **Position** of test points, including length and width of test blocks to ensure a stratified random sampling approach

The Standard Specifications contain standard sampling plans.

2.1.3.2 Tests

For each test point, the following in situ tests are carried out:

- Density determination
- Layer thickness

Details and requirements for the tests are given in Chapter 3: 2.

Samples shall be taken at test points for the following laboratory tests:

- **Indicator Samples:** Grading and Atterberg limits
- **Maximum dry density** (MDD)
- **Bearing strength** and swell (CBR)

2.1.3.3 Time Schedule to Obtain Acceptance

The duration of the relevant tests can be assessed using the guidelines given in Appendix C.

2.1.3.4 Assessment

The following items need to be assessed for acceptance control of construction lots.

(i) **Compaction**

The use of sequential mean MDD is only practical for sections with similar characteristics. In other cases, the MDD for each test point(s), representing the same quality of material, is determined for each lot.

The degree of compaction obtained at each test point shall comply with the minimum requirements. Where the minimum requirement is not obtained, an investigation should be carried out. This may involve more testing in the vicinity of the original test point and determination of an additional MDD.

(ii) **Atterberg Limits**

The test data obtained give an indication of the quality of the material regarding to cohesive materials. If a special treatment was implemented, the success of the treatment is assessed with the revised values.

(iii) **Bearing Strength**

At least two samples should be obtained for each lot. By comparing the CBR value of the first sample with the trial section results, a trend may be established. Where major differences exist, the second sample should also be tested, or additional samples taken in the near vicinity of the specified test point.

(iv) **General**

Any tests carried out during the approval design stage, or in the trial section, may be repeated for a construction lot.

Material with unacceptably low bearing strength, or other shortcoming, must be removed and replaced with suitable material of the required quality. Alternatively, other special remedial action should be implemented, such as lime stabilization.

Any unforeseen material problems should immediately be brought to the attention of both the materials and contracts engineer.

2.1.3.5 Acceptance of Construction Lots

Normally, the acceptance of the quality of the fill is the responsibility of the engineer's representative, who applies the requirements of the most recent Standard Specifications. However, in the case of a dispute, the matter shall be forwarded to the client's materials engineer, with all the necessary test data for assessment.

2.1.3.6 As-Built Data Sheets

Only the roadbed preparation, such as type of roller and number of passes, and material classification, such as G5, G6 or clay, should be recorded on the form for As-Built Road Foundation Profile and Fill Layers. The as-built forms are available from TMH10 or in spreadsheet format on the SANRAL website www.nra.co.za.

2.1.3.7 Comment

The following comments on mudrock fills and fills slopes are important.

(i) Mudrock Fill

Excessive settlements of up to nearly a metre have occurred in shale mudrock fill (FHWA, 1980). Durability is one of the main contributing factors. It is thus necessary to determine which mudrocks are durable enough to be placed in a rockfill in thick lifts, and which mudrocks must be broken down and compacted as soil in thin lifts. The Venter Test (Chapter 3: 2.9) assists in identifying a potential slaking problem.

The following key findings should be considered when constructing mudrock and shale fill:

- **Causes of distress**
 - Inadequate compaction
 - Infiltration and saturation
 - Shale deterioration
- **Contributing factors**
 - Inadequate foundation benching and drainage
 - Lack of reliable index tests and criteria for defining non-durable shales
 - Difficulties in breaking down hard shales and rock, prior to compaction
 - Uncontrolled mixing of soil, shale, and large rock in the same lift
 - Use of excessive lift thicknesses
 - Lack of specific compaction requirements and procedures
 - Lack of adequate measures to prevent infiltration of surface water

(ii) Fill Slopes

Fill slopes should be designed during the detailed planning stage. However, during construction, all fill slopes should be reviewed by the engineer. Any potentially problematic materials should be carefully observed and details referred to the materials engineer.

For example, dune sand embankments in semi-arid and arid areas are prone to erosion. Based on work by the Institute for Revegetation Ecology at Potchefstroom University, "*a final slope of 20° is required in a material with an angle of natural repose of 35°*" (Gregson, 1990). It is recommended that full slopes of 1:3 are used.

(iii) Selected Material/Fill Material for Structure Backfills

Backfilling to structures normally requires a selected fill. It is of the utmost importance to impose strict control to eliminate potential settlement with time. Reference should be made to the appropriate clauses in the Standard Specifications or project specifications for precast culverts and materials used in reinforced earth structures.

2.2 Roadbed and Cuts

An essential step in the construction of durable roads is the use of materials of consistent quality, with adequate strengths, for each pavement layer. The purpose of acceptance control is to ensure that the objectives of consistent quality and adequate strength are achieved. In fill situations, the roadbed is the natural ground surface, after vegetation and topsoil removal, on which the pavement structure rests (including any fill). In cut, the roadbed is the excavated surface on which the lowest pavement layer rests.



Unforeseen Material Problems

Any unforeseen material problems should immediately be brought to the attention of both the materials and contracts engineer.

There are many reasons for road failures. Failures within the roadbed occur due to the additional load applied to the in situ material by the construction and operation of the road. Figure 3 shows a large embankment failure. A high fill (embankment) results in significant increases in the applied loads and requires that extra attention be paid to the roadbed. Failures within the roadbed (the pavement's foundation) may be the result of:

- Inadequate **site investigations**
- Insufficient consideration of **foundation conditions** during design
- Improper implementation of the **design solutions** during construction



Cuts

Various aspects of cuts are discussed in:

- Chapter 7: **Geotechnical Investigations and Design Considerations**
 - Section 5



Figure 3. Embankment Failure

Failures originating within the fill itself may be caused by

- Poor **materials**
- Unsatisfactory **construction methods**
- Ineffective **quality control** procedures

Research has shown that most stability problems are the result of poor foundation (roadbed) conditions, rather than faulty placement of the fill (NCHRP, 1971). These roadbed problems are caused primarily by inadequate consideration of soft foundation materials, side slope locations, cut-fill transitions and groundwater conditions. In general, relatively few problems result from poor fill placement, since good construction practices and quality control procedures for the placement of fills are generally followed.

This section gives the background required to adequately apply the acceptance control processes for the roadbed, as well as to identify and address potential problems.

2.2.1 Source of Materials

The in situ material of the roadbed is the source material and should be used to its best advantage. Substandard materials should be identified and removed. CBR, gradings, Atterberg limits and compaction tests are carried out to ensure that the roadbed quality meets the design requirements.

Where the roadbed material is expansive, collapsible, contains excessive quantities of salt, or has any other unusual problems, reference should be made to the project specifications for additional testing. Other problems are extensive mole activity, cracks and/or subsidence pointing to existing secondary sinkholes. Usually these issues are covered in the Materials Report and project specifications and drawings. For discussions on problem materials see Chapter 6: 6, and Chapter 12: 3.1.



Stability Problems

Most stability problems are the result of poor foundation (roadbed) conditions rather than faulty placement of the fill.

Where density tests cannot be carried out due to the nature of the material, the roadbed is tested according to the specifications.

2.2.1.1 Sampling Plan

The sampling plan, which caters for determination of test point positions for various construction lengths and widths, is based on the same principles as given in Section 2.1.1.1. The actual areas of concern encountered in the roadbed, for each section, dictates the minimum number of test points for in situ testing and/or obtaining samples for laboratory testing.

2.2.1.2 Tests

The following properties need to be measured for the roadbed source material. Chapter 3: 2 describes the tests.

- **Roadbed (soil)**
 - Grading
 - Atterberg limits
 - Bearing strength
- **Expansive soil**
 - Grading
 - Atterberg limits
 - Expansive potential
- **Collapsible soil**
 - Grading
 - In situ density
 - Collapse potential
 - Homogeneity
- **Soluble salts**
 - Salt contamination

2.2.1.3 Time Schedule to Obtain Acceptance

The time schedule to obtain acceptance is governed by the time to obtain the required samples and the duration of specific tests. Refer to Appendix C for typical test durations. The extent to which exploratory work is carried out during the planning phase, and the construction programme constraints, may affect the verification process.

2.2.1.4 Assessment

The outcome of test results may result in the need for further treatment of the roadbed, or even replacement of substandard material.

2.2.1.5 Comments

Problems not always envisaged during the planning stage are:

- **Unstable roadbed** caused by exceptionally wet weather conditions
- High **moisture infiltration** due to seepage just prior to the commencement of construction.

These problems may also occur when the lower layers of an existing pavement structure are exposed during rehabilitation, and there is inadequate drainage or sub-drainage.

The most suitable and cost effective treatment under such circumstances may well involve the provision of a pioneering layer using end-dumped rockfill. Boulder type material is not normally successful. A trial section is required to assess the suitability of the rockfill source.

For more clayey fine-grained saturated material, such as decomposed dolerite, lime treatment may prove cost effective, if the plant can operate under the prevailing conditions. The use of sulphonated oil products for fine-grained clayey material is also claimed to yield satisfactory results, but should first be assessed in a trial section. For a discussion on sulphonated oil products, see Chapter 3: 6 and Chapter 9: 14.

2.2.2 Trial Section

A trial section is recommended, particularly for problem materials, to enable the assessment and verification of the proposed construction procedures, such as appropriate, stockpiling procedures and compaction techniques. The test standards detailed in Chapter 4 must be satisfied before proceeding with construction.

The objective of the proposed construction procedure is to obtain a firm, stable platform. The trial section can establish the following:

- **Suitability of the construction method**, i.e., can a stable platform be created using this procedure?
- Practicality of attaining at least the **minimum required in situ compaction** on materials where the density can be measured.
- **Meaningful decision on what further action** should be taken, or which tests should be carried out in the case of expansive, collapsible, compressive, or highly resilient materials.
- Suitability of **imported construction materials**.
- Assessment of the **suitability of compaction equipment**, such as type, mass, vibrator amplitude and frequency.
- **Moisture content** for compaction.

2.2.2.1 Sampling Plan

The sampling requirements for a trial section, given in the project specification, cover most of the following issues:

- Trial section at an **early stage**
- **Location** of a trial section
- **Size** of trial section
- **Number** of test points
- **Position of test points** for in situ tests and/or laboratory samples

2.2.2.2 Tests

Refer to Chapter 6, "Road Prism and Pavement Investigation", for design verification of various types of materials encountered in the roadbed.

For each test point the following in situ tests should be carried out:

- Layer **density**, where appropriate
- **Depth** of layer tested

Samples should be taken at test points for at least the following tests:

- Grading and Atterberg limits
- Bearing strength
- Compaction determination



Problem Soils

Problem soils are discussed in:

- Chapter 4: **Standards**, Section 2
- Chapter 6: **Road Prism and Pavement Investigation**, Section 6
- Chapter 9: **Materials Utilisation and Design**, Section 2

2.2.2.3 Assessment

The following assessments are made for the trial sections for cuts and the roadbed preparation.

(i) Grading

The assessment for grading is not carried out in terms of a statistical approach. However, the individual test results obtained for each sample taken, and the calculation of the mean and standard deviation give an indication of the variability and expected quality of the material in the roadbed.

The identification, classification and detailed description of the materials are given in Chapter 4, Standards.

(ii) Atterberg Limits

Atterberg Limits give an indication of the plasticity of the fine material in the material matrix. Material is regarded as potentially expansive when the liquid limit exceeds 30 and the linear shrinkage exceeds 8. In such instances, it is considered prudent to initiate a more detailed petrological examination of the material. This identifies the clay mineral, including constituents of the problematic montmorillonite group of clay minerals, i.e., saponite, nontromite or montmorillonite. In general, the greater the plasticity and percentage of clay, the higher the potential for heaving, and thus more caution and/or investigation required.

The remedial actions or treatment for highly clayey material, with high heaving or settlement potential, is given in Chapter 9: 2.1 for expansive materials and settlement of compressive soils.

Fine grained materials with little or no plasticity, particularly sands in dry areas, are not an assurance that problems will not be encountered during the lifespan of the pavement. This is because most of the samples are disturbed and any unstable soil fabric, such as bridges holding the coarser grains apart, are destroyed. These bridges are usually one, or a combination, of the following: clay, iron oxides, carbonates, gypsum (calcium sulphates), micas or even salts. The bridges make the material susceptible to sudden consolidation settlement. Inundation under load causes the collapse of the unstable soil fabric, due to softening of the bridges. The remedial actions or treatment for collapsible materials are given in Chapter 9: 2.1.

(iii) Soluble Salts

The presence of soluble salts should be identified during the soil survey, and a decision made as to whether further special studies need to be done during the preparation of the roadbed trial section. This is not as important an issue as with upper pavement layers.

Under certain circumstances, salt may migrate upwards and cause:

- **Cracking**
- **Blistering** or loss of bond of surfacing
- **Disintegration** of cemented layers
- **Loss of density** in layers

(iv) Bearing Strength and Swell

Material with a CBR of less than 3% at the specified or in situ density is not permitted in the upper region of the roadbed or the material depth. This is to ensure that adequate total cover is maintained over poor material in the lower region of the roadbed, i.e., below the "material depth".

Material within the upper region must, therefore, have a CBR equal to at least the value of the design CBR at 90 percent of MDD density, or at the in situ density. In the case of sand, this must be at 100 percent MDD density. In addition, a maximum swell of 1.5 percent at 100 percent of MDD density applies.

In the case where the roadbed is used as a structural layer, i.e., upper or lower selected layer, the minimum CBR for the appropriate layer is applicable.

With rock cuttings, the treatment of the roadbed is according the Standard Specifications.

(v) Compaction

The minimum required compaction, where density measurement is practical, should be as specified in Chapter 4, Standards: 2.8. Where the compaction cannot be satisfactorily controlled by way of testing the in situ density, because of the nature of the material, such as boulders, the engineer may instruct that the layer is compacted by a number of passes of one, or a combination of various types of compaction equipment.

2.2.2.4 Comments

Roadbed problems identified during the planning phase, as well as proposed remedial action, may require reassessment and verification by way of a trial section. Typical issues are briefly described:

- **Expansive material.** The constructability issues of the proposed remedial action in relation to the site dictates the appropriate actions. For example, at one site, the use of an emulsion membrane was ruled out due to the risk of puncturing the membrane during the placement of a subsequent layer. In this case, a "cap", was provided by treating the roadbed with an ionic stabilizer, compacting to reduce the permeability of the "cap", and to promote a more stable moisture regime below the "cap".
- **Vegetation.** Careful attention should be paid to the removal and/or planting of trees within the road reserve. Blue gum trees, for instance, take up in excess of 1000 litres of water per day, resulting in severe desiccation of the soil. See Figure 4 for an example of tree damage, which manifest as a longitudinal crack and extensive patching.
- **Collapsible materials.** A trial section is required to assess the compaction efficiency of the compaction equipment and, in particular, the impact of the equipment on the density profile at depth.



Minimum CBR

Material with a CBR of less than 3% at the specified or in situ density is not permitted in the upper region of the roadbed, or the material depth. This is to ensure that adequate total cover is maintained over poor material in the lower region of the roadbed.

- **Flaws in Structural Support.** Secondary sinkholes are experienced. Thus, in areas prone to dolomitic subsidence, special attention should be given to prevent such situations occurring. This should be attended to in the materials investigation phase.
- **Surface water.** The main issue to be guarded against during construction is the concentration of surface water along or near the roadway, and to invest in flexible paving solutions for surface drainage. Flattening fill slopes to move surface water away from the roadway should always be a prime consideration. The solutions, which should be detailed in the project specification, may include:
 - Impermeable soil mattresses
 - Fill side-slopes extending to the reserve fence to prevent water infiltration and secondary sinkholes forming
 - Protection of culvert inlets and outlets



Tree Causing Crack



Tree (showing as stump) Causing Distress Resulting in Extensive Patching

Figure 4. Tree Causing Distress on Pavement

2.2.3 Construction Lots

The quality of the fill is judged by construction lots on sections displaying similar qualities identified from the material survey, or after clearing of the roadbed, and during the implementation of a trial section for each uniform section. The test section represented by a lot should be visually homogeneous in material type and with similar quantities.

The construction lots should satisfy the criteria outlined in Chapter 4, Standards, for the applicable materials, or the appropriate project specifications.

2.2.3.1 Sampling Plan

Some guidelines are given in Chapter 6: 7.4.1, which also caters for determination of tests point positions for various construction lengths and widths. The actual problems encountered in the roadbed for each section dictate the minimum number of test points for in situ testing and/or obtaining samples for laboratory testing.

2.2.3.2 Tests

Refer to Chapter 3: 2 for comments on test methods, or special tests as required. The project specifications should also contain the minimum type and number of tests required.

For each test point, the following in situ tests should also be carried out, where possible:

- Density
- Depth of layer tested

Samples shall be taken at test points for the following laboratory tests:

- **Indicator tests:** Grading and Atterberg limits
- **MDD and CBR** for compaction and bearing strength determination
- Other **specific tests** required by the project specifications and/or particular circumstances, e.g., oedometer and collapse potential

2.2.3.3 Assessment

The following aspects must be assessed.

(i) Compaction (Non-Statistical)

The implementation of the use of sequential mean MDD is only practical for sections with similar characteristics. In other cases, the MDD for each test point, or group of test points representing the same quality of material, are determined for each lot.

The degree of compaction obtained at each test point should comply with the minimum requirements. Where the minimum requirement is not obtained, an investigation should be carried out. This may involve more testing in the vicinity of the original test point, and determining an additional MDD.

(ii) Grading

The test results of samples taken must be recorded on the applicable form. The outcome will give an indication of the homogeneity of the material and whether a MDD test should be performed at each density test point. The type and quality of material should also be recorded.

(iii) Atterberg Limits

The test data obtained gives an indication of the quality of the material regarding cohesive materials. If a special treatment was implemented, it may give an indication of the success of the treatment.

Note that when sulphonated petroleum products are used, the plasticity of the material is not affected.

(iv) Bearing Strength

At least two samples should be obtained for each lot. By comparing the CBR value of the first sample with the trial section results, or the results obtained during the material survey, a trend may be established. Where major differences exist, the second sample should also be tested, or additional samples taken in the near vicinity of the specified test point.

(v) General

Any tests carried out during an earlier stage may be repeated for a construction lot.

Material with unacceptably low bearing strength, or other shortcomings, should be removed and replaced with suitable material of the required quality. Alternatively, other special remedial actions may be implemented, such as lime stabilization, a pioneer layer, or a change in the vertical alignment, taking cost into consideration.

Where possible, avoid working on the roadbed during the rainy season, since it may become saturated. This may result in disturbance of the roadbed and affect the placing of successive layers.



Roadbed Construction in Rainy Season

Avoid working on the roadbed during the rainy season, since it may become saturated, disturbing the roadbed and affecting placing of successive layers.

Any unforeseen roadbed material problems shall immediately be brought to the attention of both the materials and contracts engineer.

2.2.3.4 Acceptance of Construction Lots

Normally, the acceptance of the quality of the roadbed is the responsibility of the engineer. The engineer should be acquainted with the potential problem areas of the project, and all possible solutions to resolve the relevant issues. However, in cases where there is a difference of opinion, specialised opinions should be sought. The outcome of a meeting with all relevant parties will indicate the steps to follow.

2.2.3.5 As-Built Data Sheets

Only the roadbed preparation, such as type of roller and number of passes and material classification, such as G5, G6, or clay, are recorded on the As-Built Road Foundation Profile and Fill Layers Forms.

3. PAVEMENT LAYERS: SOILS, GRAVELS AND AGGREGATES

The purpose of this section is to provide guidance on acceptance control procedures for granular pavement layers on completion of the construction process, as well as identifying some problems and the means to address the problems to provide an acceptable product.

The product must be assessed to comply with material and density requirements, dimensional requirements and finish, all as specified in the appropriate standard specifications, project specifications and construction drawings. The assessments are based on the requirements as set out in Chapter 4, Standards, Section 2, Soils and Gravels, and/or Section 3, Aggregates, as appropriate. Project specific requirements may also evolve from special investigations carried out during the planning and detailed design phase of the project. Such information will of necessity, assist when decisions need to be made, especially conditional acceptance.

Acceptance of granular layers is described under the following headings:

- Sampling
- Visual evaluation
- Dimensional acceptance
- Laboratory tests for acceptance
- Interpretation of laboratory tests results for acceptance control
- Assessment of non-conforming work
- As-built data sheets

3.1 Sampling

This assessment category deals with the determination of sampling positions, sampling procedures and the reinstatement of sample holes.

TMH5 contains a detailed discussion on sampling. In addition, the following should be noted:

- All samples for testing should be taken in a **random pattern**, or as prescribed in the contract. Where specified, stratified random sampling methods should be followed. For the testing of layer works, stratified random sampling methods are used for obtaining all the sample portions and for determining the locations for in situ tests.
- The **size of the test sample** (a sub-portion of a field sample) prescribed by the standard test method, is only adequate to carry out a single test or to obtain a single test value. To evaluate the quality of the material or process, the variability must also be known. The only way to obtain the variability of a certain property, or process, is to take a large enough number of field samples.
- An **increase in the size of a statistical sample**, i.e., number of test values, which represents a lot, improves the confidence level in estimating the variation of a certain material property or process.
- The various **statistical sample sizes required** to assess various quality parameters are addressed in the Standard Specifications and/or the project specifications.
- Normally, the **minimum statistical sample size** to assess material properties or processes is six.



References for Soils, Gravels and Aggregates

Gravels are covered in SAPEM in the following sections:

- Chapter 2, **Pavement Composition and Behaviour**
 - Section 4.1, Material Characteristics and Behaviour
- Chapter 3, **Materials Testing**
 - Section 2, Tests on Soils and Gravels
 - Section 3, Tests on Aggregate
- Chapter 4, **Standards**
 - Section 2, Standards for Soils and Gravels
 - Section 3, Standards for Aggregates
- Chapter 6, **Road Prism and Pavement Investigations**
 - Section 8, Materials Testing for Investigations
- Chapter 8, **Material Sources**
 - Section 2, Project Quarries and Borrow Pits
 - Section 3, Commercial Material Sources
- Chapter 9, **Materials Utilisation and Design**
 - Section 4, Pavement Layers: Soils and Gravels
 - Section 5, Pavement Layers: Crushed Stone and Waterbound Macadam
- Chapter 10, **Pavement Design**
 - Sections 7 to 9: Structural Capacity Estimation
- Chapter 12: **Construction Equipment and Method Guidelines**
 - Section 3, Construction Process Guidelines
 - Section 4, Trial Sections

Delays in sampling and testing of materials and/or completed work must be kept to the absolute minimum. It is very important that the sooner sampling and testing are carried out, the sooner the objectives can be fulfilled and immediate action taken, such as payment, proceeding with the production and construction. It is, therefore, very important for a sampler or tester to realize the possible outcome if there is a delay in sampling and/or testing.

3.1.1 Sampling Plan

The completed layer is judged using lots. The lot must also be visually homogeneous regarding grading, moisture, soil binder, surface texture, and with no segregation. Any isolated, non-homogeneous areas, such as wet patches or rough unfinished surfaces, must be excluded from the test section and treated separately as a lot. The width of the layer is normally divided, so that there is a high probability that the test points fall in zones that experience heavy wheel movement. The test points are determined in a stratified random manner.

3.1.1.1 Number of Test Points

The minimum number of test points for sampling is shown in Table 3.

Table 3. Number of Test Points

Number of Traffic Lanes	Length	Minimum Test Points
One	< 150 m	6
Two	150 to 500 m	9
Three	150 to 400 m	8

If the construction length exceeds the maximum recommended lengths, it should be divided into two equal lengths and taken as two separate lots, A and B.

3.1.1.2 Test Point Positions

The construction length is divided into test blocks. The test point positions are then determined on a random basis, using a random number generator or random number tables. A typical random number table is included in Appendix A. An example of a worksheet for calculating test point positions is included in the Standard Specifications. Test point positions are determined to the nearest 10 metres longitudinally and 0.1 metres transversely.

3.1.2 Sampling of Untreated Pavement Layers

The position of each test point is determined in a random, stratified manner. The sampling hole should be the full depth of the layer, unless otherwise specified. The hole should be large enough to yield the required size or mass of a field sample. The minimum plan dimension shall be 300 x 300 mm. The material should be loosened carefully so that the underlying layer is not disturbed, contaminating the sampled material.

To avoid excessive breaking of aggregate particles, it is mandatory to sample the constructed layer less than 24 hours after compaction. This ensures that the layer is not too hard due to drying out, or in the case of certain materials, self-cementing.

The bulk of loose material should be removed from the hole using a round-nose shovel or scoop. A small, soft paintbrush may be used to sweep the loose fine material together. Using a spoon, it should be placed in suitable containers, such as dust-proof bags, to avoid loss of the fine materials. It is important that all the fine material from the sampled layer is carefully collected. If moisture determination is necessary, then a small sealed container should be used.

Often the sample is of such a size that more than one bag is needed. For example, one small bag is required for an indicator test and two or three for a MDD and/or CBR test. If the sample is to be split in the field, the following procedure is used:

- All the **loose material should be removed** and either placed on a flat hard clean surface or on a canvas sheet.
- Thoroughly **mix the material**.
- Transfer all the sampled material into pairs of **riffler pans**. Two, four or six riffler pans are used depending on the size of the total sample.
- Make sure that all the **fine material** is also picked up using a brush and spoon.

- Before riffing out the required samples, use the riffler to cross mix the pairs of riffler pans to get **representative material** in each pan.
- Finally, riffle out the **various sized samples** needed for the tests.

Alternatively, the loose material can be placed in a number of bags and taken to the laboratory. There it is mixed by riffing, and then riffled out to the correct test sample sizes.

If the bulk relative density is to be tested, riffle out a representative sample from the small bag sample. This must be done before testing for grading and plasticity.

3.1.3 Reinstatement of Sample Holes

Sample hole reinstatement should take place as soon as possible after sampling.

3.1.3.1 Materials and Equipment

The material used for reinstatement should be the same as the layer being reinstated, except that certain fractions may be screened out. It may be necessary to maintain a small stockpile of suitable material for reinstatement. Only potable water should be used.

A suitable flat-bottomed hand operated tamper with a mass of 10 to 15 kg, and a foot area appropriate for the size of the sample hole, should be used.

A stiff broom should be used for finishing and texturing the patch, level with the adjacent pavement.

3.1.3.2 Procedure

The sample hole should be of adequate size to produce sufficient material for testing. All loose material should be removed from the hole.

To facilitate hand compaction of smaller sample holes and moisture calibration holes, aggregate larger than 28 mm may be screened out. The approved material should be thoroughly mixed at, or up to, 1% above OMC.

The sides and base of the hole should be dampened with water. The mixed material should be placed in layers 25 mm to 50 mm thick, and each layer carefully compacted with the hand tamper before adding a subsequent layer. The final layer should conform to the adjacent surface in line and level, with no mounding or sagging.

When reinstating narrow, deep holes, such as nuclear density probe holes, the hole should be filled with a damp mixture of fine, approved aggregate, not greater than 14 mm. The mixture shall be slowly, continuously and carefully compacted with a suitably sized, steel-tamping rod, to avoid air pockets.

A minimum of one out of every ten reinstated sample holes should be checked, on a random basis, for compaction, moisture content and surface finish.

3.2 Visual Acceptance

The visual acceptance items addressed below are generally applicable to the selected, subbase and base layers. Where there are differences between the visual acceptance control for these layers, this is pointed out under the relevant heading.

3.2.1 Appearance and Finish

The following aspects must be taken care of for the appearance and finish of granular layers.

- The test section must be **visually homogeneous** regarding grading, density and moisture content. Any isolated non-homogeneous areas, e.g., wet patches, must be excluded from the test section and treated separately.
- The completed layer should be **firm and stable**, free from areas of segregated material, laminations (loose, soft, thin layers), or corrugations.
- During compaction, care should be taken **not to roll the surface out of shape** and disturb the crossfall. Flat or dished shapes may act as a water trap for water coming from the upper layer during compaction, or from seepage water during rainy seasons.
- The completed base should also be firm and stable with **a closely knit surface of aggregate** exposed in the mosaic, and free from nests of segregated material, laminations and corrugations.

A checklist for visual inspections should be included with the Acceptance Control sheets, and signed off for each lot assessed. An example of such a checklist for base construction is given in the Appendix.

Where an already accepted layer has been exposed to the elements for a period of time, or rainfall, it is essential that a full visual inspection, including re-checking of moisture contents, is repeated and reported prior to construction of the following layer. This is especially relevant for layers to be surfaced.

3.2.2 Drainage and Protection

The compacted layers should be adequately drained and shaped to prevent water from standing on, or along, or scouring the completed work. Windrows should be removed to facilitate the drainage of water from the surface. No material for a subsequent layer may be placed if the underlying layer has softened from excessive moisture.

Reference must also be made to the following Standard Specifications, which include:

- Contractor's Obligations
- Protection and Maintenance for Selected, Subbase and Base Layers



Placement of Subsequent Layer

No material for a subsequent layer may be placed if the underlying layer has been softened by excessive moisture.

In the case of sand, the layer should be protected by continuous saturation, or by immediately spreading gravelly material normally used for the upper layer, to protect the sand layer against wind erosion. A 50 mm hardening layer for sand up to the upper selected layer, is a typical requirement. Sufficient allowance must be made for embedment of such a hardening layer.

3.2.3 Soluble Salts and Protection

Soluble salts are most likely to be encountered in soils in coastal areas and in arid and semi-arid regions, especially where the Weinert N value is more than 5, or as the decomposition products of sulphide minerals in a number of other rocks. In semi-arid and arid regions, they may also be introduced into the construction material by salty compaction water, in addition to water rising from the subgrade.

Under certain circumstances, salt may migrate upwards and cause cracking, blistering or loss of bond of the surfacing, disintegration in cemented layers, and loss of density in untreated layers. The recommended upper limit of soluble salt content for pavement materials is 0.2 %. This level is only valid if there is no source of additional salt below the pavement. In such cases, special measures to minimize the upward migration of salts may be needed. Possible measures are (also refer to the project specifications and Chapter 4: 2.7):

- **Use a barrier to prevent salt migration.** This can be in the form of a plastic waterproof membrane, uniform graded macadam, or gravel without fines and sand.
- Ensure that the **existing salt content** of material used does not exceed 0.2% by mass.
- Use only **fresh water** for construction.
- Programming the pavement construction to **avoid wet/dry cycles** during the construction of each of the subsequent layers.
- Ensure that each compacted layer is covered with the material of the **next layer within 14 days**. The uncompacted cover material may be left indefinitely, but, once compacted it must also be covered within 14 days.

The project specifications, or Chapter 4: 2.7, would be indicative of the precautionary measures to be implemented, or if not otherwise specified, to be given as a site instruction by the engineer.

3.3 Dimensional Acceptance Control

The completed selected, subbase and base layers should comply with the construction tolerances for:

- Level
- Layer thickness
- Grade
- Width
- Cross-section
- Surface regularity

Construction tolerances for selected, subbase and base layers are covered in the Standard Specifications and/or the project specifications.

Adhering to the required profiles within the tolerances specified, is of paramount importance. If not strictly applied from the roadbed layer upwards, the problems are progressively transferred to the base layer, ultimately leading to poor riding quality.

Where a specific layer is to be constructed in two layers, the requirements for grade, thickness, cross-section and smoothness do not apply to the lower layer. However, the lower layer should be constructed with sufficient accuracy to enable the construction of the combined layer to the specified tolerances.

Where a crushed-stone base is placed directly onto an existing layer, without it requiring the existing layer be finished to specified levels, the requirements for layer thicknesses, as normally specified, cannot apply.



Profiles and Tolerances

Adhering to the required profiles within the tolerances specified is of paramount importance. If not strictly applied from the roadbed layer upwards, the problems are progressively transferred to the base layer, ultimately leading to poor riding quality.

3.4 Laboratory Tests for Acceptance Control

3.4.1 Selected, Subbase and Base Layers

The laboratory tests conducted on selected, subbase and base layers for acceptance control are listed in Table 4 to Table 7. It should be noted that certain tests and test frequencies apply to each lot, whilst tests for strength and swell are required per volume extracted from the same source. The testing frequency used must comply with the relevant specification.

Table 4. Laboratory Tests for the Constructed Selected Layer

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Compaction	Maximum dry density	MDD	30 kg	2 samples per 500 m ³	SANS 3001–GR30
	Density	Sand replacement	N/A	1 sample per 1000 m ³ per 150 mm layer, minimum of 5 samples per layer per lot	SANS 3001–GR35
		Nuclear	N/A		SANS 3001–NG5
Moisture Content		Gravimetric analysis	1 x 1 to 1.5 kg	1 sample per test	SANS 3001–GR20
Layer Placement	Layer thickness	Measurement			
Material Properties	Grading	Sieve analysis Grading modulus Soil mortar analysis	15 kg	1 sample per 1000 m ³ per constructed layer thickness, minimum of 5 samples per layer per lot	SANS 3001–GR1
	Atterberg limits	Plasticity Index Liquid limit Linear shrinkage			SANS 3000–GR10, 11 & 12
	Bearing strength and swell	CBR	2 x 30 kg	1 sample per 2500 m ³ , minimum of 3 per source	SANS 3001–GR30 & 40

Durability tests for mudrocks are also be a material property assessed on a per volume basis. The frequency relates to the extent of exploratory testing implemented for the source of supply prior to construction, as well as how borderline the material is compared to acceptance criteria.

Soluble salts, where identified, may be roadbed, source, and/or construction water related. Again, the source of the problem, the borderline nature of the salt problem, and extent of available test results dictates the frequency of testing during construction.

Normal completion times for acceptance control testing are also listed in Appendix C of this chapter.

Duplicate samples may be required by the main laboratory, which can delay the final approval of the various parameters used for construction control.

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Table 5. Laboratory Tests for the Constructed Non-Cemented Subbase Layer

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Compaction	Maximum dry density	MDD	30 kg	2 samples per 500 m ³	SANS 3001–GR30
	Density	Sand replacement Nuclear	N/A	Minimum of 6 samples per lot	SANS 3001–GR35 SANS 3001–NG5
Moisture Content		Gravimetric analysis	1 x 1 to 1.5 kg	1 sample per test	SANS 3001–GR20
Layer Placement	Layer thickness	Measurement			
Material Properties	Grading	Sieve analysis Soil mortar analysis Grading modulus	15 kg	Minimum of 6 stratified random samples per lot	SANS 3001–GR1
	Atterberg limits	Plasticity index Liquid limit Linear shrinkage			SANS 3001–GR10, 11 & 12
	Aggregate shape	Number of fractured faces			SANS 3001–AG4
	Bearing strength	CBR	2 x 30 kg	CBR assessed prior to compaction: 1 per km CBR not assessed prior to compaction: 3 per km	SANS 3001–GR30 & 40

Table 6. Laboratory Tests G1, G2, G3 and Waterbound Macadam Base Layers

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Material Properties	Grading	Sieve Analysis	15 kg	Minimum 6 stratified random samples per lot – refer to Standard Specifications	SANS 3001–GR30
	Atterberg limits	Plasticity Index Liquid limit Linear Shrinkage			SANS 3001–GR10, 11 & 12
	Shape	Number of fractured faces		2 sample per lot	SANS 3001–AG4
Compaction	Maximum dry density	MDD	30 kg	2 samples per construction lot	SANS 3001–GR30
	Density	Sand replacement Nuclear		Minimum of 6 stratified random samples	SANS 3001–GR35 SANS 3001–NG5
Layer Placement	Layer thickness	Levels in test holes Measurement	N/A	Same as for density	Measurement
Layer Moisture Condition	Moisture content (full depth)	Gravimetric or by any other approved method	Minimum of 1 kg	Minimum of 1 test position per 100 m, selected randomly Sections: > 1 km: min of 10 tests < 1 km: min of 4 tests	SANS 3001–GR20
Surface Texture	Mosaic	Visual	Total Area	N/A	

Table 7. Laboratory Tests for the Base Layer Constructed with G4 Material

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Material Properties	Grading	Sieve Analysis	15 kg	Minimum 6 stratified random samples per lot	SANS 3001–GR30
	Atterberg limits	Plasticity Index Liquid limit Linear Shrinkage			SANS 3001–GR10, 11 & 12
	Shape	Number of fractured faces		2 sample per lot	SANS 3001–AG4
	Bearing	CBR	2 x 30 kg	1 sample per lot	SANS 3001–GR40
Compaction	Maximum dry density	MDD	30 kg	2 samples per construction lot	SANS 3001–GR30
	Density	Sand replacement			SANS 3001–GR35
		Nuclear		Minimum of 6 stratified random samples	SANS 3001–NG5
Layer Placement	Layer thickness	Levels in test holes Measurement	N/A	Same as for density	Measurement
Layer Moisture Condition	Moisture content (full depth)	Gravimetric or by any other approved method	Minimum of 1 kg	Minimum of 1 test position per 100 m, selected randomly Sections: > 1 km: min of 10 tests < 1 km: min of 4 tests	SANS 3001–GR20
Surface Texture	Mosaic	Visual	Total Area	N/A	SANS 3001–NG5

3.4.2 In Situ Moisture Content Control of Base Layer

Research has shown the sensitivity of the resilient modulus of a granular layer to moisture. Various measures are implemented to minimize the detrimental effect of moisture on:

- **Pavement life**
- **Aggregate embedment** of surface seals
- **Premature cracking** of seals and asphalt, due to lack of support

These measures include wide sealed shoulders (0.9 metres minimum), permeability checks on surfacing, and moisture content control checks on the base layer. Moisture content control tests form part of the acceptance criteria testing for base layers and are described in the following paragraphs.

The base layer moisture content should be less than 50% of the optimum moisture content in the following situations:

- **Before the water roll in upper 100 mm.**
- **Before priming or tacking in upper 100 mm.**
- **Before surfacing in upper 50 mm.** This control measure is only needed in the event of exposure to rain after priming, but prior to surfacing, as the prime cannot be considered impermeable. It is also required if it is suspected that there has been inadequate full depth moisture control prior to priming. Surplus moisture is often drawn to the zone immediately below the primed surface. It may be necessary to test for this if there is doubt about the preceding moisture controls. In the event of rain occurring prior to resealing, a cracked and/or pervious seal, then this check is recommended.

3.4.2.1 Half Width Construction

Where pavement layers, particularly those with unbound materials, are constructed in half-widths under traffic, particular care must be taken. Excessive moisture can be trapped in the zone of the construction joint in the completed first half, as a result of the “step” acting as a temporary drainage channel during subsequent rainfall. A typical failure is illustrated in Figure 5. In such cases, the moisture content within the zone of the construction joint should be checked prior to commencing construction of the adjacent lanes. The zone must be allowed to dry-out, or

be cut-back by up to 1 metre as shown in Figure 6, to ensure that no excess moisture is trapped in the layer, prior to application of the surfacing. As most G1 granular layers tend to segregate at the outer edge of the constructed width, this zone should also be cut-back sufficiently prior to constructing the adjacent layer.



Figure 5. Typical Failure Along a Poorly Constructed Longitudinal Construction Joint of a G1 Base Layer

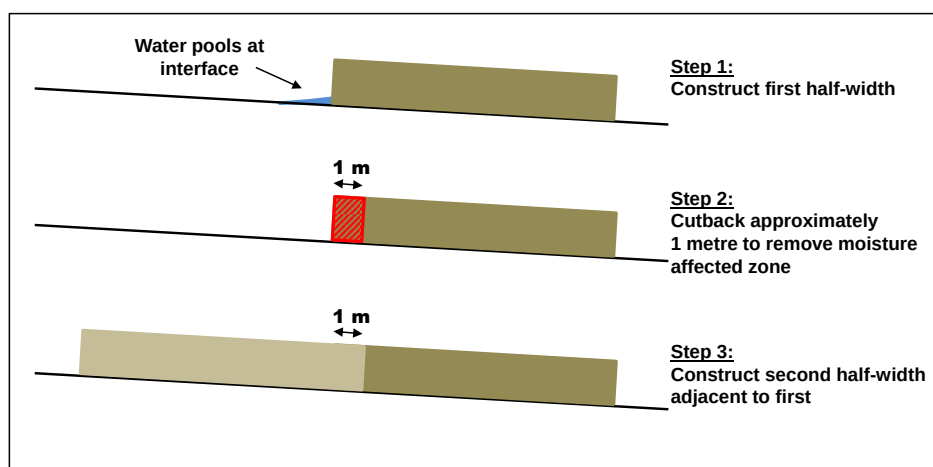


Figure 6. Effect of Staged Construction on Moisture Sensitive Zone

3.4.2.2 Testing and Calibration Procedures

Testing should be carried out using a calibrated nuclear testing gauge or other approved/specified methods. The gauge should be calibrated with the gravimetrically measured moisture contents, taken at a minimum of six reference points. It is essential that the base material, grading and prime (if applicable) of the calibration section matches the area to be finally tested with the calibrated gauge.

(vi) Calibration before Priming

To minimize calibration error, the nuclear or other approved gauge shall be calibrated with reference to the gravimetrically measured moisture content of the upper 100 mm of base, taken at a minimum of six reference points on either the trial section, or on the shoulder of the finished base.

(vii) Calibration before Surfacing

The nuclear, or other approved gauge, should be calibrated with reference to the gravimetrically measured moisture content of the upper 50 mm of base, taken at a minimum of six reference points. These reference points are taken near the outer edge of the sealed shoulder of the finished base. This is to take into account the effect of the prime on the calibration, and to limit the damage to the riding surface caused by taking the gravimetric samples.

3.4.2.3 Testing Frequency

The test frequency should be a minimum of one test per 200 metres per lane, taken early in the morning. A minimum of six tests per unit or section must be tested. The basic test points should be randomly selected. In addition, the tester shall actively seek any areas in the lane or shoulders that show any signs of moisture in excess of the typical surface. In particular, any low-lying areas where moisture, could migrate should be checked. The purpose of the testing procedure is to ensure that no portion of the base layer investigated has moisture contents greater than 50% of OMC.

Whenever isolated values in excess of the minimum occur, such areas are further assessed by locating an additional six test points randomly selected, in close proximity to the isolated spots. The mean value of the six results obtained for such an isolated area is used to determine the accepted moisture content for the isolated area. This also assists in defining the limits of local damp areas.

3.5 Interpretation of Laboratory Test Results for Acceptance Control

3.5.1 Selected and Gravel Subbase Layers

3.5.1.1 Compaction

The material properties and judgement scheme specified in the Standard and project specifications of a specific project must be used for the project.

Only compaction of the layer complies with the requirements of a statistical judgement plan, utilising the actual variability of the layer, as obtained by the measurement of in situ density at predetermined test points, according to a stratified, random sampling plan. The section to be evaluated should be worked in one process, and essentially the same materials should be used on the full section.

The time interval between final compaction and sampling affects the density results. It is, therefore, important to determine the in situ densities and obtain field samples for indicator tests between 12 and 24 hours after final compaction. Final compaction refers to the "date placed", meaning when the last roller finishes its last roller pass with the material still in a moist condition.

In the case of non-compliance with the specification, re-testing of a test point is not permissible. If the decision is in question due to the credibility of the test values, the whole construction lot should be re-tested with a new set of random test points. If a test lot is re-tested, the second set of values should be compared statistically to the first set of values to determine if they belong to the same population. A procedure to determine whether there is a significant difference between the two sets of values is described in the Standard Specification.

Conditional acceptance may be applied at the sole discretion of the Road Authority or client, unless otherwise specially allowed for in the project specifications.

3.5.1.2 Atterberg Limits

A high PI detrimentally influences the bearing strength, which may require chemical modification. A high PI, especially on the minus 0.075 mm fraction, that cannot be successfully reduced by mechanical stabilization or blending with other source, requires chemical modification.

As the statistical approach is not applicable to Atterberg limits, only the mean and standard deviation are determined for the PI and linear shrinkage, and recorded on the As-Built Data Sheets. In the case of chemical modification, the recorded values must be after the treatment and curing of the material, which are generally obtained from UCS or ITS specimens after testing.

If the mean linear shrinkage is less than 0.5%, the PI should be recorded as NP (non-plastic). With a mean linear shrinkage between 0.5 and 1.0%, the PI should be recorded as SP (slightly plastic). For a mean linear shrinkage of more than 1.5%, the mean PI and standard deviation should be recorded.

3.5.1.3 **Bearing Strength**

If more than one sample is tested for CBR, all data must be recorded. The CBR value is compared to a minimum allowable value at a specified density, as prescribed in the standard or project specification.

The variation in optimum moisture content obtained for samples in a lot, and subsequent lots, may indicate a large variation in grading. This could point to the need for stockpiling, if not already implemented, or indicate inadequate stockpiling techniques.

The coarse sand ratio and grading modulus are also good indicators of potential CBR. With the addition of a suitable binder, improvement in the CBR is possible to satisfy the specification requirements. For example, weathered dolerite with a high coarse sand ratio (in the sixties) requires a binder to reduce the ratio to around 50, and produce the desired characteristics, namely improved bearing strength and compactability. An excess of smooth, well rounded, uncrushed pebbles is also an indication of a potential CBR problem.

3.5.1.4 **Durability**

Any tests carried out during the approval stage for source and component materials may be repeated for any construction lot. Durability tests, especially in the case of shale and mudrock, should be carried out at the specific production intervals to verify the source. Such test samples can be drawn from stockpile, dumped heaps on the road or the completed layer.

3.5.1.5 **Shape**

Shape is defined as the number of fractured faces of a certain percentage of a sample retained on specific sieve sizes, and is specified in the Standard Specifications.

For alluvial and colluvial materials, the percentage fractured faces for each sieve fraction should be assessed per construction lot. Problems may arise where a source shows a trend towards yielding mostly minus 40 mm rounded, smooth gravel (pebbles) that are not crushed using a single stage crusher with a wide jaw setting. See Chapter 8: 3.2.2 and Chapter 12: 2.1.1 for more on crushers.

3.5.1.6 **Moisture Content Controls**

For untreated subbases before the base is placed on the subbase, the in situ full depth moisture content should ideally be less than 60% of the optimum moisture content, thus approaching equilibrium moisture content. However, the project specification may specify that the base is placed earlier if there is a salt problem. Placing layers in quick succession, and when backfilling behind structures, often results in unstable conditions, due to trapped surplus moisture, requiring such layers to be removed. This issue needs to be carefully considered where construction constraints result in a quick succession of layers built up above the upper selected layer, which prevents rapid air-drying.

Even under favourable warm and windy conditions, at least two days, after compaction of the layer, are required for the layer to dry out. Limestone gravels and uncrushed materials typically have a higher optimum moisture content than crushed materials, and take longer to dry out.

3.5.2 Base

3.5.2.1 **Compaction**

The compaction of the layer, after slushing if applicable, should comply with the requirements of a statistical judgement plan. The same procedure as described for the selected layer is followed.

3.5.2.2 **Grading**

It is important to note that the grading for acceptance control of base layers always refers to the grading results obtained after compaction to the required density.

(i) **G1, G2, and Waterbound Macadam Bases**

A target grading based on the principles described in Chapter 4: 3.5.1, along with researched background information substantiating the various requirements, form the basis for the setting of an approved target grading. This would normally be adjusted or confirmed following the construction of an approved trial section. Alternatively, the same principles, along with historic data, may be used to assist



Acceptance Control Gradients

The gradings required for acceptance control always refers to the gradings obtained after compaction to the required density.

in setting a provisional target for a trial section, or if such trial section is not ordered, to set a target for grading.

The Standard Specifications, as well as any specific road authority's standard project specifications, list the various constraints that may be prescribed for gradings. Statistical control for grading is not required in the Standard Specifications.

During the production stage, a specific trend may manifest, which may justify a slight adjustment to the target grading. But, any readjustment should be kept to the absolute minimum, and should only be approved at the sole discretion of the road authority or the authorized representative.

Normally an inadequate crushing plant assembly causes problems on the 5 mm and 14 mm fractions, and for alluvial and colluvial materials, on the 2.0 mm and 0.425 mm fractions.

(ii) G3 Base

The mean grading of each lot is determined from the minimum number of test points per lot, set by the specification. This mean should conform to the approved target grading within the tolerances specified for each sieve size in the Standard Specifications or the project specifications.

3.5.2.3 Atterberg Limits

For G1 and G2 materials, a minimum number of 6 tests per lot are prescribed in the Standard Specifications. The specifications have a mean value requirement, subject to a maximum value not being exceeded. A maximum value only applies for G3.

An unforeseen PI problem may be related to inappropriate quarry management, such as, inclusion of over burden at the quarry face, or inclusion of seams of material which has a higher PI. As the statistical approach is not applicable to PI, only the mean and standard deviation to the nearest first decimal are determined and recorded on the As-Built Data Sheets.

Note that when the PI requirement of the minus 0.425 mm sieve is satisfied, this does not imply that the PI of the minus 0.075 mm sieve automatically satisfies the requirement of not exceeding 12. This is dependent on the nature of the cementing matrix of the rock being crushed.

Atterberg limits are not normally a quality management control for waterbound macadam.

3.5.2.4 Strength and Durability

(i) G1, G2, G3 and Waterbound Base

The hardness and durability requirements specified in the Standard Specifications, are for 10% Fines Aggregate Crushing Values (10% FACT) and Aggregate Crushing Value (ACV), respectively. These materials generally require at least 3 fractured faces. Refer to Chapter 4: 3.5.1.

(ii) G4 Base

The minimum CBR value is specified in the Standard Specifications. Reference must also be made to Chapter 4: 2.4.

By comparing the single CBR value obtained per lot with previous lots, a trend may be established. Should large variations occur, the optimum moisture content obtained per lot may be indicative of large variations in grading. This could point to the need for stockpiling, or indicate inadequate stockpiling techniques. A high PI of the minus 0.075 mm fraction has also been found to detrimentally influence the bearing strength, and requires chemical modification only (typically 1.5 percent of lime by mass) to attain the specified bearing strength. The coarse sand ratio is also a good indicator of potential CBR. The addition of fines may improve the CBR, and satisfy the specification.

As mentioned earlier, the statistical approach is not required. Only the mean and standard deviation CBR values are recorded.

3.5.2.5 Shape

Shape is defined by the flakiness index. Flakiness index limits are specified in the Standard Specifications for G1 to G4 and waterbound macadam bases. This is recorded on the standard worksheets only.

3.5.2.6 Moisture Content Controls

After completion of the surface preparation of the base, using either the continuous process (watering and slushing) or multi-stage process (water or slurry rolling), it is required that the layer dries out to a level of 50% of OMC, before the application of a prime. Deviation from this requirement is not recommended. During this drying process, suction forces develop, which contribute to the strength of the material. The period required for this drying process is highly dependent on the prevailing climatic conditions, and has been known to exceed 7 days for the continuous process (watering and slushing). Non-conformance to this requirement has resulted in numerous instances of premature failures.

The various base construction processes are described in the Standard Specifications and in Chapter 12: 3.8.

Notwithstanding original conformance with the maximum moisture requirements, any section of completed base that has been left exposed during wet weather, should be re-evaluated, prior to the construction of the surfacing.

Moisture content is not a quality management control for waterbound macadam.

3.5.2.7 Soluble Salts

The soluble salts allowable in base materials are specified in the Standard Specifications. Base materials must be checked for compliance with these specifications.

Soluble salts are not a quality management control for waterbound macadam.

3.6 Assessment of Non-Conforming Work

In the case of non-compliance, the section should be rejected. The contractor should propose an appropriate remedial action, which is assessed by the engineer. As an example, the following specifications regarding conditional acceptance are available in the Standard Specifications, and should be studied in conjunction with the remedial measures proposed by the contractor:

- **Conditional Acceptance**
- Determining **Rejection Limits** in Accordance with Statistical Criteria

Guidance on the assessment of non-conforming work is given in the following paragraphs, for the various construction elements that require approval.

3.6.1 Visual

The following guidelines are applicable for the visual assessments:

- **Appearance and finish.** Where the appearance and finish are not to the specified standard, the construction process followed should be compared to the construction process guidelines for the construction of the granular layers as described in Chapter 12: 3.8. Variations or non-uniformities should be pointed out to the contractor.
- **Drainage and protection.** The most effective strategy, to ensure adequate drainage and protect the structural integrity of the specific layer, is to withhold payment until appropriate measures are implemented.
- **Soluble salts and protection.** Non-compliance to procedures, as required in terms of the project specifications, should result in rejecting the layer.

3.6.2 Dimensional

Where standards are not met, the following procedures need to be considered:

- Refer to Chapter 12, Construction Equipment and Method Guidelines. Compare to **procedures being adopted by the contractor**.
- Where a **trial section** was required or ordered, refer to procedures used at the time that resulted in an approved trial section. Compare to current construction procedures.
- Consider **reworking, reshaping and recompacting** the layer, with reference to the following guidelines from the Standard Specifications:
 - In Place Reworking of Pavement Layers
 - In Situ Reconstruction of Existing Crushed-Stone Layers
- **Correction layers** may also be considered. If required, the existing layer should be ripped before dumping material for the correction layer. The complete layer should then be recompacted.

3.6.3 Compaction

Normally the following options are investigated, before a layer is rejected for inadequate compaction:

- **Apply an additional roller pass or two.** This may only improve the density of the top 50 to 60 mm of the layer by not more than 1% when using a non-vibratory steel wheel roller. Care must be taken when using a vibratory roller in vibrating mode, because the incorrect amplitude or frequency selection can reduce layer density.
- In the case of a base layer, apply **additional water-rolls (slushing)**. As for other layers, this may only improve the density of the top 50 to 60 mm by not more than 1%.
- **Rework the layer.** Normally the need for reworking the layer would point towards a need for closer control on moisture, improved process control of stockpiling procedures and the correct use of appropriate compaction equipment.
- Where required, **improve the coarse sand ratio**, especially the upper end for the material, to equal to or less than 50%, by the addition of a suitable binder. Rework and recompact the layer. An example of where this is applicable, is for weathered dolerites with typical coarse sand ratios of 60.

Should this non-conforming compaction situation persist, a detailed investigation is required. The rejection of lots must be considered after three consecutive uncertain outcomes. Thereafter, a new trial section should be constructed.

Reduced payment is normally the outcome of conditional acceptance. Factors for reduced payments are provided in the Standard Specifications.

3.6.4 Grading

The targets set for G1, G2, G3 and waterbound macadam bases following a trial section, can change during the course of a project and therefore need to be continually assessed. This may require a slight adjustment to the target grading originally set.

Oversize is often a problem, especially with a non-crushed G4 base. This has serious implications for the riding quality attainable, especially where a single or double seal surface treatment is used. Oversize material may be attributable to:

- Incorrect **jaw settings** and/or **worn screens** using single or two-stage crushing (see Chapter 12: 2.1)
- Incorrect **grid-rolling procedures** (see Chapter 12: 2.10.2) or **aggregate not suitable for grid-rolling**, i.e., too soft.

The factors giving rise to oversize material should be corrected as a matter of urgency. Additional measures must be applied, if the specified measures appear to be inadequate for the situation as it develops on site.

Conditional acceptance may apply for a specific lot. For example, if oversize is limited to about 5% and problems at the crusher have been identified and corrected for subsequent lots. Similarly, the same approach may be adopted when the reduction of oversize is carried out using grid-rolling. Special attention must be paid to ballasting of the roller, and the capacity of the towing vehicle, to ensure an adequate rolling speed is attained for adequate breakdown of the oversize material.

3.6.5 Atterberg Limits

A plasticity problem may be related to incorrect quarry management, resulting in the inclusion of decomposed clayey material. This may result either from higher PI zones in the source, or from a lower layer with a higher PI.

If the PI exceeds the specified value, reworking the layer and taking remedial action such as chemical modification, typically applying 1.5% lime by mass, may be considered for full acceptance of the lot. Lime modification is preferably implemented 24 hours ahead of the normal mixing, spreading, shaping and compaction procedures. The material should be in a moist condition to allow for chemical modification to take place before compaction, and thus minimize the formation of shrinkage cracks. The admixing of the dry lime, or preferably a fine lime slurry, to the moist material, can also be implemented at the source. The admixing of a non-plastic fine natural binder material (not permitted for G1) is not the preferred solution, especially where the PI on the 0.075 mm fines exceed the maximum value of 12.

Relaxation of the PI should not be entertained for bases other than a G4 with calcrete.

3.6.6 Bearing Strength

If the CBR does not satisfy the minimum required specification at the specified compaction level, the following options may be considered for full acceptance of the lot:

- If the **compaction is well above the minimum** for the layer, and the CBR value at the in situ compaction exceeds the minimum CBR.
- **Reworking the layer taking remedial action**, such as improving the quality of the material with a suitable binder, mixing in a better quality material, or chemical modification.
- The project location is in a relatively **dry climatic region** and has **low traffic**.

In the case of G4 base, high plasticity and/or coarse sand ratio falling well outside the 35 to 50 percent range, may account for reduced CBR. The addition of 1.5% lime to modify (as described under Atterberg Limits, Section 3.6.5) and/or the addition of fines to correct the coarse sand ratio, may resolve the problem.

3.6.7 Durability

Non-compliance for durability is non-negotiable. All exploratory work previously effected, component conformance control and design verification (trial section) carried out must be re-visited to establish possible reasons for the non-compliance. The source must be investigated to assess whether the source is exploited from the correct zone, as per the original exploratory results.

3.6.8 Moisture

A special case may arise when a base does not satisfy the moisture requirements, and the surface stands to be severely damaged by a major storm looming. If, in such a situation, the base has already reached 60% of OMC (approximate equilibrium moisture content), then priming may be permitted, subject to drying out of the top 50 mm of the base before applying any surfacing.

Otherwise, no relaxation on the specified moisture content of the base is advised.

3.7 As-Built Data Sheets

The data of completed work, which has been accepted, or replaced and retested, or other remedial measures applied and accepted, should be recorded systematically on the standard As-Built Data Sheets in TMH10, also in spreadsheet format on SANRAL's website, www.nra.co.za, or as required by the relevant road authority.

4. PAVEMENT LAYERS: CEMENTED

This section provides guidance on acceptance control procedures for cemented pavement layers, on completion of the construction process.

The product must be assessed to comply with material, density and mixing requirements, dimensional requirements and finish, all as specified in the appropriate standard specifications, project specifications and construction drawings. The assessments are based on the requirements as set out in Chapter 4: 5.3. Such information assists decision making, especially on conditional acceptance. The main properties of cemented materials that are tested include the density, material properties, strengths and stabilizer content and distribution. Sampling should ensure that sufficient material is collected for this testing, and that both lateral and vertical distribution of the stabilizer is considered. It is also necessary to collect samples for the maximum dry density determination, prior to compaction, but after addition of the stabilizer, to determine the reference density of the material at each point, or as close to each point, that the compacted density is determined.

Acceptance of cemented layers is described under the following sections:

- Sampling
- Visual evaluation
- Dimensional acceptance
- Laboratory tests for acceptance
- Interpretation of laboratory tests results for acceptance control
- Assessment of non-conforming work
- As-built data sheets

4.1 Sampling

Sampling should be based on TMH5, which contains a detailed discussion on sampling. In addition, the following should be noted:

- All samples for testing should be taken in a **random pattern**, or as prescribed. Where specified, stratified random sampling methods should be used. For the testing of layer work, stratified random sampling should be used for obtaining all the sample portions, and for determining the locations for in situ tests.
- The **size of the test sample** (a sub-portion of a field sample) prescribed by the standard test method, is only adequate to carry out a single test or to obtain a single test value. To evaluate the quality of the material or process, the variability must also be known. The only way to obtain the variability of a certain property or process is to take a large enough number of field samples.
- An **increase in the size of a statistical sample**, i.e., number of test values, which represents a lot, improves the confidence level in estimating the variation of a certain material property or process.
- The **statistical sample sizes required** to assess various quality parameters are addressed in the Standard Specifications.
- Normally, the **minimum statistical sample size** to assess material properties or processes is six.

Delays between sampling and testing of cemented materials and/or completed work must be kept to the absolute minimum. It is very important that the sooner sampling and testing are carried out, the



References for Cemented Layers

Cemented layers are covered in this manual in the following sections:

- Chapter 3, **Materials Testing**
 - Section 5.3, Tests on Cementitious Materials
- Chapter 4, **Standards**
 - Section 5.3, Stabilization using Cementitious Materials
- Chapter 6, **Road Prism and Pavement Investigations**
 - Section 7, Materials Testing for Investigations
- Chapter 8, **Material Sources**
 - Section 2, Project Quarries and Borrow Pits
 - Section 3, Commercial Material Sources
- Chapter 9, **Materials Utilisation and Design**
 - Section 6, Pavement Layers: Cementitious Materials
- Chapter 10, **Pavement Design**
 - Section 7 and 8, Structural Capacity Estimation
- Chapter 12: **Construction Equipment and Method Guidelines**
 - Section 3.4, Cementitious Stabilization
 - Section 4.4, Trial Sections



Statistical Sample Size

The **minimum statistical sample size**, to assess material properties or processes, is normally six.

sooner the objectives are fulfilled and immediate action taken, such as payment. It is, therefore, very important for a sampler or tester to realize the possible outcome if there is a delay in sampling and/or testing. This is even more critical for stabilized materials, where initial curing occurs within the first few hours after hydration of the stabilizer, and then the properties change continuously over a number of years as the layer cures.

4.1.1 Sampling Plan

The completed layer is evaluated using lots. The lot must be visually homogeneous in grading, moisture, chemical additive type and quantity, surface texture and have no segregation. Any isolated, non-homogeneous areas, such as wet patches or rough unfinished surfaces, must be excluded from the test section, and treated separately as a lot. The width of the layer is normally divided so that there is a high probability that the test points fall in zones that experience heavy wheel movement.

The length is divided into equal block lengths to check the uniformity of construction. The sampling plan should be in accordance with the current TRH5 and/or the Standard Specification, but is generally in the order of 150 metres.

4.1.1.1 Number of Test Points

The typical minimum number of test points is shown in Table 8. If the construction length exceeds the maximum recommended length, it should be divided into two equal lengths and taken as two separate lots, A and B.

Table 8. Number of Test Points

Number of Traffic Lanes	Length	Minimum Test Points
One	< 150 m	6
Two	150 to 500 m	9
Three	150 to 400 m	8

4.1.1.2 Test Point Positions

The construction length is divided into test blocks. The test point positions are determined on a random basis, using a random number generator or random number tables. The test point positions are determined to the nearest 10 metres longitudinally and 0.1 metres transversely. A typical random number table is included in Appendix A of this chapter. The Standard Specifications also contain a worksheet.

4.1.2 Sampling of Treated Pavement Layers

The position of each test point is determined in a random, stratified manner. The sampling hole should be the full depth of the layer, unless otherwise specified. The hole should be large enough to yield the required size or mass of the field sample. The minimum plan dimension is 300 x 300 mm, and 600 x 600 mm for the determination of the reference density for compaction and the unconfined compressive strength. The material must be loosened carefully so that the underlying layer is not disturbed, resulting in contamination of the sampled material.

The bulk of loose material should be removed from the hole using a round-nose shovel or scoop. A small, soft paintbrush may be used to sweep the loose, fine material together. Using a spoon, it should be placed in suitable containers, such as dust-proof bags, to avoid loss of the fine materials. It is important that all the fine material from the sampled layer is carefully collected. If moisture determination is necessary, then a small sealed container should be used.

Often the sample is of such a size that more than one bag is needed. For example, one small bag is required for an indicator test, and two or three for a MDD or a UCS or ITS test. If the sample is split in the field, the following procedure is used:

- All the **loose material is removed** and either placed on a flat hard clean surface or on a canvas sheet.
- Make sure that all the **fine material** is also picked up using a brush and spoon.
- Thoroughly **mix the material**.



Laboratory Compaction with Field Mix

To ensure that the material can be representatively compacted in the laboratory, the sample should be collected immediately after the mixed in stabilizer is hydrated, and compacted in the laboratory as close as possible to the time required for compaction in the field.

- Transfer all the sampled material into pairs of **riffler pans**. Two, four or six riffler pans are required, depending on the size of the total sample.
- Before riffling out the required samples, use the riffler to cross mix the pairs of riffler pans, to get **representative material** in each pan.
- Finally, riffle out the **various sized samples** needed for the tests.

Alternatively, the loose material is placed in a number of bags and taken to the laboratory. There it is mixed by riffling, and then riffled out to the correct test sample sizes.

If the bulk relative density is to be tested, riffle out a representative sample from the small bag sample. This must be done before testing for grading and plasticity.

To ensure that the material can be representatively compacted in the laboratory, the sample should be collected immediately after the mixed in stabilizer is hydrated, and compacted in the laboratory as close as possible to the time required for compaction in the field and in accordance with the applicable SANS method. Failure to do this results in incorrect reference densities and non-comparable laboratory and field strengths. As the rate of the stabilization reactions increases rapidly with temperature, the samples should be stored under shade or in the coolest possible place before being moved to the laboratory. [

4.1.3 Reinstatement of Sample Holes

Sample hole reinstatement should take place as soon as possible after sampling.

4.1.3.1 Materials and Equipment

The material used for reinstatement should be as similar as possible to the layer being reinstated, except that certain fractions may be screened out. It may be necessary to maintain a small stockpile of suitable material for reinstatement. Only potable water shall be used for compaction and hydration of the stabilizer.

A suitable flat-bottomed hand operated tamper, with a mass of 10 to 15 kg and a foot area appropriate for the size of the sample hole, should be used.

A stiff broom should be used for finishing and texturing the patch, level with the adjacent pavement.

4.1.3.2 Procedure

The sample hole should be of adequate size. All loose material is removed from the hole.

The sides and base of the hole are dampened with water. The mixed material is placed in layers 25 mm to 50 mm thick, and each layer carefully compacted with the hand tamper before adding a subsequent layer. The final layer should lie at the same line and level as the adjacent surface, with no mounding or sagging.

To facilitate hand compaction of smaller sample holes and moisture calibration holes, aggregate larger than 28 mm may be screened out. The approved material should be thoroughly mixed at, or up to, 1% above OMC.

When reinstating narrow, deep holes, such as nuclear density probe holes, the hole should be filled with a damp mixture of fine, approved aggregate, not greater than 7.1 mm. The mixture shall be slowly, continuously and carefully compacted with a suitably sized, steel-tamping rod to avoid air pockets.

A minimum of one out of every ten reinstated sample holes should be checked (on a random basis) for compaction, moisture content and surface finish.

4.2 Visual Acceptance

The visual acceptance items addressed below are generally applicable to cement stabilized selected, subbase and base layers. Where there are inadequacies in the visual acceptance control for these layers, this is pointed out in the relevant section.

4.2.1 Appearance and Finish

The following aspects must be taken care of in the appearance and finish of stabilized layers.

- The completed layer must be **visually homogeneous** with respect to grading, density and moisture content and surface texture/appearance. Any isolated non-homogeneous areas, e.g., wet, dry or segregated areas must be excluded from the test section and assessed separately.
- The completed layer should be **firm and stable**, free from areas of segregated material, laminations (loose, soft, thin layers), or corrugations. Particular care should be taken that no depressions or sags are filled with dry material from a windrow, or material that has not been properly treated with the stabilizing agent. It is not uncommon for depressions or holes created by larger particles removed during grader cutting to be filled with dry or unstabilized material during the final grader pass. Such areas cannot be tolerated, and must be properly identified and corrected.
- During compaction, **the surface should not be rolled out of shape**, and disturb the crossfall. Flat or dished shapes act as a water trap for water coming from the upper layer during compaction, or from surface water during rainy seasons.
- The completed stabilized layer should also be firm and stable with **a closely knit surface of aggregate** exposed in the mosaic, and free from nests of segregated material, laminations and corrugations.



Placement of Subsequent Layer

Material for a subsequent layer may not be placed if the underlying layer has been softened by excessive moisture.

A checklist for visual inspections should be included with the Acceptance Control sheets, and signed off for each assessed lot.

Where an already accepted layer is exposed to the elements for a period of time, or rainfall, it is essential that a full visual inspection, including re-checking of moisture contents, is repeated and reported prior to construction of the following layer. This is especially relevant for stabilized layers, where exposure to wet/dry conditions accelerates carbonation of the upper surface, forming a weak layer that is easily disrupted by brooming, resulting in an uneven, powdery layer, as illustrated in Figure 7.



Figure 7. Carbonated Surface

4.2.2 Curing, Drainage and Protection

The compacted layers should be adequately drained and shaped to prevent water from standing on or along, or scouring the completed work. Windrows should be removed, to facilitate the drainage of water from the surface. No material for a subsequent layer may be placed if the underlying layer is softened by excessive moisture.

Where the layer is not covered by the subsequent layer in 48 hours, the stabilized layer is cured for at least 7 days, in accordance with one or more of the methods prescribed in the Standard Specifications. Vehicles, including water tankers for spraying, should be kept off the treated layer during the 7 day curing period. If the subsequent layer is

placed prior to the completion of 7 day curing, the trucks should not drive directly on the exposed stabilized surface, but should end tip the material onto the layer.

Reference should be made to the following in the Standard Specifications:

- **Contractor's Obligations**
- Protection and Maintenance for **Selected and Subbase** Layers
- Protection and Maintenance of **Base** Layers

4.3 Dimensional Acceptance Control

The completed stabilized layers should comply with the construction tolerances for:

- Level
- Layer thickness
- Grade
- Width
- Cross-section
- Surface regularity

The construction tolerances specified in the Standard Specifications or project specifications, for the relevant layers are applicable.

Adhering to the required profiles within the tolerances specified is of paramount importance. If not strictly applied from the roadbed layer upwards, the problems are progressively transferred to the base layer and ultimately lead to poor riding quality.

Where a specific layer is constructed in two layers, the requirements for grade, thickness, cross-section and smoothness do not apply to the lower layer. However, the lower layer should be constructed with sufficient accuracy to enable the construction of the combined layer to the tolerances specified.

4.4 Laboratory and Field Tests for Acceptance Control

4.4.1 Stabilized Selected, Subbase and Base Layers

The laboratory tests conducted on stabilized materials for acceptance control are listed in Table 4 to Table 7, for the specific layer materials. Additional tests are required for the stabilized materials, given in Table 9. Note that the grading and Atterberg limit tests are done on UCS or ITS specimens after testing.

Duplicate samples may be required by the Control Laboratory, which could delay the final approval of the various construction control parameters.

Table 9. Laboratory and Field Tests for Stabilized layers

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Compaction	Maximum dry density	MDD	30 kg	1 test of material from each density site	SANS 3001–GR51
	Density	Sand replacement	N/A	1 sample per 1000 m ³ per 150 mm layer, minimum of 5 samples per layer per lot	SANS 3001–GR35
		Nuclear	N/A		SANS 3001–NG5
Moisture Content		Gravimetric analysis	1 x 1 to 1.5 kg	1 sample per test	SANS 3001–GR20
Layer Placement	Layer Thickness	Measurement			
Material Properties	Grading	Sieve analysis Grading modulus Soil mortar analysis	15 kg	1 sample per 1000 m ³ per constructed layer thickness, minimum of 5 samples per layer per lot	SANS 3001–GR1
	Atterberg Limits	Liquid limit Plasticity Index Linear shrinkage			SANS 3001–GR10, 11 & 12
	Strength	UCS, ITS	150 kg for each	1 sample per 800 m ² , minimum of 4 per layer lot	SANS 3001–GR51, 52, 53 & 54
Stabilizer Content	Distribution and quantity of added stabilizer	Laboratory determination of calcium content	6 kg	20 samples per lot, 10 at the top and 10 at the bottom of layer	SANS 3001–GR58

4.5 Interpretation of Laboratory Test Results for Acceptance Control

All test results are assessed in terms of the material standards outlined in Chapter 4: 2, 3 and 5, further enhanced by the applicable Standard Specifications and/or project specifications.

4.5.1 Stabilized Layers

4.5.1.1 Compaction

The material properties and judgement scheme specified in the Standard and project specifications of a specific project must be used for the construction and material control.

Compaction of the layer should comply with the requirements of the statistical judgement plan, utilising the actual variability of the layer, as obtained by the measurement of in situ density at predetermined test points, according to a stratified, random sampling plan. The section evaluated should be worked in one process and essentially the same materials, with a single stabilizer content, should be used on the full section.

The time interval between final compaction and testing affects the density results. The density of stabilized materials achieved in the field depends on the compaction time relative to the hydration of the stabilizer, therefore, compaction must be completed as quickly as possible. It is important that immediately after mixing the stabilizer and the compaction water, samples of the uncompacted material are removed from the designated (random) sampling sites, the locations of which must be clearly noted and/or marked. These samples must be dispatched to the laboratory as quickly as possible, and compacted within the same time frame as the road section. Density testing for compaction control is carried out within 24 hours of completion of the compaction of the road at the marked points, with the laboratory densities used as the reference densities. Samples for strength testing (UCS/ITS) are removed from the same points for laboratory testing.

Where the field densities do not comply with the specification, the failed area cannot be compacted further. The area must be reconstructed with the addition of half of the original cement content. Should the densities still not be achieved, the material must be removed and replaced. The addition of extra cement cannot be accepted. Laboratory determined



Inadequate Densities

Where the field densities do not comply with the specification, the failed area cannot be compacted further. The area must be reconstructed with the addition of half of the original cement content. Should the densities still not be achieved, the material must be removed and replaced. The addition of extra cement cannot be accepted.

strengths are normally higher than those obtained in the field, as the curing conditions are much better controlled. Marginal strengths obtained in the laboratory thus indicate that the actual field strengths are probably sub-standard. The structural implications of this should be assessed.

Conditional acceptance of stabilized materials should only be applied at the sole discretion of the road authority or client, after careful consideration of the pros and cons.

4.5.1.2 Atterberg Limits

The plasticity index of stabilized materials is carried out on the crushed material remaining after the UCS or ITS test specimens have been compressed to failure. If the PI does not meet the design specification, the material is not adequately stabilized, and should be rejected. This is particularly important for basic crystalline rocks, where the PI has the potential to increase in service, leading to structural failure of the layer.

If the mean linear shrinkage is less than 0.5 percent, the PI is recorded NP (non-plastic). With a mean linear shrinkage between 0.5 and 1.5 percent, the PI is recorded SP (slightly plastic). For a mean linear shrinkage of more than 1.5 percent, the mean PI and standard deviation are recorded.

4.5.1.3 Strength

Both UCS and ITS are normally specified for stabilized materials. Often it is more difficult to achieve the ITS than the UCS, and, to obtain the required ITS, the stabilizer content is increased. This typically results in a UCS higher than the specified upper limit. As the durability of the stabilized materials depends more on the ITS than the UCS, it is more important that the ITS requirement is met. This may result in slightly more stabilization (block) cracking than normally expected, but these can be sealed during routine maintenance.

4.5.1.4 Durability

Durability testing of stabilized materials is usually carried out during the design phase and is not part of the quality assurance programme. Any tests carried out during the approval stage for source and component materials may, however, be repeated for any construction lot, if requested by the engineer or client.

4.6 Assessment of Non-Conforming Work

In the case of non-compliance, the section is rejected and the contractor proposes an appropriate remedial action, which is assessed by the engineer. As an example, the following specifications for conditional acceptance are available in the Standard Specifications, and should be studied in conjunction with the remedial measures proposed by the contractor:

- Conditional Acceptance
- Determining Rejection Limits in Accordance with Statistical Criteria

Guidance on the assessment of non-conforming work is given in the following paragraphs for the various construction elements requiring approval.

4.6.1 Visual

Notwithstanding conformance to all specified product specifications, the following guidelines are applicable for visual assessment of the completed layer:

- **Appearance and Finish.** Where the appearance and finish are not to the specified standard, the construction process followed should be compared with the construction process guidelines for the construction of the stabilized layers as described in Chapter 12, and compared to the original trial section. Variations and non-uniformities should be pointed out to the contractor.
- **Curing.** Excessive material loss during brooming, before application of the following layer or priming, indicates carbonation and weakening of material as a result of ineffective curing. If the damage is relatively localised, it may be repaired using a bituminous slurry. If, on a base



Targeting UCS vs ITS

Both UCS and ITS are normally specified for stabilized materials. Often it is more difficult to achieve the ITS than the UCS, and, to obtain the required ITS, the stabilizer content is increased. This typically results in a UCS higher than the specified upper limit. As the durability of the stabilized materials depends more on the ITS than the UCS, it is more important that the ITS requirement is met. This may result in slightly more stabilization (block) cracking than normally expected, but these can be sealed during routine maintenance.



Reworking Cement Stabilized Layers

Reworking a layer, without the addition of extra stabilizer must not be carried out. Reworking more than once must also not be permitted.

layer, it is widespread and likely to result in a loss of bond between the base and prime/seal, the layer should be rejected. Occasionally, the base thickness may be in excess of the design requirement, in which case skimming of the weak layer can be attempted, provided that the exposed layer is uncarbonated (red when sprayed with phenolphthalein) and oversize material does not result in the formation of holes, drag-marks or depressions.

- **Drainage and Protection.** The most effective strategy, to ensure adequate drainage and protect the structural integrity of the selected layer, is to withhold payment until appropriate measures are implemented.

Note that reworking, without the addition of extra stabilizer must not be carried out. Reworking more than once must also not be permitted.

4.6.2 Dimensional

Where standards are not met, the following procedures need to be considered:

- Refer to Chapter 12, Construction Equipment and Method Guidelines. Compare with **procedures being adopted by the contractor**.
- Where a **trial section** was required or ordered, refer to procedures used at the time that resulted in an approved trial section. Compare to current construction procedures.
- Consider **reworking**, once only.
- Otherwise, rip and **replace** with a new layer.

4.6.3 Compaction

Normally the following options are investigated before a layer is rejected for inadequate compaction:

- **Rework the layer, but not more than once.** Normally the need for reworking the layer points towards a need for closer control on moisture, compaction time, utilised plant or improved process control of stockpiling procedures, and the correct use of appropriate compaction equipment. Add 50% of original stabilizer content if reworked.
- Otherwise rip, remove and **replace** with a new layer.

Should this non-conforming compaction situation persist, a detailed investigation must be done. The rejection of lots must be considered after three consecutive uncertain outcomes. Thereafter, a new trial section should be constructed.

Reduced payment is normally the outcome of conditional acceptance. Factors for reduced payments are provided in the Standard Specifications.



Repeated Non-Conforming Compaction

Should a non-conforming compaction situation persist, a detailed investigation must be done. The rejection of lots must be considered after three consecutive uncertain outcomes. Thereafter, a new trial section should be constructed.

4.6.4 Cementitious Binder Content

For materials containing normal calcium and magnesium contents, testing according to SANS 3001-GR58 is carried out. Acceptance according to the Standard Specifications is made. For materials containing high percentages of calcium or magnesium, e.g., limestones, dolomite, calcite and previously stabilized materials, these methods are unsuitable and no suitable alternative is available. In these cases, the binder content should be checked by confirming the quantity of stabilizer added, i.e., number of pockets or quantity spread from bulk spreader relative to the area and depth treated. It is also advisable to check when removing samples for strength testing that the full depth has been treated and the distribution is uniform by spraying a wall of each sample hole with phenolphthalein, and confirming a uniform colour over the full depth. Should this not be confirmed, the application rate is incorrect and the lot should be investigated in more detail.

4.7 As-Built Data Sheets

The data from completed work, which has been accepted, or replaced and retested, or other remedial measures applied and accepted, is recorded systematically on the standard as-built data sheets contained in TMH10, or as required the relevant road authority. Example as-built data sheets, in spreadsheet format, are available at www.nra.co.za.

5. PAVEMENT LAYERS: BITUMEN STABILIZED

The controls applicable for the acceptance of layers constructed from bitumen stabilized materials (BSMs) are adequately described in the Technical Guideline published by the Asphalt Academy, entitled "Bitumen Stabilised Materials, A Guideline for the Design and Construction of Bitumen Emulsion and Foamed Bitumen Stabilised Materials", TG2. This publication is available as a free download under the Bitumen Stabilization section of the Asphalt Academy website www.asphaltacademy.co.za.

A chapter in TG2 deals with Construction. Section 6.8, "Quality Control Aspects" includes a comprehensive description of both process and acceptance controls.

5.1 Process Control

Appendix D in TG2 details the specific requirements for controlling the activities involved in constructing a BSM layer by in situ recycling. Also included is a pro forma checklist used when mixing in plant.

5.2 Acceptance Control

Regardless of how the material was treated (recycled in situ or mixed off site and imported) and whether bitumen emulsion or foamed bitumen was used, the various control measures applicable to the acceptance of a layer constructed from a BSM are the same.

The following five features of new layers constructed from BSMs are subjected to acceptance control:

- **Thickness of the completed layer:** physical measurements
- **Application rate of stabilizing agent and active filler:** consumption controls
- **Material strength as an indicator of mix quality:** ITS tests on 100 mm diameter specimens
- **Density of the material in the completed layer:** "intelligent compaction" technology, nuclear gauge, sand replacement tests
- **Layer geometry:** physical measurements of surface levels, width, cross-section shape and surface regularity

Details of specific control measures for each feature are covered in TG2.



Bitumen Stabilization

The following is a comprehensive guideline for all aspects of BSMs:

- **TG2**, Second Edition: Technical Guideline: Bituminous Stabilised Materials – A Guideline for the Design and Construction of Bitumen Emulsion and Foamed Bitumen Stabilised Materials.

Various aspects of bitumen stabilization are discussed in:

- Chapter 2: **Pavement Composition and Behaviour**, Section 4
- Chapter 3: **Materials Testing**, Section 4.6
- Chapter 4: **Standards**, Section 4.6
- Chapter 9: **Materials Utilisation and Design**, Section 9
- Chapter 10: **Pavement Design**, Section 7
- Chapter 12: **Construction Equipment and Method Guidelines**, 2.7 and 3.5

6. ASPHALT

The purpose of this section is to provide guidance on acceptance control procedures for asphalt. It includes acceptance control testing of:

- **Raw materials** used in the mix: aggregates, sand, filler and bituminous binders
- **Mixed asphalt** for optimum binder content and engineering properties
- **Constructed layer**

Acceptance control includes assessments of the constructed asphalt layer, to ensure that the layer complies with dimensional requirements and finish, as specified in the appropriate standard specifications, project specifications and construction drawings. The acceptance should also be based on the requirements as set out in Chapter 4: 4, "Standards for Bituminous Materials". Project specific requirements also evolve from special investigations carried out during the planning and detailed design phase of the project. Such information assists in decision making, for example, on non-conforming work and associated conditional acceptance assessment.

The processes involving material component control and design verification through the implementation of a trial section, or acceptance of historical data, are covered in Chapter 9, Materials Utilisation and Design: 10 and Chapter 12, Construction Equipment and Method Guidelines: 3.11 and 4.1.

The obligations of the client, engineer and contractor are set out in the Standard Specifications:

- Routine Tests and Inspection by the Engineer
- Quality of Materials and Workmanship
- Testing of Roads

All sections of completed work are submitted to the engineer for routine inspection and testing. The contractor should not cover up, or construct any work on top of sections of completed work, before being advised by the engineer of the outcome of the testing and inspection. The contractor should make arrangements for the submission of work for testing, or for test results obtained by an approved laboratory to be made available to the engineer. The contractor should allow sufficient time for the engineer to inspect and test the work, if deemed necessary.

Acceptance control for asphalt is described in the following sections:

- Sampling
- Visual assessment
- Dimensional acceptance
- Laboratory tests for acceptance of the mix and constructed layer
- Interpretation of laboratory tests results for acceptance control
- Assessment of non-conforming work
- Reporting
- As-built data sheets

6.1 Sampling

This assessment category deals with the determination of sampling positions and procedures, and the reinstatement of core holes. In addition to Chapter 5 of TMH5, "Sampling Methods for Road Construction Materials", the following should be noted:

- All **samples for testing should be taken in a random pattern**, or as prescribed by the engineer. Where specified or required by the engineer, **stratified random sampling** methods should be followed.
- The **test sample size** (a sub-portion of a field sample), prescribed by the standard test method, is only adequate to carry out a single test or to



Hot Mix Asphalt (HMA)

Various aspects of hot mix asphalt are discussed in:

- Chapter 3: **Materials Testing**, Section 4.2
- Chapter 4: **Standards**, Section 4.2
- Chapter 9: **Materials Utilisation and Design**, Section 10
- Chapter 10: **Pavement Design**, Section 7
- Chapter 12: **Construction Equipment and Method Guidelines**, Section 3.11 and 4.1



Acceptance Control of Asphalt Layers

All sections of completed work should be submitted to the engineer for routine inspection and testing. The contractor should not cover up, or construct any work on top of sections of completed work, before being advised by the engineer of the outcome of the testing and inspection.

obtain a single test value. To evaluate the quality of the material or process, the variability must also be known. The only way to obtain the variability of a certain property or process is to take a large enough number of field samples.

- An increase in the size of a **statistical sample**, i.e., number of test values, which represents a lot, improves the confidence level in estimating the variability of a certain material property or process.
- The **various statistical sample sizes** to assess various quality parameters, are covered in TMH5. Details of testing frequencies are covered in this section in Table 10 to Table 16.
- Normally, the **minimum statistical sample size** to assess material properties or processes is six.



Sampling and Testing

Sampling and testing should only be carried out subject to a visual assessment indicating that the section of work under consideration appears to be uniformly of acceptable standard, in terms of density, texture and finish.

Delays in sampling and testing of materials and/or completed work must be kept to the absolute minimum. It is very important that the sooner sampling and testing is carried out, the sooner the objectives are fulfilled and immediate action taken, such as payment, continued production and construction. It is, therefore, very important for a sampler or tester to realize the impact of any delays.

6.1.1 Sampling Plan

The completed layer is judged using lots. The lot must have a visually homogeneous surface texture, with no visual signs of segregation.

Any isolated, non-homogeneous areas, such as poorly constructed joints or areas where there are signs of segregation, must be excluded from the test section and assessed separately. The width of the layer is normally divided so that there is a high probability that the test points fall in zones that experience heavy wheel movement. The length is divided into equal block lengths so that the uniformity of construction is checked.

Details of the minimum number of test points, as well as positioning of the test points, where applicable, is covered in Chapters 4 and 5 of TMH5.

6.1.2 Reinstatement of Core Holes

To prevent the ingress of water into the pavement structure, it is imperative to reinstate core holes as soon as possible after extraction. When testing newly constructed layers, core holes should be appropriately reinstated utilising the same asphalt mix type utilised for the current construction (maintained at the appropriate temperature). In the case of post construction investigations, core holes may be reinstated utilising "fit for purpose" cold mix asphalt products that ensure an impermeable "plug". Aspects such as ensuring the application of an adequate tack coat as well as compaction should also be ensured in all cases.



Core Holes

Core holes should be filled as soon as possible after sampling. Core holes should be properly filled with the appropriate asphalt product to prevent the ingress of water into the pavement.

6.2 Visual Assessment

Special care must be taken to ensure that construction plant is checked on a daily basis, to ensure that there are no diesel or oil leaks. Contamination of the asphalt layer by these petroleum products may not seem serious at the time of construction, but deterioration of areas contaminated in this way worsens in time under the action of traffic, resulting in fatty/bleeding spots.

The visual acceptance items addressed below are generally applicable to hot mix asphalt layers.

6.2.1 Appearance and Finish

The test section must have a visually homogeneous surface texture without areas of segregation or fattening. Both transverse and longitudinal joints should be properly compacted and flush with the surrounding surface. Any isolated non-homogeneous areas should be excluded from the test section and assessed separately.

An example of a visual acceptance checklist for a constructed asphalt layer is included in Appendix A of Chapter 12.

6.3 Dimensional Acceptance Control

The constructed asphalt layer should comply with the following construction tolerances:

- Level
- Layer thickness
- Grade
- Width
- Cross-section
- Surface regularity

The above tolerances are specified in the applicable standards or project specifications. The following Standard Specifications normally apply:

- Construction Tolerances and Finish Requirements

6.4 Tests for Acceptance Control

Acceptance control testing is divided into three distinct areas:

- **Raw materials** used in the mix, such as aggregates, sand, filler and bituminous binder
- **Newly mixed asphalt** for binder content and engineering properties
- **Constructed asphalt layer**

6.4.1 Acceptance Testing of Asphalt Mix Components

The mix components subject to acceptance control testing are:

- Aggregates
- Fillers
- Cellulose fibre (if used)
- Binders



Tests and Standards

All laboratory tests referred to are discussed in Chapter 3, and the standards associated with the tests in Chapter 4. Aggregates are included in Section 3, and bituminous materials in Section 4 of both chapters.

6.4.1.1 Aggregates

The majority of aggregate sources, from a commercial or project quarry, are seldom totally uniform in quality. The existence of distinct geological formations, i.e., weathered seams in the aggregate source, or a variable slightly weathered overburden, can significantly affect the quality of aggregate. Such variations in quality are, however, often not identified through normal routine coarse aggregate testing, such as 10% FACT.

Wherever practical, regular visual inspections of the specific face worked are required. Special attention should be given to the quality of the crusher sand (< 5 mm fraction), produced. Regular testing of the sand equivalent, plasticity index, water absorption and even Methylene Blue should be carried out on the aggregate samples, to confirm that no excessive weathered materials are present in the product. Details of the tests and testing frequencies are summarised in Table 10. Details of the tests and associated standards are included in Chapter 3: 4.2 and Chapter 4: 4.2.

When asphalt is reclaimed during the rehabilitation of road pavements, it can be utilized in mixes specifically designed to incorporate a proportion of reclaimed asphalt (RA). In such cases, the reclaimed asphalt, which is usually a milled product, is crushed and screened into two or three fractions to improve its consistency. The processed RA is used by substituting a percentage of the aggregate in the asphalt mix. Asphalt mix designs should be done to establish binder requirements and mix properties of the mix containing the RA. The acceptance control testing required to assess the quality and variability of the RA, are shown in Table 11. TRH21 Hot Mix Recycled Asphalt covers the recycling of asphalt in detail. Reclaimed asphalt should be stored under cover to avoid excessive moisture in the stockpiled RA.

6.4.1.2 Fillers

If the combined aggregate gradings show a deficiency of fines, an approved filler may be used to improve the grading. Fillers are either inert fillers, such as rock dust, or active fillers, such as lime or cement. In some cases, active fillers are used to modify the stiffness and moisture sensitivity properties of the asphalt mixes.

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Chapter 13: Quality Management

If cement or lime are used as fillers, they must be protected from environmental elements to keep them dry. The product can be stored for maximum of 3 months.

Lime does not become inactive as quickly as cement. However, if exposed to the atmosphere it carbonises to form calcium carbonate, which is non-reactive. Lime should, therefore, also be stored in a manner that affords protection from the environmental elements, and should preferably not be stored for longer than 6 months. If lime gets wet as a result of rain, or is contaminated, it shall not be used as active filler in asphalt mixes.

Milled blast furnace slag and fly ash are chemically non-reactive and, as such, small amounts of moisture or air do not have any major detrimental effect on the properties of the mix. However, to prevent contamination or the forming of clods, the product should be stored in a dry environment.

Acceptance control tests on fillers used in asphalt mixes are shown in Table 12.

Table 10. Tests and Testing Frequencies for Aggregates Used in Asphalt

Property	Test	Quantity Per Test (Maximum)	Lot Size (Maximum)	Samples Per Lot (Minimum)	Test Number
Grading	Sieve analysis	1 000 m ³	Stockpile	4	SANS 3001-AG1
Shape	Flakiness index	1 000 m ³	Stockpile	4	SANS 3001-AG4
Resistance to crushing	Aggregate crushing value (ACV)	5 000 m ³	Stockpile	4	SANS 3001-AG10
	10% FACT (wet & dry)	5 000 m ³	Stockpile	4	
Sand equivalent	Sand equivalent on fine aggregate	2 000 m ³	Stockpile	4	SANS 3001-AG10
Polishing	Polished stone value (PSV)	per source		1	SANS 3001-AG11
Adhesion	Adhesion test	5 000 m ³	Stockpile	4	TMH1 B11
Absorption	Absorption test	5 000 m ³	Stockpile	4	TMH1 B14 & B15
Plasticity of added fines	Plasticity index	2 000 m ³	Stockpile	4	SANS 3001-GR10
Durability	Methylene Blue test	per source		1	SANS 3001-AG44

Table 11. Acceptance Control Tests on Reclaimed Asphalt (RA) in Asphalt Mixes

Property	Test	Quantity Per Test (Maximum)	Lot Size (Maximum)	Samples Per Lot (Minimum)	Test Number
Grading	Sieve analysis	1 000 m ³	Stockpile	4	SANS 3001-AG1
Recovered binder properties	Penetration of recovered binder	1 000 m ³	Stockpile	1	EN 1426
	Softening Point (R & B)	1 000 m ³	Stockpile	1	ASTM D36

Table 12. Acceptance Control Tests on Fillers used in Asphalt Mixes

Property	Test	Quantity per Test (Maximum)	Lot Size (Maximum)	Samples per Lot (Minimum)	Test Number
Fineness	Percent mass passing 0.075 mm sieve	100 tons	per delivery	4	SANS 3001-AG1
Bulk density	Bulk density in toluene	100 tons	per delivery	1	BS 812
Void content	Void content in dry compacted filler	100 tons	per delivery	1	BS 812

6.4.1.3 Cellulose Fibre

Cellulose fibre is used as a binder carrier in some asphalt mixes, such as Stone Mastic Asphalt (SMA). It must be stored under cover, to stay dry.

6.4.1.4 Binders

Binders used in asphalt mixes include conventional bitumen, and modified binders.

(i) Penetration Grade Bitumen

Unmodified bituminous binders must conform to the applicable SANS specifications. As these specifications are frequently reviewed and amended, it is important that the latest applicable specifications are available on site. It is important to be aware the SABS mark only implies conformance at the refinery despatch point. Although the bitumen manufacturers try to ensure the tanker used to transport the product is free from any form of contamination prior to loading, they do not provide guarantees. This, together with the difficulty in monitoring and controlling the heating protocols for transport and storing, implies that conformance of the product to the relevant SANS standard, when delivered on site, cannot be automatically assumed. The bitumen binder producers are generally required to supply a batch test data sheet with every load dispatched. These should be continuously requested and retained with the site records.

Excluding contamination, the factor with the greatest influence on the change in bitumen properties is temperature. Excessively high temperatures, poor circulation within the holding tanks, and long-term storage at elevated temperatures all contribute to the degradation of the bituminous binder. Continuous vigilance is therefore required on site to ensure that the storage of hot bitumen binders is within the specified limits, and follows good practice. Similarly, as the properties of hot-applied binder alter with each heating and cooling cycle, it should be standard practice to take duplicate samples from each tanker load delivered to site, prior to discharge into the site storage tanks. One sample is utilised for testing, the other is retained for further testing, if necessary. Dependant on the length of storage time, it may also be necessary to regularly sample the product from the site storage tanks, followed by testing for conformance.



Transporting Bitumen

Although the bitumen manufacturers try to ensure the tanker used to transport the product is free from any form of contamination prior to loading, they do not provide guarantees. This, together with the difficulty in monitoring and controlling the heating protocols for transport and storing, implies that conformance of the product to the relevant SANS standard, when delivered on site, cannot be automatically assumed. The bitumen binder producers are generally required to supply a batch test data sheet with every load dispatched. These should be continuously requested and retained with the site records.

Each delivery of bituminous binder should be sampled, with 3 x 1 litre samples. One of the samples should be tested for penetration and ring and ball softening point. If the laboratory test results indicate that the product is out of specification, tests for compliance with SANS 4001-BT1 are carried out. Alternatively, 2 x 1 litre samples are kept on site as replicate samples.

Table 13. Test Frequencies for Penetration Grade Bitumen

Property	Manufacturer	Haulier	Site Storage	Sprayer	Test Method
Before Ageing					
Softening point	Every batch	Every load	Every day	Every load	ASTM D36
Penetration	Every batch	Every load	Every day	Every 5 th load	EN 1426
Dynamic viscosity @ 165 °C	Every batch			Every 5 th load	ASTM D4402
Flash point	Once, at start of project				ASTM D92
After Ageing (RTFOT)					
Mass change	Every 10 th batch			Every 10 th load	ASTM D2872
Difference in softening point	Every 10 th batch			Every 10 th load	
Dynamic viscosity @ 165 °C ²	Every 10 th batch				ASTM D4402

Notes

1. This test is performed on a frequency basis, or when there is a change in the source of base bitumen or bitumen crude type.
2. Only required if the binder is used for HMA.

(ii) Modified Binders

An extensive range of modified bituminous binders are available. Modified binders are divided into two groups, homogenous and non-homogenous binders. Non-homogenous modified binders include those manufactured using crumbed rubber. TG1 covers the use of modified binders in road construction, and some discussion is also included in Chapter 9: 8.1.3.

Temperatures and storage times are important for all modified binders. Typical temperature/time limits for polymer modified binders are shown in Table 16 in TG1, while those pertaining to bitumen rubber are presented in Table 18 of TG1. The testing frequencies for hot polymer modified binders and bitumen rubber are shown in Tables 19 and 21 of TG1, and are repeated here in Table 14 and Table 15.



Modified Binders

The following is a comprehensive guideline for all aspects of modified binders:

- **TG1 Technical Guideline: The Use of Modified Bituminous Binders in Road Construction.** Published by the Asphalt Academy, and available for download on www.asphaltacademy.co.za.

Table 14. Test Frequencies for Hot Polymer Modified Binders (From TG1)

Property	Manufacturer	Haulier	Site Storage	Sprayer	Test Number
Before Ageing					
Softening point	Every batch	Every load	Every day	Every load	MB-17
Elastic recovery @ 15 °C	Every batch			Every 5 th load	MB-4
Dynamic viscosity @ 165 °C	Every batch			Every 5 th load	MB-18
Storage stability @ 160 °C ¹	Every 10 th batch				MB-6
Flash point	Once, at start of project				ASTM D93
After Ageing (RTFOT)					
Mass change	Every 10 th batch			Every 10 th load	
Difference in softening point	Every 10 th batch			Every 10 th load	MB-17
Elastic recovery @ 15 °C	Every 10 th batch			Every 10 th load	MB-4
Dynamic viscosity @ 165 °C ²	Every 10 th batch				MB-18

Notes

3. This test is performed on a frequency basis, or when there is a change in the source of base bitumen or bitumen crude type.
4. Only required if the binder is used for HMA.

Table 15. Testing Frequencies for Bitumen Rubber (From TG1)

Property	Spray Tanker	HMA Storage Tank	Test Number
Softening point	Every load	Every batch	MB-12
Dynamic viscosity @ 190 °C	At the start of every load	At the start of every batch	MB-13
Compression recovery: • 5 minutes • 1 hour • 4 days	Every 5 th batch	Every 5 th batch	MB-11
Resilience	Every load	Every batch	MB-10
Flow	Every load	Every batch	MB-12

Test methods and standards for modified binders are included in Chapter 3: 4.1.4 and Chapter 4: 4.1, and also in TG1.

Besides the modified binders covered in TG1, other modifying technologies are already available, or in the latter stages of development. These include "warm mix asphalt" technologies, which enable asphalt mixes to be manufactured, paved, and compacted at significantly lower temperatures than those of conventional mixes.



Bitumen Test Methods

All bitumen test methods and standards are in the process of being adapted to SANS 4001 and 4002 methods. As the methods are published, they will be available from the SABS webstore, www.sabs.co.za. See the Appendix to Chapter 3 for a list of the old and new tests.

6.5 Acceptance Testing of the Asphalt Mix

The specified requirements of the asphalt mix are first established in the mix design stage. Thereafter, full-scale plant, paving and compaction trials are undertaken to verify these results, and to prove constructability of the mix.

Adequate quantities of the various aggregates should be stockpiled and dedicated to the project. It should also be insisted upon that production for a particular project is on a continuous basis, and not interrupted by the batching of other mix types for other customers. Failure to follow this approach makes it very difficult to exercise an acceptable level of proactive acceptance control, as errors easily occur due to non-uniform aggregate supply, as well as frequent changes in plant settings.

Continually ensuring the approved production mix design targets, is critically important in the overall quality management process. If at any time it becomes evident that the asphalt produced consists of component materials no longer representative of those used in the approved production mix, the situation should be rectified. Alternatively, a review of the production mix design should be implemented without delay. Such a review process may result in the adjustment of the relative proportions of the components, to meet the prescribed engineering properties and/or mix performance characteristics.



Changes in Component Materials

If at any time it becomes evident that the asphalt produced consists of component materials no longer representative of those used in the approved production mix, the situation should be rectified.

During the manufacturing process, the temperature of the binder used in the mix should be monitored to ensure that it is kept within the specified limits for mixing. The storage time, as well as temperature, should be monitored when modified binders are used, in accordance with the requirements set out in TG1.

As part of quality control, the temperature of the mixed asphalt should be taken at the plant. Mix temperatures are taken in the skip, before the mix is stored in the silo, and also in the delivery truck at the mixing plant's weighbridge. Temperature measurements, as part of acceptance control, should be taken at each delivery truck, as it arrives at the paving site. A suitable report form should be used, showing:

- Date
- Truck arrival time
- Time that mix is tipped into the paver hopper
- Mix temperature
- Details of the section paved

Acceptance control testing for bitumen content and aggregate grading is usually carried out on samples taken from the paved asphalt. Due to the asphalt's lower temperature behind the paver, other tests, such as void content and Marshall properties, are carried out at the mixing plant, where briquette specimens can be compacted at the correct temperature. The relevant SANS test method should be followed when increasing the sample temperature to the required value.

Table 16 summarises the tests and testing frequencies required on the newly mixed asphalt, as well as the asphalt layer once, it has been paved and compacted.

Table 16. Test Requirements and Testing Frequencies on Asphalt Mix and on the Constructed Asphalt Layer

Property	Quantity Per Test (Maximum)	Lot Size (Maximum)	Samples Per Lot (Minimum)	Test Number
Grading and binder content	200 tons	days work	6	SANS 3001-AG1
Sand equivalent	5 000 tons	week	1	SANS 3001-AG5
Marshall stability, flow and void content	500 tons	days work	2	SANS 3001-AS1, AS2, AS10
Relative compaction	2 000 m ²	days work	6	SANS 3001-AS11
Spread of rolled-in chips	2 000 m ²	days work	6	
Immersion index	Every change in aggregate or design			TMH1-C5

6.6 Acceptance Testing of the Constructed Asphalt Layer

6.6.1 Construction Tolerance and Finishing Requirements

Acceptance testing of the constructed asphalt layer includes the following specified construction tolerances and finish requirements:

- Level and grade
- Width
- Thickness
- Cross section
- Surface regularity
- Spread rate of precoated rolled-in chips

6.6.2 Sampling for Compaction Assessment

Compaction, for acceptance control purposes, is measured by taking core samples from the asphalt layer. Coring of asphalt layers should always be carried out using core barrels with unworn cutting edges. The coring rate should be such that no heating of the barrel and adjacent asphalt occurs, as this causes “smearing” of bitumen on the sides of the asphalt core, which can mask the existence of interconnected voids in the layer. For similar reasons, coring of freshly laid asphalt should always be carried out early in the morning when the layer is still relatively cool, i.e., $< 20^{\circ}\text{C}$. If this is not possible, measures should be implemented to reduce the temperature of the layer and the core drilling water.

Where relatively thin layers of asphalt are cored, a larger diameter core barrel, i.e., 150 mm, should be considered. It results in a larger sample size for testing, thus increasing the accuracy of the test. Testing of cores for compaction control, with a thickness of less than 30 mm, should be viewed with caution, as highly variable results can be obtained.



Coring of Asphalt Samples

Coring of asphalt layers should always be carried out using core barrels with unworn cutting edges. The coring rate should be such that no heating of the barrel and adjacent asphalt occurs, as this causes “smearing” of bitumen on the sides of the asphalt core, which can mask the existence of interconnected voids in the layer. For similar reasons, coring of freshly laid asphalt should always be carried out early in the morning when the layer is still relatively cool, i.e., $< 20^{\circ}\text{C}$.

Testing of cores for compaction control with a thickness of less than 30 mm should be viewed with caution, as highly variable results can be obtained.

To confirm that adequate compaction is achieved over the total area paved, it is considered good practice to extract, on a regular basis, cores over the longitudinal as well as transverse construction joints. As the methodology followed for the determination of compaction utilises the maximum voidless density (Rice density, SANS 3001–AS11, Chapter 3: 4.2.5) of the sample, the total core, including any precoated chippings, should be utilised for testing. Where interconnected voids are visible on the wall of the core, the bulk density used to determine the void content should be carried out by coating the test specimen with an elastomeric film, as specified in SANS 3001–AS10 Bulk Density.

6.6.3 Requisition for Inspection/Testing

On completion of any portion of the asphalt layer, the onus is on the contractor to submit work for approval and request inspection of the completed portion, for compliance with the specifications. In the interests of all parties, it is essential that such a process is carried out in a formal and structured manner. Informal procedures frequently result in accusations of delays in testing or other issues. It should thus be standard practice to institute a system whereby a “request book” is made available for the contractor to formally request the acceptance of any portion of the asphalt layer completed. Such a request will thus initiate all the final acceptance control procedures, such as, visual inspection, sampling and testing measurements.



Requests for Approval

On completion of any portion of the asphalt layer, the onus is on the contractor to submit work for approval and request inspection of the completed portion, for compliance with the specifications. In the interests of all parties, it is essential that such a process is carried out in a formal and structured manner. Informal procedures frequently result in accusations of delays in testing or other issues. It should thus be standard practice to institute a system whereby a “request book” is made available for the contractor to formally request the acceptance of any portion of the asphalt layer completed.

6.6.4 Trend Sheets

The implementation of trend sheets, displaying the key product properties during continuous asphalt production, has long been the norm for process control. It is, however, considered good practice to implement a similar trend sheet for acceptance control, resulting in comprehensive assessment of individual lots, rather than continuously assessed in isolation. Trend sheets greatly contribute to a proactive approach, by identifying undesirable trends timeously, thus allowing for corrective actions to be suggested or instructed before the product is rejected. See Section 1.14 for discussion on trend sheets.

6.7 Interpretation of Laboratory Test Results for Acceptance Control

The assessment or interpretation of laboratory test results is a complex procedure requiring skill and experience. It is part of the primary duties of the senior materials personnel on site, the resident engineer or SANAS approved signatory. The final interpretation of the results remains the responsibility of the engineer.

All test results are assessed in terms of the applicable Standard Specification and/or project specifications. The following specifications form the basis for the Standard Specifications:

To assess whether certain requirements specified for material properties and workmanship are complied with, judgement plans should be implemented. This minimizes the risk of accepting a non-compliant product, which will not yield the anticipated long term performance, or rejecting a compliant product, which will yield the expected performance. Thus, each material property requires either a minimum number of stratified random samples per lot, or per volume/area produced, to ensure that judgment based on the outcome of the test results is within acceptable risk to all involved parties.

A statistical judgment scheme offers the least subjective outcome for all involved parties. Even though it is not always called for in the project specifications, it may be implemented, subject to the availability of a minimum of 4 test results, but ideally not less than 6. The higher the road category, the higher the required design reliability of the road, and the more important the need for statistical control, because less risk can be tolerated. The uppermost structural layers are more at risk, and thus require an appropriate judgment scheme to limit the risk to an acceptable level.

Most current judgment schemes permit acceptance of work that may fall outside of the prescribed acceptance limits. Extreme caution should, however, be taken to ensure that any acceptance of such work remains fit for the intended purpose over the expected design life. Conditional acceptance of such work at reduced payment is not a contractor's right. A simple example of such a situation as follows: Asphalt surfacing placed has a bitumen content above the allowable tolerance, but still within the "conditional acceptance" range. While this mix is expected to perform adequately if it was placed in the fast lane of a multi-lane freeway, the same cannot be said if it was placed in the heavily trafficked slow lane. Thus, for the same mix properties, any conditional acceptance should be based on sound engineering judgement relative to the associated risk.

6.7.1 Treatment of Outliers

Outliers are handled as described under quality management in the project specifications. While the relevant judgement schemes do make allowances for the identification of outliers within a population of results, the discarding of any such results should be viewed with extreme caution. Wherever possible, the test should be repeated on a retained sample. Where this is not possible, consideration should be given to extracting a sample from a representative area in the completed portion of the asphalt layer, for further evaluation. Where the result of the outlier is confirmed, it should be included in the total population of assessed results. Where such a proven result deviates significantly from the remainder of the population, the total area represented by that result should be identified, investigated and evaluated according to "fit for purpose" criteria.

In essence, each outlier should be treated with due attention and should be properly investigated as to its exact cause.

6.7.2 Sampling

It is common perception that sampling is a relatively simple operation and is thus often entrusted to very junior and/or unskilled personnel. In numerous instances, disputes with respect to the validity of test results on non-conforming work are as a result of questionable sampling techniques.



Sampling Staff

It is common perception that sampling is a relatively simple operation and is thus often entrusted to very junior and/or unskilled personnel. In numerous instances, disputes with respect to the validity of test results on non-conforming work are as a result of questionable sampling techniques.

6.7.2.1 Sampling Methods

For the results of testing to be meaningful and representative of the assessed product or lot, it is essential that all sampling is carried out in a consistent and correct manner. It is, therefore, required that all sampling is carried out strictly according to the methods and procedures as contained in TMH5, "Sampling for Road Construction Materials". Where more than one sampling technique is allowable for a specific product, it is advisable that a method be selected and agreed to by all parties, prior to commencement of the actual work.

Due to possible difficulties in maintaining the asphalt at the specified compaction temperature when sampled at the paving site, it is usually more practical to sample and compact briquettes at the mixing plant.

6.7.2.2 Random Sampling

When a lot is tested, whether a normal sized lot, or an isolated section that clearly exhibits an abnormal variation of the property under consideration, all samples shall be taken in a random pattern. To ensure that the total length of the constructed layer is properly represented in the lot, the random sampling must be carried out in a stratified manner. This means that the lot is subdivided into a number of sub lots dependent on the length, after which a random number is selected from the tables in TMH5 or in the Appendix of this chapter. Notwithstanding requirements for random sampling, samples for testing should also always be taken from areas exhibiting different characteristics from that evident over the major portion of the assessed lot.



Sampling

When a lot is tested, whether a normal sized lot, or an isolated section that clearly exhibits an abnormal variation of the property under consideration, all samples shall be taken in a random pattern. Notwithstanding requirements for random sampling, samples for testing should also always be taken from areas exhibiting different characteristics from that evident over the major portion of the assessed lot.

6.8 Assessment of Non-Conforming Work

In the case of non-compliance, the section is rejected and the contractor has to propose an appropriate remedial action to be assessed by the engineer. The following Standard Specifications for conditional acceptance are available and should be studied in conjunction with the remedial measures proposed by the contractor:

- Determining Rejection Limits in Accordance with Statistical Criteria
- Conditional Acceptance

Non-conformance does not automatically imply that the constructed layer needs to be reconstructed by removal and replacement. Each instance should be judged on the principles of "fit for purpose". Such judgements require a high level of engineering knowledge and experience, based on known and acceptable levels of risk and cost implications.

Where it is intended that non-conforming work is permitted to remain in place, with or without remedial work, the standard process to be followed commences with the submission by the contractor of a formal request supported by technical data, performance history, proposed price discount and any other mitigating factors relevant to the situation.

The assessment of an asphalt layer subject to non-conformance requires particularly careful consideration. The layer, located in the upper part of the pavement, is subjected to the heaviest traffic loadings, and has to be durable and able to resist the ingress of moisture. In addition, asphalt layers cannot be reworked in situ or re-compacted as is possible with granular materials. This emphasizes the need for a high degree of quality management for hot mix asphalt. Examples of typical non-conformities, and their consequences, are given in Table 17.

6.9 As-Built Data Sheets

The data of completed work, which has been accepted, or replaced and retested, or other remedial measures applied and accepted, are recorded systematically on the standard As-built Data Sheets. TMH10 contains as-built data sheets, which can also be downloaded in spreadsheet format from the SANRAL website, www.nra.co.za.

Table 17. Examples of Typical Non-Conformities and their Consequences

Parameter	Non-Conformity	Consequence
Binder content	High binder content	• Reduction in rut resistance • Loss of skid resistance in surface course
	Low binder content	• High permeability enables ingress of water and air • Reduces durability • Increases chance of cracking and stripping
Void content	High void content	• High permeability enables ingress of water and air • Reduces durability • Increasing chance of stripping
	Low void content	• Reduction in rut resistance • Loss of skid resistance in surface course
Compaction	Low field compaction	• High permeability enables ingress of water and air • Reduces durability • Increasing chance of stripping
	High field compaction	• Low voids with reduction in rut resistance
Filler content	High filler content	• Low void content, stiff mix with reduced durability and early flushing
	Low filler content	• High void content, high permeability, reduction in rut resistance

7. SPRAY SEALS

For a road to perform optimally both functionally and structurally, a durable, waterproof, skid-resistant and all weather dust-free surfacing is required. This is to provide the road user with an acceptable level of service and to protect the structural layers of the road pavement from the abrasive forces of traffic and environmental effects.

In South Africa, both spray seals and slurries are commonly used for new construction, and for the resealing of existing bituminous surfacings. These bituminous surfacings are relatively inexpensive in comparison with asphalt overlays, and have proved to be successful on highways, rural roads and urban streets, under traffic conditions varying from low to high volume trafficked roads.

As a result of many years of experience in the use of seals and slurries, the road construction industry has built up extensive knowledge on their design, quality control and construction. In addition, a wide range of road experiments and laboratory studies, carried out in South Africa by researchers and practitioners, have contributed to the establishment of guidelines for the construction and maintenance of durable bituminous seals for use under local conditions.

Drawing from this expertise and research findings, this chapter is a practical guide to the surface preparation, quality control of materials and the construction aspects of the sealing process. Apart from providing a clear, concise guide to bituminous seals, it is the intent of this section to improve the understanding of this facet of road construction and to promote the appropriate use of seals in South Africa.

This section deals with quality management of various types of surfacing dressings, using both conventional and modified binders. The issues are dealt with in the following sections:

- **Pre-construction meeting**
- **Preparation prior to seal work**
 - New construction
 - Reseal
- **Materials:** General aspects, sampling, testing, interpretation, reporting and assessment regarding:
 - Aggregate
 - Bituminous binders
 - Slurry and microsurfacing
- **Process and acceptance control**

Terminology for bituminous surfacings is defined in Figure 8. HMA is hot mix asphalt and CMA is cold mix asphalt.

7.1 Pre-Construction Meeting

The purpose of the pre-construction meeting is to ensure that all parties involved with the project are well informed of the project requirements and time lines.

Good quality seal work is sensitive to climatic conditions, timeous availability of good quality materials, good quality equipment and workmanship. Non-availability of materials at critical times could result in an increase in risk. Therefore, the emphasis is placed specifically on the responsibilities of suppliers and subcontractors to the main contractor.



Surfacing Seals

The following is a comprehensive guideline for all aspects of surfacing seals:

- **TRH3:** Design and Construction of Surfacing Seals.

Various aspects of seals are discussed in:

- Chapter 2: **Pavement Composition and Behaviour**, Section 2.3.1.2
- Chapter 3: **Materials Testing**, Section 4.4
- Chapter 4: **Standards**, Section 4.4
- Chapter 9: **Materials Utilisation and Design**, Section 11
- Chapter 12: **Construction Equipment and Method Guidelines**, Section 3.10

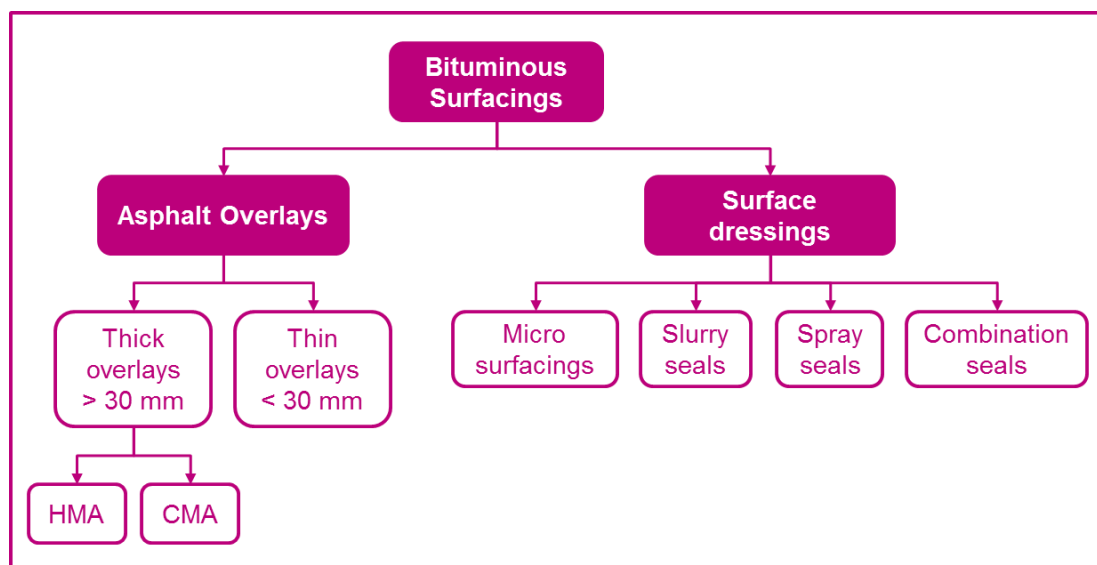


Figure 8. Definition and Terminology

7.1.1 Attendance

The meeting should be organized and facilitated by the engineer and specifically attended by:

- Main contractor
- All subcontractors
- Material suppliers
- Equipment suppliers (in case of specialized equipment)
- Laboratory representatives
- Design engineer and supervisory staff

7.1.2 Specifications

Project specifications are often not well understood by the contractor and/or his sub-contractors and suppliers at the time of tender. This meeting provides the opportunity for the design engineer and supervisory staff to discuss:

- Specific **issues and sensitivities** regarding the seal design and construction
- Sensitivities to **traffic accommodation** and **climate**
- Variation to **standard specifications**
- **Trial section** details
- **Contingency plans**

The responsibility of material suppliers regarding sampling, testing and submission of results must be confirmed.

The higher the traffic volumes, the higher the degree of control is required. In addition, good practice for lower volume roads is not necessarily good practice for very high volume roads. Appropriate practice must, therefore, be determined for the level of road.

7.1.3 Volumes

Based on the Contractor's approved program, the availability of sufficient quantities of materials is essential, in advance, to allow sampling, testing and acceptance. Dedicated stockpiles at the crusher may be required to pre-test construction materials before arrival on site.

It is recommended that suppliers, in conjunction with the Contractor and the laboratory, prepare schedules for production, delivery and testing.



Appropriate Practices for the Level of Road

Good practice for lower volume roads is not necessarily good practice for very high volume roads. For example, to improve adhesion and reduce the negative effect of dust, dampening of aggregate is normally recommended. In the case of very high traffic volume roads, this practice is not recommended and tighter specifications on dust, precoating and covering of aggregate stockpiles are required.

7.2 Preparation Prior to Seal Work

The preparation for new seals and reseals differs. Both are discussed in this section.

7.2.1 New Construction

7.2.1.1 Visual Inspection and Reporting

The preparation of the surface prior to construction of a seal is as important as the construction of the seal. A thorough and effective preparation of the surface ensures the maximum service life, with the minimum amount of maintenance. No seal work should be permitted prior to the completion of all the necessary preparatory work.

Base layers must be inspected for defects that should be repaired before and/or after priming. The following surface preparation activities may be required:

- Filling **sample holes** (new construction seals)
- **Texture** variation correction
- **Rain damage**
- Uneven and or **bumpy areas**
- Uneven surface due to **coarse base layer material**
- **Cleaning**
- **String line**
- **Dampening**

7.2.1.2 Surface Repair and Preparation

(i) Filling of Sample Holes (New Construction Seals)

Holes that remain after the measurement of densities of the base layer, or for purposes of layer thickness and moisture content determination, must be filled and properly compacted, before priming. Holes should be filled with appropriate material, for example, natural gravel, chemically treated gravel or asphalt, to provide at least the same strength and impermeability as the surrounding material.

(ii) Texture Variation Repairs

Texture variation repairs are normally carried out after the base layer is primed and has dried out in accordance with the specifications. Coarse areas should, depending on the coarseness of the surface, be treated with a medium to coarse graded slurry mix with the typical binder content (140 to 160 l/m³), cement content (1.5 to 2.0%) and rolled properly with a pneumatic tyred roller. The reduced binder content and increased cement content ensures a stiffer and more stable mix, to prevent possible punching of the surfacing aggregate into the mix.

Coarse areas can also be repaired by using medium continuously graded asphalt mixes. A 30% emulsion tack coat is applied at a rate of 0.60 l/m² on the primed coarse area. After this, the asphalt mix is spread by means of rakes, and levelled using a straight edge to ensure a smooth even surface. The placing and levelling of the asphalt mix must be done as quickly as possible, before the asphalt cools down. Rolling, using small self-propelled vibratory rollers, must preferably be done while the asphalt mix is still hot, between 120 and 140 °C.

(iii) Rain Damage

Texture variations also occur on crushed stone base layers, especially when heavy rains occur prior to priming of the layer. The fines in-between the coarse aggregate on the surface of the layer are normally washed out by the rain water, resulting in a coarse appearance of the surface texture.

The best way to repair this rain damage is to slush the layer very lightly, and to broom the slush to-and-fro and sideways to ensure that all interstices are filled with fines before superfluous fines, if any, are broomed off the road. Before the option of slushing is selected, it is extremely important to ensure that enough fines (passing 0.075 mm) are still available in the damaged layer. More harm can be done to the layer if there is a lack of fines, as the layer can become loose as result of additional slushing.



Preparation Prior to Sealing

The preparation of the surface prior to construction of a seal is as important as the construction of the seal. A thorough and effective preparation of the surface ensures the maximum service life, with the minimum amount of maintenance. **No seal work should be permitted prior to the completion of all the necessary preparatory work.**

If there are too little fines present in the damaged layer, it is advisable to rather cover the layer with a fine thin slurry by means hand rubber squeegees. The thin slurry must have sufficient thickness to fill the voids in between the coarse aggregate, but leaving the top of the coarse aggregate exposed. The binder content of this slurry mix must also be reduced to typically 140 g/m^3 , and the cement content increased to a maximum of 1.5 to 2.0%. The layer should be properly rolled with pneumatic tyred rollers, and opened to traffic for at least four weeks before sealing.

(iv) Uneven/Undulated Areas

Uneven and or bumpy areas should be repaired with a medium continuously graded asphalt mix. If the degree of the defect is not serious, a coarse graded slurry mix can also be used. These repair methods are discussed under Texture Variation Repairs above.

(v) Uneven Surface Due to Coarse Base Layer Material

Under normal circumstances, coarse base layer materials are crushed to ensure a relatively smooth finish of the end product. Nevertheless, it can happen that the only base layer material available is coarse, with no provision for crushing. This is a problem, especially when a chip and spray double seal is prescribed as a final surfacing.

With an uneven base layer finish, an asphalt levelling layer, or even a fairly dry coarse slurry levelling layer, are desirable options to improve the smoothness, before constructing of the chip and spray seal. However, due to financial constraints, this is not always possible and it may be necessary to construct the seal on this base layer with the minimum preparation actions taken. In this situation, the best and cheapest solution for this problem is to clean the base layer properly, by means of rotary and hand brooms, to demarcate the section to be primed by means of string lines, and to dampen the section before it is primed. After the prime has dried sufficiently, a dry run of 7.1 mm or even a 10 mm (depending on the coarseness of the base layer surface) is applied with a chip spreader without applying any bituminous binder. The spread rate for this dry run depends on the coarseness of the surface, but can vary between 300 and 400 m^2/m^3 .

A drag broom is slowly pulled, at a rate of 2 to 3 km/h, over this dry run of aggregate in such a manner as to only fill the hollows. Any excessive aggregate that remains on the surface, but not in hollows, must be carefully broomed off the road with hand brooms. No traffic must be allowed on this section after this process has been completed. The tack coat for the double seal is then sprayed on this treated layer, but the design application rate must be increased by at least 10%.

(vi) Cleaning

The layer to be primed must be broomed and cleaned of all loose or deleterious material with a rotary broom and hand brooms, no longer than 24 hours before spraying. Sweeping should be done carefully, so as not damage the layer.

(vii) String Line

The section to be primed must be properly demarcated by means of string lines to indicate the width and length to be sprayed. Reinforced paper strips must be placed at the beginning and end of sections, on which the prime is sprayed to accurately calculate the actual prime application rate. The string lines and paper strip are illustrated in Figure 9. The application rate is calculated by dividing the volume of binder sprayed, by the effective area of full coverage. The effective spray width takes into account the reduced binder, due to the flair of the end nozzles. Figure 10 to Figure 12 indicate string line positioning options, and the calculation of the effective spray width.

The Standard Specifications specify a 100 mm overlap on joints, implying a double flair. A triple flair configuration is more common at the moment, resulting in the need for amended project specifications.



Slushing to Correct Rain Damage

The best way to repair rain damage is to slush the layer very lightly, and to broom the slush to-and-fro and sideways, to ensure that all interstices are filled with fines before superfluous fines, if any, are broomed off the road. Before the option of slushing is selected, it is extremely important to ensure that enough fines (passing 0.075 mm) are still available in the damaged layer. More harm can be done to the layer if there is a lack of fines, as the layer can become loose as result of additional slushing.



Double and Triple Overlaps

The COLTO Standard specifications specify a 100 mm overlap on joints, implying a double flair. A triple flair configuration is currently more common, resulting in the need for amended project specifications.



Figure 9. String Line and Reinforced Paper Strip

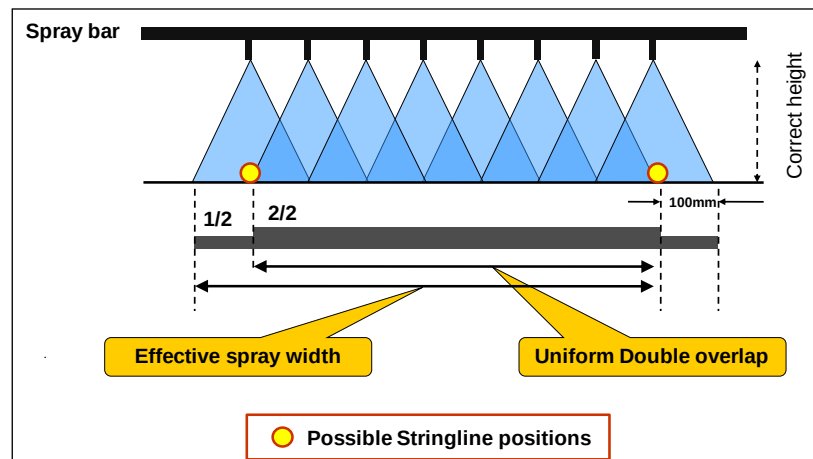


Figure 10. Spray Application: Double Overlap

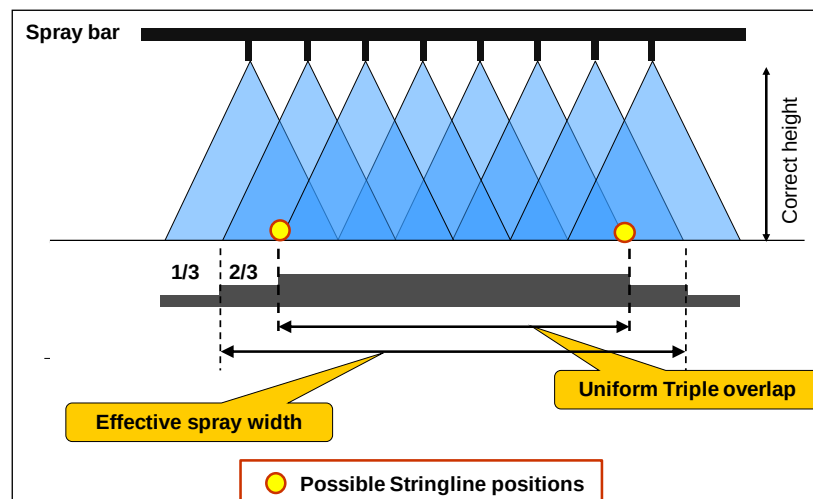


Figure 11. Spray Application: Triple Overlap

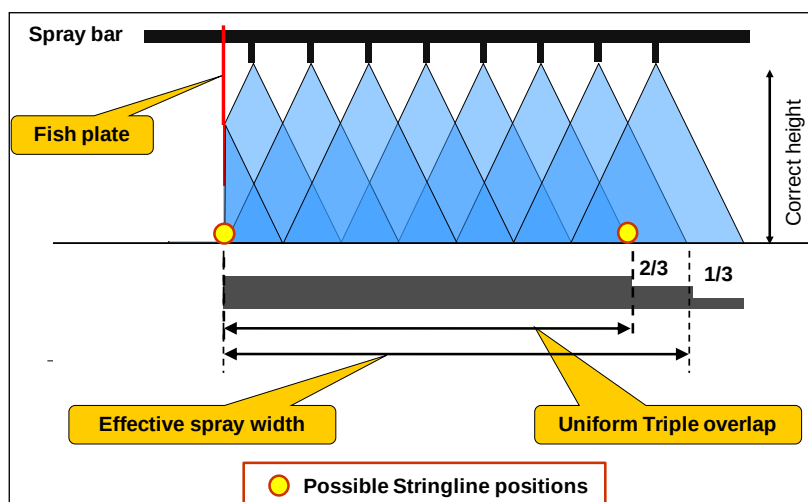


Figure 12. Spray Application: Triple Overlap with Fish Plate

(viii) Dampening

A sufficiently light spray of water, to dampen the surface and break the surface tension should be uniformly applied to the layer, immediately before the application of the prime. The water tanker speed is typically 15 to 20 km/h. It is important that the water must not pond on the surface after it is sprayed.

(ix) Base Moisture Content

The Standard Specifications specify that the granular base moisture content must reduce to 50% of OMC before priming. Although this standard might be relaxed under certain conditions, higher moisture contents can result in excessive seal aggregate embedment and flushing of the binder.

7.2.1.3 Prime Coat

The function of a prime coat is threefold, namely:

- Serve as a post treatment **curing membrane** on chemically stabilized layers.
- **Promote bonding** between the seal and the base layer.
- Prevent uneven permeability on the base layer surface.

Note that a prime is not impermeable.

(i) Selection

The selection and application of a prime coat should suit its function. There is no reason why a prime coat should penetrate deep into the base layer, other than to form a proper bond with the surface. It is unfounded to use a more volatile prime coat to facilitate quicker penetration, when problems may be experienced with the drying out of the prime coat. This practice is disadvantageous for developing strength in chemically stabilized layers.

With chemically stabilized layers, the prime coat's function as a post treatment membrane is extremely important for developing strength in the layer. The aim is to cover the base layer as quickly as possible, so that it forms a dense membrane, protecting the base layer from the atmosphere, rain and occasional traffic. This is also important where carbonation of the stabilized material is possible.

The most common primes used under normal circumstances are:

- **MC-30** cut-back bitumen (SANS 4001-BT2)
- Inverted bitumen **emulsion** (SANS 4001-BT5)
- **Tar-based** products are not permitted



Dampening of the Surface Prior to Sealing

A sufficiently light spray of water to dampen the surface and to break the surface tension should be uniformly applied to the layer, immediately before the application of the prime. **It is important that the water must not pond on the surface after it is sprayed.**



Prime on Granular Base

A prime on a granular base is not permeable!

Cold weather or high humidity can result in the prime staying wet for several days. In such cases, it is recommended to cut-back with 10 to 15% paraffin, or to use a quicker drying, commercially available prime.



Tar-based Primes

Tar-based products are not permitted for use in primes or precoating fluids.

(ii) Application Rates

Although the application rate is specified for tendering purposes, typically with a nominal application rate of 0.7 l/m^2 , the final specification must be practically determined in the field during trials.

As a general rule, the ideal application rate, approximately 0.6 l/m^2 to 0.8 l/m^2 , is obtained if the surface is ready for sealing within 3 to 4 days in summer or 6 to 8 days in winter. The minimum spray rate of hot binder that a binder distributor can practically and accurately spray is 0.6 l/m^2 .

The actual spray rates measured at the spraying temperature should not deviate by more than 8.0% from that ordered by the engineer. The engineer may, at his discretion, conditionally accept application rates falling outside this tolerance at reduced payment, in accordance with the Standard Specifications. Any deviation outside these limits is not paid for. However, the engineer has the right to instruct the contractor to make up any deficiency, or blind excessive prime without additional payment.

The prime must be applied 150 mm wider than the intended edge position of the surfacing. Where the prime is applied in more than one lane, the overlap (according to the double overlap configuration) must be 100 mm.

(iii) Blinding

When traffic needs to be carried on the prime, it should be blinded by placing crusher dust with the fines washed out or clean, fine sand on the prime. Blinding of the prime is a similar operation to the construction of a sand seal. Blinding should only be done to accommodate traffic.

Where blinding is instructed, the material for blinding consists of screened 5 mm nominal single size aggregate. The use of crusher dust for blinding is not permitted, unless the filler portion is washed out.

Puddles of prime should be absorbed with crusher dust, which should then be removed.

If, for good reason, seal work must commence, wet areas on the prime coat should be treated prior to sealing. Treatment is applying dry 7.1 mm aggregate, rolling properly with pneumatic tyred rollers, and removing the excess 7.1 mm.

(iv) Reporting

Application rates achieved per sprayed section must be reported on a binder application worksheet. This information must then be transferred to the as-built data sheets.

(v) After Care

No traffic is allowed on the prime coat until it is completely dry and no longer tacky. However, where it is essential that traffic is allowed onto the prime, a layer of 7.1 mm stone must be spread over the prime coat and rolled. If 7.1 mm stone is not available, clean river sand or coarse sand, without an excess of fines (less than 5% minus 0.075 mm material, can be used. The use of fine sand, or any sand with a high dust content, is risky, as the seal stone may penetrate the sand layer on hot days, causing bleeding.

7.2.2 Reseal

7.2.2.1 Preparation, Pre-Treatment and Repair

The purpose of surface pre-treatment for resealing is to ensure uniform and good performance of the new seal, the pavement structure and to ensure a safe, smooth ride. Repairs are normally done using bituminous materials that require sufficient age-hardening time to prevent excessive aggregate embedment. This is typically a minimum of 6 weeks. A varying surface texture and non-uniform permeability in the existing surface either leads to premature aggregate loss or bleeding.

The design should incorporate the location of pre-treatment, and specifications regarding repair methods and materials.



Reassessment of Necessary Repairs

Due to deterioration of the road from the design stage to establishment on site, reassessment of the road is always required to update the location and extent of repairs.

(i) Road Markings

Unless geometric changes to the road require redesign of the road marking layout, the existing road markings must be recorded and referenced for reinstatement after the reseal.

(ii) Patching

Deficiencies in the substrate soon manifest on the surface of the seal, once trafficked. It is imperative that all distressed areas are repaired as far in advance of any seal work as possible. This allows time for any patchwork to be assessed and age hardened, to limit potential embedment of the seal's aggregate.



Age-Hardening

Continuous ball penetration testing is advised to check the age-hardening of the patch. The ball penetration values will reduce over time, until fairly constant values are achieved.

7.3 Aggregate

Aggregate for seals are obtained from stockpiles of the various individual aggregate sizes.

7.3.1 Stockpiles

7.3.1.1 Preparation of Stockpile Areas

All stockpile areas must comply with the following:

- **Easily accessible to heavy vehicles and plant.**
 - The distance between stockpiles should be appropriate for the circumstances. A suitable distance between stockpiles is between 4 and 6 km.
 - No objects at the stockpile area, that make loading inconvenient. Stockpiles under power lines must be avoided to prevent loading equipment from accidentally touching the power line.
 - Stockpiles near trees cause problems, especially in autumn and winter with pollution from leaves and branches.
 - Stockpiles should not be exposed to dust.
- **Well drained.** Slopes, hollows or old borrow pit floors must be avoided. The use of side drains for stockpiles must also be avoided. Drains and/or embankments must be shaped in such a way that water drains from the stockpile, without forming ponds around the pile.
- The **stockpile area must be cleaned**, levelled and all organic material must be removed by means of a grader.
- The **area must be well compacted** and must have a solid work surface even under wet conditions. A hard surface, such as an old road, is appropriate as a stockpile area and does not require much preparation. Clayey or stony ground must always be avoided.



Stockpile Approval

Environmental approval for stockpile areas is required. See Chapter 8.

7.3.1.2 Delivery, Stockpiling and Covering

Aggregates from different sources or crushers should be stockpiled separately. Covering of stockpiles is considered good practice to:

- Keep the aggregate **dry**
- Prevent **contamination** by dust
- Keep the aggregate **temperature** compatible with the binder

7.3.1.3 Precoating

Precoating of aggregate should preferably be done at a plant before delivery.

7.3.2 Sampling and Testing

The purpose of sampling and testing of aggregates is twofold:

- Ensure aggregate properties are **within specification**
- Calculate appropriate **binder application rates** (design)

7.3.2.1 Pre-Delivery (Basic Properties)

Before aggregate is delivered on site from crushers, samples of all the aggregate to be used must be taken at the crusher for testing in the laboratory. If possible, it is advisable to take two to three conveyor belt samples of each aggregate size. These samples are normally more representative of what can be expected in a stockpile, because they are not segregated.



Binders and Aggregates

Only binders and aggregate that meet the prescribed specifications should be used for surfacings. All bituminous binders and aggregate that do not meet these criteria must be rejected, and removed from site.

If it is not possible to take belt samples, all samples must be sampled in accordance with TMH5, at the source of production and from the stockpiles.

Aggregate used for seal work must meet the requirements of the SABS 1083. The tests shown in Table 18 must be carried out before delivery to site. Most of these tests are discussed in Chapter 3: 3 and the associated standards are discussed in Chapter 4: 3.

Table 18. Pre-Delivery Aggregate Tests

Test	Method	Sample Size Required	Testing Frequency
Sieve analyses	SANS 3001-AG1	2.0 to 3.0 kg	3 per 100 m ³
Fines content	SANS 3001-AG1		
Dust content	SANS 3001-AG1		
Flakiness index	SANS 3001-AG4		
Aggregate crushing value	SANS 3001-AG10		
10 % FACT	SANS 3001-AG10		
Polished stone value	SANS 3001-AG11	20.0 kg	1 only
Sulphate soundness test	AASHTO T04		
Freezing and thawing test	AASHTO T103		
Los Angeles abrasion test	AASHTO T96-45		
Deval abrasion test	AASHTO T4-35		
Ethylene glycol test	SANS 3001-AG14		

7.3.2.2 From Stockpiles (Design and Control)

With the delivery of aggregate on site, sampling and testing should be carried out systematically. One test must be done on 5 random samples, i.e., 1 sample from each 10 m³ load. For the correct sampling procedures, refer to TMH5. The tests shown in Table 19 must be performed.

Table 19. Post-Delivery Aggregate Tests

Test	Method	Sample Size Required	Testing Frequency
Sieve analyses	SANS 3001-AG1	2.0 to 3.0 kg	1 per 10 m ³
Fines content	SANS 3001-AG1		
Dust content	SANS 3001-AG1		
Flakiness index	SANS 3001-AG4		
Aggregate crushing value ¹	SANS 3001-AG10		

Note:

1. When hardness is suspect.

7.3.3 Design Re-evaluation and Quality Optimization

This section discusses some practical hints for design re-evaluation and quality optimization.

7.3.3.1 Allocation of Stockpiles to Road Sections

The ideal spacing of stockpiles is approximately 4 to 6 km apart. However, due to environmental constraints, stockpile areas must be approved before delivery to site. The situation could result in massive stockpiles, with high variation in aggregate properties.

For design purposes, the application area of each stockpile must be known, specifically if the properties of aggregate from stockpiles vary. This requires continuous communication with the contractor.

7.3.3.2 Shape of Aggregate (Elongation)

The shape of the aggregate affects its interlocking in the compacted layer and, hence, the stability of the seal. The shape and size also affect the macro texture and void content in the seal, and therefore, the ability of the seal to displace surface water.

During construction and under traffic loading, the aggregate tends to orientate itself in the flattest position, i.e., the smallest vertical dimension. Flaky and elongated aggregate normally bridge over high points in the existing

substrate, preventing them from making full contact in the sprayed binder. In the case of double seals, it also prevents the second application of aggregate interlocking with the first application, causing possible premature stone loss.

Another disadvantage of too much flaky aggregate is that some of the flaky aggregate lie in-between angular cubic aggregate, resulting in a seal that does not look good, and increases the possibility of bleeding. One of the more important factors to consider when designing a seal, is the Average Least Dimension (ALD) of the aggregate. The ALD of flaky aggregate is normally about 50% of that of the other measured stone.

The use of aggregate that does not have a uniform size results in a small contact area between the tyre and the seal. This results in:

- Decrease in **skid resistance**, especially in wet weather
- High **noise level** because the larger particles are spaced further apart
- **Loss of larger stone** from traffic action
- **Concentrated wear** on the larger particles

A good quality, single sized stone develops good interlock, and provides maximum contact area between the tyres and the stone surface. This increases the friction area, causes the stone to resist polishing and abrasion, and gives good skid resistance, provided the correct quantity of binder is used.

With large single sized aggregates, more voids are available to accommodate variations in the binder application rate. Larger aggregates allow more binder to be used, resulting in a more impermeable, longer lasting seal. The smaller the aggregate size, the greater the possibility of filling the voids with binder.

7.3.3.3 Aggregate for Double Seals and Steel Wheel Rolling

The ideal situation for successfully constructing double seals is for the ALD of the second layer of aggregate to be 50% of the first layer's ALD. For example, a double seal of -20.0 mm and +10 mm aggregate, should have an ALD for 20.0 mm stone = 12.00 mm, and an ALD for 10 mm stone = 6.0 mm. However, the ALD of the aggregate is a fundamental input in the seal design process, and should thus be considered early in the design phase.

If the ALD for the second layer of aggregate is more than 50% of that of the first layer of aggregate, proper interlocking between the two layers is not achieved. Additional voids in the layer are created, which are not filled with binder. The possibility of stone loss of the second layer of aggregate is increased. When a situation like this occurs, it is advisable to reduce the spread rate of the first layer of aggregate by approximately 5 to 10%, so the stone is not shoulder to shoulder, but creates spaces for the second layer to interlock properly.

To construct a proper double seal with a smooth surface, it is essential to use a light steel wheel roller of 6 to 8 tons "to iron out" the layer. When the ALD of the second layer of aggregate is more than half of that of the first layer, and proper interlocking is not possible, the steel wheel roller tends to crush some of the second layer of aggregate.



ALD of Double Seals

The ideal situation for successfully constructing double seals is for the ALD of the second layer of aggregate to be 50% of the first layer's ALD. For example, a double seal of -20.0 mm and +10 mm aggregate, should have an ALD for 20.0 mm stone = 12.00 mm, and an ALD for 10 mm stone = 6.0 mm.

7.3.3.4 Flakiness of Small Aggregate

From crushing of the aggregate, a certain percentage of the aggregate tends to be flaky, especially when utilizing jaw breaker crushers. The percentage flaky aggregate from cone type crushers is normally lower. Nevertheless, the smaller the aggregate fraction to be crushed, the higher the expected flakiness index. For example, a 20 mm aggregate has a lower flakiness index than a 10 mm or even a 7.1 mm aggregate. See Chapter 12: 2.1 for a discussion on the different types of crushers.

Although a maximum flakiness index of 30% is specified for a 7.1 mm single sized aggregate, this specification is seldom met when using a jaw breaker crusher, without screening out the flaky particles. Many 14 mm + 7.1 mm double seals are constructed successfully using 7.1 mm aggregate, with a maximum flakiness index of 50%.

The following are some hints for dealing with flakiness in aggregates:

- Even though the aggregate could be within the **grading, flakiness and minimum ALD specifications**, the packing of the aggregate in a double seal might be sensitive to aggregate loss, due to low flakiness and high ALD of the smaller aggregate. The following could be considered during the trial section construction:

- Lower the spread rate of the larger aggregate
- Apply steel wheel rolling after spreading the smaller aggregate
- Change binder distribution between applications
- Apply a fog spray
- **Acceptance or rejection of aggregate based on minimum ALD and flakiness.** Relaxing specifications on these properties for the second layer of a double seal can be considered.

7.3.3.5 Aggregate Temperature

Although minimum road surface temperatures, ambient temperatures and binder application temperatures are specified and monitored, no minimum temperature is specified for the seal aggregate.



Aggregate Temperature

Although minimum road surface temperatures, ambient temperatures and binder application temperatures are specified and monitored for seal construction, no minimum temperature is specified for the seal aggregate. It is, however, advisable that the **minimum aggregate temperature must be at least the same as the minimum specified road temperature**. Covering of stockpiles is thus advisable.

In some parts of the country, in high lying areas, the temperature of surfacing aggregate can easily drop to freezing, and even below freezing point, at night time. Heating up of the stockpiled aggregate during the day occurs slowly. Similar situations occur close to the sea, where cool winds cool down the stockpiled aggregate.

Although the road surface and binder temperature are within specification, the low aggregate temperature results in poor adhesion and a risk of stone loss. It is advisable that the minimum aggregate temperature must be at least the same as the minimum specified road temperature. Covering of stockpiles is thus advisable.

7.3.3.6 Trial Sections

Trial sections are essential to:

- **Confirm the ability** of the contractor, the equipment, safety, traffic accommodation and the seal process management.
- Verify appropriateness of **design application rates** and aggregate spread rates.
- Verify **sampling and testing** location and frequency.
- Verify the appropriate **rolling** type, methodology and sequence.

A relatively short section, typically approximately 400 meters, of binder is sprayed at the design application rate. The ability of the distributor to spray the binder within the prescribed tolerances, and to spray evenly over the whole area is checked.

The aggregate is spread at the designed spread rate with a chip spreader. After the aggregate has been rolled with pneumatic tyred rollers, the matrix or spread of the aggregate is visually checked to see if the aggregate is lying shoulder to shoulder, or if there are openings. Adjustments must then be made to the gates of the chip spreader, until the desired spread rate is achieved.

7.3.3.7 Change of Aggregate Source

A change of aggregate source during construction requires re-testing for acceptance and design purposes. It is considered good practice to construct a trial section when such a change occurs. Samples must be taken from the new source, and tested according to Table 18 and Table 19.

7.3.4 Precoating of Aggregate

The purpose of precoating is to improve adhesion between the binder and the aggregate. Where hydrophilic or other aggregates that may cause adhesion problems are encountered, it is advisable to precoat the stone. An example of precoated and uncoated stones is given in Figure 13.



Figure 13. Uncoated and Precoated Aggregate

There are various products available for precoatting. SABITA Manual 26 contains guidelines as to the most appropriate products available. Precoatting fluids must be manufactured from petroleum based products. The use of tar-based precoatting fluids is not permitted.

(i) Application

The application (mixing) quantities given in Table 20 can be used as a guideline for the different aggregate sizes. In addition to these guidelines, the following should be noted:

- Approximately 1.0 to 2.0 ℓ/m^3 less is required when **precoatting at a plant**.
- **Different products require different applications.** For example, precoatting minus 5 mm stone requires 14 – 16 ℓ/m^3 of an appropriate precoatting fluid, while minus 13 mm requires significantly less.
- It is advisable to **make up samples with varying precoatting fluid application rates**, and to visually inspect the coverage of the aggregate.

(ii) Mixing Process

Precoatting should, for environmental purposes, preferably be done at a plant. However, when this is not possible:

- The **untreated aggregate stockpile** is thoroughly sprayed with water and allowed to drain off.
- The damp aggregate is loaded into a bucket of a front end loader (1.0 m^3). The required quantity of an approved precoatting fluid is **sprayed evenly over the aggregate** with a watering can.
- The mixture of aggregate and precoatting fluid is **dumped on the prepared stockpile area**.
- This process continues until a **stockpile of approximately 15 to 20 m^3** is built up.
- This small stockpile must be turned over with the front end loader, until the aggregate is uniformly coated with precoatting fluid. Three **complete turnings of the stockpile** are normally required.



Hints for Precoatting

- **What must it look like?** The precoatting fluid must completely cover the aggregate, without blotches of excess binder.
- **Wetting agents.** If adhesion remains a problem, a commercial wetting agent can be added to the precoatting fluid at a rate of 0.5% of the volume of the precoatting fluid.
- **Timing before seal construction.** The time between the precoatting of the aggregate and the placing of it must not exceed the time specified in the project specifications, or as agreed on site.
- **Incompatibility with emulsions.** *"No precoatting of aggregate must be done when conventional and or modified emulsions are to be used as a binder for seal work"*. This clause in the standard specifications and previous manuals was particularly relevant to tar-based precoatting fluids as breaking of the emulsion took several days. Experience now indicates that similar problems do not occur when the petroleum based precoat is dry.

Table 20. Guidelines for Precoating Application Quantities

Aggregate Size	Application (Mixing) Quantities
20 mm	10 – 12 ℓ/m ³
14 mm	12 – 14 ℓ/m ³
10 mm	14 – 18 ℓ/m ³
7.1 mm	16 – 22 ℓ/m ³

7.4 Bituminous Binders

The typical bituminous binders used in South Africa are shown in Figure 14. Due to the different compositions and stability, different sampling approaches and testing methods apply.

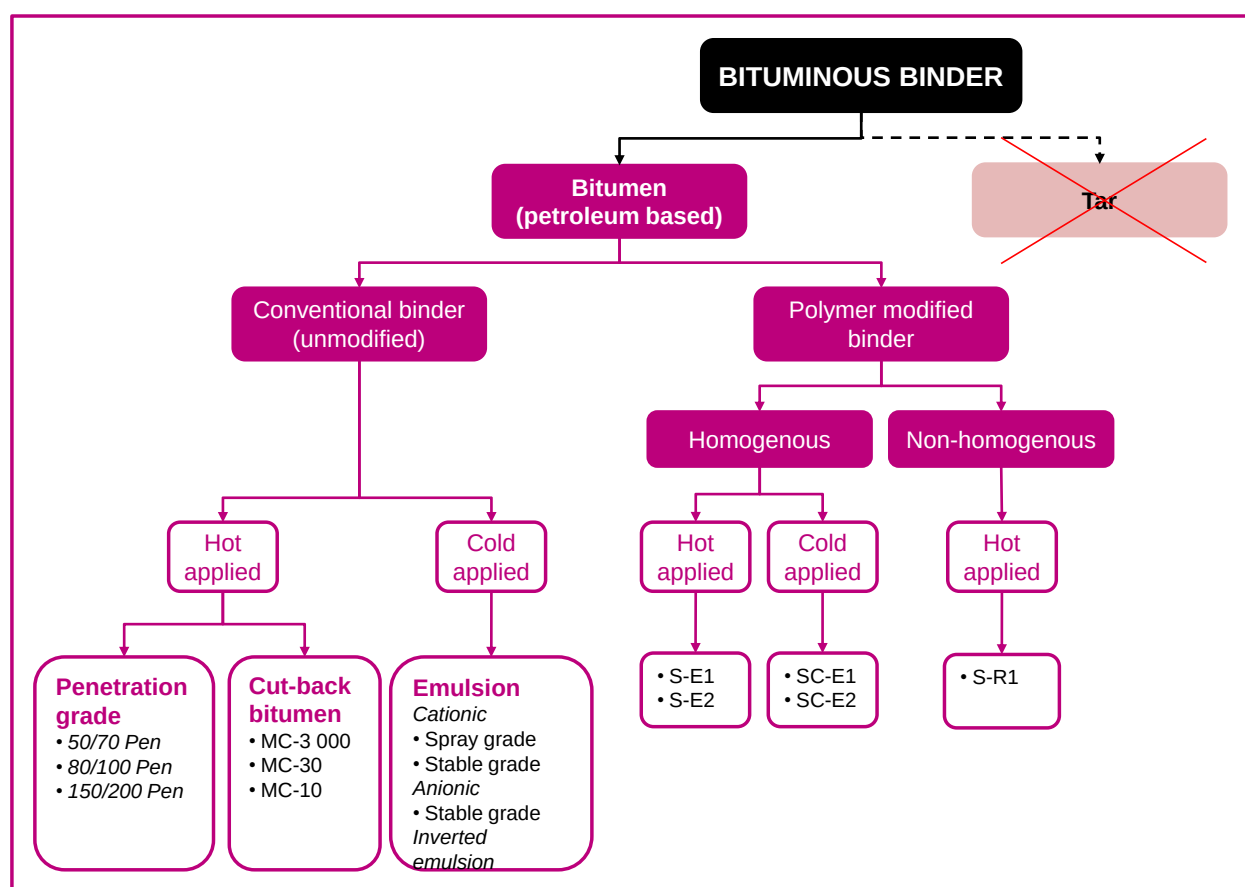


Figure 14. Typical Binder Types Used in South Africa

7.4.1 Sampling and Testing

Sampling and testing requirements differ for conventional and modified binders.

7.4.1.1 Conventional Binders

Conventional unmodified bituminous binders, used in the construction of seals, should conform to the latest edition of the SANS specifications, as listed in Table 21. All producers of bituminous products bearing the SABS mark are obliged to test the relevant products for conformance with the specification, and to make those results available to the purchaser.

Some of the tests on penetration grade bitumen are not normally done on site. It is therefore essential that arrangements are made with the suppliers for a complete set of tests to be performed on each batch prepared at the refinery. If necessary, the supplier can also be asked for the constituent composition of the base binder, in terms of the:

- Asphaltenes
- Saturates
- Aromatics
- Resins

Knowledge of the constituents of the base binder assists in the formulation of bitumen rubber binders particularly, as well as in the cutting-back of binders in the field.

Table 21. Specifications for Conventional Binders

Binder	Specification
150/200 Penetration Grade Bitumen	SANS 4001-BT1
70/100 Penetration Grade Bitumen	SANS 4001-BT1
MC-3 000 Cut-back Bitumen	SANS 4001-BT2
Anionic bitumen emulsion (spray and stable grade)	SANS 4001-BT3
Cationic bitumen emulsion (spray and stable grade)	SANS 4001-BT4

(i) Sampling

Key aspects for sampling of conventional binders are:

- **Three samples** of one litre each of every truck load are required.
- The samples should be **clearly marked**, indicating the
 - Application position on the road
 - Batch number
 - Source
 - Date
- The samples are **properly sealed** to prevent volatiles and/or water evaporating.
- One sample is kept as a **reference sample**
- The second sample is sent to a **commercial laboratory** for more detailed testing, if so required.
- The third sample is **tested on site**, as soon as possible.



Tests and Standards

The laboratory tests referred to are discussed in Chapter 3, and the standards associated with the tests are discussed in Chapter 4. Bituminous materials are in Section 4 of both chapters.

(ii) Testing

The tests required in the refinery and temporary (site) laboratories are given in Table 22.

Table 22. Tests for Conventional Binders

	Penetration Grade	Cut-Back Bitumen	Emulsion
Laboratory Testing	Penetration @ 25 °C/100 g/5 s Softening point (Ring and ball), °C Viscosity @ 135 °C, Pa.s Rolling Thin Film Oven Test	Viscosity @ 60 °C, Pa.s Flash point, °C Water % Distillation and % distillate	Binder content Viscosity (Saybolt Furol) Residue on sieving (g/100 mℓ) Particle charge Sediment flux content Coagulation value
Site Testing	Penetration @ 25 °C/100 g/5 s Softening point (Ring and ball), °C Viscosity @ 135 °C, Pa.s		Binder content Viscosity (Saybolt Furol) Residue on sieving (g/100 mℓ)

Note the following regarding testing:

- Frequency of laboratory testing is dependent on **degree of risk**, which should be clarified with the client as part of the quality plan.
- Requests for more laboratory testing are dependent on the **early performance of the seal**.
- Tests could include all aspects to **verify SABS specifications**.

(iii) Cut-back Bitumen

Cutting-back penetration grade bitumens is to:

- Improve aggregate **adhesion**
- Facilitate the **spraying** of bitumen at low residual binder application rates
- Reduce the **viscosity** of the binder

Cut-back bitumens are specified in terms of the properties of the final product only. No reference is made in the SANS 4001–BT2 specification to the properties of the cutters used.

It is not recommended that binders are cut-back on site, for safety reasons. However, where this is done, the cutters used (diesel or paraffin) should comply with the current SABS specifications (SABS CKS 342, 1969; SABS CKS 78, 1972; SABS CKS 215, 1972). Where paraffin is used as a cutter, care should be taken to ensure that the paraffin and bituminous binder are compatible. Should it be necessary to cut back bitumen in the field, the manufacturer/supplier of the base bitumen should be consulted, to determine the most appropriate cutter to use.

(iv) Bitumen Emulsions (Cationic and Anionic)

The service life of an emulsion is similar to that of bitumen. A major advantage of using an emulsion is that it can be sprayed at road surface temperatures as low as 10 °C. Bitumen emulsions also allow for low quantities of residual binder, if required.

During the manufacturing process, water is added to the bitumen, together with approximately 2% positively or negatively charged emulsification liquid, which results in the production of a cationic or anionic emulsion. The nature of the emulsion can be determined in the field by its pH, as cationic emulsions are acidic and anionic emulsions are alkaline. The manufacture of emulsion is discussed in Chapter 9: 8.1.4.

A bitumen emulsion is classified as a stable grade when it can be successfully mixed with cement to a smooth paste. A spray grade emulsion forms lumps when mixed with cement.

The adhesion potential of emulsion is very good, and it reacts successfully with most types of aggregates. Cationic emulsion reacts better with acidic stones, e.g., quartzite, and anionic emulsions react more favourably with alkaline stones, e.g., dolomite.

7.4.1.2 Modified Binders

Recommendations regarding the frequency of sampling and testing for modified binders are given in TG1, “The Use of Modified Bituminous Binders in Road Construction”, published by the Asphalt Academy.

7.4.2 Binder Acceptance

7.4.2.1 Conventional Binders

Product properties must conform to the specifications in SANS 4001–BT1.

7.4.2.2 Cutback Binders

Product properties must conform to specifications in SANS 4001–BT2.

7.4.2.3 Modified Binders: Bitumen Rubber

(i) Bitumen Rubber Acceptance

The following specifications for the blend apply:

- **Base bitumen** for the manufacturing bitumen rubber must comply with SANS 4001–BT1.
- **Rubber crumbs** as specified in Table 1 of TG1.
- **Bitumen rubber blend** as specified in Table 8 of TG1.
- **Viscosity** of the binder must, at all times, be between 20 and 40 dPa.s, measured with a hand-held Haake viscometer.

The following implications for bitumen rubber acceptance must be noted:



Selection of Appropriate Binders

Refer to Chapter 9, **Materials Utilisation and Design**, Section 8.2 for information on the selection and application of appropriate binders for different uses.



Modified Binders

The following is a comprehensive guideline for all aspects of modified binders

- **TG1: Technical Guideline: The Use of Modified Bituminous Binders in Road Construction.** Second edition. Published by the Asphalt Academy.

- When the **viscosity drops below 20 dPa.s**, the softening point of the product also tends to drop below the specified limits, while the flow increases to above what is specified. At this point, it is clear that the binder is getting softer.
- It is advisable that the **spray temperature is kept between 195 and 210 °C**. Lower application temperatures (below 195 °C) normally results in tramlining, as illustrated in Figure 15. Too high application temperatures (above 210 °C) are harmful for the product as digestion of the rubber crumbs is much faster, and the bitumen can be burnt.
- If the recommended **time period has been exceeded**, the binder should be re-sampled and tested to ensure that the properties of the binder are still within the specifications.



Figure 15. Tramlining

(ii) Bitumen Rubber Reconstitution

If the plant breaks down and/or sudden changes in weather conditions occur, not all of the bitumen rubber blended for a specific day can be sprayed. In these cases, it is very important to allow the left over product to cool down to retard the digestion process. The supplier is allowed to reconstitute (re-blend) 25% of left over product with new bitumen and rubber crumbs, provided that the end product complies with all the specifications.

(iii) Binder Temperature

Dial temperature gauges are normally mounted on the sides or top of distributor tanks and storage tanks. Modern distributors are equipped with digital temperature gauges installed inside the cabin of the distributors. These temperature gauges must be calibrated regularly by suppliers, and calibration certificates must be available on request at all times.

The temperature readings of these gauges can be verified on site by using calibrated thermometers capable of measuring such high temperatures. A sample of the binder is taken during the circulation process at the valve mounted on the circulation system near the circulation pump of the distributor. Care should be taken to use heat resistant hand gloves during the sampling process. After the sample has been taken, the temperature of the sample must be measured immediately with the calibrated thermometer. The temperature readings from the gauges of the distributor and the thermometer must not differ by more than 5%.

Application temperatures below the recommended minimum normally result in poor transverse distribution due to the viscosity being too high for the distributor pump to deliver a uniform and evenly spread application. Application temperatures above the specified values could be harmful to the binder, causing degradation and poor performance.

The recommended storage temperature for storage longer than 24 hours is always lower than the application temperature. The specified values are determined to prevent degradation of the binder.

7.4.3 Safe Handling and Storage

The most significant hazard associated with bitumen is heat burns. Conventional and modified hot binders are handled at temperatures ranging from 150 °C to 210 °C. Skin contact with bitumen at these high temperatures causes severe burns and shock, which can be fatal. It is important to always wear the required Personal Protection Equipment (PPE), including overalls, heat resistant gloves, face shield and safety boots.

For more detailed information regarding the safe handling of bituminous products see SABITA Manual 8, "Guidelines for the Safe and Responsible Handling of Bituminous Products" and Chapter 2 of TG1.

7.4.4 Cutting Back Binders on Site

The effective viscosity of the bitumen at the time of application may be changed to accommodate local conditions during, and for a short period, after construction. This can be done by adding a lighter fluid from the distillation process, such as aromatic paraffin, to the bitumen. The current preference in South Africa is, however, to cut back a binder with MC 30, which is a SANS controlled product and also has a higher flash point than the standard paraffinic products available.

Before the bitumen is cut-back, the expected minimum and maximum temperatures for the next 24 hours should be estimated. Appropriate spray temperatures for air and road temperatures are suggested in Table 23.



Comments on Cutting Back Bitumens

- It is not advisable to do any surfacing work if **wet or cold weather** is anticipated, particularly continuous rain.
- **Thunderstorms** are usually unpredictable. As a safety precaution, to limit stone loss, allowance could be made by introducing 1 to 2% aromatic paraffin into the bitumen.
- During the **rainy season**, it is recommended that 1 to 2 % cutter is added as a safety factor. Only **petroleum-based cutters** should be used with bitumen.
- Due to **safety risks**, cutting back should **preferably not be done** on site.

7.4.4.1 Precautionary Measures

When aromatic paraffin is added to bitumen, the temperature of the bitumen should not exceed 140 °C.

The aromatic paraffin should be siphoned out of 200 litre drums in measured quantities by means of a bitumen pump, and added to the distributor. It should be circulated with the bitumen in the distributor for a minimum of 45 minutes. During this process, all burners should be off and there should be no open flames.

Aromatic paraffin should not be poured through the manhole of the distributor, which should be kept closed.

There should always be a minimum of two fire extinguishers in working condition, at each distributor.

Unless good and responsible control is exercised, the cutting back of bitumen is highly inadvisable.



Safety of Cutting Back

Unless good and responsible control can be exercised, the cutting back of bitumen is highly inadvisable.

Table 23. Cutting Back of Penetration Grade Bitumen

Minimum in 24 hours (Projected)	Temperatures (°C)		% Cutter ¹ in 70/100 Penetration Bitumen	Spray Temperature (°C)
	Road	Approximate Air		
0 – 3	16 – 24	10 – 16	9 – 7	100 – 118 ²
3 – 6	24 – 32	16 – 21	7 – 5	115 – 135
6 – 9	32 – 40	21 – 26	4 – 3	121 – 138
9 – 12	40 – 48	26 – 31	2 – 1	132 – 149
> 12	> 48	> 31	0	150 – 175

Note

1. Aromatic paraffin
2. Upper temperature range is the maximum

7.5 Slurry Seals

A slurry is a homogenous mixture of fine aggregate, stable-mix grade emulsion (anionic or cationic) or a modified emulsion, water and filler (cement or lime). Slurry seals are used as maintenance treatments and for surfacings on roads and airfields. Slurry seals are also used to provide a uniform texture on existing surfacings, to improve rideability, and to improve the transverse and longitudinal profiles of roads (rut filling).

Slurry types used in southern Africa are divided into two groups:

- **Conventional** slurry
- **Microsurfacing**, including rapid setting, polymer modified slurries

In microsurfacing, a polymer and chemical additives are used to control the speed of curing/breaking.

Typical applications and the relevant thicknesses for both types of slurries are shown in Table 24.

Table 24. Basic Slurry Types and Utilisation

Conventional Slurry	Microsurfacing
Texture slurry (1 – 3 mm)	Medium overlay (6 – 8 mm)
Thin overlay (4 – 6 mm)	Thick overlay (8 – 15 mm)
Medium Overlay (6 – 8 mm)	Shape correction (8 – 15 mm)
Thick overlay (8 – 12 mm)	Rut filling (8 – 30 mm)
Cape Seal	
Slurry Bound Macadam	

7.5.1 Sampling and Testing

For the sampling and testing of aggregate and binder, refer to Sections 7.3.2 and 7.4.1.

7.5.1.1 Emulsion

Sampling and testing must be done continuously during the construction of slurry mixes. At least three samples, each of one litre, of every batch of emulsion delivered on site, must be taken for testing, before the work commences. The samples should be clearly marked, indicating its application position on the road, batch number, source and date. The samples must be properly sealed to prevent volatiles and water evaporating.

One sample is kept as a reference sample while the second sample is sent to a commercial laboratory for more detailed testing, for example, particle charge, sediment flux content and coagulation value. The third sample is tested on site, as soon as possible within one day after sampling, as this can have an influence on the residue on sieving results.

The following tests are normally performed on site in the temporary laboratory:



Slurry Seals

Slurries are discussed in the following guidelines:

- **TRH3:** Design and Construction of Surfacing Seals.
- **SABITA Manual 28:** The Design and Construction of Slurry Seals.
- Chapter 9, **Materials Utilisation and Design**, Section 11.2
- Chapter 12, **Construction Equipment and Method Guidelines**, Section 3.10.8.2

- **Bitumen content** of the emulsion
- **Viscosity** using the Saybolt Furol
- **Residue on sieving** (g/100 ml)

All the final test results on the bitumen emulsion must be transferred from the laboratory worksheets to the relevant as-built data forms.

7.5.1.2 Aggregate

Sampling and testing of slurry aggregate is essential to verify the basic properties of the aggregate, grading and moisture content.

Aggregate for slurry mixes delivered on site must at all times comply with the grading, hardness and sand equivalent requirements. With the delivery of aggregate on site, samples must be taken on a daily basis for compliance testing, before any slurry work is done. For more details, see the Standard Specifications.

The aggregate used in the manufacture of slurries generally consists of crusher sand, or of a blend of crusher sand and natural sand. The sand should conform to the recommendations given in TRH14 as well as conform to the relevant standard and/or project specifications, including:

- Hardness of parent rock
- Grading
- Sand equivalent
- Immersion index

The gradings of aggregate used in rapid-setting slurries are given in Table 25. Natural sand should not form more than 50% (the Standard Specification specifies 25%) by mass of the aggregate blend, unless a cationic bitumen emulsion is used, or an adhesion agent is added. The aggregate used in rapid-setting slurries should have the same properties as those specified for conventional slurries. In addition, they should be checked for compatibility with the emulsions to be used.

Table 25. Properties of Aggregates for Rapid-Setting Slurries

Sieve Size (mm)	Nominal Maximum Aggregate Size (mm)			
	5	7.1	10	14
	Overlays		Rut Filling	
	Cumulative Percentage Passing			
14	100	100	100	100
10	100	100	100	80 – 100
7.1	100	100	66 – 100	60 – 84
5	100	70 – 100	57 – 75	50 – 70
2	64 – 80	46 – 60	42 – 56	38 – 57
1	40 – 55	32 – 47	28 – 43	28 – 43
0.600	27 – 38	20 – 34	18 – 30	18 – 33
0.300	14 – 24	10 – 22	10 – 20	10 – 20
0.150	9 – 18	7 – 16	7 – 14	7 – 14
0.075	5 – 15	5 – 10	5 – 10	5 – 10
Sand Equivalent	35 minimum			
Modified emulsion	200 ℓ/m ³	190 ℓ/m ³	160 ℓ/m ³	150 ℓ/m ³

7.5.1.3 Slurry or Microsurfacing Mix

Before slurry work commences, an approved slurry seal design must be available, indicating the required bitumen and filler contents, and the layer thickness. Initial designs are often done by a specialized laboratory, before the aggregate is delivered to site.

Sampling and testing of the slurry mix is essential to verify the bitumen content and the consistency. In the case of hand application, a slump test, illustrated in 7.5.1, should be performed. The required flow for hand application is 30 to 40 mm.



Figure 16. Slump Test

Full time supervision at the batch plant or during the mixing process is essential to ensure consistency and adherence to the design composition. The different components are accurately measured and adjustments made based on the moisture/volume expansion.

(i) Design Verification

Due to the variation in the grading of slurry aggregate delivered on site, there is often uncertainty regarding the required binder content. A practical method, known as the “Colas method”, to verify the appropriate binder content on site, is done as follows:

- Make up several slurry mixes, **varying the emulsion content** from 180 l/m³ to 240 l/m³.
- Pour slurry mixtures into **Marshall briquette moulds** to approximately 15 mm in depth.
- **Heat the samples** overnight to 60 °C to allow water evaporation.
- **Compact the samples** using a Marshall hammer, with 150 blows on one side only.

The ideal binder content results in:

- **No plastic deformation** at the edges between the hammer and the side of the mould.
- **Dark grey to black** specimens.
- **Dull brown colour** indicates too low a binder content.
- **Slightly pliable** when broken in two.

If the crusher sand contains too little fines, or segregation occurs in the slurry mix, up to 1.5 % slag or cement or 1.0 % lime can be added. This also improves the workability of the mix.

(ii) Impact of Moisture Variations

Moisture variation in the aggregate for slurry seals has a huge influence, on both the volume of slurry used and the binder content of the mix. During seasonal rains, moisture variation in stockpiles is common. Moisture/volume expansion tests should thus be done more often, ideally in the mornings before work commences and about midday.

All slurry aggregate should be dried by exposing it to the sun, and then covered with canvas to reduce or prevent the influence of moisture/volume expansion. The binder content specified in the mix design of slurry seals is based on absolutely dry aggregate. If it is not possible to keep the aggregate dry, moisture/volume expansion adjustments (bulking) must be done on a daily basis.

If moisture/volume expansion is not taken into consideration, slurry mixes can be too rich. This can result in bleeding, and the contractor doing the work will be overpaid.



Adding Active Fillers to Slurries

If the crusher sand contains too little fines, or segregation occurs in the slurry mix, up to **1.5 % slag or cement or 1.0 % lime** can be added. This also improves the workability of the mix.

(iii) Moisture/Volume Expansion Determination

A practical method to determine the approximate moisture/volume expansion of sand can be done on site as follows:

- Fill a **container of a known volume** with sand from the stockpile.
- **Dry the sand** and determine the volume.
- Calculate the **moisture content** and **volume expansion**.
- A **moisture/volume expansion curve** can be derived in the laboratory for a specific sand, by adding water to dried samples and measuring the change in volume.

Alternatively:

- Fill a **container of a known volume** with sand from the stockpile.
- **Saturate the sample with water** and determine the reduced volume of sand.

Although this method is not necessarily correct, the saturated volume is similar to the dry volume for the calculation of the required amount of emulsion.

If a moisture/volume expansion of approximately 7% is measured, the bitumen content of the slurry mix must be reduced accordingly, because the actual volume of slurry mixed is, in reality, also 7% less.

For a true determination of the saturated volume (bulking of aggregate) see the Standard Specifications.

7.5.2 Sampling and Testing of Slurry Mixes

It is very important that the aggregate used for slurry mixes complies with the requirements regarding grading, hardness and sand equivalent. For more details, see the Standard Specifications on Materials and General Requirements for Aggregate for Slurry Seals.

If the aggregate cannot be kept dry at all times during the construction of the slurry seal, moisture/volume expansion adjustments (bulking) must be done on a daily basis, for the calculation of the required emulsion in the slurry mix.

Samples of the slurry mix should be taken randomly on a daily basis for extraction testing to determine the binder content in the mix. Slump testing of the slurry mix must be done on a daily basis as the work progresses, to ensure consistency in the slurry mix.

7.5.3 Acceptance

The acceptance of slurry is dependent on the quality of the:

- Aggregate
- Binder
- Slurry mix
- Constructed end product (compaction and segregation)

7.5.4 Reporting

Apart from the aggregate and binder properties, the following must be reported:

- The **quantity of emulsion** used per cubic meter, measured with every truck load, as well as the quantity of slurry aggregate used.
- The **area covered with slurry** must be measured accurately to determine the layer thickness of the slurry seal.

The results from the daily worksheets must be transferred to the relevant as-built data sheet.

7.5.5 Construction of Seals

The successful construction of seals depends on:

- Effective and acceptable completion of all **preparation work**. The **preparation work** has been discussed earlier in this chapter.
- **Quality of materials**, including the aggregates, binders and slurries, as discussed in Section 7.3 and 7.4.
- Use of the correct **construction equipment**, see Chapter 12: 2.



Hot Bitumen!

Hot bituminous binders are applied between up to 210 °C, requiring the use of protective clothing. Specific attention should be given to training and dealing with bitumen burns. It should be noted that immediate evacuation to an appropriate medical care facility is required. **DO NOT EVEN TOUCH.** Refer to SABITA Manual 8.

- Meeting the **specifications** for binder and aggregate application, and construction techniques.

Apart from all aspects mentioned already, final checks are required prior to, during, and after the binder and aggregate application. These are discussed below.

7.5.5.1 Just Prior to Binder Application

The following must be checked before the binder is applied:

- Confirm **weather conditions** are appropriate for seal work. If rain threatens, the seal work should be delayed.
- Confirm that all **staff are aware of their responsibilities**.
- Confirm of **binder application and aggregate spread** rates.
- **Spray the area clean**. No unwanted material should be carried over on the surface, e.g., mud or loose material dust.
- Where bitumen binder is to be sprayed directly adjacent to existing concrete kerbs, channels, side drains, concrete edge beams, bridge balustrades, and over bridge joints, such concrete elements should be covered with an approved **reinforced jointing paper**.
- Make sure that the **correct type and grade of bituminous binder** is in the distributor. The batch certificate should be obtained from the distributor operator, stating the type, grade and batch number.
- Confirm that the binder is at the **correct temperature** and that the gauges are calibrated.
- Make sure that the contractor has made adequate arrangements and that enough **suitable material** is available to cover the sprayed area in the specified time.
 - The length of each section sprayed should be such that the **available aggregate** cover the section with the minimum delay.
 - Depending on the supply of aggregate to the chip spreader and the available equipment, it is advisable to **limit the spray length** to:
 - Conventional and homogeneous binders: no longer than 400 metres
 - Non-homogeneous modified binders, i.e., bitumen rubber: no longer than 200 meters.
 - The air, road and binder application temperature should be continuously assessed. The constructed section should be shorter if the temperatures are at the lower end of the accepted ranges.
- Check that there are **no obstructions** in the line of spray.
- **Record the dipstick readings** on a level surface, where possible. Take readings after each spray to ensure accurate application.
- Confirm that the **road surface temperature** is appropriate for the binder.
- Ensure that the specified **reinforced paper is available and placed properly** at the beginning and end of the section to be sprayed, and that arrangements are made to remove and dispose the jointing material as soon as possible after the seal work is finished. Special "drip trays" may be required when the distributor is parked on the road prior to spraying.
- Make sure that the area to be sprayed is **properly demarcated**, with string lines held in place with steel nails at 15 meter intervals on straight sections, and at 3 meter intervals on curves, to guide the distributor operator.
- There must be **no joints in the wheel tracks**.
- Check the alignment of the **distributor**:
 - Width of spray
 - Overlap configuration, bar height and fish plate
 - Position of the guide marker



Dipsticks

A dipstick is only calibrated for one distributor.

7.5.5.2 Binder Application

Apart from the prime coat, two to three applications of binder can be sprayed for a seal:

- Tack coat
- Penetration coat
- Cover spray

The control process for each of these applications is to a large extent the same, and is therefore not discussed separately.

Important checks during the physical seal construction, not covered previously, are:

- Continuously check that all **nozzles are open** and **proper flairs are achieved**.
- **Line of spray and joint overlap** is correct. The binder overlap on two adjacent sprays should be effective to retain the aggregate. Traffic situations often result in the adjacent lane being sprayed several days or even weeks after the first lane. If the wait is more than a few days, the joint overlap configuration (4/3) as shown in Figure 17, could be considered. Note that using this configuration requires additional width, which means additional binder, for which the contractor should be compensated.



Parked Distributor

Make sure that after spraying, the distributor is not parked on the road without reinforced jointing paper or a drip tray under the spray bar.

Make sure that after spraying, the distributor is not parked on the road without reinforced jointing paper or a drip tray under the spray bar.

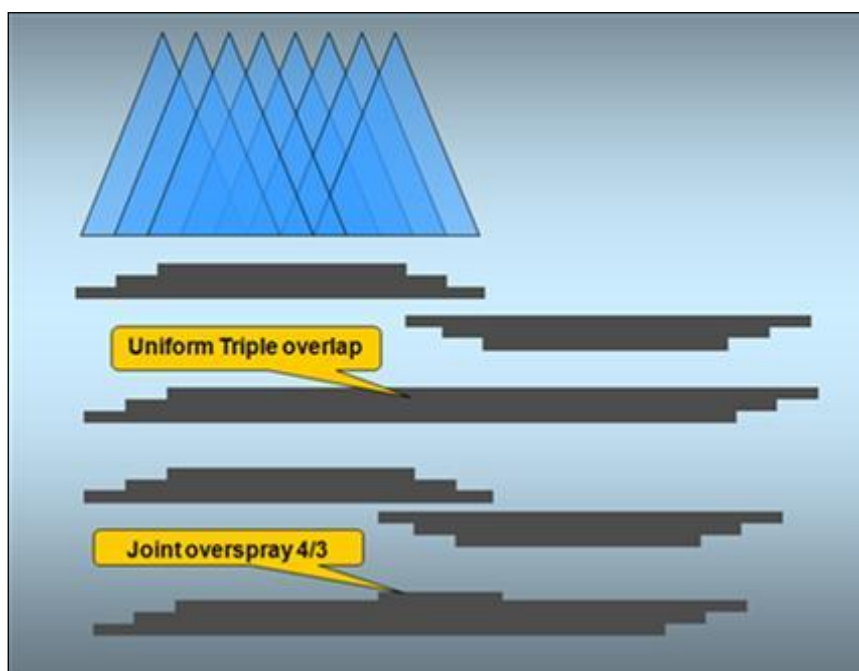


Figure 17. Joint Overlap Configurations

The following issues must be taken care of with the cover spray application:

- Unless otherwise specified, the **bitumen emulsion cover spray** should be applied at least one day after the second layer of aggregate, on new construction seals.
- It is important that all **excess aggregate is removed** from the surface before the cover spray is applied.
- In the case of reseal projects using **hot binders without high cutter contents**, the cover spray can be applied on the same day, if the precoat is dry.
- Better penetration as well as wetting, is achieved if the **cover spray is preceded by a light spray of water**, to break the surface tension of the aggregate. The water is applied by a fast moving water tanker, 10 to 15 km/hour, to prevent ponding of water.
- Where low quantities of residual binder are required, e.g., high traffic volume roads, the **bitumen emulsion should be diluted with water** and applied as a fog spray. The dilution is normally 50% emulsion to 50% water. The dilution of the emulsion minimizes the tackiness on the aggregate, and allows quicker opening to traffic.
- A cationic spray grade and or anionic/cationic stable grade bitumen emulsion can be used as a **fog spray**. However, the purpose of the fog spray dictates the type of emulsion most suitable:
 - Cover spray during seal construction: Cationic spray grade emulsion
 - Cover spray to minimize early aggregate loss: Cationic spray grade emulsion
 - Fog spray rejuvenator on old seals: Anionic stable grade emulsion

- After the fog spray is applied, **traffic should be kept off the road** until the emulsion has broken and is not tacky anymore.
- Some suppliers manufacture a **specially formulated emulsion** for use as a fog spray, which has reduced tackiness and pick up at ambient temperatures. There is currently an initiative to develop generic specifications for this type of product, which will allow it to be specified for use in a project.

(i) Reporting

The actual binder application rate should be established after each application, by measuring the surface area covered and the quantity of binder used. Refer to Figure 10, Figure 11 and Figure 12 for the effective width. The application rates of binder and stone must be recorded on the appropriate as-built data form. The road surface temperature of each sprayed section, ambient temperatures and wind conditions must be recorded.

7.5.5.3 Application of Aggregate

In addition to the aggregate quality and chip spreader condition, the following aspects must be considered to ensure a high quality final seal layer:

- **General precautions**
- Application of the **second aggregate layer** for double seals
- Application of **sand** on seals

Note that the specified application rates used at the tender stage, are only a guideline and the final application rate should be decided upon during the construction of the trial section.

(i) General Rules and Precautions

The following general rules and precautions should be followed:

- The aggregate should preferably be spread with a **pre-calibrated, self-propelled mechanical chip spreader** in good working condition. Where the **chip spreader is hooked onto the back of a truck**, the hitch connection should be firm enough to prevent relative movement between the truck and the chip spreader. Excess aggregate that falls onto the road surface during hitching of the chip spreader, should be removed immediately.
- There should be as **little lag time** as possible. The chip spreader should follow the binder distributor as closely as possible, while the pneumatic tyred rollers follow directly behind, to complete the compaction as quickly as possible.
- Check the correct **line and width of chipping**.
- The aggregate must be spread **shoulder to shoulder**.
- The supervisor, or a responsible person, should **walk next to the chip spreader** during operation to direct the operator to change speed, when necessary, to obtain the required application rate. It is advisable to visually inspect the aggregate application rate behind the chip spreader, where the pneumatic tyred rollers are busy rolling. Due to the large difference in viscosity between conventional, homogeneous polymer modified and non-homogeneous binders (bitumen rubber), the aggregate spread rate and visual appearance of the matrix differ.
- Precautions should be taken against **excessive application of aggregate**. Areas with **too much aggregate** should be rectified by lightly sweeping off excess aggregate, so that the entire surface is covered by an even, continuous layer of aggregate.
- Areas on the surface which show a **shortage of aggregate** should be supplemented by hand. If required, a **back chipping** team should follow behind the chip spreader to fill any bare places with aggregate by hand. Note that these teams tend to spread too much aggregate.
- **Excess stone removal** beyond the area demarcated by the string line should be done as soon as possible.
- The **spreader box of the chip spreader should not be allowed to run empty**, except during the last application of a certain aggregate size for the day. If the spreader box of the chip spreader runs empty or nearly empty, the chip spreader tends to start wobbling, resulting in corrugations on the road, as illustrated in Figure 18.



Visual Appearance

Due to the large difference in viscosity between conventional, homogeneous polymer modified and non-homogeneous binders (bitumen rubber), the aggregate spread rate and visual appearance of the matrix differs.



Figure 18. Empty Chip Spreader causing Corrugations



Empty Spreader Box

The spreader box of the chip spreader should not be allowed to run empty, except during the last application of a certain aggregate size for the day. If the spreader box of the chip spreader runs empty, or nearly empty, the chip spreader tends to start wobbling and leads corrugations on the road, as illustrated in Figure 18.

- Ensure that the **chip spreader completely moves off the chipped area** to allow rolling up to the end of the construction.
- Should aggregate be **spread by hand** (only applicable if emulsion binders are being used), it should be accurately measured using measuring containers and placed on heaps on either side of the road at short, regular distances. The measuring containers should always be levelled off.
- **Stone spread checks, sampling, measurement and recording** should be done continuously during sealing.
- The **application rate of aggregate** on completed sections should be calculated and noted regularly on the worksheets, to check with the specified values.

(ii) Application of the Second Aggregate Layer

In addition to the above precautions, the following aspects are important during the construction of a double seal:

- Before the application of the second layer of aggregate, the **first layer is broomed and rolled thoroughly**, and all excess aggregate removed.
- The **spread rate** is about half that of the rate for the first layer of aggregate.
- The second layer of aggregate must **interlock** with the first layer of aggregate.
- During **brooming**, care should be taken to remove excess aggregate without disturbing the first layer of aggregate, especially before a cover spray is applied.

(iii) Application of Sand on Seals

The aggregate of new seal layers tends to loosen during the first few weeks after construction at intersections, and where turning action of heavy vehicles takes place. Such stone loss can be reduced by applying a light layer of coarse sand or grit, typically 5 mm, without adding further binder.

The tackiness of emulsions for a fog spray can be reduced or even eliminated, if a thin layer of sand is applied after the application of a fog spray. The tackiness can also be reduced by wetting the seal a day or two after the fog spray application.

7.5.5.4 Rolling and Sweeping the Aggregate

Unless specified for particular reasons, only 22 to 27 tons pneumatic tyred rollers are used for single seal work on undulated existing surfacings. Light steel wheel rollers (6 to 8 tons) can be used in combination with pneumatic tyred rollers, when double seals are constructed.



Rolling Seals

Rolling with pneumatic tyred rollers should be done as thoroughly as possible. **The more the seal is rolled, the better.**

(i) General Precautions

The following general precautions should be followed:

- **Initial rolling**
 - Check the roller sequence according to the trial section and minimum number of roller passes.
 - Check rolling is done up to the edge of the constructed seal.
- **Final rolling**
 - Check if in accordance with the trial section.
 - Once the brooming is completed, the aggregate should be rolled properly by means of heavy pneumatic tyred rollers.
 - If it is a new construction seal, or the surface is smooth, it is advisable to use a light steel-wheel roller (6 to 8 ton) to “iron” out the aggregate.
- The spread aggregate should be **rolled with pneumatic tyred rollers as soon as possible** after the application of the aggregate.
- For the first roller pass, the **drive wheels of the rollers should be in front.**
- Rolling should be done **systematically**, at low speeds, from side to side. Sharp turning movements of the rollers and trucks should be avoided on the fresh seal.
- Rolling with pneumatic tyred rollers should be done as thoroughly as possible. **The more the seal is rolled the better.**
- The length of road sealed every day should be appropriate to the **number of rollers available.**
- When **excessive aggregate is disturbed and lifted by pneumatic tyred rollers**, it is an indication that the viscosity of the binder is too low. Rolling should thus be delayed until the temperature of the binder has dropped, or until more volatiles have evaporated from the binder. The disturbed aggregate can also be a result of the rollers moving too fast.

(ii) Rolling and Sweep Combination with Light Type of Drag Brooms

Systematically rolling, with simultaneous drag brooming, is of great importance to obtain a uniform shoulder-to-shoulder mosaic in the first layer of aggregate.

The combination of rolling and brooming is of particular importance during construction of the second layer of aggregate in double seals, to ensure that a good interlocking action develops between the various aggregate sizes.

(iii) Drag Brooming

The T or Z shaped drag broom (Figure 19) is very effective to spread the aggregate uniformly over the full surfaced area. Brooming takes out corrugations that may be caused by the chip spreader, and improves the final ride quality of the surfacing.

The drag broom is highly effective on stone seals with smaller aggregate, e.g. 14 mm, 10 mm and 7.1 mm aggregate, and could be used on both layers of a 14/7.1 mm double seal and on the 10 mm aggregate of a 20/10 mm double seal. The broom is not effective on 20 mm aggregate.

Once each layer of aggregate has been spread and rolled, it should only be swept with a light drag broom, if necessary, to evenly spread loose aggregate, which has not bonded to the surface.

The length of the rope used to pull the drag broom must be at least 4.0 meters long, and the broom must be pulled at a convenient walking speed, 2 to 3 km/h. The minimum length for the pull rope is necessary to ensure that the front part of the broom is not lifted up during the brooming process. The slow tow speed is necessary to prevent the broom from wobbling on the surfacing.

Brooming must take place as early in the mornings as possible on the previous day's seal work, when the road temperature is low, and the binder sprayed the previous day is cold and stiff. The broom is dragged to and fro on the surface. Thereafter, when the road surface temperature increases, the seal is rolled with a 6 to 8 ton steel wheel roller. The broom moves surplus aggregate to areas where there is a lack of aggregate to fill open gaps. Brooms are discussed in Chapter 12: 3.10.8



Figure 19. Z Shaped Drag Broom

(iv) Rotary Brooming

When excess aggregate has been applied on any layer, it should be swept off by the rotary brooms in such a way that the underlying aggregate is not disturbed. The brooms can be adjusted and controlled to just touch the surface. This is sensitive operation, and should be carried out cautiously.

All excess aggregate must be swept off before the seal is opened to traffic. If necessary, rotary brooming should continue to remove loose stone after opening to traffic.

(v) Opening to Traffic

Opening to traffic is governed by the development of adhesion between the binder and the stone, cohesion of the binder, prevailing and expected temperatures, as well as the traffic situation. The appropriate time is highly dependent on the binder type. Visual assessment and taking out of a few stones, is required to assess the strength of the seal.

The speed of the traffic on the completed reseal should be limited during the day of application and the following night.

If rain falls on a newly constructed reseal, traffic should if possible, be kept off until the rain has stopped and the seal has dried.

7.5.5.5 Reporting

The following reporting is necessary:

- **Emulsion for slurry complies** with requirements for
 - Bitumen content
 - Viscosity
 - Residue on sieving
- **Slurry aggregate** is acceptable for
 - Grading
 - Hardness
 - Sand equivalent
- **Moisture/volume–expansion measurements** are done regularly, and are used to adjust the binder content of slurry seal design.
- **Application rates** of slurry mix applied are checked for:
 - Binder content
 - Layer thickness



Rotary Brooming

The effectiveness of rotary brooming is dependent on the loading on the broom, the hardness of the bristles and the speed of brooming. Great care should be taken to not dislodge the aggregate.

7.5.5.6 Enrichment of Surfacing (Dilute Emulsions)

The enrichment of surfacings is to a large extent preventative maintenance. It can be considered when one or all of the following defects occur in seals, and sufficient voids exist:

- Stone loss
- Surfacing cracks
- Dry binder

The following construction practices should be kept in mind during the application of diluted emulsions to enrich existing surfacings:

- **Emulsion dilution:**
 - The water to be used for the diluting of emulsions should be **fit to drink**. Water from municipal sources can generally be accepted as suitable. If the suitability of water is in doubt, particularly in remote areas or where the water is derived from sources not normally used for domestic purposes, the water should be tested before use.
 - During the **dilution process of the emulsion**, the water must be added to the emulsion and not the reverse. Dilution should not be done with water colder than 7 °C and when the road temperature is below 10 °C. The diluted emulsion should be applied between 50 °C and 70 °C.
 - It is advisable to spray diluted emulsions during the **colder periods of the year** when road temperatures are fairly low. Road temperatures higher than 50 °C can cause problems, as the emulsion tends to break on the surface before it can penetrate into the existing surfacing.
 - **Do not add left over diluted emulsion to undiluted emulsion.**
- Apply a **light spray of water before** spraying of the diluted emulsion. In this way, the surface tension of the aggregate of the existing surfacing is broken and allows effective penetration of the diluted emulsion.
- It is advisable to **extend the distributor's spray bar** so that the application of the binder overlaps by approximately 300 mm on the centre of the road, to obtain a double application of emulsion in the middle. The existing surfacing on the centre portion of roads tend to be much dryer than the rest of the surfacing.
- **Existing surfacing:**
 - If the **existing surfacing is very dry or porous**, and the design application rate for the diluted emulsion is in excess of approximately 1.0 l/m², it is advisable to apply the diluted emulsion in two separate applications. Due to the low viscosity of diluted emulsions, it tends to flow or run off surfacings when the application rate is too high. This normally occurs on curves with high super elevations and roads with steep cross falls.
 - Should the **strips on the edges and between the wheel tracks be very dry and or porous**, the spray bar must be adjusted to enrich these areas first. These areas are normally enriched separately, followed by the full width afterwards.
- Should a road be moderately deformed and **pools of emulsion occur**, the emulsion must be removed by means of hard brooms, to prevent bleeding.

7.5.5.7 Sampling and Testing of Diluted Emulsion

Samples must be taken from the emulsion before it is diluted and tested, as described in Section 7.4.1. One sample of every distributor load should also be taken after the emulsion is diluted, properly circulated and heated to the specified temperature, before it is applied on the road. The sample must be thoroughly sealed and is used to determine the binder content.

A trial section should be first sprayed to verify the application rate achieved before further spray applications continue.

All application rates achieved on the road must be recorded on the worksheets, and transferred to the as-built data form.

7.6 Process and Acceptance Control

Process and acceptance control before and during construction of surfacing seals is very important, and is done on a continuous basis to ensure reliable, durable and economical seals.

Process control is the continuous control testing and evaluation of test results by the contractor during construction to determine if the construction, methods and material used ensure an end product that complies with the specifications. Acceptance control is the continuous control testing and evaluation of test results carried out by the

supervisory personnel, to determine if the quality of material and workmanship is acceptable, according to the specifications.

7.6.1 Typical Units and Variation

The pay items and applicable units for the various materials used are:

- **Bituminous binder application rates for chip and spray seal** are normally measured per square meter (m^2), while the pay item for **aggregate** applied is measured per cubic metre (m^3).
- **Bituminous binder** variations for application rates over or under specified rates, are measured in litres. Aggregate variations for over and under application are measured per cubic metre (m^3).
- **Precoating fluids** for precoating aggregate are measured in litres (l).
- The rate for the first application of **slurry for Cape seals** is normally included in the rate for the application of the tack coat, and 20 mm aggregate is measured per square metre (m^2).
- The **second slurry application** is normally measured per square metre (m^2) as an extra over item.
- **Slurry** application rate variations are measured in tons.
- Variations in the **active filler content** (cement) are measured in tons.
- **Work in restricted areas** inaccessible to mechanical equipment is measured per square meter (m^2).



Process and Acceptance Control

Process and acceptance control before and during construction of surfacing seals is very important, and is done on a continuous basis to ensure reliable, durable and economical seals.

7.6.2 Measurement and Payment

7.6.2.1 Measurement Guidelines and Procedures

Measurement and payment is in accordance with the relevant provisions of the Standard Specifications, as amended in the Scope of Works.

A bituminous binder distributor used for spraying the binder must have a valid calibration certificate and must have passed the transverse distribution “bakkie” test, shown in Figure 20 and discussed in Chapter 12: 2.4.2.4. The surface areas, demarcated with string lines and with reinforced paper at the beginning and end of the sections (see Figure 9), must be accurately pre-measured with a standard measuring wheel, to determine the exact surface area.



Figure 20. Bucket/“Bakkie” Test

When the binder in the distributor is at the correct spray temperature, and well circulated, the distributor is parked on a level area and dipped by means of its dipstick to determine the volume of binder in the tank. After the distributor has sprayed one of the demarcated areas, the volume of the binder left in the tank is dipped, again on a level area. The difference between the first and second dip is the volume binder sprayed on the specific demarcated area. The actual binder application rate sprayed is calculated by dividing the surface area sprayed by the volume of binder used.

Under normal circumstances, and for measurement and payment purposes, the actual volume of binder sprayed on a specific surface area will be paid, providing it is within the allowable tolerances.

7.6.2.2 Data Analyses and Interpretation

(i) **Variation of Bituminous Binders**

All binder application rates sprayed on every section must be determined accurately and noted on the relevant as-built data sheets. Any variation in application rates must be addressed as specified in the relevant specification document, applicable to the project.

It is, however, important that each and every section that has been surfaced is evaluated individually, and not the day's work as a whole.

(ii) **Decisions: Acceptance Rejection and Partial Payment**

With the construction of seals, the aim is always to end up with a durable, waterproof, skid resistant all weather surfacing. Accepting out of tolerance binder application rates with partial payment, could defeat this objective. Low binder application rates lead to premature stone loss and permeable seals with enormous negative effects on the pavement behaviour as a whole. High binder application rates lead to fatty or even bleeding surfacings with skid resistant problems, which can cause accidents, especially in wet weather conditions. A photo of a bleeding seal is given in Figure 21.



Figure 21. Bleeding Seal

While there are contractual requirements generally in place, the following guidelines can be applied for "out of tolerance" acceptance or rejection of binder sprays for surfacing seals:

- The **permissible spray tolerance** by which sprays with conventional and homogeneous modified binders may deviate from the specified application rate is 0.06 l/m^2 of cold net binder. The allowable tolerance for non-homogeneous binders (bitumen rubber) is 5.0% at the spray temperature.
- **Sprays of 0.07 l/m^2 to 0.10 l/m^2 above or below the specified application rate** for conventional and homogeneous modified binders should be rejected. If the surface appears to be reasonable, acceptance can be considered, but at reduced payment.
- **Sprays of 5.0% to 10.0% above or below the specified spray application rate at spray temperatures** with non-homogeneous binders (bitumen rubber) should be rejected. Acceptance thereof, if the surfacing appears acceptable, may be considered at a reduced payment.
- When a **percentage reduction in the tendered rate is applied**, no adjustments in respect of variation from the ordered rate are to be made.
- Sprays with conventional and homogeneous modified binders that are **lower by more than 0.10 l/m^2** of cold net binder than the specified application rate should be rejected. The contractor may propose remedial measures, such as the applying of a cover spray, that may be acceptable.
- Spray application rates with non-homogeneous binders (bitumen rubber) that are **lower by more than 5.0%** of the specified application rate should be rejected. The contractor may propose remedial actions, such as to apply a cover spray, that may be acceptable.

- **Sprays in excess of 0.10 l/m²** of cold net binder for conventional and homogeneous modified binders, and sprays which exceed 10.0% of the spray application for non-homogeneous binders (bitumen rubber), should be rejected outright. The contractor may submit proposed remedial measures, although in this case there is not much that can be done other than completely re-work the surfacing. An exception can be made where an excessive application rate occurred in the first spray of a two spray application. For example, a Cape Seal, or in the 1st spray of a double seal, in which case adjustments may be made to the original application rates determined for the 2nd spray.
- An **increase or decrease in the binder content of the slurry** in Cape seals is not a suitable remedial measure when the tack coat of the 1st binder application rate was out of tolerance.

8. CONCRETE

Concrete is a very commonly used product, however, problems are frequently encountered due to a lack of understanding of the product. Unfortunately, there is still a commonly held belief that the compressive strength of a concrete mix is the only acceptance criteria required. With concrete being a fairly “robust” product, any deficiencies or non-conformance during batching, placing, curing, etc., invariably only manifests long after the expiry of the normal Defects Notification Period of a project. It makes apportionment of liability very difficult when failures only occur much later in the performance life.

The optimum performance of any concrete element is fundamentally related to the following “5 C’s”:

- **Cement:** type and content, i.e., design
- **Consistency:** aggregate grading and batching
- **Climate:** particularly with concrete pavements
- **Cover:** particularly with thin structural elements
- **Curing:** all concrete

While the appropriate design of the relevant concrete mix is determined prior to actual construction, the other 4 elements play just as important a role, and need to be continuously monitored during construction to ensure optimum performance. This section covers quality control issues for concrete for both structures and pavements.



References for Concrete

- **Fulton’s Concrete Technology.** 2009. 9th edition, Cement & Concrete Institute.
- **Concrete Road Construction.** 2009. Cement and Concrete Institute (C&CI).
- **A Guide to the Common Properties of Concrete.** 2009. Cement and Concrete Institute (C&CI).

8.1 Concrete Constituents

8.1.1 Cement

The type of cement used in any concrete element is selected considering the function of the particular element, the environmental conditions, and durability requirements at the specific location. The cement type should always be as approved by the design engineer. For example, certain cement extenders, such as milled blast furnace slag or pulverised fuel ash, may improve watertightness (permeability) of a mix for water retaining structures, or durability. However, in concrete pavements, they may have a negative influence on abrasion resistance or joint sawing times, when utilised in significant proportions. Thus, any proposed changes to cement type during construction, after the initial approval of a design, should be thoroughly assessed for all desired properties, prior to approval.

In addition, with the exception of the standard SANS approved cement blends supplied by the primary cement producers, the blending of CEM1 and any extenders should not be permitted, unless specifically approved by the engineer, on the basis of an acceptable quality assurance procedure.

Storage of cement should conform strictly to the requirements contained in the published good practice guidelines, such as Fultons and the Standard Specifications.

8.1.2 Aggregate

Consistent concrete demands consistent aggregates. Reasonable variations in coarse aggregate grading should



Bridges and Structures

Quality management of concrete bridges and structures are not covered in this chapter. Their monitoring is not restricted to merely sampling and testing the concrete for compressive strength. SANRAL has published a very comprehensive guide as to the accepted processes and requirements in this regard, which is available on www.sanral.co.za.

Construction Monitoring Manual for Bridges and Structures. 2nd edition, 2011.



Concrete Pavements

Various aspects of concrete pavements are discussed in:

- Chapter 2: **Pavement Composition and Behaviour**, Section 2.4
- Chapter 3: **Materials Testing**, Section 5.1
- Chapter 4: **Standards**, Section 5.1
- Chapter 9: **Materials Utilisation and Design**, Section 12
- Chapter 10: **Pavement Design**, Section 8
- Chapter 12: **Construction Equipment and Method Guidelines**, Section 3.12
- Chapter 14: **Post Construction**, Section 3.2

not significantly affect the consistency of the concrete. However, variations in fine aggregate grading can have a significant effect. For this reason, the Standard Specification limits the variation in Fineness Modules (FM) of the fine aggregate to 0.2. Such a limitation requires careful selection of the sand at source, as well as blending, if necessary. Signs of excessive bleeding should be immediately investigated, as it is invariably a sign that a fundamental change in fine aggregate properties, or recipe, has occurred.

The maximum chloride ion content of fine aggregate is 0.03% by mass of aggregate as specified by SANS 1083. Where concrete is situated in a chloride environment, the value shall be reduced from 0.03% to 0.01%.

To avoid the possibility of alkali silica reaction (ASR), the following should be taken into account both during the mix design process, and with any change in aggregate sources during the execution of the project:

- Where the **total cementitious content** is less than 350 kg/m^3 , the maximum equivalent sodium monoxide content (calculated as Na_2O) permitted should be 0.60%, unless a test certificate from the CSIR Built Environment is provided, stating that the long term testing has proven the aggregate to be non-reactive.
- Where the **cement content** exceeds 350 kg/m^3 , the maximum equivalent sodium monoxide content permitted should be 2.1 kg/m^3 of concrete.
- Where potentially **reactive aggregate** is used, the maximum cement content should be 400 kg/m^3 and the equivalent sodium oxide (Na_2O) content permitted should be 2.4 kg/m^3 of concrete.
- The contractor should, prior to the use of cement, provide **test certificates** from an approved laboratory, confirming the equivalent sodium oxide (Na_2O) content of the batch of cement.
- **Special literature** should be consulted, e.g., Fulton's Concrete Technology.

8.1.3 Water

Where non-potable water is utilized for manufacturing concrete, it should be regularly assessed for conformance to the requirements. Water for concrete other than pre-stressed concrete, should not contain chlorides, calculated as sodium chloride, in excess of 3 000 parts per million (ppm) nor sulphates, calculated as sodium sulphate, in excess of 2000 ppm.

Water for curing concrete should not contain impurities in sufficient amounts to cause discolouration of the concrete, or produce etching of the surface. No sea-water or water containing salts should be used.

No water should be added on site to ready mix concrete to improve workability prior to placing. All concrete delivered to site shall be checked for workability using the slump cone test. Slump measured outside of the limit set from the design mix is rejected.

The generally acceptable limits necessary to ensure that the water is not detrimental to the concrete are given in Table 26.

8.1.4 Admixtures

Any admixtures added to concrete should always be incorporated strictly in accordance with the suppliers' instructions, as well as the project specifications. Admixtures, which have a retarding effect on the rate of hydration of the cement, should not be used when the concrete temperature is below 20°C . A retarding admixture should be used if the temperatures of concrete mixes using cements of strength class 42.5 or higher, is between 20 to 30°C , or where the ambient temperature is between 20 to 30°C . Only admixtures of the type that do not increase the water content of the mix should be considered. In addition, no admixtures should be added on site to any ready-mixed concrete prior to placing to improve workability.

South African Pavement Engineering Manual

Chapter 13: Quality Management

Table 26. Water Quality Classification Code

Property	Water Type					
	Pure water (AR)	Clean water (Rain)	Treated water (Municipal)	Silty (muddy) water with low salt content	Highly mineralised chloride, sulphate water (brackish)	Waste, brack, sewage marsh, sea, etc. water
	H0	H1	H2	H3	H4	H5
pH ¹ (SANS M113)	7.0	5.7 – 7.9	4.5 – 8.5	4.5 – 8.5	9.0	–
Dissolved solids ¹ (ppm) (maximum) (SANS 213)	0	1000	1500	3000	–	–
Total hardness ¹ (maximum) (SANS 215)	None	None	Temporary	Temporary	Permanent	–
Suspended matter (ppm) (maximum) (SANS 1049)	0	2000	2000	5000	–	–
Electrical conductivity (Ms/m) (maximum) (SANS 1057)	0	200	200	500	–	–
Sulphates, SO ₄ (ppm) (maximum) (SANS 212)	0	200	300	500	1000	–
Chloride, Cl (ppm) (maximum) (SANS 202)	0	500	1000	3000	5000	–
Alkali carbonates, CO ₃ & bicarbonate, HCO ₃ (ppm) (maximum) (SANS 241)	0	500	1000	1000	2000	–
Sugar (SANS 833)	Negative	Negative	Negative	Negative	Negative	–
Suitability of Water						
	H0	H1	H2	H3	H4	H5
Untreated layer works	N/A	✓	✓	✓	✓	Investigate effect on quality of material
Chemically treated layer works	N/A	✓	✓	✓	Investigate effect on quality of material	✗
Concrete – mass	N/A	✓	✓	✓	Investigate effect on structural strength	✗
Concrete prestressed	N/A	✓	✓	✗	✗	✗
Slurry emulsion	N/A	✓	✓	✗	✗	✗
Soil/gravel tests	N/A	✓	✓	✗	✗	✗
Chemical or control tests	N/A	✓	✓	✗	✗	✗

Notes

1. A primary property. The quality of the water is that quality where all three of the primary properties are within the limits.

8.2 Concrete for Structures

The cement content, or more correctly the water/cement ratio, dictates the ultimate strength of the concrete. Where normal “strength” concrete is prescribed, conformance to the minimum compression strength class is usually the limiting criteria. Recently, however, a lot of emphasis is placed on ensuring the long term durability of concrete. To ensure that a durable concrete is placed in the coastal regions, or other specifically aggressive environments, the required class is usually specified with a prefix W, e.g., W30/19. The maximum water/cement ratio and minimum cement content should be as prescribed in the project document, usually 0.42 and 420 kg/m³ respectively. In these situations, it is important to remember that strength properties are not the limiting criteria as, due to the low water/cement ratio, the minimum compressive strength values are always significantly exceeded. Conformance should thus be based on the highest value compressive strength obtained at the minimum specified cement content, or maximum water/cement ratio of the mix meeting the specified durability requirements.

Durability is influenced by the materials used in the concrete, their mix proportions, transporting, placing, compacting and, in particular, curing of the finished cover concrete. The cover concrete layer is between the outermost layer of steel reinforcement and the exposed outer surface of the concrete element.

It is the engineer’s responsibility to approve the component materials and their mix properties. However, it is the contractor’s responsibility to utilise acceptable component materials and to achieve mix properties complying with the specifications. It is the contractor’s responsibility to design and blend materials to produce concrete of the specified quality.



Long Term Durability of Concrete

To ensure that a durable concrete is placed in coastal regions, or other specifically aggressive environments, the required class is usually specified with a prefix W, e.g., W30/19. The maximum water/cement ratio and minimum cement content should be as prescribed in the project document, usually 0.42 and 420 kg/m³ respectively.

In these situations, it is important to remember that strength properties are not the limiting criteria as, due to the low water/cement ratio, the minimum compressive strength values are always significantly exceeded.

Conformance should thus be based on the highest value compressive strength obtained at the minimum specified cement content, or maximum water/cement ratio of the mix meeting the specified durability requirements.

8.2.1 Durability Parameters

The durability properties of concrete are assessed using the following terms:

- **Water sorptivity:** Sorptivity is sensitive to surface effects, and may be used to assess the effectiveness of initial curing.
- **Oxygen permeability:** Permeability is sensitive to changes in the coarse pore fraction, and is thus a means of assessing compaction of concrete. It is used to quantify the microstructure of the concrete and is sensitive to macro-defects such as voids and cracking.
- **Chloride conductivity:** Chloride conductivity provides a method of characterising concretes in marine environments, and is used to assess the chloride resistance of concrete.
- **Cover concrete:** Cover concrete is the outer concrete layer that protects reinforcing steel. Concrete cover is a requirement for all concrete, whether specified as durability concrete (Class “W”) or normal reinforced concrete.
- **Individual cover depth measurement (CDM):** Individual cover depth measurement determined by an electromagnetic cover meter, complying with BS 1881, Part 204.
- **Average cover:** The average of at least 30 individual CDM’s per m² determined on a clearly identified area.
- **Overall cover:** The mean average cover determined for the scanned area per structure.
- **Scan area:** Areas of approximately 1 m², randomly distributed over the entire structure, representing at least 5% of total surface area for that structure.
- **Individual bar reading:** A minimum of 3 linear CDM’s, spaced at 100 mm intervals, representing a single bar of reinforcement.
- **Capped CDM:** The value applied to all CDM’s in excess of the maximum allowed CDM, determined by the engineer. For example, 40 mm (specified cover) + 15 mm (upper limit) = 55 mm.
- **Capped Value:** A value in mm, assigned to a cover reading, where the raw reading exceeds the specified cover, plus a value (mm) specified by the engineer.
- **Quick/linear scan:** To evaluate cover depth measurements taken perpendicular to the closest rebar, in a line covering the required area to be scanned.

- **Image/block/grid scan:** Provides an overview of rebar layout. Measurements taken over a square meter clearly indicate the position of the first and second layer of rebar.

Water sorptivity and oxygen permeability tests are required to assess carbonation resistance of the mix proposed. Water sorptivity, permeability and chloride conductivity tests are required to assess chloride resistance of the mix proposed. The specific limits for the various properties, as well as the minimum cover requirements, should be appropriate for the applicable environmental location and specific concrete element, and should be adhered to, irrespective of the actual compressive strengths obtained.

8.3 Concrete Pavements

Research has shown that, in the majority of instances, areas of premature failures on concrete pavements can be attributed to poor workmanship or construction problems, i.e., the failures were “built in”. A very high and continuous level of supervision and quality batching, as well as placing operations, is therefore necessary to eliminate the risk of premature failures.

8.3.1 Monitoring of Batching Operations

Variations in material or batching lead to variations in concrete strengths and consistency. A very useful approach for assessing and/or identifying variation, as well the probable causes thereof, is to manufacture standard mixes in the laboratory. This entails screening out the aggregates, to produce a constant grading. The standard mix is then batched in the laboratory on a daily basis, using the same materials, i.e., cement and admixtures, as used for the works mix, and with the same properties as the approved working mix. A minimum of five cubes should be manufactured from the standard mix, and tested as follows:

- 1 cube for accelerated, **24 hours** testing
- 1 cube for **7 day** testing
- 3 cubes for **28 day** testing

The results of the standard mix testing give a good indication as to the reasons for variations in test results. For example, if the working mix produced low results and the standard mix produced normal results, errors in batching would be the probable cause.

In addition to the manufacture of standard mixes, the following monitoring procedures should also be carried out on a daily basis:

- **Grading and fineness modulus** of aggregates in stockpile
- **Moisture content** of aggregate
- Checking and recording of **batch plant scale settings**
- Record **minimum and maximum temperatures**, and mixing water temperature
- **Sample works concrete from tracks**, remix in the laboratory using a pan type mixer, and manufacture cubes and beams
- **Wet grading** of total mix for grading and fineness modulus
- **Workability testing**, Vebe or slump
- Record results and use **trend sheets**

8.3.2 Monitoring of Paving Operation

Wherever practical, all items and issues listed in the trial pavement checklist should be repeated on a daily basis during the paving operations. Occurrences such as very high/low air temperature or hot berg winds have a significant impact on the integrity of the constructed pavement. High temperatures or strong winds frequently result in the development of drying shrinkage cracks, which are often only noticeable some period after completion of the section. It is a requirement that comprehensive records are maintained with respect to batch delivery, placing, finishing and commencement of initial sawing times. Historically, the repair of spalled edges has only met with limited success and invariably results in a long-term maintenance liability. An example of a spalled edge as a result of form removal is shown in Figure 22. Repair and maintenance of concrete pavements is a specialized field, which should only be undertaken by appropriately



Failures in Concrete Pavements

In the majority of cases, areas of premature failures on concrete pavements can be attributed to poor workmanship or construction problems, i.e., the failures were “built in”. A very high and continuous level of supervision and quality batching, as well as placing operations, is therefore necessary to eliminate the risk of premature failures.

experienced organisations. Considering that concrete pavements are generally designed for a service life exceeding 30 years, any deficiencies or poor workmanship will undoubtedly manifest itself sooner or later. Given the difficulties relating to repair work, a philosophy of “prevention is better than cure” should be followed.



Figure 22. Spalled Edge from Side Form Removal

8.4 Sampling and Testing of Fresh Concrete for Pavements and Structures

When sampling fresh concrete for the manufacture of specimens for compressive and flexural strength characteristics and/or workability or consistency (slump or Vebe), the ideal situation is to do this at the point of final discharge into the relevant formwork. This is, however, not always logistically possible. The following issues need to be evaluated and the most appropriate and practical approach agreed to, prior to commencement of the works:

- **Batch plant:** Is the batch plant dedicated to, or especially erected for, the project, or is it a “commercial” plant simultaneously producing a number of different mixes for other projects/clients? In such cases, it is always preferable to sample at the construction site, as it is often the case that ready-mix suppliers hold back on some of the water, which is only added on site. In such a case, extreme caution should also be exercised when transporting any “green” cubes/beams already extruded from the moulds to the temporary (site) laboratory. Suitable foam trays should always be utilised to prevent any damage during early transport, with resulting questions over the validity of test results,.
- **Place of concrete discharge:** If the place of discharge of the concrete into its final position is relatively close to the temporary (site) laboratory, then it is preferable to sample the concrete on site, and then transport to the laboratory for the manufacture of the relevant test specimens. In situations where a high workability concrete (slump > 50 mm) is tested, such samples should always be remixed in the laboratory prior to placing the concrete in the moulds, to prevent segregation. In addition, it is generally accepted that the level of supervision in the laboratory is generally at a higher level, and, therefore, preferable than a relatively inexperienced person carrying out this operation in isolation. Figure 23 shows the inappropriate manufacture of concrete specimens in a side drain, on an uneven surface.
- **Project location:** The location of the project is also a consideration. Tampering with the specimens, or even the theft of the moulds themselves, has unfortunately, in some instances, been reported.

It is, therefore, essential that the procedure, location and transport of all concrete specimens, both fresh and hardened, is agreed to prior to commencement of the works.



Figure 23. Inappropriate Site Manufacture of Concrete Specimens

9. BLOCK PAVEMENTS

There are various specifications and guideline documents published to assist in the successful construction of block paving. These documents provide adequate information on the construction and quality management of concrete block pavements, and are not repeated herein.

The following publications are most widely used in South Africa:

- **The current specification** in South Africa for the requirements for concrete paving blocks is SANS 1058 – Concrete Paving Blocks.
- **The current specification** in South Africa for the construction of concrete block paving is SANS 1200 MJ – Standard Specification for Civil Engineering Construction: Segmented Paving.
- **The Standard Specifications** also have specifications for block paving, which need to be complied with on COLTO based projects. These specifications may be different to those of SANS and CMA.
- Cement & Concrete Institute (C & CI) issued a technical note “**The Manufacture of Concrete Paving Blocks**” that covers the basic principles of block paving and aims to assist manufacturers to produce a durable and consistent product. This note can be downloaded from www.theconcreteinstitute.org.za.
- CSIR published the **Urban Transport Guideline (UTG2):** Structural Design of Segmental Block Pavements for Southern Africa.
- The **Concrete Manufacturers Association** (CMA) has four manuals on **Concrete Block Paving**. These books can be downloaded from www.cma.org.za. The books are titled:
 - Book 1: Introduction
 - Book 2: Design Aspects
 - Book 3: Specification and Installation
 - Book 4: Site Management and Laying
- The **CMA** also has guideline brochures on several aspects of **concrete block paving**, which can be downloaded from www.cma.org.za.
 - A Step-by-Step Guide to Perfect Paving
 - Good Earthworks Practice
 - Drainage of Concrete Block Paving
 - Technical Note for Steep Slopes
 - Efflorescence is only a Temporary Problem
 - An Introduction to Permeable Concrete Block Paving
- Other very useful guides on various aspects of concrete block paving are publications by the **Concrete Masonry Association of Australia** (CMAA), which can be downloaded from www.cmaa.com.au.

10. PROPRIETARY AND CERTIFIED PRODUCTS

Agrément South Africa carries out quality surveillance on certificate holders for proprietary/certified products. However, unless specific performance issues are brought to its attention, monitoring is carried out on an annual basis and at the time of certificate review only. Therefore, the use of a certified product, as with any other product, does not do away with the need for adequate site supervision. It must also be recognised that the non-standard or innovative nature of the product may mean that the product is not encountered often, and that specific requirements for its successful application are not readily available.

To assist in quality assurance, Agrément South Africa has introduced quality requirements and various conditions of certification that, if adhered to, should ensure that quality is achieved consistently. However, the responsibility for compliance with the requirements of certification and the quality of certificated products reside with the certificate holder.

10.1 Documented Quality System

A requirement of Agrément certification is that the certificate holder and the licensee/s, if any, have an acceptable and documented quality system in place, which covers the manufacture and application or installation, as applicable, of the product. The quality system is based broadly on the requirements of SANS 9001, "Quality Management Systems – Requirements".

10.2 Validity of Agrément Certificates

Users of a product, which is claimed to have an Agrément certificate, should check that the certificate is valid or active. This can be done by visiting Agrément South Africa's website at www.agrement.co.za or by contacting its offices. Inactive certificates are those which, for various reasons, are not currently being used, and therefore certificate holders are not monitored.

Certificates approved by the Board are public documents and should be readily available from the certificate holder, or may be downloaded free of charge from Agrément South Africa's website. Certificates contain sufficient information for site supervisory staff to be able to identify areas of non-compliance or concern.

10.3 Compliance with Certification

Only the certificate holder or appointed licensees registered with Agrément South Africa may claim compliance with the requirements of any Agrément certificate.

10.4 Conditions of Certification

The validity of certificates is reviewed every three years, but remains valid for as long as Agrément South Africa is satisfied that:

- The certificate holder **complies with the general and specific conditions of certification** and the technical requirements of the certificate.
- The **performance in use** of the product is acceptable.
- Changes in legislation, regulations, relevant standards or Agrément performance criteria have not **invalidated the technical assessment** that formed the basis of certification.

Agrément South Africa reserves the right to withdraw a certificate at any time, should reasonable cause exist.

Currently there are a number of road products for which Agrément assessment criteria is available, such as:

- Bridge joints
- Ultra Thin Asphalt Friction Courses (UTFC)
- Non-traditional soil stabilizers
- Bitumen emulsion primes
- "Non-tacky" tack coats



Proprietary and Certified Products

Various aspects of proprietary products are discussed in:

- Chapter 3: **Materials Testing**, Section 6
- Chapter 4: **Standards**, Section 6.2
- Chapter 9: **Materials Utilisation and Design**, Section 14

Agrément South Africa is discussed in Chapter 3: 6.3.

11. REPORTING

11.1 As-Built Reports

Accurate records of all construction work are essential and mandatory. These serve as a measurement of quantity during construction, as well as a post-construction reference for performance monitoring or defects evaluation.

These records must be included in the as-built materials records submission for the construction project and presented in hard copy and electronic format within 6 months of completion of the project. The data sheets, as well as methods of data recording are prescribed in TMH10: Completion of As-Built Materials Data Sheets. The forms are also available in spreadsheet format on the SANRAL website (www.nra.co.za).

11.1.1 Requirements

The following requirements must be included in the as-built records.

(i) Number of Reports

One hard copy and an electronic copy, must be forwarded to the relevant road authority.

(ii) Size

The size of the hard copy is to be the same as for the TMH10 sheets, i.e., A3, or as otherwise agreed with the client.

(iii) Title Page

A green cover is recommended. The title must be the same as that on the Contract documents, and the following must be added:

- **As-Built Materials Test Results** (in the centre of the page)
- Contractor's and Consulting company **names**
- **Commencement and completion dates** of the contract

(iv) Table of Contents

A table of contents must be included as the first page of each book. Where applicable, the data for carriageways, interchanges, and cross roads must be shown separately in the table of contents. Each item is subdivided into the various pavement layers, fills and structures. For dual carriageway roads, most of the structures do not form part of a particular carriageway and must therefore be grouped separately. The actual page numbers on which the test results for the various layers and structures appear should be used.

(v) Table of the True Kilometre Reference versus the Construction Kilometre Reference

Instead of adjusting the kilometre references, a table may be inserted directly after the table of contents, showing the reference kilometres used during construction in relation to the true kilometres references for the road and section. If a simple conversion factor serves the same purpose, it may be used instead. However, an example of how it should be applied must also be included.

(vi) Key Plan

A key plan showing the road constructed under the contract is required. Normally this is a reproduction of the key plan in the contract documents. If not indicated, the following information should be clearly marked on the key plan as referred to on the test results sheets:

- Kilometre distance
- Carriageways
- Cross roads, names and road numbers
- Names of interchanges
- Numbering of interchange ramps
- Structure numbers and actual distances
- Culverts and their numbers, normally these are numbered by the site staff
- Numbers of fills and cuts, also numbered by site staff
- Borrow pits, quarries and their numbers. In many cases, it is not possible to have all the information on one key plan, in which case separate plans for borrow pits or quarries are preferred.

At the start of the contract, the engineer should prepare key plans for the structures in section and plan, indicating the numbering system for piles, footings, abutments, columns and beams to serve as an index for the tests results. These key plans are, however, not to be bound in front of the book but under the subsection for the relevant structures.

11.1.2 Design Sheets

Design sheets should be divided into the following:

- Pavement designs (freeway and minor roads)
- Asphalt mix designs
- Surface seals
- Concrete mix designs
- Stabilization designs

These designs are to be bound in a separate section of the most appropriate book of the set.

(i) Pavement Designs

These are to be listed in A3 size, or a reproduction of some of the relevant plans in the contract documents may be used. These designs should, however, reflect the as-built conditions, which are not always according to the original plans. The addition of extra layers, or stabilization or modification of certain layers, due to unstable in situ conditions requires special mention.

(ii) Asphalt, Concrete and Stabilization Mix Designs

The complete designs, with reference to the material properties as required in the contract documents, description, source, properties of the mixes with relevant confirmation data, must be prepared separately on appropriate forms. These are to be included under the subsection "design" in the as-built materials books.

11.1.3 Subsurface Drainage

A table or diagrammatic representation showing the location, and lengths, of subsurface drains is required. If possible, the average depth of installation and the typical design(s) is also to be indicated.

11.1.4 Non-Conforming Work

For future ease of reference and possible assessment, a suitable table for inclusion in the record books should be compiled, listing all the conditionally accepted work, as well as rejected work, which has been allowed to remain in place.

11.1.5 Weather Record

A chart showing the rainfall record, and the minimum and maximum temperature for the duration of the contract, is required. When strong wind conditions prevail during times of curing of structures or pavement layers, this must be recorded and included as part of the weather record.

11.1.6 Miscellaneous

The test results of materials delivered into stockpiles prior to their use for asphalt and concrete are not required for as-built purposes, but these are to be kept by the engineer for two years. The results of loading tests performed on beams, piles or any other part of structures must be bound into the as-built book in the appropriate subsection.

The treatment of roadbeds is to be entered on the AB 2+3 sheets, and/or on a separate sheet showing the details, e.g., 3 pass roller compaction, 90% roadbed preparation, or pioneer layer.

For easy reference purposes, dividers of coloured paper must be used between sections, subsections and test results for the various layers. The correct



As-Built Pavement Designs

The pavement designs in the as-built records should reflect the as-built conditions, which are not always the same as the original designs. The addition of extra layers, or stabilization or modification of certain layers, due to unstable in situ conditions, requires special mention.



Non-Conforming Work

For future ease of reference and possible assessment, a suitable table for inclusion in the record books should be compiled, listing all the conditionally accepted work, as well as rejected work which has been allowed to remain in place.



Payment of Supervisory Fee

The retention monies retained by the client from the Engineers supervisory fee claims can only be released on submission of the as-built Materials records, together with the as-built drawings and contract reports.

symbols and codes must be utilised wherever applicable.

The presentation of the test results in draft form must be discussed and approved by the client before the as-built materials Books are finally printed and bound.

The engineer must retain and safeguard the original laboratory sample register, laboratory working forms and working copies of the TMH10 sheets until the end of the official maintenance period. Once this period has expired, application must be made in writing to the client for approval to destroy these records.

It should be noted that the retention monies retained by the client from the engineer's supervisory fee claims can only be released on submission of these as-built Materials records, together with the as-built drawings and contract reports.

11.2 Completion/Construction Report

11.2.1 Contractual Aspects

Part of the engineer's fulfilment of their construction monitoring obligations is the submission of an accepted contract report. Only after acceptance of the final report by the client, are all retention monies or outstanding fee claims released for payment.

11.2.2 Requirements

The following information, as pertaining to the project, is to be recorded and included in the final Contract Report:

- **Pavement layers.** Report briefly on the type of layers constructed and the material source.
- **Special and/or unusual methods.** There is no need to describe routine or normal activities. Mention only special and/or unusual methods, activities or equipment used by the contractor and the results of such use on production and/or quality. Problems overcome by special techniques should be mentioned.
- **Adjustments to program.** Any adjustment to the programme of works, giving reasons for, adjustments made and results thereof must be included.
- **Problems with materials.** Report on any problems experienced in the supply of materials and the result thereof, such as work stoppage and/or delay, re-scheduling, reprogramming, alternative materials or methods used. Report on problems, or unusual or interesting aspects, encountered with the materials used.
- **Additional work.** Describe any additional work of a significant nature or quantity, including any effect on the contract period and programme.
- **Traffic accommodation.** Give a brief description of the method used. If there are unusual or special aspects of this topic, enlarge upon the subject. Report on traffic related incidents related to traffic accommodation measures.
- **Changes to plans and specifications.** Include any changes to plans or specifications not already covered, and explain the reasons for the changes.
- **Unforeseen conditions.** Include any other unusual or unforeseen conditions and problems encountered, how they were dealt with, and the effect on progress and/or cost.
- **Improvements to specifications.** Give examples of problems that arose under any of the following items, together with proposals for improvement, with a view to preventing a recurrence on future projects:
 - General and special conditions of contract
 - Standard specifications and project specifications
 - Roadwork plans
 - Materials documentation
 - Standards or laid down procedures of the client
 - Other
- **Changes to material usage and/or specifications.** Discuss any changes made to the planned materials usage and/or treatment, explaining why the changes were considered necessary, and the reasoning behind the adopted solution.
- **Experimental work.** Report on the nature of, and reasons for, any experimental work included in the permanent work. The precise locality of the experimental work must be clearly defined, and the method used to



Traffic Accommodation

A brief description of the traffic accommodation method used must be included in the Completion/Construction Report. This includes discussion on unusual or special aspects, and traffic related incidents.

identify the experimental work at the site described. State what arrangements have been made for future monitoring.

- **Sub-Standard work.** List all work that does not comply with the specifications, but which has been permitted to remain in place. The details of the work and action taken, e.g., guarantee given or reduced payment, the estimated level of performance, together with the precise locality, must be stated.
- **Testing.** Provide information on laboratories used, and whether combined laboratories were used. Discuss correlation of results of tests carried out on site and those processed elsewhere, as well as test result disputes. Discuss problems encountered.
- **Photo record.** Provide photos and descriptions of the construction process. Ensure “before” and “after” type photos are available for stockpile, precoating, borrow areas and quarries.

REFERENCES AND BIBLIOGRAPHY

- AASHTO. 1966. **Highway Materials, Part 2: Standard Methods of Sampling and Testing Highway Materials.** 9th edition. Washington, DC. American Association of State Highway Officials.
- AFCAP. 2013. **Guideline on the Use of Sand in Road Construction in the SADC Region.** African Community Access Program. InfraAfrica (Pty) Ltd, Botswana; CSIR, South Africa; TRL Ltd, UK; Roughton International, UK; CPP Botswana (Pty) Ltd. AFCAP/GEN/028/C. Download from www.afcap.org.
- ASTM International. **Standards and Test Methods for Road Building Materials.** www.astm.org.
- CMA. 2009. **Concrete Block Paving.** Book 1: Introduction; Book 2: Design aspects; Book 3: Specification and installation; Book 4: Site management and laying. 5th edition 2009. Published by the Concrete Manufacturers' Association (CMA). Download from www.cma.org.za.
- COLTO. 1998. **Standard Specifications for Road and Bridge Works for State Road Authorities.** Committee for Land and Transport Officials. Pretoria. These specifications are currently being revised.
- FULTON'S Concrete Technology.** 2009. 9th edition, Cement & Concrete Institute, Midrand, South Africa, 2009. ISBN 978-0-9584779-1-8
- FHWA. 1980. **Design and Construction of Shale Embankments.** Report FHWA-TS-80-219. U.S. Department of Transportation, Federal Highway Administration. Washington 1980.
- GREGSON, K. 1990. *The Lime Acres Experience – Rehabilitation in Semi-Desert Conditions.* **Institute of Quarrying Conference.** March 1990.
- HIGGS, N.B. 1976. *Slaking Basalts.* **Bulletin of the Association of Engineering Geologists.** Volume 13, Number 2.
- KANTEY, B.A. and Brink, A.B.A. 1995. *Laboratory Criteria for Recognition of Expansive Soils.* **NBRI Bulletin No 9.** pp 25-28.
- MATHESON, G.M. 1986. *Relationship Between Compacted Rockfill Density and Grading,* **Journal of Geotechnical Engineering,** Vol. 112 No 12, December 1986, pp 1119-1125.
- NCHRP. 1971. **Construction of Embankments High.** National Cooperative Highway Research Program 8. Transportation Research Board, 1971.
- SABITA Manual 8. 2011. **Guidelines for the Safe and Responsible Handling of Bituminous Products.** Fourth Edition. ISBN 978-1-874968-51-1. Available for a fee from www.sabita.co.za
- SABITA Manual 26. 2011. **Interim Guidelines for Primes and Stone Precoating Fluids.** ISBN 978-1-874968-54-2. Available for a fee from www.sabita.co.za
- SABITA Manual 28. 2011. **The Design and Construction of Slurry Seals.** Sabita. ISBN 978-1-874968-42-9 Available for a fee from www.sabita.co.za.
- SABS 309. 1972. **Standard Specifications for Anionic Bitumen Road Emulsions.** Amended. South African Bureau of Standards. (soon to be updated to SANS 4001-BT3)
- SABS 548. 1972. **Standard Specifications for Cationic Bitumen Road Emulsion.** Amended. South African Bureau of Standards. (soon to be updated to SANS 4001-BT4)
- SABS CKS78. 1972. **Standard Specifications for Illuminating Paraffin.** Amended. South African Bureau of Standards.
- SABS CKS215. 1972. **Standard Specifications for Power Kerosene.** Amended. South African Bureau of Standards.
- SABS CKS342. 1969. **Standard Specifications for Automotive Diesel-Fuel.** Amended. South African Bureau of Standards.
- SANRAL. 2006. **Drainage Manual.** 5th - Edition fully Revised. South African National Roads Agency Limited. ISBN 1-86844-328-0.

South African Pavement Engineering Manual

Chapter 13: Quality Management

- SANRAL. 2011. **Construction Monitoring Manual for Bridges and Structures**. 2nd Edition. South African National Roads Agency SOC Limited. www.nra.co.za
- SANS 1200 Series. 2010. **Standardized Specifications for Civil Engineering Construction**. SABS webstore www.sabs.co.za.
- SANS 3001 Series. 2010. **Test Methods to Replace Those in TMH1**. SABS webstore www.sabs.co.za.
- SANS 4001 Series. 2012. **Civil Engineering Test Methods**. SABS webstore www.sabs.co.za. (Note: Part BT1, Penetration Grade Bitumen and BT2, Cutback Bitumen published in 2012. Part BT3, Anionic Emulsions, BT4, Cationic Emulsions and BT5 Inverted Emulsions are currently under review by SABS.)
- SANS 9001. 2000. **Quality Management Systems – Requirements**. SABS webstore www.sabs.co.za.
- TARRY, V.H. and Donaghe, R.T. 1994. *Compaction Control of Earth-Rock Mixtures: A New Approach*, **Geotechnical Testing Journal**, Volume 17, Number 3, September 1994, pp 371-386.
- TG1. 2007. Technical Guideline: **The Use of Modified Bituminous Binders in Road Construction**. Second edition. Published by the Asphalt Academy. (available for download on www.asphaltacademy.co.za)
- TG2. 2009. **Technical Guideline: Bituminous Stabilised Materials – A Guideline for the Design and Construction of Bitumen Emulsion and Foamed Bitumen Stabilised Materials**. Second edition May 2009. ISBN 978-0-7988-5582-2, published by the Asphalt Academy. (available for download on www.asphaltacademy.co.za)
- TMH5. 1981. **Sampling Methods for Road Construction Material**. Committee of State Road Authorities. Pretoria (available for download www.nra.co.za)
- TMH10. 1993. **Manual for Completion of As-built Data Sheets**. Committee of State Road Authorities. Pretoria (available for download www.nra.co.za)
- TRH3. 2007. **Design and Construction of Surfacing Seals**. Technical Recommendations for Highways. ISBN 0 7988 2272 4. CSRA. Pretoria (available for download www.nra.co.za)
- TRH14. 1985. **Guidelines for Road Construction Materials**. Technical Recommendations for Highways. ISBN 0 7988 3311 4. CSRA. Pretoria (available for download www.nra.co.za)
- TRH21. 2009. **Hot Recycled Asphalt**. Draft published by Sabita. (Available for download on www.sabita.co.za)
- VERHAEGHE, B.M.J.A., 1998. **Draft Framework for Quality Assurance Contracting in the South African Asphalt Industry**. SABITA/CSIR Report: Contract Report CR-98/041. Pretoria.



TRH Revisions

Many of the TRH guideline documents are in the process of being updated. See the SANRAL website, www.nra.co.za for the latest versions.

CHAPTER 13: QUALITY MANAGEMENT: APPENDICES

Appendix A.	Example Random Number Table	A-1
Appendix B.	Acceptance Control Worksheets.....	B-1
Appendix C.	Normal Completion Times for Acceptance Control Testing	C-1
Appendix D.	Testing Frequency Tables	D-1

APPENDIX A. EXAMPLE RANDOM NUMBER TABLE

Rx	Ry	Rx	Ry	Rx	Ry
0.9382	0.1974	0.1816	0.1308	0.8038	0.7468
0.9692	0.8352	0.5755	0.5277	0.2194	0.3679
0.0031	0.5427	0.5255	0.9595	0.7420	0.6207
0.2824	0.0921	0.2175	0.3737	0.2825	0.2732
0.0029	0.3959	0.4083	0.9840	0.5795	0.6093
0.8135	0.0074	0.9436	0.7691	0.6999	0.9282
0.3164	0.6203	0.2410	0.9739	0.5388	0.0448
0.5667	0.5692	0.7944	0.6084	0.3193	0.7897
0.5727	0.3291	0.6811	0.9487	0.0927	0.5091
0.7958	0.0158	0.0532	0.0362	0.2384	0.5648
0.6505	0.8856	0.6415	0.1780	0.9638	0.8343
0.0046	0.8355	0.2551	0.4469	0.8047	0.2107
0.6789	0.9031	0.2813	0.1812	0.1247	0.1025
0.9472	0.7666	0.1854	0.4851	0.6159	0.9342
0.0366	0.2449	0.0109	0.7280	0.7982	0.6456
0.6273	0.7974	0.8792	0.0453	0.5197	0.1924
0.3527	0.0242	0.4902	0.8378	0.4569	0.0458
0.2990	0.1661	0.6217	0.2721	0.6138	0.6924
0.5060	0.6044	0.6295	0.7802	0.8232	0.1349
0.4661	0.3611	0.9479	0.5600	0.2458	0.3912
0.6254	0.5987	0.5890	0.0748	0.8701	0.9951
0.8826	0.1206	0.6431	0.5535	0.0133	0.4959
0.0898	0.8705	0.7787	0.4909	0.8202	0.9584
0.5522	0.4329	0.7424	0.1472	0.7640	0.4634
0.5282	0.5329	0.8589	0.0483	0.1461	0.6068
0.7291	0.5362	0.5310	0.4856	0.5957	0.0007
0.8194	0.9492	0.7396	0.0163	0.5704	0.7724
0.9169	0.9189	0.5440	0.9632	0.8559	0.0650
0.0924	0.7329	0.5812	0.9146	0.0658	0.5372
0.8697	0.3193	0.5665	0.2245	0.1421	0.8632
0.7260	0.7470	0.7936	0.5216	0.8549	0.2331
0.4914	0.7255	0.6339	0.1642	0.3023	0.8524
0.3492	0.1050	0.0371	0.8300	0.4105	0.4423
0.3358	0.3760	0.0311	0.9266	0.4340	0.7397
0.8409	0.1700	0.2218	0.1362	0.4552	0.9968
0.6070	0.7590	0.2934	0.9064	0.8849	0.4819
0.3299	0.5554	0.5079	0.9507	0.9616	0.9786
0.1586	0.6127	0.2058	0.7481	0.2524	0.2863
0.1952	0.1245	0.3056	0.0432	0.1524	0.7198
0.9948	0.9254	0.8037	0.3462	0.3845	0.6097

APPENDIX B. ACCEPTANCE CONTROL WORKSHEETS

Acceptance Control Work Sheet for Lime/Cement Stabilised Layers

Acceptance Control Work Sheet for G1 - G3 Granular Layers

Acceptance Control Work Sheet for G4 - G9 Granular Layers

Acceptance Control for G10 Earthworks

Acceptance Control Work Sheet for Asphalt: Binder Content and Percent Voids

Acceptance Control Work Sheet for Asphalt: Compaction and Layer Thickness

Check List for Visual Acceptance Control Testing of Asphalt Layers

Acceptance Control for Concrete Pavement

Nuclear Density Check List

Normal Completion Times for Acceptance Control Testing

Acceptance Control Work Sheet for Lime/Cement Stabilised Layers																
CONTRACT:					LAYER:					CARRIAGEWAY:						
LANE:					CHAINAGE: _____ to _____ km											
SECTION WIDTH: _____ m					SECTION LENGTH: _____ m					DATE:						
RELATIVE COMPACTION: $L_s =$ _____ %																
% RELATIVE COMPACTION																
SAMPLE SIZE (n)	4	5	6	7	8	9	n	%	n	%	n	%	n	%		
Ka	0.220	0.300	0.358	0.403	0.440	0.470	2		5		8					
T	1.46	1.67	1.82	1.94	2.03	2.11	3		6		9					
RELATIVE COMPACTION:																
L_a _____ $X_n =$ _____ $S_n =$ _____																
OUTLIER TEST:							JUDGEMENT LIMITS:									
Sample No _____ Value (X_o)							$L_a = L_s - k_a S_n =$ _____ - _____ = _____									
$T_o = \frac{X_o - X_n}{S_n} =$ _____							$L'a = L_s - k_{ad} S_n =$ _____ - _____ = _____									
If T_o is bigger than T, result is an outlier. Analyse reasons.							$L_r = L_a - 2.00 \% =$ _____ - 2.00 = _____									
							$fr = \frac{\{0.67 + 0.3 \frac{X_n - L_r}{L_a - L_r}\}}{L_a - L_r} =$ _____									
STABILISER CONTENT: $L_s =$ _____ %							n	%	n	%	n	%	n	%	n	%
SAMPLE SIZE (n)	10	12	14	16	18	20	1		5		9		13		17	
ka	0.713	0.755	0.789	0.817	0.840	0.860	2		6		10		14		18	
T	2.18	2.29	2.37	2.44	2.50	2.56	3		7		11		15		19	
							4		8		12		16		20	
STABILISER CONTENT:																
$L_a =$ _____ $L'a =$ _____ $X_n =$ _____ $S_n =$ _____																
OUTLIER TEST:							JUDGEMENT LIMITS:									
Sample No _____							$L_a = L_s - k_a S_n =$ _____ = _____ = _____									
Value (X_o) = _____							$L'a = L_s - k_{ad} S_n =$ _____ = _____ = _____									
$T_o = \frac{X_o - X_n}{S_n} =$ _____							$L_r = 0.08 L_a =$ _____ = _____ = _____									
If T_o is bigger than T, result is an outlier. Analyse reasons.							$fr = \frac{\{0.67 + 0.3 \frac{X_n - L_r}{L_a - L_r}\}}{L_a - L_r} =$ _____ = _____ = _____									
ASSESSMENT: RELATIVE COMPACTION							ASSESSMENT: STABILISER CONTENT									
$X_n \geq L_a$ Accept							$L_a \leq X_n \leq L'a$ Accept									
$L_r \leq X_n \leq L_a$ Accept Payment							$L_r \geq X_n \leq L_a$ % Payment									
$X_n \leq L_r$ Reject							$X_n \leq L_r$ Reject									
VISUAL ASSESSMENT:																
Stabiliser spread rate checked: tanker/bags							Wet areas/Soft spots									
Moisture content at compaction (%)							Layer thickness, Dmax: D90 within tolerances									
Completion within allowed time hours							Surface tolerances: Grade and level									
Segregation evident: Yes/no							Curing adequate: No rapid drying out									
Signature Inspector							Signature Resident Engineer									
Date:							Date:									

Acceptance Control Work Sheet for G1 - G3 Granular Layers														
CONTRACT:				LAYER:				CARRIAGEWAY:						
LANE:				CHAINAGE:				to km						
SECTION m		WIDTH:		SECTION LENGTH:				m		DATE:				
PROPERTY		PERCENTAGE PASSING SIEVE												
SIEVE SIZE (mm)		37.5	26.5	19.0	13.2	4.75	2.00	0.425	0.075	PI				
SAMPLE		n	TEST VALUES: X_o											
	1													
	2													
	3													
	4													
	5													
	6													
	7													
	8													
SPECIFICATION REQUIREMENTS : RELATIVE COMPACTION % $L_s =$														
						COMPACTION								
SAMPLE SIZE (n)	6	7	8	9	10	n	%	n	%	n	%	n	%	
ka	0.358	0.403	0.440	0.470	0.496	1		4		7		10		
kr	0.089	0.158	0.211	0.255	0.292	2		5		8		11		
T	1.82	1.94	2.03	2.11	2.18	3		6		9		12		
OUTLIER TEST:						JUDGEMENT LIMITS:								
Sample No						$X_n =$ _____								
Value (X_o)						$S_n =$ _____								
$To = \frac{X_o - X_n}{n} =$						$K_a =$ _____								
If To is bigger than T , result is an outlier. Analyse reasons.						$La = L_s + k_a \times S_n =$ _____ + _____ = _____								
ASSESSMENT: RELATIVE COMPACTION														
$X_n \geq La$						ACCEPT				REJECT				
VISUAL ASSESSMENT:														
Previous layer still acceptable						Wet Areas								
Segregation evident						Layer thickness, $D_{max}:D_{ave}:D_{90}$ within tolerances								
Excess fines brought to the surface						Surface Tolerances: Grade & Level								
Excess fines swept from surface						Insitu moisture 50% of OMC								
Layer firm and stable in mosaic						Actual in situ moisture content								
Signed Inspector:						Signed Resident Engineer:								
Date						Date								

Acceptance Control Work Sheet for G4 - G9 Granular Layers

CONTRACT:			LAYER:			CARRIAGEWAY:		
LANE:			CHAINAGE:			to km		
SECTION WIDTH: m			SECTION LENGTH: m			DATE:		

PROPERTY		PERCENTAGE PASSING SIEVE							GM	PI
SIEVE SIZE: (mm)		53.0	37.5	19.0	4.75	2.00	0.425	0.075		

SAMPLE	n	TEST VALUES: X_o									
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										

RELATIVE COMPACTION REQUIREMENTS:								$\emptyset = 15 \%$			
--	--	--	--	--	--	--	--	---------------------	--	--	--

FACTORS								% RELATIVE COMPACTION					
SAMPLE SIZE (n)	4	5	6	7	8	9	10	n	%	n	%	n	%
ka	0.220	0.300	0.358	0.403	0.440	0.470	0.496	1		4		7	
kr	0.148	0.04	0.089	0.158	0.211	0.255	0.292	2		5		8	
T	1.46	1.67	1.82	1.94	2.03	2.11	2.18	3		6		9	

OUTLIER TEST: Sample No: _____ Value (X_o) = _____ $To = \frac{X_o - X_n}{S_n}$ If To is bigger than T, result is an outlier. Analyse reasons.	JUDGEMENT LIMITS: $X_n =$ _____ $L_s =$ _____ $La = L_s + k_a * S_n = \quad + \quad =$ _____
--	--

ASSESSMENT:	
$X_n \geq La$	ACCEPT
$X_n < La$	REJECT

MDD (kg/m³)	OMC (%)	CBR @ SPECIFIED DENSITY			SWELL@	
		98%	95%	93%	%	
					%	
					%	
					%	

VISUAL ASSESSMENT					YES / NO	
Previous layer still acceptable Segregation evident Over size removed Firm well-knit surface obtained Excess fines swept from surface		Presence of Biscuit Layers				
		Wet areas / Soft spots				
		Layer thickness, Dmax: Dave: D 90 within tolerances				
		Surface tolerances: Grade and level				

Signature Inspector Date	Signature Resident Engineer Date
--	--

Acceptance Control for G10 Earthworks													
CONTRACT:				LAYER:				CARRIAGEWAY:					
LANE:				CHAINAGE:				to km					
SECTION WIDTH: m				SECTION LENGTH: m				DATE:					
PROPERTY		PERCENTAGE PASSING SIEVE								GM		PI	
SIEVE SIZE: (mm)		63.0	53.0	37.5	19.0	4.75	2.00	0.425	0.075				
SAMPLE	n	TEST VALUES: X _o											
	1												
	2												
	3												
	4												
	5												
	6												
	7												
	8												
RELATIVE COMPACTION REQUIREMENTS:										Ø = 15 %			
FACTORS								% RELATIVE COMPACTION					
Sample Size (n)	4	5	6	7	8	9	10	n	%	n	%	n	%
k _a	0.220	0.300	0.358	0.403	0.440	0.470	0.496	1		4		7	
k _r	0.148	0.040	0.089	0.158	0.211	0.255	0.292	2		5		8	
T	1.46	1.67	1.82	1.94	2.03	2.11	2.18	3		6		9	
OUTLIER TEST: Sample No: Value (X _o) = To = $\frac{X_o - X_n}{S_n}$ = If To is bigger than T, result is an outlier. Analyse reasons.								JUDGEMENT LIMITS: X _n = _____ L _s = _____ La = L _s + k _a * S _n = + = _____					
ASSESSMENT: X _n ≥ L _a ACCEPT/REJECT													
MDD (kg/m³)	OMC (%)	CBR @ SPECIFIED DENSITY				90%	SWELL@						
		100 %	95 %	93 %									
							%						
							%						
							%						
VISUAL ASSESSMENT:													
Moisture content at compaction					Oversize material removed								
Wet area					Biscuit layers								
Signature Inspector					Signature Resident Engineer								
Date					Date								

Acceptance Control Work Sheet for Asphalt: Binder Content and Percent Voids																					
CONTRACT:						LAYER:						CARRIAGEWAY:									
LANE:						CHAINAGE: to km															
SECTION WIDTH: m						SECTION LENGTH: m						DATE:									
SAMPLE SIZE (n)	FACTORS					VOIDS								% BINDER CONTENT							
	4	5	6	7	8	n	%	n	%	n	%	n	%	n	%	n	%				
ka	0.220	0.300	0.358	0.403	0.440	1		4		7		1		4		7					
kad	0.061	0.163	0.235	0.290	0.334	2		5		8		2		5		8					
T	1.46	1.67	1.82	1.94	2.03	3		6				3		6							
BINDER CONTENT SPEC									% VOIDS SPEC												
Ls = Ls' = Xn =									Ls = Ls' = Xn =												
STANDARD DEVIATION Sn =									STANDARD DEVIATION Sn =												
OUTLIER TEST Sample No Value (Xo) To = $\frac{X_o - X_n}{S_n}$ = If To is bigger than T, result is an outlier. Analyse reasons.									OUTLIER TEST Sample No Value (Xo) To = $\frac{X_o - X_n}{S_n}$ = If To is bigger than T, result is an outlier. Analyse reasons.												
JUDGEMENT LIMITS									JUDGEMENT LIMITS												
La	=	Ls + kaSn	=	+	=	La	=	Ls + kaSn	=	+	=	La	=	Ls + kaSn	=	+	=				
L'a	=	Ls + kadSn	=	+	=	L'a	=	Ls + kadSn	=	+	=	L'a	=	Ls + kadSn	=	+	=				
Lr	=	La – 0.2 %	=	– 0.2%	=	Lr	=	La – 0.3 %	=	– 0.3%	=	Lr	=	La – 0.3 %	=	– 0.3%	=				
L'r	=	L'a + 0.2 %	=	+0.2%	=	L'r	=	L'a + 0.3 %	=	+ 0.3%	=	L'r	=	L'a + 0.3 %	=	+ 0.3%	=				
fr _i	=	$0.67 + 0.3 \frac{X_n - L_r}{L_a - L_r}$	=		=	fr _i	=	$0.67 + 0.3 \frac{X_n - L_r}{L_a - L_r}$	=		=	fr _i	=	$0.67 + 0.3 \frac{X_n - L_r}{L_a - L_r}$	=		=				
fr _u	=	$0.67 + 0.3 \frac{L'_r - X_n}{L'_r - L'_a}$	=		=	fr _u	=	$0.67 + 0.3 \frac{L'_r - X_n}{L'_r - L'_a}$	=		=	fr _u	=	$0.67 + 0.3 \frac{L'_r - X_n}{L'_r - L'_a}$	=		=				
ASSESSMENT: BINDER CONTENT									ASSESSMENT: % VOIDS												
La ≤ Xn ≤ L'a		ACCEPT							La ≤ Xn ≤ L'a		ACCEPT										
Lr ≥ Xn ≤ La		% PAYMENT							Lr ≥ Xn ≤ La		% PAYMENT										
L'a ≤ Xn ≤ L'r		% PAYMENT							L'a ≤ Xn ≤ L'r		% PAYMENT										
Lr ≥ Xn ≥ L'r		REJECT							Lr ≥ Xn ≥ L'r		REJECT										
Signature Inspector									Signature Resident Engineer												
Date:									Date:												

Acceptance Control Work Sheet for Asphalt: Compaction and Layer Thickness

CONTRACT:				LAYER:				CARRIAGEWAY:							
LANE:				CHAINAGE: to				km							
SECTION WIDTH: m				SECTION LENGTH: m				DATE:							
Ls = 97% - Design mix voids								Ø = 15 %							
FACTORS:								n	%	n	%	n	%		
SAMPLE SIZE (n)	4	5	6	7	8	9	10	1		4		7			
ka	0.220	0.300	0.358	0.403	0.440	0.470	0.49	2		5		8			
T	1.46	1.67	1.82	1.94	2.03	2.11	2.18	3		6		9			
La = Xn =								STANDARD DEVIATION: Sn =							
OUTLIER TEST: Sample No Value (Xo) To = $\frac{X_o - X_n}{S_n}$ If To is bigger than T, result is an outlier. Analyse reasons.								JUDGEMENT LIMITS: La = Ls + kaSn = + = Lr = La - 1.00% = + 1.00 % = fr = 0.67 + 0.3 $\frac{X_n - L_r}{L_a - L_r}$							
Base Surfacing			D90 -15 -15		Actual		Dmax -20 -8		Actual		Dave -5 -2		Actual		
SAMPLE SIZE (n)	4	5	6	7	8	9	10								
ka	0.220	0.300	0.358	0.403	0.440	0.470	0.49								
T	1.46	1.67	1.82	1.94	2.03	2.11	2.18								
SPECIFICATION REQUIREMENTS : LAYER THICKNESS								LAYER THICKNESS: mm							
MEAN Xn =								STANDARD DEVIATION Sn =							
OUTLIER TEST Sample No Value (Xo) To = $\frac{X_o - X_n}{S_n}$ If To is bigger than T, result is an outlier. Analyse reasons.								JUDGEMENT LIMITS D ₉₀ = _____ % Dmax = _____ % Dave = _____ %							
ASSESSMENT: RELATIVE COMPACTION								ASSESSMENT: LAYER THICKNESS							
Xn ≥ La		ACCEPT				D90		ACCEPT							
Lr ≥ Xn ≤ La		ACCEPT PAY				Dmax		ACCEPT							
Xn ≤ Lr		REJECT				Dave		REJECT							
VISUAL ASSESSMENT								YES / NO							
Segregation evident								Binder rich spots							
Mix temp on delivery								Layer thickness within tolerances							
Mat temp during rolling								Surface tolerances: Grade and level							
Tearing of mat behind screed								Uniform App of PC chips							
Signature Inspector								Signature Resident Engineer							
Date:								Date							

Acceptance Control Visual Checklist For Asphalt

Acceptance Control Visual Checklist For Asphalt					
Contract No.					
Date					
Asphalt layer					
Location					
Section limits					
		Acceptance			
		Yes	No	Comments	
Surface Condition	Segregated areas				
	Fatty areas				
	Contamination (oil or diesel spills)				
Condition of joints	Longitudinal				
	Transverse				
Comments: 					
Inspector Details					
Name:			Signature:		
			Date		

Acceptance Control for Concrete Pavement												
CONTRACT:			CARRIAGEWAY:					LANE:				
CHAINAGE:			to km					DATE:				
CLASS			SLUMP mm					TIME:				
SPECIFICATION REQUIREMENTS : 28- DAY STRENGTH:											Ø = 5 %	
SAMPLE SIZE (n)	4	5	6	7	8	9	10	12	14	16	18	20
ka	0.745	0.821	0.878	0.923	0.961	0.993	1.020	1.065	1.101	1.131	1.155	1.177
T	1.46	1.67	1.82	1.94	2.03	2.11	2.18	2.29	2.37	2.44	2.50	2.56
COMPRESSIVE STRENGTH						FLEXURAL STRENGTH						
Sample No	MPa		Sample No	MPa		Sample No	MPa		Sample No	MPa		
MEAN: Xn =						MEAN: Xn =						
STANDARD DEVIATION: Sn =						STANDARD DEVIATION: Sn =						
OUTLIER TEST: Sample No: Value (Xo) To = $\frac{Xo - Xn}{Sn}$ If To is bigger than T, result is an outlier. Analyse reasons.						OUTLIER TEST: Sample No: Value (Xo) To = $\frac{Xo - Xn}{Sn}$ If To is bigger than T, result is an outlier. Analyse reasons.						
JUDGEMENT LIMITS:						JUDGEMENT LIMITS:						
La	=	LS + kaSn	=	+	=	La	=	LS + kaSn	=		=	
Lr	=	0.85 * LS	=	0.85 *	=	Lr	=	0.85 * fc	=	0.85 *	=	
Fr	=	$0.67 + 0.3 \frac{Xn - Lr}{La - Lr}$	=	0.67 +	=	fr	=	$0.67 + 0.3 \frac{Xn - Lr}{La - Lr}$	=	0.67 +	=	
ASSESSMENT : COMPRESSIVE STRENGTH						ASSESSMENT: FLEXURAL STRENGTH						
Xn ≥ La			ACCEPT			Xn ≥ La			ACCEPT			
Lr ≤ Xn ≤ La			% PAYMENT			Lr ≤ Xn ≤ La			% PAYMENT			
Xn ≤ Lr			REJECT			Xn ≤ Lr			REJECT			
VISUAL ASSESSMENT:												
Segregation evident								Surface texture to spec				
Time lapse from mixing to placement, max 60 mins								Curing as specified				
Bleeding evident								Joints, formed within time period				
								Joints, washed out and sealed				
Signature Inspector						Signature Resident Engineer						
Date:						Date:						

Nuclear Density Check List	
Check	Confirm/ Reject (Y/N)
1. Has the operator proved capable of operating the instrument and is acquainted with all the safety precautions?	
2. Confirm the log-book has been completed every time the gauge has been, and is, removed from its storing facility.	
3. All transport radiation labels are placed on the transport vehicle when transporting the gauge.	
4. The gauge source is locked in the shielded or off position.	
5. The emergency procedures in case of an accident, and the relevant emergency telephone numbers are available.	
6. The shutter mechanism is thoroughly cleaned.	
7. The battery is fully charged.	
8. The gauge is locked in its shipment box when not in use.	
9. The following documents are with the gauge: a. <i>Monthly standard counts log-book</i> b. <i>Operational manual</i> c. <i>Compliance certificate (12 months)</i> d. <i>Leak test results (certified)</i> e. <i>Authorisation to operate the nuclear gauge</i> f. <i>Authority to possess a nuclear gauge issued by the Department of Health</i>	
10. The following must be carried out before the operation of any count: a. <i>Gauge is in the correct test mode.</i> b. <i>All offsets have been disabled.</i> c. <i>Correct depth measurement has been selected.</i> d. <i>Correct time duration of the count has been selected (4 minutes for standard count and 1 minutes for field count).</i> e. <i>Material's MDD and OMC are entered into the gauge's memory.</i> f. <i>Area is cordoned off with appropriate signage.</i> g. <i>Gauge is warmed-up for 20 minutes, or according to the manufactures instructions, before operation to allow the regulators and detectors to stabilise. Source rod should be in the "safe" position at all times during the warm-up period.</i>	
11. Gauge should be at least 10 m away from any other nuclear device, and at least 3 m away from other objects, to prevent external factors influencing the density measurements.	
12. The following is ensured during pre-drilling of the hole to accommodate the source probe. and during insertion of the source probe into the hole: a. <i>Hole is vertical, or the gauge will not seat properly causing inaccurate test results.</i> b. <i>The pre-drilled hole is 50 mm deeper than the desired depth to be tested.</i> c. <i>The drill rod does not vibrate when it is hammered into the test material.</i> d. <i>The guide plate is seated level on the surface of the test material.</i> e. <i>The source probe or rod rests snugly in the hole before a count is taken.</i>	
13. The following checks are carried out before commencing with the count: a. <i>All offsets are disabled.</i> b. <i>Correct standard density for the material has been entered.</i> c. <i>Gauge is in the correct mode.</i> d. <i>Correct depth of measurement has been selected.</i> e. <i>Correct time for the duration of the count has been selected.</i> f. <i>Testing is done as soon as possible after final compaction ($\pm$ 24 hours).</i> g. <i>No testing in rainy or wet conditions, or directly onto water-laden material.</i> h. <i>Surface of the test material is level, smooth and free from voids.</i> i. <i>Shutter mechanism is thoroughly cleaned.</i> j. <i>Handle of the source rod engages properly into the catch position for the different positions of measurements.</i> k. <i>Bottom of the gauge does not stand proud of the level surface of the test area due to excessive wear of the base of the gauge (rocking).</i> l. <i>Only half the counts are received due to faulty detector tube, or only one is functioning.</i> m. <i>Detector tubes out of alignment due to excessive bumping of the gauge.</i> n. <i>Voltage low, or voltage module is broken, leading to the incorrect quantity of counts detected by the detector tubes being recorded.</i> o. <i>Incorrect count ratio due to excessive source decay, or standard count determined in a cold state, i.e., gauge not sufficiently warmed-up.</i> p. <i>Source probe or rod depth divisions out of alignment.</i>	

APPENDIX C. NORMAL COMPLETION TIMES FOR ACCEPTANCE CONTROL TESTING

The following is estimated as being reasonable times for the carrying out of tests, from the start of field sampling to receipt of site test results.

Description	Type of Material	Type of Result	Start Of Field Testing											
			Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
			Before 10:00	After 10:00	Before 10:00	After 10:00	Before 10:00	After 10:00	Before 10:00	After 10:00	Before 10:00	After 10:00	Before 10:00	After 10:00
Percentage Compaction	Normal	Normal	Tues 11:00	Wed 11:00	Wed 11:00	Thu 11:00	Thu 11:00	Fri 11:00	Fri 11:00	Sat 11:00	Sat 11:00	Mon 11:00	Tue 11:00	Mon 11:00
		Overtime		Tues 11:00		Wed 11:00		Thurs 11:00		Fri 11:00		Sat 11:00		Tues 11:00
	MC > 4% of OMC	Normal	Wed 11:00	Wed 11:00	Thurs 11:00	Thurs 11:00	Fri 11:00	Fri 11:00	Sat 11:00	Sat 11:00	Mon 11:00	Mon 11:00	Mon 11:00	Mon 11:00
		Overtime	Tues 11:00	Tues 11:00	Wed 1:00	Wed 11:00	Thurs 11:00	Thurs 11:00	Fri 11:00	Fri 11:00	Sat 11:00	Sat 11:00	Tues 11:00	Tues 11:00
Sieve Analysis PI	All	All	Tues 16:00 Thurs 12:00		Wed 16:00 Fri 12:00		Thurs 16:00 Sat 12:00		Fri 16:00 Mon 12:00		Mon 16:00 Wed 12:00		Mon 16:00 Wed 12:00	
CBR	All	Normal	Next Mon	Next Mon	Next Mon	Next Tues	Next Tues	Next Wed	Next Wed	Next Fri	Next Fri	Sat Week	Mon Week	Mon Week
		Overtime		Next Mon		Next Mon		Next Tues		Next Wed		Next Fri	Next Sat	Next Sat

Other Standard Tests					
Test	Time	Test	Time	Test	Time
Indicators Stabilised	3 wd ¹	10 % Fact: - Dry - Wet	1 wd 2 wd	Analysis of Fresh Concrete	Immediate
Hydrometer Analysis	3 wd	Ethylene Glycol Durability Index	8 wd	Check Curing Compounds	3 wd
Initial Lime Demand	4 wd	Flakiness Index	1 wd	Asphalt Control Tests	1 wd
% Compaction Stabilised	Next day	Organic Impurities	2 wd	Immersion Index	Next day
Accelerated UCS Stabilised	Next day	Bulk Density	1 wd	Asphalt Cores Compaction	1 wd
Back Titration	4 wd	Fineness Modulus	1 wd	Static/Dynamic Creep	Next day
I.T.S Stabilised	8 wd	BD, AD & Water Absorption	2 wd	Bitumen Rubber Testing	2 wd
Wet/Dry Durability	30 days	Average Least Dimension	Same day	Penetration of Bitumen	Next day
P.H	Same day	Sand Equivalent	1 wd	Softening Point (R & B)	Next day
Moisture Content: Process	Same day	Cube Strengths	29 days	Ductility	2 wd
Analysis and Acceptance of all data	1 wd	Beam Flexural Strengths	29 days	Viscosity	2 wd
A.C.V	1 wd	Accelerated 24 hr Cubes	2 wd	Water Content of Emulsions	Next day

Note

1. wd = working days

APPENDIX D. TESTING REQUIREMENTS AND FREQUENCY TABLES

Soils, Gravels and Aggregates	D-2
Stabilised Layers.....	D-4
Asphalt	D-5
Seals	D-7

Soils, Gravels and Aggregates

Table D.1. Laboratory Tests for the Constructed Selected Layer

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Compaction	Maximum dry density	MDD	30 kg	2 samples per 500 m ³	SANS 3001–GR30
	Density	Sand replacement	N/A	1 sample per 1000 m ³ per 150 mm layer, minimum of 5 samples per layer per lot	SANS 3001–GR35
		Nuclear	N/A		SANS 3001–NG5
Moisture Content		Gravimetric analysis	1 x 1 to 1.5 kg	1 sample per test	SANS 3001–GR20
Layer Placement	Layer thickness	Measurement			
Material Properties	Grading	Sieve analysis Grading modulus Soil mortar analysis	15 kg	1 sample per 1000 m ³ per constructed layer thickness, minimum of 5 samples per layer per lot	SANS 3001–GR1
	Atterberg limits	Plasticity Index Liquid limit Linear shrinkage			SANS 3000–GR10, 11 & 12
	Bearing strength and swell	CBR	2 x 30 kg	1 sample per 2500 m ³ , minimum of 3 per source	SANS 3001–GR30 & 40

Table D.2. Laboratory Tests for the Constructed Non-Cemented Subbase Layer

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Compaction	Maximum dry density	MDD	30 kg	2 samples per 500 m ³	SANS 3001–GR30
	Density	Sand replacement	N/A	Minimum of 6 samples per lot	SANS 3001–GR35
		Nuclear			SANS 3001–NG5
Moisture Content		Gravimetric analysis	1 x 1 to 1.5 kg	1 sample per test	SANS 3001–GR20
Layer Placement	Layer thickness	Measurement			
Material Properties	Grading	Sieve analysis Soil mortar analysis Grading modulus	15 kg	Minimum of 6 stratified random samples per lot	SANS 3001–GR1
	Atterberg limits	Plasticity index Liquid limit Linear shrinkage			SANS 3001–GR10, 11 & 12
	Aggregate shape	Number of fractured faces			SANS 3001–AG4
	Bearing strength	CBR	2 x 30 kg	CBR assessed prior to compaction: 1 per km CBR not assessed prior to compaction: 3 per km	SANS 3001–GR30 & 40

Table D.3. Laboratory Tests for the Base Layer Constructed with G1, G2, G3 and Waterbound Macadam Materials

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Material Properties	Grading	Sieve Analysis	15 kg	Minimum 6 stratified random samples per lot – refer to Standard Specifications	SANS 3001–GR30
	Atterberg limits	Plasticity Index Liquid limit Linear Shrinkage			SANS 3001–GR10, 11 & 12
	Shape	Number of fractured faces		2 sample per lot	SANS 3001–AG4
Compaction	Maximum dry density	MDD	30 kg	2 samples per construction lot	SANS 3001–GR30
	Density	Sand replacement Nuclear		Minimum of 6 stratified random samples	SANS 3001–GR35 SANS 3001–NG5
Layer Placement	Layer thickness	Levels in test holes Measurement	N/A	Same as for density	Measurement
Layer Moisture Condition	Moisture content (full depth)	Gravimetric or by any other approved method	Minimum of 1 kg	Minimum of 1 test position per 100 m, selected randomly Sections: > 1 km: min of 10 tests < 1 km: min of 4 tests	SANS 3001–GR20
Surface Texture	Mosaic	Visual	Total Area	N/A	

Table D.4. Laboratory Tests for the Base Layer Constructed with G4 Material

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Material Properties	Grading	Sieve Analysis	15 kg	Minimum 6 stratified random samples per lot	SANS 3001–GR30
	Atterberg limits	Plasticity Index Liquid limit Linear Shrinkage			SANS 3001–GR10, 11 & 12
	Shape	Number of fractured faces		2 sample per lot	SANS 3001–AG4
	Bearing	CBR	2 x 30 kg	1 sample per lot	SANS 3001–GR40
Compaction	Maximum dry density	MDD	30 kg	2 samples per construction lot	SANS 3001–GR30
	Density	Sand replacement			SANS 3001–GR35
		Nuclear		Minimum of 6 stratified random samples	SANS 3001–NG5
Layer Placement	Layer thickness	Levels in test holes Measurement	N/A	Same as for density	Measurement
Layer Moisture Condition	Moisture content (full depth)	Gravimetric or by any other approved method	Minimum of 1 kg	Minimum of 1 test position per 100 m, selected randomly Sections: > 1 km: min of 10 tests < 1 km: min of 4 tests	SANS 3001–GR20
Surface Texture	Mosaic	Visual	Total Area	N/A	SANS 3001–NG5

Stabilised Layers

Table D.5. Laboratory and Field Tests for Stabilised layers

Component	Aspect to be Controlled	Type of Control	Sample Size	Sampling Frequency	Test Method
Compaction	Maximum dry density	MDD	30 kg	1 test of material from each density site	SANS 3001–GR51
	Density	Sand replacement	N/A	1 sample per 1000 m ³ per 150 mm layer, minimum of 5 samples per layer per lot	SANS 3001–GR35
		Nuclear	N/A		SANS 3001–NG5
Moisture Content		Gravimetric analysis	1 x 1 to 1.5 kg	1 sample per test	SANS 3001–GR20
Layer Placement	Layer Thickness	Measurement			
Material Properties	Grading	Sieve analysis Grading modulus Soil mortar analysis	15 kg	1 sample per 1000 m ³ per constructed layer thickness, minimum of 5 samples per layer per lot	SANS 3001–GR1
	Atterberg Limits	Liquid limit Plasticity Index Linear shrinkage			SANS 3001–GR10, 11 & 12
	Strength	UCS, ITS	150 kg for each	1 sample per 800 m ² , minimum of 4 per layer lot	SANS 3001–GR51, 52, 53 & 54
Stabiliser Content	Distribution and quantity of added stabiliser	Laboratory determination of calcium content	6 kg	20 samples per lot, 10 at the top and 10 at the bottom of layer	SANS 3001–GR58

Asphalt

Table D.6. Tests and Testing Frequencies for Aggregates Used in Asphalt

Property	Test	Quantity Per Test (Maximum)	Lot Size (Maximum)	Samples Per Lot (Minimum)	Test Number
Grading	Sieve analysis	1 000 m ³	Stockpile	4	SANS 3001-AG1
Shape	Flakiness index	1 000 m ³	Stockpile	4	SANS 3001-AG4
Resistance to crushing	Aggregate crushing value (ACV)	5 000 m ³	Stockpile	4	SANS 3001-AG10
	10% FACT (wet & dry)	5 000 m ³	Stockpile	4	
Sand equivalent	Sand equivalent on fine aggregate	2 000 m ³	Stockpile	4	SANS 3001-AG10
Polishing	Polished stone value (PSV)	per source		1	SANS 3001-AG11
Adhesion	Adhesion test	5 000 m ³	Stockpile	4	TMH1 B11
Absorption	Absorption test	5 000 m ³	Stockpile	4	TMH1 B14 & B15
Plasticity of added fines	Plasticity index	2 000 m ³	Stockpile	4	SANS 3001-GR10
Durability	Methylene Blue test	per source		1	SANS 3001-AG44

Table D.7. Acceptance Control Tests on Reclaimed Asphalt (RA) in Asphalt Mixes

Property	Test	Quantity Per Test (Maximum)	Lot Size (Maximum)	Samples Per Lot (Minimum)	Test Number
Grading	Sieve analysis	1 000 m ³	Stockpile	4	SANS 3001-AG1
Recovered binder properties	Penetration of recovered binder	1 000 m ³	Stockpile	1	EN 1426
	Softening Point (R & B)	1 000 m ³	Stockpile	1	ASTM D36

Table D.8. Acceptance Control Tests on Fillers used in Asphalt Mixes

Property	Test	Quantity per Test (Maximum)	Lot Size (Maximum)	Samples per Lot (Minimum)	Test Number
Fineness	Percent mass passing 0.075 mm sieve	100 tons	per delivery	4	SANS 3001-AG1
Bulk density	Bulk density in toluene	100 tons	per delivery	1	BS 812
Void content	Void content in dry compacted filler	100 tons	per delivery	1	BS 812

Table D.9. Test Frequencies for Penetration Grade Bitumen

Property	Manufacturer	Haulier	Site Storage	Sprayer	Test Method
Before Ageing					
Softening point	Every batch	Every load	Every day	Every load	ASTM D36
Penetration	Every batch	Every load	Every day	Every 5 th load	EN 1426
Dynamic viscosity @ 165 °C	Every batch			Every 5 th load	ASTM D4402
Flash point	Once, at start of project				ASTM D92
After Ageing (RTFOT)					
Mass change	Every 10 th batch			Every 10 th load	ASTM D2872
Difference in softening point	Every 10 th batch			Every 10 th load	
Dynamic viscosity @ 165 °C ²	Every 10 th batch				ASTM D4402

Notes

1. This test is performed on a frequency basis, or when there is a change in the source of base bitumen or bitumen crude type.
2. Only required if the binder is used for HMA.

Table D.10. Test Frequencies for Hot Polymer Modified Binders (From TG1)

Property	Manufacturer	Haulier	Site Storage	Sprayer	Test Number
Before Ageing					
Softening point	Every batch	Every load	Every day	Every load	MB-17
Elastic recovery @ 15 °C	Every batch			Every 5 th load	MB-4
Dynamic viscosity @ 165 °C	Every batch			Every 5 th load	MB-18
Storage stability @ 160 °C ¹	Every 10 th batch				MB-6
Flash point	Once, at start of project				ASTM D93
After Ageing (RTFOT)					
Mass change	Every 10 th batch			Every 10 th load	
Difference in softening point	Every 10 th batch			Every 10 th load	MB-17
Elastic recovery @ 15 °C	Every 10 th batch			Every 10 th load	MB-4
Dynamic viscosity @ 165 °C ²	Every 10 th batch				MB-18

Notes

1. This test is performed on a frequency basis, or when there is a change in the source of base bitumen or bitumen crude type.
2. Only required if the binder is used for HMA.

Table D.11. Testing Frequencies for Bitumen Rubber (From TG1)

Property	Spray Tanker	HMA Storage Tank	Test Number
Softening point	Every load	Every batch	MB-12
Dynamic viscosity @ 190 °C	At the start of every load	At the start of every batch	MB-13
Compression recovery: • 5 minutes • 1 hour • 4 days	Every 5 th batch	Every 5 th batch	MB-11
Resilience	Every load	Every batch	MB-10
Flow	Every load	Every batch	MB-12

Table D.12. Test Requirements and Testing Frequencies on Asphalt Mix and on the Constructed Asphalt Layer

Property	Quantity Per Test (Maximum)	Lot Size (Maximum)	Samples Per Lot (Minimum)	Test Number
Grading and binder content	200 tons	days work	6	SANS 3001-AG1
Sand equivalent	5 000 tons	week	1	SANS 3001-AG5
Marshall stability, flow and void content	500 tons	days work	2	SANS 3001-AS1, AS2, AS10
Relative compaction	2 000 m ²	days work	6	SANS 3001-AS11
Spread of rolled-in chips	2 000 m ²	days work	6	
Immersion index	Every change in aggregate or design			TMH1-C5

Table D.13. Pre-Delivery Aggregate Tests

Test	Method	Sample Size Required	Testing Frequency
Sieve analyses	SANS 3001-AG1	2.0 to 3.0 kg	3 per 100 m ³
Fines content	SANS 3001-AG1		
Dust content	SANS 3001-AG1		
Flakiness index	SANS 3001-AG4		
Aggregate crushing value	SANS 3001-AG10		
10 % FACT	SANS 3001-AG10		
Polished stone value	SANS 3001-AG11	20.0 kg	1 only
Sulphate soundness test	AASHTO T04		
Freezing and thawing test	AASHTO T103		
Los Angeles abrasion test	AASHTO T96-45		
Deval abrasion rest	AASHTO T4-35		
Ethylene glycol test	SANS 3001-AG14		

Table D.14. Post-Delivery Aggregate Tests

Test	Method	Sample Size Required	Testing Frequency
Sieve analyses	SANS 3001-AG1	2.0 to 3.0 kg	1 per 10 m ³
Fines content	SANS 3001-AG1		
Dust content	SANS 3001-AG1		
Flakiness index	SANS 3001-AG4		
Aggregate crushing value ¹	SANS 3001-AG10		

Note:

1. When hardness is suspect.