

SOUTH AFRICAN PAVEMENT ENGINEERING MANUAL

Chapter 1

Introduction



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

Date of Issue: October 2014

Second Edition

South African Pavement Engineering Manual
Chapter 1: Introduction

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Introduction



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FOREWORD

The South African Pavement Engineering Manual (SAPEM) is the culmination of many hours of work by dedicated and passionate road industry professionals. SANRAL will always remain indebted to those who so generously gave of their time. The spirit and generosity of South Africa's road industry is reflected in the manual.

This manual captures the knowledge and expertise of each task group ably led and supported by many contributors, who were driven by their sheer passion for the industry and willingness to share their experience with all of us.

It is worth noting the evolution of this manual, which started off as a 'materials manual' for SANRAL. As time proceeded, the value of the 'materials manual' was recognized by the other road authorities (Provincial and Metropolitan) who supported the idea of a unified guideline – taking into account the different needs of the authorities – for the design of road pavements.

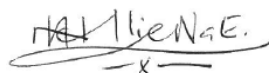
Infrastructure for the transportation of goods and people is crucial for generating economic growth, alleviating poverty and increasing South Africa's global competitiveness. Roads play a critical role – being the arteries of the economy – in the socio-economic development of South Africa. And, as one of the largest capital spending agencies in Government in this sector, we are duty bound to maximize value for money for those whom we serve, and to reduce overall spending through efficient design and construction of pavements in these challenging economic times, without compromising the standards, quality and excellent service we deliver to motorists.

The manual comprises fourteen chapters covering a range of elements of pavement engineering. The chapters, inter alia, include the history of roads, the development of pavement engineering with time through the understanding of the behaviour of materials and their utilization, the influence of the environment and traffic, the interface between tyre and pavement, references to testing methods guiding the reader through the numerous tests to be conducted, and laboratory management. It explains relevant concepts, tells the reader of the do's and don'ts, and also contains guidelines on the investigation of the road prism, the pavement and geology, and suggests the expertise required for carrying out geotechnical investigations.

This is a comprehensive guideline manual, *not a policy manual*. It is to be regarded as a best practice guideline, providing the sequence of steps for practitioners. Its benefits will manifest over time with its use, with the harmonization of designs and standards. It predominantly provides advice and guidance for the design of safe, state of the art, cost effective – taking into account the carbon footprint – pavements for motorists, thus reducing the cost of transport.

SAPEM is a guide to all users – students, academics and practitioners – and is not a replacement for the principles of pavement engineering design and good engineering judgement. We trust that this manual will assist in the education and development of future pavement engineers, and continue to promote cost effective designs of road pavements. It is a living document, and will be periodically updated to make provision for newly adopted technologies.

I would like to acknowledge the contribution of the many individuals who, over the years, have knowingly, or otherwise, contributed to the development of this manual. Thank you all.



Nazir Alli
CEO
The South African National Roads Agency SOC Limited

You are
here



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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 1.

Chapter 1: Introduction discusses the purpose, scope, contents and application of this SAPEM manual. A history of roads, the basic principles of roads and the purpose and classification of roads are discussed. In addition, for pavement engineering projects, the institutional responsibilities; statutory requirements in terms of environmental, mineral exploitation, and health and safety; and planning and time scheduling are given. The life cycle of road design is also discussed. 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 1: Introduction

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 includes acceptance control processes, and quality plans. All the pavement layers and the road prism are discussed. The documentation involved in quality management is also discussed, and where applicable, provided.

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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Chapter 1: Introduction

ACKNOWLEDGEMENTS

This compilation of this manual was funded by the South African National Road Agency SOC Limited (SANRAL). The project was coordinated on behalf of SANRAL by Kobus van der Walt and Steph Bredenhann. Professor Kim Jenkins, the SANRAL Chair in Pavement Engineering at Stellenbosch University, was the project manager. The Cement and Concrete Institute (C & CI) and Rubicon Solutions provided administrative support.

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1. BACKGROUND

1.1 Purpose of SAPEM

The purpose of the South African Pavement Engineering Manual (SAPEM) is to provide a “Best Practice Guideline” for pavement engineering in the South African roads industry. This includes application at National, Provincial and Tertiary levels of Government. The need for such a manual arises for a number of reasons:

- **Guiding inexperienced engineers:** New entrants into pavement engineering, of all ages, need a “roadmap”, or an overview of different areas of pavement technology and best practice, steps to follow, and the do’s and don’ts as developed by the road authorities over time.
- **Capturing experience:** The skewed distribution of ages in the industry is resulting in the “baby-boomers” going into retirement. The loss of their knowledge and expertise will be detrimental to the roads industry and therefore needs to be captured, where possible.
- **Referencing:** Many manuals and technical, best practice guidelines are in existence, but some have become redundant or been superseded. SAPEM aims to provide an overview and reference of all of the pertinent standards and guidelines. References for all relevant guidelines are provided, including, where possible, links to where the documents are available for download.
- **Education and training:** Educational institutions require applicable reference material for their educational courses in pavement engineering. SAPEM fulfils this need.
- **Road Authority needs:** Significant overlap exists between the pavement technologies used by the three tiers of government. Many road authorities do not have the capacity to develop their own, or to update, outdated materials manuals. SAPEM fulfils this role by providing for the needs of all road authorities. The divergent areas, e.g., low volume roads versus heavily trafficked roads, are addressed through caveats, which make provision for the different requirements and methods used in Metro, Municipal, Provincial and National Road Authorities.
- **Future revisions:** Technology used in pavement engineering is constantly developing and advancing. Through web-based downloads, SAPEM’s chapters can be effectively updated and accessed. This system supports the living nature of the document.

SAPEM covers all aspects of roads, including fills, cuts, tunnels and foundations.

1.1 Scope and Style of SAPEM

The scope of SAPEM extends beyond that of merely a materials manual. SAPEM provides an overarching perspective of all aspects of pavement engineering, incorporating associated specialities such as geotechnical investigations and tunnelling, material behaviour and selection, and pavement design principles. SAPEM places each of these activities in perspective giving insight into their function and provides the applicable guiding documents, but does not provide unnecessary detail that can be found in the best practice references. The only areas of detail in SAPEM are the undocumented technologies, for which accepted and up to date guideline documents are not available. This document refers only to accepted practice. Where possible, insights into the application of principles and topics in other guidelines are provided.

The entire road prism is covered in SAPEM, incorporating embankments and cuttings and their investigation, as well as the investigation of bridge foundations. The main focus is on the pavement structure, i.e., subgrade, selected subgrade, subbase, base and surfacing layers. However, because guideline documentation for the rest of the road prism is not well defined elsewhere, it is incorporated into SAPEM.

SAPEM is a guideline and not a policy manual – there is a difference:

- **Policy manuals** are structured to encourage practitioners to strictly follow the process. This results in “going through the motions” without the need for a critical analysis for why each step is taken and whether other steps are necessary.
- **Guidelines** aim to strike a balance between prescription and freedom of interpretation. Sufficient information is provided for a practitioner to make interpretations and where necessary, to adapt methodologies and approaches for a given set of circumstances. SAPEM provides a “sequence of processes” for practitioners with a logical approach to pavement engineering practice to be carried out for a road authority, starting with applicable documents/contracts, through investigation and testing, culminating in the appropriate materials design and documentation.



Role of SAPEM

SAPEM aims to be the first stop for all issues relating to pavement engineering. It is not an all encompassing reference, but provides links to other useful and necessary references, guidelines and manuals.

1.2 Contents and Structure of SAPEM

SAPEM is structured in several modules with each incorporating several chapters:

- **Background:** The background module includes discussion on the scope and structure of technical, environmental and legal issues.
 - **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.
- **Laboratory and Testing:** This module has three chapters, and includes all topics related to laboratories and materials testing.
 - **Chapter 3: Materials Testing** presents the tests used for all material types 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.
 - **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, and gives material classification systems, and 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.
- **Investigation:** The investigation module covers the investigations pertaining to the road prism, pavement, geotechnical aspects, as well as material sources.
 - **Chapter 6: Road Prism and Pavement Investigation** discusses all aspects of the road prism and road pavement investigations, including legal and environmental requirements, materials testing, and reporting on the investigations.
 - **Chapter 7: Geotechnical Investigations and Design Considerations** covers the investigations into potential problem subgrades, fills, cuts, structures and tunnels. 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.
- **Design:** The design module deals with material utilisation, mix designs and structural designs, and the analysis of traffic.
 - **Chapter 9: Materials Utilisation and Design** discusses materials in the roadbed, earthworks and all the pavement layers. The mix designs of all materials are included.
 - **Chapter 10: Pavement Design** presents the philosophy of pavement design, methods of estimating design traffic and the pavement investigation process. Methods of structural capacity estimation for flexible, rigid and concrete block pavements are discussed.
- **Documentation and Tendering**
 - **Chapter 11: Documentation and Tendering** covers the different forms of contract typical for road pavement projects, the design, contract and tender documentation, and the tender process.
- **Implementation**
 - **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.
- **Quality Management**
 - **Chapter 13: Quality Management** includes acceptance control processes and quality plans. All the pavement layers and the road prism are discussed. The documentation involved in quality management is also discussed, and where applicable, provided.
- **Post-Construction**
 - **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.



SAPEM is a Guideline

SAPEM is best practice guideline. It is not a specification and does not have legal standing in a court of law.

1.3 How to Use SAPEM

SAPEM has been created by practitioners for practitioners, representing all sectors of the roads industry, including road authorities, consultants, contractors, suppliers, researchers and machine manufacturers. You should follow the tips provide in the green and red boxes when using SAPEM.



Using SAPEM: Do

- Do use SAPEM as a **roadmap** to guide you through a particular process in road engineering to help you access the most relevant and up-to-date approaches, methods and techniques.
- Do use the **references** provided to gain more detailed knowledge on a specific area. This will not only supplement your knowledge, but can also provide the necessary specification guidelines, test methods and available standard documentation.
- Do be aware of differences between the **requirements of road authorities**. SAPEM has been drawn up generically for the highest level of application of pavement technology. However, where possible, caveats for provincial, municipal, district and metro roads are provided.



Using SAPEM: Don't

- Don't consider SAPEM as an exhaustive compilation of all the details that you may require. SAPEM only **provides an overview**, and includes many references to the latest detailed approaches, and procedures to cover the rest. Use the references.
- Don't follow SAPEM by **rote without critical consideration** and decision making for your particular road's needs.
- Don't ignore basic engineering judgement. SAPEM can only **supplement knowledge** and cannot replace judgement.
- Don't consider SAPEM to replace mentors. Use it as a **supplementary source of guidance** and reference.
- Don't use SAPEM as the main source of information for affiliated fields that have some relation to pavements, e.g., geotechnical investigations and tunnelling. SAPEM aims to include some information on these areas for completeness, but is by **no means a definitive source of guidance** in specialist areas.

2. HISTORY OF ROADS

This section looks at the history of roads, from their development, to the history of pavement design. The necessity of roads is also discussed.

2.1 Development of Roads

An understanding of how pavement technology evolved requires a look back into the historical developments of roads. In ancient times there was nothing more than a sparse network of tracks for humans to reach feeding and drinking places. These tracks differed only slightly from the tracks made by the movement of foraging animals. The primary difference was that obstacles, e.g., boulders, were removed from the more important routes and thorn bushes were trimmed back by humans. More elaborate lines of communication than these simple tracks did not appear until the number of humans in certain areas reached a stage where their social structures and networks demanded more permanent contact between communities.

Roads thus appeared when groups of people started to interact with each other by travelling, doing business, fighting, and socializing. This occurred around 3500 BC. At this time, the invention of the wheel and development of chariots and wagons showed that the existing soil or subgrade on the interlinking routes was inadequate. Layers of better quality material were required to protect the subgrade, giving rise to the pavement structure.

The earliest records of paved roads for wheeled traffic date from about 2200 BC in Babylonia (modern Iraq), in Crete from about 1500 BC and in Egypt from about 540 BC. In Europe, the first substantial roads were built by the Romans, with a network of more than 100 000 kilometres of road built between 400 BC and 400 AD. The Roman roads were cambered to shed rainwater and were constructed on a foundation of large stones with a wearing course of smaller stones and gravel, constrained between raised stone kerbs, as illustrated in Figure 1 from McCauley, 1974).

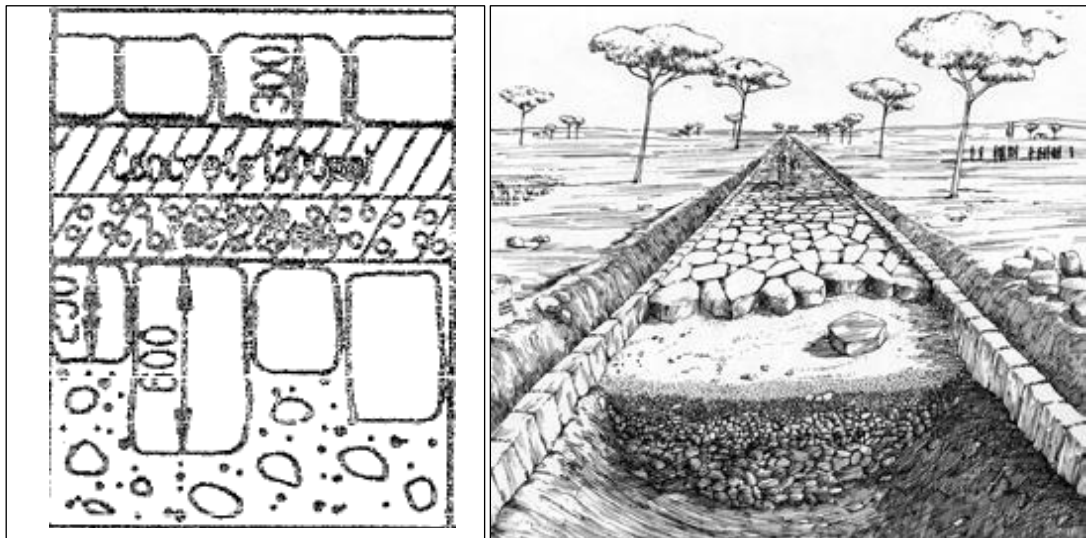


Figure 1. Typical Roman Pavement

The **Romans** were the best road builders of the remote ages. Conquests achieved through war games were one of the reasons for this. The Romans needed a good network of roads to control their conquered subject-nations. The army needed to be able to move fast to quell any revolting groups. The Roman roads were cobbled with a base system that was dependent on the subgrade. They developed a three or four layer system, illustrated in Figure 2, consisting of:

- Top layer
- Base, sometimes stabilized
- Subbase
- Subgrade

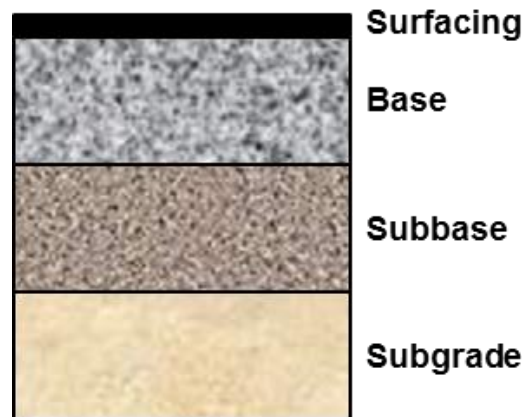


Figure 2. Pavement Structure

Napoleon was responsible for the construction of a considerable network of roads in Europe in the late 18th and early 19th centuries. In 1747, the "Ecole des Ponts et Chaussées" was founded in Paris, France. In 1765, Tresaguet developed the Roman road structure further. His basic principle was to construct the first layer with big blocks and then to place little rocks in between. By doing this, he attempted to ensure that the first layer was consistently subjected to compressive stresses and improved load spreading on the subgrade was achieved.

At the same time, in about 1810 in England, people such as Telford and Metcalf made valuable developments, including:

- Design of **drainage**
- Design of the **road camber**
- Active and regular **maintenance**

Telford and Metcalf found that through drainage design and the inclusion of a crossfall, maintenance could be substantially reduced and the required layer thickness dramatically reduced.

In Great Britain, the Industrial Revolution required a road building programme for the movement of materials and goods, and many kilometres of road were built by various means. During this time, Macadam (1756 to 1836) invented a method of road building as follows: after careful preparation and draining of the roadbed (or subgrade), he laid a 25 cm layer of stone (aggregate size that could fit in a man's mouth), followed by a surfacing of smaller stones. This type of roadway was ideal for animal drawn wagons and coaches, and was cheap to build. John Macadam's roads lasted well under traffic and many British roads were "macadamised". They were a good solution in the nineteenth century for iron rimmed wheels, i.e., treads.

However, the invention of motorised transport by Marcus, who invented the first car with traction in Vienna in about 1870, and rubber tyres developed by Dunlop in 1888, changed the requirements once again. Speeds increased, making safety an important consideration. Rubber-tyred wheels "sucked" the dust from the road surface, loosening the stones and causing blinding clouds of dust. Hence, in the early part of the 20th century, tar was spread over the road surface to hold the stones in place and to prevent dust. Sand, stone and tar formed a "surface dressing". Later the "tar-macadam" surface of stone coated with tar and rolled to a smooth surface was used, hence the term *tarmac*. Today we still make waterbound macadam, washing sand into the interstices between the larger stones and penetration macadam by vibrating bitumen-emulsion slurry into the interstices.

In South Africa, the pioneer road-builder was Thomas Bain (1830 – 1893), son of Andrew Geddes Bain. Thomas Bain constructed 23 major mountain passes, nearly all in the Cape Province. Some of his roads are still in use today, e.g., Bain's Kloof Pass, shown in Figure 3. The book "Romance of the Cape Mountain Passes" by Dr G. Ross provides interesting facts about this era of road construction.

Some other important developments in the nineteenth century included the train and as a result of technical breakthroughs, the steamroller (a roller powered by steam). Much attention went on the development of the train and in many countries, with a focus on building new railway lines, the roads deteriorated. In 1863, Lemoine invented the two-wheel steamroller, and at the same time Clark and Butler developed the three-wheeled steamroller. This made compaction of granular layers significantly easier and the quality of compaction increased. The impact of changes in technology on the development of roads is conceptualised in Figure 4.



Figure 3. Bain's Kloof Pass

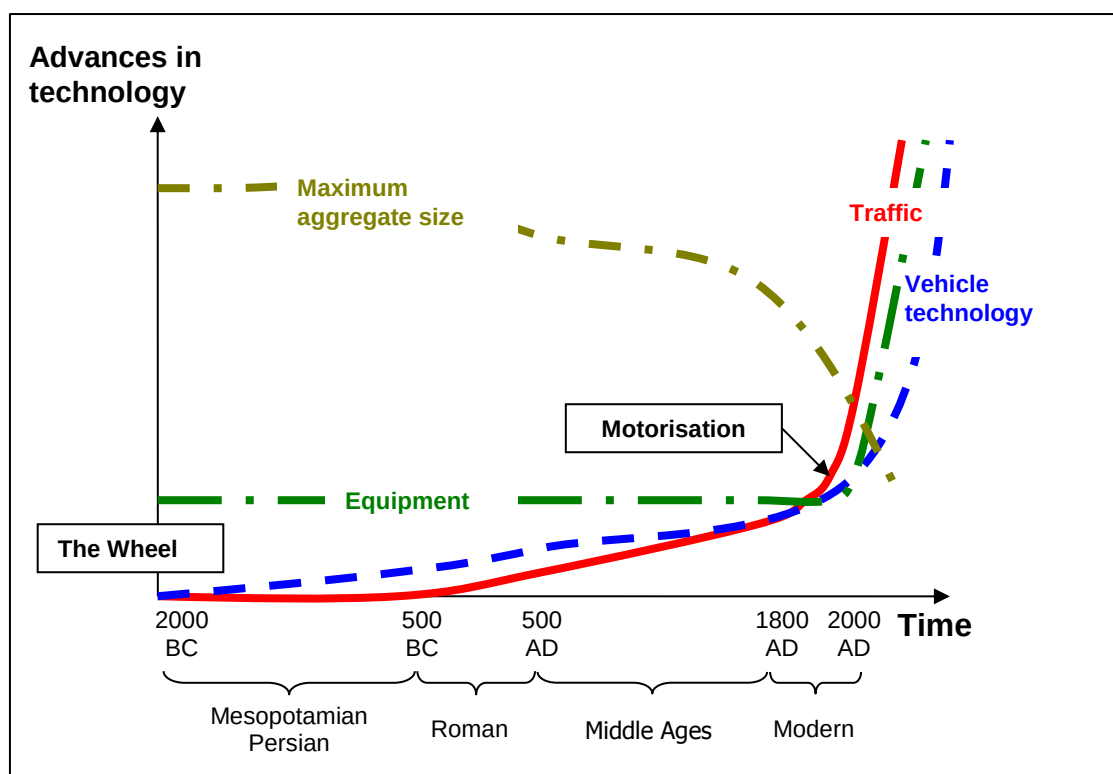


Figure 4. Conceptual Impact of Technological Developments on Roads

2.2 History of Pavement Design

Prior to the early 1920s, the thickness of pavement layers was based purely on experience. The invention of the car and the introduction by Henry Ford of his Model T-Ford in 1908 gave a strong impetus to look at the design of roads more seriously. Twenty million Model T Fords were sold between 1908 and 1927. The traction of a car, i.e., the

friction between tyre and road, and the vehicle dynamics, damage the surface of the road. Unpaved roads could not cater for this. This resulted in use of the following in the 20th century:

- **Empirical design systems:** experience- and observation-based designs
- **Mechanistic design systems:** linking performance to critical pavement properties and failure mechanisms
- **Mechanistic-empirical design systems:** linking critical pavement properties to experience based limits

In Scotland and Ohio, expensive solutions were found through experimentation. At the same time, experiments were undertaken to investigate tar or natural asphalt, found in a lake in Trinidad, and split (aggregate). Skid resistance and a lack of bond to existing layers, proved problematic. Typical problems of the time, which included impassibility of many unsurfaced roads in wet conditions, can be seen in Figure 5, taken from Floor (1985).



Figure 5. Impassable Unsurfaced Roads Due to Wet Conditions, Early 20th Century

In the period between the First and Second World Wars, the growing importance of roads drove necessary improvements in pavement design. After the Second World War, the growth in traffic, loads and tyre pressures, and the higher speeds, necessitated the development of pavement technology beyond empiricism or designs based on experience only. Functional performance had to be defined, being the basis of the service that is provided to the road users in relation to the cost. This is indicative of fitness for use. Performance also needed to be better understood and more predictable. This required knowledge of structural behaviour and pavement distress in relation to time. This motivated the AASHO road test.

2.2.1. AASHO Road Test

The AASHO Road Test took place in Ottawa, Illinois about 100 km south-west of Chicago between 1956 and 1958. It was an enormous effort to systematically quantify the complex interaction between road deterioration, traffic and composition of the pavement structure on a closed loop test track with trucks. The test track is illustrated in Figure 6. AASHO stands for American Association of State Highway Officials and later became AASHTO (Highway and Transportation).

The aims of the AASHO road test are still very relevant:

- Developing satisfactory **pavement design procedures** to meet the growing demands of traffic.
- Aid legislators in setting user **taxation** and **control of vehicle size** and **weight**.

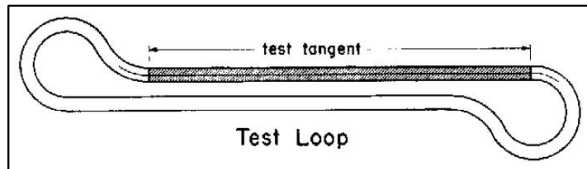


Figure 6. AASHO Road Test

The cost of the AASHO road test was \$29 million in 1954 (equivalent to about \$300 million in 1996). As a result of the experiment, for the first time the relationship between performance and loading was investigated. The main findings were:

- Definition of **serviceability** as the degree to which the road pavement serves the road users.
- Development of the **Present Serviceability Rating** (PSR), where road users rated the serviceability of various roads.
- **Present Serviceability Index** (PSI) was developed when it was shown that the PSR was more closely correlated with riding quality than with any other variable. Hence, it became possible to estimate the PSR from more objective measurements of roughness, rather than from subjective user ratings. PSI values range from 1 (very good) to 5 (poor).
- The concept of **load equivalency** was defined where the equivalent damage caused by different axle loads and configurations was quantified relative to the 80 kN single axle that was the norm at the time. The AASHO road test showed that different equivalencies also existed for different pavement types (asphalt and concrete).



E80s & MESA

An **E80** is an equivalent 80 kN axle load. Typically, varying axle loads are converted to E80s using Equation 1. Another popular term is **MESA**, which is Million Equivalent Standard Axles.

The load equivalency factor is normally simplified using Equation (1):

$$LEF = \left(\frac{P}{80} \right)^n \quad (1)$$

where LEF = Load equivalency factor, the relative damage caused by axle load P compared to a 80 kN single axle load

P = Axle load (kN)

80 = Equivalent Standard Axle Load (ESAL or E80 in SA) in (kN)

n = damage exponent

The damage exponent depends on the pavement and distress type, but typically 4.2 is used for flexible pavements in South Africa. See Chapter 10: 4.1.3.

A design method was developed from the results of the AASHO Road Test, known as the AASHTO Structural Number method (AASHTO, 1986). This method is discussed in Chapter 10: 7.4.

2.3 Necessity of Roads

In the modern world it is well known that apart from social factors such as transport to hospitals, quick access to a fire and emergencies, visiting friends and tourism, a good road system is the backbone for all kinds of economic activity.

It is generally acknowledged that global competitiveness necessitates good road infrastructure. Rural road construction is enormously important and plays a major role in stimulating the economy (farm to market routes).

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This has been observed in many African countries, where agricultural and mining output increases by an order of magnitude through provision of new road infrastructure. Links to ports are especially important.

The 21st century has commenced with an emphasis on:

- Improvements in material science and introduction of **specialist materials** that provide enhanced performance e.g., polymer modified bitumen.
- An **environmental focus** that includes sustainable practice; minimal impact on the environment, i.e., minimising the carbon-footprint and recycling with minimal utilisation of non-renewable resources; and, permeable pavements to reduce run-off.
- New priorities and frameworks for **procurement and road delivery**, including the needs of developing areas, such as Public-Private-Partnering (PPP). See Chapter 11 for procurement and contracting.
- Increases in traffic volumes have resulted in the need for **increased pavement structural capacity**. At the same time, design strategy has moved towards perpetual or long-life pavements. These pavements aim to provide structural capacity for 30 to 50 years with only functional maintenance requirements. It is necessary to adopt long-life pavements in areas where the opportunities for maintenance and rehabilitation interventions are severely restricted for the following reasons:
 - Road user costs, particularly costs relating to traffic delays, are exorbitant.
 - Access to the road pavement is restricted, resulting in construction being carried out at night or over weekends.



John F Kennedy

"Building a road or highway isn't pretty. But it is something that our economy needs to have!"

3. BASIC PRINCIPLES OF ROADS

The history of the development of roads shows that a shift in the paradigm of pavement technology occurred in the 20th century. Since then, the needs extend beyond the technical issues into the functional, environmental and political needs, and amplified with the advent and traffic motorization and growth. The Netherlands Roads Authority, Rijkswaterstaat, captured this trend in a pamphlet (Rijkswaterstaat, 1991) by providing an overview of the different abstraction levels for roads, using two pyramids, as shown in Figure 7.

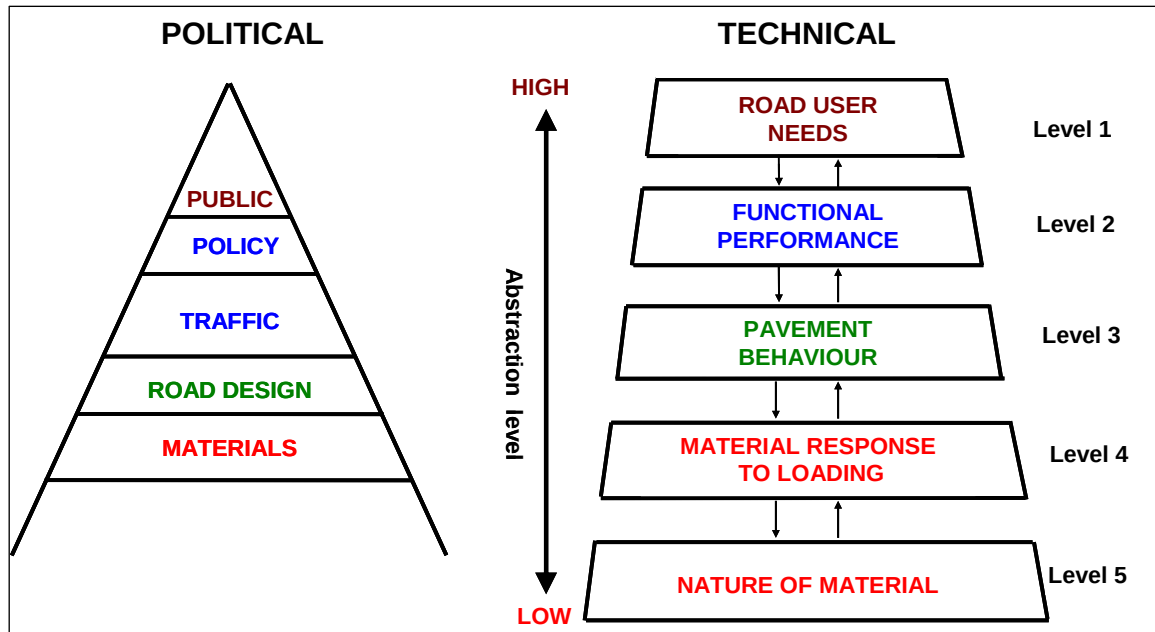


Figure 7. Road Concepts Political and Technical Pyramids for Roads

3.1 Political Pyramid

The political pyramid includes issues such as:

- The **public** is the customer of road infrastructure, whose perceptions, opinion and needs place high demands on road authorities. In turn, the road authorities have become more aware of their customers' requirements.
- **Policy** related to road infrastructure evolves with changing social, economic and environmental needs, the "triple bottom line". Examples include: Incentives for labour enhanced construction, or percentage labour component in contracts, toll roads (user pays principle) and carbon credits.
- **Traffic** considerations need to take cognisance of vehicle types and quantities, traffic safety, congestion, accommodation of traffic, geometric capacity and road user costs. The Road Transport Management Systems and Performance Based Standards for heavy vehicles, provide guidance in the field in South Africa. (Nordengen and Naidoo, 2014; Nordengen and Oberholzer, 2006; Nordengen and Roux, 2013; CSIR, 2014)
- **Road design** considerations need to take account of environmental issues, material availability, climate, social issues and traffic requirements.
- **Materials**, both raw and processed, need to be selected based on performance and environmental priorities.



Environmental Priorities

These include:

- Re-use of **waste materials**, e.g., rubber, slag
- **Recycling** existing pavement materials
- Prohibiting use of materials with **carcinogenic** emissions or leachate
- Use of **low energy consumption** materials

3.2 Technical Pyramid

The technical pyramid represents the pavement engineer's understanding of how to manage the pavement's response to loads, its subsequent behaviour and ultimately its performance in terms of how well it serves the road users over time. The technical pyramid translates road user needs and functional requirements into measurable

technical requirements at lower abstraction levels. A better understanding of the technical pyramid is normally achieved when it is viewed from the basic building blocks at the bottom to the user requirements at the top:

- **Nature of Materials.** This involves the nature of individual component materials that are used to make up the pavement layers. The pavement engineer needs to have an in-depth understanding of the nature of all the materials that are incorporated in a layer, i.e., mineral aggregates, binders, moisture, additives and how these materials interact and change over time. The nature of materials is discussed further in Chapter 2: 5 and 6 and Chapter 10: 3.5.3.
- **Material Response to Loading.** The pavement engineer needs to understand how all the various pavement layers respond to loading and the stresses that occur within the layers. To understand these interactions, it is first necessary to have a good understanding of the concepts of stress and strain, i.e., mechanics of materials, and typical pavement material models. These concepts are discussed in Chapter 2: 3 (Mechanics of Materials) and Chapter 2: 4.1 (Material Characteristics and Behaviour).
- **Pavement Behaviour.** Pavement behaviour involves understanding the behaviour of the composite system after repeated loads and how the pavement material properties change over time. Structural behaviour is a measure of the rate of change in key structural characteristics, such as deflection, with time. Structural behaviour depends on material properties such as stiffness, resilient modulus, tensile strength, compressive strength and shear strength, amongst others, as well as the interaction between different layers. Pavement behaviour is discussed in more detail in Chapter 2: 4.1 in Chapter 10: 3.5.
- **Functional Performance.** The pavement engineer needs to understand how different distress patterns translate into functional problems and affect road users over time, and vice versa. Distress types, and their effect on road users, are discussed in Chapter 2: 5 and Chapter 14: 4, and functional performance in Chapter 2: 6.
- **Road User Needs.** At the top of the technical pyramid are the requirements of the road user, set for the pavement. Safety and comfort are amongst the highest priorities, although the environment, economics and health are also considered.

4. PURPOSE AND CLASSIFICATION OF ROADS

Roads are provided to serve stakeholders, including individuals, communities, agriculture, industries and government. They serve this process by providing mobility and accessibility to services, jobs and other economic opportunities and activities.

In essence, roads are provided for either:

- **Mobility** to facilitate the quick, safe and economic movement of people, goods and services, or
- **Accessibility** to facilitate access for people, goods and services to the higher order mobility road network.

South Africa has adopted a road functional classification to identify and differentiate the service levels applied. This is set out in detail in the TRH26 (South African Road Classification and Access Management Manual), and is the system as used in the Road Infrastructure Strategic Framework of SA (RIFSA). The TRH26 manual also includes guidelines on providing access and spacings of intersections to reduce potential conflict from turning movements. Figure 8 shows how the different classes of road should be geared to either mobility or accessibility.

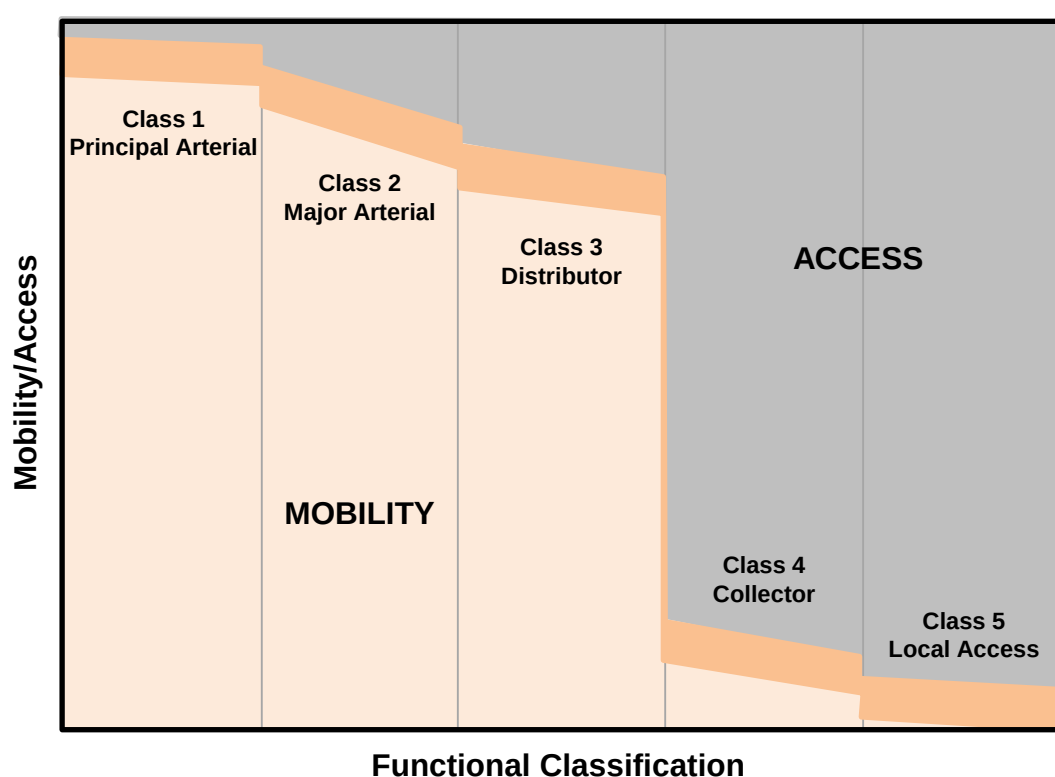


Figure 8. Functional Classification of Roads in South Africa

The function of the higher classes of road is almost entirely mobility with some minor accessibility functions. The function of the lower class 5 roads is almost entirely accessibility, although at times they can play a minor mobility role.

The higher classes of road have substantial economic and commercial importance. They require greater reliability, higher speeds and better service levels than access roads and, therefore, their pavements are normally designed with this in mind. This differentiation has been given expression by allocating the higher order road network better terminal conditions than the lower order network in the TMH22 Road Asset Management Manual with the road categories defined in TRH4. The TRH26 (RIFSA) and TRH4 road categories with their typical names are given in Table 1.

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Table 1. Road Classification Systems

TRH26 Functional Class (RIFSA)	TRH4 Category	Preferred Route Numbering Convention		Preferred Road Numbering Convention
		Rural	Urban	Rural
1	A	N	M1 - M9	Road number with "N" prefix
2	A	R10 - R99	M10 - M99	Road Number with "P" or "TR" prefix
3	B	R100 - R999	M100 - M999	Road Number with "P" or "D" prefix
4	C	None	None	Road Number with "D" prefix
5	D	None	None	Road Number with "L" or "m" prefix

5. INSTITUTIONAL RESPONSIBILITIES

There are several role players involved with pavement engineering, including:

- **Road owners:** Ministers, MECs, Councillors and related bodies and structures, or Company Boards in the case of private sector roads.
- **Road administrators:** Public sector departments and agencies, or private sector divisions.
- **Planners and designers:** Typically private sector engineering consultants.
- **Construction:** Typically contractors with some public sector maintenance and construction units.

Each party needs to play its role properly in order to achieve cost-effective results, which are in turn required to keep transportation costs low and ensure country competitiveness. These traditional roles are:

- **Owners:** Policy and funding
- **Administrators:** Administration and programme management
- **Designers:** Investigations, designs and contract administration
- **Construction:** Tendering, work planning and execution

5.1 Owners

In South Africa, owners are typically constituted at the three levels of Government, i.e., national, provincial and municipal. The political component of the Government needs to understand the issues related to road provision to prioritise funding for roads relative to other needs, such as education and health, and to initiate the desired programmes. Owners need to ensure that the underlying administrative bodies are properly staffed and have the requisite skills to carry out their duties. This oversight role should be carried out at a high level without undue interference and micro-management of the administration, while still maintaining an understanding of the quality of service being provided and how this should be improved and/or sustained. Such high level understanding will typically be provided through regular reporting of progress on programmes and also providing indicators of performance and cost-effectiveness. Such benchmarks of effectiveness are typically established at a national level to provide guidance.

In certain cases, owners require financial and technical audits to be carried out on their administrators to assess performance.

5.2 Administrators

Administrators in South Africa also typically constitute officials at the three levels of Government. These administrators ensure that their operations, maintenance and construction programmes are drawn up to meet the owners' requirements and that the necessary work is procured and carried out cost-effectively. Just as the owners need to understand high level issues associated with road provision, administrators need to have a more detailed understanding of pavement performance to guide planning, investigations, designs and execution, while complying with all the statutory requirements. This entails both day-to-day administration and guidance of their consultants and contractors, as well as making sure that the necessary guidance documentation, such as this manual, are available for use.

Administrators include Road Agencies, e.g., SANRAL, as well as Concessionaires, who manage the functional and structural performance a section of road for a defined period, using of toll income generated from vehicles trafficking the route.

5.3 Designers

Designers are typically private sector consulting engineers. These firms need to ensure that they have the necessary expertise available to carry out the investigations and designs. They also need to be familiar with the owners, administrator requirements and related legislation.

5.4 Construction

Construction is typically carried out by private sector contractors. These firms need to ensure that they have the necessary skills to tender for work and also have the resources available to plan and carry out the work. Such resources involve; management, labour, plant, materials and finance.

6. STATUTORY REQUIREMENTS

All planning, investigations, designs and construction must be carried out in compliance with statutory requirements. As technocrats, pavement engineers prefer to focus on the technical issues pertinent to the design process. The legal issues pertaining to pavement engineering are, however, extremely important and cannot afford to be ignored. These include the following three major areas of legislation:

- **Environmental** legislation
- **Mineral exploitation**, including all materials from borrow pits and quarries
- **Health and safety** legislation



Legal, Environmental and Other Requirements

The legal, environmental and other requirements provided in this manual are an indication of those appropriate to the road authorities. The user/practitioner should ascertain the client's specific requirements and be conversant with the necessary legal requirements and procedures prior to embarking on these activities.

These areas of legislation, and the specific requirements, are highlighted in broad terms below to create awareness. All parties should be aware of the specific legislation and regulations that need to be complied with during the course of their work. The legal, environmental and other requirements provided in this manual are an indication of those appropriate to the road authorities. The user/practitioner should ascertain the client's specific requirements and be conversant with the necessary legal requirements and procedures prior to embarking on these activities.

SAPEM is not intended to be a complete definitive guide to the legal framework and regulations that must be considered in pavement engineering. It must also be recognized that such regulatory requirements are subject to continual review and update. Consequently, this section, along with other related sections, will form

part of a living document which will be updated periodically as required. Specific requirements and principles, as advocated by the relevant environmental regulatory authorities, will be highlighted.

6.1 Environmental Requirements

The protection of the environment is enshrined in the Bill of Rights, which dictates that everyone has a right to a healthy and well protected environment. In the case of roads, typical environmental issues are:

- **Social** environmental impacts caused by both the presence of the road such as noise and traffic adjacent to living areas, schools and hospitals, and the effects of construction of the road, for example, migrant workers.
- **Physical** environmental issues related to the destruction of natural habitat and environmentally sensitive areas by the presence of the road, as well as damage to the environment during construction, such as through diesel spillage, materials excavations, drainage structures and river crossings.

Management of the environment is legislated in South Africa through the National Environmental Management Act 107 of 1998, as amended by:

- **National Environmental Management**
 - Act 56 of 2002
- **Mineral and Petroleum Resources Development**
 - Act 28 of 2002
- **National Environmental Management Amendment**
 - Act 46 of 2003
- **National Environmental Management Amendment**
 - Act 8 of 2004
- **Any other amendments** that may be promulgated from time to time



Environmental and Mineral Requirements

Environmental and mineral requirements are also covered in:

- Chapter 6: **Road Prism and Pavement Investigation**
- Chapter 8: **Material Sources**

The regulations published by the Department of Environmental Affairs and Tourism in Government Gazette No. R. 385 21 April 2006, set out who may carry out Environmental Impact Assessments and apply for authorisation of activities, and who can review reports and authorise such activities.

Important issues to note are:

- The **Environmental Assessment Practitioner (EAP)** carries out a basic or environmental assessment in relation to any potential activities. The EAP must be independent and have no business, financial, personal or

other interest in the works or related activities. There must be no circumstances that may compromise the objectivity of that EAP.

- An **Environmental Impact Assessment (EIA) Report** must be prepared by a competent practitioner and submitted to the Competent Authority to assess. The Authority has 60 days to assess it, or refer it for expert assessment.
- Road design and construction is listed as an activity requiring a **scoping report** to be submitted to the Competent Authority prior to carrying out the comprehensive EIA. It is subject to carrying out the necessary public participation processes, in which potentially interested and affected parties are given an opportunity to comment, or raise issues relevant to the application to carry out the activity. Such interested and affected parties should be registered in terms of the regulations.
- **Road rehabilitation** does not necessarily need an EIA, provided the work is confined to the existing width of the road.
- In all cases, the EIA should follow the guidelines laid down by the relevant Competent Authority, usually the **Provincial Department of Environmental Affairs**. The application for authorisation will be made to the same Department.
- The EIA and related authorisation processes can be **long and complex**, and also include procedures for interested and affected parties to appeal against any authorisation.

It is up to the pavement engineer to ensure that road design and construction activities minimize any environmental impacts, and that the benefits to society outweigh the potential environmental damage. Note should be taken of the time required to carry out the scoping and EIA exercise, including public participation, and finally, authorisation by the Provincial Departments. Environmental issues with sourcing materials are discussed in Chapter 8: 2.

6.2 Mineral Exploitation

6.2.1. Definitions

The Minerals and Petroleum Resources Development Act, 2002 (MPRDA) does not refer to the terminology "borrow pits" and/or "quarries". The Act refers to a "mineral" (including gravel, rock and stone) and a "mining area". In this manual, the terminology borrow pit and quarry are used, but are understood to be a mining area in terms of the act.

A list of relevant definitions is included in Chapter 8: 1.

6.2.2. Background

A consistent and high standard of environmental performance is required of contractors and consultants by road authorities in South Africa. Materials investigations and exploration activities associated with road construction activities have the potential to impact adversely on the environment, if not managed appropriately. As such, this section provides an introduction to environmental legal and statutory requirements for these activities. More details are provided in subsequent chapters, particularly Chapters 6 and 8.

Prior to any exploration, it is essential for any third party that conducts work on behalf of a roads authority to familiarize themselves with the legislation that relates to their proposed activities. Mineral exploration and mining in South Africa are administered in terms of the Mineral and Petroleum Resources Development Act (MPRDA) (Act No 28 of 2002) (as amended). Note that National Department of Environment Affairs is in the process of amending the 2006 EIA Regulations. It is anticipated that the environmental studies associated with mining areas (borrow pits and quarries) will be included in the new regulations. Through the administration of this MPRDA act, in association with the National Environmental Management Act, applicants for mining permits and/rights can acquire authorizations for access to mineral resources. Other associated legislation impacting on mining activity and as such, on materials investigation and acquisition, are discussed below, as appropriate.

For responsible codes of conduct that apply the principles of sound environmental management and industry best practice, please refer to Chapter 6: 3 and Chapter 8.

6.2.3. Regulatory Overview

The regulatory requirements for the various stages of mining are discussed in more detail in Chapters 6 and 8, which fully explain the investigation and management of mining areas. However, the key elements of the Mineral and Petroleum Resources Development Act (MPRDA) that are applicable to road authorities are shown in Table 2.

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Table 2. Key Environmental Requirements for the Mineral and Petroleum Resources Development Act

Key Requirement	MPRDA Reference	Procedure for Roads Authorities in terms of the MPRDA
1. Application for prospecting right	Section 16	Exempted from application process
2. Permission to remove and dispose of minerals	Section 20	Exempted from application process
3. Application for mining right	Section 22	Exempted from application process
4. Application for mining permit	Section 27	Exempted from application process
5. Environmental requirements		
5.1 Consultation with interested and affected parties	Section 10	Not exempted
5.2 Environmental Management Programme and/or Plan	Section 39	Not exempted
5.3 Consultation with state departments	Section 40	Not exempted
5.4 Financial provision for remediation of environmental damage ¹	Section 41	Not exempted
5.5 Issuing of Closure certificate	Section 43	Not exempted

Note

1. SANRAL has secured a Memorandum of Understanding (MOU) with DME that stipulates the requirements with regard to provision for remediation of environmental damage.

Note in Table 2 that the road authorities are generally exempted from the application processes for prospecting and mining related to borrow pits, but have to comply with all the environmental requirements. Therefore, no application needs to be submitted to the DME for prospecting, reconnaissance, mining permit or mining right. However, road authorities are not exempted from conducting and submission of the necessary environmental reports for mining areas to be opened. These include:

- An **Environmental Management Plan (EMP)** needs to be submitted for mining areas less than 1.5 hectares in extent. The EMP needs to be completed by a suitably qualified Environmental Assessment Practitioner (EAP) for submission to the relevant regional office of the Department of Minerals and Energy.
- An **Environmental Management Programme (EMProg)** needs to be submitted for mining areas that exceed 1.5 hectares in extent. The EMProg needs to be prepared following an Environmental Impact Assessment (EIA) process for mining areas exceeding the prescribed limit. The EMProg needs to be completed by a suitably qualified Environmental Assessment Practitioner for submission to the relevant regional office of the Department of Minerals and Energy.

In addition to the requirements of the MPRDA, other South African legislation impacting on exploring and mining activity associated with materials investigation and acquisition include (inter alia):

- Mine Health and Safety Act
- National Water Act
- National Environmental Management Act (NEMA) EIA Regulations (2006) (as amended)
- Explosives Act
- National Forestry Act
- National Heritage Resources Act

6.3 Health and Safety Legislation

The health and safety of all people involved in the road construction process cannot be compromised. Issues of primary concern are:

- Safety in respect of **traffic** during construction.
- Safety in **deep excavations and cuttings** and during the construction of all structures.
- Safety in respect of **harmful materials** such as hot bitumen, unhealthy vapours and contact with cement, lime and cement dust.
- Health of all in respect of **good sanitation**, food and drinking water.
- Protection from the **sun**.

The proper management of health and safety is legislated through the Occupational Health and Safety Act 85 of 1993 and its regulations. There are many regulations, of which the Construction Regulations are of primary concern during road construction.

The pavement engineer should note that this Act and Regulations places responsibilities on various parties, including:

- The **owner** to ensure that the designers, agents and contractors all ensure compliance with the Act.
- The **designer** to highlight any particular Occupational Health and Safety (OHS) issues that could arise due to the design.
- The **contractor** must have an approved OHS plan and ensure that this plan is always adhered to during construction through regular audits. This must include:
 - Carrying out risk assessments to be incorporated into the OHS plan.
 - All personnel and visitors to site must receive OHS induction training and be issued with suitable safety equipment.
 - All potentially hazardous areas and procedures are identified, and the necessary steps are taken to mitigate these hazards.
- All **suppliers** to ensure their equipment and materials are handled safely and that the necessary guidelines are available to users.
- All **employers** to ensure that their employees are not unduly subjected to risks in respect of OHS and their procedures, processes and workplaces are safe and healthy. This typically involves the appointment of Health and Safety committees, and ensuring that emergency procedures are readily available and medical help is available for incidents and emergencies.

Compliance with the Act has to be ensured through the development of appropriate procedures and monitoring by competent professionals. In the case of roadworks, many guidelines in this regard are available from industry bodies such as SAFCEC, Sabita and C & CI.

7. ROAD DESIGN LIFE CYCLE

Road design follows several phases. The activities in each phase follow a typical design, construction, operation and maintenance life cycle as set out in Table 3. Generally each phase needs to be completed before moving onto the next phase.

The pavement engineering “cycle of technology” is defined by a loop, illustrated in Figure 9, comprising:

- **Awareness** of the pavement distress mechanisms, followed by
- **Acquiring knowledge** of the performance of the pavement materials and key performance properties, leading to
- **Developing design tools** for the entire pavement system in the climatic and traffic environment, including response to loading and material damage models, culminating in
- **Implementation** of the pavement construction.

Closing the loop requires evaluation of the actual pavement performance and recalibration the design models, which were originally based on laboratory and APT testing.

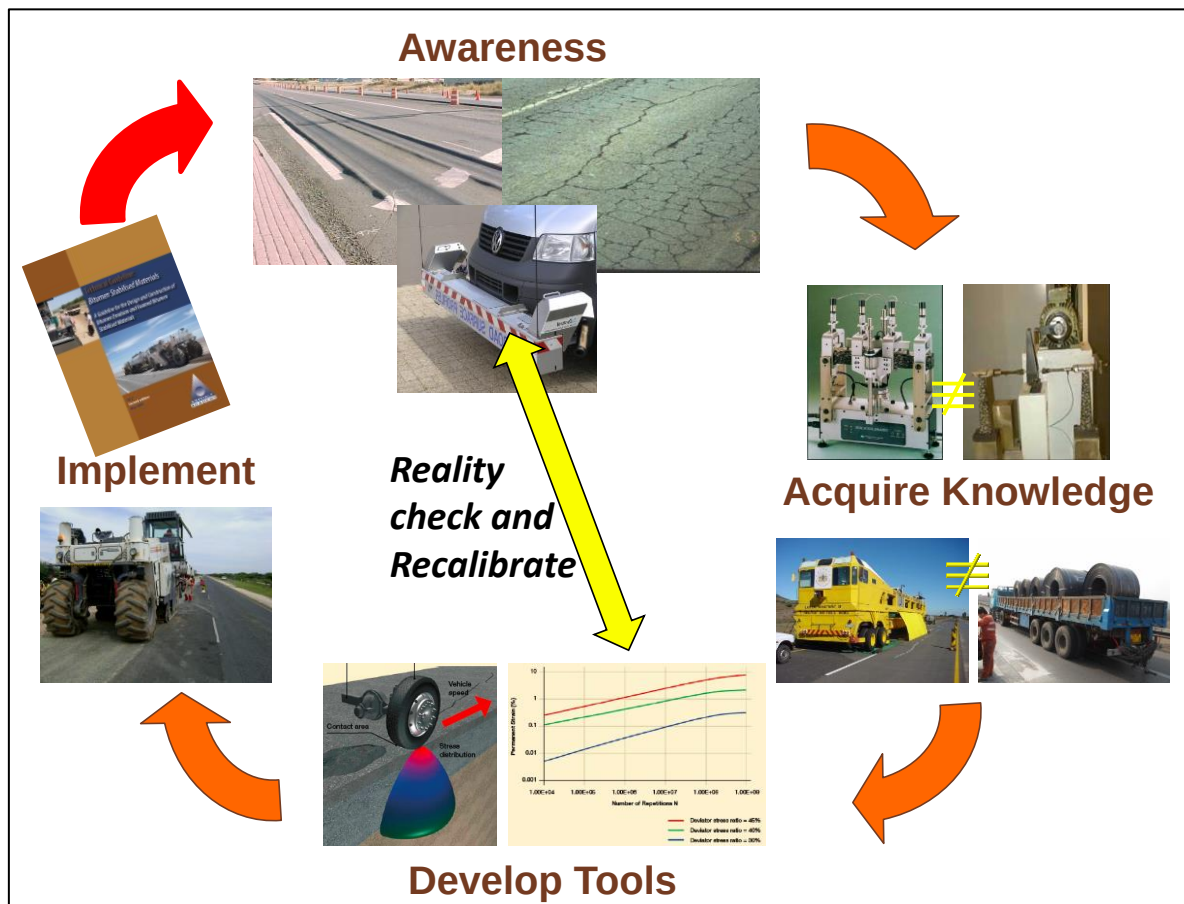


Figure 9. Pavement Engineering Cycle of Technology

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Table 3. Phases of Road Design

Purpose of Investigation	Techniques	Content
Phase: Planning		
Project Stage: Greenfields: Project Statement	Geotechnical/Soils/Route/Investigation: Published Geological and Soil Maps	
- Options identification - Possible impediments: environmental, natural ground risks, property, topography, etc. - Interfaces with existing infrastructure - Likely usage and impacts on existing infrastructure - Identification of significant cost elements	- Desk study, including literature review (e.g., case studies) - Asset management documents - Specialist studies, including: wetland studies, Geographical Information Systems (GIS) - Public participation - Social-economic studies - Preliminary economic assessment	- Potential environmental risks - Possible options - Likely Costs - Limitations - Social benefits
Project Stage: Upgrading of Existing: Problem Identification		
Options identification and prioritisation	- Pavement surveillance data - Traffic data - Road Asset Management Systems (RAMS) needs assessment and decision support systems	- Options - Priorities - Budget/options assessments
Phase: Pre-Feasibility		
Project Stage: Initial Assessments	Geotechnical/Soils/Route/Investigation: Reconnaissance Surveys	
- Basic assessment report (BAR) including route location for greenfields - Environmental scoping - Refinement of alternatives - Interpretation of information collected - Recommendations for additional investigations - Determination of general geological conditions - Preliminary indications of foundation conditions - Preliminary indication of construction material resources	- Additional public participation, if required - Data collection - Field investigation (walk over investigation) - Regional mapping (geological, land use, agricultural, topographical) - Identification of potential quarry and borrow pit locations and commercial sources - Road and pavement visual assessments - Surveillance measurements - Geophysical investigations - Traffic predictions - Benefit/cost analysis	- Initial Assessment Report - Layout plan - Regional engineering geological map - Physiography (topography, climate and geology) - Record of available information - Description of geological conditions - Economic analysis - Recommendations for additional investigation

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Purpose of Investigation	Techniques	Content
Phase: Feasibility		
Project Stage: Preliminary Design		
Geotechnical/Soils/Route/Investigation: Geotechnical & Materials Report		
- Final option selection - Determination of general engineering geological conditions - Preliminary design of road (horizontal and vertical alignment) and structures - Interfacing with environmental impact assessment - Interpretation of information collected, needs assessment for the detailed site investigation - Cost assessment - Confident alternative design options - Final scope definition - Environmental and mining approvals - Property expropriation diagrams	- Initial drilling and borehole tests for quarries and bridges - Field sampling and surveillance tests - Laboratory testing - In situ testing to obtain quantitative information on the extent of geotechnical problems - Soil and rock mapping	- Engineering geological map and profiles of sites (route and material resources) - Detailed materials report (Detailed Assessment and Design Report) - Deterioration modelling and effects of maintenance - Life cycle analysis - Preliminary Pricing Schedule - Provisional costing - Final economic evaluation - Recommendations for specialised testing
Phase: Detailed Design and Documentation		
Project Stage: Final Design		
Geotechnical/Soils/Route/Investigation: Final Investigations. Convert investigation results into designs, specifications and quantities		
- Final design, drawings and tender documentation documentation - Obtain quantitative and qualitative information on route alignment, foundation conditions, subsurface drainage and construction materials - Description of final design - Specifications - Pricing Schedule	- Core drilling for foundations - Input from initial assessment report - Site and resource mapping - Extensive material testing (test pitting, auger samples, material sampling, penetration tests) - Laboratory testing and classification - Pavement design	- Detailed drawings - Detail engineering geological maps and profiles - Quantitative and qualitative description on foundations and roadbed /subsurface, design and drawings - Pricing Schedule - Specifications - Final cost estimate - Material Investigation and Utilisation Report
Phase: Construction		
Project Stage: Construction		
Geotechnical/Soils/Route/Investigation: Geotechnical Foundation & Bridge Report, Geotechnical Report		
- Comparison of predicted with encountered conditions/cut and slopes - Observation of behaviour of permanently anchored bridge foundations and founding conditions - Recording all design changes	- Detailed mapping/photography and final design - Record of design changes and slope stability measures - Monitoring of bridge foundations and major culverts	- Detailed maps - Photos - Design changes - Quality assessment records - As-builts drawings - Materials test results - Construction Report

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Purpose of Investigation	Techniques	Content
Phase: Operations and Maintenance (Monitoring)		
Project Stage: Assessment Report	Geotechnical/Soils/Route/Investigation: Special Maintenance & Integrity Reports	
Maintenance of road infrastructure and furniture integrity and cost determination	- Route inspections - Maintenance of drainage - Integrity of road pavement structures - Subsurface monitoring	- Maintenance and monitoring reports - Project management report - Budget for holding and remedial actions, and maintenance
Project Stage: Short Term Monitoring	Geotechnical/Soils/Route/Investigation: Integrity Reporting (Structures and Slope Stability Measures)	
- Comparison of actual and predicted conditions - Attending to ad hoc problems - Observation of behaviour or permanently anchored bridge foundations, lateral support systems and permanently anchored or bolted cuttings and fills, during the Defects Notification Period	- Detailed site records - Photos - Monitoring foundation or slope treatments and behaviour via instrumentation and surveillance	- Detailed mapping - Photos - Records, measurements and results - Further long term actions or recommendations
Project Stage: Long Term Monitoring (~ 8-10 years)	Geotechnical/Soils/Route/Investigation: Integrity Reporting (Structures and Slope Stability Measures)	
Same as above for short term monitoring, but at regular intervals during the expected eventual design life of the particular facility	Monitoring of permanently installed devices and/or instruments (mechanically and/or electronically, e.g. deflections, stresses, pressures and water flow) and ongoing verification of integrity.	- Records, measurements and results - Evaluation and discussions - Conclusions - Recommendations for either immediate or longer term actions

8. PLANNING AND TIME SCHEDULING

Significant documentation has been published on planning and time scheduling. The aim of this section is to highlight aspects that need to be considered in the planning and time scheduling of a project.

The management of any project always has a 3-dimensional goal:

- **Delivering** the correct project, as agreed upon
- Not exceeding an approved **budget**
- Delivering **on time**, as specified

To achieve the above, planning needs to be carried out in phases, with the end in mind. It is normally difficult to plan activities a few years, or even a few months ahead, in too much detail. Therefore, it is normally more convenient to break a project into phases:

- Preliminary Investigation and/or Route Location
- Preliminary Design
- Detailed Design and Documentation
- Tender and Construction
- Defects Notification

These phases can be broken up further into smaller activities, with milestones linked to each activity. The time required for carrying out these technical activities can be determined and scheduled.

There are a number of useful software packages on the market to aid project management.

8.1 Non-Technical Factors

There are a number of non-technical activities and issues that need to be resolved before a project can proceed. Each project has elements of uniqueness, which need to be identified at the start of the planning process, and considered in the project management programme. The following non-technical issues and activities will typically delay delivery of the programme if not properly managed:

- **Land requirements:** Allow enough time to acquire land including:
 - Road reserve
 - Access roads
 - Borrow pits and quarries
 - Stockpile areas
 - Temporary deviations
- **Climate restrictions:** Embargo periods for certain activities and areas.
- **Survey and testing:** Topographical surveys and mapping, traffic surveys and geotechnical and materials investigations and testing.
- **Budget:** The project can only start when the cash flow is available.
- **Environmental approval:** No control over time taken to get approval.
- Approval for **mineral exploitation** of borrow pits and quarries.

8.1.1. Land Acquisition

The land acquisition procedures for the different Road Authorities vary. SANRAL's procedures are dealt with in detail in the relevant chapters of this manual.

It is necessary to be aware of the types of land normally encountered in any design. The land type holds the unique factors that influence the ultimate timeframes and construction of a designed road, and dictate the parameters within which a design is confined. There is a need to differentiate between the types of land, as shown in Table 4.



Project Management

The expression "on time, on budget, on brief" is often used to describe the basic project management requirements.



Time Required for Environmental Approvals

The time required for environmental approvals and approvals for mineral exploitation can be extensive, and must be considered at all stages of a project. Chapter 8: 2.5 contains more information on these processes.



Land Acquisition

The land acquiring process can run parallel with the Preliminary and Detailed Design, but must be resolved before the site is handed over to the Contractor.

8.1.2. Climate Restrictions

Due to low day and night temperatures at certain times of the year, an embargo is enacted for when road surfacing is not allowed. The embargo period is normally between May and September. Road surfacing actions therefore need to be programmed to take place between September and April. This means that the time for completion should be by mid-April to allow for a possible contract time extension. Other activities can still proceed during this period. The embargo period also impacts on the type of surfacing described for a project.



Surfacing Construction Embargo

Due to low day and night temperatures at certain times of the year, an embargo is enacted for when road surfacing is not allowed. The embargo period is normally between May and September.

Table 4. Types of Land

Land Type	Comment
Existing roads	Proclaimed or declared within defined spatial area.
Privately owned land	Registered in the name of a juristic person. Are there rights on the land and is the land owner willing to sell land?
State owned land	Registered in the name of the Republic of South Africa (RSA) or State Department. Land needs to be "vested" before alienation. Most land cannot be alienated and should be avoided. Seek expert advice.
Unalienated state and tribal lands	Most of these lands are within former homelands and are linked to obsolete chiefship boundaries to which no property rights were linked. To acquire such land takes between 12 and 18 months and can hamper construction works.
Ingonyama Trust	The majority of the state owned land in Kwazulu-Natal became the property of the King of the Zulus. Design engineers are advised to seek expert advice on how best to deal with such land as soon as possible.
State domestic land assets	State domestic land assets are registered and managed by the Department of Public Works. Design engineers are advised to stay clear of this land, or expect delays.
Quitrent	A form of individual title closely analogous to freehold, originally introduced in the Cape by the Glen Grey Act and later extended to the former Transkei. The dominium of the land remains with the State as land cannot be transferred. Acquiring these lands may cause delays. Design engineers are advised to rather steer clear of such land if possible.
Transnet and SARCC land	Land cannot be acquired, but wayleaves need to be negotiated or a bridge agreement entered into.

8.1.3. Survey Considerations

All technical surveys can take time to carry out. For example, aerial photography can normally only be carried out when there is no cloud cover. Once the field work has been carried out, time is required to process the results or carry out testing. For example, many laboratory tests require up to 28 days to complete. In addition, traffic survey results, for example, are influenced by seasonal and weekly variations in traffic patterns. See Chapter 10: 4.4 for further discussion on the variations in traffic.

In many instances, investigations will identify other issues that need further investigation and the whole cycle will have to be repeated. For this reason, the timing of all surveys needs to be carefully planned to ensure that reliable results can be obtained and used with confidence.

8.1.4. Budget

A project budget consists of the following 3 components:

- **Schedule of Quantities:** Contains all the items with quantities and rates required for the completion of the project.
- **Contingencies:** Allowance for unforeseen costs. Normally not more than 10% of the Schedule of Quantities.
- **Escalation:** As projects take place over time, with durations of 6 months and more, the estimate of the costs cannot fully take all the variables into account, and costs must be escalated to account for inflation.

For proper programme management and planning, the programme manager needs to know the estimated cost of projects as well as when funding will become available. The project execution should be programmed to stay within the budget and related timeframes. Project costs that vary significantly during the project development process make programme management very difficult. Therefore, accurate estimates must be developed. Good

communication is required between the various parties to ensure that orderly planning and programme execution can proceed.

8.1.5. Environmental Approvals

An environmental specialist is normally approved for each project, to assist the design team and point out any sensitive issues which could impact on the environment, including quarries and borrow pits. The approval process is, however, out of their hands and needs to be followed up regularly to avoid project delays.



Handing over Sites

A site must not be handed over to the Contractor until written approval is received from the relevant authorities.

8.2 Typical Time Scheduling Requirements for Road Projects

This section looks at the typical time scheduling requirements for the various stages of road construction projects.

8.2.1. Preliminary Investigation and/or Route Location

The timeframe varies considerably depending on the difficulties involved and interfaces with other infrastructure and environmental constraints. It also depends on the complexity of the work and related non-technical factors. The design team normally prepares a programme for this work, and the programme is adjusted as difficulties arise and are overcome.

In many instances, route locations and related preliminary investigations form part of the owner's planning processes. Environmental considerations and the like need to be addressed to ensure that sensitive areas are identified and resolved adequately, and do not become stumbling blocks preventing the project from advancing. The time associated with environmental approvals can be significant and non-approval may have far-reaching consequences in terms of wasted design and consultation efforts. Therefore, it is often more productive to do initial conceptual work as part of planning. The concept is then converted into a project when the route is largely defined and the location form and function of the work is known.

8.2.2. Preliminary Design Phase

The timeframe for the preliminary design phase is normally linked to the completion date agreed with the Road Authority. It can also include some time allowance for surveys and interfaces with interested and affected parties. The time allowed must be sufficient to advance the concept into a well-defined design that can address all potential technical problems to ensure feasibility and constructability. The design team must prepare a programme for this work.

There is normally a delay between the Preliminary Design and Detailed Design. This is to allow for motivating the project to obtain funding and ensure it is placed on the applicable budget(s).

8.2.3. Detailed Design

The period required for detailed design also depends on the project complexity, the project type and related land acquisition, mineral rights and environmental issues. This could typically involve between 36 and 100 weeks.

8.2.4. Tender Documentation

The tender documentation period is normally included in the Detailed Design period. However, it is more critical as it influences the milestone date required for construction commencement and site handover. The diagram in Figure 10 highlights all the periods that are critical for construction to proceed as planned. Refer to Chapter 11 for more on tender documents and contract types.

8.2.5. Construction and Defects Notification Period

The construction and defects notification period is shown in Figure 10 for a typical contract.



Time Scheduling Requirements for Road Authorities

Contact the relevant Road Authority to obtain the time scheduling requirements for a particular project.

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Chapter 1: Introduction

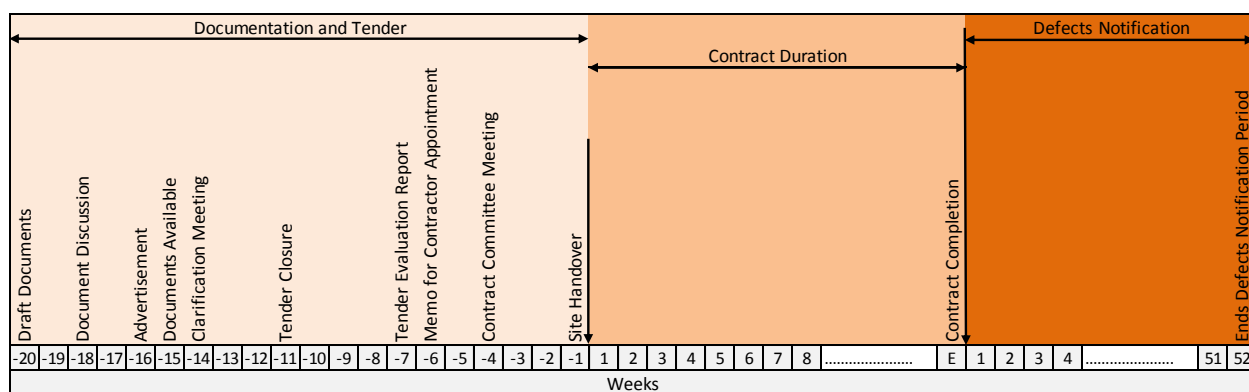


Figure 10. Construction and Defects Notifications

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TRH Revisions

Many of the TRH guideline documents are in the process of being updated. See the SANRAL website, www.sanral.co.za for the latest versions.

ε	Epsilon, used to represent strain
δ	Deflection
σ	Sigma, used to represent stress
ν	Poisson's Ratio
10% FACT	10% Fine aggregate angularity test
AADE	Annual average daily equivalent traffic
AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials. Used to be AASHO, American Association of State Highway Officials.
AC	Code for continuously graded asphalt
Active filler	Fillers that chemically alter the mix properties. This includes fillers such as lime, cement and fly ash, but excludes natural fillers such as rock flour.
ACV	Aggregate crushing value
AD	Apparent density
ADE	Average daily equivalent traffic
Adhesion	Ability of the aggregate to form a strong and lasting bond with the binder.
Adit	Horizontal entrance to a tunnel
ADTT	Average daily truck traffic
AG	Code for gap-graded asphalt
Aggregate	Inert hard rock-type material, crushed and screened to produce stone, sand or grit.
Aggregate crushing value	The ability of aggregate to resist crushing under a compressive load (see also Hardness).
ALD	Average least dimension of aggregate
Analysis period	A selected period over which the present worth of construction costs, maintenance costs, user costs and salvage value are calculated for alternative designs, and during which full reconstruction of the pavement is undesirable.
AO	Code for open graded asphalt
Anionic emulsion	Has negatively charged bitumen globules. Anionic emulsions break predominantly when the bitumen particles agglomerate with the evaporation of the water, and through mechanical action such as rolling.
Average least dimension (ALD)	The overall average of the least dimension for a number of particles (at least 200) where the least dimension of the aggregate particle is the smallest perpendicular distance between two parallel plates through which the particle will just pass.
ARD	Apparent relative density, now known as the AD
AS	Code for semi gap-graded asphalt
ASO	Code for semi open-graded asphalt
Asphalt	A mixture of bituminous binder and aggregate in a prescribed ratio
ASTM	American Standard Test Methods
Azimuth	Horizontal angle measured clockwise from a defined north base line or meridian. Used in tunnel terminology.
Ball penetration test	A test for measuring the penetration resistance of a road surface using a steel ball with a diameter of 19 mm. The result, corrected for temperature and nature of existing surface, is used in the design of surface treatments.
Base	Layer occurring immediately beneath the base or concrete slab, and above the selected layer(s).

BD	Bulk density
BBBEE	Broad Based Black Economic Empowerment
Bitumen	A non-crystalline solid or viscous mixture of complex hydrocarbons which possesses characteristic agglomeration properties. Bitumen, obtained from crude petroleum by refining processes, softens gradually when heated and is substantially soluble in trichloroethylene.
Bitumen emulsion	A liquid mixture in which a substantial amount of bitumen is suspended in a finely divided condition in an aqueous medium of one or more suitable emulsifying agents. (See anionic and cationic emulsions).
Bitumen rubber	Bitumen modified by the addition of approximately 20 percent rubber crumbs to improve certain properties of the binder. Additionally, 2 to 5 percent of liquid additive is often added to further improve its properties.
Bituminous binder	A product such as bitumen or derivatives thereof, e.g., cut-back bitumen, modified binder or bitumen emulsion, which acts as a binder for the aggregate.
Bituminous surfacing	A surfacing seal or layer of premix asphalt, which is directly subjected to traffic forces.
Bleeding	Excess binder present in a seal or asphalt mix, causing a layer of tacky binder to appear on the surface. Also called flushing.
Blinding	The application of fine aggregate such as crusher sand (not dust) at a low application rate ($0.0025 \text{ m}^3/\text{m}^2$) on top of fresh binder, to reduce the tackiness.
Borrow pit	Describes an area where material, usually soil, gravel, sand, or weathered rock, has been dug for use as a natural granular material for use in road construction.
BRD	Bulk relative density, now known as the BD.
Brittleness	When a seal cracks, splinters or breaks under traffic impact or as a result of rapid deformation because of its rigidity.
BRT	Bus Rapid Transport
BSM	Bitumen stabilized materials: BSM-foam or BSM-emulsion
BTB	Bitumen treated base
C & CI	Cement and Concrete Institute, now The Concrete Institute (TCI)
C1 to C4	TRH14 classification of cemented materials. C1 is the strongest material with the highest cement content. C4 is a lightly cemented material.
Cationic emulsion	Has positively charged bitumen globules. Cationic emulsions break in a physical-chemical reaction, through the evaporation of the water phase and through mechanical actions, such as rolling.
CBR	California Bearing Ratio
CETA	Construction Education and Training Authority
Chimneying	Process of internal erosion of ground working its way upwards along decomposed material as a result of high rates of gravitational groundwater inflow.
CIDB	Construction Industry Development Board
Closure plan	The document that accompanies the application for closure and forms part of the Environmental Management Programme or Environmental Management Plan. This plan includes the description of the closure objectives as well as rehabilitation provisions and details any long-term management and maintenance. Where no mining plan has been developed for a particular borrow pit, a closure plan may be developed as a proactive step for closure of the site.
Coarse-sand ratio	coarse sand fraction : soil fraction (minus 2 mm)
Collapsible soils	Collapsible soils have a grain structure that collapses, sometimes with a large magnitude, in the presence of water.
COLTO / COTO	Committee of Land Transport Officials, now Committee of Transport Officials
CSF	Condensed silica fume
CTO	Comprehensive Traffic Observations Stations

CPT	Cone Penetration Tests
Cut-back bitumen	A penetration grade bitumen whose viscosity has been reduced by the addition of 5 to 20 percent of a volatile solvent (kerosene or diesel).
D&C	Design and Construct
DBFO	Design, build, finance and operate
DBO	Design, build and operate
DCP	Dynamic Cone Penetrometer
DEAT	Department of Environmental Affairs and Tourism
Defects liability period	The defects liability period is the period during which the Contractor is liable for any defects that are not part of normal "wear and tear". Normally 12 months.
Deformation	A mode of distress, manifest as unevenness in the surface profile.
Diluted emulsion	A mixture of a stable grade emulsion with water, generally in a 50/50 ratio, to obtain a lower binder content by volume. It is sprayed to enrich and/or soften the binder of an existing seal.
Dispersive Soils	Dispersion occurs when the repulsive forces between the individual clay particles exceeds the attractive (van der Waal's) forces so that when the soil is in contact with water the individual particles become detached and go into suspension.
Distress	The visible manifestation of the deterioration of the pavement with respect to either the serviceability or the structural capacity.
Distress mechanism	The physical process that causes the distress.
DME	Department of Minerals and Energy (now DMR)
DMR	Department of Mineral Resources
Dolomite	Dolomite is formed by chemical precipitation and comprises carbonates of calcium and magnesium with iron, manganese oxides, chert and a siliceous deposit, depending on the tidal zones in which it was formed. The carbonate components of these rocks are soluble in acidic solutions, resulting in the development of solution cavities.
Double seal	An application of bituminous binder followed by a layer of stone followed by another layer of bituminous binder and a layer of smaller stone.
E	Often used as abbreviation for material stiffness.
E80	Equivalent single axle load, also known as ESAL.
E80/HV	E80 per heavy vehicle
EAP	Environmental Assessment Practitioner
EAPSA	Environmental Assessment Practitioners of South Africa
ECSA	Engineering Council of South Africa
EIA	Environmental Impact Assessment
elv	Equivalent light vehicles
EMC	Equivalent moisture content
EMP	Environmental Management Plan
EMProg	Environmental Management Programme
Environment	The surroundings within which humans exist and that are made up of: • Land, water and atmosphere of the earth. • Micro-organisms, plant and animal life. • Any part or combination of the above and their inter-relationships. • Physical, chemical, aesthetic and cultural properties, and conditions that influence human health and well-being.
elv	Equivalent light vehicles
Equivalent granular state	The equivalent granular state is when a lightly cemented layer has cracked or weakened to the extent that the effective stiffness is similar to that of an unbound granular layer. The "cracked" state does not imply the material has reached the consistency of a granular material, or that it has necessarily visibly cracked into smaller, granular like pieces. The cracks are generally micro-cracks that are not that visible, but result in a loss of stiffness.

Equivalent light vehicles (elv)	One car or light delivery vehicle per lane per day. A vehicle larger than a car or light delivery vehicle is taken to be equal to 40 light vehicles.
Equivalent traffic	The number of equivalent 80 kN (standard) single axle loads (E80s) which cause the same cumulative damage as the actual traffic spectrum.
ES	Equivalent traffic class, i.e., ES0.003 to ES100
ESP	Exchangeable sodium percentage
ETQA	Education and Training Quality Authority
evu	Equivalent vehicle units
Expansion ratio (ER)	Maximum volume of foamed bitumen relative to the original volume of bitumen.
Expansive clays	Clay prone to large volume changes directly related to changes in water content.
Expropriation	To surrender a claim to exclusive property; to take ownership or proprietary rights.
FA	Fly ash
FI	Flakiness Index
FIDIC	Fédération Internationale des Ingénieurs-Conseils (International Federation of Consulting Engineers)
fill	Subgrade material placed over the roadbed
Fineness modulus	The fineness modulus of sand is used as a parameter in the proportioning of concrete mixes at the design stage.
Flakiness Index (FI)	The mass of particles in the aggregate, expressed as a percentage of the total mass of that aggregate, which pass through the slot or slots of specified width for the appropriate size fraction. The widths and lengths of the slots are respectively half and double those of the sieve openings through which each of the fractions pass.
Flushing	See bleeding
FMC	Field moisture content
Fog Spray	A light application of bitumen emulsion to the final layer of aggregate of a surfacing seal or to an existing bituminous surfacing as a maintenance treatment.
Fresh concrete	Concrete that is still in a plastic or semi-plastic workable state.
FWD	Falling Weight Deflectometer
Hardness	The ability of aggregate to resist crushing under a compressive load (see also Aggregate Crushing Value).
G1 to G10	TRH14 classification of granular materials. G1 is the highest quality, G10 the poorest.
Geology	Science of the earth's crust, its strata, relations and changes.
Geometric design	Design of the geometry of the road surface for traffic flow and for the safety and convenience of the road user.
Geomorphology	Study of the physical features of the earth and its geological structures.
GGBS	Ground granulated blast furnace slag.
Gravels	Naturally occurring materials which are predominantly coarser aggregate particles, and have considerable strength due to aggregate interlock.
Hardened concrete	Concrete that has gained sufficient strength to no longer be termed a semi-liquid or weak solid, i.e., it can no longer be worked or finished.
half-life ($\tau_{1/2}$)	The time foam bitumen takes to collapse to half of its maximum volume.
heavies	Heavy Vehicles
Heavy vehicle	A vehicle with an axle load > 4 000 kg, usually with dual rear wheels.
HMA	Hot mix asphalt
HSE	Health, Safety and the Environment
HRI	Half Car Index, a measure of roughness
IAIA	International Association of Impact Assessment
ICL	Initial consumption of lime. This is now known as the initial consumption of stabilizer.

ICS	Initial consumption of stabilizer
IEC	International Electrotechnical Commission
Invert level	Bottom level of the inside of the tunnel
Inverted emulsion	Distinct from normal oil in water cationic and anionic emulsions. With inverted emulsions, the water is dispersed in the binder phase. These emulsions are manufactured with cut-back bitumens and have water contents of less than 20%.
IRI	International Roughness Index, a roughness measure
ISO	International Organisation for Standards
ITS	Indirect tensile strength
kPa	kiloPascals
Latent defects	Defects that are not immediately apparent, but will probably result in the pavement not achieving its design life.
LEF	Load equivalency factor
Liquid limit	The liquid limit of a soil is the moisture content of the soil at which the soil passes from a plastic to a liquid state.
LUPO	Land-Use Planning Ordinance
LVR	Low volume road
Maintenance	Remedial measure(s) to improve the serviceability of the structural capacity or a road, not usually the geometric properties.
Materials depth	The depth below the finished road level wherein the physical properties of the materials have a significant effect on the pavement behaviour. The materials depth is also the depth to which the moisture regime needs to be controlled.
MDD	Maximum dry density
Mechanistic analysis	Analysis of a system, taking into account the interaction of various structural components as a mechanism.
MESA	Million equivalent standard axles or million E80s.
Mine	Any operation or activity for the purposes of winning a mineral on, in or under the earth, water or any residue deposit, whether by underground or open working or otherwise, and includes any operation or activity incidental thereto.
Mining operation	Any operation relating to the act of mining and matters directly related.
Mining plan	A plan detailing the approach to the development, operation and decommission phase of a borrow pit operation.
Mod.	Abbreviation for modified (mod) AASHTO density
Modified binder	Any standard bituminous binder which has been mixed with additives to produce a more durable binder with better mechanistic properties and/or lower temperature susceptibility than the original binder. Additives used are mineral fillers, rubber, plastic, fibres, metal bonds and polymers.
Modular ratio	Ratio of the stiffness of the upper layer and the stiffness of the lower layer.
MIST	Moisture induced sensitivity test
MPRDA	Minerals and Petroleum Resources Development
MPa	megaPascals
M_R	Resilient modulus
MSDS	Material Safety Data Sheets
MTRD	Maximum theoretical relative density (also known as "Rice Density"). This is now termed the maximum voidless density (MVD)
MVD	Maximum voidless density, previously known as the maximum theoretical relative density ("Rice Density").
NEMA	National Environmental Management Act
NMISA	National Metrology Institute of South Africa
NQF	National Qualification Framework

O&M	Operations and maintenance
Overbreak	Overexcavation of rock broken out in excess of the neat tunnel line
OHS	Occupational Health and Safety
Overburden	Layer of soil immediately beneath the topsoil, but above the mineral that is the target of the mining activities.
Patent defects	Defects that are patently obvious and require immediate repair.
Pavement balance	One of the design principles for flexible pavements is that the material quality gradually, and smoothly, increases from the in situ subgrade up to the structural layers and surfacing. Such a pavement structure is referred to as a well-balanced pavement.
Pavement behaviour	The function of the condition of the pavement with time.
Pavement number	A structural design method for flexible pavements.
Pedogenic materials	Pedogenic materials are formed by a chemical process where either transported or residual soils are altered to a cemented granular structure, resulting in the engineering properties being altered. The cementing agent and degree of cementation can vary. Calcretes and ferricretes are the most common pedogenic materials.
Pen	Penetration of bitumen
Penetration grade bitumen	A viscous material obtained from petroleum by refining processes.
Performance	The measure of satisfaction given by the pavement to the road user over a period of time, quantified by a serviceability/age function.
Periodic maintenance	Planned interventions, undertaken every 5 to 7 years, such as reseals.
Phreatic Surface	This is the subsurface zone of soil or rock in which all pores and interstices are filled with fluid.
PI	Plasticity Index
Plastic concrete	Concrete from the time it is mixed until it sets.
Plasticity Index	The Plasticity Index (PI) is a measure of the moisture content range of the plastic state. Calculated as the difference between the liquid limit and plastic limit.
Plastic limit	The plastic limit of a soil is the lowest water content at which the soil remains plastic.
PMB	Polymer modified binder
PN	Pavement Number
Polishing	The tendency of certain stone types to become smooth and rounded under the action of traffic. This should not be confused with attrition or bleeding.
Pollution	Changes in the environment caused by substances; noise, odours or dust, emitted from any activity, including the storage or treatment of waste or substances, construction and the provision of services, where that change has an adverse effect on human health or well-being or on the composition, resilience and productivity of natural or managed ecosystems, or on materials useful to people, or will have such an effect in the future.
Polymer-modified binder (PMB)	A standard bituminous binder to which a polymer has been added to produce a more durable binder with improved mechanical properties.
Portals	Entrances and exits of the tunnel
PPE	Personal protective equipment
ppm	Parts per million
Pre-coating	Pre-coating of a seal stone with a binder (tar or bitumen-based) to improve the initial adhesion between the stone and the seal binder.
Premix	Premix refers to asphalt used for patching, i.e., a mix of binder and aggregate which should meet specific requirements. (See also Asphalt)
Present worth of cost	Sum of the costs of the initial construction of the pavement, the later maintenance costs and the salvage value discounted to a present monetary value.

Prime coat	A layer of binder applied directly on top of the base course to promote and maintain adhesion between the surfacing and the base. This layer also prevents the absorption of surfacing binder by the base and assists in sealing the voids near the surface. It acts as a curing membrane on stabilized bases.
PSI	Present Serviceability Index, a measure of roughness
PSV	Polished stone value
Pumping	The mechanism causing water to move soil fines from within the pavement up through the surface of the pavement. Also used as a description of the appearance of the pavement as a result of the pumping occurring.
PWOC	Present worth of cost
QCTO	Quality Committee for Trades and Occupations
Quarry	Describes an open excavation from where rock is obtained, usually by blasting, to produce rock aggregate for use in road construction.
QMS	Quality Management System
RA	Reclaimed asphalt
RAMS	Road Asset Management Systems
Reconnaissance	Investigation, scouting, inspection or surveying of aspects or sites.
Reflection cracks	Cracks in asphalt overlays or surface treatments that reflect the crack pattern of the pavement structure underneath.
Regolith	Layer of loose rock resting on bedrock
Rehabilitation design period	The chosen minimum period for which a pavement rehabilitation is designed to carry the traffic in the prevailing environment, with a reasonable degree of confidence, without necessitating further rehabilitation.
Reseal	A surfacing seal for maintenance purposes.
Riding quality	The general extent to which the road users experience a ride that is smooth and comfortable or bumpy, and, thus, unpleasant and perhaps dangerous.
Road prism	The portion of road construction between the outer boundaries of fill and cut slopes of cuttings and side drains.
Road reserve	The entire area, as proclaimed, which is reserved for a road.
Roadbed	The natural in situ material on which the fill, or in the absence of any fill, pavement layers are constructed/exist.
Road pavement	The upper layers of the road comprising the selected subgrade layer/s, subbase layer/s, base and surfacing or wearing course.
Routine maintenance	Maintenance activities carried out on a daily or routine basis, including , blading of unpaved roads and shoulders, road reserve and vegetation maintenance, drainage repair and reinstatement, crack sealing and patching, repair of cut and fill slopes.
RPL	Recognition of Prior Learning
S/m	Siemens per metre, a measure of electrical conductivity
SABITA	South African Bitumen Association
SABS	South African Bureau of Standards
SACNASP	South African Council for Natural Scientific Professions
SAFCEC	South African Forum of Civil Engineering Contractors
SAGA	South African Geophysical Association
SAIEEG	South African Institute for Environmental and Engineering Geologists
SAICE	South African Institute of Civil Engineers
SAMDM	South African Mechanistic-empirical Design Method
SAMI	Stress Absorbing Membrane Interlayer
SANAS	South African National Accreditation System
SANRAL	South African National Roads Agency SOC Limited

SANS	South African National Standards
SAPDM	South African Pavement Design Method (update to SAMDM)
SAPEM	South African Pavement Engineering Manual
SARF	South African Roads Federation
SAQA	South African Qualification Authority
sdp	Structural design period
Selected layer(s)	Lowest layer of the pavement consisting of controlled material, either in situ or imported.
serviceability	The measure of satisfaction given by the pavement to the road user at a certain time, quantified by factors such as riding quality and rut depth.
SFC	sideways force coefficient of friction
SHV	Short heavy vehicle
Sideways force coefficient (SFC)	A wheel is dragged along a pavement by a test vehicle at a specific speed and angle of inclination of 20° to the direction of travel. The SFC is the ratio of the friction force normal to the plane of the wheel of the test vehicle and the normal load on the wheel and depends on the angle of inclination of the wheel to the direction of travel and gives an indication of the skidding resistance of the road surface at the test speed.
Single seal	An application of bituminous binder followed by a layer of stone.
Skid resistance	The ability of a surfacing layer to provide resistance through friction to skidding of a vehicle tyre moving over the surface.
Slab	The pavement concrete layer placed over a prepared subbase and acts as a base and surfacing combined.
Slurry	A mixture of suitably graded fine aggregate, cement or hydrated lime, bitumen emulsion and water.
Slurry seal	A surfacing seal consisting of a layer of slurry.
SMA	Stone mastic asphalt
Soft (wet) clays	These clays are wet to saturated, have high organic contents and are highly compressible. Their shear strengths and corresponding bearing capacities are very low.
Soils	Gravels with a large proportion of fine materials.
Solid waste	Includes construction debris, chemical waste, excess cement or concrete, wrapping materials, timber, tins and cans, drums, wire, nails, food and domestic waste (e.g., plastic packets and wrappers).
Spalling	Breakdown, flaking or pitting of concrete, typically at edges and cracks.
Special maintenance	Special maintenance activities such as: resurfacing preceded by extensive patching and repair, bridge joints and bearing replacement, major repair of damage to roads, ancillary assets and structures.
SPP	Sulphonated petroleum products
Spray rate	Rate of application of the bituminous binder expressed in litres per square metre (l/m ²) at a given temperature.
Spread rate	Rate of application of the surfacing stone (chips) expressed in cubic metres per square metre (m ³ /m ²) of stone applied at the loose bulk density in the truck or heap.
SPT	Standard Penetration tests
State land	Land which vests in the national or a provincial government, and includes land below the high water mark and the Admiralty Reserve (land above and adjoining the high water mark, but which is a Navy/Defence force reserve) but excludes land belonging to a local authority.
Stone	A single-sized aggregate used in single or double seals
Structural capacity	The number of loads, typically equivalent single axle loads of a specified mass (E80s), that the pavement can support within the given climate before it reaches a defined terminal condition.
Structural design	The design of the pavement layers for adequate structural strength under the design conditions of traffic loading, environment and subgrade support.
Structural design period	The period for which the structural capacity is designed.

Spoil	Excavated material which is unsuitable for use as material in the Works, or material which is surplus to the requirements of the Works.
Subbase	Layer occurring beneath the base or concrete slab and above the selected layer.
Subgrade	The completed earthworks within the road prism before the construction of the pavement. This comprises the in situ material of the roadbed and any fill material.
Surfacing	Uppermost pavement layer, which provides the riding surface for vehicles and a uniform, skid-resistant impermeable coating to the underlying pavement structure. Surfacing consists of two components, namely aggregate and binder.
Surfacing seal	A thin layer of aggregate and bituminous binder which, being the uppermost pavement layer, is directly subjected to the forces of vehicular traffic. See single and double seal.
Sustainable development	The integration of social, economic and environmental factors into planning, implementation and decision making so as to ensure that mineral and petroleum resources development serves present and future generations.
Tack coat	With asphalt construction: A coat of binder applied to an existing surface as a preliminary treatment to promote adhesion between the existing surface and subsequently applied asphalt layer. With seal construction: First spray of bituminous binder applied during the sealing process.
Tar	A viscous material produced entirely from crude tars. Tars, commonly known as road tars, are either produced as a by-product of the carbonisation of coal in high temperature coke ovens or by the low temperature Sasol gasification (Lurgi) process. Tars manufactured at high temperatures are commonly referred to as RTH road tars and those manufactured at low temperatures are known as RTL road tars. Tar products are no longer allowed for road construction or maintenance purposes.
TCI	The Concrete Institute
Terminal condition	The degree and extent of distress or serviceability for a given class of road at which point it requires immediate repair or rehabilitation, both in terms of road user and asset value considerations.
Texture depth	A measure of the relative height difference between the troughs and the crests of the aggregate in the seal or asphalt.
Texture treatment	The treatment of an existing seal to achieve a more uniform texture or to make a rough texture finer in preparation for resealing. Texture treatment usually takes the form of a thin sand seal or a slurry swept or brushed into the existing seal.
TG	Technical Guideline
TMH	Technical Methods for Highways
Topsoil	A varying depth (usually up to 300 mm) of the soil profile irrespective of the fertility appearance, structure, composition or agricultural potential of the soil.
TRH	Technical Recommendations for Highways
Uniform sections	Sections where the pavement's condition in terms of functional properties, such as riding quality and rut depth, is similar, and, the types of materials, condition of materials and pavement structures are similar. Uniform sections are assigned one rehabilitation design.
UCS	Unconfined compressive strength
UTFC	Ultra-thin friction course
UTG	Urban Transportation Guidelines
Viscosity	A measure of the degree of internal friction or the power to resist a change in the arrangement of molecules in a viscous material.
Volatiles	Solvents used in cutting-back agents and those constituents of bituminous binders which are readily vaporisable at relatively low temperatures.
vpd	Vehicles per day
Watercourse	Any river, stream and natural drainage channel, whether carrying water or not.
Water body	Body containing any form of water and includes dams and wetlands, whether temporary or permanent. Wetland means all areas where the soils are seasonally, or permanently, saturated.
W/C	Water to cement ratio

WCPA	Western Cape Provincial Government
WIM	Weigh-in-motion: a method of measuring axle loads
WM	Waterbound macadam

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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.

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