Chapter 8

Material Sources
Chapter 8

Material Sources
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You are here: 7. Geotechnical Investigations and Design Considerations
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 appropriate 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. A brief description of each chapter is given below to provide the context for this chapter, Chapter 8.

Chapter 1: Introduction discusses the application of this SAPEM manual, and the institutional responsibilities, statutory requirements, 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.

Chapter 2: Pavement Composition and Behaviour includes discussion on the history and basic principles of roads. Typical pavement structures, material characteristics and pavement types are given. The development of pavement distress and the functional performance of pavements are explained. 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 the reporting of the investigations. Chapters 6 and 7 are complementary.

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. For project quarries and borrow pits, the full process for sourcing materials is described, from prospecting and material investigations, to land acquisition and authorisation, mining planning and operations, and finally, to closure and reporting and monitoring. For commercial material sources, the resources for producers are provided, quarrying processes are described, as are the quality assurance and quality control required. The suitability of rocks for particular applications is given, as well as the typical products available from commercial quarries. For alternative sources, the procedures for evaluating a new material are given, including methods of classifying and using waste products. The types of alternative sources discussed are 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 precoating fluids and tack coats, bituminous binders, bitumen stabilised materials, asphalt, spray seals and micro surfacings, concrete, proprietary and certified products and block paving. The mix designs of all materials are discussed.
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.

Chapter 11: Documentation and Tendering covers the different forms of contracts typical for road pavement projects; the design, contract and tender documentation; and, the tender process.

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 is available in electronic format since January 2013. It is envisaged that SAPEM will be updated after one year. Feedback from all interested parties in industry is appreciated, as this will keep SAPEM appropriate.

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

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1. INTRODUCTION

Political, legal, economic, environmental and technical level interventions are making the upgrading and maintenance of the road network increasingly more challenging. A primary concern is the difficulty surrounding the identification and exploitation of road construction materials. The enactment of the Minerals and Petroleum Resources Development Act (No 28 of 2002) (DME, 2002), which includes the mining of construction materials, sets more onerous standards for compliance and is having a major effect on how road authorities (and their agents) manage quarries and borrow pits to ensure legal compliance. Other limiting issues include the dearth of suitable materials in many areas of South Africa, high costs of material processing, landowner reluctance and apathy, increased environmental and legal awareness, and budget constraints.

This chapter covers the sourcing of granular materials and aggregates used in road construction and maintenance projects from other than within the road prism. The most desirable option, however, remains to source the material from within the road prism. The three main options for the supply of road construction materials are considered to be:

- **Project borrow pits and quarries**: sources developed and operated to supply materials for a specific project.
- **Commercial sources**: quarries with permanent infrastructure established to service a viable market.
- **Alternative sources**: recycled materials sourced either from the existing road prism, or other local supply.

The sourcing of materials plays a critical role in most road construction and maintenance projects. The principal factors that influence the selection of materials sources are:

- Availability
- Quality requirements
- Technical feasibility
- Environmental considerations
- Commercial viability

Ideally, the required quantities of good quality materials are locally available. Furthermore, these sources should be exploited with no adverse environmental impacts and supplied at commercially attractive rates. However, projects are not ideal and can be very challenging if the selection of suitable material sources is to meet the technical, environmental and commercial objectives. Some of the more common problems typically experienced with materials supply include:

- Material sources may be located far from the site, leading to excessive haulage distances, and consequently, high costs.
- Opportunities to **develop project quarries or borrow pits** are severely restricted due to
  - Environmental constraints.
  - Long lead in time required for environmental authorization.
- Commercial sources available close to the site supply at high cost.
- Opportunities for recycling materials exist, but due to clients’ reluctance to consider “new technology”, these opportunities are not exploited.

Considering these challenges, it is crucial to explore all possible options for supplying the needed construction materials at the earliest onset of a project.

The objective of this chapter is to provide an overview of the various options available for materials supply as well as provide guidance on key aspects. The following three sections of the chapter each cover a primary type of material source, i.e.:

- **Section 2**: Project Borrow Pits and Quarries
- **Section 3**: Commercial Quarries
- **Section 4**: Alternative Sources

**Section 2** provides an overview of the process required to develop a project borrow pit or quarry and covers the following topics:

- Prospecting
- Materials investigations
- Developing mine plans
• Environmental authorization
• Securing land rights
• Operational procedures
• Closure of quarries and pits

The development process is not only demanding from technical and environmental perspectives but also requires fulfilling legal requirements. The information contained in this section is considered essential knowledge for those involved with identifying, planning, operating and closing quarries and borrow pits.

Section 3 looks at commercial aggregate suppliers and in particular provides an overview of:
• South African aggregate market
• Typical quarrying processes
• Raw materials and commercial aggregate products
• Specification issues relating to the supply of commercial aggregate products

In Section 4, the emphasis is the use of alternative materials in place of traditional materials. The use of alternative materials as a viable option stems from the depletion of natural resources, the need to conserve power, as well as a heightened awareness of environmental issues and the regulatory consent requirements for developing quarries and borrow pits. Wherever feasible, the utilization of recycled construction and industrial by-products should be considered.

The use of waste products for construction materials in South Africa is limited and more emphasis needs to be placed on the potential use of such products by the industry. Much of the information provided in this section relates to overseas experience, however, where possible South African references have been included.

Section 4 covers the types of alternative materials available, their classification and the advantages and disadvantages of their use as road construction materials. Alternative materials that are readily available in South Africa are discussed in detail and include:
• Recycled road pavement materials
• Construction and demolition waste
• Slags
• Fly ash
• Other mine waste
Definitions

Contaminated water: water contaminated as a result of the mining activities, e.g., runoff from refuelling areas and sediment laden storm water.

Current mining area: assuming a phased approach, the area that is being mined at any one point in time and which would be the subject of the Mining Plan.

Closure Plan: typically 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 of any long-term management and maintenance expected. 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.

Environment: the surroundings within which humans exist and that are made up of:
- The land, water and atmosphere of the earth.
- Micro-organisms, plant and animal life.
- Any part or combination of the above and the inter-relationships among and between them.
- Physical, chemical, aesthetic and cultural properties and conditions that influence human health and well-being.

Environmental Management Plan (EMP): plan to manage and rehabilitate the environmental impact as a result of prospecting, reconnaissance, exploration or mining operations conducted under the authority of a reconnaissance permission, prospecting right, reconnaissance permit, exploration right or mining permit.

Environmental Management Programme (EMProg): a plan to manage and rehabilitate the environmental impact as a result of prospecting, reconnaissance, exploration or mining operations conducted under the authority of a mining right.

Environmental Risk Report: a report detailing the risks, as identified in a risk assessment, and management measures, that accompanies an application for closure.

Expropriation: the act of expropriating; the surrender of a claim to exclusive property; the act of taking of ownership or proprietary rights.

Mine: any operation or activity for the purposes of winning any 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.

Overburden: the layer of soil immediately beneath the topsoil but above the mineral that is the target of the mining activities.

Pollution: any change 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.

Reconnaissance: investigation, scouting, inspection or surveying of aspects or sites.

Solid waste: all solid waste, including 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.

Spoil: excavated material which is unsuitable for use as material in the Works or is material which is surplus to the requirements of the works.

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.

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.

Topsoil: means a varying depth (usually up to 300 mm in depth) of the soil profile irrespective of the fertility appearance, structure, composition or agricultural potential of the soil.

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. In this regard, wetland means all areas where the soils are seasonally, or permanently, saturated.
2. PROJECT QUARRIES AND BORROW PITS

The purpose of this section is to provide an overview of the entire process of exploiting a material source for the production of road construction materials. This process proceeds from the identification of a suitable material source (feasibility), through to the planning and operational stages, to finally achieving successful closure. Failure to effectively manage this process can have serious negative impacts on road quality, project programme and costs, as well as to the environment. Fulfilling the legal requirements is an essential part of the process. Quarries and borrow pits cannot be operated without prior authorisation from the relevant government departments.

The typical borrow pit or quarry project cycle consists of the following 5 stages:

- Feasibility
- Planning
- Operation
- Closure
- Monitoring and reporting

The timeframe required to complete the feasibility and planning stages of the process typically extends up to one year, but may take significantly longer for hard rock quarries. Therefore, it is critical that the process be managed effectively and commences as far in advance of the works as practically feasible.

In the context of this manual, the following definitions apply:

- **Borrow pit** (Figure 1) 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. The types of materials normally obtained from a borrow pit are:
  - Natural soil or gravel (G4 to G10)
  - Natural soil and gravel for the production of gravel wearing course

- **Quarry** describes an open excavation from where rock is obtained, usually by blasting, to produce rock aggregate for use in road construction. Road construction materials obtained from quarries include:
  - Graded, crushed stone for bases (G1 to G4)
  - Crushed stone for subbase production (G5), where natural gravels are not available
  - Graded, crushed stone for the production of surfacing stone
  - Graded, crushed aggregates for the production of asphalt
  - Graded, crushed concrete aggregates (coarse and fine)
  - Blasted rock for dump-rock, rip-rap, gabions and stone pitching

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**Figure 1. Borrow Pit**
The required steps in the identification, proving, authorising, operation and closure of material sources are shown in Figure 2 (from WCPA, 2006).

![Flowchart of required steps](image)

**Figure 2. Required Steps in the Identification, Proving, Authorising, Operation and Closure of Material Sources**
The five stages of a project cycle are shown in Table 1. Personnel managing and supervising the various disciplines required in the process should be professionally registered and preferably also be member affiliated as indicated in Table 2, or have similar foreign registrations or affiliations.

### Table 1. Quarries and Borrow Pits Project Cycle

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### Table 2. Registration and Affiliations Requirements

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<td>SAICE³ Geotechnical Division</td>
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<tr>
<td>Engineering Geologist</td>
<td>SACNASP²</td>
<td>SAIEEG⁴</td>
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<tr>
<td>Geophysicist</td>
<td>SACNASP</td>
<td>SAGA¹</td>
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<td>Geohydrologist</td>
<td>SACNASP</td>
<td>SA Groundwater Association</td>
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<tr>
<td>Materials or Pavement Engineer</td>
<td>ECSA</td>
<td>SAICE Transportation Division</td>
</tr>
<tr>
<td>Environmentalist</td>
<td>EAPSA⁶</td>
<td>IAIA⁷</td>
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Note
1. ECSA is the Engineering Council of South Africa
2. SACNASP is the South African Council for Natural Scientific Professions
3. SAICE is the South African Institute of Civil Engineers
4. SAIEEG is the South African Institute for Environmental and Engineering Geologists
5. SAGA is the South African Geophysical Association
6. EAPSA is the Environmental Assessment Practitioners of South Africa
7. IAIA is the International Association of Impact Assessment

#### 2.1 Prospecting

The purpose of this section is to give guidance for the various steps taken when prospecting for a new material source. The objectives of the prospecting stage are:

- **Identify** prospective exploitable sources of materials (desk study).
- Carry out **site reconnaissance** to determine if prospective sites are technically and environmentally feasible.
- **Select** sites for further investigation.

Prospecting for materials sources is a skilled activity that should be carried out by a professionally registered engineering geologist, or professionally registered civil engineer or civil engineering technologist, with appropriate experience.

The following factors are the critical determinants in the identification and selection of a suitable material source:

- Material quality and quantity
- Haul distance
- Environmental sensitivity and impact
- Land-use sensitivity and expropriation value

In selecting a site for investigation, all of the above factors should be considered. The aim is to select a site that optimises the interaction between these variables. However, this is often not achievable and a balance needs to be found to maximize the overall benefit to the road users, landowners, roads authority and the environment.
maximize the overall benefit to the road users, landowners, roads authority and the environment.
The various steps in the process of prospecting for a new material source are shown in Table 3.

### Table 3. Prospecting for Quarries and Borrow Pits

<table>
<thead>
<tr>
<th>Step</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Obtain relevant plans, maps, photographs and reports</td>
</tr>
<tr>
<td>Step 2</td>
<td>Identify prospective sites for reconnaissance (desk study)</td>
</tr>
<tr>
<td>Step 3</td>
<td>Obtain relevant landowner information &amp; permission from landowner(s) to access the site</td>
</tr>
<tr>
<td>Step 4</td>
<td>Carry out site reconnaissance</td>
</tr>
<tr>
<td>Step 5</td>
<td>Screen sites (technical and environmental feasibility)</td>
</tr>
<tr>
<td>Step 6</td>
<td>Select site(s) for further investigation</td>
</tr>
</tbody>
</table>

Key sources of information for identifying prospective sites are:
- **Topographical** maps
- **Geological** maps
- **Land-use** and vegetation maps
- **Aerial** photographs
- **Google earth** imagery
- **Historical, geological, geotechnical** and materials reports
- **Local knowledge**, i.e., communications with relevant parties

Many of these are discussed in Chapter 7, Section 2.

Utilising the above sources of information, sites can be identified based on favourable conditions for location, access, geology, land-use and topography, as shown in Table 4.

### Table 4. Considerations for Identifying Sites

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Consideration</th>
</tr>
</thead>
</table>
| Location   | • Locate sources so as to achieve **minimum feasible haul distances**.  
• Borrow pits for fill should be **optimally located**, as required by the preliminary long sections for the road and/or mass-haul diagrams (See Chapter 9, Section 3.2.4).  
• Borrow pits for layer works should be located at **suitably spaced distances** along the entire route. |
| Access     | • Avoid sites that require the construction of **significant lengths of access roads**.  
• Avoid sites where **steep access roads** are required. |
| Geology    | • Select sites where geological conditions are likely to provide **materials of the required quality**. |
| Land-use   | • Avoid **nature conservation areas**.  
• Avoid sites in **close proximity to human habitation**.  
• Avoid sites of **cultural significance**, e.g., graves, fossils, archaeological artefacts.  
• Consider cost of **compensation** to secure land (expropriation).  
• Consider costs for **relocation of services**, e.g., electricity and telecoms.  
• Avoid sites in close proximity to **water bodies**, e.g., (rivers and wetlands) |
| Topography | • Select sites that can be mined and **rehabilitated effectively**.  
• Avoid sites that would create negative **visual impact**. |

Prior to commencing with site reconnaissance, the prospective sites should be marked up on appropriate plans or maps, and permission to access the site obtained from the landowner.

The initial field reconnaissance for a site should include both a technical and environmental assessment. Important information to gather and record during the initial reconnaissance of a site includes:
Table 5. Information to Gather during Initial Reconnaissance

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td>• Site access conditions and potential traffic safety hazards.</td>
</tr>
<tr>
<td></td>
<td>• Occurrence of services, e.g., power cables and telephone lines.</td>
</tr>
<tr>
<td><strong>Technical</strong></td>
<td>• Geological conditions such as description of soil profile if exposed</td>
</tr>
<tr>
<td></td>
<td>in cuttings or excavations, description of rock outcrops, i.e., rock</td>
</tr>
<tr>
<td></td>
<td>type, weathering and discontinuity data.</td>
</tr>
<tr>
<td></td>
<td>• Evaluation of how a pit could be developed on the site.</td>
</tr>
<tr>
<td></td>
<td>• Requirements for a materials investigation to evaluate the quality and</td>
</tr>
<tr>
<td></td>
<td>quantity of materials occurring at the site.</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>• Potential visual impact of quarry or borrow pit.</td>
</tr>
<tr>
<td></td>
<td>• Topography and soils: The lay of the land and erosion potential</td>
</tr>
<tr>
<td></td>
<td>• Land capability and land-use of site and surrounds and potential to</td>
</tr>
<tr>
<td></td>
<td>reinstate status quo</td>
</tr>
<tr>
<td></td>
<td>• Heritage Assessment, including input from specialist archaeologists</td>
</tr>
<tr>
<td></td>
<td>and palaeontologists</td>
</tr>
<tr>
<td></td>
<td>• Vegetation:</td>
</tr>
<tr>
<td></td>
<td>− Quality of vegetation</td>
</tr>
<tr>
<td></td>
<td>− Sensitive habitats</td>
</tr>
<tr>
<td></td>
<td>− Ecosystems</td>
</tr>
<tr>
<td></td>
<td>− Conservation areas</td>
</tr>
<tr>
<td></td>
<td>• Animal life: Types of animals and movements.</td>
</tr>
<tr>
<td></td>
<td>• Surface water: Location of drainage lines and waterways.</td>
</tr>
<tr>
<td></td>
<td>• Groundwater:</td>
</tr>
<tr>
<td></td>
<td>− Ground water abstraction in vicinity</td>
</tr>
<tr>
<td></td>
<td>− Potential for contamination</td>
</tr>
<tr>
<td></td>
<td>• Air quality: Ambient air quality and dust.</td>
</tr>
<tr>
<td></td>
<td>• Noise:</td>
</tr>
<tr>
<td></td>
<td>− Ambient noise levels</td>
</tr>
<tr>
<td></td>
<td>− Proximity to noise generating activities that could serve to “muffle”</td>
</tr>
<tr>
<td></td>
<td>− Noise levels</td>
</tr>
<tr>
<td></td>
<td>• Archaeological and cultural interest:</td>
</tr>
<tr>
<td></td>
<td>− Burial sites</td>
</tr>
<tr>
<td></td>
<td>− Sites of interest</td>
</tr>
<tr>
<td></td>
<td>− Sites of importance to locals</td>
</tr>
<tr>
<td></td>
<td>• Sensitive landscapes from a visual perspective, or a tourist route.</td>
</tr>
<tr>
<td></td>
<td>• Interested and affected parties:</td>
</tr>
<tr>
<td></td>
<td>− Landowners</td>
</tr>
<tr>
<td></td>
<td>− Land-users</td>
</tr>
<tr>
<td></td>
<td>− Adjacent communities</td>
</tr>
</tbody>
</table>

The information gathered during the site reconnaissance should be used to determine the technical and environmental feasibility of the sites, i.e., a site screening exercise. If sites exhibit specific features that make them unacceptable from either a technical or environmental perspective, i.e., fatal flaws, the sites should be excluded from further consideration.

Information gathered during the initial site reconnaissance should be recorded. A typical summary sheet recording information gathered during a preliminary assessment is shown in Figure 3. In addition to the assessment record, a locality plan is required for each site, as well as supporting photographs to show important features of the sites.

It is recommended that a competent, suitably qualified environmental practitioner carry out the environmental screening exercise. It is crucial to exclude environmentally flawed sites at this early stage of the process, rather than risk the later rejection of a mining application, on environmental grounds. Feasible sites should be considered on their relative advantages and disadvantages, and favoured sites selected for further investigation.

---

**Damage from Prospecting**

Any damage to property to gain access to land for prospecting, such as, cut fences, shall be properly reinstated to the satisfaction of the landowner.
# Borrow pit number and farm name

<table>
<thead>
<tr>
<th>Borrow pit number and farm name</th>
<th>BP/Q12.5 QUAGGASKIRK</th>
</tr>
</thead>
</table>

## Description

<table>
<thead>
<tr>
<th>Property name</th>
<th>Quaggaskirk Sahara 5255</th>
</tr>
</thead>
</table>

### General

The new quarry site is located on the south side of a dolerite dyke, east of the N11/3. It is also located fairly close to an abattoir.

## Ownership

<table>
<thead>
<tr>
<th>Owner</th>
<th>L C S Meintjies</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Contact Person</th>
<th>L C S Meintjies</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Tel/Cell numbers</th>
<th>083 284 9986</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Address</th>
<th>P O Box 1343, Dundee, 3000</th>
</tr>
</thead>
</table>

## Locality

The quarry site is located 840 m east of the N11 at km 7.8 in a dolerite dyke running south east.

## Access

Access is east at km 12.5 through a farm gate for 750m then sharp north for 200m and then east for 180m to the proposed site.

## Existing Condition

Virgin land covered with boulders.

## Topsoil

Unknown depth of dark brown red soil.

## Vegetation

Medium length dense grass coverage with several indigenous shrubs.

## Constraints:

- Abattoir to the north east 250m
- Overhead power lines 100m west
- Farm residence 680m south

## Deleterious material

No deleterious material was observed

## Assessment of suitability

The material is assessed to be possibly suitable for G1 and G4/G5 crushed material.

## Available quantities and possible development of borrow pit.

More than 100,000 m³ estimated.

## Recommendation

Normal procedure followed for quarry investigation is proposed.

---

**Figure 3.** Typical Preliminary Site Assessment Sheet

### 2.2 Material Location

Material location should follow a logical process entailing:

- Developing a basic understanding of the **local geology** and geomorphology
- Developing an understanding of **gravel indicators**
- A desktop study of **maps and aerial photographs**

---

Section 2: Project Quarries and Borrow Pits

Page 9
2.2.1 Local Geology and Geomorphology

The general geology of the area can be determined from geological maps. An understanding of the geology should embrace a number of characteristics:

- **Material type:** The mineralogical components of the rock dictate how the rock weathers, what the end-products are and how they will perform in the road. Only acid and basic crystalline, e.g., granite and basalt, respectively, materials are considered to decompose. The remaining material groups essentially disintegrate, depending on climatic influences. Decomposing rocks are likely to yield materials that are more plastic, while disintegrating materials give better gravels.

- **Topography:** The topography has a major influence on ground water profiles and gravitational movement of materials, which in turn affect the weathering process.

- **Depth of weathering:** The depth of weathering is highly variable and is a function of the material type and structure, the main erosion cycles that have affected the material, availability of water and topography. The depth of weathering varies from a few centimetres where only a thin layer of gravel is found at the surface to very deep soils where, for example, granites beneath the African erosion surface (often underlaying a laterite/ferricrete layer) can be weathered to a depth of 20 metres or more. In general, the soil profile consists of an organic top soil (A horizon), overlying weathered in situ material (B horizon) grading into the C horizon of weathered rock which overlies the R horizon or in situ mostly unweathered rock.

Natural gravel materials suitable for road construction are typically obtained from the B (residual material without relict structure) and C horizon (residual material with original rock structure or saprolite) and thus various depths of material need to be sampled and tested. In general, the plasticity of the material decreases with depth towards the unweathered rock, whilst the material coarseness and gravel component increase.

2.2.2 Understanding and Selecting Gravel Indicators

Three types of gravel indicators are typically used for material location. These are the landform, botanical indicators (specialised plants) and animal indicators (traces left by animal activity).

2.2.2.1 Landform

Landform refers to the configuration of the ground surface in a distinctive shape. It is important in gravel location, as different types of gravel are associated with particular landforms. This association is due to:

- The **presence of material near the surface** giving rise directly to a particular type of landform. For example, a band of harder rock gives rise to a bump on a slope or a flat hill top, depending upon the rock’s position and orientation.

- The **development of a particular type of gravel** in relation to a geomorphological feature. For example, a river terrace is typically made up of alluvial gravel.

(i) Landforms of Rock Regions

Rock regions have the typical range of gravel landforms illustrated in Table 6. This table is the key to the landform names given in Table 7.
Table 6. Landforms of Rock Regions Associated with Gravel Deposits

<table>
<thead>
<tr>
<th>Landform</th>
<th>Description</th>
<th>Cross-sectional Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat hill top</td>
<td>Flat, level hill top (plateau) with sharp edges at margins.</td>
<td></td>
</tr>
<tr>
<td>Sloping hill top</td>
<td>Inclined, flat hill top with sharp edge between steep sharp slope and more gentle dip slope.</td>
<td></td>
</tr>
<tr>
<td>Conical hill</td>
<td>Hill with pointed top, more or less circular in plan. Sides may be irregular or smooth.</td>
<td></td>
</tr>
<tr>
<td>Mound</td>
<td>Rounded hill top with convex slopes, or convex ‘bump’ on a plateau or hill top.</td>
<td></td>
</tr>
<tr>
<td>Ridge</td>
<td>Long, straight, narrow ridge running across country. Usually formed by an igneous intrusion (dyke or sill) or a quartz vein.</td>
<td></td>
</tr>
<tr>
<td>Trench</td>
<td>Long, straight, narrow depression running across country. Like the Ridge landform, usually formed by an igneous intrusion. However, in this case, the surrounding rocks are more resistant than the intrusion. Sometimes the trench is formed by a pair of closely-spaced parallel ridges, formed by the surrounding rock being ‘baked’ hard by the heat of the intrusion.</td>
<td></td>
</tr>
<tr>
<td>Footslope</td>
<td>Gentle slope at the foot of a steeper slope, formed (in this case) by the accumulation of pedogenic gravel, usually ferricrete, in the soil profile.</td>
<td></td>
</tr>
<tr>
<td>Terrace</td>
<td>Raised platform situated at the edge of a valley, deposited by a river.</td>
<td></td>
</tr>
<tr>
<td>Floodplain</td>
<td>Broad, flat valley floor with winding river. Sand and gravel accumulate on the inside of river bends.</td>
<td></td>
</tr>
</tbody>
</table>

(ii) Landforms of Sand Regions

Landforms found in sand regions are given in Table 8, and the gravels associated with them are given in Table 9. If gravel particles are present in the soil, the processes of weathering and erosion tend to bring some of these to the surface. The accumulation of a layer of stones and gravel on the surface can give the false impression that the soil is composed of gravel, or that a gravel layer lies at depth. Before considering the area as a potential source of gravel, it is important to check that a gravel layer is actually present, by finding an exposed profile.

Finding Gravel Layers

The accumulation of a layer of stones and gravel on the surface can give the false impression that the soil is composed of gravel, or that a gravel layer lies at depth. Before considering the area as a potential source of gravel, it is important to check that a gravel layer is actually present, by finding an exposed profile.
### Table 7. Types of Gravel Associated with Rock Regions

<table>
<thead>
<tr>
<th>Gravel Type</th>
<th>Parent Material</th>
<th>Landform</th>
<th>Possible Engineering Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residual Gravels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weathered rock</td>
<td>Lava</td>
<td>Flat hill top, sloping</td>
<td>Lava of basic composition may contain weatherable minerals.</td>
</tr>
<tr>
<td></td>
<td>Igneous dyke</td>
<td>Ridge or trench</td>
<td>Lavas of basic composition may contain weatherable minerals.</td>
</tr>
<tr>
<td></td>
<td>Igneous sill</td>
<td>Ridge on side of hill</td>
<td>Lavas of basic composition may contain weatherable minerals. Sill may be difficult to exploit,</td>
</tr>
<tr>
<td></td>
<td>Granite, gneiss</td>
<td>Mound, none</td>
<td>Gneiss may contain weatherable minerals.</td>
</tr>
<tr>
<td></td>
<td>Quartzite</td>
<td>Ridge, sloping hill top,</td>
<td>Poor mechanical interlock of particles.</td>
</tr>
<tr>
<td></td>
<td>Sandstone</td>
<td>flat hill top, mound</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conglomerate, breccia</td>
<td>Flat hill top, sloping</td>
<td>Conglomerate particles are rounded. Properties of the coarse particles may be different from those</td>
</tr>
<tr>
<td></td>
<td>Limestone, marble,</td>
<td>flat hill top, mound,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>dolomite</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>Vein quartz</td>
<td>Granite, gneisses</td>
<td>Ridge</td>
<td>Poor mechanical interlock of particles.</td>
</tr>
<tr>
<td></td>
<td>of all types</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transported Gravels</td>
<td>Quartz stone line</td>
<td>Footslope, none</td>
<td>Poor mechanical interlock of particles. May tend to contain too many fines.</td>
</tr>
<tr>
<td></td>
<td>Colluvium</td>
<td>Footslope</td>
<td>May contain too many fines.</td>
</tr>
<tr>
<td></td>
<td>Alluvium</td>
<td>Terrace, floodplain</td>
<td>Rounded particles, often sandy and lacking in fines.</td>
</tr>
</tbody>
</table>

Note: Some of these rock types are illustrated in Chapter 4, Figure 2.

### Table 8. Landforms of Sand Regions, Associated with Gravel Deposits

<table>
<thead>
<tr>
<th>Landform</th>
<th>Diagram (cross-section)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pan with 'platform'</td>
<td><img src="pan.jpg" alt="Diagram" /></td>
</tr>
<tr>
<td>Pan without 'platform'</td>
<td>![Diagram](pan_no plataforma.png)</td>
</tr>
<tr>
<td>Depression</td>
<td><img src="depression.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Inter-dune hollow</td>
<td><img src="inter_dune.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Valley (old river channel)</td>
<td><img src="valley.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Grey sand</td>
<td><img src="grey_sand.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Note: Platform is not usually as distinctive or obvious as shown here.
### Table 9. Gravel Types Associated with Sand Regions

<table>
<thead>
<tr>
<th>Landform</th>
<th>Material</th>
<th>Characteristics and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pan with platform</td>
<td>Calcrete, possibly hardpan or nodular Silcrete</td>
<td>The best quality calcrete is found in the pan platform.</td>
</tr>
<tr>
<td>Around rim</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan without platform</td>
<td>Calcrete Silcrete</td>
<td>Good calcrete may occur, but is not usual. Quality is not predictable. Large pans may contain hard or boulder calcrete.</td>
</tr>
<tr>
<td>Around rim</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>Calcrete</td>
<td>Usually poor quality calcrete. May occur on the side slopes.</td>
</tr>
<tr>
<td>Inter-dune hollow</td>
<td>Calcrete and silcrete hardpan or honeycomb or nodular.</td>
<td>Locally, good quality materials but generally none over most of the hollow's length.</td>
</tr>
<tr>
<td>Valley (old river channel)</td>
<td>Calcrete, possibly hardpan or nodular.</td>
<td>Locally, good quality materials but generally none over most of the valley's length. Some valleys contain extensive calcified sands.</td>
</tr>
<tr>
<td>No landform - grey sand only, contrasting with surrounding red sand.</td>
<td>Calcareous sand. Possibly some calcrete.</td>
<td>Usually poor quality calcrete, but may be better if sand is non-plastic. Blackish sands usually yield better quality material.</td>
</tr>
</tbody>
</table>

#### 2.2.2.2 Botanical Indicators

The presence of certain plant species and sometimes the nature of their growth can depend upon the mineralogical and physical properties of the soil in which they are growing. Botanical indicators can thus be a useful aid to materials location. However, plants are adaptable and the absence of an indicator species does not necessarily mean that the material is absent; whilst the presence of the indicator species does not always signify that the underlying material is suitable for engineering purposes.

The correct identification of plants is often difficult without botanical training. However, identification is generally not necessary. Instead, distinct changes in the species type, a dense thicket of a particular species or a change in the form (e.g., multi-stemmed instead of single stemmed, stunted, etc.) of the plants are easily observed and are useful ways of identifying a potential source. Plant indicators are particularly useful for locating pedocretes, i.e., ferricrete and calcrete, and dykes and intrusions that are not easily visible on the surface.

#### 2.2.2.3 Animal Indicators

The activity of certain animals results in gravel particles, soil or stones being brought to the surface. Examples are termites, porcupines, suricates and squirrels. Examination of the material in termite mounds and anthills, and material excavated from burrows should be carried out.

### 2.3 Materials Investigations

This section gives guidance to the various steps taken to conduct a materials investigation, i.e., an investigation to prove the quality and quantity of material occurring in a prospective material source. The steps for a new material source are shown in Table 10.

#### Table 10. Materials Investigations for Quarries and Borrow Pits

<table>
<thead>
<tr>
<th>Step</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Plan the investigation</td>
</tr>
<tr>
<td>Step 2</td>
<td>Carry out the exploratory works</td>
</tr>
<tr>
<td>Step 3</td>
<td>Evaluate the material source (quality of materials and estimated reserves)</td>
</tr>
<tr>
<td>Step 4</td>
<td>Report investigation</td>
</tr>
</tbody>
</table>

Planning and supervising materials investigations are skilled activities that should be carried out by a professionally registered engineering geologist, or materials engineer, with the appropriate experience.

The **technical objectives** of a materials investigation are to:

- Evaluate **geological conditions**
  - Soil or rock profile to the required depth
  - Variations in the profile over the lateral extent of the source area
  - Soil or rock mass characteristics
• Prove the quality of material available.
• Estimate the quantity of compliant material available.

Materials investigations should be planned with regard to:
• Achieving the required technical objectives.
• Meeting specific requirements that may be set by individual roads authorities, or other organisations.
• Obtaining the necessary permits and permissions to carry out the investigation.

The planning of a materials investigation should cover:
• Investigation methods to be employed
• Scope of the investigation
• Material sampling requirements
• Testing requirements
• Permits and permissions

Various investigation methods are available to perform materials investigations, which include test pitting and rotary core drilling.

• Test pitting (illustrated in Figure 4)
  - Typically used for investigation of borrow areas.
  - Depth of investigation limited.
  - Entering test pits is a potentially hazardous activity and must only be carried out under the supervision of a competent person and in strict compliance with Operational Health and Safety (OHS) requirements. For guidance on OHS issues, refer to SAICE (2003).
  - Useful guidelines for sampling procedures can be found in TMH5 (Sampling Methods MA2 and MA3) and in the Western Cape Provincial Government, Department of Transport Materials Manual, Chapter 5 “Materials Investigations and Reporting” available at http://mis.pgwc.gov.za/mis/mis_web_reports.main.
  - Harder materials are difficult to excavate in test pits.

• Rotary core drilling (illustrated in Figure 5)
  - Typically used for the investigation of hard rock quarries.
  - No depth limitation.
  - Usually higher cost than test pitting.

Figure 4. Test Pit
Other investigation methods that are readily available can provide important data, depending on the specific requirements of the investigation. These include: large diameter auger holes; geophysical surveys such as seismic refraction; ground penetrating radar; and, resistivity and trial blasts.

The scope of the materials investigation should be adequate to prove the quality and quantity of material available. In scoping an investigation, the aspects given in Table 11 should be addressed:

**Table 11. Scoping a Materials Investigation**

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>- Investigation methods to be employed</td>
</tr>
<tr>
<td></td>
<td>- <strong>Technical specifications</strong> for the investigation methods to be employed:</td>
</tr>
<tr>
<td></td>
<td>- Depth of boreholes</td>
</tr>
<tr>
<td></td>
<td>- Drilling methods</td>
</tr>
<tr>
<td></td>
<td>- <strong>Location</strong> of investigation points</td>
</tr>
<tr>
<td></td>
<td>- <strong>Sampling requirements</strong>, such as the sampling methods and the sampling frequencies to be adopted</td>
</tr>
<tr>
<td></td>
<td>- <strong>Testing requirements</strong></td>
</tr>
<tr>
<td></td>
<td>- Test methods to be employed</td>
</tr>
<tr>
<td></td>
<td>- Testing regimes</td>
</tr>
<tr>
<td></td>
<td>- Testing frequencies</td>
</tr>
<tr>
<td>Environmental</td>
<td>- Details of any <strong>environmental constraints</strong> influencing the investigation, e.g., no-go areas</td>
</tr>
<tr>
<td></td>
<td>- Details of <strong>permits</strong> or permissions required</td>
</tr>
</tbody>
</table>
Specific information on subsurface conditions, required from a materials investigation for a **hard rock quarry** includes:

- **Soil and rock profile** across the site to the depth of investigation
- **Extent** of source
- **Depth** to sound rock
- Degree and depth of rock **weathering**
- **Boundaries** of rock types
- Rock **strength** and hardness characteristics
- Rock **durability** characteristics
- Location of **fault or fracture zones**
- Orientation, attitude (how strata are lying), spacing and infill of **joints** and bedding planes
- **Position of water table**

Care should be taken to drill sufficient boreholes to determine the information. Angle-boreholes should be used to obtain data on sub-vertical jointing and other geological features.

Specific information on subsurface conditions required from a materials investigation for a **borrow pit** include:

- **Soil and rock profile** across the site to the depth of investigation
- **Boundaries** between soil types (variations vertically and horizontally)
- **Overburden** description and depth
- Occurrence of **hard or oversize materials** or contaminants
- Material **excavation** characteristics
- **Depth of water table**

Sufficient test pitting should be carried out to determine the required information to an acceptable accuracy. Sampling and testing of materials should be carried out with sampling plans, indicating the appropriate sampling methods, sampling frequencies and testing requirements. The sampling plans discussed in the next two sections are recommended.

### 2.3.1 Borrow Pits for Fill or Gravel Wearing Course

Trial pits should be evenly spaced over the borrow area with a maximum distance of 100 metres between any two pits. In cases where the material is very uniform, the spacing may be increased, depending on client requirements.

Samples are required from each trial pit for an indicator test on each layer of material 300 mm or thicker, excluding overburden, which should be saved and used for eventual rehabilitation purposes. Layers of less than 300 mm thickness that appear suitable may be sampled and tested together with one of the adjacent layers.

A CBR test should be carried out on material from each trial pit in a potential borrow pit, including overburden. The minimum number of CBR tests recommended for borrow pits intended to provide fill material is given in Table 12.

#### Table 12. Number of CBR tests from Borrow Pits for Fill or Gravel Wearing Course

<table>
<thead>
<tr>
<th>Size of Borrow Pit</th>
<th>Number of CBR Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smaller than 40 000 m³</td>
<td>4</td>
</tr>
<tr>
<td>40 000 m³ to 80 000 m³</td>
<td>5</td>
</tr>
<tr>
<td>Larger than 80 000 m³</td>
<td>6</td>
</tr>
</tbody>
</table>

### 2.3.2 Borrow Pits for Pavement Layers

Trial pits should be uniformly spaced over the borrow area; with a maximum spacing of 100 metres between any two pits for large borrow areas, and 30 metres for small areas. In cases where the material is very uniform, the spacing may be increased, depending on client requirements. Excavation of a trial pit in a borrow pit is shown in Figure 6.
Borehole Spacing

Boreholes should be spaced no greater than 30 metres apart and be drilled to depths at least 5 metres below the proposed bottom of the quarry.

Samples for indicator tests should be taken as described for fill materials. However, should any layers of material, in any of the trial pits appear unsuitable, only a few representative samples need to be obtained.

Sufficient CBR tests should be carried out to obtain representative test results of the range of materials encountered in the borrow pit. The recommended minimum number of CBR tests required for borrow pits for pavement layers is given in Table 13. For stabilised subbases, additional material must be sampled for UCS, ITS and wet-dry durability tests.

<table>
<thead>
<tr>
<th>Size of Borrow Pit</th>
<th>Number of CBR Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smaller than 20 000 m³</td>
<td>5</td>
</tr>
<tr>
<td>20 000 m³ to 40 000 m³</td>
<td>6</td>
</tr>
<tr>
<td>40 000 m³ to 80 000 m³</td>
<td>8</td>
</tr>
<tr>
<td>Larger than 80 000 m³</td>
<td>10</td>
</tr>
</tbody>
</table>

The following stabilisation tests are recommended for borrow pits supplying subbases and gravel bases. Where a selected subgrade is to be stabilised, the same requirements apply:

- Firstly, at least one sample per borrow pit, or 2 in the case of borrow pits larger than 40 000 m³, should be tested with various stabilising agents to determine which stabiliser reacts best with the material. On this sample, the wet-dry durability test should also be done. Should unsatisfactory results be obtained with the amount of stabilising agent used, a higher percentage of the most suitable agent should also be tested. The purpose of this testing is to establish the most suitable type, and quantity, of stabilising agent.

- Secondly, once the most suitable type and percentage of stabilising agent has been established, the remaining samples should be tested with the particular type and percentage of stabilising agent for UCS, ITS and wet-dry durability. (see Chapter 3, Section 5.3)

2.3.3 Quarries for Aggregates

Hard rock sources for the production of crushed aggregates should be investigated by drilling boreholes. The depth and spacing of boreholes will be dependent on the nature of the rock source being investigated. However, it is recommended that boreholes should be spaced no greater than 30 metres apart and be drilled to depths at least 5 metres below the proposed bottom of the quarry.

Before the investigation of a potential quarry site can proceed, it is essential to:

- **Scope** the drilling investigation
- Prepare a drilling **specification** and other necessary contractual documentation
- Establish the drilling **programme**
- Determine the **budget** to carry out the investigation
- Identify potential **service providers**
• Discuss aspects of the investigation with the client and obtain approval to proceed

During the execution of the exploratory works the following data should be collected:

• **Location** where test pits and/or boreholes were sited (coordinates from a hand held GPS suffice)
• Representative photographs of the source area
• **Test pit profiles** and/or borehole logs
• Representative photographs of test pits and/or cores
• **Sample details**, i.e. location, depth, soil layer or rock type, sample type, sample description
• Position of **water table** in test pits and/or boreholes

The necessary tests for evaluating the potential sources of crushed aggregate are carried out on core samples. These testing requirements are listed in Table 14. The tests listed are described in Chapter 3, Sections 4.2, 4.6 and 5.7.

### Table 14. Testing Required to Prove Quality of Road Construction Materials

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Testing Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural soil or gravel G4 to G10</td>
<td>• Grading&lt;br&gt;• Atterberg limits&lt;br&gt;• Compaction characteristics (Mod. AASHTO)&lt;br&gt;• CBR&lt;br&gt;• Durability tests on rocks that may have potential to rapidly deteriorate with exposure to the elements, e.g., mudstones</td>
</tr>
<tr>
<td>Natural gravel for the production of gravel wearing course</td>
<td>• Grading&lt;br&gt;• Atterberg limits&lt;br&gt;• Compaction characteristics (Mod. AASHTO)&lt;br&gt;• CBR&lt;br&gt;• Venter durability</td>
</tr>
<tr>
<td>Graded, crushed stone base G1 to G4</td>
<td>• Petrographic analyses for all basic igneous and metamorphic rocks&lt;br&gt;• Grading&lt;br&gt;• Atterberg limits&lt;br&gt;• Water absorption (%) for various fractions and degree of saturation&lt;br&gt;• Bulk and apparent relative density&lt;br&gt;• ACV &amp; 10% FACT&lt;br&gt;• 10% FACT Ethyl Glycol (especially on dolerite and basalt)&lt;br&gt;• Wet/dry ratios&lt;br&gt;• Chemical testing as per COLTO Section 3602 (1988)&lt;br&gt;• Durability tests, e.g., modified ethylene glycol test, on basic crystalline rocks that may have potential to rapidly deteriorate with exposure to the elements</td>
</tr>
<tr>
<td>Stabilised layers C1 to C4</td>
<td>• Grading&lt;br&gt;• Atterberg limits&lt;br&gt;• Compaction characteristics (Mod AASHTO)&lt;br&gt;• Initial consumption of cement and lime (ICL and ICC)&lt;br&gt;• UCS and ITS&lt;br&gt;• Wet and dry durability</td>
</tr>
<tr>
<td>Surfacing stone and asphalt aggregate</td>
<td>• Grading&lt;br&gt;• Fines and dust content&lt;br&gt;• Average least dimension (ALD)&lt;br&gt;• Appropriate tests for bitumen adhesion properties&lt;br&gt;• ACV &amp; 10% FACT&lt;br&gt;• Flakiness index (FI)&lt;br&gt;• Polished Stone value (PSV)</td>
</tr>
<tr>
<td>Concrete aggregate</td>
<td>• Grading&lt;br&gt;• Water absorption&lt;br&gt;• Fineness modulus&lt;br&gt;• Flakiness index&lt;br&gt;• Organic impurities&lt;br&gt;• Relative and bulk densities&lt;br&gt;• ACV &amp; 10% FACT&lt;br&gt;• Alkali reactivity</td>
</tr>
</tbody>
</table>
2.3.4 Personnel Requirements for Materials Investigations

It is crucial that experienced personnel adequately supervise materials investigations. Without adequate supervision, substandard information will almost certainly be the result. Competent professionals should be responsible for profiling and core logging as described in Table 15.

Table 15. Profiling and Logging Responsibility

<table>
<thead>
<tr>
<th>Activity</th>
<th>Responsible Person</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profiling of test pits</td>
<td>Engineering geologist or materials engineer</td>
<td>Profiling should be carried out in accordance with the “Revised Guide to Soil Profiling for Civil Engineering Purposes in Southern Africa” (Jennings et al, 1973), or other appropriate standard (Brink and Bruin, 1990).</td>
</tr>
<tr>
<td>Logging of boreholes</td>
<td>Engineering geologist</td>
<td>Profiling should be carried out in accordance with “A Guide to Core Logging for Rock Engineering” (AEG, 1976), or other appropriate standard (Brink and Bruin).</td>
</tr>
</tbody>
</table>

Site investigations are potentially hazardous activities. Exploratory works should be carried out in accordance with the requirements of the:

- Occupational Health and Safety Act No. 85 of 1993
- Construction Regulations, 2001
- Client’s specific OHS requirements

2.3.5 Reporting of Materials Investigations

Evaluation of the information gathered during the materials investigation should be collated, reviewed and analysed to fully assess the potential of the source. The evaluation process includes:

- Assessment of material quality
  - Evaluate if materials meet the required specifications. Compare test results with relevant specified acceptance limits.
  - Assess material quality variation.
- Estimation of material reserves
  - Calculate material reserves.
  - Calculate overburden quantity.
  - Consider how the source could be extended to optimally provide additional materials.

The various road authorities have standard formats for the compilation of materials reports. Where relevant, such standard report formats should be adhered to. In general, reporting of materials investigations includes the following information:

- Material source data
  - Proposed material usage
  - Haul distances to point of construction
- Site description
  - Location
  - Access
  - Topography
  - Geomorphology
  - Vegetation
  - Limitations or restrictions
  - Land-use
  - Presence of services
- Description of the geological and geotechnical conditions
  - Soil and rock profile
  - Description of soil and/or rock types
  - Soil and/or rock characteristics and properties
  - Excavation characteristics of soil and/or rock
  - Geohydrological information
- Material quality and quantity
  - Evaluation of material quality in relation to relevant material specifications
- Estimation of material reserves
- Particular technical concerns relating to the material source

**Supporting information**
- A locality plan showing the location of the site, as shown in Figure 7
- Site plans showing the location of test pits and/or boreholes. The plan should provide GPS coordinates of the trial pits and/or boreholes as well as all other pertinent information such as the presence of services, extent of borrow or quarry area, kilometre reference to nearest road access, north arrow, and geological features. An example is given in Figure 9.
- Test pit profiles and/or borehole logs
- Photographs of test pits, cores and typical materials (Figure 8)
- Test results

![Figure 7. Locality Plan](image)

![Figure 8. Typical Materials](image)
2.4 Land Acquisition

After the quality and quantity of material occurring in a prospective material source has been satisfactorily proved, the planning stage to develop a borrow pit or quarry can proceed. This planning stage covers land acquisition, authorisation and planning of mining. These aspects of the planning process are discussed in this and the following two sections, namely, Authorisation Process (Section 2.5) and Planning of Mining (Section 2.6).

The purpose of this section is to give guidance on the various steps required to secure the rights to operate a borrow pit or quarry on private or state land. Ownership and access are key planning considerations. As early as possible, it is important to establish:

- **Legal requirements** for utilising a particular source.
- **Restrictions or prohibitions** that may be in place on an affected property.
- **Landowner’s attitude** towards the possible acquisition.
- **Preferred options** to secure the right to occupy land include:
  - Expropriation
  - Landowner agreements and leases

Whether land rights should be obtained through expropriation, agreement or lease must be carefully considered. The optimum approach to achieve the project objectives, as well as meeting client and landowner needs, must be chosen. Certain of the provincial road authorities favour the expropriation route. SANRAL, however, prefers land owner agreements of fixed duration. The basic elements of the land acquisition process are shown in Table 16.

### Table 16. Land Acquisition Process

<table>
<thead>
<tr>
<th>Step</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Consideration of ownership</td>
</tr>
<tr>
<td>2</td>
<td>Consideration of access</td>
</tr>
<tr>
<td>3</td>
<td>Consultation with landowner</td>
</tr>
<tr>
<td>4</td>
<td>Expropriation or agreement and Leases</td>
</tr>
<tr>
<td>5</td>
<td>Planning and/or rezoning</td>
</tr>
</tbody>
</table>
2.4.1 Consideration of Ownership

It is important to obtain up to date and accurate information regarding the landownership status of land earmarked for mining. Details required for different land ownership scenarios are given in Table 17.

Table 17. Landownership Scenarios

<table>
<thead>
<tr>
<th>Land Type</th>
<th>Information to be Recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm land outside of the &quot;urban edge&quot;</td>
<td>• Farm name</td>
</tr>
<tr>
<td></td>
<td>• Erf number/farm number and portion number</td>
</tr>
<tr>
<td></td>
<td>• Extent</td>
</tr>
<tr>
<td></td>
<td>• Owner</td>
</tr>
<tr>
<td></td>
<td>• Contact person</td>
</tr>
<tr>
<td>Land within the &quot;urban edge&quot;</td>
<td>• Erf number and portion number</td>
</tr>
<tr>
<td></td>
<td>• Extent</td>
</tr>
<tr>
<td></td>
<td>• Owner</td>
</tr>
<tr>
<td></td>
<td>• Contact person</td>
</tr>
<tr>
<td>State land</td>
<td>• Erf number and portion number</td>
</tr>
<tr>
<td></td>
<td>• Extent</td>
</tr>
<tr>
<td></td>
<td>• Department with which ownership rests or has been ceded</td>
</tr>
<tr>
<td></td>
<td>• Contact details</td>
</tr>
</tbody>
</table>

2.4.2 Consideration of Access

Access is a key consideration when planning mining. Access issues include:

- Obtaining permission to access the property to undertake prospecting and mining.
- Identifying registered access servitudes that may limit the access to or use the site.
- Clarifying the access rights of others over the land.

2.4.3 Consultation with Landowner

Once a site has been identified and ownership confirmed, the landowners should be consulted to discuss the proposed use of the site. Consultation with landowners includes:

- Proposed use of the site
- Access to the site
- Security issues
- Water rights
- Post mining rehabilitation and closure
- Compensation
- Landowner’s materials requirements
- Expropriation and landowner agreement
- Any concerns the landowner may have

Many of these aspects are important to provide input into the expropriation process, or the compilation of a formal landowner agreement.

2.4.4 Expropriation

In terms of the Constitution of the Republic of South Africa (No 108 of 1996), organs of state are empowered to expropriate land subject to various provisions. Expropriation by road authorities is generally undertaken in terms of the Expropriation Act (No 63 of 1975, or as subsequently amended), read in concert with the powers provided for in the Road Ordinance (No 19 of 1976). Section 1 of the road ordinance specifically provides that a road authority may “take the right temporarily to use property and to raise and remove materials ... from a property” for road construction purposes.

The Act distinguishes between temporary and permanent expropriation:
Chapter 8: Material Sources

- **Temporary Expropriation:** Taking the right to use the land temporarily. The duration of use would be stipulated in the notice of expropriation. Ownership of the land is not transferred to the organ of state and the land reverts to the landowner following its use.

- **Permanent Expropriation:** Ownership of the land is transferred to the organ of state.

The following activities are required to commence the expropriation process:

- **Landowner consultation**
- **Survey** of the exact extent of land to be expropriated
- **Serve a notice** to the landowners in accordance with Section 7(2) of the Expropriation Act and Section 29 of the Roads Ordinance

### 2.4.5 Land Owner Agreements and Leases

If the landowner permits the use of his/her land for use as a borrow pit or quarry, a formal agreement can be entered into. Such agreement should at least cover:

- **Duration** of use of land
- **Extent** of land to be utilised
- **Special requirements** of the landowner or client
- **Provision for financial compensation**
- **Responsibilities** of the road authorities and landowner

#### 2.4.5.1 Compensation

In terms of the Minerals and Petroleum Resources Development Act (DME, 2002), all of South Africa’s mineral resources have been placed in the custodianship of the State. It is important to recognise that during the expropriation process, gravel or water resources are not expropriated, but rather the right to remove the materials is granted. Nevertheless, the market value of the gravel is still relevant in calculating compensation since it can be deemed that the landowner has suffered a financial loss due to the removal of the material (under Section 12(1)(b) of Expropriation Act 63 of 1975). Accordingly, compensation is payable for both aspects of the expropriated right, the right of use of land by the landowner and the gravel removed. Determining the compensation is based on:

- Term of usage
- Recovery period
- Market value of land
- Surface area

#### 2.4.5.2 Rezoning

Any change in land-use needs to be authorised in terms of the Land-Use Planning Ordinance 15 of 1985. Planning approval may be required if the site falls within an urban area or is included in the zoning scheme for a town, and its zoning does not provide for mining use. In general, most areas outside of the urban edge can be mined, as this use is in line with its “rural” zoning.

Some municipalities may require a formal planning process to be undertaken for a site where the envisaged change in land-use (to allow for mining) is not accommodated in the zoning scheme. One of two processes could apply, i.e., a rezoning or a departure. A departure is formal permission from the controlling authority to deviate from an official requirement.

### 2.5 Authorisation Process

All prospecting, material investigations and mining must be conducted within the legal requirements of the various Acts, Ordinances, Regulations and Bylaws. The purpose of this section is to provide an overview of the legal requirements and focuses on the specific requirement of the mining legislation, the Mineral and Petroleum Resources Development Act (No 28 of 2002). The understanding detailed in this section is based on current (2008) legislation, but the law, and its interpretation, are subject to constant change.

The extraction of materials for use in road works constitutes a mining activity, and any proposed material sources (borrow pits or quarries) require approval.
from the relevant Department of Minerals and Energy (DME), in terms of the requirements outlined in the Mineral and Petroleum Resources Development Act. For borrow pits and quarries for road construction or maintenance purposes, DME has indicated that permission only needs to be sought for mining and not for the reconnaissance and prospecting phases.

The Act distinguishes between mining permits and mining rights as follows:

- **Mining Permit:** Required where the activity will last less than two years and affects an area of less than 1.5 hectares in extent. The permit is valid for 3 years. In terms of the Act, a mining permit requires the submission of an Environmental Management Plan (EMP) to DME for approval prior to the onset of activities.

- **Mining Right:** Required for larger mining operations. It is renewable and valid for 30 years. In terms of the Act, a mining right requires the submission of an Environmental Management Programme (EMProg) to DME for approval prior to the onset of activities.

In light of their limited spatio-temporal extent, borrow pit and quarry operations would typically require a mining permit.

In June 2004, the Minister of Minerals and Energy exempted various organs of state, including SANRAL and Provincial Governments, from the provisions of Sections 16, 20, 22 and 27 of the Mineral and Petroleum Resources Development Act. In terms of this exemption, where an organ of state is undertaking the construction or maintenance of roads under its control, no application would need to be submitted for a mining right or permit. However, according to the provisions of Section 106(2) of the Act, prior to the extraction of any material from a proposed borrow pit or quarry, it would still be required to prepare and submit an EMP or EMProg to DME for their approval.

### 2.5.1 Application Process

The application process for exempted organs of state is illustrated in Figure 10. The Act attaches specific timeframes to various stages of the application process, and an attempt has been made to indicate these timeframes where relevant.

The following critical issues must be taken into consideration:

- **Authorisation** is an essential requirement and without it, mining activities are illegal.

- The **timeframe** to complete the authorisation process is extensive, requiring a minimum period of six months but could be far longer.

The preparing of mining applications and EMPs or EMProgs are specialised activities.
2.5.2 Closure

It is important to recognise that the mining right or permit holder’s liability continues until such time as a Closure Certificate has been issued by DME.
Pursuant to the successful implementation of the rehabilitation plan contained in the EMProg, an Application for Closure needs to be prepared and submitted within 180 days of cessation of the mining operation. The Application for Closure includes:

- Closure Plan
- Environmental Risk Report
- Financial Performance Assessment Report

The need to ensure continuity and integration between the EMProg, Mining Plan, mining operations and Closure Application is obvious as the EMProg specifies the closure objectives and approach to environmental management and is a critical informant of the Application for Closure.

DME may not issue a Closure Certificate unless it has been confirmed that the provisions pertaining to health, safety and management of potential pollution to water resources have been addressed.

### 2.6 Mining Plan

Developing an appropriate and adequate Mining Plan is a fundamental part of the planning operation. A mine plan should cover the commissioning, operation, decommissioning and closure of a material source. A sound mining plan is essential to achieve optimal and sustainable resource development and utilisation. Sustainable mining requires an approach that balances the curbing of environmental degradation with the optimising of materials extraction and the minimisation of cost.

This section outlines how to effectively develop and implement a mining plan. The various steps in the development of a mine plan are shown in Table 18.

<table>
<thead>
<tr>
<th>Step</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Set the mining and closure objectives</td>
</tr>
<tr>
<td>2</td>
<td>Carry out a risk assessment</td>
</tr>
<tr>
<td>3</td>
<td>Design pit or quarry</td>
</tr>
<tr>
<td>4</td>
<td>Develop the mine plan</td>
</tr>
<tr>
<td>5</td>
<td>Document the design</td>
</tr>
</tbody>
</table>

#### 2.6.1 Set the Mining and Closure Objectives

The mining and closure objectives provide the framework for the basic approach to the establishment, operation and closure of a particular site. Overall mining objectives include:

- **Optimising yield** and economic viability
- Enhancing **technical efficiency** of extraction
- Optimising **operational efficiency**
- Minimizing adverse **environmental impacts**
- Promoting **health and safety**
- Maintaining **legal and technical compliance** at the highest level
- Mitigating **risks** to all stakeholders, including landowners
- Meeting **budget**
- Meeting affected parties and local and provincial authorities **constraints**
- Honouring **conditions** of agreement with landowners
- Assuring that land is **restored** to beneficial use thereafter, if practical

The aim of closure should be to reclaim the site methodically and progressively. Rehabilitation practices should ensure the physical stabilisation of the soils to achieve a sustainable land-use so the land may be returned to a productive state as soon as practically possible after mining activities have ceased. Rehabilitation must be recognized as an integral part of the extraction process, and must therefore be included in mine planning.
2.6.2 Risk Assessment

The critical step in formulating a Mining Plan is to undertake a risk assessment. The key question is “What are the risks associated with exploiting a particular material source and how can these risks be mitigated?” Risk can be managed in the following ways:

- **Avoiding risk** by not doing particular things or not working in particular areas.
- **Minimizing risk** by doing things in a particular way, e.g., minimizing the area of active extraction, progressive rehabilitation, regular inspection and contingency planning.
- **Controlling risk** through the utilization of specific control measures, e.g., sediment traps.
- **Transferring risk**, e.g., by obtaining the requisite permits (commissioning and closure), reallocating the risk to the landowner or establishing dual-operator agreements.

The measures to be implemented to manage the risks associated with exploiting a particular source must be incorporated into the Mining Plan.

2.6.3 Pit Design

The characteristics of borrow pits and quarries developed for the sourcing of road construction materials vary extensively with respect to the extent of the material reserves, natural environment, topography, geology and intended life span. Some pits may be of limited extent and mined in a single operation for a particular project. Others may be larger and mined in multiple phases to provide materials over extended time duration. Accordingly, the design solutions applied to develop successful mining operations also vary extensively and depend on the particular conditions encountered at each pit location, as well as the intended use of the pit. The level of design required is dependent on the size and nature of the pit, as well as its intended use. The design of open pit mines is a specialised field and it is recommended that for larger pits, mined in multiple phases to provide materials over extended time durations, specialist professional input from a mining engineer be sought. Drill and blast design for pits is also a specialised field, and should be carried out by a specialist blasting engineer. An example of a typical quarry is shown in Figure 11.
2.6.4 Develop Mine Plan

Basic information needed to develop a mine plan includes:

- **Topography** of the area to be mined from a topographic survey
- **Environmental conditions** surrounding the pit
- **Extent** (hectares) and **depth** (metres) of the proposed pit from the geotechnical or materials report
- Extent of the **overburden** (waste material)
- Approximate quantity of material to be **excavated** ($m^3$)
- Characteristics of the **materials** to be mined from the geotechnical or materials report
- **Excavatability** of material, i.e., if it requires blasting or if it can be mechanically excavated
- Information regarding any **additional processing** that may be required for the material to meet the specifications
- **Stockpiling** requirements
- **Mining equipment** requirements
- **Time-frames** for mining
- **Legal** requirements, particularly as they relate to the Mine Health and Safety Act and the obligations attached to the EMProg
- Relevant **closure** objectives
- **Risk** assessment
- Special requirements of **interested and affected parties**

2.6.5 Document the Design

The pit or quarry design forms the technical guideline for the future operation and therefore needs to be documented clearly and with sufficient detail to allow the design to be put into practice. The pit design needs to be developed in a drawing, or series of drawings (plans and cross-sections) that indicate how the pit is to be mined and rehabilitated.

The drawings are used by the technical staff responsible for mining and should provide a clear picture of what they are required to achieve. The design should also include a schedule of tonnes (or cubic metres) of material reserves to be mined during each mining stage, such as topsoil, borrow material and waste material.

The mine plan should indicate:

- **Areas to be mined**, clearly indicating no-go areas
- **Cut slope** angles
- Different **phases of operation**
- **Security** requirements, e.g., location of fencing and gates
- **Access roads** to and from the pit
- **Stockpile locations** for topsoil, temporary or waste stockpiles
- **Drainage** structures around the pit
- **Temporary areas** for the contractor’s camp or workshop areas and explosive storage magazines, if necessary
- **Ablution** facilities

In addition the mine plan should provide guidance on:

- Emergency procedure
- Securing the site
- Traffic management
- Topsoil management
- Hydrocarbon (petrol, diesel, engine oils) management
- Waste management
- Stormwater management and erosion
- Fire management
- Dust and noise control

---

**Blasting of Borrow Pits**

If the borrow material requires blasting, this places a restriction on the location of the borrow pit with respect to existing settlements and infrastructure, contractors camp, etc. Generally, blasting must not take place within 500 metres of any permanent or temporary infrastructure. If this is seen to be unachievable, special blasting permits can be applied for, provided that certain precautions are taken during blasting (covered blasting, restriction of access/traffic, temporary vacation of premises, etc.). Similar restrictions apply to the location of explosive magazines, transport of explosives, etc.
• Protection of flora and fauna
• Protection of archaeological and palaeontological remains
• Protection of natural features
• Material processing requirements
• Rehabilitation of the pit

The documented mine plan should form a key component of the EMP or EMProg submission to DME.

2.7 Operations

The operation of a borrow pit or quarry should be in accordance with the requirements of the: Mine Health and Safety Act (No 29 of 1996); mine plan; EMP/EMProg; and any other relevant legislation pertaining to a particular site. Prior to commissioning and operating a pit, it is crucial that the operational staff are familiar with these requirements and that they clearly understand the mining and closure objectives.

2.7.1 Mine Health and Safety Act

The Mine Health and Safety Act (No 29 of 1996) deals with the prevention of occupational accidents and injuries in mines and quarries. The objectives of this Act are to:

• Protect the health and safety of persons at mines.
• Ensure that employers and employees identify hazards and eliminate, control and minimise the risks relating to health and safety at mines.
• Give effect to the national and international legal obligations for health and safety at mines.
• Provide for employee participation in matters of health and safety.
• Provide for effective monitoring of health and safety conditions at mines.
• Provide for investigations and inquiries to improve health and safety at mines.
• Promote:
  - A culture of health and safety in the mining industry.
  - Training in health and safety in the mining industry.
  - Co-operation and consultation on health and safety between the State, employers, employees and their representatives.

The Act establishes the employers’ responsibility to ensure, as far as reasonably practical, that the mine, pit or quarry, is commissioned, operated, maintained and decommissioned in such a way that employees can perform their work without endangering their health and safety. The Act requires:

• Appointment of a mine manager.
• Maintenance of a healthy and safe mine environment.
• Providing adequate health and safety equipment and facilities, including providing adequate ablutions.
• Staffing of the mine with due regard to health and safety considerations.
• Establishing and implementing a health and safety policy.
• Developing and implementing codes of practice to guide health and safety strategies.
• Providing health and safety training for the employees for both routine operations and emergency situations.
• Assessing, managing or mitigating risk, whether by physical means or staff awareness.

In terms of the provisions of the Act, employees also have the right to leave any working place where circumstances arise which may reasonably pose a danger to their health and/or safety. Moreover, employees may not be charged for the health and safety equipment and facilities, which must be provided to them in terms of the Act.
It should be noted that the Act is clear that the on-going responsibility for the management of the health and safety of a mine vests with the mine owner or manager. This responsibility only ceases once a closure certificate has been issued by DME. This emphasises the importance of applying for the closure of exhausted or unsuitable materials sources.

### 2.7.2 Pit Management

The following aspects of pit management are important to ensure a pit is worked in a sustainable and sensitive manner, that is, environmental impacts are minimised, material extraction is optimised and costs are curtailed.

- **Training of staff.** Ensure site staff are familiar with:
  - Mining and closure objectives
  - Mine plan requirements
  - Mine Health and Safety Act
  - EMP or EMProg

- **Securing perimeter.** Fence the pit and erect signage to:
  - Clearly indicate the mining area to the public
  - Keep mining activities within the designated area
  - Restrict access in and out of the pit to ensure adequate security and public safety

- **Demarcate areas.** Set out and demarcate:
  - Location and extent of areas to be mined to limit the extent of any environmental impacts and minimise unnecessary remediation
  - No-go areas
  - Stockpile areas
  - Access roads
  - Infrastructure

- **Access and haul roads.** Set out and establish access and haul roads in accordance with the Mining Plan.

- **Traffic management.** Establish and maintain the necessary traffic management measures, such as signage and flag persons, to ensure safety of site staff and road users.

- **Topsoil management.** Remove vegetation and topsoil, including roots and seeds, separately and stockpile alongside pit for reuse during the rehabilitation. Topsoil must be handled and stored correctly to ensure it is not contaminated, dispersed or degraded. The stockpiles should be of limited height to avoid deterioration of potential seeds and rhizomes necessary to encourage later vegetation.

- **Stockpiling of materials.** Maintain separate stockpiles for topsoil, waste material and products. Establish and maintain procedures for preventing contamination, dispersion or degradation of materials in stockpiles. Unsuitable material can be used during rehabilitation for reshaping and smoothing prior to replacement of the topsoil.

- **Construction Plant.** Maintain plant in good operating order and operated by licensed, qualified personnel. Utilise plant only for the tasks it is designed to perform.

- **Ablution facilities.** Establish and maintain adequate on-site ablution facilities.

- **Fuel management.** Establish and maintain procedures to manage the risk of fuel leaks and spills and the associated risk of pollution.

- **Waste management.** Establish and maintain the necessary procedures to minimise waste generation and dispose of waste to prevent pollution of the environment.

- **Stormwater management and erosion.** Take the necessary measures to limit erosion and prevent polluted runoff entering watercourses or water bodies.

- **Water resources.** Minimise the use of water and take measures to limit wastage to an absolute minimum. Construction water must be legally sourced and natural water resources protected.

- **Fire management.** Take reasonable and proactive steps to minimise the risk of fire and manage the risk to the public and environment. Basic fire fighting equipment should always be available on-site and site staff should be trained on its use.

- **Dust and noise control.** Take the necessary measures to minimise the generation of dust and noise associated with mining activities. Dust and noise are a nuisance and health hazards, which must be managed effectively.

- **Protection of flora and fauna.** Follow the requirements provided in the EMP or EMProg and Mining Plan.

- **Protection of archaeological and palaeontological remains.** Follow the requirements provided in the EMP/EMProg and Mining Plan. Should any remains be unearthed, immediately protect such remains, cordon off and report to the relevant authorities.

- **Clean up and rehabilitation.** On completion of the mining operation:
- Clean up the site
- Remove all infrastructure
- Create final slope profiles
- Prepare slopes for rehabilitation
- Install permanent drainage
- Follow mining plan specifications for topsoiling, rehabilitation and revegetation

- **Emergency procedures.** Ensure emergency procedures are documented, communicated to all staff and a copy of the emergency procedures is kept on-site.

- **Interested and affected parties.** Establish and foster good relationships with affected parties. Inform affected parties of the onset of mining. Establish mechanisms for dealing with complaints.

The Western Cape Provincial Administration, Department of Transport and Public Works, Road Infrastructure Branch, has developed a series of "Operator Instruction Sheets" designed to provide guidance to personnel operating borrow pits. There are 24 sheets in the series and each sheet deals with a specific borrow pit management activity. For each activity the what, why, when and where to do it is discussed as well as the "do's and don'ts" associated with the activity. The sheets are a useful reference and are available in English, Afrikaans and isiXhosa. The sheets are available on the web at [http://tdr.wcape.gov.za/tdr/doc.user_manual_web.main](http://tdr.w cape.gov.za/tdr/doc.user_manual_web.main).

### 2.8 Closure

Once a material source has been exhausted, or for some reason is no longer suitable for use, it is essential to undertake a closure process whereby, once operations have ceased, the site must be rehabilitated and returned to a safe and stable state. An example of a well rehabilitated borrow pit is shown in Figure 12.

Historically, rehabilitation was typically limited to the removal of equipment following the cessation of activities. This practice is not only lax, but is unacceptable from both community safety and environmental sustainability perspectives. Moreover, as outlined previously, in terms of the Minerals and Petroleum Resources Development Act (2002), the holder of a mining right or permit remains liable for any pollution or ecological degradation, and the management thereof, until DME has issued a closure certificate for the subject site. The operator retains liability for the borrow pit or quarry, until a Closure Certificate has been issued for each site by DME.

Accordingly, following the implementation of the rehabilitation measures, an Application for Closure, supported by the requisite Closure Plan, Environmental Risk Report and Financial Performance Assessment Report, should be prepared for submission to DME. The Act requires that the Application for Closure be submitted within 180 days of cessation of the mining operation at the subject borrow pit). The financial provision takes place in accordance with signed Memorandum of Understanding secured between SANRAL and DME.

In terms of the requirements of the Mineral and Petroleum Resources Development Act, financial provision must be made for the closure or sudden cessation of work, and for any rehabilitation and revegetation work.

Closure should ensure that:

- Operations are ended **efficiently and cost effectively.**
- The site is **rehabilitated** and returned to a safe and stable state.
- The **final land use** conforms to the concept of sustainable development.
- **Legal liability** is transferred from the operator.

Required measures for site clean-up include:

- **Demolish and remove infrastructure** that was erected at the site.
- **Remove all equipment,** plant, concrete footings, fencing (except where permanently required), etc. from site
- **Remove all foreign materials** from site.
- Not disposing **domestic or other waste** in the pit. Waste must be disposed of off-site at an approved landfill.
- Not disposing **soil contaminated** with oil, grease, fuel or other hydrocarbon in the excavation.
Figure 12. Opening, Using and Rehabilitating a Borrow Pit
Each borrow pit should be finished off, if feasible, in such a way that:

- **It blends in with the surrounding area** and appears as a natural extension to the adjacent, undisturbed ground profiles.
- Sharp **angles or corners** are avoided.
- **Smooth and flowing curves** are created that blend with the surrounding landscape.
- **Even contours** are created.
- The borrow pit is free-draining.
- Where feasible, no slopes steeper than **1:3** are created.
- The site is stabilised by **revegetation**.

Where the need for revegetation has been identified, specialist guidance should be sought to determine the exact requirements of a specific borrow pit. The mix of vegetation types, i.e., indigenous, naturalised or alien species, and approach to revegetation, such as seeds, cultivated plants or search and rescue from adjacent areas, should be tailored to the environment and meet the specific closure objectives. Where quick cover is required, reliance on natural regeneration is inappropriate, and a revegetation programme needs to be implemented. Unless an elaborate and extensive approach to the rehabilitation of the borrow pit is envisaged, the re-vegetation programme should focus on using species which:

- **Establish rapidly** on disturbed land.
- **Rapidly bind and cover soil**, thereby affording effective protection against erosion.
- Are resilient to the prevailing **environmental conditions**.
- Will **not invade** the surrounding habitat.
- Are **endemic and indigenous** to the area.
- Will **not prevent indigenous species colonising** the rehabilitated areas from the surrounding areas.

### 2.9 Reporting and Monitoring

The preceding sections give considerable guidance on the planning, commissioning, operation and decommissioning of borrow pits. However, to ensure that the required management measures are effectively and timeously implemented, regular compliance monitoring and auditing of all borrow pits is essential. Ultimately, compliance monitoring and auditing is an essential quality management tool that assists in achieving the effective management of risk and sustainable utilisation of gravel material sources.

To adequately assess the progress of the rehabilitation measures, and rectify any problems that may arise, sequential and regular photographs of the site from fixed points should be taken from the onset of the mining operations.

Factors to monitor and audit for each quarry or borrow pit include:

- **Status of the mining process**, particularly as it relates to the phased mining and rehabilitation process.
- **Compliance** with
  - Mining or Closure Plan.
  - Mining and Closure Objectives.
  - Commitments in terms of any environmental authorisations, expropriations or landowner agreements.
- Adequacy of **safety and security** aspects.
- **Environmental impacts**, in particular any concerns regarding negative environmental impacts.
- **Material usage**, including the status (percentage completion) and quantity and quality of material used.
- **Status of progressive rehabilitation efforts**.
- **Status of budget** compared to actual spending.
3. COMMERCIAL MATERIAL SOURCES

A commercial quarry is defined as “a quarry with permanent infrastructure established to service a viable market.” Because aggregates are a “low value, high volume” commodity, commercial quarries are usually located as close as possible to urban growth nodes. “Non-commercial quarries”, also referred to as temporary quarries, typically include borrow pits and project quarries. Non-commercial material sources are discussed in detail in Section 2 of this Chapter.

Project quarries generally supply aggregate for a specific project, for example, a road resurfacing contract, or construction of a bridge. In most cases, project quarries are opened in remote areas, generally where haul distances from commercial quarries are too far. Commercial quarries tend to be larger, satisfy more sustainable development criteria, create stable employment and offer more benefits to the community than non-commercial project quarries. A comparison of commercial and non-commercial quarrying is presented in Table 19 (ASPARSA, 2005).

The aggregate industry comprises both the formal and informal sectors. The formal aggregate and sand producers are legally required to declare production volumes to the Department of Minerals and Energy (DME). The informal sector consists of three distinct groups, namely:

- **Mobile operators** producing from licensed borrow pits
- **Small scale miners**
- **Illegal miners**, i.e., operators without the required legal authorizations to operate

<table>
<thead>
<tr>
<th>Table 19. Commercial Quarries vs Non-Commercial Quarries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aspect</strong></td>
</tr>
<tr>
<td>Optimal resource recovery</td>
</tr>
<tr>
<td>Closeness to market (transport optimization)</td>
</tr>
<tr>
<td>Quality of product for general construction</td>
</tr>
<tr>
<td>Product range</td>
</tr>
<tr>
<td>Mining charter</td>
</tr>
<tr>
<td>Environment – Dust control</td>
</tr>
<tr>
<td>Environment – Noise control</td>
</tr>
<tr>
<td>Environment – Blast vibration control</td>
</tr>
<tr>
<td>Environment – Sustainable end-use</td>
</tr>
<tr>
<td>Environment – Sustainable end-use</td>
</tr>
<tr>
<td>Employment opportunity</td>
</tr>
<tr>
<td>Health and safety</td>
</tr>
<tr>
<td>Employee training</td>
</tr>
<tr>
<td>Social responsibility and community investment</td>
</tr>
<tr>
<td>Long term servicing of community need</td>
</tr>
</tbody>
</table>

The South African aggregate and sand market was estimated at about 120 million tons in 2007. Road construction materials are estimated to account for around 26% of the total aggregate and sand market in South Africa, see Figure 13. Road construction materials that are typically sourced from commercial sources include crushed stone base and subbase, surfacing stone, and asphalt and concrete aggregates.

The decision whether to source materials from a commercial or project quarry depends on several factors:

- **Location** of commercial quarry sources in the project proximity.
- **Availability** of the required materials, in quality and quantity, from commercial sources.
- **Commercial viability** commercial aggregates compared with obtaining aggregates from a project quarry.
- **Feasibility** of opening project quarries in the project area. The potential to open a quarry could be severely constrained by legal, environmental and land-use issues.
3.1 Resources for Quarrying, Sand and Aggregate Producers

Some useful resources relating to quarrying and sand and aggregate producers in South Africa are the Department of Minerals and Energy, Aggregate and Sand Producers Association of Southern Africa (ASPASA) and The Institute of Quarrying.

(i) Department of Minerals and Energy

The Minerals Economics Department of the Department of Minerals and Energy (DME) regularly produces directories of South Africa’s various minerals industries. These directories are regularly updated and provide useful information. The "Producers of Sand and Aggregate in the Republic of South Africa" (DME 2006) directory lists and provides contact details of sand and aggregate producers, and is comprehensive. Producers are listed according to province, alphabetically by magisterial district and then alphabetically by mine or quarry.

This publication is issued by, and available from:
The Director: Mineral Economics
Mineralia Centre
234 Visagie Street, Pretoria 0001
Private Bag X59, Pretoria 0001
Telephone (012) 317-8538
Telefax (012) 320-4327
Website: http://www.dme.gov.za

(ii) Aggregate and Sand Producers Association of Southern Africa (ASPASA)

This national body represents aggregate and sand companies, and is also responsible for promoting the aggregate and sand industry. ASPASA’s objectives are to set standards and guidelines with regard to health, safety and environmental issues. To be a member of ASPASA, their stringent policies must be met and adhered to. In addition, members are regularly audited to ensure compliance with the standards. ASPASA’s website is www.aspasa.co.za.
(iii) The Institute of Quarrying

The Institute of Quarrying ([www.iqsa.co.za](http://www.iqsa.co.za)) is the international professional body for quarrying, surface mining and the related extractive, processing and construction industries. Membership is open to individuals, rather than companies. The stated objective of the institute to act as the forum representing the individual in the quarrying industry, which aims to:

- Provide value through an expanding network of well-informed members.
- Provide ongoing professional development through regional meetings, technical conferences and social events.
- Co-ordinate education and training.
- Promote the image and professionalism of the quarrying industry.

3.2 Quarrying Process

Quarrying is the multistage process by which rock is extracted from the ground and crushed to produce aggregate. This is then screened into the sizes required for immediate use, or for further processing, such as coating with bitumen to produce asphalt.

A stone quarry typically produces the following types of products:

- **Large size blocks** blasted from the quarry face, approximately 0.5 m$^3$ to 1.25 m$^3$, are called rip rap or rock armour. They are used in coastal and river flood defence schemes to shore up sea fronts and river banks. Figure 14 shows their use in a dam wall.

- Material screened immediately prior to primary crushing is called **scalpings** or **grizzly**, which is often used for fill on construction sites.

- **Direct, unscreened output** from a crusher contains a complete mix of sizes from dust up to the maximum size that the crusher can pass, see Figure 15.

- Some screens have **multiple decks** and can screen out several grades. As with crusher run, screened fractions contain a mix of sizes, from the maximum size that the screen mesh can pass, down to dust. These go through further screening to extract the dust.

- **Screened, graded aggregate** for concrete production.

![Figure 14. Large Size Blocks Used on Dam Wall](image)
3.2.1 Blasting

Rock is usually extracted from the ground in a drill and blast operation. This operation typically consists of the following sequence of activities:

- **Survey** the quarry face
- **Design** the blast
Drill shotholes
Charge shotholes with explosives
Detonate the explosives

After the blast, the face and shotpile (sometimes called the muck-heap) are inspected to check that all the shot holes have fired correctly. The face shovel or loader then tidies up the shotpile and starts to load dumper trucks to take the rock to the crusher. Boulders that are too big to go through the crusher are set to one side for secondary breaking at a later date. Secondary breaking is typically done using a hydraulic excavator fitted with a hydraulic hammer, although drop-balls are also sometimes used.

3.2.2 Crushing

Crushing can be done in up to four stages, primary (first stage), secondary (second stage), tertiary (third stage) and, in some quarries, a quaternary (fourth stage). The primary crusher is fed via a hopper and vibrating feeder. The base of the feeder is made of steel “grizzly” bars. Fine material and dust produced by the blast, along with any remaining subsoil or weathered rock from the top of the quarry face, drops through the bars onto a separate conveyor belt and onto a stockpile. This screened material is called scalpings and is used as rock fill.

The output from the primary crusher is conveyed onto the primary stockpile, from which the secondary crusher is fed. After passing through the secondary crusher, usually small size crushed stone and dust is screened out onto stockpiles.

The larger sized stone goes through the final crushing stages (tertiary and possibly quaternary) where it is fed through a series of crushers and screens. The output from the final crushers is conveyed to a screening plant where large multiple deck screens sort the crushed stone into the required aggregate sizes.

In general, particular crushers are used for the various stages of crushing, as given in Table 20. Primary crushing is usually by a jaw crusher. The size of the crushed stone which passes through the jaws is partly governed by the gap set at the bottom of the jaws, though larger size rocks can pass through if the rock is slaky or elongated in shape. Large scale gyratory crushers can also be used. Various types of crushers are illustrated in Figure 17.

<table>
<thead>
<tr>
<th>Crusher Stage</th>
<th>Type of Crusher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Single or double jaw crusher</td>
</tr>
</tbody>
</table>
| Secondary     | Gyratory crusher  
                   Standard head cone crusher  
                   Impactor  
                   Hammermill |
| Tertiary      | Fine (short) head cone crusher  
                   Impactor  
                   Hammermill  
                   Vertical shaft impactor |
| Quaternary    | Sand cone impactor  
                   Hammermill  
                   Vertical shaft impactor (VSI) |

Secondary, tertiary and quaternary crushers are typically gyratory or cone crushers. These operate on the principle of a steel mantle mounted on an eccentric bearing and vertical shaft assembly. Rotation of the eccentric assembly makes the mantle gyrate within a static outer concave. Between the mantle and the concave there is a gap, which is tapered towards the base. As the mantle gyrates inside the concave, the gap between it and the concave narrows and widens on each gyration, producing the required crushing action. Stone is fed in at the top and crushed product falls out the bottom of the cone. The concave can be raised or lowered to a limited degree within the bowl, changing the gap, and consequently the size of the crushed product to be varied.

Vertical shaft impactor (VSI) crushers usually produce stone with very good shape, minimizing flat and elongated particles. A properly fed cone or gyratory crusher can also give good particle shape.
(i) Single Jaw Crusher
(ii) Standard Head Cone Crusher
(iii) Double Jaw Crusher
(iv) Vertical Shaft Impactor
(v) Gyratory Jaw Crusher
(vi) Hammermill

Figure 17. Crusher Types
3.3 Source Materials and Products

It is critically important that rock types utilized for the production of road construction materials are fit for the required purpose. Not all rock types are suitable for use in concrete or asphalt. In some cases, the mineral (chemical) composition of the rock may be incompatible with the cement resulting in a premature failure. In other cases, the physical characteristics of the rock may result in structural weakness in the concrete or slippery road surfaces when used in asphalt.

In South Africa, commercial quarries exploit a wide range of different rock types to produce aggregates. The natural road building materials used for road construction in southern Africa are listed in Table 21 (Weinert, 1980). The rocks more commonly quarried in the different regions of South Africa are given in Table 22.

A wide range of road construction products is available from commercial quarrying operations. These products include concrete aggregates, sand, gravel and crushed stone for pavement layers and surfacing aggregates, as well as special products produced for specific uses. The standard products available are given in Table 23. Not all products are available from each quarry.

Table 21. Natural Road Building Materials Used for Road Construction in Southern Africa

<table>
<thead>
<tr>
<th>Group</th>
<th>Materials</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Surfacing Aggregate</td>
</tr>
<tr>
<td>Basic crystalline rocks</td>
<td>Amphibolite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Andesite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Anorthosite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Basalt</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Diabase</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Diorite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Dolerite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Gabbro</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Greenschist</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Norite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Peridotite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Phonolite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Serpentinite</td>
<td>✓</td>
</tr>
<tr>
<td>Acid crystalline rocks</td>
<td>Felsite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Gneiss</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Pegmatite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Rhyolite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Syenite</td>
<td>✓</td>
</tr>
<tr>
<td>High-silica rocks</td>
<td>Chert</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Hornfels</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Quartzite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Vein quartz</td>
<td>✓</td>
</tr>
<tr>
<td>Arenaceous rocks</td>
<td>Arkose</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Conglomerate</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Gritstone</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Mica schist</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Sandstone</td>
<td>✓</td>
</tr>
<tr>
<td>Argillaceous rocks</td>
<td>Sericite schist, phyllite</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Shale, slate, mudstone</td>
<td>✓</td>
</tr>
</tbody>
</table>
Table 22. Typical Rocks Found in South Africa

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Gauteng</th>
<th>Western Cape</th>
<th>Kwazulu-Natal</th>
<th>North West</th>
<th>Limpopo</th>
<th>Mpumulanga</th>
<th>Free State</th>
<th>Eastern Cape</th>
<th>Northern Cape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andesite</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chert</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dolerite</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Dolomite</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gneiss</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granite</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metagreywacke</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norite</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartzite</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Sandstone</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shale</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tillite</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Table 23. Standard Products Available from Commercial Quarries

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete aggregate</td>
<td>53.0 mm</td>
</tr>
<tr>
<td></td>
<td>37.5 mm</td>
</tr>
<tr>
<td></td>
<td>26.5 mm</td>
</tr>
<tr>
<td></td>
<td>19.0 mm</td>
</tr>
<tr>
<td></td>
<td>13.2 mm</td>
</tr>
<tr>
<td></td>
<td>9.5 mm</td>
</tr>
<tr>
<td></td>
<td>6.7 mm</td>
</tr>
<tr>
<td>Crusher sand</td>
<td>Washed</td>
</tr>
<tr>
<td></td>
<td>Unwashed</td>
</tr>
<tr>
<td>Base</td>
<td>G1</td>
</tr>
<tr>
<td></td>
<td>G2</td>
</tr>
<tr>
<td></td>
<td>G3</td>
</tr>
<tr>
<td>Subbase</td>
<td>G5</td>
</tr>
<tr>
<td></td>
<td>G6</td>
</tr>
<tr>
<td></td>
<td>G7</td>
</tr>
<tr>
<td>Surfacing aggregates</td>
<td>19 mm</td>
</tr>
<tr>
<td></td>
<td>13.2 mm</td>
</tr>
<tr>
<td></td>
<td>9.5 mm</td>
</tr>
<tr>
<td></td>
<td>6.7 mm</td>
</tr>
<tr>
<td>Ballast</td>
<td>63.0 mm</td>
</tr>
<tr>
<td></td>
<td>73.0 mm</td>
</tr>
<tr>
<td>Specials and non-standard products</td>
<td>Various</td>
</tr>
</tbody>
</table>

**SANS Sieve Sizes**

Note that most quarries and commercial laboratories are still using the old sieve sizes for their screens. With the move to the SANS sieve sizes (see Chapter 3, Section 1.2), they will slowly change over to the new sieve sizes.
ASPASA COLTO Exclusion Clauses

ASPASA has issued COLTO exclusion clauses relating to the supply of various road construction products. It is important that the implications of these exclusion clauses are considered when considering utilizing commercial products from ASPASA members.

(i) Base Material

ASPASA members agree to supply G1 to G9 materials as defined in the following sections of the COLTO Standard Specification for Road and Bridge Works for State Road Authorities, Series 3000: Earthworks and pavement Layers of Gravel or Crushed Stone (1998), specifically Section 3400: Pavement Layers of Gravel Material and Section 3600: Crushed Stone Base, subject to the following conditions.

- **Table 3402/1 Requirement for types G4 to G6 materials, Grading:** ASPASA members do not draw a distinction between crushed and uncrushed material as defined under G4 material. Unless agreed with the ASPASA members, all G4 material will therefore conform to the limits specified for uncrushed material.
- **Section 3602 (c) Grading requirements:** ASPASA members shall not comply with an after compaction grading specification since the members have no control over the manipulation of the material after it has been delivered to site. ASPASA members will endeavour to achieve only the limit as defined in Table 3602/1 – Crushed stone base and subbase: Material Requirements, Grading.
- **Section 3602(c)(i)(5) Grading requirements:** Since the coarse sand ratio (CSR) is a factor of the crushing property of the rock, and hence cannot be physically controlled without occasional addition of non-parent materials, ASPASA members shall not comply with the limits specified in this section.
- **Table 3602/1 Crushed stone base and subbase, Material Requirements, Compaction requirements:** Because ASPASA members are not responsible for the achieved in situ density, no reduced payment as defined in section 8208 (b) (2) Conditional acceptance: Notes, shall apply.
- **Table 3602/4 Tolerance on target grading:** Because ASPASA members are not responsible for the grading limits after compaction, the tolerance on target grading specified in this table shall not apply.
- **Section 3603 Trial section and other requirements before the crushed stone layer may be constructed:** ASPASA members will assist their customers in attempting to achieve a final layer that conforms to specification requirements. Full payment for material supplied for a trial section will however still be insisted upon even if the trial section is removed as excess/unsuitable material.

(ii) Surfacing Material

ASPASA members agree to supply surfacing material as defined in COLTO Standard Specification for Road and Bridge Works for State Road Authorities Series 4000: Asphalt Pavements and Seals, and Section 4200: Asphalt Base and Surfacing, subject to the following conditions.

- **Section 4202 (b) Aggregate:** ASPASA members shall not comply with the second sentence of clause 3602 (a), namely, “It shall not contain any deleterious material such as weathered rock, clay, shale or mica”, since the vast majority of commercial rock available contains some traces of these components.
- **Section 4202 (b) (iii) Polishing:** Due to the variability achieved with the Polished Stone Value (PSV) test in recent round robin test programmes, ASPASA members reserve the right to specify potential test houses for testing of materials. Historical tests should also be used as a guide to determine the acceptability of a material source for use under the conditions specified in this section.
- **Section 4202 (b) (viii) Grading:** Where all-in materials are supplied in accordance with limits specified in Tables 4202/6 to 4202/10, the average grading of material supplied by ASPASA members shall conform to the limits specified in these tables, and is not subject to the tolerance specified in sub-clause 4213 (c) and Table 4213/1.

(iii) General

Where there is a dispute regarding the quality or achieved grading of material supplied by ASPASA members, the members reserve the right to only accept test results from a SANAS accredited laboratory for the tests in question. Disputes related to quality or the achieved grading of material tested after compaction shall not be entertained.
3.4 Quality Assurance and Quality Control

Road construction materials sourced from commercial quarries need to meet project requirements, including that:

- They meet the required material **product specification**.
- They are produced from a **constant source of rock**.
- The properties of a material product supplied **do not vary significantly**, especially during the supply period for a project.
- The quality of the material products are not significantly **negatively affected due to transportation** to site and/or **poor on-site stockpiling** procedures.

To assure the quality of their products, quarrying operations should implement an ISO 9000 series based quality management system (QMS). As part of a QMS, procedures should be in place to control the processes that affect the quality of the products produced. Such procedures cover:

- Ensuring the **quality** of the source material.
- **Maintaining** the required performance of the production plant.

Quarrying operations should run a quality control testing programme that continually monitors if the products produced comply with relevant specifications and client requirements. Typically, such programmes consist of performing a suite of appropriate laboratory tests on a particular product based on a production rate. For example, Afrisam quarries perform gradings and flakiness index (FI) testing on concrete aggregates based on samples obtained every 500 tons produced. The sampling rate may be adjusted up or down, depending on the material produced and level of variability. Monthly testing is conducted on road materials that includes, but is not limited to, polishing stone value (PSV), CBR, Mod. AASHTO, aggregate crushing value (ACV) and Atterberg limits. These tests are all described in Chapter 3, Section 3. Annual testing is also done to determine any changes in the mineralogy of the rock in the quarry being mined.

The results of quality control testing provide:

- **Assurance** that products meet the relevant specifications and client requirements.
- Data of the **material properties**.
- Test data indicating the **historical quality** of products produced from the quarry.

Access to the above data is essential when evaluating whether to utilize a commercial source for the supply of road construction materials.
4. ALTERNATIVE SOURCES

In the past, materials for the construction of road pavements have typically comprised of natural soils and gravels for fill, selected and subbase layers, and crushed aggregates for base layers, concrete pavements and surfacing. However, recently there has been an increased pressure, where feasible, to utilize alternative materials in place of the traditional materials. Some of the main issues promoting the use of alternative materials include:

- **Depletion** of natural resources.
- **Regulatory consent requirements** for developing quarries and borrow pits.
- Heightened awareness of **environmental issues** associated with quarrying and road construction in general.
- **Conservation of power.**

This has resulted in pressures to not only conserve existing aggregate resources, but also to recycle construction and industrial by-products wherever possible. The use of recycled materials has a win-win effect in that there is reduced demand for quarried aggregates and a reduced volume of material being dumped in landfills. The use of recycled materials could also have the benefit of reduced transportation costs if the recycled material is located at, or close to, the site where it is being re-used.

There are potential barriers to recycling of materials, including (Reid, 2000):

- Many **older specifications** do not permit the use of alternative materials.
- Lack of awareness of **methods available for recycling**, developments in specifications and successful projects.
- **Perception** that the use of alternative materials and recycling is a **high-risk activity**.
- Where cheap natural aggregates are available, alternative materials may not be **price competitive**.
- Concerns about **leaching of contaminants** from alternative materials.
- **Practical difficulties** with individual materials and methods, which are often site specific.

This section is intended only as an introduction and general overview to the use of alternative materials, and is limited to discussing the types of waste products that have potential to be recycled for road construction as well as their potential uses.

Considerations for whether or not to use an alternative material include:

- **Quality**
  - Classification or suitability for proposed usage
  - Standards and specifications
  - Test protocols
- **Supply**
  - Cost
  - Availability
  - Haul routes and distances
- **Environmental**
- **Health and safety**

There are possible disadvantages in the use of waste material, which should be carefully considered. Such disadvantages could relate to:

- **Haulage** costs
- **Greater variability** of waste materials
- **Long-term pollution** problems

The following sections discuss a procedure for evaluating a new material (Section 4.1), and the classification and use of waste products (Section 4.2). Sections 4.3 to 4.7 provide an overview of the classification and use of the more widespread alternative materials used for road construction including:

- Recycled pavement materials (Section 4.3)
- Construction and demolition waste, excluding recycled pavement materials (Section 4.4)
- Slags (Section 4.5)
- Fly ash (Section 4.6)
- Mining waste (Section 4.7)
4.1 Procedure for Evaluating a New Material

The decision to use alternative materials on a road construction project should be taken after a thorough evaluation. The procedure proposed for evaluating a new material is summarised in Table 24.

Table 24. Five-Stage Procedure for Evaluating a New Material

<table>
<thead>
<tr>
<th>Stage</th>
<th>Objective</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Desk study</td>
<td>To assess and evaluate existing information on the material</td>
</tr>
<tr>
<td>2</td>
<td>Laboratory study</td>
<td>Tests of the mechanical properties of materials to allow theoretical predictions of performance.</td>
</tr>
<tr>
<td>3</td>
<td>Pilot-scale trials</td>
<td>Evaluate construction and performance of materials in small scale trials.</td>
</tr>
<tr>
<td>4</td>
<td>Full-scale trials</td>
<td>Trial to establish whether the previous assessments obtained from Stages 2 and 3 are realized.</td>
</tr>
<tr>
<td>5</td>
<td>Road authority specification trials</td>
<td>This stage is necessary to carry out further evaluation of the material and to test the specification under contract conditions.</td>
</tr>
</tbody>
</table>

A valuable source in the field of alternative materials is Philip Sherwood’s book "Alternative Materials in Road Construction: A Guide to the Use of Recycled and Secondary Aggregates" (2001). This book provides practical guidance on the selection of substitute materials, including the economic and technical considerations of their use and advice on the benefits and pitfalls of each material. The book is divided into four parts that cover the following topics:

- **Part 1:**
  - Requirements for road making materials
  - Classification and sources
  - Specifications and standards for road making materials.

- **Part 2:**
  - Alternative materials available
  - Quantities, locations, general properties and potential uses
  - China clay wastes
  - Colliery spoil
  - Construction and demolition wastes
  - Glass waste
  - Municipal waste
  - Power station wastes (pulverized fuel ash and furnace bottom ash)
  - Rubber
  - Slags
  - Slate waste
  - Spent oil shale

- **Part 3:**
  - Environmental and economic considerations
  - Environmental effects of aggregate and waste production
  - Decision making
  - Traditional or alternative materials
  - Encouraging the use of alternative materials
  - Policy and controls on the supply and use of construction materials
  - Health and safety considerations

- **Part 4:**
  - References

4.2 Classification and Use of Waste Products

Sherwood states that: "If alternative materials are to be used in road construction they have to be classified and meet specification requirements in the same way that classification systems and specification systems have been drawn up for road making materials already in use. In theory, the specifications for alternative materials need not necessarily be the same as those for traditional materials, but in current practice this is usually the case, although it is rapidly changing."

The potential uses of alternative materials in road construction are given in Table 25.
Table 25. Summary of Potential Uses of Alternative Materials in Road Construction

<table>
<thead>
<tr>
<th>Material</th>
<th>Bulk fill</th>
<th>Unbound capping layer</th>
<th>Unbound subbase</th>
<th>Cement bound material</th>
<th>Concrete aggregate or additive</th>
<th>Bitumen bound material</th>
<th>Surface dressing aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed concrete</td>
<td>High³</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Some</td>
<td>None</td>
</tr>
<tr>
<td>Asphalt planings</td>
<td>High³</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>None</td>
<td>High</td>
<td>None</td>
</tr>
<tr>
<td>Demolition waste</td>
<td>High</td>
<td>Some</td>
<td>Some</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>Blast-furnace slag</td>
<td>High³</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Steel slag</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Some</td>
<td>High</td>
</tr>
<tr>
<td>Burnt colliery spoil</td>
<td>High</td>
<td>High</td>
<td>Some</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>Unburnt colliery spoil</td>
<td>High</td>
<td>Low</td>
<td>None</td>
<td>Some</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Spent oil shale</td>
<td>High</td>
<td>High</td>
<td>Some</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>PFA¹</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>FBA²</td>
<td>High</td>
<td>Some</td>
<td>Some</td>
<td>High</td>
<td>Some</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>China clay sand</td>
<td>High</td>
<td>High</td>
<td>Some</td>
<td>High</td>
<td>High</td>
<td>Some</td>
<td>Low</td>
</tr>
<tr>
<td>Slate waste</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Some</td>
<td>Some</td>
<td>Low⁴</td>
<td>None</td>
</tr>
</tbody>
</table>

Notes:
1. PFA = Pulverised Fuel Ash
2. FBA = Furnace Bottom Ash
3. Suitable but inappropriate (wasteful) use.
4. Fly ash and slate dust can be used as filler.

The results of a survey of the use of alternative materials in UK roads (Mallett et al, 1997) are summarized in Table 26. This survey indicates that the most widespread use of alternative materials relate to the production of secondary aggregates by reclamation of bituminous materials, in situ recycling of pavement layers, as well as processing of concrete waste, pulverized fuel ash and slag.
Table 26. Survey of the Use of Alternative Materials in UK Road Schemes

<table>
<thead>
<tr>
<th>Material</th>
<th>No. of schemes identified</th>
<th>Filter Drains</th>
<th>Road layer in which the material was frequently used</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surfacing</td>
</tr>
<tr>
<td>Reclaimed bituminous material</td>
<td>146</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Shallow cold-mix in-situ</td>
<td>101</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Deep cold-mix in-situ</td>
<td>93</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Crushed concrete</td>
<td>55</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Pulverized fuel ash</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel slag</td>
<td>40</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Blast-furnace slag</td>
<td>36</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Colliery spoil</td>
<td>23</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Crushed demolition material</td>
<td>11</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Shallow hot mix in-situ</td>
<td>9</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Hot mix off site</td>
<td>7</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Slate</td>
<td>7</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Phosphoric slag</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyres</td>
<td>7</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>China clay sand</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold-mix off site</td>
<td>5</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Crushed brick</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail ballast</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furnace bottom ash</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass</td>
<td>1</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Spent oil shale</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3 Recycled Road Pavement Materials

Waste from road reconstruction has a high potential for re-use in road construction. In South Africa, a growing emphasis is being placed on the use of recycled pavement materials for road projects. The different types of recycled pavement product are summarized in Table 27.

Table 27. Types of Recycled Pavement Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclaimed Asphalt (RA)</td>
<td>Asphalt millings comprising aggregate (± 95%) and bituminous binder. Milling and crushing yields a bitumen coated aggregate. If stockpiled for excessive periods (particularly in warm weather), particles may become bonded together but can be readily broken up.</td>
</tr>
<tr>
<td>Reclaimed Concrete Pavements</td>
<td>Crushed concrete is obtained from the demolition of concrete road pavements. See Section 4.4. The concrete has the potential to be contaminated by chloride ions (usually from de-icing salts in cold climates) or sulphates from contact with sulphate-rich soils.</td>
</tr>
<tr>
<td>Reclaimed Base and Subbase Materials</td>
<td>This is a broad range of materials suitable for the production of subbase and base layers. Recycling of these materials is potentially suitable for stabilised layers, granular subbase and fill.</td>
</tr>
<tr>
<td>Mixed materials</td>
<td>The above types of material may occur as uncontrolled mixtures. Due to the inherent variability of such materials, there is less scope for recycling.</td>
</tr>
</tbody>
</table>

The benefits of the recycling of bituminous materials are (OECD, 1977):
- **Reduce transport costs** and fuel requirements.
- **Reduce aggregate requirements** and eliminate potential disposal problems.
- **Reduce bitumen content** by up to 75%.
- **Reduce energy** required for dying of aggregates.
- Generally **lower emissions** during construction.
Basic approaches for recycling pavements are given in Table 28.

### Table 28. Recycling Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Summary of Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot In Situ Recycling (HIR)</strong></td>
<td>Generally, total depth of treatment is about 50 mm.</td>
</tr>
<tr>
<td><strong>Process:</strong></td>
<td>• Heating of the surface layer</td>
</tr>
<tr>
<td></td>
<td>• Scarifying</td>
</tr>
<tr>
<td></td>
<td>• Reinforcing with thin asphalt overlay</td>
</tr>
<tr>
<td><strong>Cold In Situ Recycling (CIR)</strong></td>
<td>Total depth of treatment up to 300 mm.</td>
</tr>
<tr>
<td><strong>Process:</strong></td>
<td>• Milling in situ and reshaping of the existing road</td>
</tr>
<tr>
<td></td>
<td>• Addition or removal of aggregate to achieve desired profile</td>
</tr>
<tr>
<td></td>
<td>• Addition and mixing in of foamed bitumen, bitumen emulsion, cement or lime</td>
</tr>
<tr>
<td></td>
<td>• Compaction</td>
</tr>
<tr>
<td></td>
<td>• Apply surfacing</td>
</tr>
</tbody>
</table>

In situ recycling and stabilising with cement, lime, bitumen emulsion or foamed bitumen are well established technologies in South Africa. These are discussed in several other chapters of this guideline as well as in other industry guideline documents, such as TG2 (2009) for Bitumen Stabilised Materials and the Stabilisation Manual (GDPTRW, 2004).

#### 4.3.1 Reclaimed Asphalt (RA)

When considering the use of RA on road construction projects, the following aspects should be carefully considered:

- Recovery
- Classification
- Storage
- Design protocols and guidelines
- Manufacturing process

Examples of the process of reclaiming asphalt from a road are shown in Figure 18.
4.3.2 Recovery of RA

The mechanical properties of RA depend on the original asphalt pavement type, the methods utilized to recover the material, and the degree of processing necessary to prepare the RA for a particular application. Because RA may be obtained from any number of old pavement sources, its quality varies. The number of times the pavement has been resurfaced, the amount of patching and/or crack sealing, and the possible presence of prior seal coat applications will all influence the RA composition. The presence of geofabric patches significantly affects the usability of recycled asphalt.

4.3.3 Classification of RA

Milled or crushed RA can be used in a number of road construction applications. These include its use as an aggregate (and binder) supplement in recycled asphalt paving either with hot or cold mix, a granular base or subbase, or as a fill material. The use of RA as fill is, however, not encouraged as it is considered wasteful. However, it may be a practical alternative for RA that has been stockpiled for a considerable time, or is mingled from many different sources. The use of RA as fill material within the same carriageway could also be a suitable alternative to the disposal of excess asphalt that is generated on a project, where transport to an asphalt plant would be uneconomical.

Use of RA in Fill

The use of RA as fill is not encouraged as it is considered wasteful. However, it may be a practical alternative for RA that has been stockpiled for a considerable time, or is mingled from many different sources. The use of RA as fill material within the same carriageway could also be a suitable alternative to the disposal of excess asphalt that is generated on a project, where transport to an asphalt plant is uneconomical.
4.3.4 Storage of RA

Storage of RA requires particular attention to ensure a consistent and reliable RA product. RA stockpiles need careful handling to ensure that they remain useable. Stockpiles need to be kept below 2 metres high. Heavy vehicles must not be allowed to drive over the RA, to minimize consolidation of the material. The RA must be protected from the elements. Indications are that the moisture content increases while in storage, particularly if exposed to rain. During periods of extensive rainfall, the moisture content of some RA stockpiles may be as high as 7 to 8%. Lengthy stockpiling of RA should, therefore, be kept to a minimum.

4.3.5 Manufacturing Process

Typically asphalt batch plants in South Africa are capable of blending in up to 20% RA into their standard mixes. This is done via a RA feed into the hopper, at the end of the aggregate heating drum. The RA has therefore only got a short time to be heated by the other aggregates. The heat transfer rate is a constraint on the percentage of RA that can be incorporated into mixes. Higher (>20%) utilization of RA requires costly plant upgrades, to enable RA to feed directly into the drying drum.

4.4 Construction and Demolition Waste

Construction and demolition waste, in this chapter, includes recycled pavement materials. Waste products are produced as a consequence of the demolition of roads, airfield runways, buildings include: concrete, masonry, bituminous road materials, aggregates and soils. These materials are potentially suitable for recycling and reuse in road construction.

Concrete and masonry waste reused for producing secondary aggregates are termed Recycled Aggregates (RCA). Various schemes for the classification of RCA have been suggested, based on the composition of the waste. Mulheron (1991) distinguished four main categories of construction and demolition waste (excluding asphalt road planings).

- **Clean crushed concrete**: Crushed and graded concrete containing less than 5% of brick of other stony material.
- **Clean crushed brick**: Crushed and graded containing less than 5% of other materials such as concrete or natural stone.
- **Clean demolition debris**: Crushed and graded concrete and brick.
- **Crushed demolition debris**: Mixed crushed concrete and brick that has been screened and sorted to remove excess contamination, but still contains a proportion of wood, glass or other impurities.

The BRE Digest (BRE, 1998) defines recycled aggregates as “crushed concrete and brick masonry” and gives three classes of RCA depending on the relative amounts of brick and concrete, as shown in Table 29.

<table>
<thead>
<tr>
<th>Class</th>
<th>Origin</th>
<th>Brick Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCA I</td>
<td>Brickwork</td>
<td>0 – 100</td>
</tr>
<tr>
<td>RCA II</td>
<td>Concrete</td>
<td>0 – 10</td>
</tr>
<tr>
<td>RCA III</td>
<td>Concrete &amp; brick</td>
<td>0 – 50</td>
</tr>
</tbody>
</table>

A Dutch classification for recycled granular base materials (Sweere, 1991) defines crushed concrete as shown in Table 30.

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main components</strong></td>
<td>At least 80% by mass of crushed gravel or crushed aggregate concrete.</td>
</tr>
<tr>
<td></td>
<td>At most 10% by mass of other broken stony material, the particles of which shall have a</td>
</tr>
<tr>
<td></td>
<td>particle density of at least 2 100 kg/m³.</td>
</tr>
<tr>
<td><strong>Additional elements</strong></td>
<td>At most 10% by mass of all other materials, such as crushed stone or</td>
</tr>
<tr>
<td></td>
<td>broken stony material. Asphalt shall not exceed 5% by mass.</td>
</tr>
<tr>
<td><strong>Impurities</strong></td>
<td>Maximum 1% non-stony material, i.e., plastic, plaster and rubber acceptable.</td>
</tr>
<tr>
<td></td>
<td>Maximum 0.1% decomposable organic matter such as wood and vegetable remains.</td>
</tr>
</tbody>
</table>
Potential uses for different types of demolition waste, classified according to composition are summarized in Table 31.

### Table 31. Potential Uses for Demolition Waste

<table>
<thead>
<tr>
<th>Product</th>
<th>Potential Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed concrete</td>
<td>May be used as a substitute for natural aggregates for most purposes. Concrete derived from the demolition of buildings is likely to contain reinforcement, making it difficult to crush. It is also likely to be contaminated with other building waste materials.</td>
</tr>
<tr>
<td>Recycled crushed cement bound subbase and base</td>
<td>May be crushed or milled to produce granular materials meeting the requirements for a subbase. May also be restabilised with cement or bitumen to produce a stabilised material.</td>
</tr>
<tr>
<td>Crushed brick</td>
<td>Where bricks are available in quantity but are unsuitable for re-use, they may be crushed to produce granular materials meeting the requirements for a subbase. Contamination from gypsum plaster could result in crushed bricks having an unacceptably high sulphate content. Some brick types have soluble sulphate contents high enough to be deleterious.</td>
</tr>
<tr>
<td>Crushed demolition debris (other than concrete and masonry)</td>
<td>May be used as general fill. Rubble containing timber should be avoided because, when it rots, cavities remain in the fill.</td>
</tr>
</tbody>
</table>

### 4.5 Slags

Various types of metallurgical slag are produced as waste products of metallurgical processes. These include:

- Blast furnace slag
- Steel slag
- Non-ferrous slag

#### 4.5.1 Blast Furnace Slag

Blast furnace slag is a by-product obtained in the manufacture of pig iron in the blast furnace. In the blast furnace, iron ore and limestone flux are combined and heated at high temperatures (between 1300 °C and 1600 °C) by the burning of coke. These materials react to produce molten iron, carbon dioxide and molten slag. The slag is then cooled, either by air or water producing:

- **Air-cooled slag** (Figure 19(i)), a rock-like material with crystalline structure, which when crushed can produce an excellent substitute for natural aggregates.
- **Water-cooled slag** (Figure 19(ii)), a granulated glassy material.

![Figure 19. Water and Air-Cooled Slag](image)

**Blast Furnace Slag**

This is a by-product obtained in the manufacture of pig iron in a blast furnace. Iron ore and limestone flux are combined and heated at very high temperatures by burning coke. These materials react to produce molten iron, carbon dioxide and molten slag. The slag is then cooled.
The chemical composition of slag is variable. The ranges in mineral composition reported by Lee (1974) are shown in Table 32.

### Table 32. Mineral Composition of Slag

<table>
<thead>
<tr>
<th>Component</th>
<th>Range (% by mass)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>36 – 43</td>
</tr>
<tr>
<td>SiO₂</td>
<td>28 – 36</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>12 – 22</td>
</tr>
<tr>
<td>MgO</td>
<td>4 – 11</td>
</tr>
<tr>
<td>Total sulphur (as S)</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Total iron (FeO+Fe₂O₃)</td>
<td>0.3 – 2.7</td>
</tr>
</tbody>
</table>

For most purposes, blast furnace slag is generally regarded as being at least as good as natural aggregates. However, the physical and chemical properties differ from natural aggregates and hence specifications and testing methods for natural aggregates do not necessarily apply. Generally speaking, slag meeting the requirements of BS 1047 should prove suitable for aggregate for concrete and road construction.

When crushed and screened by normal quarrying procedures, blast furnace slag generally produces good quality aggregate with a cubic shape and a rough surface texture giving good frictional properties and good adhesion to bituminous and cementitious binders.

Ground granulated blast furnace slag (GGBS) is used as a cement extender in the production of concrete. The use of GGBS as a cement extender is discussed in more detail in Chapter 9, Section 6 and 12.

A potential problem related to the use of blast furnace slag in road construction is its instability, as it is not inert. Two forms of instability have been recognized; unsoundness and the potential to corrode steel. The instability is related to expansive reactions causing the slag to disintegrate. BS EN 11744-1 includes methods for detecting unsoundness. When used as a concrete aggregate, the possibility of corrosion of steel reinforcement due to sulphur in the slag has been alluded to, but there do not appear to be any recorded cases of slag concrete affecting the corrosion of reinforcing steel (Everett and Gutt, 1967).

The use of slag below water could give rise to problems with water pollution. There is a risk of corrosion if slag comes into contact with metals that corrode in an alkaline environment.

#### 4.5.2 Steel Slag

Steel or Linz-Donawitz (LD) slag, is produced in the conversion of raw iron into steel using the Linz-Donawitz process. It is also referred to as Blast Oxygen Furnace Slag (BOF) slag. LD slag is produced in all the steel producing regions in South Africa, the most important of which are the Witwatersrand area, Newcastle in KwaZulu-Natal and the Saldhana region in the Western Cape. However, all the slag produced is suited to use as a road-building aggregate.

The chemical composition of steel slag depends on the method of production, but when cooled yields a product that resembles igneous rock, as illustrated in Figure 20. The suitability of all types of steel slag as an alternative to natural aggregates is viewed with caution. This is because, when freshly produced, they can contain both free calcium oxide (CaO) and free magnesium oxide (MgO) that originate from the limestone or dolomite used as flux in the smelting process. These oxides, in the presence of water, hydrate and swell leading to instability. Hydration times can be prolonged; it may take decades or even centuries for magnesium oxide and hard burnt lime to hydrate completely (Collins and Sherwood, 1995).
Due to the presence of free lime and magnesium, with the consequent risk of expansion, the use of steel slags in road construction was viewed as being limited to situations where expansion is unlikely, e.g., where aggregate particles are coated with bitumen and water has difficulty penetrating the particle to cause hydration, and where any expansion that does occur is not likely to be a serious problem. Lieuw Kie Song and Emery (2001) reported that experience with LD slag in South Africa was not satisfactory. It was used as a base in roads in the Vanderbijlpark area, but the roads deteriorated quickly after construction and required reconstruction. The likely reasons given for the performance was swelling due to the presence of free lime which hydrated.

However, the process to remedy the expansive properties has improved and steel slag is now considered an alternative to natural aggregates in the road construction industry. To prevent expansion, the steel slag needs to be weathered prior to use. This is to hydrate the free calcium oxide, which if not done, results in water causing hydration and breaking down on the aggregate. In a steel slag mix, this is characterised by isolated white deposits from the formation of calcium carbonate, which pop out. Steel slag for road construction aggregate should be stockpiled for a minimum of 3 months and kept constantly wet by rain or water spraying. The storage or ageing is to allow potentially destructive hydration and the associated expansion to take place prior to using the material as an aggregate. There is wide variation in the amount of time required for adequate exposure to the elements. Up to 18 months may be required.

Using Steel Slag as an Aggregate in Asphalt or Crushed Stone Base
Before using steel slag as an aggregate in asphalt or in a crushed stone base, it is critically important that the material is pre-weathered to prevent expansion. It is not necessary to weather steel slag when used in seal work.

It is important to keep the stockpiles covered after weathering during rainy weather, and to open the covers during hot weather to facilitate drying. Because of the high permeability, the slag retains water, which makes drying during the mixing process more costly.

For seals, pre-weathering is not necessary because the stone is always exposed and minor fragmentation is not an issue. The smaller than 3 mm aggregate, when used in asphalt, is assumed to be coated completely by bitumen, and hence the pre-weathering is again not critical. Storage stockpiles of crushed fines for use in asphalt must be covered to ensure that they do not get wet. Moisture results in cementing and solidifying that requires additional breaking down.

It is not advisable to use steel slag as the fine aggregate in an untreated base as it is unlikely that the hydration and slaking process is complete. Hydration of the fines can result in cementing/solidifying the material, with the fines getting lumpy. This requires additional crushing. Crushing previously weathered aggregate for fines can mitigate the risk of unhydrated fines, and reduce the risk of expansion.
Since 2004, steel slag asphalt with an SBS polymer modified binder and penetration grade binder has been successfully used on the N3 Toll Concession roads. One of the steel slag sections is shown in Figure 21. See the side box for a case study. Work is currently underway to investigate ways to use steel slag as an aggregate for bases.

Figure 21. Steel Slag on N3TC Section

4.5.3 Non-Ferrous Slag

Non-ferrous slag is produced from the smelting of other metal ores. The use of these materials is not widespread, however ferro-chrome slag has been used fairly extensively on the N4 toll concession (TRAC). Potential problems with non-ferrous slags are that they may contain unstable components in the presence of water and/or that water leaching through them may contain harmful pollutants.
**South African Case Study: The Use of Steel Slag Asphalt on the N3 Toll Road**

The N3 between Durban and Johannesburg is the most heavily trafficked route in South Africa. As a result of changes in traffic spectrum, steep gradients, variable moisture conditions and high road surface temperatures, it was necessary to find an alternative to conventional hot mix asphalt to improve durability, rut and skid resistance of the asphalt surfacing. In addition, the material needs to be workable and still show good fatigue properties. To overcome these challenges, steel slag aggregate was used. The information presented in this case study comes from Bouwmeester et al., “The Use of Steel Slag Aggregate in Hot-mix Asphalt in South Africa” (2008) and Mr Douglas Judd, Technical Manager of the N3TC.

Steel slag is a waste by-product of the steel making process. Utilising steel slag as an aggregate is a means to reduce the large waste stockpiles, as well as to preserve natural resources by not quarrying natural aggregates. The steel slag used on the N3 is from the ArcelorMittal works in Newcastle.

On the N3, steel slag was found to provide a high quality aggregate, with the following notable properties:

- **The particle density** of steel slag is denser and heavier, approximately 20% more than dolerite and quartzite. This impacts transport costs and less kilometres are covered for the same tonnage. However, depending on the location of the project, the higher haul cost can be compensated by the lower purchase price as the procurement cost of steel slag is significantly less than that of conventional aggregates.

- **The water absorption** (determined by standard test methods) is higher than dolerite and quartzite, because of the shape of some particles with cavities from the water cooling process, rather than the aggregate being porous. More binder is required to fill the cavities than with conventional aggregates. The use of a high softening point modified binder allows coating of the particles without filling all the cavities. Good practice procedures must be followed to manage and prevent segregation, which helps in managing the risk of interconnecting voids.

- **The pH** is between 8 and 11, and hence has a strong affinity to bitumen. The aids in retaining the binder coating, preventing stripping. This is important for long-term durability, especially in high moisture regions.

- **Steel slag particles** have a **cubical shape**, and therefore a dense packing. However, the **rough surface texture** makes compaction more difficult than with conventional aggregates. The binder content and binder filler ratio must be carefully controlled to ensure workability. Steel slag retains heat longer than conventional aggregate, aiding compaction.

The application of steel slag aggregates is only practical if the slag is stable with a low risk of expansion. Stability is indicated by the presence of free lime. Expansion, measured using the ASTM standard expansion test, must be below 7% for use in asphalt. The work on the N3 has indicated that the minimum weathering time in South Africa is 3 months at a moisture content exceeding 6%. The volumetric expansion should be tested.

For the N3 mix, a continuously graded coarse grading was used. Agricultural lime was used as a filler when the percentage fines were low, but generally the raw aggregate gradings can be managed to ensure a 100% steel slag mix. The binder was a Styrene Butadiene Styrene (SBS) polymer modifier, used because of its consistency and reduced temperature susceptibility, resilience and toughness, improved stability and cohesion, and improved binder aggregate adhesion. Even with the SBS binder, the mix is stiff and should only be placed on bases with relatively low deflections (< 400 μm). The binder copes with high daily and seasonal temperature fluctuations and meets the stability and flexibility requirements for high traffic. The binder also allows a sufficient film thickness coating of the steel slag particles, without filling all cavities of the hollow particles.

Various tests were done on the mix to assess the properties:

- **Marshall stability and flow** indicated the mix is stable and has some flexibility.
- **ITS test stiffness** was significantly higher than South African requirements, indicating the mix was ideally suited for rut resistance.
- **Gyratory testing** results exceeded the minimum South African standards. The mix would not be easily compacted under traffic.
- **Wheel tracking** results showed the mix had better deformation resistance than dolerite and some SMAs.

The first steel slag section was an approximately 150 mm thick asphalt inlay, constructed in 2004 on Van Reenen’s Pass. In the first four years, the inlays carried approximately 18.5 MESA. The conventional mix used on Van Reenen prior to the steel slag asphalt typically started rutting within one year with a rut rate of up to 10 mm per year. At the time, a concrete inlay seemed to be the only solution. Annual performance measurements during the 6 years after construction show that the riding quality significantly improved, and remained below an IRI of 1.6 m/km, and rutting measurements remained below 2.5 mm. Some problems related to cracking were experienced, where the support was insufficient.

Subsequent to the use of steel slag asphalt on Van Reenen’s Pass, it has been widely used on the N3 for inlays, overlays and new construction. At the end of 2011, approximately 400 lane km of the 1660 lane km N3TC network has steel slag asphalt. This equates to approximately 300 000 tons. In addition, there are approximately 420 lane km of single seals using steel slag aggregate.
South African Case Study: The Use of Ferro-chrome Slag in Construction on the N4 Toll Road

Since the initial construction phase of the N4 Toll Concession Contract, ferro-chrome slag has been identified and used as a versatile construction material. The information presented in this case study was provided by Mr. Gawie Jordaan, Road Pavement and Materials Specialist, Trans African Concessions (Pty) Ltd (TRAC).

Three main sources of ferro-chrome slag waste material are found along the N4 toll road at: Witbank, from Samancor; Middelburg, from Ferraloys marketed by Enviro aggregates; and, Machadodorp, from Asmangchrome. The slag is usually crushed, either as part of the chrome extraction process at the works, or to specifically comply with various specifications. The pre-crushed slag is usually processed for road works by screening out required fractions for specific applications. Material processed in such a manner has been used for various purposes.

Potential negative aspects of using ferro-chrome slag include the possible presence of Chrome VI, which is considered toxic if leached out in the ground water, and blow holes in the slag that may lead to higher binder absorption in asphalt and seals.

On the N4, ferro-chrome slag has been used for drainage, layer works and asphalt. In excess of 175 000 tonnes of ferro-chrome slag asphalt have been used on the N4 by 2008. A paper on the use of the slag by Jooste, Verhaeghe and Jordaan was presented at the 1999 CAPSA.

(i) Drainage: The pre-crushed slag is screened to produce aggregate complying with the COLTO specification (1987) for drainage aggregate. Considerable quantities of the slag have been used for this purpose all along the N4. No problems have been experienced and the relatively coarse size particles of slag utilised for this application should only contain trace amounts of Chrome VI, and are therefore not considered a significant environmental hazard.

(ii) Layer Works: An attempt was made to use the crushed slag as a G1 or G2 base material. However, it required blending slag from various sources, as well as a small quantity of sand. A short, 300 metre, trial section was built for rehabilitation works between Belfast and Machadodorp on the N4/5X. It worked successfully after the correct grading was attained.

The ferro-chrome slag has been successfully used in mixtures with other natural soils and gravel layer materials to improve the properties of the material. By 2008, the following approximate quantities of slag have been used for this purpose:

- Rebuilding shoulders along the N4, mixed with in situ gravel: 5 500 m³ (10 000 t)
- Subbase construction on ± 30% of N4/5 (Wonderfontein to Belfast), mixed with borrow-pit material: 20 000 t

(iii) Asphalt: By far the most ferro-chrome slag used on the N4 has been for asphalt manufacture. At the asphalt plant, located in Witbank, the slag, mixed with pit sand, has been used for the production of asphalt for many years with great success. When the N4 was originally upgraded between 1999 and 2000, appreciable quantities of this type of asphalt was used for patching and mill and inlay work.

In 2004, the slow lanes of the first 14.8 km of the N4/3, west of Witbank, was inlaid with 40 mm of this particular ferro-chrome asphalt. Approximately 60 km of the N4/6N and N4/7N between Machadodorp and Montrose, through Watervalonder, was overlaid with 40 mm of ferro-chrome asphalt from Machadodorp. At that time, the ferro-chrome plant at Machadodorp had a significant quantity of crushed slag in stock with a grading that complied with the requirements of the continuous medium asphalt grading in the COLTO (1988) specification. The crushed slag was used without further processing, but with small adjustments to the filler content. This was the first large scale use of ferro-chrome slag in asphalt. A complete series of design tests were conducted to ensure its suitability.

Other applications include an ultra-thin friction course (UTFC) overlay constructed on the N4/3 old concrete road in 2008. On the widened section between Wonderfontein and Belfast, a 35 mm asphalt surfacing was used.

Comments on the construction and performance of the asphalt:

- **Haul costs** increase by ± 20% compared to natural aggregates, due to the high relative density of the slag.
- **Water absorption** of the slag is relatively high due to blow holes in its structure. This may lead to a slightly higher binder content due to some binder being lost in these blow holes. However, there are no micro fissures in the slag as in some natural aggregates with high absorption, so that selective absorption of the bitumen is not considered to be a problem.
- Initially the **fatigue life** of the asphalt was doubted, but its performance exceeded expectations, even on pavements with relatively high deflections. After 11 years, the asphalt is still performing, although some sections have been sealed to improve skid resistance. The asphalt performs as well as, if not better, than conventional aggregates.
4.6 Fly Ash

Ash is produced as a by-product in a coal burning power station. Pulverized coal, in fine powder form, is burned in a furnace to produce electricity. As part of this process, a very fine, pulverized fuel ash (PFA) is produced and is carried out of the furnace with the flue gases. The coarser ash falls to the bottom of the furnace where it sinters and forms furnace bottom ash (FBA). Of the ash produced in a coal-fired power station, 75% to 85% of the ash is PFA. Various photos of fly ash are shown in Figure 22.

![Figure 22. Fly Ash](image)

PFA is removed from the flue gases by mechanical and electrostatic precipitators, collected, and usually, stockpiled. PFA is collected in hoppers in the dry form, or mixed with water and hydraulically transported, by pipeline, to waste stockpiles. Classified PFA is used as a cement extender in the production of concrete. PFA is a valuable bulk fill material for road construction. The following should be taken into consideration when using the material for this purpose:

- Grain shape and particle size make the upper layers of PFA difficult to compact.
- Freshly placed PFA behaves in a similar manner to silt and if not protected may liquefy under wet conditions.
- Capping and subbase layers tend to be relatively permeable and a layer of general fill over PFA is considered desirable to add some protection.
- PFA has a relatively low density compared to other natural fill materials.
- PFA is usually compacted to an end-product specification.
- PFA may possess self-cementing properties when compacted. Should hardening occur, settlement within the PFA fill will be less than with other materials.
- The composition and properties of PFA from different power stations may vary significantly.
- PFA is not suitable for selected or subbase layers.

FBA (clinker ash) is a coarse granular material ranging in particle size from fine sand to coarse gravel. The grading makes it suitable for selected and natural subbase. Because the particles have a porous structure, they tend to be relatively weak compared to most granular materials.

Work carried out by the CSIR, Transportek (Lea and Heath, 1999) showed that clinker and fly ash produced as a by-product of the coal gasification process at the Sasolburg plant in South Africa could be successfully utilized, when processed and blended in optimal proportions, as base for the construction of low volumes roads. Although the ash material did not perform as well as a 100 mm crushed stone base, it was equivalent to good quality natural gravel. The cost of construction of the base sections constructed using clinker ash was less than half of that of crushed stone, despite the fact that the test sections were located over 150 km from the Sasol plant.

Tohoku Electric Power (2008) report on their website on research being carried out to use coal ash as a substitute for filler for asphalt mixtures in road paving works. In this research project, the fillers made from coal ash were used at three road construction points on a national highway in Akita prefecture (Japan). Tohoku and the Tohoku...
Regional Bureau of Ministry of Land, Infrastructure and Transport have jointly developed the technology to use coal ash (clinker ash) as banking materials for road construction. This technology has been adopted in the "Guideline for Utilization of Coal Ash for Road Banking and Displaced Soil at Construction" (2008).

4.7 Mine Waste

South Africa is home to a large mining industry that produces massive quantities of waste rock products. Typically, these waste materials are spoiled in mine dumps. These dumps are potentially good sources of sound rock for crushing to produce aggregates for construction. The use of this type of waste has significant positive environmental impacts. An example of an old mine dump in Stilfontein, which is being used as a source of crushed rock, is shown in Figure 23.

![Crushed Rock from a Mine Dump](image)

The old gold mine dumps at South Deep Gold Mine were excavated to produce gold-bearing fines. As a by-product, aggregate of various sizes for use in road works were produced. The final outcome of the project is that an unsightly mine dump will be removed in its entirety, creating rehabilitated open land which will become available for further development.

Another example of mine waste being recycled to produce road construction materials is from an old copper mine in Musina in Limpopo. This mine dump is producing commercial aggregates. The mine spoil consists of a mixture of rock types comprising quartzite, granite and slag. After processing, (crushed) spoil has been successfully used for:

- G1 base
- 13.2/6.7 mm surfacing aggregate
- Concrete aggregate

In all cases, processes mine waste should conform to COLTO (1988), or other applicable specifications. The description for G1 material in COLTO (Table 3602/1) allows for the use of mine waste: "Parent material: Sound rock from an approved quarry, or clean, sound mine rock from mine dumps, or clean sound boulders."

Prior to using aggregates derived from mine waste, an appropriately scoped testing programme should be carried out to confirm the quality of the material. Also, it must be confirmed that the material does not contain any toxic substances potentially considered an environmental hazard.
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BS. British Standards Institution. Standards available for a fee for download from [www.bsigroup.com](http://www.bsigroup.com), click on BSI Shop.


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