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# *General Design Standards Revision 0*

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## *Gravel Roads Manual*

Western Cape Provincial Administration

Department of Transport and Public Works  
Roads Infrastructure Branch





# Gravel Roads Manual

*First Edition*

## *Chapter 2*

### *General Design Standards*

Provincial Administration: Western Cape  
Department of Transport and Public Works  
Roads Infrastructure Branch



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# GENERAL DESIGN STANDARDS

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# GEOMETRY

## INTRODUCTION

The road network in the Western Cape has developed over several years to provide accessibility and safety to road users. Although the network is by no means perfect in terms of meeting minimum guideline standards at all times, the current unsurfaced road network largely fulfils the purpose of providing accessibility in rural areas and major improvements are, therefore, not warranted on the majority of lower volume roads.

During the provision or maintenance of unsurfaced roads, the emphasis should be placed on appropriate standards.

## ROAD CLASSES

Currently the Geometric Design Manual (GDM)<sup>1</sup> classifies rural roads according to the 24 hour equivalent vehicle units (EVU).

Table 2-1: Road Classes	
AADT (EVU)	CLASS
>3000	Ultimate 6 lane divided
2000 – 3000	Ultimate 4 lane divided
1000 – 2000	1
400 – 1000	2
200 – 400	3
<200	4

1. WCPA: Geometric Design Manual, Cape Town, 1983

Unsurfaced roads normally fall under Class 4. However, cognisance should be taken of the current and potential future traffic on existing unsurfaced roads with the objective of gradually improving these to the standards recommended for the relevant class.

## DESIGN SPEED AND ALIGNMENT

Except for mountain passes, the design speed for a particular road section should be constant for a minimum length of 4 km. The recommended minimum design speed for Class 4 roads is 60 km/h. Due to the existing proclaimed road reserves and alignments following the topography, the improvement of many unsurfaced roads to achieve the recommended design speed is not possible without major expense.

*The Department’s Geometric Design Manual is currently being adjusted to incorporate more appropriate standards for low volume unsurfaced roads.*

*Current suggested guidelines for improvement of the horizontal and vertical alignment can be obtained from the “AASHTO Guidelines for geometric design of very low-volume local roads (ADT < 400)”<sup>2</sup>.*

Guidelines<sup>2</sup> for minimum radii on unsurfaced roads without super elevation are summarised in Table 2-2 on page 2-2.

2. “Guidelines for geometric design of very low-volume local roads (ADT < 400)”. American Association of State Highway and Transportation Officials, Washington, 2001.

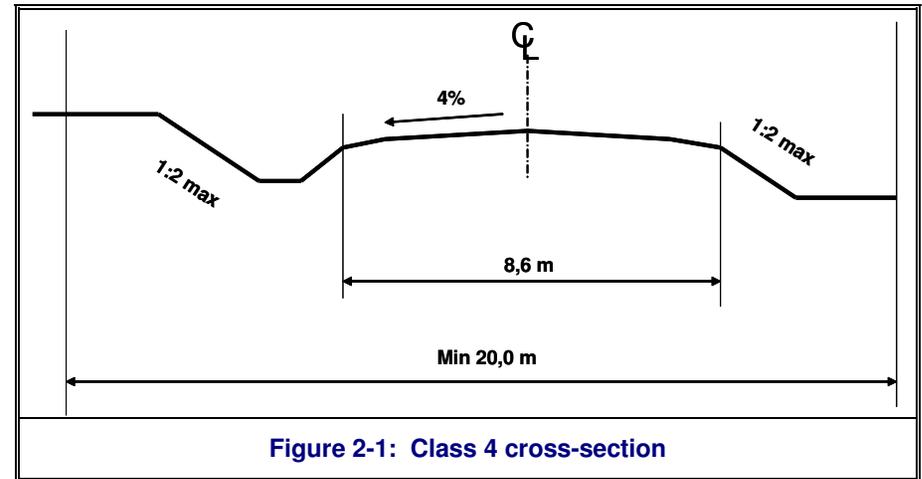
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Table 2-2: Minimum recommended radii									
		Gravel compacted (Dry)							
		Gravel compacted (Wet)							
		Gravel loose (Dry)							
		Gravel loose (Wet)							
		Earth (Dry)							
		Earth (Wet)							
					Clay (Wet)				
Design Speed (km/h)	Traction coefficient	0,8	0,7	0,6	0,5	0,4	0,3	0,2	
20	Minimum Radius (m)		15	15	15	20	35		
30			15	20	25	40	75		
40			30	35	45	65	130		
50			40	50	70	100	200		
60			60	75	95	145	285		
70			80	100	130	195	385		

## CROSS-SECTION

### GENERAL

The current recommended cross-section for Class 4 roads is applicable to road reserve widths of 20 m or more. However, numerous unsurfaced proclaimed roads, especially Minor roads, have reserve widths of less than 15 m, resulting in non-adherence to the recommended cross-sectional detail.



## WIDTH

Road widths on formed Divisional and Main roads in the Western Cape vary from 4 m to 9 m. The road width is often governed by the number of grader passes required for blading (equal number to maintain a crown e.g., 2 or 4, resulting in 4,0 m to 5,0 m or 6,0 m to 8,0 m road widths). Figure 2-1 on page 2-2 shows a Class 4 cross-section.

Experience elsewhere<sup>3</sup> indicates that the following unsurfaced road widths are considered safe and appropriate:

- 6,0 m for roads carrying less than 50 vehicles per day
- 7,5 m for roads carrying between 50 and 200 vehicles per day
- 8,6 m for roads carrying more than 200 vehicles per day or those carrying large vehicles.

3. "Unsealed roads manual". Australian Road Research Board, August, 2000.

Experience in the Western Cape suggests different appropriate widths based on road reserve widths, topography, traffic and potential upgrading strategies. Table 2-3 on page 2-3 serves as a guideline.

However, experience gained in the Western Cape indicates that 1 percent crossfall is lost soon after construction. Therefore, it is recommended that the initial crossfall be specified as 4 to 6 percent, dependant on the terrain.

## CROSSFALL

Typical recommendations for crossfall and camber on unsurfaced roads vary between 3 percent on narrow slippery roads and 5 percent on straight sections with a minimum width of 6 m.

## SUPERELEVATION

Camber at curves can be designed for the operating speed. However, several publications recommend a maximum of 5 percent in order to reduce erosion damage.

**Table 2-3: Minimum Road Widths**

TERRAIN	EXISTING TRAFFIC (VPD)	MINOR ROADS AND TRACKS	FORMED MINOR ROADS	DIVISIONAL ROADS	MAIN ROADS	TRUNK ROADS
FLAT & ROLLING TERRAIN	< 20	3 m (Note 1)	4 m (Note 1)	6 m	6 m	8,6 m
	20 – 50	5 m	5 m			
	50 – 200		6 m	7,5 m	7,5 m	
	> 200		6 m	8,6 m	8,6 m	
MOUNTAINOUS		4 m (Note 2)	4 m (Note 2)	5 m (Note 2)	6 m (Note 2)	7 m (Note 2)
SURFACING			Formation 8,6 m Surface 6,8 m			
Notes 1 Clearances (turnouts) to be provided at regular intervals to allow vehicles passing. Widening at crests should be considered. 2 Each situation should be assessed for selection of an appropriate solution						

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# CROSS DRAINAGE

## GENERAL

Cross drains must be provided to facilitate the natural flow of water across the surrounding topography. The road formation should not act as a dam under any circumstances, nor should water flow across the road, unless:

- A low level structure is provided,
- Flood design periods are in excess of 10 years,
- Causeways or low lying areas allow easy repair and accessibility can be achieved using other routes, or
- Downstream protection walls are installed.

## BRIDGE STRUCTURES

Bridge structures are expensive and require proper investigation and design. Practitioners are referred to SANRAL's Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa<sup>4</sup>.

## CULVERTS

### TYPE AND MINIMUM SIZE RECOMMENDED

On unsurfaced roads, cross drains are usually concrete pipes or box culverts. 600 mm diameter pipes are preferred, but 450 mm diameter is the minimum size permitted. The minimum box culvert size is 750 x 450 mm. Several pipes can be laid next to each other if flow volumes are high.

### PLACEMENT

The flow of water through a culvert should be disrupted as little as possible and thus should align with the natural flow and have the same slope as the natural ground.

During periodic maintenance investigations, information should be obtained from local inhabitants regarding drainage problems, and each situation evaluated on its merits.

### SLOPE AND COVER

*A minimum fall of 2 percent and a cover thickness of 300 mm* is recommended, excluding the wearing course layer (refer also to supplier specifications).

However, situations often occur where additional layers must be imported for cover, or extensive excavation is required to daylight side drains. Isolated cases could therefore be accepted where the absolute minimum cover is 200 mm (excluding the wearing course) with a 1,5 percent fall.

4. SANRAL: Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa. Pretoria, 2002.

## HEAD AND WINGWALLS

Protection must be provided on both the inlet and outlet of a culvert to prevent erosion and scour. Only concrete wingwalls are permitted. An

apron consisting of a concrete slab or a gabion mattress should be provided downstream of the culvert to prevent scour of the outlet. Standard drawings are available for construction of headwalls.

# SIDE DRAINAGE

## SIDE DRAINS

Side drains should run parallel to the road, collecting the surface water from the pavement and shoulders and removing it through mitre drains (or turnouts) as far from the road as practically possible, where it can soak into the ground or flow into a natural drainage course without influencing the road structure.

Side drains can be flat bottomed (table drains) or V-shaped. The former are less susceptible to erosion than V-shaped drains. The bottom of the ditches should preferably be at least 0,5 m below the subgrade breakpoint to ensure that water that infiltrates the road from the ditch does not affect the pavement layers. Typical side drains are shown in Figure 2-2 on page 2-5.

- ❑ Side drains should only be used where natural dispersion of surface water is disrupted, as concentration of water is the root cause of erosion.
- ❑ Table drains (flat bottom) are time-consuming to construct and to maintain unless wide enough for a grader to operate within them.
- ❑ The majority of all unsurfaced road side drains in the Western Cape are V-shaped.
- ❑ Although typical sketches indicate a depth of 500 mm below subgrade level, this is often not practical or necessary, e.g., dry areas or shallow rock formations.

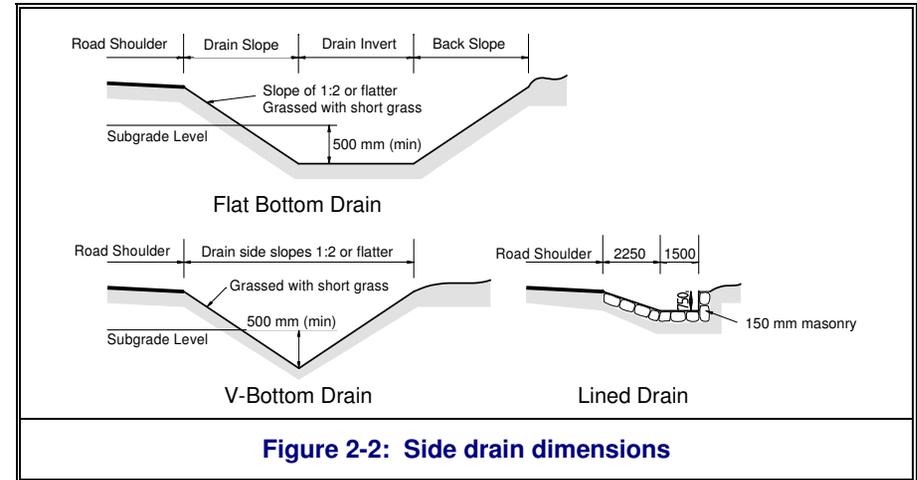


Figure 2-2: Side drain dimensions

## MITRE DRAINS

Mitre drains must be provided at regular intervals to transport the water from the side drains to a place away from the road structure where the water can be discharged—see Figure 2-3 on page 2-6. The design must also take into account the amount of siltation that is likely to occur between maintenance activities and which will effectively reduce the drainage capacity. Mitre drains should generally be between 1,0 and 1,5 m wide and spaced at approximately 50 m intervals in flat ground, decreasing to about 10 m as the slope increases to 1:10. Spacing of mitre drains should be such that ponding adjacent to the road is avoided, but that the build-up of high concentrations of water does not occur and flow velocities do not increase to the point that scouring begins.

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### CUT-OFF DRAINS

Catchwater drains are used to protect the road from water that flows towards the road from the surrounding area, and are often used at the top of deep cuttings—see Figure 2-4 on page 2-6. The requirements in terms of slope and shape are similar to those of side drains.

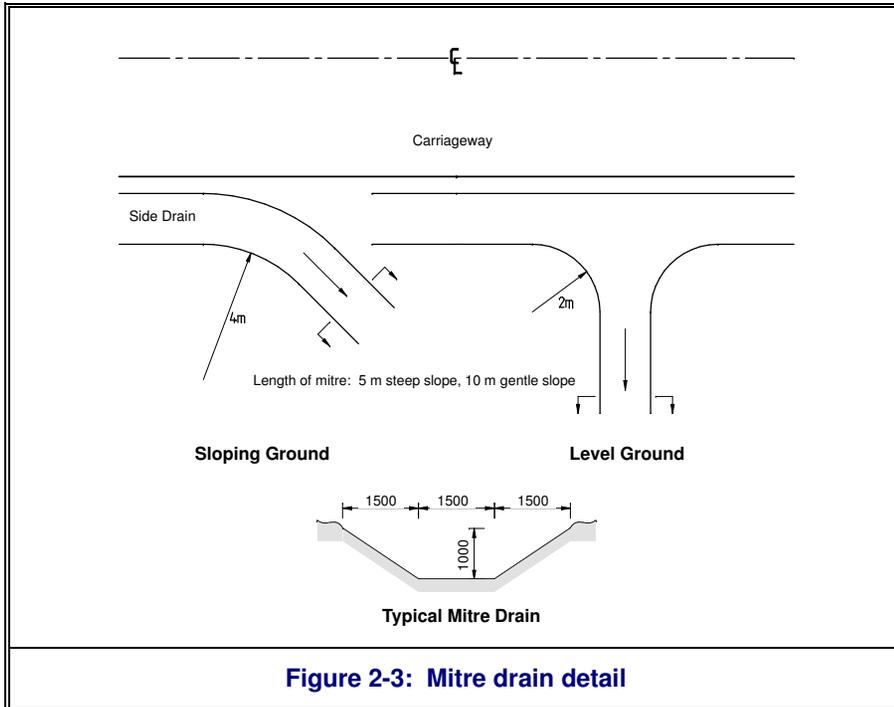


Figure 2-3: Mitre drain detail

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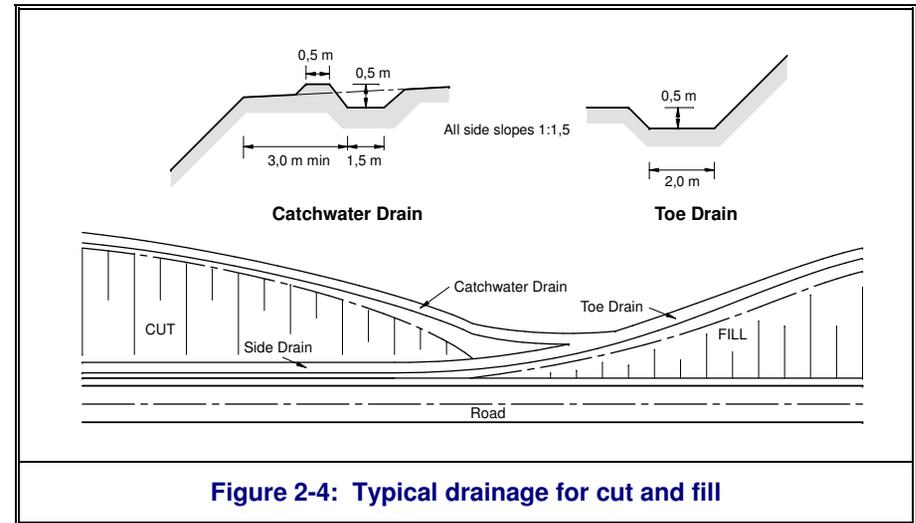


Figure 2-4: Typical drainage for cut and fill

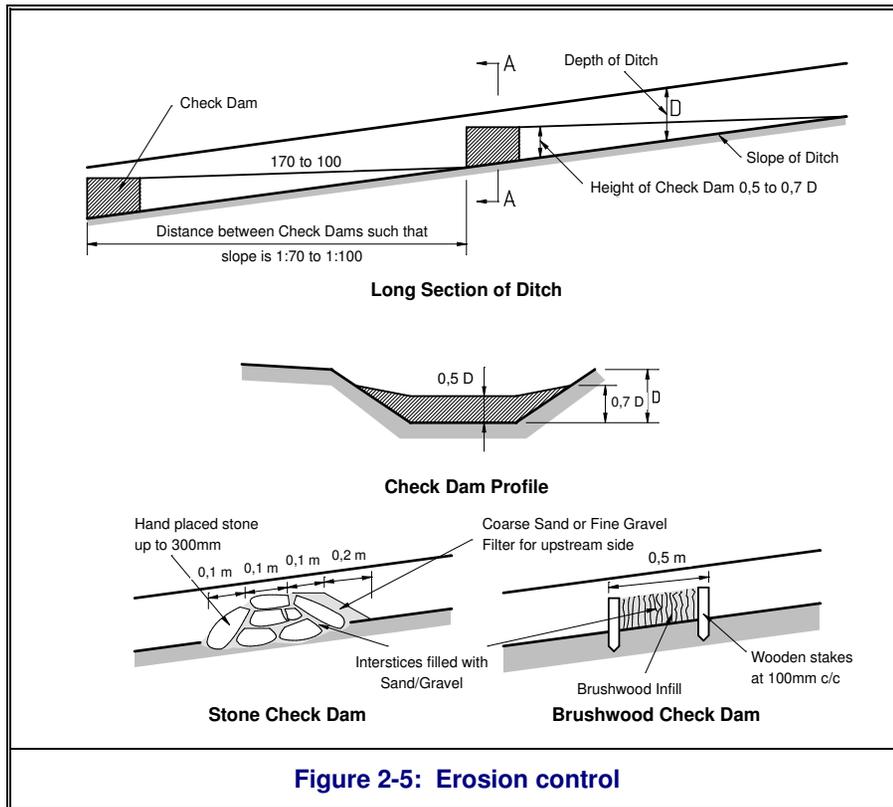
### ACCESS ROADS AND FARM ENTRANCES

Where necessary, culverts should be installed in the side drain to allow safe access to the road while allowing free flow of water. The minimum pipe culvert dimension permitted is 300 mm, but the preferred size is 450 mm.

### SIDE DRAIN SLOPE AND EROSION CONTROL

The longitudinal slope of side drains must be adequate to avoid silting, and less than a certain grade to avoid scouring and erosion. The minimum slope required to avoid silting and to ensure self-cleaning of culverts is about two percent (1:50) for an unlined drain. The maximum slope should not exceed five percent (1:20) for an unlined drain. If the drain slope cannot be restricted to less than five percent due to the topography, provision must be made to prevent erosion damage. The drains can be lined with stone or cement masonry, or can be stepped down with erosion protection on the steps. Checkwalls and dropwalls placed at appropriate intervals will also reduce erosion. Grass lining in drain provides economical erosion protection, but is not suitable on

steep slopes. Grass must be kept short so as not to restrict the flow of water or this will lead to siltation. Erosion protection measures are illustrated in Figure 2-5.



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# PAVEMENT DESIGN

## GENERAL

The purpose of the wearing course is to provide a maintainable surface, as skid-free, dust-free and impermeable to moisture as possible.

Ideally a pavement should consist of wearing course and structural layer(s) which cover the *in situ* material.

The purpose of the structural layer(s) is to protect the *in situ* material from excessive deformation while not breaking or deforming within a specific design period.

The appropriate initial thickness of the wearing course is dependent on the expected rate of gravel loss, the policy regarding minimum regravelling frequency, and a minimum “buffer” thickness to prevent deterioration of the structural layer(s).

The appropriate thickness of the structural layer(s) is dependent on the strength of material to sufficiently reduce the stress on the *in situ* material. The strength is a function of the material properties, the density and the moisture content under which it operates.

Several areas in the Western Cape are blessed with excellent *in situ* road building materials, to the extent that the existing materials, if properly compacted, provide a strong enough pavement structure to carry the expected traffic for many years. The **implication of strong *in situ* materials** is that, provided the drainage is adequate for the situation, no additional structural layers might be required even if application of a bituminous surfacing is considered as a feasible strategy.

Given that a high proportion of unsurfaced roads carries a very low volume of traffic (80 percent carrying less than 50 vehicles per day), the *in*

*situ* material is often both suitable as a wearing course and strong enough to carry the traffic load for at least ten years. In such cases, the road could be formed, shaped and compacted, using only material from within the road reserve. The entire pavement structure is therefore made up of the *in situ* material, where the upper part functions as a wearing course and structural layer(s).

## PAVEMENT STRUCTURE

### APPROACH

Several models have been developed and are used world-wide for determining the required gravel thickness to protect the subgrade. However, the majority of these do not take into consideration the volume and load characteristics of traffic.

Typical traffic volumes (Average Daily Traffic) on gravel roads in the Western Cape range from less than 50 to more than 500 vehicles per day, often with a heavy vehicle component of more than 20 percent.

Therefore, although a simplified approach is useful and applicable to minor or very low volume roads, it is not considered sufficient in terms of a longer-term road maintenance strategy and phased upgrading.

A sound approach, which is applied more and more by road authorities, is to accept that the only difference in the design of the pavement structure for a surfaced and unsurfaced road is the following issues:

- The design life
- Design reliability
- Wearing course type.

The pavement structure should, therefore, be able to carry the traffic load over the design life with a reasonable estimate of the risk of failure.

The intention is that:

- Only the wearing course would need replacement at intervals related to the annual gravel loss, and
- Geometry and drainage are upgraded to acceptable minimum levels during periodic maintenance operations.

This approach ties in well with a strategy of phased upgrading to surfaced standards as traffic increases, in that:

- Optimum use could be made of historical traffic compaction,
- The quality of material on a higher-trafficked gravel road would be at least G7 (Soaked CBR  $\geq 15$  percent @ 93 percent Mod. AASHTO density),
- The *in situ* strength of the subgrade or formation layers protecting the subgrade would be CBR  $\geq 15\%$  at *in situ* density and moisture as measured with a DCP.

## PROCEDURE

### MOISTURE REGIME

The first important decision to optimise design is to estimate under which moisture conditions each layer in the pavement structure will perform. This could relate to the climate and the elevation above natural ground level.

### MATERIAL CLASSIFICATION

Test pits to determine the existing pavement profile (at least to a depth of 500 mm in the case of lower traffic volume, unsurfaced roads) and quality of materials.

### DETERMINE THE EXISTING PAVEMENT STRENGTH USING DCP MEASUREMENTS

Measurements during or just after the wet season will normally reflect the worst expected conditions (highest moisture contents). Spacing of DCP measurements is dependent on the observed variation in condition and could vary from 25 m to 500 m apart.

### SELECTION OF AN APPROPRIATE PAVEMENT STRUCTURE

- Calculate the design traffic (typically 10 years for unsurfaced roads, but depends on the strategy adopted).
- Select an appropriate pavement structure from the catalogue (refer Table 2-4 on page 2-10) and draw up a layer-strength diagram.
- Plot the DCP layer-strength diagram on similar scale.
- Adjust the DCP layer strength diagram (*in situ* CBR values) to reflect the expected moisture conditions under which each layer/part of the pavement structure will operate.

### Notes

Surfacing of an existing gravel road will normally result in higher moisture contents within the base layer (60 – 80 percent of optimum moisture content).

DCP measurements on unsurfaced roads often show poor strength in the top 30 – 50 mm. This is normally due to horizontal displacement of the material and can be ignored.

Table 2-4: Simplified pavement catalogue for gravel roads					
EXISTING MOISTURE CONDITION	IN SITU CBR FROM DCP (TOP 300 mm) (%)				
Dry	< 15	16 – 25	26 – 45	46 – 80	> 80
Moist	< 10	11 – 15	16 – 25	25 – 45	> 45
Wet	< 5	6 – 10%	11 – 15	16 – 25	> 25
PAVEMENT CLASS	ADDITIONAL STRUCTURE REQUIRED (Depth in mm)				
ES 0.0003	WC, 200 G7	WC, 150 G7	WC, 100 G7	WC	WC
ES 0.01	WC, 250 G7	WC, 200 G7	WC, 150 G7	WC	WC
ES 0.03	WC, 275 G7	WC, 225 G7	WC, 175 G7	WC	WC
ES 0.1	WC, 150 G6, 150 G7	WC, 125 G6, 125 G7	WC, 100 G6, 100 G7	WC, 100 G6	WC
ES 0.3	WC, 150 G5, 150 G7	WC, 125 G5, 125 G7	WC, 100 G5, 100 G7	WC, 100 G5	WC
Notes					
This catalogue is conservative and does not take into account the strength of the wearing course layer.					
Example: Testing a dry existing structure and obtaining say 20% <i>in situ</i> CBR would require, for ES 0.003 traffic category (3000 80 kN axles), an additional 150 mm G7 material before placement of the wearing course.					

### IDENTIFY REQUIRED IMPROVEMENT

- Compare the *in situ* strength to the required pavement strength.
- Based on the properties of the materials within the existing pavement structure, decide on a strategy to either recompact the existing layers, or add layers of acceptable quality.

## WEARING COURSE

### TRH 20 GUIDELINES<sup>5</sup>

Guidelines for wearing course materials published in TRH 20<sup>5</sup> are based on extensive research in southern Africa and can be summarised in Table 2-5.

Table 2-5: Guidelines for wearing course materials	
PARAMETER	GUIDELINE
Maximum size (mm)	37,5
Oversize index (%)	<5
Grading coefficient <sup>1</sup>	16 - 34
Shrinkage product <sup>2</sup>	100 - 365 <sup>3</sup>
Strength <sup>4</sup> (%)	>15
Hardness (Tretton Impact Value)	20 - 65
Notes	
1. $([\% \text{ passing } 26,5 \text{ mm sieve} - \% \text{ passing } 2 \text{ mm sieve}] \times \% \text{ passing } 4,75 \text{ mm sieve}) / 100$	
2. Bar linear shrinkage x % passing 0,425 mm sieve	
3. Max 240 preferable to reduce dust levels	
4. Soaked CBR at 95% Mod AASHTO density	
5. Los Angeles Abrasion Hardness: 30 - 60	

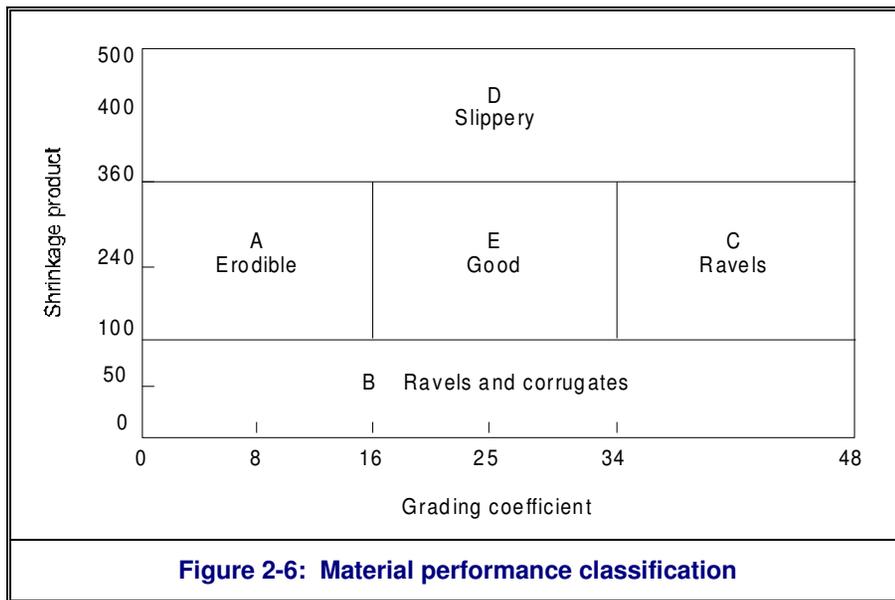
In terms of binding characteristics the ideal wearing course material is classified as a material with a shrinkage product between 100 and 365 and a grading coefficient between 16 and 34. These parameters are defined as follows:

5. TRH 20: The structural design, construction and maintenance of unpaved roads. Department of Transport, Technical Recommendations for Highways No. 20, Pretoria, 1990.

Shrinkage product (Sp) = % linear shrinkage x % passing  
0,425 mm sieve

Grading coefficient (Gc) =  $([\% \text{ passing } 26,5 \text{ mm} - \% \text{ passing } 2,0 \text{ mm}] \times \% \text{ passing } 4,75 \text{ mm}) / 100$

Figure 2-6 indicates the expected performance according to the binding characteristics, i.e., the relationship between the Shrinkage Product and Grading Coefficient.



## RECOMMENDATIONS

The WCPA recommendations for the gravel wearing course are essentially the same as the recommendations provided in TRH20 with the exception of the following:

- A minimum density of 97 percent Mod. AASHTO density.

Although E-category materials are not always available, an effort should be made to modify the material through processing and/or blending of materials to achieve both strength and E-category status. More information on modification and blending can be found in Chapter 3, Materials Investigation and Design.

### Notes

- Good performance has been experienced with materials slightly below the E category, i.e., Shrinkage Product below 100.
- Although good initial performance has been observed with over-size in excess of 5 percent, rapid deterioration normally occurs after blading.
- Materials falling within the E category may perform poorly if the grading is not continuous.

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WCPA: Geometric Design Manual, Cape Town, 1983.