Table 8.19: Preparation of subgrade and required selected layers for the different subgrade design CBRs*

DESIGN CBR OF SUBGRADE	<3	3 - 7	7 - 15	15 - 25	>25
Add selected layers:					
Upper	Not applicable	150 mm G7	150 mm G7	-	-
Lower		150 mm G9	-	-	-
Treatment of in-situ subgrade	Special treatment required	Rip and recompact to 150 mm G10	Rip and recompact to 150 mm G9	Rip and recompact to 150 mm G7	Use subbase or base layer**

* Not applicable to category UD roads: for these use only one selected layer (G7) if required.
** Compacted to the appropriate density (see Table 8.14).

The factors influencing the choice of surfacing are:

- local experience;
- availability;
- street category;
- design traffic class;
- environment (e.g. moisture, temperature and ultraviolet radiation);
- pavement type and deflection;
- maintenance capability;
- turning movements, intersections, braking movements; and
- gradients.

The catalogue specifies the surfacing type, but allows a choice of surfacings for the lower categories of street. The controlling authority should select a surfacing from the catalogue that will give satisfactory performance (SABITA 1993).

If a waterbound macadam is used in the base in the place of a GI to G4 material, the thin surfacings will be inadequate to provide acceptable riding quality on the coarse surface typically obtained. In such cases, up to 50 mm of asphalt premix may be required.

Practical considerations

A host of practical issues that need to be considered are covered in the section on practical considerations above.

Economic analysis

The purpose of the economic analysis is to identify the most economically viable design. The economic analysis is strongly linked to the design strategy and the life-cycle cost of the alternative designs. In the case of category UC and UD streets, where a design strategy is not necessarily formulated, only the construction cost needs to be considered for designs without a design strategy.

PAVED BASIC ACCESS STREETS

The functional classification of basic access streets (see street categories under "compiling a street profile" above) indicates that traffic volumes are so low that the traditional design guidelines are not applicable in most cases. (CUTA 1988b). Non-traffic related factors such as layout planning, stormwater management and drainage, climate, environment, topography and in- situ materials have a major influence on the design of basic access streets. Adherence to the guidelines for layout planning and stormwater management (CUTA 1988a) is a prerequisite for the sound design of basic access streets.

As mentioned in the earlier section on the drainage of basic access streets, there may be a number of reasons for paving a basic access street. The decision process is illustrated in Figures 8.1 and 8.16.

If erosion problems are identified, erosion protection must be supplied. Dust palliatives may be considered as one option in this regard.

Structural design of paved basic access streets

Although basic access streets normally carry light traffic, the final desired pavement structure should be designed and constructed only after the infrastructure development is completed to avoid damage by construction traffic. The street can be constructed up to subbase level and used in an unpaved state during infrastructure development, before correction of the subbase and application of the base and surfacing.

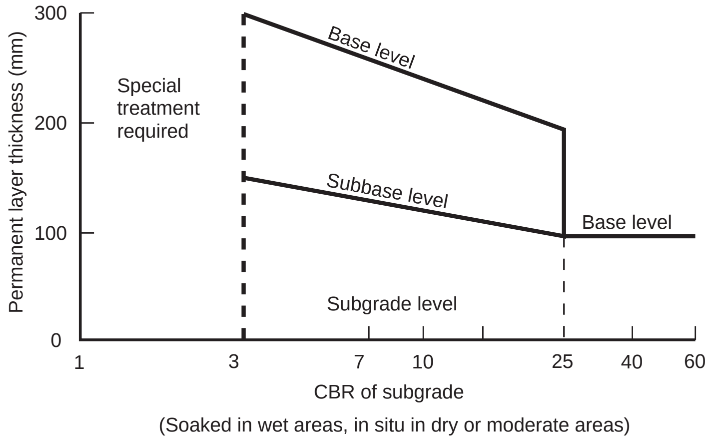


Figure 8.16: Pavement design curves for basic access streets

Selection of pavement type

Because of the very low bearing capacities for which basic access streets are designed, the pavement structures of these streets will be very light. Coal and refuse-removal lorries, however few, are bound to be overloaded with destructive effects on surfacings and the pavement structure. This should be recognised in the design phase and pavement types sensitive to overloading should not be selected.

Selection of design method

The dynamic cone penetrometer (DCP) design method, the catalogue in Appendix A, or the design method described below could be used for the structural design of paved basic access streets.

Pavement structures are bound to be mostly granular on basic access streets and therefore the use of the DCP model (Kleyn and van Zyl 1987) is strongly recommended. The minimum number of blows to penetrate 800 mm of the pavement structure is 110 in a dry condition and 60 in a wet condition (Kleyn 1982). Streets with even fewer pavement structural layers than the traditional three have been found to perform satisfactorily as basic access streets (Horak 1988), but designs should be checked with the DCP model.

Figure 8.16 can also be used as a guideline for the design of the pavement structure. It is suggested that a soaked CBR be used only in wet areas while in-situ CBR values from DCP soundings can be used in moderate to dry areas (Emery 1984). The quality of in-situ material will determine the need for a subbase layer. Where an asphalt surfacing of 25mm is used, the base thickness may be reduced by the surfacing thickness, provided that the deflections do not increase to the level that rapid fatigue failure of the asphalt occurs.

The implications and problems with relaxing material specifications for paved streets have been fully discussed by Netterberg and Paige-Green (1988). Each layer in the street should be treated as a separate entity with respect to the materials used and the construction procedures.

Selected layers:
If the in-situ material is not of at least G9 quality (NITRR 1984c) material of this quality or better should be imported and placed on the compacted in-situ material. If the in-situ material is of G9 or better quality, no selected layer is necessary. The subgrade or selected layers should be compacted to at least 93% Mod AASHTO density, but preferably to refusal density.

A summary of the recommended quality of the platform for the subbase is therefore as follows:

- min CBR at OMC and 90% Mod AASHTO compaction: 7;
- min. field compaction: 93% Mod AASHTO.

Subbase:
Once the foundation of the subbase has a CBR of at least 7 (i.e. at least G9), material of G6 or better quality should be used for the subbase. The moisture content at which the CBR values are determined should be near the expected field moisture content (OMC is often considered a reasonably conservative estimate).

The following specifications are recommended for subbase material:

- minimum CBR at OMC and field compaction: 25;

- min compaction: 95% Mod AASHTO, preferably refusal;
- max size: two-thirds of layer thickness.

Specifying the material strength makes it unnecessary to limit properties such as grading (of the matrix in particular) and plasticity, as it is these properties which determine the strength at any specific moisture content and density.

It is important to carry out the CBR test in a standard manner and the recommended method is that all oversize material (larger than 19,0mm) is discarded. This procedure is considered to result in a slightly conservative CBR as the larger material would generally produce more interlock and shear resistance.

In many cases where the in-situ material has a CBR of 25 or more, no subbase is necessary and the base can be applied directly onto the in-situ material compacted to at least 95% Mod AASHTO density.

Base:
The base is the most important structural layer of a lightly trafficked street, and must have adequate strength and durability to perform satisfactorily during the life of the street. Structurally, a material with a CBR strength of 30 to 50 at field moisture and density is adequate for lightly trafficked streets (Kleyn and Van Zyl 1987). A compaction of 98% Mod AASHTO is necessary to limit traffic-associated compaction to an acceptable amount, although it should preferably be compacted to refusal density. The durability of the material, however, must be ascertained for many aggregates - especially basic igneous rocks.

It is considered necessary to provide different requirements for each material group. The bearing capacity is the major criterion in each case, and this should be related to the prevailing environmental conditions. The bearing capacity of bases for lightly trafficked streets is best specified in terms of the CBR value at 98% Mod AASHTO compaction at the expected field moisture conditions. In poorly drained and wet areas it may be necessary to use the soaked values, while in arid areas a test at the OMC (Emery 1984) may be used for the design. In South Africa the ratio of the equilibrium moisture content (EMC) in the base to the optimum moisture content (OMC) seldom exceeds 0,6 (Emery 1984).

The risk of using an unsoaked CBR in the subgrade for the design can be quantified and expressed as the probability of the street failing before the design traffic has been carried for varying moisture contents (Emery 1987). The example discussed by Emery (1984) indicates that, even with an EMC/OMC ratio of more than 1,5, the probability of the street not carrying 0,2 M E80s is less than about 6%.

UNPAVED ARTERIAL AND ACCESS STREETS

The most common causes of poor performance of gravel streets are slipperiness and potholing when wet, and producing excessive dust and ravelling when dry. The formation of corrugations is normally the result of inadequate compaction or low cohesion combined with traffic. Frequent maintenance (e.g. grading, watering and the addition of material) is necessary and the frequency of maintenance will increase with increasing traffic.

Street category

Normally, unpaved streets could be considered for use as Category UC or UD streets, although there may be special cases where they can be regarded as Category UB streets.

Design strategy

A gravel street may be regarded as a long-term facility or as an interim step towards a paved street. This will influence the level of the surface with regard to stormwater facilities and geometric considerations.

Materials

Material will usually have to be imported for at least the wearing course of gravel arterial and access streets. Possible material sources must be identified early in the design process.

Design of imported layers

Selected layers for gravel streets

The selected layers for gravel streets should preferably be designed as for paved arterial and access streets, although this is not critical as discussed earlier. The minimum subgrade CBR, however, should be 3 for less than 100 vpd and 5 for more than 100 vpd, or else 150 mm of “subbase” with a CBR of 5 and 10 respectively should be imported to support the base. It is advisable, however, that at subgrade level there is no distinction between paved and unpaved streets, to simplify possible later changes from unpaved to paved streets.

Design of gravel wearing course

The standards for gravel wearing courses are laid down in Appendix B. The quality and thickness of the wearing course may also depend on the design approach, as follows:

- The gravel street may be regarded as a long-term facility, in which case the most suitable wearing course will be selected for the prevailing conditions (climate, material availability and traffic). On more heavily trafficked streets, the gravel wearing course should be used as a future subbase. On access streets it could constitute the future base course.

- The gravel wearing course may be regarded as an interim riding surface, which will be overlaid or removed when the street is paved. If the gravel wearing course is going to be overlaid later, the material should comply with the subbase standards applicable to the future pavement. If the wearing course is to be removed later, consideration should be given to the inclusion of a proper subbase during construction, should such a subbase be necessary.

- The gravel wearing course may be regarded as the base layer of the future paved street. This will normally be possible only for some Category UC or UD streets, but then special restrictions may be placed on the plasticity index of the fines.

The thickness of the gravel wearing course will usually be a standard 150 mm. Passability during the wet season is best determined by the soaked laboratory CBR of the surfacing gravel material. Figure 8.17 gives a proposed limit related to the average daily traffic (ADT).

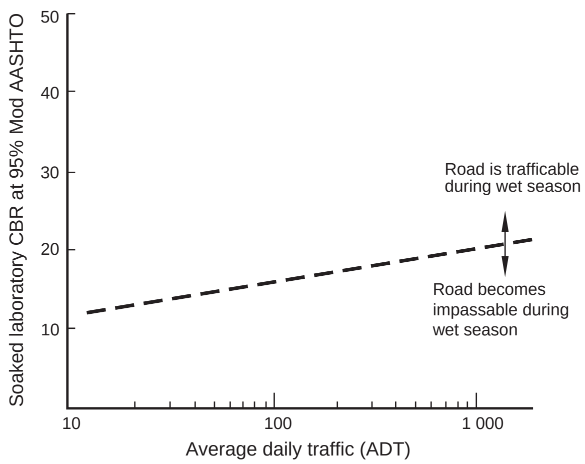


Figure 8.17: Design curves for the passability of unpaved roads

When a gravel wearing course has to be provided because the existing subgrade cannot support the traffic loads adequately under all climatic conditions, the thickness requirement for the gravel wearing course can be determined analytically. A thickness design method which gives the required material thickness for adequate subgrade protection, regulated gravel loss and deficiencies in compaction is described in TRH20.

UNPAVED BASIC ACCESS STREETS

The functional classification of basic access streets (see section on categories of street) indicates that traffic volumes are so low that the traditional design guidelines are not applicable in most cases. (CUTA 1988b). Non-traffic related factors such as layout planning, stormwater management and drainage, climate, environment, topography and in situ materials have a major influence on the design of basic access streets. Adherence to the guidelines for layout planning and stormwater management (CUTA 1988a) is a prerequisite for the sound design of basic access streets.

Figures 8.1 and 8.18 illustrate the decision process for the design of basic access streets. If the decision is taken not to pave a basic access street, attention should be paid to erosion protection, the quality of the in-situ material and the quality of the wearing course (if required).

Erosion-prone in-situ materials should be identified (Rooseboom and Mulke 1982). The length of erosion-free in situ material can be determined if the gradient and basic material information is available. If erosion problems are identified, erosion protection must be provided. Surface stabilisers may be considered in this regard.

As shown in Figure 8.18, in-situ material can be used without a surfacing if it meets the appropriate material standards for basic access streets (TRH20).

The thickness of a gravel wearing course should be 100mm unless experience suggests otherwise. If in-situ material meets the specified material requirements of TRH20, a gravel wearing course need not be imported to the street (Netterberg 1985).

TERTIARY WAYS

As settlements develop, so does an infrastructure of narrow ways which carry predominantly pedestrians, cattle and bicycles. These non-trafficked (motorised traffic) tertiary ways are mostly informal and unserviced, but in older settlements in developing areas they are formalised (upgraded) by the provision of surfacings, drainage or even services like water and electricity (Clifford 1987).

Layout

In an informal settlement development no layout planning for tertiary ways is done. The existence of these ways is dictated by pedestrians' need to follow the shortest possible routes. At a later stage of

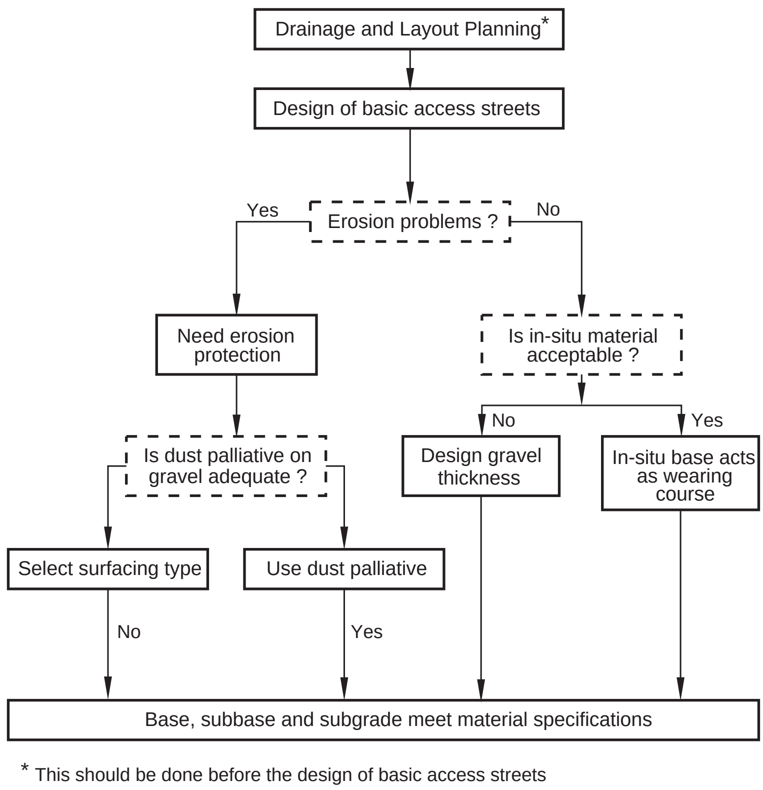


Figure 8.18: Flow diagram of design process for basic access streets

development some of these tertiary ways may be replaced by basic access streets. It is advisable to design for tertiary ways during layout planning as these form the basic links between dwellings. In a formal design they can enhance the design principles applicable to the higher order of streets.

Material

The in-situ material is mostly used for tertiary ways. However, no standards are applicable, as no formal construction is carried out during the initial informal development stages. In general, where problem materials exist, they should be covered or improved to ensure passability. The discussion on material types covered in Appendix C is applicable to the identification of possible material problems.

Design of tertiary ways (standard cross-sections)

No formal design exists during the early stages of growth in a developing community. In the later stages of development these tertiary ways can be upgraded to have an appropriate profile, with side drains. In such cases, and for those tertiary ways which are designed from the outset, various cross-sections are suggested for various ground slopes (Figure 8.19). The cross-slopes of a tertiary way are limited to 10%. In the case of very steep sloping ground, the camber is replaced by a 7% cross-slope against the ground slope. Dimensions are also given for ditches, berms and retaining walls. In Figure 8.20, typical cutting and embankment cross-section details are given, with a table on embankment details.

Dust palliatives

Unacceptable levels of dust are experienced on many of these roads, especially those in rural and urban communities. In the past, dust was only considered a nuisance factor. However, recent studies have indicated that the dust generated by vehicles on unpaved roads could have significant environmental and social impacts in terms of health and safety issues, visual pollution, and economic impacts pertaining to loss of road construction material, increased building maintenance and higher vehicle-operating costs.

Consequences of dust

The main consequences of dust include discomfort for pedestrians, vehicle occupants and residents of properties adjacent to the road. Visibility for following and approaching vehicles is greatly reduced, creating a safety risk for motorists, cyclists, pedestrians and livestock. In addition, vehicle-operating costs increase dramatically on dusty roads. Other important effects of dust include health hazards, reduced agricultural yields, pollution and loss of road construction material.

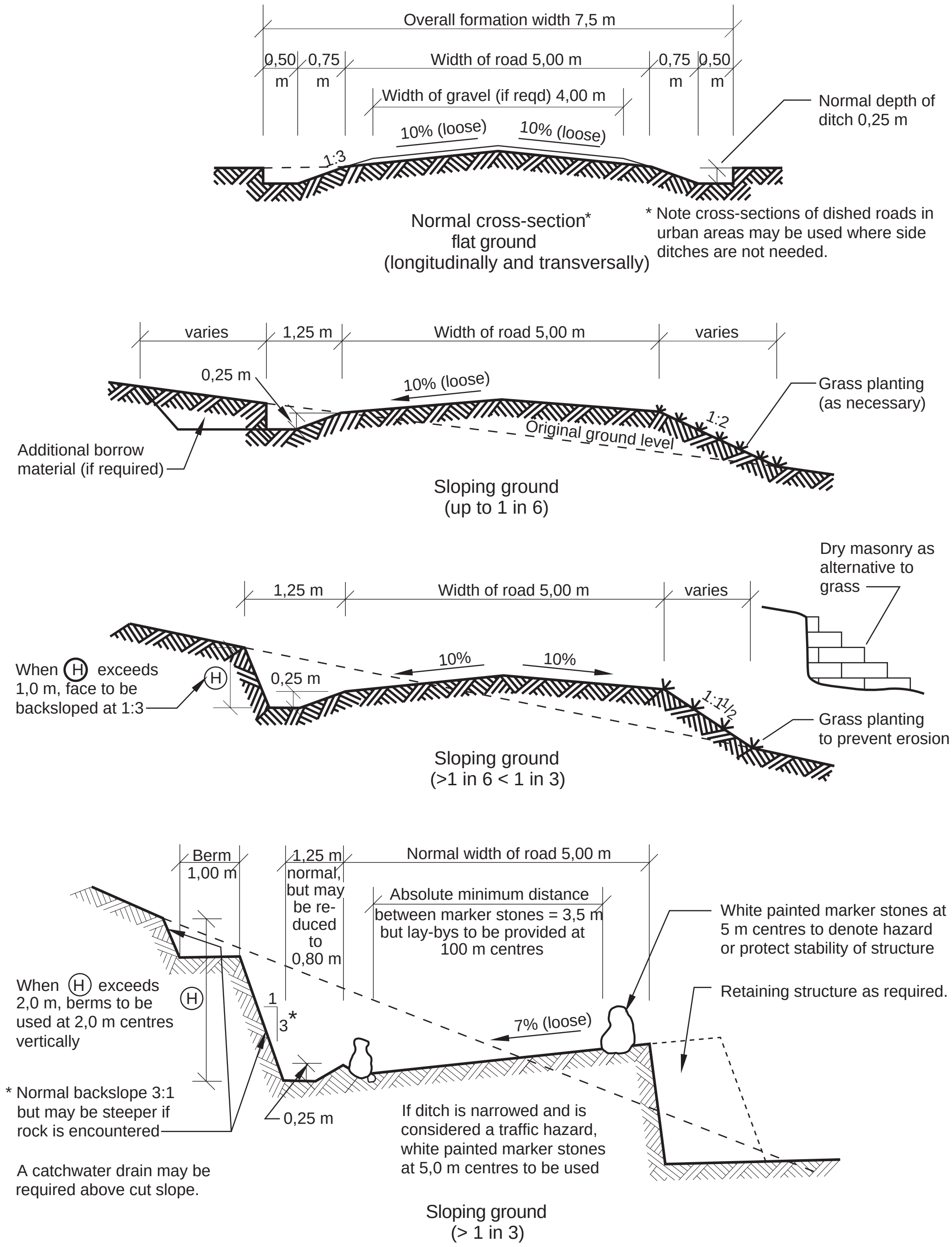


Figure 8.19: Tertiary ways: cross-sections

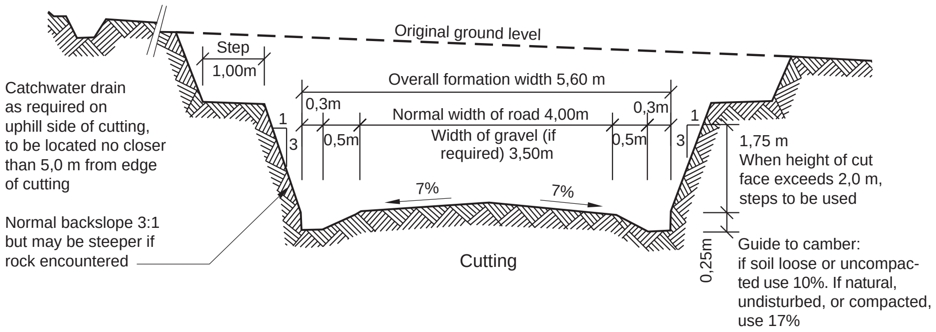
Processes affecting the generation of dust

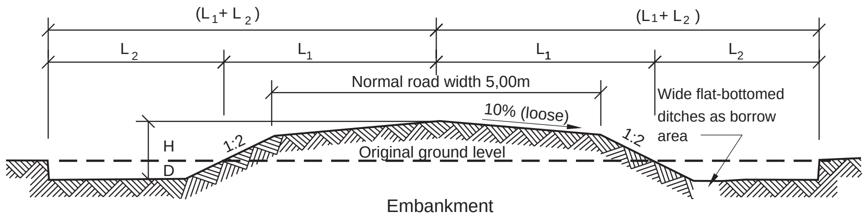
Dust generation is predominantly related to the silt content, plasticity characteristics, hardness and relative density of the aggregate, and the threshold shear velocity of the wind generating the dust. The moisture content of the material and the period since the road was last bladed will also influence the level of dust. The parameters used in dust prediction include plasticity index, linear shrinkage, percentage passing 0,075 mm, the aggregate impact value and the relative density.

Dust control

In terms of the total unpaved road network in South Africa, minimal dust control is currently being carried out. The last few years have seen a proliferation of products which the manufacturers claim will reduce both dust and maintenance on unpaved roads. However, minimal specification of their properties or records of their performance are available and very few properly controlled comparative tests on the effectiveness of the products from different producers and suppliers have been carried out in full-scale field trials.

Research on dust palliatives has been conducted by the CSIR over a period of six years on behalf of road authorities and product manufacturers. In order to facilitate the selection of an appropriate product for particular conditions, dust palliatives are divided into the following ten categories:





Embankment dimensions											
Embankment height H	Area of embankment A	Depth of ditch D	Offset from ℄ L_1	Offset to edge L_2	Total offset (L_1+L_2)	Embankment height H	Area of embankment A	Depth of ditch D	Offset from ℄ L_1	Offset to edge L_2	Total offset (L_1+L_2)
0,30	2,12	0,30	3,10	3,83	6,93	1,10	8,36	0,50	4,70	10,20	14,30
0,35	2,43	0,30	3,20	4,35	7,55	1,20	9,32	0,50	4,90	10,61	16,28
0,40	2,76	0,30	3,30	4,90	8,20	1,30	10,32	0,50	5,10	11,37	17,60
0,45	3,09	0,30	3,40	5,45	8,85	1,40	11,36	0,50	5,30	12,50	18,81
0,50	3,44	0,30	3,50	6,03	9,53	1,50	12,44	0,50	5,50	13,51	20,10
0,55	3,79	0,40	3,60	5,14	8,74	1,60	13,56	0,60	5,70	14,60	22,52
0,60	4,16	0,40	3,70	5,60	9,30	1,80	15,92	0,75	6,10	16,82	25,50
0,65	4,53	0,40	3,80	6,06	9,86	2,00	18,44	0,75	6,50	19,41	27,82
0,70	4,92	0,40	3,90	6,55	10,45	2,20	21,12	1,00	6,90	21,32	30,23
0,75	5,31	0,40	4,00	7,04	11,04	2,40	23,96	1,00	7,30	23,33	32,50
0,80	5,72	0,40	4,10	7,55	11,65	2,60	26,96	1,25	7,70	25,20	34,90
0,85	6,13	0,40	4,20	8,06	12,26	2,80	30,12	1,25	8,10	27,20	37,20
0,90	6,56	0,40	4,30	8,60	12,90	3,00	33,44	1,25	8,50	29,10	43,50
0,95	6,99	0,40	4,40	9,14	13,54	3,50	42,44	1,50	9,50	34,00	49,32
1,00	7,44	0,40	4,50	9,70	14,20	4,00	52,44	1,75	10,50	38,82	49,32

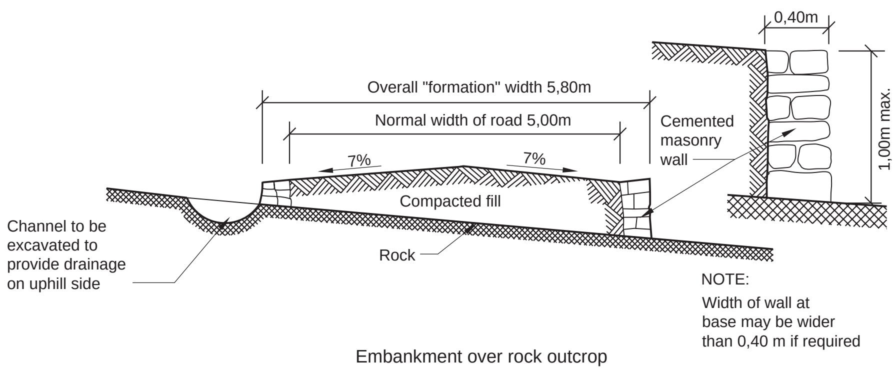


Figure 8.20: Labour-intensive tertiary ways: cross-sections, cuttings and embankments

- water and wetting agents;
- waste oils;
- emulsified petroleum resins;
- hygroscopic materials;
- ligno-sulphonates;
- modified waxes;
- acrylate polymers;
- tars and bitumens;
- sulphonated oils; and
- other products.

Environmental considerations

Growing environmental awareness in the roads industry has necessitated the development of appropriate tests for assessing the impact of spraying chemical dust palliatives onto unpaved roads. A series of interim test methods to determine the toxicity of additives to surface water, groundwater and vegetation has been developed and is currently being perfected. Initial results indicate that all the products are toxic to aquatic life in an undiluted form, and standard precautions for the handling and transportation of chemicals should be adhered to. Testing of the leachate from soils to which the product has been applied at the recommended application rates indicated that none of the leachates from any of the products tested is likely to influence groundwater or surface water. Certain products are likely to kill plants if they are sprayed directly onto the leaves. However, root uptake of the leachate by plants is unlikely to cause death.

CONSTRUCTION

Staged construction and upgrading

Two concepts that need to be considered as part of the life-cycle strategy of a street during design are staged construction and upgrading. Although it is difficult to exactly define and completely separate these concepts, certain characteristics may be more typical of one than of the other.

The aim of staged construction is to spread some of the financial load from the initial construction period to some stage later during the life cycle of the facility. However, right from the onset, the aim is to provide a particular level of service for the duration of the structural design and analysis period of the facility. There may be slight changes in, for instance, the riding quality of the facility, but these should have a marginal influence on the operating cost of the facility to the user.

On the other hand, upgrading will normally take place when the demands placed on an existing facility far exceed the level of service the facility can provide. The new facility has to provide a much higher level of service at a much reduced cost to the user. An example would be the upgrading from a gravel to a surfaced street.

Staged construction may be done by adding a final layer, or reworking an existing layer at some stage early during the structural design period of the facility. Most of the money spent during the initial construction of the facility should therefore be invested in the lower layers of the structure, providing a sound foundation to build on in the future.

During the upgrading process, maximum use should be made of the existing foundation provided by the pavement being upgraded. Dynamic cone penetrometer (DCP) and impulse deflection meter (IDM) surveys may provide the information required to incorporate the remaining strength of the existing pavement in the design of the future facility. Special equipment may also be used to maximise the bearing capacity of the in-situ material. Impact roller compaction can prove very useful in the urban environment. With this equipment, it is usually possible to compact the in-situ material to a depth of 600mm at densities well above those normally specified for the subgrade and selected layers of a pavement, without excavating and replacing any material. This results in few layers or thinner layers being required in the pavement structure.

One of the problems that may be associated with staged construction in the urban environment is the limitation placed on street levels by the other services in the street reserve, particularly the stormwater drainage system. If a system of kerbs, gutters and stormwater pipes is used, it may not be possible to add an additional structural layer to the pavement system at a later stage. In such cases, consideration should be given to initially providing a subbase-quality gravel base, and to rework this layer at some early stage in the structural design period of the pavement by doing deep in-place recycling and stabilisation with cement, bitumen emulsion or a combination of the two. A second problem that requires consideration is the cost of repeated mobilisation on a project. The mobilisation of plant and resources for a light pavement structure in an urban area (usually of short length) is often a significant portion of the total cost.

Table 8.20 provides a number of staged construction examples developed from the catalogue of pavement designs contained in Appendix A. Both the initial and final pavement structures are illustrated for the staged construction options. The staged construction of these examples is not achieved by merely taking a design for a high bearing capacity and removing the base layer. The structures for the initial construction phase are actually also taken from the catalogue and have a known bearing capacity. This should assist in determining the time allowed to elapse before completing construction without allowing too much damage to the initial structure. By adding the required base layer or stabilising an existing base layer of the pavement at the initial construction phase, the bearing capacity is increased to the actual bearing capacity required.

The present worth of cost (PWOC) values for the staged construction options listed in Table 8.20 vary from being almost the same as for the full construction options to values significantly less than the PWOC for the full construction options. In general, staged construction therefore spreads the financial burden of construction and is economically more viable than initial full construction. The economics of each project must, however, be considered on merit. It must also be kept in mind that because some of the cost of construction is shifted a few years into the life cycle of a pavement, future budgets must allow for this cost plus inflation.

The details of upgrading from a gravel street to a surfaced street will depend largely on individual projects and will be determined by the bearing capacity of the material on the existing street. As already mentioned, the strength of the existing pavement should be optimally utilised in the new design and if material is imported to the gravel street,

Table 8.20: Example of staged construction

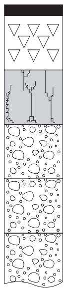
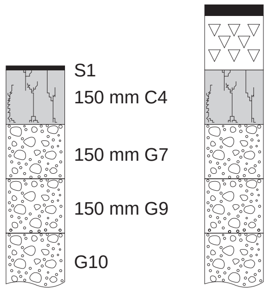
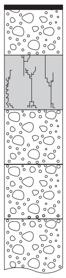
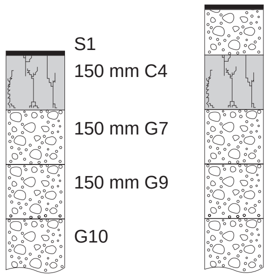
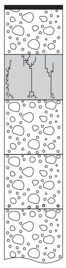
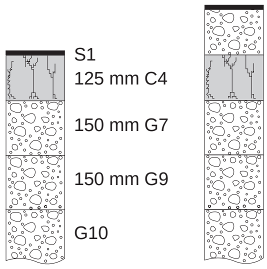
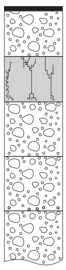
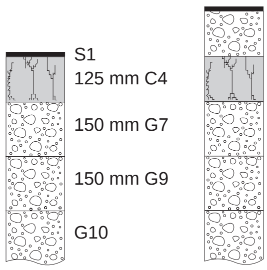
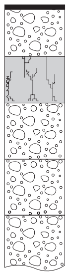
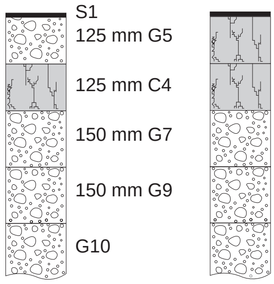
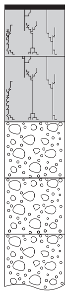
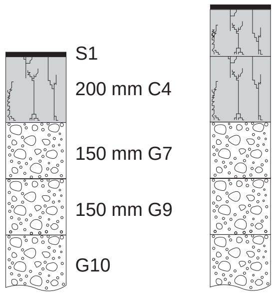
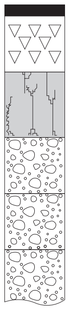
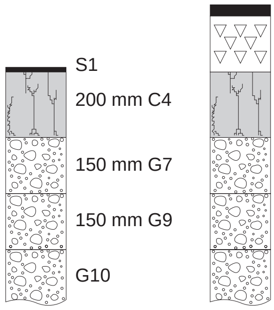
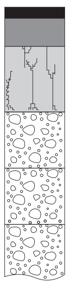
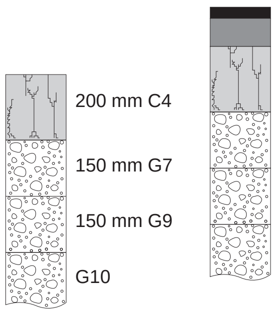
Description	Full construction	Staged construction
Initial construction: Lightly cemented base (pavement catalogue, street category UD): design bearing capacity 100 000 E80s *Final construction:* Granular base (pavement catalogue for dry regions, street category UB): design bearing capacity 3 million E80s Final pavement suitable for minor arterials, collectors and bus routes	 	 Addition of granular base during final construction
Initial construction: Lightly cemented base (pavement catalogue, street category UD): design bearing capacity 100 000 E80s *Final construction:* Granular base (pavement catalogue for dry regions, street category UB): design bearing capacity 1 million E80s Final pavement suitable for minor arterials, collectors and bus routes	 	 Addition of granular base during final construction
Initial construction: Lightly cemented base (pavement catalogue, street category UD): design bearing capacity 30 000 E80s *Final construction:* Granular base pavement (catalogue for dry regions, street category UC): design bearing capacity 1 million E80s Final pavement suitable for residential collector streets and lightly trafficked bus routes	 	 Addition of granular base during final construction
Initial construction: Lightly cemented base (pavement catalogue, street category UD): design bearing capacity 30 000 E80s *Final construction:* Granular base pavement (catalogue for dry regions, street category UC): design bearing capacity 300 000 E80s Final pavement suitable for residential collector streets and lightly trafficked bus routes	 	 Addition of granular base during final construction

Table 8.20: Example of staged construction (continued)

Description	Full construction	Staged construction
Initial construction: Granular base (pavement catalogue for dry regions, street category UC): design bearing capacity 100 000 E80s *Final construction: Lightly cemented base* (pavement catalogue, street category UC): design bearing capacity 1 million E80s Final pavement suitable for residential collector streets and lightly trafficked bus routes		 Deep in-place milling and stabilisation of granular base during final construction
Initial construction: Lightly cemented base (pavement catalogue, street category UC): design bearing capacity 300 000 E80s *Final construction:* Lightly cemented base (pavement catalogue, street category UC): design bearing capacity 3 million E80s Final pavement suitable for minor arterials, collectors and bus routes		 Addition of lightly cemented base during final construction
Initial construction: Lightly cemented base (pavement catalogue, street category UC): design bearing capacity 300 000 E80s *Final construction:* Granular base pavement (catalogue for **wet regions**, street category UB): design bearing capacity 3 million E80s Final pavement suitable for minor arterials, collectors and bus routes in **wet regions**		 Addition of a crushed stone base layer during final construction
Initial construction: Lightly cemented base (pavement catalogue, street category UC): design bearing capacity 300 000 E80s *Final construction:* Ashalt hot-mix base (pavement catalogue, street category UB): design bearing capacity 1 million E80s Final pavement suitable for minor arterials, collectors and bus routes in **wet regions**		 Addition of asphalt hot-mix base layer during final construction

the possible utilisation of this material in a future upgrading to a paved street should be kept in mind.

The cost analysis for upgrading from a gravel to a surfaced street must at least include the savings in vehicle-operating cost as part of the benefit to the street user. The cost of upgrading should be weighed against the benefits by means of a cost-benefit analysis, expressing the benefits as a ratio to the cost. The CB-Roads or SURF+ (refer to manuals) computer programs are ideally suited for this type of analysis.

Construction approaches

Construction of urban streets has become a highly mechanised process but, over the past few years, the possibility of creating employment opportunities has led to greater use of labour-intensive technologies. Additionally, the encouragement of small businesses, owned by the previously disadvantaged, has led to the greater use of these affirmable business enterprises (ABEs) as subcontractors to established contractors or as contractors for small projects. The benefits of using labour-intensive construction or of using ABEs would include a reduction in unemployment, by creating productive jobs and opportunities.

There are thus three construction approaches that can be adopted, although a mix may also be appropriate:

- conventional construction (mechanised);
- labour-intensive construction; and
- construction using ABEs.

The method of construction that is to be used may have some impact on the selection of materials and the structural design. The construction method should be clearly understood before the design proceeds, as a design suitable for plant-intensive construction may be unsuitable for labour-based construction and vice versa.

Conventional construction

Conventional construction is generally well understood by engineers and most design in the recent past has been for this type of construction. Conventional construction is suited to most new street-construction jobs, perhaps with the exception of construction in confined areas. Advantages may include rapid mobilisation and completion, while disadvantages may include limited expenditure on the local community.

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Labour-based construction

If it is important to include the achievement of socio-economic goals as part of service provision, the designer should consider the use of labour-based construction to achieve these goals. Socio-economic goals that could motivate the use of labour-based construction could include relief of unemployment and the transfer of construction skills to the unemployed, particularly previously disadvantaged persons, with the aim of developing SMMEs.

It is important that labour-intensive construction be carried out using a payment-for-production, or task-based, approach. This is the only way in which economic efficiency has been realised.

Small, medium and micro-enterprises (SMMEs)

Where there is a motivation to use labour-based construction (if it is important to include the achievement of socio-economic goals as part of service provision), the designer should also consider the promotion of local contractors to achieve these goals. Socio-economic goals that could motivate the use of SMMEs could include the promotion of entrepreneurship and the advancement of local businesses, particularly those owned by previously disadvantaged persons.

DESIGNING FOR LABOUR-BASED CONSTRUCTION

In order to ensure the maximisation of job creation to the extent that is economic and feasible, the terms of reference for technical consultants engaged to carry out feasibility studies should require the consultant to examine the appropriateness of designs that are inherently labour-intensive, to report on the economic implications of using such designs and, thereafter, to design a project based on designs and technology appropriate for construction that maximises labour-intensive methods.

All construction activities cannot always be executed by means of labour-intensive methods. This must be recognised in the design. Examples of activities demanding greater mechanisation are:

- deep excavation - apart from safety considerations, material can only be thrown a certain height by shovel;
- excavation and spreading of very coarse material;
- in-situ mixing of stabilising material (cement or lime) effectively into coarse aggregates;
- application of tar - due to safety considerations;
- compaction of thick layers or very large aggregates (e.g. rock fill) with small (pedestrian) rollers;
- mixing of high-strength concrete;

- excavation of medium to hard material;
- haulage by wheelbarrows over long distances; and
- placement of heavy pipes.

Labour-intensive construction should, in general, strive to obtain the standards set for conventional construction. However, the design should ensure that the standards specified are appropriate. This necessitates a critical review of all specifications during the design stage.

Table 8.21 gives generalised information on the employment potential of roadwork projects. The information in the table is of a general nature, and should be used with caution.

The following are some guidelines that can be used in the design of civil engineering projects to maximise the use of labour:

- Once the type of project has been selected, the information in Table 8.22 can be used to indicate the potential for employment creation.
- Select the construction activities that have the biggest impact on employment creation (where the contribution of this activity forms a significant part of the project cost and the activity has the potential for employment creation). Information in the following paragraphs will be useful in this selection. A preliminary cost analysis can be done.
- Consider using local plant and materials (i.e. rent plant and purchase material from the community).
- Consider the involvement of ABEs, which generally use more labour-intensive methods, in the construction.

Table 8.21: Summary of employment potential

PROJECT	CONVENTIONAL CONTRIBUTION (%)			POTENTIAL CONTRIBUTION (%)		
	LABOUR	PLANT	MATERIAL	LABOUR	PLANT	MATERIAL
Rehabilitation*	9	53	37	29	26	45
Gravel road*	15	66	19	49	35	16
Drainage (culverts)	34	36	30	54	24	22
Bridges	20	10	70	22	8	70
Urban street	13	54	33	36	27	37

*Earthworks and pavements only.

Table 8.22: Relative contribution of main activities

DESCRIPTION	% CONTRIBUTION TOWARDS PROJECT COSTS		
	REHABILITATION	PAVED	GRAVEL
Site accommodation	3	2	4,5
Accommodation of traffic	5	5	4
Clearing and grubbing	0,5	1	2
Drainage	3	3	7,5
Culverts	3	15	11
Kerbs and edging	3,5	8,5	0
Earthworks	6	4	22
Pavement layers	10	14	16
Base	8	10	0
Prime and seal work	35	15	0
Ancillary works	5	4	6,5
Landscaping	2	1	

- Conduct a detailed investigation into the activities selected for labour-intensive construction, and the possibilities for using ABEs, local plant and materials. The result of this investigation may indicate that some activities cannot be done by means of labour, due to construction practicalities or the availability of materials. A more detailed cost analysis can then be done. Further, make sure that the design can be specified.

  Tables 8.23 and 8.24 may be of assistance for determining the most appropriate activities to be undertaken by labour-intensive methods. The contribution of the various elements towards the contract value and the potential of the various elements for employment enhancement are given.

Construction using ABEs

ABEs that are interested in carrying out some of the project work should be identified. A certain amount of technical and business training may be required for inexperienced ABEs.

In the case of street construction projects, the use of ABEs is likely to include
- emerging small contractors;
- emerging materials suppliers; and
- emerging materials hauliers.

The activities in which ABEs may be engaged can include all construction operations, including the entire works for small projects. Once the ABEs who might wish to work on a project have been identified, the technical consultant should propose,

Table 8.23: Potential of pavement layers for labour-intensive construction methods

LAYER	TYPE	POTENTIAL
Subbase	In-situ soil	Good
	Imported	Good*
	Stabilised soil	Fair, not practical
Base	In-situ soil	Good
	Natural gravel	Good
	Emulsion treated gravel	Good
	Crusher run	Fair, not practical
	Cement stabilised gravel	Not practical**
	Lime stabilised gravel	Fair, good***
	Bituminous premix	Fair, good
	Waterbound macadam	Good
	Penetration macadam	Good
Surfacing	Sand seal	Good#
	Slurry	Good
	Double seal	Good#
	Cape seal	Good#
	Asphalt	Fair
	Roller compacted concrete	Good
	Concrete (plain)	Good
	Concrete (reinforced)	Good
	Segmental blocks	Good##

Notes:
- * The suitability of this will depend entirely on the haul distance.
- ** Cement-stabilised gravel is not suitable for labour intensive methods due to its quick setting time.
- *** Lime-stabilised gravel is more suitable as it reacts and sets more slowly, but achieving an even mix is difficult by entirely manual means and labourers must take extreme care to avoid contact between the lime and skin during application: protective clothing is essential.
- # In the case of a bitumen surfacing, only certain types of emulsion have a non-critical application temperature and are suitable for hand laying.
- ## Quality control of on-site manufacture is critical.

and obtain agreement to, the procurement format that is best suited to the size and scope of the project and the capabilities of the ABEs. He may need to identify packages of work that can be carried out by ABEs, in which case the tender documents for the main contractor should specifically identify such packages of work. Typically, ABEs have been used in the activities shown in Table 8.24 .

MAINTENANCE

The object of maintenance is to preserve, repair and restore the maintainable features of a street network to their designed standard or to a predetermined condition. In this sense, even rehabilitation may be considered a maintenance activity as the object would be to restore the pavement to its original condition. Proper, timely maintenance that is managed efficiently will result in long-term savings to the street authority and street user.

In addition to normal street maintenance activities, the situation in densely populated areas is further complicated by the installation and maintenance of all the other services found in the street reserve in such areas. These services include stormwater, electricity and water supply, sewerage and telecommunication systems. Although the street authority is not responsible for the maintenance of these systems, it remains the legal custodian of the street reserve and

Table 8.24: Typical activities suited to ABEs

COMPONENT	ACTIVITIES
Accommodation of traffic	Watering of gravel diversions
Clearing and grubbing	As required
Drainage	Catchpits and manholes Excavation of open drains Lined open drain Subsoil drains
Culverts	Inlet and outlet structures Excavation of trenches Installation of lightweight pipes Manufacture of reinforced concrete slabs, walls and decks Masonry walls
Kerbing and edging	Manufacture of concrete elements Laying of kerbing and edging
Earthworks	Minor earthworks
Pavement layers	Crushing of aggregates Screening of stockpiles Haulage of materials Spreading of materials Removal of oversize materials
Base	Construction of labour-intensive base types (waterbound macadam, emulsion-treated base, stabilised or unstabilised gravel) Manufacture of paving blocks Laying of paving blocks
Prime and seal work	Hand spraying of prime Manufacture and laying of slurry Seals (Cape seal, double seal, single seal)
Ancillary works Masonry walls	Fencing Gabions Concrete structures Painting of roadmarkings
Landscaping	Grassing Planting of trees

as such must authorise and coordinate the efforts of the various other departments or companies involved. Complaints regarding the poor or delayed repair of the street surface operations of other parties will more often than not be directed at the streets department, and these activities should therefore be monitored by the streets department.

The two main components of the maintenance process are the actual physical execution of the work and the management of the process. Of these two, the biggest challenge is the efficient management of the process. Management systems may vary from being highly sophisticated systems of a pro-active nature with a large computerised component, to less technical needs-driven systems of a reactive nature, or even a combination of the two. The success of a particular system largely depends on the environment in which it is applied and may well fail if it is not appropriate to the specific conditions and demands of the area where it is applied and the type of maintenance activity to which it is applied.

Maintenance activities may be classified as being routine or periodic maintenance, or rehabilitation. Within these categories, some activities may be specific to paved streets and some to unpaved streets, while others may be applicable to both street types. By defining the scope of the maintenance for which a particular authority will be responsible, in terms of the maintenance activities applicable to the particular street network, a better understanding of exactly what is required is achieved. Table 8.25 lists some maintenance activities according to maintenance category.

Some estimate of the extent of the maintenance workload will set the scene for planning, executing and monitoring maintenance activities. This may be done by dividing the whole network into maintenance zones and preparing an inventory, indicating the expected amount of work for each maintenance activity in each zone. For instance, the length of unpaved street will directly determine the workload in terms of watering and blading for a particular zone.

Once the scope and extent of maintenance are known, several options may be considered for deciding on when to do a specific activity and on the best means of doing the work.

The simplest approach to routine maintenance activities is to work according to predetermined schedules, repeated at regular intervals. Maintenance teams will therefore be set up to perform one or more maintenance activities and will be allocated a specific maintenance zone. They will then work through the zone according to a predetermined schedule and will repeat the schedule in cycles. The resources should be balanced with the maintenance workload in the maintenance zones, to control the duration of the cycles. If these cycles are too short, the teams will be under-utilised and if too long, maintenance problems will be left unattended to for lengthy periods.

Typically, the cycles could have a duration of a few months for activities such as vegetation control to a few years for painting street markings. The planning horizon is determined by the duration of these cycles. Actual performance may be measured against the set schedules and planning revised accordingly. This approach implies that the maintenance team is responsible for identifying the need for maintenance as it works through its area of responsibility. The approach may also fail to utilise the maintenance teams to full capacity and may be expensive as the whole team is moved through the maintenance zone regardless of the need for maintenance. It does, however, remain a fairly straightforward, unsophisticated approach.

Table 8.25: Street maintenance categories and limited examples of maintenance activities

FACILITY	MAINTENANCE CATEGORY		
	ROUTINE	PERIODIC	REHABILITATION
Paved streets	• Painting street markings • Cleaning stormwater inlets • Pothole patching • Crack sealing • Sidewalk and cycle path repair.	• Reseal	• Recycle • Overlay • Recycle and overlay
Unpaved streets	• Watering • Blading • Patch gravelling • Cleaning side drains and ditches	• Regravel	• Shape and regravel
Non-specific	• Street sign maintenance • Vegetation control	• Street sign replacement	

The alternative is to have inspectors identifying the need for maintenance at specific locations and then targeting maintenance teams at those problems with a planning horizon of about two weeks.

Periodic maintenance and rehabilitation are normally triggered by the street condition. In these cases, the process may be initiated by a pro-active system, based on a history of condition-assessment data collected over years, processed by computer and enhanced by the experience of the persons involved in the management system, or by a reactive system where areas requiring immediate action are identified and attended to. If the latter approach is selected, a rapid response is, however, required to prevent excessive deterioration. In addition to the normal working procedure opted for, a complaints register should also be kept. Prompt reaction to the complaints raised by the public in such a register is, however, essential.

Maintenance activities may be done by in-house maintenance teams or given out on contract. The recent trend is towards appointing contractors to do maintenance. Because of the low level of technical expertise required - especially by routine maintenance activities - this offers an excellent entry point for aspiring future contractors. Maintenance activities are also ideally suited to manual labour. Proper training and logistical support of the maintenance teams are, however, essential and must be specifically targeted at the activities they will perform.

The lack of logistical support in terms of transport, hand tools and materials may seriously handicap maintenance efforts. On the other hand, over- supply, by keeping too much stock of an item for which there is a low demand, will also tie up capital. This situation may easily arise when there is too much diversity in, for instance, the selection of paving blocks used. Stocks of a particular block will have to be acquired and stored for replacing broken blocks in future. If there is too wide a selection of blocks used, stocks will have to be obtained and stored for each type, resulting in a major logistical and financial problem. It is therefore advisable to standardise on certain bulk items.

Maintenance activities are in essence simple procedures to be carried out with the proper training and equipment. Management during all stages - including planning, execution, monitoring and re-planning, as well as addressing the vast logistical demands of maintenance teams - may at the end of the day determine the success of the maintenance efforts.

MAINTENANCE OF BASIC ACCESS STREETS

Maintenance funds for basic access streets constructed with severe budgetary constraints are likely to be limited. Local authority resources or experience may also not be able to meet the need. Because of the light traffic and possible limitations in the maintenance applied, basic access streets are designed to withstand environmental deterioration. Under such a policy, maintenance of drainage channels is more important than grading unsurfaced streets. The emphasis is on labour-intensive types of maintenance rather than equipment.

Labour and mechanisation

Some construction and most maintenance activities offer considerable scope for the application of labour-based methods, and some activities are only possible by such methods. Table 8.26 indicates the potential for mechanical and labour-based methods in different maintenance operations. In choosing between mechanical and labour-based methods, consideration should be given to the standard of work achieved by each method, as well as to costs and the organisation of work. On basic access streets it is not always necessary for labour-based operations to have the same standard of finish that can be obtained using machines. A decision to do labour-based maintenance may influence design details such as the shape of side drainage channels.

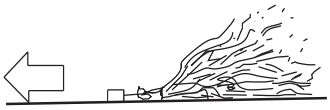
Environmental maintenance

Erosion is the main form of wear in basic access streets. The maintenance of such streets is therefore primarily related to the environmental maintenance of the drainage facilities. This includes the shaping, cleaning, desilting and scour protection of the drainage channels. Grass-cutting and other forms of vegetation control will also constitute part of this type of maintenance. The emphasis is on the efficient functioning of drainage channels.

The integrity of a surfacing on light-structure streets determines the lifespan of a street. Crack-sealing or pothole-patching should be done on a preventive basis, as cracked or potholed streets may show rapid deterioration when structural layers are wet and carrying traffic.

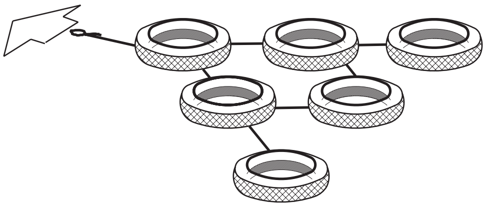
MAINTENANCE OF TERTIARY WAYS

The construction of tertiary ways is mostly labour-intensive and maintenance should be as well. This type of maintenance can be classified as environmental maintenance, as most would be focused on ditch-cleaning, grass-cutting, scour protection and replacing gravel. Various labour-intensive means exist to enable the scraping of tertiary ways. Figure 8.21 illustrates typical drags that can be used for this purpose.



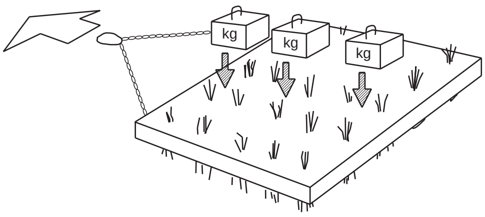
BRUSHWOOD DRAG

Small branches tied together



TYRE SLEDGE

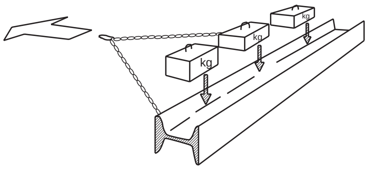
Old truck tyres chained together



CABLE DRAG

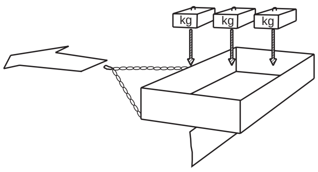
Bundles of steel cables bound together and fixed in a frame, weighed with concrete blocks to enable it to cut into the surface. Wooden sticks may be used if steel cables are not available.

Care must be taken that pieces of the steel cable which may break off the drag are not left lying on the road.



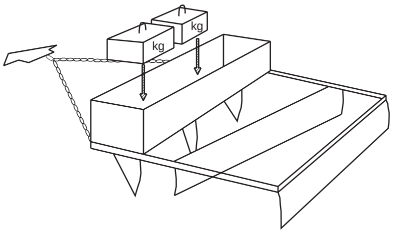
STEEL DRAG

Rolled steel joist or steel rail weighted with concrete blocks and towed at an angle to the road.



BOX DRAG

Wooden box filled with concrete blocks on top of an old grader blade.



TOLARD

Five blades at different angles under a box weighted with concrete blocks.

Figure 8.21: Simple drags for maintenance of tertiary ways

Table 8.26: Suitability of mechanical equipment and labour for maintenance activities

ACTIVITY	MECHANICAL EQUIPMENT	LABOUR
Ditch-cleaning and cutting	Good*	Good*
Cleaning and minor repair to culverts and bridges	Poor	Good
Building scour controls	Poor	Good
Repair of structures	Poor	Good
Grading unpaved surfaces	Good	Impracticable
Dragging and brushing of unpaved surfaces	Poor	Poor
Filling potholes	Poor	Good
Filling unpaved surfaces and slopes	Poor	Good
Grass cutting	Good**	Good
Repairing and replacing traffic signs	Poor	Good
Stockpiling gravel	Good	Fair
Regravelling gravel surfaces	Good	Fair

* The labour potential in these activities depends on suitable design of the ditch cross-section (see Figure 8.5).

** The labour potential in this activity depends on the width of the shoulder and the presence of obstructions, such as road furniture and culvert headwalls.

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CSRA:	Committee of State Road Authorities, South Africa
CUTA:	Committee of Urban Transport Authorities, South Africa
HRB:	Highway Research Board, Washington
KZN:	KwaZulu-Natal Department of Transport, Pietermaritzburg
NITRR:	National Institute for Transport and Road Research, CSIR, Pretoria

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Theyse, H L (1997b). Interim guidelines on the structural design of pavements with emulsion treated layers. Confidential contract report CR-97/045. CSIR, Pretoria.

Van Vuuren, D J, Otte, E and Paterson, W D O (1974). The structural design of flexible pavements in South Africa. *Proceedings of the 2nd conference on asphalt pavements in South Africa*. Durban.

Visser, A T (1994). A cast in-situ block pavement for labour-enhanced construction. *Concrete/beton,* No 71, February.

Visser, A T and Hall, S (1999). A flexible portland cement concrete pavement for low-volume roads. Paper offered to the *Seventh international conference on low-volume roads*, Baton Rouge, 23 -27 May, Los Angeles.

Walker, R N, Paterson, W D O, Freeme, C R and Marais, C P (1977). The South African mechanistic pavement design procedure. *Proceedings of the 4 th international conference on the structural design of asphalt pavements.* Ann Arbor, University of Michigan, Michigan.

Yoder, E J and Witczak, M W (1975). *Principles of pavement design*. 2nd edition. John Wiley Interscience publications, New York.

APPENDIX A

THE CATALOGUE OF PAVEMENT DESIGNS

The catalogue of pavement designs contained in this appendix was compiled from various sources, with the aim of addressing the specific needs of pavement design in urban areas. The catalogue pages dealing with the granular base pavements for both wet and dry regions, the cement-treated base pavements, and the asphalt hot-mix base pavements were obtained from the TRH4 document. These designs were developed from the SAMDM and were checked with the DCP design method.

The macadam page was obtained form the TRH4 document and supplemented by the category D designs.

The emulsion-treated base pavement designs were developed using the DCP design method.

The block paving pavement designs were obtained from the UTG2 document.

The cast-in-situ block paving designs were obtained from the original proposal by Visser (1994), which was subsequently validated by Visser and Hall (1999).

Notes regarding the use of the catalogue

- The designs in the catalogue are merely suggested designs, and the designer may modify and adjust them on the basis of sound engineering principles and experience.
- The layer thicknesses indicated in the catalogue represent minimum thicknesses required. Practical construction issues and layer thickness tolerances should be allowed for.
- Although the catalogue generally indicates a fixed thickness of asphalt, regardless of the grading of the asphalt and the binder type, these values serve only as suggested starting values. The designer should consider the particular properties of the asphalt mix that will be used.
- Designs are valid for the upper bearing-capacity boundaries of the pavement classes.
- It is assumed that all the requirements regarding material quality, moisture condition and compaction are met during the construction of the pavements.

RECOMMENDED READING

CSRA (1996). *Structural design of flexible pavements for inter-urban and rural roads.* Department of Transport Technical Recommendations for Highways Draft TRH4. Pretoria.

CUTA (1987). *Structural design of segmental bloc*k pavements for southern Africa. Department of Transport Urban Transportation Guidelines Draft UTG2. Pretoria.

Hefer, A W (1997). Towards design guidelines for macadam pavements. *M.Eng thesis*. University of Pretoria, Pretoria.

GRANULAR BASES (DRY AND MODERATE REGIONS)

1998

ROAD CATEGORY	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										
	ES0,003 0,1-0,3x10^4	ES0,01 0,3-1,0x10^4	ES0,03 1,0-3,0x10^4	ES0,1 3,0-10x10^4	ES0,3 0,1-0,3x10^6	ES1 0,3-1,0x10^6	ES3 1,0-3,0x10^6	ES10 3,0-10x10^6	ES30 10-30x10^6	ES100 30-100x10^6	Foundation
UA: Trunk roads, primary distributors, freeways, major arterials and by-passes							40A 125 G2 150 C3 40A 150 G2 150 G5	40A 150 G2 250 C3	50A 150 G1 250 C3	50A 150 G1 300 C3	
UB: District and local distributors, minor arterials and collectors, industrial roads, goods-areas and bus routes						S 125 G4 150 C4 S 150 G4 150 G5	S*/30A 150 G3 150 C4 S*/30A 150 G3 150 G5	40A 150 G2 200 C4 30A 150 G2 200 G5			150 G7 150 G9 G10
UC: Residential access collectors, car parks and lightly trafficked bus routes				S 100 G5 125 C4 S 125 G4 125 G6	S 125 G5 125 C4 S 125 G4 150 G6	S 125 G4 125 C4 S 125 G4 150 G5	S 150 G3 150 C4 S 150 G3 150 G5				
UD: Local access roads, -loops, -ways, -courts, -strips and culs de sac	S1 100 G5 100 G7	S1 100 G5 125 G7	S1 100 G4 125 G7	S1 100 G4 125 G6 S1 100 G5 100 C4	S 125 G4 125 G6 S 100 G5 125 C4	S 125 G4 150 G6 S 125 G5 150 C4					150 G9 G10

Symbol A denotes AG, AC, or AS.
A0, AP may be recommended as a surfacing measure for improved skid resistance when wet or to reduce water spray
S denotes Double Surface Treatment (seal or combinations of seal and slurry)
S1 denotes Single Surface Treatment
* If seal is used, increase C4 and G5 subbase thickness to 200mm.

(Shaded) Most likely combinations of road category and design bearing capacity.

GRANULAR BASES (WET REGIONS)

1998

ROAD CATEGORY	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										
	ES0,003 0,1-0,3x10⁴	ES0,01 0,3-1,0x10⁴	ES0,03 1,0-3,0x10⁴	ES0,1 3,0-10x10⁴	ES0,3 0,1-0,3x10⁶	ES1 0,3-1,0x10⁶	ES3 1,0-3,0x10⁶	ES10 3,0-10x10⁶	ES30 10-30x10⁶	ES100 30-100x10⁶	Foundation
UA: Trunk roads, primary distributors, freeways, major arterials and by-passes							30A 150 G1** 200 C3	40A 150 G1 300 C3 *(250 C3)	50A 150 G1 400 C3 *(300 C3)		150 G7 150 G9 G10
UB: District and local distributors, minor arterials and collectors, industrial roads, goods-areas and bus routes						S 150 G2 150 C4 S 150 G2 200 G5	S/30A 150 G1** 200 C4	40A 150 G1 300 C4 *(250 C4)			
UC: Residential access collectors, car parks and lightly trafficked bus routes				S 100 G5 125 C4 S 125 G4 125 G6	S 125 G5 125 C4 S 150 G4 150 G6	S 125 G2 150 C4 S 150 G2 150 G5	S 150 G2** 200 C4 S 150 G2 150 G4				
UD: Local access roads, -loops, -ways, -courts, -strips and culs de sac	S1 100 G5 100 G7	S1 100 G5 125 G7	S1 100 G4 125 G7	S1 100 G4 125 G6 S1 100 G5 100 C4	S 125 G4 125 G6 S 100 G5 125 C4	S 150 G4 150 G6 S 125 G5 150 C4					150 G9 G10

Most likely combinations of road category and design bearing capacity.

Symbol A denotes AG, AC, or AS.
A0, AP may be recommended as a surfacing measure for improved skid resistance when wet or to reduce water spray
S denotes Double Surface Treatment (seal or combinations of seal and slurry)
S1 denotes Single Surface Treatment
* If water is prevented from entering the base, the subbase thickness may be reduced to the values indicated in brackets.
** Base thickness may be reduced by 25 mm if cemented subbase thickness is increased by 50 mm.

CEMENTED BASES

ROAD CATEGORY	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										
	ES0,003 0,1-0,3x10^{4}	ES0,01 0,3-1,0x10^{4}	ES0,03 1,0-3,0x10^{4}	ES0,1 3,0-10x10^{4}	ES0,3 0,1-0,3x10^{6}	ES1 0,3-1,0x10^{6}	ES3 1,0-3,0x10^{6}	ES10 3,0-10x10^{6}	ES30 10-30x10^{6}	ES100 30-100x10^{6}	Foundation
UA: Trunk roads, primary distributors, freeways, arterials and by-passes							30A 150 C3 200 C4				
UB: District and local distributors, minor arterials and collectors, industrial roads, goods-areas and bus routes						S 125 C3 150 C4	S 125 C3 200 C4	S/30A 150 C3* 300 C4			150 G7 150 G9 G10
UC: Residential access collectors, car parks and lightly trafficked bus routes				S 100 C4 100 G6	S 200 C3 S 125 C4 125 G6	S 125 C3 125 C4	S 150 C3 150 C4				
UD: Local access roads, -loops, -ways, -courts, -strips and culs de sac	S1 100 C4 100 G8	S1 100 C4 125 G8	S1 125 C4 125 G7	S1 150 C4 150 G7	S 125 C4 125 G6	S 125 C4 150 G6					150 G9 G10

Symbol A denotes AG, AC, or AS.

A0, AP may be recommended as a surfacing measure for improved skid resistance when wet or to reduce water spray

S denotes Double Surface Treatment (seal or combinations of seal and slurry)

S1 denotes Single Surface Treatment

* Crushing of cemented base may occur

(Shaded cells:) Most likely combinations of road category and design bearing capacity.

1998

ASPHALT HOT-MIX BASES

ROAD CATEGORY	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										Foundation
	ES0,003 0,1-0,3x10 4	ES0,01 0,3-1,0x10 4	ES0,03 1,0-3,0x10 4	ES0,1 3,0-10x10 4	ES0,3 0,1-0,3x10 6	ES1 0,3-1,0x10 6	ES3 1,0-3,0x10 6	ES10 3,0-10x10 6	ES30 10-30x10 6	ES100 30-100x10 6	
UA: Trunk roads, primary distributors, freeways, major arterials and by-passes							40A 80 BC 250 C3	40A 90 BC 300 C3	40A 120 BC 400 C3	50A 180 BC 450 C3	
UB: District and local distributors, minor arterials and collectors, industrial roads, goods-loading areas and bus routes							30A 80 BC 200 C4	30A 80 BC 300 C3			150 G7 150 G9 G10
UC: Residential access collectors, car parks and lightly trafficked bus routes											
UD: Local access roads, -loops, -ways, -courts, -strips and culs de sac											150 G9 G10

Symbol A denotes AG, AC, or AS.
A0, AP may be recommended as a surfacing measure for improved skid resistance when wet or to reduce water spray
Symbol BC does not include LAMBS (BC1 Table 13)
S denotes Double Surface Treatment (seal or combinations of seal and slurry)
S1 denotes Single Surface Treatment

[shaded] Most likely combinations of road category and design bearing capacity.

EMULSION-TREATED BASES

1998

ROAD CATEGORY	ES0,003 0,1-0,3x10 ^{4}	ES0,01 0,3-1,0x10 ^{4}	ES0,03 1,0-3,0x10 ^{4}	ES0,1 3,0-10x10 ^{4}	ES0,3 0,1-0,3x10 ^{6}	ES1 0,3-1,0x10 ^{6}	ES3 1,0-3,0x10 ^{6}	ES10 3,0-10x10 ^{6}	ES30 10-30x10 ^{6}	ES100 30-100x10 ^{6}	Foundation
	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										
UA: Trunk roads, primary distributors, freeways, major arterials and by-passes								40A 125 E1 250 C4			
UB: District and local distributors, minor arterials and collectors, industrial roads, goods-loading areas and bus routes						S 100 E2 150 C4 S 125 E2 150 G5	S*/30A 125 E2 150 C4 S*/30A 150 E2 150 G5	40A 125 E1 200 C4 40A 150 E1 150 C4			150 G7 150 G9 G10
UC: Residential access collectors, car parks and lightly trafficked bus routes				S 100 E3 150 G6	S 100 E2 150 G6	S 100 E2 125 C4					
UD: Local access roads, -loops, -ways, -courts, -strips and culs de sac			S1 100 E3 100 G6	S1 100 E3 125 G6							150 G9 G10

Symbol A denotes AG, AC, or AS.
A0, AP may be recommended as a surfacing measure for improved skid resistance when wet or to reduce water spray
S denotes Double Surface Treatment (seal or combinations of seal and slurry)
S1 denotes Single Surface Treatment

(Shaded) Most likely combinations of road category and design bearing capacity.

MACADAM BASES

1998

ROAD CATEGORY	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE) ES0,003 0,1-0,3x10 4	ES0,01 0,3-1,0x10 4	ES0,03 1,0-3,0x10 4	ES0,1 3,0-10x10 4	ES0,3 0,1-0,3x10 6	ES1 0,3-1,0x10 6	ES3 1,0-3,0x10 6	ES10 3,0-10x10 6	ES30 10-30x10 6	ES100 30-100x10 6	Foundation
UA: Trunk roads, primary distributors, freeways, major arterials and by-passes							30 - 40A 125 M 150 C3	40A 150 M 125 C3 125 C4	50A 150 M 150 C3 150 C3		150 G7 150 G9 G10
UB: District and local distributors, minor arterials and collectors, industrial roads, goods-loading areas and bus routes					S 100 M 150 G5	S 125 M 150 G5	S or 30A 125 M 150 C4	40A 125 M 125 C4 125 C4			
UC: Residential access collectors, car parks and lightly trafficked bus routes				S 100 M 100 C4 S 100 M 125 G5	S 100 M 125 C4	S 100 M 150 G5	S 125 M 100 C4 S 125 M 150 G5				
UD: Local access roads, -loops, -ways, -courts, -strips and culs de sac	S1 100 M 150 G7 S1 100 M 125 C4	S1 125 M 150 G7 S1 100 M 125 C4	S1 125 M 150 G7 S1 75 M 125 C4	S1 150 M 150 G7 75 M 125 C4 150 G7	S 100 M 125 C4 150 G7						150 G9 G10

Symbol A denotes AG, AC, or AS.
A0, AP may be recommended as a surfacing measure for improved skid resistance when wet or to reduce water spray
S denotes Double Surface Treatment (seal or combinations of seal and slurry)
S1 denotes Single Surface Treatment

[shaded] Most likely combinations of road category and design bearing capacity.

BLOCK PAVEMENTS (MODERATE AND DRY REGIONS)

1998

ROAD CATEGORY	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE) ES0,003 0,1-0,3x10 ^{4}	ES0,01 0,3-1,0x10 ^{4}	ES0,03 1,0-3,0x10 ^{4}	ES0,1 3,0-10x10 ^{4}	ES0,3 0,1-0,3x10 ^{6}	ES1 0,3-1,0x10 ^{6}	ES3 1,0-3,0x10 ^{6}	ES10 3,0-10x10 ^{6}	ES30 10-30x10 ^{6}	ES100 30-100x10 ^{6}	Foundation
UA: Trunk roads, primary distributors, freeways, major arterials and by-passes											
UB: District and local distributors, minor arterials and collectors, industrial roads, goods-loading areas and bus routes						60 S-A S-B or S-C 20 SND 125 C4 60 S-A S-B or S-C 20 SND 100 - 150 G5	60 S-A S-B or S-C 20 SND 150 C4 60 S-A S-B or S-C 20 SND 150 G5	80 S-A 20 SND 100 C4 100 C4	80 S-A 20 SND 125 C3 125 C3		150 G7 150 G9 G10
UC: Residential access collectors, car parks and lightly trafficked bus routes				60 S-A S-B or S-C 20 SND 100 - 125 G5		60 S-A S-B or S-C 20 SND 125 C4 60 S-A S-B or S-C 20 SND 100 - 125 G5	60 S-A S-B or S-C 20 SND 125 C4 60 S-A S-B or S-C 20 SND 150 G5	60 S-A S-B or S-C 20 SND 125 C4 125 C4	80 S-A S-B or S-C 20 SND 150 C3 150 C4		
UD: Local access roads, -loops, -ways, -courts, -strips and culs de sac			60 S-A S-B or S-C 20 SND								150 G9 G10

Shaded: Most likely combinations of road category and design bearing capacity.

BLOCK PAVEMENTS (WET REGIONS)

1998

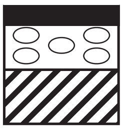
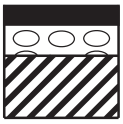
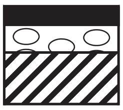
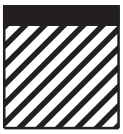
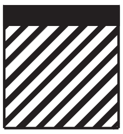
ROAD CATEGORY	PAVEMENT CLASS AND DESIGN BEARING CAPACITY (80 kN AXLES/LANE)										
	ES0,003 0,1-0,3x10^4	ES0,01 0,3-1,0x10^4	ES0,03 1,0-3,0x10^4	ES0,1 3,0-10x10^4	ES0,3 0,1-0,3x10^6	ES1 0,3-1,0x10^6	ES3 1,0-3,0x10^6	ES10 3,0-10x10^6	ES30 10-30x10^6	ES100 30-100x10^6	Foundation
UA: Trunk roads, primary distributors, freeways, major arterials and by-passes											
UB: District and local distributors, minor arterials and collectors, industrial roads, goods-areas and bus routes						60 S-A S-B or S-C 20 SND 150 G5 60 S-A S-B or S-C 20 SND 150 C4	60 S-A S-B or S-C 20 SND 150 C4	60-80 S-A 20 SND 125 C4 125 C4	80 S-A 20 SND 150 C4 150 C4		150 G7 150 G9 G10
UC: Residential access collectors, car parks and lightly trafficked bus routes				60 S-A S-B or S-C 20 SND 100 - 125 G5 60 S-A S-B or S-C 20 SND 100 C4		60 S-A S-B or S-C 20 SND 100- 150 G5 60 S-A S-B or S-C 20 SND 100- 150 C4	60 S-A S-B or S-C 20 SND 150 G5 60 S-A S-B or S-C 20 SND 125 C4				
UD: Local access roads, -loops, -ways, -courts, -strips and culs de sac			60 S-A S-B or S-C 20 SND								150 G9 G10

Most likely combinations of road category and design bearing capacity.

Table A1: Cast in-situ block pavement codes for use in Figure A1

ROUTE AND ENVIRONMENT CLASSIFICATION	DESIGN TRAFFIC DURING STRUCTURAL LIFE (E80)		
	<0,2 x 10^6	0,2-0,8 x 10^6	0,8-3,0 x 10^6
Minor arterial, wet climate, CBR 3-7*		A	A
Minor arterial, wet climate, CBR >7		A	A
Minor arterial, dry climate, CBR 3-7		B	B
Minor arterial, dry climate, CBR >7		C	B
Access street, wet climate, CBR 3-7	D	C	B
Access street, wet climate, CBR >7	E	C	B
Access street, dry climate, CBR 3-7	D	C	B
Access street, dry climate, CBR >7	E	C	B

*Special precautions have to be taken if the design CBR <3

Pavement code	Pavement structure	
A		75/30 MPa cell slab 150 G5 or 150 C4 In-situ*
B		75/30 MPa cell slab 150 G5 or 125 C4 In-situ*
C		75/30 MPa cell slab 125 G5 or 100 C4 In-situ*
D		75/20 MPa cell slab In-situ*
E		50/20 MPa cell slab In-situ*

Note: The strength of the cell slab indicated is the 28 day cube strength
* Special precaution have to be taken if the design CBR <3

Figure A1: Catalogue of structural designs for cost in-situ block pavements

APPENDIX B

EXAMPLES OF STRUCTURAL DESIGN BY THE CATALOGUE METHOD

A. EXAMPLE OF THE STRUCTURAL DESIGN OF A CATEGORY UB STREET

SERVICE OBJECTIVE, STREET CHARACTERISTICS AND STREET PROFILE

The structural design of the pavements for a new residential area needs to be done. The layout plan and stormwater design have been completed. For the purpose of this example, the design of one of the streets will be considered. The following general information is available:

- The pavement structure for a local distributor that will serve as a bus route needs to be designed. The facility must open for traffic in five years time.
- The route is regarded as an important link in the transportation system.
- Drainage will consist of a pipe system with kerbs and gutters. The pipe system is installed to avoid any future disruption on the bus route due to upgrading the drainage system.
- The traffic is expected to exceed 700 vehicles per day with 15% being heavy vehicles, mostly buses. The expected annual average daily equivalent (AADE) design traffic is 180 E80s/lane/day for this route. (If the traffic information is not readily available from the planning office (or client body), consult and follow the guidelines set out in the section on levels of service in this document).
- The street surface will be paved because of the importance of the road and the volume of traffic.
- A paved walkway and bus stops will be provided for pedestrian traffic, with controlled pedestrian crossings at intersections.

Design pavement structures of different base types and compare these on the basis of present worth of life-cycle costs before making a final selection.

Street category:
After consideration of the characteristics listed and consultation with the client, it is decided to design for a category UB street.

Design strategy

Select analysis period

The alignment will probably not change and therefore a period of 30 years is selected.

Select structural design period

As this is a new facility and there is considerable uncertainty about the traffic volume and growth rate, a period of 15 years is selected. Therefore AP = 30 years; SDP = 15 years.

Estimate design traffic

The current equivalent traffic (180 E80s/lane/day) is projected to the initial year using Equation 8.3 and the growth factor, g, from Table 8.8. The cumulative equivalent traffic over the structural design period (Equation 8.5) is determined by multiplying the initial equivalent traffic by the cumulative growth factor, f, from Table 8.9. Because of the uncertainty regarding the traffic growth rate, a sensitivity analysis with growth rates ranging from 2 to 8 percent (higher values are unrealistic for this road) is done. Table B1 shows the cumulative equivalent traffic and the applicable traffic class for a structural design period of 15 years. Regardless of the selected growth rate, the design traffic class is ES3.

Materials

Table B2 indicates the availability and cost of material. The unit prices listed are all 1995 prices.

Table B1: Cumulative equivalent traffic and applicable traffic class for SDP = 15 years

GROWTH RATE (%)	g (TABLE 8.8)	f (TABLE 8.9)	CUMULATIVE EQUIVALENT TRAFFIC (E80s) OVER SDP	DESIGN TRAFFIC CLASS (TABLE 8.5)
2	1,10	6 440	1,3 x 10^6	ES3
4	1,22	7 600	1,7 x 10^6	ES3
6	1,34	9 010	2,2 x 10^6	ES3
8	1,47	10 700	2,8 x 10^6	ES3

Table B2: Checklist of material availability and cost (base year 1995)

Symbol	Code	Material	Availability	Unit cost/m^3	
				Borrow pit	Commercial
	G1	Graded crushed stone	✔	R86,00	R122,00
	G2	Graded crushed stone	✔	R86,00	R122,00
	G3	Graded crushed stone	✔	R78,00	R116,00
	G4	Natural gravel	✔	R42,59	R57,64
	G5	Natural gravel	✔	R39,23	R53,50
	G6	Natural gravel	✔	R35,31	R50,36
	G7	Gravel/soil	✔	R33,03	R45,65
	G8	Gravel/soil	✔	R32,31	R44,87
	G9	Gravel/soil	✔	R31,40	R44,00
	G10	Gravel/soil	✗	-	-
	C1	Cemented crushed stone or gravel	✔	R106,05	R145,00
	C2	Cemented crushed stone or gravel	✗	R102,00	R140,00
	C3	Cemented natural gravel	✔	R63,00	R76,70
	C4	Cemented natural gravel	✔	R61,70	R71,70
	BEM	Bitumen emulsion modified gravel	✗	-	
	BES	Bitumen emulsion stabilised gravel	✗	-	
	BC1	Hot -mix asphalt	✔	-	
	BC2	Hot -mix asphalt	✔	R320,00	
	BC3	Hot -mix asphalt	✔	-	
	BS	Hot -mix asphalt	✔	-	
	AG	Asphalt surfacing	✔	-	
	AC	Asphalt surfacing	✔	R350,00	
	AS	Asphalt surfacing	✔	R430,00	
	AO	Asphalt surfacing	✗	-	
	AP	Asphalt surfacing	✗	-	
	S1	Surface treatment	✔	R5,10/m^2	
	S2	Surface treatment	✔	R6,00/m^2	
	S3	Sand seal	✗	R2,35/m^2	
	S4	Cape seal	✗	R6,90/m^2	
	S5	Slurry	✗	R561,00/m^3	
	S6	Slurry	✗	-	
	S7	Slurry	✗	R616,00/m^3	
	S8	Surface renewal (30%)	✗	R1,20/litre	
	S9	Surface renewal (60%)	✗	R2,03/litre	
	WM1	Waterbound macadam	✗	R150,00/m^3	
	WM2	Surface treatment	✗	R150,00/m^3	
	PM	Penetration macadam	✗	-	
	DR	Dumprock	✗	R30,00/m^3	

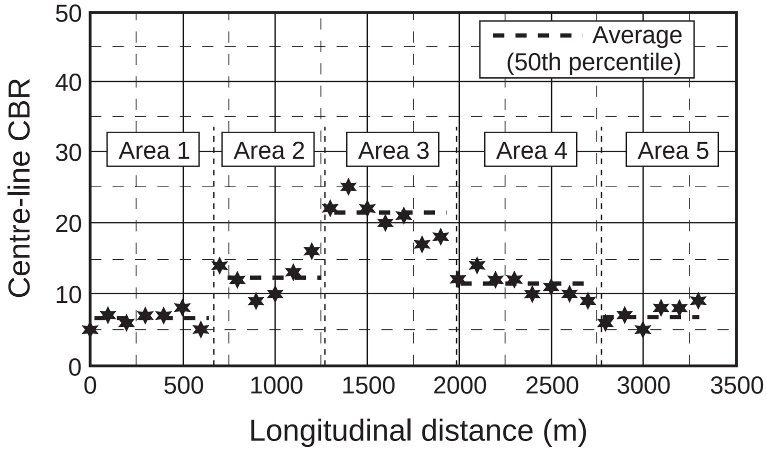


Figure B1: Centre-line CBR-values for the examples

Climatic region

The road lies within a moderate climatic region.

Delineation of subgrade areas and design CBR of subgrade

Centreline subgrade CBR values taken at 100m intervals:

5;7;6;7;7;8;5;14;12;9;10;13;16;22;25;22;20;21;17;18;12;14;12;12;10;11;10;9;6;7;5;8;8;9.

The given CBR values are illustrated in Figure B1. Visual inspection of the CBR values reveals five subgrade areas:
Subgrade area 1 : CBR = 5;7;6;7;7;8;5
Subgrade area 2 : CBR = 14;12;9;10;13;16
Subgrade area 3 : CBR = 22;25;22;20;21;17;18
Subgrade area 4 : CBR = 12;14;12;12;10;11;10;9
Subgrade area 5 : CBR = 6;7;5;8;8;9.

Table B3 gives the CBR percentile values and design CBR of the subgrade. Ten percent of the measured CBR values are allowed to be below the minimum specified for a particular material quality, and the design CBR of the subgrade is therefore determined by the 10th percentile value of the measured CBR values.

Structural design and pavement type selection

Pavement type selection

From the section on materials and Table 8.17 it follows that a granular, cemented or asphalt hot-mix base layer may be used with cemented subbase layers recommended for the cemented and hot-mix base layers.

Table B3: Design CBR of the subgrade in example

SUBGRADE AREA	PERCENTILE VALUES*		CBR CLASS	DESIGN CBR OF SUBGRADE
	50 %	10 %		
1	6,2	4,4	SG3	3 - 7
2	12,0	8,8	SG2	7 - 15
3	20,5	16,7	SG1	> 15
4	11,0	8,6	SG2	7 - 15
5	7,0	4,6	SG3	3 - 7

Selected layers

The selected layers necessary for the different subgrade areas are given in Table B4 (according to Table 8.20).

Possible pavement structures

Table B5 shows possible pavement structures according to the catalogue (category UB streets, class ES3 traffic). Using a surface treatment instead of the asphalt wearing course may result in a lower riding quality. As this is an urban road with relatively low speed restrictions, this should not be a problem. A double seal is therefore used for all the designs except the hot-mix asphalt base.

Practical considerations

The designer should consider the consequences, if any, of the practical considerations given in the sections on street categories and materials.

Cost analysis

Construction cost

For the comparison of different pavement options, the construction cost of only the subbase, base and surfacing need be considered. These costs follow directly from the unit costs given in Table B2.

Future maintenance and life-cycle strategy

The structural design period is 15 years and the analysis period 30 years. The future maintenance for each pavement type can be estimated from Tables 8.16 and 8.17. Table B6 shows estimated maintenance measures during the life cycles of the different pavement options.

Discount rate

For the purposes of this example, a discount rate of 8% is normally selected. However, it is better to do a sensitivity analysis with discount rates of 6, 8 and 10%.

Salvage value and road-user costs

Although the salvage value and road-user costs may vary with pavement life, it is unlikely that the relative effect will influence the present worth of costs significantly. This can be confirmed with trial values.

Present worth of costs

The present worth of costs can be calculated from Equation 8.10. Table B7 shows the 1995 present worth of costs for each pavement type, taking the construction cost and maintenance strategy from Table B6 into account. The sensitivity analysis shows that the discount rate can vary from 6 to 10 percent without having a significant influence on the present worth of costs.

It also follows from Table B7 that the pavements with granular bases are significantly less costly than the others. Therefore, a pavement with a granular base will be selected. Considering the behaviour of the different pavement types (refer to the relevant section in this document) it is proposed that a structure with a granular base and a cemented subbase should be used. Such a pavement will probably not show the cracking and crushing problems of a pavement with a cemented base.

Table B4: Selected layers for the different subgrade areas

SUBGRADE AREA	DESIGN CBR	LOWER SELECTED LAYER	UPPER SELECTED LAYER	TREATMENT OF IN-SITU SUBGRADE
1	3 - 7	150 mm G9	150 mm G7	R+R* to 150 mm G10
2	7 - 15	-	150 mm G7	R+R to 150 mm G9
3	> 15	-	-	R+R to 150 mm G7
4	7 - 15	-	150 mm G7	R+R to 150 mm G9
5	3 - 7	150 mm G9	150 mm G7	R+R to 150 mm G10

* R+R = Rip and re-compact.

Table B5: Possible pavement structures for the design example

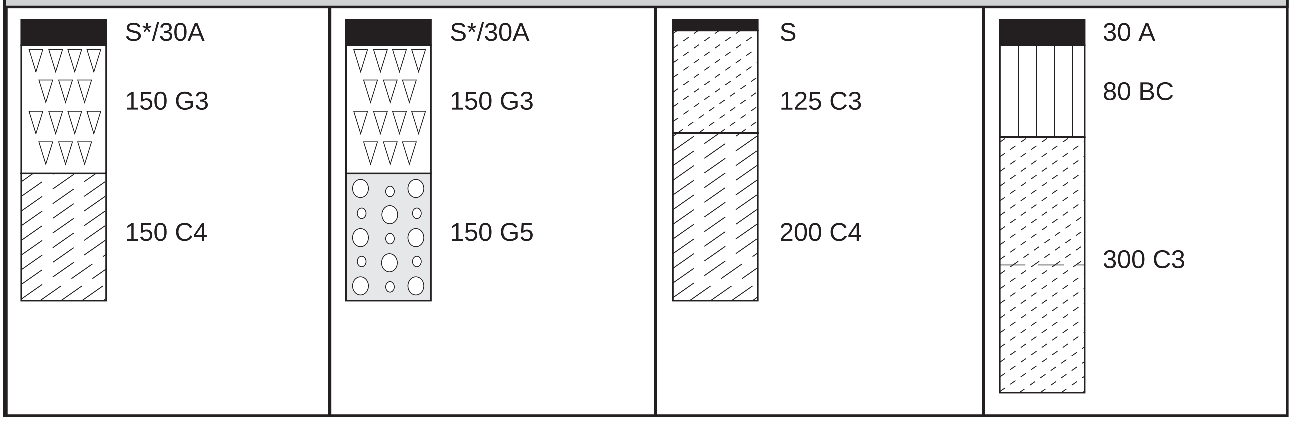


Table B6: Typical maintenance measures for the different flexible and semi-rigid pavement types over their life cycles

PAVEMENT TYPE		MAINTENANCE MEASURES	
BASE	SUBBASE	FOR SURFACING	STRUCTURAL MAINTENANCE
Granular	Granular	S1 (9 yrs) S1 (25 yrs)	40 AG (15 yrs)
	Cemented	S1 (10 yrs) S1 (25 yrs)	35 AG (15 yrs)
Cemented	Cemented	S1 (5 yrs) S1 (10 yrs) S1 (24yrs)	150 G1+S2 (15 yrs)
Hot-mix asphalt	Cemented	S1 (12yrs) S1 (25yrs)	30 AG (15 yrs)

Table B7: Present worth of costs (base year 1995)

PAVEMENT STRUCTURE	INITIAL COSTS/m² (R)	MAINTENANCE	INITIAL COSTS/m² (R)	DISCOUNTED MAINTENANCE COSTS/m² (R) DISCOUNT RATE			PRESENT WORTH COSTS/m² (R) DISCOUNT RATE		
				6%	8%	10%	6%	8%	10%
S2 150 G3 150 G5	6,00 11,00 5,88	S1 (9 yrs) 40 AG (15 yrs) S1 (25 yrs)	5,10 14,00 5,10	3,02 5,84 1,19	2,55 4,41 0,74	2,16 3,35 0,47			
	23,58			**10,05**	**7,70**	**5,98**	**33,63**	**31,28**	**29,56**
S2 150 G3 150 C4	6,00 11,70 9,26	S1 (10 yrs) 35 AG (15 yrs) S1 (25 yrs)	5,10 12,25 5,10	2,85 5,11 1,19	2,36 3,86 0,74	1,97 2,93 0,47			
	26,96			**9,15**	**6,96**	**5,37**	**36,11**	**33,92**	**32,33**
80 BC2 300 C4	25,60 18,90	S1 (12 yrs) 30 AG (25 yrs) S1 (25 yrs)	5,10 10,50 5,10	2,53 2,45 1,19	2,03 1,53 0,74	1,62 0,97 0,47			
	44,50			**6,17**	**4,30**	**3,06**	**50,67**	**48,80**	**47,56**
S2 125 C3 200C4	6,00 7,88 12,34	S1 (5 yrs) S1 (10 yrs) 150 G1 base (15 yrs) S2 (15 yrs) S1 (25 yrs)	5,10 5,10 12,90 6,00 5,10	3,81 2,85 5,38 2,50 1,26	3,47 2,36 4,07 1,89 0,80	3,17 1,97 3,09 1,44 0,52			
	26,22			**15,80**	**12,59**	**10,19**	**42,04**	**38,81**	**36,41**

B. EXAMPLE OF THE STRUCTURAL DESIGN OF A CATEGORY UD STREET

SERVICE OBJECTIVE, STREET CHARACTERISTICS AND STREET PROFILE

The residential street network needs to be designed for the same residential area as in the previous example. The layout plan and stormwater design have been completed. For the purpose of this example, the design of one of the streets will be considered. The following general information is available:

- The pavement structure for a basic access street needs to be designed.
- The route is *not* regarded as an important link in the transportation system.
- Drainage will consist of a lined channel next to the roadway
- The traffic is expected to be below 75 vehicles per day with very little heavy traffic (< 5%). Because of the absence of economic activity the growth rate will be very low (< 2%).
- The street has a steep slope in places and will be paved for erosion-protection reasons.
- Pedestrian traffic will be accommodated on the roadway and children will probably use the street as a playground.

Design pavement structures with different base types and compare them on the basis of construction costs before making a final selection.

Street category

After consideration of the characteristics listed, it is decided to design a category UD street.

Estimate design traffic

With the expected traffic (< 75 vpd), very few heavy vehicles (< 5%) and low traffic growth rate (< 2%) the calculated design traffic will not exceed 30 000 E80s even in 30 years. The street is therefore designed for an ES0,03 pavement class.

Materials

The same material availability and cost apply as for the previous example.

Structural design and pavement type selection

From the section on materials and Table 8.17 it follows that pavements with a granular, cemented, paving block or waterbound macadam base layer may be selected. The paving block structure will require a cemented subbase while the macadam base may be built with or without stabilising the subbase. The granular and cemented base layers may be used with a granular subbase. The cemented base on a granular subbase is not regarded as a sound option and will not be considered for further analysis. An emulsion-treated base layer may also be used with 1% emulsion and 1% cement (E3) at a cost of R71 (1995) per m^3. The cost for the paving block layer is R24,80 (1995) per m^2 , including the sand bedding layer.

Subgrade CBR and selected layers

The centreline CBR values are:
12,12,10,11,10,9,6,7,5,8,8,9

The subgrade is divided into two sections:

Subgrade section 1:	12,12,10,11,10,9 with a 10^{th} percentile CBR value	= 9,5
Subgrade section 2:	6,7,5,8,8,9 with a 10^{th} percentile CBR value	= 4,6

The design CBR for subgrade section 1 is between 7 and 15 and no selected material will be imported. The in-situ material will be ripped and compacted to a G9 standard (CBR>7) for a depth of 150 mm.

The design CBR for subgrade section 2 is between 3 and 7 and selected material will be imported. The in-situ material will be ripped and compacted to a G10 standard (CBR>3) for a depth of 150 mm and 150 mm material with a CBR>7 will be imported.

Possible pavement structures

Table B8 gives the design options for the basic access street, Category UD, pavement class ES0,03.

Cost analysis

Only the construction cost is considered in Table B9. The granular and emulsion-treated base pavements may be considered as the mechanical construction options. The cost difference of 16,6% between these two options is regarded as significant (more than 10%).

The paving block and macadam options may be considered labour-intensive construction. Although there is not a significant difference in the cost of the block paving and the 75 mm macadam options, the block paving option does offer the advantage of easy access to services if these are installed under the street, or crossing the street.

Table B8: Possible pavement structures for the basic street design example

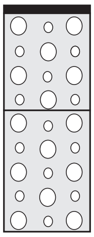
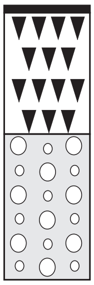
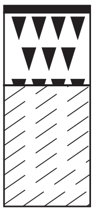
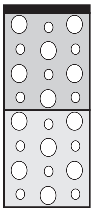
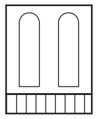
 S1 100 G4 125 G7	 S1 125 M 150 G7	 S1 75 M 125 C4	 S1 100 E3 100 G6	 60 S-B 20 SND

Table B9: Construction cost for the pavement design options for the basic access street example

PAVEMENT	CONSTRUCTION COST (R/m²)	
	LAYER COST	TOTAL PAVEMENT COST
S1 100 G4 125G7	5,10 4,26 4,10	13,49
S1 125 WM 150 G7	5,10 18,75 4,95	28,80
S1 75 WM 125 C4	5,10 11,25 7,71	24,06
S1 100 E3 100 G6	5,10 7,10 3,53	15,73
60 S-B 20 SND	22,80 2,00	24,80

APPENDIX C

MATERIAL TYPES

Materials for paved basic access streets

The specific requirements of each of the material groups for use in paved basic access streets, according to the Weinert Classification are discussed separately below. It should be noted that for arterials, traditional material specifications must be adhered to.

Basic crystalline rocks

The basic crystalline group of materials consists of those rock types which essentially have no quartz component. They include dolerite, gabbro, norite, basalt, greenschist amphibolite, etc. The pyroxene content (and possibly some of the feldspar, to a lesser extent) in basic crystalline rocks generally decomposes to form expansive, highly plastic smectite clays under wet conditions or where drainage is impeded. It should be noted that these clays may also be encountered in dry areas as a result of palaeo-climates and weathering of materials with a natural smectite component.

The presence of smectites is not always adequately shown by plasticity or strength testing and a durability mill test (Sampson and Netterberg 1988), is required to release the clays held in the aggregate. A maximum DMI of 125 is permitted for these materials. In addition a dry aggregate impact value (AIV) (Sampson and Roux 1982) should be carried out and a maximum value of 29 is acceptable. Two samples should be soaked, one in water and the other in ethylene glycol, before AIV tests are carried out on them. If the increase in AIV from the water-soaked to the glycol-soaked samples is more than five units, the material should be rejected. A first indication of the possible presence of smectite clays can be obtained by immersing fragments of the material in ethylene glycol - if they disintegrate within a couple of hours, there is a strong likelihood that smectites are present.

Acid crystalline rocks

The main rock types comprising this group in South Africa are granite, felsite, gneiss, rhyolite and syenite. Quartz makes up a significant proportion of these rocks and, as a result of its hardness and durability, it usually comprises a major proportion of the residual material. Acid crystalline materials thus generally weather to a sandy material comprising quartz, illite and kaolinite, all of these being relatively stable components. As long as the CBR strength at the expected moisture and density regimes is in excess of 50 and the plasticity index is less than 15 (Richards 1978) the material will perform satisfactorily in basic access streets. It is, however, important not to include lumps of oversize material which will break down under traffic and a maximum AIV of 30 is recommended.

A number of problems with acid crystalline rock bases have been attributed to the addition of excessive plastic fines to improve workability. The common practice of adding plastic fines to non-plastic materials for this purpose is discouraged, and where practised should be done only under strict supervision and with careful judgement.

High silica rocks

High silica rocks consist of quartzite, porphyry, hornfels and chert, where quartz or other siliceous materials - possibly with minor amounts of feldspar and clays - comprise the bulk of the rock. The materials are generally strong (provided the grading is not too uniform) and durable and if the CBR strength exceeds 50 the material should perform adequately. It is highly unlikely that durability problems will be encountered with these materials. Care should be taken with the use of chert as this is often derived from the weathering of dolomite in South Africa and is in close association with manganiferous wads and clays, which can have significant plasticities.

Arenaceous rocks

Arenaceous rocks are composed mostly of quartz, feldspars and clays, and occur as sandstone, mica schist, arkose, conglomerate and gritstone in South Africa. The clay minerals in the residual weathering products are generally inactive kaolinite and illite. Arenaceous rocks, apart from having a CBR of 50 at the expected in-situ moisture and density conditions, should have a 10% FACT value of not less than 140 kN (AIV not more than 27) and a soaked value of not less than 75% of the dry value where $N < 5$, and 55% where $N > 10$, in order to identify potentially degrading materials. A maximum fineness product of 125 with a maximum of 35% passing the 40 mesh sieve indicates an adequately durable material (Sampson 1988). If the cementing matrix is siliceous the 10% FACT limit can be dropped to 110 kN.

Argillaceous rocks

Like basic crystalline materials, argillaceous rocks are particularly troublesome as road bases, as they have a strong tendency to slake and disintegrate on exposure to moisture. The rock types making up this group in South Africa are mostly shale, mudrock, phyllite and slate and they should be used in basic access streets with care. The only argillaceous rocks which may be suitable are those relatively hard, partly weathered to unweathered, slightly baked mudrocks which could require extensive treatment (including blasting and crushing) before use and are therefore often not cost-effective for lightly trafficked roads. Certain fissile shales which can be ripped have been successfully used in lightly trafficked roads, particularly in moderate to drier areas where Weinert's N-value exceeds about 3,5. Many mudrocks are likely to slake and disintegrate in service, usually leading to distress if drainage is poor. If no other materials are available, mudrocks can be considered, but their durability according to the recommendations of Venter (1988) should be investigated. A maximum fineness product (Sampson 1988) of 125 with not more than 35% passing the 40 mesh sieve will result in an adequately durable material.

Carbonate rocks

Dolomite, limestone and marble are the main members of this group of rocks. Carbonate rocks are generally unsuitable for base courses for basic access streets, as the unweathered rocks are extremely hard and require blasting and crushing. Weathering of carbonate materials usually results in the rock proceeding directly into solution and not forming adequate residual gravel suitable for base construction. The residual material tends to be fine, consisting of insoluble residue and/or quartz or chert sand with a small quantity of hard, often coarse calcareous and cherty gravel. Where dolomite contains an appreciable quantity of chert, this forms a good gravel but it is classified as a high-silica material, as discussed previously.

Diamictites

Tillite and certain fault breccias are the sole representatives of this material group. The use of diamictite in roads has been investigated (Paige-Green 1984) and has been shown to perform well, even where existing specifications are not met. The durability of some of these materials has sometimes been a problem and the following limits for tillites are thus proposed (mostly after Paige-Green 1984):

maximum PI:	13
minimum CBR:	80
min 10% FACT:	180 kN
min soaked/dry ratio	(10% FACT): 70 if N<2; 56 if N>2
minimum Washington degradation value:	55

A maximum DMI and percentage passing the 40 mesh sieve of 125 and 35, respectively, identify materials unlikely to degrade to plastic fines in service (Sampson 1988).

Metalliferous rocks

This is a very restricted rock group in South Africa, consisting of ironstone, magnetite, haematite and magnesite, which are primarily available as the waste products of iron and magnesium mines. These rocks' very high specific gravities result in excessive haulage costs and they are probably not viable construction materials for basic access streets. If they do, however, occur close to a road project, they can be used with no problems, as they are generally unweathered, already crushed and unlikely to degrade in service. They can, however, like many waste materials, be fairly variable in quality and properties.

Pedocretes

Calcretes and ferricretes (possibly with small quantities of silcretes) are the main pedocretes used in construction in South Africa. Extensive work has been carried out on calcretes (Netterberg 1971; 1982; Lionjanga et al 1987a, 1987b) while local work on the other materials has so far been minimal. It has been shown that calcretes, in particular, exhibit self-cementation properties, and materials with high plasticities (up to 20%) and poor gradings (up to 80% finer than 0,425 mm) have performed well in roads in southern Africa.

A maximum fineness product of 480, with up to 55% passing the 40 mesh sieve is allowable for pedogenic base materials (Sampson 1988). However a minimum CBR of 50 should be obtained.

Surfacing

Bitumen surfacings are described in CSRA 1998 and range from high-quality asphalt surfacings (CSIR, NITRR 1987) to various surface treatments and slurry and sand seals (CSRA 1998). The use of asphalt surfacings (CSIR, NITRR 1987) is probably not affordable for basic access streets carrying less than 75 vehicles per day, but may be the most cost-effective surfacing in the long term, particularly when the maintenance capability is low (SABITA 1992). Traditional asphalt does not have the fatigue properties necessary to avoid cracking under the higher deflections common to light pavement structures.

It is recommended that the surfacing is applied with the prime objectives of waterproofing the underlying pavement layers and providing an all-weather, passable, dust-proof road. Aspects such as bleeding should be tolerated (Netterberg and Paige-Green 1988a) and high skid-resistance is not necessary on those access streets carrying light traffic at low speeds (a PSV of 45-50 will usually be adequate) especially in built-up areas where traffic-calming measures can be justified.

Some of the recommended limits for material properties (CSRA 1998) are probably too strict for basic access streets and relaxations may be implemented. The maximum chipping size recommended for basic access streets is 13,2mm, in order to permit comfortable use of the street for pedestrians and as a recreational area associated with high-density housing. While dusty chippings should be avoided (unless carefully precoated), the use of graded gravel or "Otta" seals (Overby 1998) should be seriously considered. The use of a graded seal results in a smaller percentage of the aggregate being wasted after crushing and a smoother, less noisy pavement. They have been found to absorb high deflections, require low maintenance, have a good resistance to hardening and be very forgiving in terms of their construction.

A relatively recent development in seals is the use of bitumen binders which have been modified by the addition of finely ground rubber or an elastomer. These add significant elasticity to the surfacing which allows it to deflect to a far greater extent without failing by fatigue. Although these binders are more expensive than traditional binders, their cost-effectiveness in terms of years of useful service is usually far greater.

The strength requirement of TRH14 (NITRR 1987) of a 10% FACT of not less than 210 kN is too strict for basic access streets, a value of 120 kN or even 80 kN being satisfactory elsewhere, provided the wet value is not less than 75% of the dry value (Netterberg and Paige-Green 1988a). It is recommended that a minimum soaked value of 80 kN should be taken as the limit for general use in basic access streets, provided the material is unlikely to disintegrate in service (e.g. mudrocks and weathered basic igneous rocks). The minimum aggregate crushing value (ACV) should not be less than 30% with a similar value for the aggregate impact value being recommended, the latter test being much simpler and quicker (Sampson and Roux, 1982). With these weaker aggregates, only pneumatic tyred rollers should be used during rolling of the surfacing stone.

Sands for slurry and sand seals should comply with the sand-equivalent requirements of TRH14 (CSIR, NITRR 1987) but the grading requirements may be relaxed slightly if no better sand is available.

It is expected that most basic access streets will be surfaced with single or Cape seals (CSRA 1998) and the following specifications are thus recommended:

Gradings:

Nominal size:	13,2 m	9,5 mm
% passing 13,2 mm	85-100	
% passing 9,5 mm	0-30	85-100
% passing 6,7 mm	0-5	0-30
% passing 4,75 mm	-	0-5

Other properties:

Flakiness index:	<30
Aggregate impact value:	<30%
Polished stone value:	<40
Dust content (passing 0,075mm):	<1,5 %

A slight relaxation of the grading and flakiness of the coarse aggregate in Cape seals is possible if no other material is economically available.

Stabilised layers

The use of stabilisation for basic access streets is probably not cost-effective much of the time, unless no other suitable materials are available. To adequately avoid carbonation of marginal materials stabilised with lime, cement, slagment or combinations of these (Netterberg and Paige-Green 1983), the stabiliser content should be equivalent to at least the initial consumption of lime (ICL) plus one percent. Bitumen emulsion stabilisation (using low residual emulsion contents) can be cost-effective for improving marginal materials.

Bituminous stabilised sand bases

Three sand-stabilisation techniques using bitumen or tar as a binder can be used (Theyse and Horak 1987) namely

- the cold wet-mix process;
- the foaming process; and
- the hot-mix process.

The sand used in the bituminous stabilised sand bases should contain between 5 and 20% material passing through the 75 mm sieve. If a particular sand type does not comply with the above criterion, filler should be added to the sand.

Cut-back bitumen of a RC-250 or RC-2 grade or a cut-back tar of 15-35C EVT grade may be used in the cold wet-mix process. For the foaming process a 60/70 penetration grade bitumen is normally used, but a 55-60 EVT tar may also be used.

The amount of binder used should preferably be determined by a factorial design method (Theyse and Horak 1987). This will ensure that a true optimum binder content is determined.

Stability criteria for basic access streets are 71 for the Hveem Rt value after moisture-vapour soak, and 200 kPa for vane shear strength (Theyse and Horak 1987). Control during construction is also done with the vane shear (Marais 1966).

Concrete blocks

Concrete or clay blocks are also viable alternatives as a surfacing/base for basic access streets. Blocks are specified as fully interlocking paving blocks, partly interlocking paving blocks and non-interlocking blocks (Clifford 1984). The crushing strength of concrete blocks should be sufficient to avoid excessive breakage during handling. It is possible to make concrete blocks for paving with local materials such as calcrete, laterite and silcrete, including the screened (and washed, if necessary) nodules (Netterberg and Paige-Green 1988a). Bedding sand should be angular with a maximum size of 9,5 mm. Material finer than 75 µm should constitute less than 15% (Shackel 1979). For higher traffic volumes, the design requirements should be considered in more detail (UTG 2 1987).

Material problems

It is important to identify problem materials timeously. Particular note should be made of potentially problematic subgrades, such as expansive clays, collapsible and dispersive soils and saline materials. Techniques have been summarised by Netterberg (1988) and in the SAICE special publication on problem soils (SAICE 1985).

The influence of these geotechnical problems associated with subgrades should not be underestimated for basic access streets where any differential movement in the soil may result in cracking. Poor or infrequent maintenance (e.g. crack-sealing, pothole-patching) will allow water access to a pavement which has not been designed to a standard which will allow for weakening by moisture ingress.

Materials for unsealed streets

The requirements of an ideal wearing course material for unsealed roads are as follows (mostly after Paige-Green and Netterberg 1987):

- stability, in terms of resistance to deformation under both wet and dry conditions (i.e. essentially resistance to rutting and shearing of the wearing course);

- ability to provide adequate protection to the subgrade by distributing the applied loads sufficiently;

- ability to provide an acceptably smooth and safe ride without excessive maintenance;
- ability to shed water without excessive scouring or erosion;
- freedom from excessive dust in dry weather;
- freedom from excessive slipperiness in wet weather without excessive tyre wear;
- resistance to the abrasion action of traffic;
- freedom from oversize stones; and
- low cost and ease of maintenance.

Unsealed basic access streets in urban areas should be designed to satisfy these requirements as far as possible, especially with respect to providing adequate protection of the subgrade. Aspects such as slipperiness, dust and oversize material should be attended to whenever possible, but the prevailing traffic and local situation should be taken into account and reductions in standards may be allowed if:

- the cost of alternative materials is prohibitive; and
- the influence of these factors is acceptable to the community in terms of frequency and consequences.

Earth streets

If the in-situ material (subgrade) conforms with the specifications of normal wearing course materials (described below), no imported layer is necessary. This is the most economic solution in many cases but it is important to ensure that the material is capable of performing adequately. The in-situ material often needs only to be shaped and compacted to a density of not less than 95% Mod AASHTO. Problems with drainage and maintenance may, however, occur if the street is not raised (at least 300 mm) above natural ground level, and it is recommended that, as a minimum, the top-soil (containing vegetable matter) be removed over a width equal to the street and side-drains, the side-drains are excavated, and the gravel from the side-drains is used to form the street. The side-drains should be below the level of the adjacent properties to avoid flooding of these properties during heavy storms.

Many proprietary products are available which claim to "stabilise" and strengthen in-situ materials, but the effectiveness and permanence of each need to be investigated before it is used. These products are mostly material-dependent, performing well with some materials and being totally ineffective with others.

Gravel wearing courses

Numerous specifications for gravel wearing course materials exist in southern Africa (Netterberg and Paige-Green 1988b), but the following performance-related specifications which were developed in southern Africa are recommended for unsealed basic access streets (mostly after CSRA 1990):

Maximum size:	37,5mm
Oversize index (I_o):	0
Shrinkage product (S_p):	100-240
Grading coefficient (G_c):	16-34
Soaked CBR:	>15 at 95% Mod AASHTOdensity
Treton impact value:	20 to 65

where

I_o = mass of material larger than 37,5mm in a bulk sample as a percentage of the total mass (Paige-Green 1988);

S_p = product of linear shrinkage and percentage passing 0,425 mm (calculated as a percentage of the material finer than 37,5 mm);

G_c = product of the percentage retained between the 26,5 mm and 2,0 mm sieves and the percentage passing the 4,75 mm sieve/100.

The plasticity-grading relationship in terms of performance is illustrated graphically in Figure C1 with the performance of the materials falling into each zone (A, B, C, etc) being identified.

All material testing follows standard TMH 1 (CSRA 1986) methods, although particle size distributions (for both G_c and S_p) are normalised for 100 per cent passing the 37,5 mm sieve (Paige-Green 1988). The performance illustrated in Figure C1 is that predicted by the two properties illustrated. Other aspects such as excessive oversize material or soft aggregate will have separate effects on the performance. An advantage of the figure is that the consequences of being slightly out from the ideal specification can be judged and the acceptably of using these materials can then be evaluated.

Specific characteristics and problems related to the various Weinert material groups identified previously are summarised below:

Basic crystalline rocks

Basic igneous rocks generally provide good wearing course materials but commonly contain rounded ("spheroidal") cobbles and boulders formed during weathering, particularly in the drier areas (Weinert N > 5). All of the cobbles and boulders must be removed (generally by hand, as they will not be broken down by a grid roller) prior to use of the material in unsealed roads, in order to eliminate their influence on riding quality and facilitate easy maintenance. In the intermediate areas (N = 2 to 5), the material often weathers to a sandy material (e.g. "sugar dolerite"), which makes a good wearing course but may corrugate quite badly. In the wetter areas (N < 2) basic crystalline rocks usually weather to a high plasticity material which becomes slippery when wet and dusty when dry.

Field evidence indicates that the use of basic crystalline rocks with few spheroidal boulders (less than 5 percent by mass larger than 37,5 mm), a plasticity index (PI) between 6 and 12 and a linear shrinkage of between 3 and 6 result in acceptable performance with minimal maintenance. A shrinkage product of less than 240 is recommended to minimise dust.

Acid crystalline rocks

These materials generally weather to a low-plasticity, sandy material with a few large, round boulders of hard rock. Corrugations are a significant problem on many streets constructed with acid crystalline rocks but regular maintenance with a simple tyre, brush or other type of drag can remove the corrugations. A PI of at least 6 will generally give good results, but in drier areas (N > 5) a PI higher than this (> 12) is recommended. Acid crystalline materials tend to be less dusty than most other materials, particularly in arid areas.

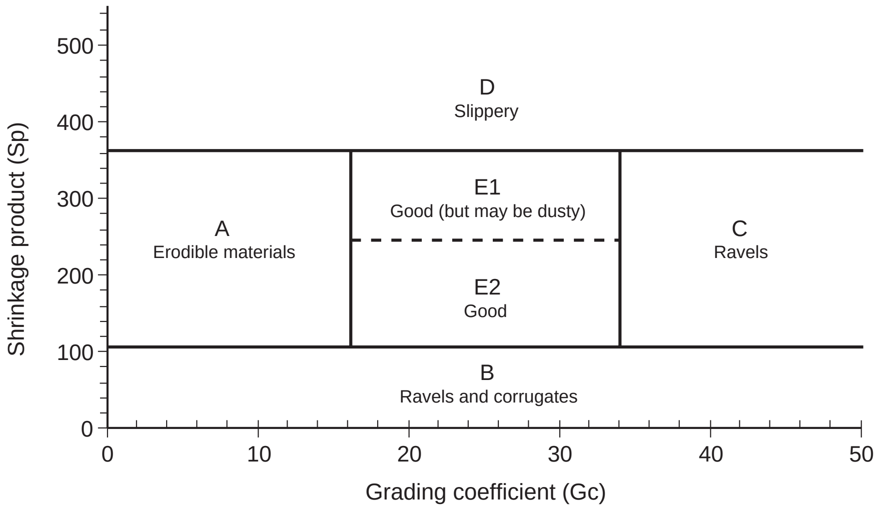


Figure C1: Relationship between shrinkage product, grading coefficient and performance (CSRA 1990)

High silica rocks

Suitable high-silica rocks for gravel wearing course are chert and quartz porphyry, both providing good wearing courses, provided the large stones are removed (especially from the chert gravels) but often producing dusty conditions - especially in wet areas. These materials often have a lack of fines and low plasticity which results in ravelling and corrugation development. Some plasticity (a linear shrinkage of more than 3) is necessary to avoid the formation of severe corrugations.

Arenaceous rocks

These materials either tend to weather to very sandy materials with little coarse aggregate or else coarse gravels with a lot of oversize, which will not break down adequately under a grid roller (particularly siliceous sandstones and quartzites). Without crushing, the latter materials are generally unsuitable. The softer sandstones (Treton value higher than 65) tend to break down and form potholes while if the linear shrinkage is less than about 3, corrugations tend to develop. The plasticity index is not a suitable indicator of performance.

Argillaceous rocks

Argillaceous rocks tend to be very stony or very clayey, depending on the weathering environment and their stage of weathering, and are invariably extremely dusty. In wet weather the argillaceous materials tend to become slippery due to their high clay-mineral content. The fissile (laminated) shales provide a relatively good wearing course, but the angular fragments frequently cause tyre damage and make the road difficult to maintain. Argillaceous rocks are therefore not recommended for wearing course unless well fragmented and treated with an appropriate dust palliative.

Carbonates

These materials seldom form an adequate quantity of material for the establishment of a viable borrow-pit in southern Africa, and are not considered as suitable wearing course materials. Many South African cherts (classified as high-silica materials) usually contain fragments of dolomite in their aggregate component.

Diamictites

Weathered diamictites have been successfully used as wearing course gravels, provided the erratic content (medium to large boulders of hard material, especially quartzite) is not too high. Their glacial origin results in a tendency to be relatively variable, and some of the tillites may form excessive plastic material that results in slippery streets when wet, while most weathered tillites give dusty conditions.

Metalliferous rocks

Because of the hardness, low plasticity and high specific gravity (resulting in high haulage costs) that are typical of these materials, they are not particularly suitable for unsealed streets. In mining areas, some waste may be suitable as a wearing course for unsealed streets but local experience will be the best guide. If the plasticity is too low (mostly the case) corrugations can be expected. Because most gravels in this class have been produced by mining and crushing, they tend to be dusty.

Pedocretes

Pedocretes are potentially the most important materials for unsealed streets in southern Africa, with calcrete being widespread in the more arid areas and ferricrete predominating in the less arid eastern areas of South Africa. Sources with good properties for unsealed road construction are, however, rapidly being used up in developing areas. The performance of calcrete wearing courses is generally good (although the materials are often extremely dusty and may contain large cobbles and boulders which are not easily broken down during construction). Ferricretes are equally satisfactory materials but like calcretes are likely to contain an excess of oversize material which should be removed or adequately broken down. Pedocretes with a PI of between 6 and 15 have provided good performance in wet and dry areas of southern Africa.

Stabilised earth streets

The use of lime- or cement-stabilised earth streets is common in certain parts of Europe (Kézdi 1979) and could possibly be considered for local application. No research has as yet been carried out on these materials locally, but the problem of carbonation (Netterberg and Paige-Green 1983) and the potential loss of strength resulting from this process may be significant. However, it is considered that, even with carbonation, the ravelling and abrasion will probably be less than with a natural gravel although maintenance may be a problem as the loose material is likely to be non-plastic (and very dusty). Further research into this possible solution is necessary but, for the present, its use should be based on sound engineering judgement.

Dust palliatives

It is often difficult to obtain materials which will provide a dust-free surface. Dust palliatives are chemical or bituminous agents which are mixed into the upper parts or sprayed on the surface of a gravel wearing course and bind the finer portions of the gravel, thus reducing dust. A wide variety of dust palliatives is available and economic analyses need to be carried out for each product in each situation to determine their viability. The social impact of dust is, however, difficult to quantify in economic terms but should not be neglected from any analyses. Recent research has shown that the deliquescent products (usually calcium chloride), the ligno sulphonates, certain polymers and some liquid chemical stabilisers (LCS) can provide good dust palliation, cost-effectively. Dust palliatives have been fully discussed earlier in this chapter.

Most dust palliatives have so far been tested on rural and inter-urban roads. The environment in a residential area is completely different in terms of drainage, traffic volumes and speed, intersections, etc. One aspect which needs to be considered is the ease of maintenance of treated roads. Road surfaces which are treated with products that do not penetrate into the layer cannot easily be maintained once potholes and ravelling initiates. Similarly, materials which strengthen the road considerably (e.g. liquid chemical stabilisers) do not allow grader maintenance should large stones protrude from the surface, as they are not easily plucked out and lead to unacceptable roughness. The optimum solution is to mix appropriate products through the layer, ensuring that all large stones (greater than 37,5 mm) are removed from the wearing course material.

No general guideline for dust palliatives is currently available but a research project involving a performance-related study of a limited number of generic dust palliatives is in progress.

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