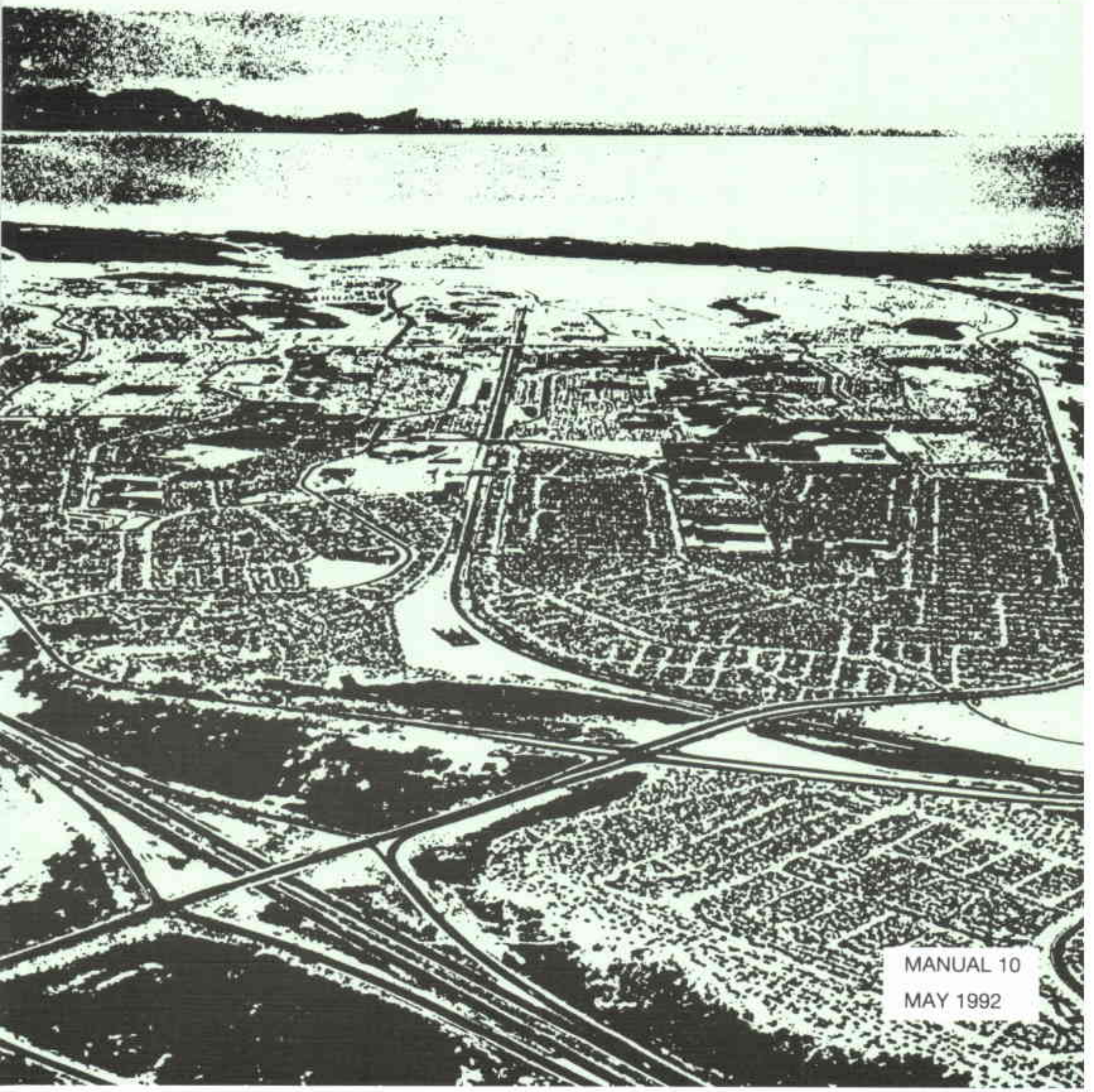
Appropriate Standards for Bituminous Surfacings

FOR LOW VOLUME ROADS



SOUTHERN AFRICAN BITUMEN AND TAR ASSOCIATION

APPROPRIATE STANDARDS FOR BITUMINOUS SURFACINGS

Manual 10
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SOUTHERN AFRICAN BITUMEN AND TAR ASSOCIATION

Preface

The Southern African Bitumen and Tar Association began its needs driven Asphalt Research Programme in 1988 by means of an Asphalt Research Strategy Task Force (AREST). This task force established a number of directions for research based upon the needs of industry and its clients.

The research project *Appropriate Standards for Effective Bituminous Seals* was commenced at the CSIR Division of Roads and Transport Technology with the goal of providing consulting engineers and client bodies with guidelines on the selection of suitable surfacings for low volume roads throughout southern Africa.

The research work focussed on existing and accepted economic assessment models and obtained performance criteria from practice, through interviews and field inspections in the broader southern African region.

Roads in urban, township, rural and semi-rural areas were tested. The economic analysis were performed on a wide range of surfacings for varying assumptions to measure their cost-effectiveness.

The purpose of this manual is to provide guidelines to practitioners from rural road authorities, city and town engineers and development agencies on the choice and selection of bituminous surfacings for low volume roads. This manual is a complement to the existing surfacing design manuals used in South Africa, such as TRH 3: surfacing seals for rural and urban roads, and other design manuals such as TRH 4 and TRH14.

Sabita's *Manual 10: Appropriate Standards for Bituminous Surfacings for Low Volume Roads* has addressed the needs identified at AREST and has incorporated the wider range of design criteria to be addressed in selecting bituminous surfacings for use in the broader southern African region. The manual forms part of the ongoing implementation strategies of Sabita's Asphalt Research Programme.

Acknowledgments

Many individuals associated with the asphalt and bituminous surfacing industry, its clients and consulting engineers in southern Africa have contributed towards this manual and their assistance is acknowledged. Special acknowledgment is due to:

CSIR Division of Roads and Transport Technology

Project Leader	S.J. Emery	Consultant,	DRTT, CSIR
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Scope

The manual covers the choice of bituminous surfacings for low volume roads. In Section 2, comprehensive but easy to use graphs are presented to assist in the choice of bitumen or gravel surfacings for low volume roads. These have been developed from economic and financial cost analyses.

In section 3, methods are presented to choose the bituminous surfacings which will give good performance for various conditions. These choices encompass first and third world environments, rural and urban areas, and wet and dry climates. They take into account the environment (first or third world), gradient, drainage and maintenance capabilities; other factors such as intersections, basecourse stabilisation, soil wash and communal water systems are also considered.

In Section 4, a method is provided to rapidly determine the lifecycle cost of the alternative surfacing choices. The most cost effective surfacing can then be chosen.

List of manuals published by Sabita

Manual 1	Construction of bitumen rubber seals
Manual 2	Bituminous products for road construction
Manual 3	Test methods for bitumen-rubber
Manual 4	Specifications for rubber in binders
Manual 5	Manufacture and construction of hot-mix asphalt.
Manual 6	Interim specification bitumen-rubber
Manual 7	Economic warrants for surfacing roads
Manual 8	Bitumen safety handbook
Manual 9	Bituminous surfacings for temporary deviations
Manual 10	Appropriate standards for bituminous surfacings

Contents

1. INTRODUCTION

1.1 *Background*

The guidelines contained in this document are based on the findings of a SABITA-sponsored research project "Appropriate Standards for Effective Bituminous Seals". The project is aimed at low volume roads. The background information required to produce this document is mainly contained in the final report of the project (Emery et al, 1991).

The project consisted of interviews with a wide range of practitioners, field investigations of surfacing performance at 98 roads across South Africa, and cost/benefit analyses of various bituminous surfacings under a comprehensive range of conditions.

The surfacing types considered covered the full range of thin bituminous surfacings from dust palliatives to asphalt.

1.2 *Interviews*

Interviews were held with a cross-section of engineers and technicians from a wide range of backgrounds: bitumen industry, provincial and regional and urban authorities, consultants, contractors, and rural road authorities. Because this project is aimed at low volume roads, and in particular roads which hitherto had lain outside the normal market for bituminous surfacings, the focus tended to be on roads outside the arena of the provincial road authorities.

1.3 *Field work*

In the fieldwork 98 roads were visited to investigate as many different surfacings as possible and determine the influence of the full range of external factors. A factorial experimental design approach was used. The factors included systematically were: urban and rural drainage (eg kerb vs shoulders), climatic conditions, and pavement structure. The factors included randomly were traffic volume, surfacing type, and surfacing age.

The first stage of the fieldwork was to visit each road and perform various measurements and field and laboratory tests.

The second stage was to revisit each road with a panel of experienced engineers to evaluate the surfacing performance and surfacing life.

1.4 *Cost benefit analysis*

Cost benefit analysis, using the SABITA computer programme SURF1, was undertaken to compare the economics of bitumen surfaced roads with gravel roads. Life cycle costs were determined for a full range of surfacing types. This was done in terms of financial costs (construction and maintenance) and economic costs (construction, maintenance, vehicle operating costs, accident and time).

The cost analysis covered a full range of factors including location of project, cost of aggregate and binder, size of contract, haulage, pavement upgrade prior to surfacing, maintenance, street cleaning, discount rate, traffic growth rate, economic region, terrain, and surfacing life.

1.5 *Scope*

This document is aimed at providing guidelines for:

- the economic justification for bitumen surfacings compared to gravel roads;

- the selection of appropriate surfacings to ensure that the surfacing will give good performance under the actual conditions of gradient, traffic, turning vehicles, road maintenance capability, pavement structure, climate, etc.

- determining the life cycle costs of appropriate surfacings and therefore the most cost effective surfacing.

Additional guidelines are provided for surfacings for forestry and parks roads, and the use of marginal materials in surfacings for low volume roads.

2. CHOOSING A BITUMEN OR GRAVEL SURFACING

Low volume roads may have either a gravel surface or a bitumen surface. A gravel surface is less expensive initially, but the maintenance costs are higher than those of a paved road. Bituminous surfacings have the advantage of improved riding quality, absence of dust, all weather access and an improved quality of life for the community. The decision to pave the road is made on the basis of costs and benefits.

2.1 *Decision to pave the road*

The decision to pave the road will fall into one of three groups of increasing complexity, reflecting an increasing level of decision sophistication:

FINANCIAL	is it less expensive to the road authority to pave the road **OR** keep the road as a gravel road and pay the high costs of maintenance, i.e. grading and regravelling
ECONOMIC	is it less expensive to the community to pave the road **OR** keep the road as a gravel road and pay the relatively higher costs of maintenance, vehicle operating costs, safety and productivity
SOCIO-POLITICAL	is the road to be paved to improve the quality of life (factors such as dust, mud, all-weather access) or to create employment opportunities or development spin-offs

One should determine whether a financial, economic or socio-political decision would be more appropriate. At present the methodology to quantify socio-political decisions does not exist, and these are generally incorporated by making qualitative assessments. It is suggested that economic analysis should generally be used as the starting point for projects where socio-political decisions are to be overlaid onto the analyses. The recommendation for the use of financial or economic analyses is made in Table 2.1

Table 2.1 **ANALYSIS TO BE USED FOR ROAD SURFACING DECISION**

ROAD / PROJECT	APPROPRIATE BASIS FOR DECISION
Urban Urban/township Rural (Bank* funded) DOT funded roads Parks, forestry Socio-political decision to upgrade Politically sensitive issue	ECONOMIC ANALYSIS
Rural (non-Bank* funded) Private roads Military	FINANCIAL ANALYSIS

* Bank: i.e. World Bank, Development Bank of Southern Africa, African Development Bank, etc.

2.2 *Cost benefit analysis*

Extensive cost benefit analyses were performed for a wide range of conditions and factors including construction costs, size of project, location of project, maintenance, economic region, traffic growth rate, terrain, and discount rate. The costs were calculated as life cycle costs in real terms over a standard 10 year analysis period. Salvage value was included to ensure the results were valid for longer analysis periods. The costs were discounted at a rate of 8% to give present worth of costs (PWOC). Undiscounted lifecycle costs were also considered.

For the financial analyses the following costs were considered:

construction costs
maintenance costs

For the economic analyses the following costs were considered:

construction costs
maintenance costs
vehicle operating costs
accident costs
time costs

Example:	Determine the financial life cycle costs of a pavement:

Surfacing life	8 years
Analysis period	10 years
Construction cost	20 000/km
Reseal cost	10 000/km
Routine pavement maintenance	500/km/year

ANNUAL MAINTENANCE AND CONSTRUCTION COSTS		
YEAR	ACTUAL	DISCOUNTED (8%)
0	20 000	20 000 (construction cost)
1	500	463 (maintenance cost)
2	500	429
3	500	397
4	500	368
5	500	340
6	500	315
7	500	92
8	500 + 10 000	5673 (maint. cost + reseal cost)
9	500	250
10	500 - (10 000*6/8)	-3242 (maint. cost - salvage value)
DISCOUNTED TOTAL		25285

(A more detailed explanation and more examples are given in Emery et al., 1991).

2.3 *Benefit of a bitumen surfacing at varying traffic volumes*

The benefit of a bitumen surfacing was computed for three traffic volumes: 50, 200 and 500 vpd. From this data, the breakeven traffic volume (at which the benefits and costs were equal) was calculated on both a financial and economic basis. This breakeven traffic volume is the number of vehicles per day at which surfacing the road can be justified. Below this level the gravel road is more cost-effective.

This analysis does not include the benefits accruing from socio-political and socio-economic aspects such as development benefits, job creation and skills transfer.

The breakeven traffic volumes were calculated for several different sets of assumptions:

AVE Average assumptions, average construction cost

- no basecourse upgrade
- rip and recompact the gravel wearing course
- 3% traffic growth rate, which is average
- 8% discount rate
- rolling terrain
- average construction costs

LOW Average assumptions, low construction cost

- no basecourse upgrade
- no rip and recompact unless implicitly required
- 3% traffic growth rate
- 8% discount rate
- rolling terrain
- low construction costs

HIGH Average assumptions, high construction cost

- basecourse upgrade, where the existing gravel road needed a new 150mm layer of basecourse material before surfacing
- 3% traffic growth rate
- 8% discount rate
- rolling terrain
- high construction costs

MAX Worst assumptions, highest cost

- basecourse upgrade as discussed for high construction cost
- 1% traffic growth rate, which is low
- 10% discount rate
- flat terrain
- high construction costs

MIN Best assumptions, lowest cost

- no basecourse upgrade
- no rip and recompact unless implicitly required
- 5% traffic growth rate, which is high
- 6% discount rate
- mountainous terrain
- low construction costs

2.4 *Traffic volume to justify a bitumen surfacing*

The analysis of traffic volume to justify a bitumen surfacing is illustrated in Figure 2.1. For the LOW assumptions, there are three ranges of traffic volume which give rise to three different answers to the question of whether a surfacing is justified or not:

- at the lower traffic levels, no surfacing is justified;
- in the middle range of traffic (shown by the bar for each set of assumptions), the various surfacings become progressively justified as the traffic volume rises. Generally at the lower volumes only the thin surfacings such as seals are justified. As the traffic volume rises additional surfacings such as Cape Seals and asphalt also become justified;
- at the higher traffic levels, all surfacings are justified.

The graph in Figure 2.2 should be used for a financial analysis and the graph in Figure 2.3 for an economic analysis.

Two factors to be borne in mind are that the traffic volume may jump sharply just as an unpaved road is paved due to the attracted traffic from other routes, and this should be allowed for in addition to the long term traffic growth rate. Secondly, gravel is becoming more scarce as the available deposits are used up and in future this will result in bitumen surfacing being justified at lower traffic volumes.

WORKED EXAMPLE

There is an existing gravel road in an established Transvaal township. The existing pavement structure is reasonable, but the gravel wearing course is poorly maintained. The houses are of reasonable standard, with no squatters. Traffic is 300 vehicles per day and growing at 5% per annum. Gradients average 3 - 7%, with occasional steeper sections. No commercial traffic is expected, and bus traffic is confined to selected roads.

STEP A	WHAT SURFACING IS JUSTIFIED

A1: **Choose analysis method**
This is an urban/township road with socio-political overtones. From Table 2.1, choose economic analysis.

A2: **Is bitumen justified?**

The basecourse will need some work before surfacing. Construction costs are low because the work is close to a major Reef city. Traffic growth rate is 5%. From Section 2.3, the assumptions are probably AVE. From Figure 2.3, clearly a bitumen surfacing is justified at any traffic over 160 vehicles per day.

FIGURE 2.1
EXAMPLE OF THE USE OF FIGURES 2.2 AND 2.3

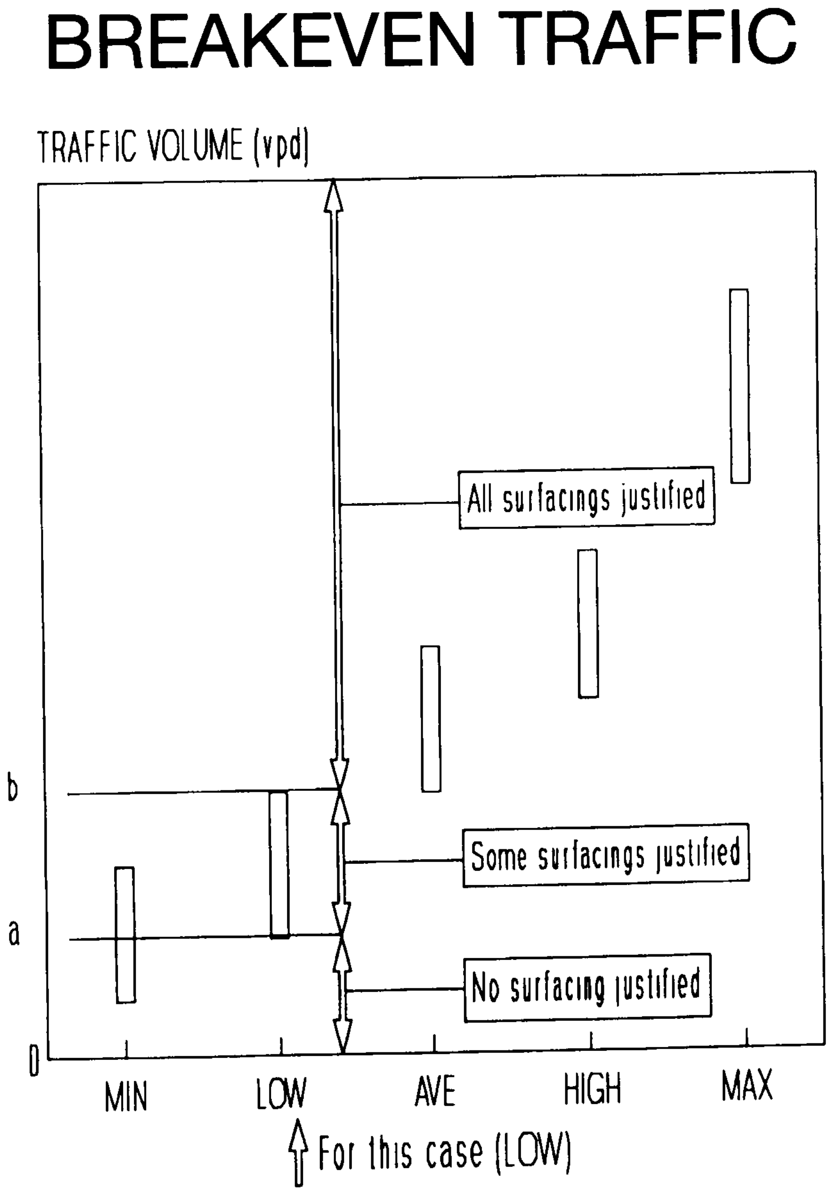


FIGURE 2.2
JUSTIFICATION FOR SURFACING - FINANCIAL ANALYSIS (EXCLUDING ROAD USER COSTS)

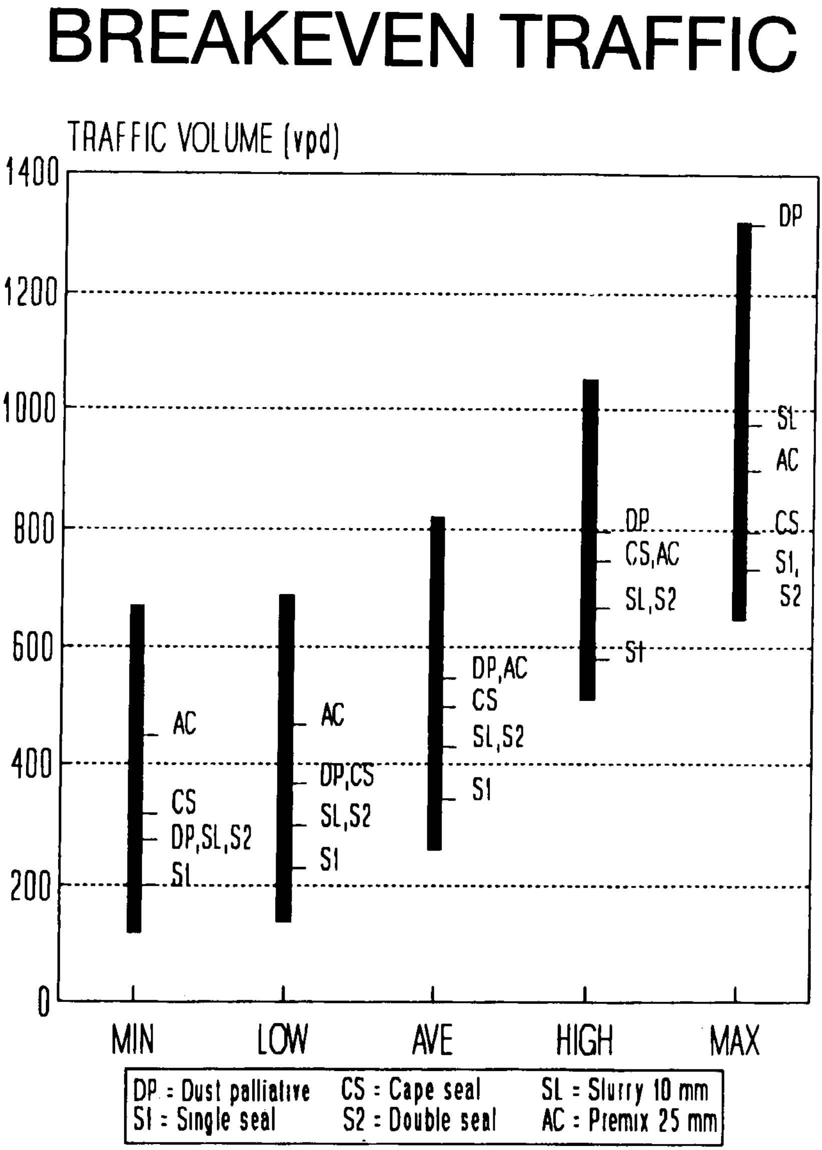
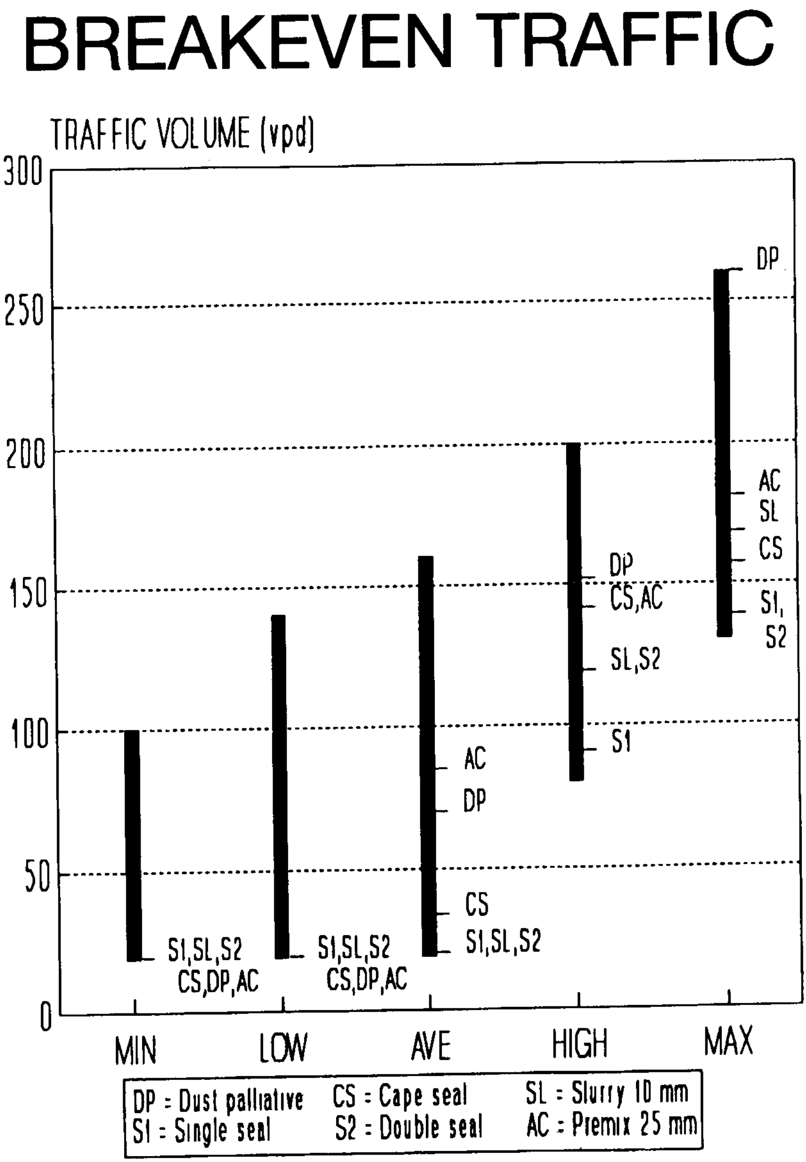


FIGURE 2.3
JUSTIFICATION FOR SURFACING - ECONOMIC ANALYSIS (INCLUDING ROAD USER COSTS)



3. CHOICE OF APPROPRIATE BITUMINOUS SURFACINGS FOR GOOD PERFORMANCE

Once the decision has been made to surface the road (Section 2), the selection of the appropriate bitumen surfacing types is done to take into account the actual conditions on the road.

The surfacing type must be reviewed for each set of conditions. One should not assume that any previous good experience with a particular surfacing type is applicable for different environmental conditions. This is particularly true for the lighter surfacings such as single seals, sand seals and thin slurries.

In choosing the appropriate surfacing, there are three main aspects to consider: environment, maintenance capability, and gradient, and a surfacing should not be chosen if it is unsuitable for one or more aspects. The various sub-sections contain the various recommendations:

Section 3.1	Environment
Section 3.2	Maintenance capability
Section 3.3	Gradient
Section 3.4	Notes on individual surfacings
Section 3.5	Intersections
Section 3.6	Pavement structure
Section 3.7	Reseals

The worked example is continued at the end of this section.

3.1 *Environment*

Environment in terms of climate and socio-economic aspects is a major factor in determining surfacing performance. There were many variables which described the environment, and factor analysis was used to extract the underlying factors. As a result, four main environments were found for bitumen surfacing design in South Africa:

First world higher pavement standards	Busier roads, well constructed surfacing, good pavement structure.
First world lower pavement standards	Light pavements with rural drainage but including some urban areas, not mountainous, light pavement structure.
Wet/hilly	Mountainous, Thornthwaite's climatic 1m>0, typically wet areas of Natal, Eastern Transvaal and Eastern Cape.
Third world	Essentially urban, essentially lower socio-economic groups, dense housing, urban drainage, little or no maintenance capability.

For these different environments, the choice of surfacing must be varied.

Table 3.1 **ENVIRONMENT**

ENVIRONMENT	SURFACING RECOMMENDATION
First world - high pavement standards	Any
First world - lower pavement atandards	Any: caution with thin surfacings because they need timeous maintenance; refer to maintenance table
Wet/hilly[a]	Refer to maintenance and gradient tables
Third World[a]	Refer to maintenance and gradient tables

Note:

a. No direct recommendation possible due to the wide variation in conditions. Asphalt is the only surfacing which showed up as consistently appropriate.

3.2 *Maintenance capability*

The thinner seals can give good performance if they receive adequate routine maintenance. If there is no maintenance capability, then only those surfacings which are inherently tough can survive, which generally means the thicker surfacings. The observed maintenance capabilities of the various road authorities varies widely depending on institutional capability and budget.

Table 3.2 **MAINTENANCE CAPABILITY**

MAINTENANCE CAPABILITY	DEFINITION	SURFACING RECOMMENDED
High	Can perform any type of maintenance whenever needed	Any
Medium	Routine maintenance patching and crack sealing on a regular basis, but no MMS[d]	Asphalt, Cape Seal slurry[a], double seal single seal[b]
Low	Patching done irregularly, no committed team, no inspection system	Asphalt, Cape Seal, thick slurry, double seal[c]
None	No maintenance	Asphalt

Notes:

a. Thin slurries can lead to construction problems.

b. Rural only.

c. This is sensitive to construction problems and should only be used where there is a long maintenance period.

d. A maintenance management system is not in itself essential but its presence indicates a certain level of sophistication.

3.3 *Gradient*

Gradient limits are important to limit damage caused by water running on the surfacing, especially for roads with urban drainage systems such as kerbs. Gradient limits also apply to limit damage caused by shoving.

Table 3.3 **GRADIENT LIMIT**

GRADIENT	SURFACING RECOMMENDATION FOR INITIAL SURFACING
< 6%	any surfacing
6 - 8%	asphalt, Cape Seal[d], thick slurry[ad], double seal[cd], single seal[bcd], sand seal[bc]
8 - 12%	asphalt, Cape Seal[de], double seal[cde], single seal[abcde], sand seal[abc]
12 - 16%	asphalt, Cape Seal[ad], double seal[acd]
> 16%	concrete block/concrete

<u>Notes:</u>

a. Not on stabilised basecourse.

b. Not if channelling of water flow expected due to soil wash which is common in third world environments.

c. Not if urban drainage.

d. Not if communal water systems present, since these lead to detergents washing on the road and erosion of the bitumen.

e. Not at gradients above 10% if channelling of flow expected due to soil wash which is common in third world environment.

General: Geotextile-reinforced bituminous surfacing not recommended at gradients above 6% at present: further research is underway on gradients of 8-10%.

Table 3.4 **NOTES ON INDIVIDUAL SURFACING TYPES**

ASPHALT	Excellent performance under all conditions. Requires asphalt plant nearby and good quality control. High construction cost, good lifecycle cost, generally maintenance free, poor if very weak pavement structure. Excellent for urban roads. The smooth strong appearance gives an image of a high quality surfacing. Good for areas where the road forms a large part of the habitat. Good if the road is used as a playground. This is the lowest risk surfacing of all. General agreement that minimum thickness required is 25mm.
CAPE SEAL	Good performance under most conditions. Reported to need good construction quality. The smooth strong appearance gives an image of a high quality surfacing. Good for areas where the road forms a large part of the habitat. Good if the road is used as a playground. This is a medium risk surfacing. It is a stiff surfacing which can cause problems on roads with weak pavement layers.
DOUBLE SEAL	Both stone/stone and stone/sand seals where there are at least two engineered applications of binder) Good performance in rural areas and fair performance in urban areas. Needs at least 50 v.p.d. to keep binder alive. This is a medium risk surfacing. The use of sand as the second application of aggregate (in an engineered application with a second spray of bitumen) has the advantage that the sand binds the lower layer of stone and reduces complaints about broken wind screens, but makes for a stiff seal and it was observed that this gave problems on roads with weak pavement layers.

Continued on page 22

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SLURRY	Fair performance if thick, and poor performance if thin, when used as an initial surfacing. It is vulnerable to pedestrian and vehicle damage while fresh. As an initial surfacing it should be applied in two layers each of 6-10mm since a single 6mm layer will ravel quickly due to inadequate depth on high spots in base. Thin slurry is not recommended on its own as an initial seal. Suitable for labour enhanced construction. This is a medium risk surfacing. The smooth appearance gives an image of a quality surfacing. Good for areas where the road forms a large part of the habitat. Good if the road is used as a playground. The quickset slurries are very useful where road closure time is limited, or in shade or cool weather. It is a stiff surfacing which can cause problems on roads with weak pavement layers.
SINGLE SEAL	Fair to poor performance. Often gives problems due to nozzle blockages and other defects during construction, and is only acceptable if good maintenance and construction expected. This is a high risk surfacing.
SAND SEAL	Fair performance if thick, and fair to poor performance if thin. It is more of a temporary surfacing and must be resurfaced (often with a second sand seal) within a year. Botswana report good performance from thick graded sand seals (Otta seals). This is a high risk surfacing if thin, and medium risk if thick. It is a stiff surfacing which can cause problems on roads with weak pavement layers.
DUST PALLIATIVE	Fair to poor performance. It is more of a temporary surfacing. It is vital to reseal timeously before maintenance costs rise. Not suitable for low maintenance environments. This is a high risk surfacing. Can be a good temporary surfacing prior to stone reseal.

3.5 *Intersections*

When the road is subject to turning heavy vehicles, the thinner surfacings can be damaged due to scuffing.

Table 3.5 **INTERSECTION AND OTHER AREAS SUBJECT TO TURNING VEHICLES**

LOCATION	SURFACING RECOMMENDATION
Rural with occasional heavy vehicles	Any
Residential-first world	Most (not single seal, sand seal, thin slurry, dust palliative)
Residential-third world	Asphalt, thick slurry, Cape Seal
Urban - occasional heavy vehicles	Cape Seal, asphalt, double stone seal with fogspray and sand blinding
Urban - many heavy vehicles	Asphalt, concrete/concrete blocks, epoxy asphalt

3.6 *Pavement structure*

The performance of the surfacing depends to an extent on the surface deflection and thus the pavement structure. The minimum pavement structure required varies widely with traffic and surfacing type. It is known that for low volume roads the pavement structure can be reduced below that of TRH 4. Structurally a material with a CBR strength of 30 to 50 at field moisture content (Kleyn and Van Zyl, 1987) with 95% Mod AASHO density (Paige-Green and Sampson, 1990) is adequate for lightly trafficked roads, although this would have to be classified as weak by normal road standards.

The more flexible surfacings can accommodate higher deflections without fatigue failure; modified binders improve the ability of most surfacings (except slurries) to accommodate these higher deflections. Geotextile reinforcement enables most surfacings to accommodate high deflections.

Table 3.6 **RECOMMENDED SURFACING PROPERTIES FOR VARYING PAVEMENT STRUCTURE AND TRAFFIC**

WEAK PAVEMENT STRUCTURE

(DSN_{800} < 88)

Traffic	**Surfacing properties**
Heavy	strength, flexibility
Light	high binder content, richness, flexibility

STRENGTH AND FLEXIBILTIY OF SURFACINGS

STRENGH (HIGH at top) / FLEXIBILITY (LOW to HIGH)		
asphalt	mod asphalt	
thick slurry S2 - stone/ sand seal	triple seal S2 - stone only	mod.51
	thin slurry sand seal dust pall.	single seal

NORMAL PAVEMENT STRUCTURE

(DSN_{800} > 88)

Traffic	**Surfacing properties**
Heavy	strength
Light	high binder content,

high film thickness

3.7 *Reseals*

The selection of surfacing for a reseal depends on the current condition and distress types and severity, the requirements of the condition after reseal, and the cost of the different possible actions. The performance of a surfacing as a reseal can be quite different from its performance as an initial seal, and the selection of reseal type is more complex than the selection of the initial surfacing.

Table 3.7 **SIMPLIFIED DECISION TABLE FOR THE SELECTION OF RESEAL TYPES FOR LOW VOLUME ROADS**

RUTTING	TEXTURE	CRACKING	RECOMMENDATIONS[a]
< 10mm	Coarse or varying	Little	Sand seal, slurry, Otta seal, inverted double seal, asphalt
		Severe	Inverted double seal[b], double seal[b], texture treatment+single seal[b], asphalt
	Fine	Little	Single seal, sand seal, slurry, Otta seal, doubleseal, Cape Seal, asphalt
		Severe	Double seal[b], single seal[b], asphalt
> 10mm		Little	Inverted double seal, coarse slurry, asphalt
		Severe	Inverted double seal[b], coarse slurry+single seal[b], asphalt

<u>Notes</u>:

a. Refer to constraints in this section as well.

b. Modified binder preferred for high crack severity.

WORKED EXAMPLE

There is an existing gravel road in an established Transvaal township. The existing pavement structure is reasonable, but the gravel wearing course is poorly maintained. The houses are of reasonable standard, with no squatters. Traffic is 300 vehicles per day and growing at 5% per annum. Gradients average 3 - 7%, with occasional steeper sections. No commercial traffic is expected, and bus traffic is confined to selected roads.

A bitumen surfacing is justified *(Section 2).*

STEP B CHOOSE ALL POSSIBLE APPROPRIATE SURFACINGS

B1: **Select by environment**
Existing township with high population density, lower socio-economic groups, and urban drainage. Table 3.1: Third World - closely check the maintenance and gradient tables.

B2: **Select by maintenance**
Routine maintenance on the existing road infrastructure is known to be irregular and poor. Budget restrictions and lack of skills means that this is not expected to improve. Assess maintenance capability as low. Table 3.2: select all of asphalt, Cape Seal, thick slurry, double seal. Note that double seal is only suitable if there is a long maintenance period.

B3: **Select by gradient**
The gradients are 3 - 7%. Table 3.3: from 6-8%, select all of asphalt, Cape Seal, thick slurry, double seal. Note that single seal and sand seal are not considered because they were ruled out on maintenance grounds. There is no communal water system so there are no problems with Cape Seal, thick slurry or double seal. The new basecourse will not be stabilised so thick slurry is not ruled out. The drainage is urban, so double seal is ruled out.

B4: **Check notes of each surfacing type**
Table 3.4: Asphalt: there is a plant nearby; construction cost may be a problem; the roads will probably be used as play-grounds; use 25mm as a minimum thickness. Cape Seal: need adequate supervision/good contractor; the roads will probably

be used as playgrounds; recheck that the pavement is not too weak (see step B6 for this). Slurry: thick slurry is suitable; there will be problems with pedestrian and vehicle traffic during construction in this built up area; apply in two layers; check with client if labour enhanced construction is an objective; check if quickset slurries are available for the busier roads.

B5: **Check intersections**
Table 3.5: most of the township will be residential third world, so the choice of asphalt, thick slurry, or Cape Seal will be suitable for intersections. At the bus terminus and in the truck unloading area of the shops, the area will be classified as urban - many heavy vehicles, requiring asphalt, concrete/concrete blocks, or epoxy asphalt.

B6: **Check pavement structure**
The existing pavement structure with a new basecourse will be structurally adequate for the traffic with the DCP blow count to 800mm depth (DSN_{800}) over 88. Consider higher binder content in the detailed surfacing design.

Appropriate surfacings are asphalt, Cape Seal and thick slurry.

COST-EFFECTIVENESS OF CHOSEN BITUMEN SURFACINGS

Once the appropriate surfacing types have been selected using Section 3, their life cycle cost is determined to enable the most cost-effective surfacing type to be chosen. The decision process is to choose the surfacing with the lowest life cycle cost and compare its risk profile, construction cost and life with the other appropriate surfacings which are close to it in terms of lifecycle cost. The final selection is then made in accordance with all these factors.

The lifecycle cost can be found from the construction cost and the life of the surfacing. The actual values of each can be used or reference can be made to Tables 4.1 and 4.2. Since the surfacings have been chosen in accordance with section 3 and are all appropriate, it can be assumed that the maintenance costs are similar and this can be disregarded; accordingly lifecycle costs are expressed here as "comparative lifecycle costs".

4.1 *Surfacing life*

Table 4.1 **SUGGESTED SURFACING LIVES FOR COST CALCULATIONS**

SURFACING	URBAN ENVIRONMENT		RURAL ENVIRONMENT	
	poor conditions	good conditions	poor conditions	good conditions
asphalt	10-14	15 - 20	10 - 14	15 - 20
double seal, Cape Seal	5 - 7	8 - 11	6 - 8	9 - 13
single seal	3 - 5	5 - 8	4 - 6	5 - 9
sand seal				
single	1 - 3	2 - 4	1 - 3	2 - 4
double	4 - 6	6 - 10	5 - 7	7 - 11
dust palliative	1 - 3	2 - 4	1 - 3	2 - 4
slurry				
thin	2 - 4	4 - 6	2 - 4	4 - 6
thick	4 - 7	7 - 9	4 - 7	8 - 10

Notes:

1. Poor conditions means third world environment or problems such as weak pavement structure, poor quality control, poor drainage provision, etc.
2. Good conditions means first world environment with no problems.
3. Surfacing life is highly variable and this table can only be a guide to life.
4. This assumes that the surfacing is being used in an appropriate context (see section 3).

4.2 *Surfacing cost*

Table 4.2 **SURFACING CONSTRUCTION COST (1990/1 VALUES)**

SURFACING	Cost R/m² in 1990/1		
	Low	Medium	High
Dust palliative	1.74	2.22	2.70
Sand seal (2-3mm thick)	1.38	1.90	2.42
Sand seal (10mm thick)	3.20	4.13	5.07
Slurry (6mm thick)	1.53	2.03	2.53
Slurry (10mm thick)	2.71	3.42	4.13
Asphalt (25mm thick)	7.88	8.70	9.52
Asphalt (30mm thick)	9.41	10.36	11.31
Single seal (10mm stone)	1.41	1.92	2.43
Double seal (13mm/6mm)	3.28	4.17	5.06
Double seal (13mm stone/sand)	2.82	3.61	4.40
Cape Seal (19mm + slurry)	4.13	5.15	6.17
add for Prime	0.80	0.94	1.09

Note:
Prime is not included in these individual costs but is recommended for all initial surfacings except dust palliative.

Lifecycle cost

Once the likely surfacing life and the construction cost of any particular surfacing have been determined, the comparative lifecycle cost can be found from Figures 4.1 and 4.2. These figures allow your actual costs to be used (up to a limit of R25/m²) which therefore takes account of inflation and makes the figures valid for many years to come. They show, respectively, comparative lifecycle costs discounted at 8% and not-discounted (discounted at 0%). Whilst economists and funding agencies generally recommend using discounted costs, some engineers prefer to use costs which are not discounted.

FIGURE 4.1: LIFE CYCLE COST
8% DISCOUNT RATE

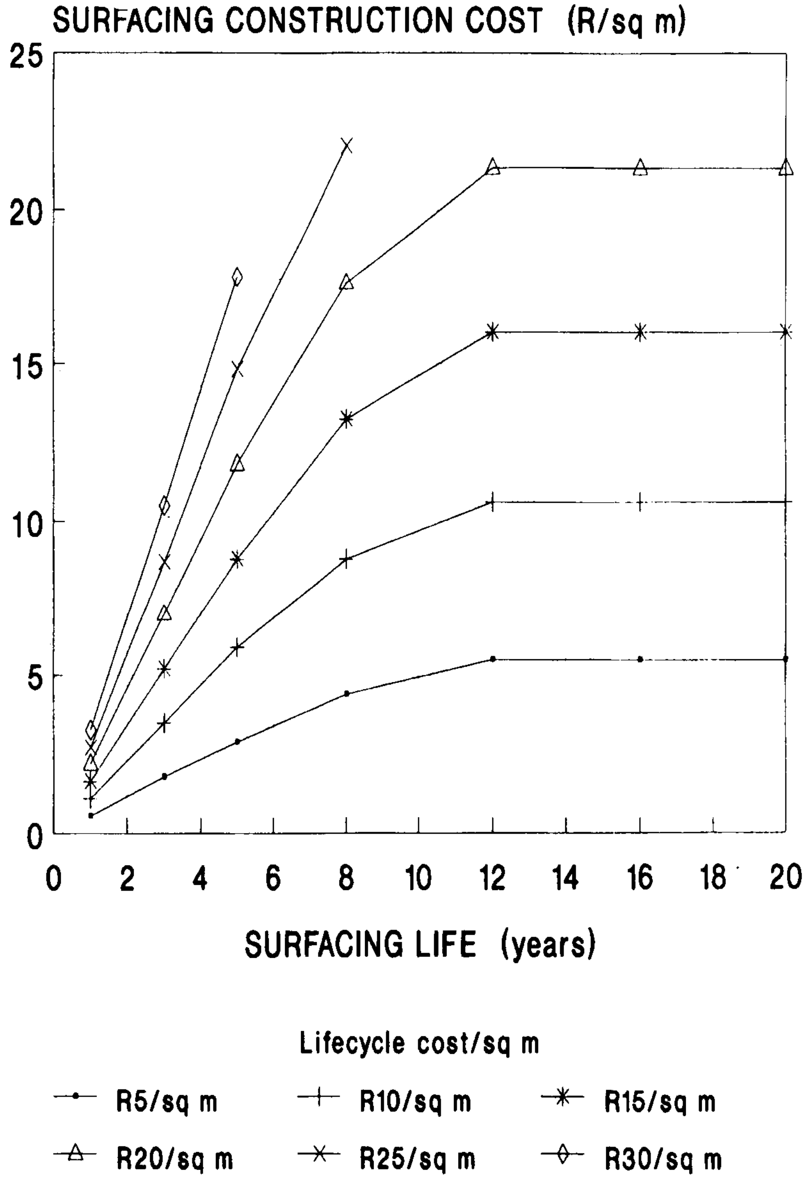
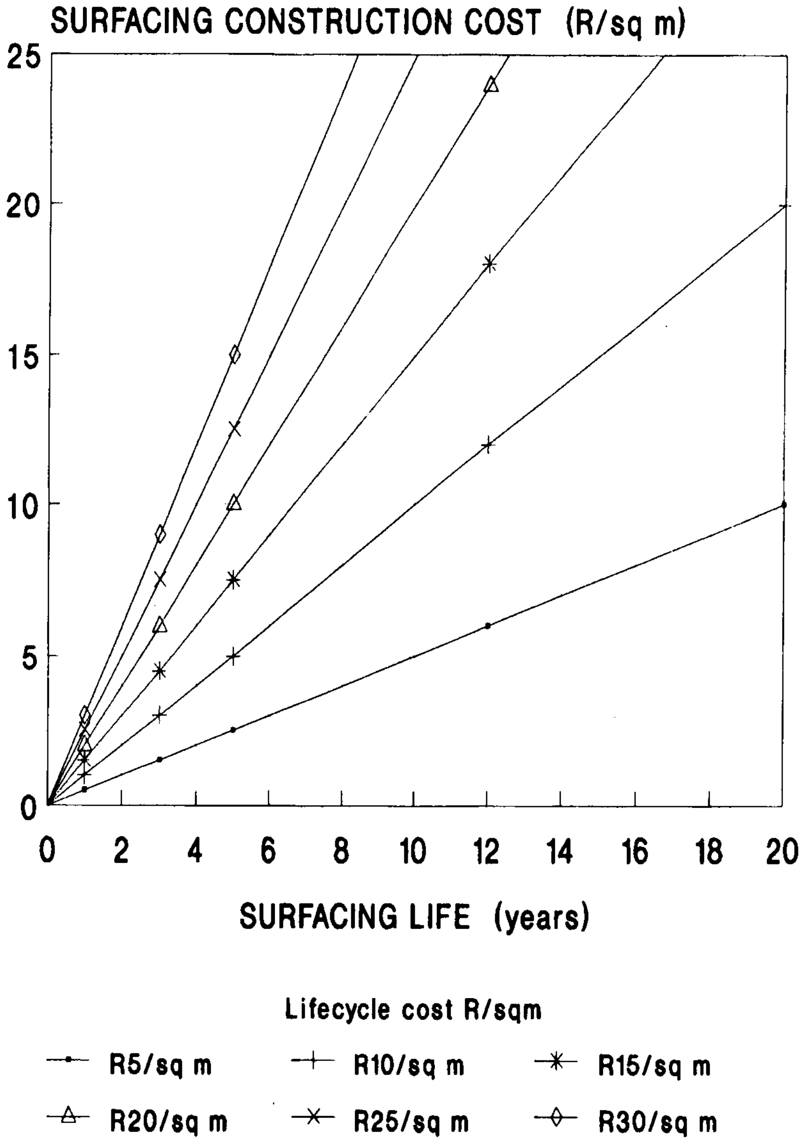


FIGURE 4.2: LIFE CYCLE COST
NO DISCOUNT



In the figures, the comparative life cycle cost is found from the contours as rand per square metre, and is found by entering the y-axis with construction cost which is actual total cost of surfacing in Rand per square metre including prime (if applicable), engineer's fees, profit, P & Gs; and the X-axis with life of surfacing which is life before reseal is needed according to normal engineering standards.

The comparative life cycle cost given in the figures is based on a 10 year analysis period, includes salvage value at the end of the 10 years, and allows for reseals of the same surfacing type (without prime) if required. Maintenance cost is not included because it is assumed to be equal for all surfacing alternatives.

WORKED EXAMPLE

There is an existing gravel road in an established Transvaal township. The existing pavement structure is reasonable, but the gravel wearing course is poorly maintained. The houses are of reasonable standard, with no squatters. Traffic is 300 vehicles per day and growing at 5% per annum. Gradients average 3 - 7%, with occasional steeper sections. No commercial traffic is expected, and bus traffic is confined to selected roads.

A bitumen surfacing is justified *(Section 2).*
The appropriate surfacings are asphalt, Cape Seal and thick slurry *(Section 3).*

STEP C CHOOSE MOST COST EFFECTIVE SURFACING

C1: **Determine surfacing life**
No historical information is available about surfacing lives in this township. It is an urban environment, third world environment, normal pavement, reasonable quality control during construction, and although the drainage is adequate at construction the drains are expected to block up soon in this third world environment. From Table 4.1, it is assessed as urban and top of poor conditions. The surfacing life is: asphalt 14 years, Cape Seal 7 years, and thick slurry 7 years.

C2: **Determine surfacing costs**
The latest price from contractors is R9,62/m^2 for 25mm asphalt; R6,07/m^2 for Cape Seal and R5,50/m^2 for 15mm thick slurry in two layers.

C3: **Find comparative life cycle cost**
The client has requested a discounted cost basis to be used, so Figure 4.1 applies. From Figure 4.1:

Surfacing	Cost R/m^2	Life years	Life cycle cost disc. 8% R/m^2
Asphalt	9,62	14	8,89
Cape Seal	6,07	7	7,86
Slurry	5,50	7	7,14

Decision: thick slurry.

5. SPECIAL SITUATIONS

5.1 *Forestry*

Situation

The forestry roads are generally located in wet and hilly areas, the drainage is rural with no kerbs, the roads tend to be private roads, and the trucks are often overloaded. The maintenance level tends to be low, the gradients can be steep and corners can be of short radius. Corners and intersections are also a problem because the percentage of heavy vehicles is high and most heavy vehicles are truck/trailer combinations with tandem and tridem axles.

Recommendations

On unstabilised basecourses: double seals with fogspray and sand blinding, or Cape Seals. Modified binders should be considered because of possible high deflections. The lighter seals (sand, single, dust palliatives) are not recommended because of the low maintenance environment typical of the forestry industry and the stress from turning vehicles. Slurry is not recommended if there is a possibility of weak pavement structure. There can be problems with quality of construction of the pavement and the surfacing and this should be allowed for.

5.2 *Parks, game farms, nature reserves*

Situation

The traffic is generally light with few heavy vehicles, speeds are low, pavement structures and construction quality are often good. Animals can cause problems with waste matter and high point loads which cause localised shear failures on thin surfacings. The maintenance level is usually good with adequate staff and equipment and a reasonable level of technical expertise. Gradients, drainage, corners and intersections are rarely a problem.

Recommendations

The surfacings should be thick such as multiple sand seals, double seals, Cape Seals, thick slurries, since the thinner surfacings are susceptible to damage from hooves. Consideration may be given to blending the road in with the landscape by using, for example, calcrete chips for a light coloured surfacing in dry sandy areas, and omitting the penetration cost.

5.3 *Use of marginal aggregate*

Marginal aggregates, in terms of grading and strength requirements, are sometimes considered in order to reduce the cost of bituminous surfacings. A breakdown of surfacing cost components (Wright et al, 1990) showed that aggregate cost made up about 20% of the total surfacing cost. By using marginal materials, this cost could perhaps have been cut by a third (i.e. 7% of the total cost of the surfacing). The advantage of lower cost must to be weighed against the increased risk of failure and in addition other factors, such as long surfacing life are likely to be more important in reducing the lifecycle cost of bituminous surfacings.

If marginal materials are being considered for low volume roads, the normal standards (SABS 1083, CSRA, TRH 14) could be relaxed in some instances. There have been a number of investigations into the use of marginal materials in South Africa, Botswana, and Zimbabwe and these have shown where standards can be relaxed. A summary of specifications and possible areas of relaxation are given in the following sections.

5.3.1 *Grading*

The recommended grading envelopes for crushed stone (chips) for stone seals are unchanged from TRH 14 and are given in Table 5.1

Table 5.1 **GRADING OF SINGLE-SIZED CRUSHED STONE**

Sieve size (mm)	Nominal size (mm) (percentage passing by mass)				
	19,0	16,0	13,2	9,5	6,7
26,5	100				
19,0	85-100	100	100		
16,0	-	85-100	-		
13,2	0-30	0-30	85-100	100	
9,5	0-5	0-5	0-30	85-100	100
6,7	-	-	0-5	0-30	85-100
4,75	-	-	-	-	0-30
3,35	-	-	-	-	0-5
2,36	-	-	-	-	-

The grading of natural sand for sand seals or stone/sand double seals can be relaxed and the relaxed grading is presented in Table 5.2 (from Paige-Green and Savage, 1990).

Table 5.2 **GRADING OF NATURAL SANDS**

SIEVE SIZE (mm)	PERCENTAGE PASSING BY MASS		
	Ideal	Average	Fine
9.5	100	100	
4,75	85-100	85-100	100
2,36	-	-	85-100
1,18	25-50	50-85	-
0,600	0-20	20-50	50-80
0,300	0-5	0-10	-
0,075	0-2	0-2	0-2

The suggested grading of "crusher dust" for dust palliatives is given in Table 5.3 (from Paige-Green and Savage, 1990).

Table 5.3 **GRADING OF "CRUSHER DUST" FOR DUST PALLIATIVES**

SIEVE SIZE (mm)	PERCENTAGE PASSING BY MASS	
	10mm nominal	7mm nominal
13,2	100	
9,5	85-100	100
6,7	0-40	85-100
4,75	0-10	-
3,35	-	0-30
2,36	0-1	0-10
0,600	-	0-2

The grading of aggregate for slurries should conform to Table 5.4, which is based on the Petrocol handbook. No relaxations are recommended. Whilst the design of slurries with modified gradings is possible, in the long term, their performance is uncertain. The existing design procedures are based on materials adhering to the specifications and of proven performance. It is therefore not recommended that specifications in this regard are relaxed without proper testing on the available materials.

Table 5.4 **GRADING OF SLURRY AGGREGATES**

SIEVE SIZE (mm)	PERCENTAGE PASSING BY MASS		
	Fine	Medium	Coarse
9.5			100
6,7		100	-
4,75		85-100	70-90
2,36	100	65-90	45-70
1,18	65-90	45-70	28-50
0,600	40-60	30-50	19-34
0,300	25-42	18-30	15-25
0,150	15-30	10-21	7-18
0,075	10-20	5-15	5-15

Otta seals are thick, graded seals developed by the Botswana Roads Department and used successfully on a number of roads in Botswana. The suggested grading of aggregate for Otta seals is given in Table 5.5 (from Botswana Roads Department, 1990).

Table 5.5 **GRADING OF AGGREGATE FOR OTTA SEALS**

SIEVE SIZE (mm)	PERCENTAGE PASSING BY MASS		
	Coarse	Fine	Wide
19	100	100	100
16	85-100	85-100	85-100
13,2	60-80	80-100	60-100
9,5	36-56	56-96	36-96
6,7	20-40	40-80	20-80
4,75	10-30	30-70	10-70
2,36	2-16	16-50	2-50
1,18	0-10	10-38	0-38
0,425	0-5	5-25	0-25
0,075	0-2	2-10	0-10

Note:
Coarse grading <100 vpd; fine grading >100 vpd; Grading curve should fall smoothly within envelope.

5.3.2 *Crushing Strength*

The crushing strength requirement of TRH 14 can be relaxed in the light of the adequate performance of lower crushing strength materials on low volume roads, provided that construction rolling with a steel wheeled roller is restricted. The experiences of other authorities are in Table 5.6 (from Netterberg and Paige-Green, 1988).

Table 5.6 **CRUSHING STRENGTH**

APPLICATION	10% FACT (min)	ACV (max)
TRH 4	210	21
Zimbabwe	120[ab]	30
Australia	80[ab]	30
Otta seal - sand	-	40[c]

Notes:

a. Limited application.

b. Soaked must be >75% of dry value, do not use steel wheeled roller in construction.

c. Demonstrated in Botswana with traffic less than 100 vpd.

5.3.3 *Polished stone value*

Polishing of stone by traffic lowers the skid resistance of the surfacing under wet conditions. For low volume roads, it is rarely a problem and for traffic less than 500 vpd, the PSV requirement can be dropped.

5.3.4 *Fines and sand equivalent*

No reduction from TRH 14 is proposed because of the importance of quality in constructing these seals. To limit the degree of contamination of the sand by clayey material, the sand equivalent value should be not less than that specified in Table 5.7.

Table 5.7 **SAND EQUIVALENT VALUE**

APPLICATION	SAND EQUIVALENT (min)
Sand seal	30
Otta seal	25
Slurry seal	30
Dust palliative	30

5.3.5 *Stone-bitumen adhesion*

Not all types of rock adhere equally well to bitumen or tar. Bitumen, in particular, does not adhere well to "acid" rocks. Although there is experience of the different adhesive properties of "acid" and "basic" rocks, it is safer to be guided by the surface texture of the crushed stone. However, when tar or cationic bitumen emulsions are used, such problems do not usually occur.

The crushing of medium to fine grained rocks produces a rough textured face which usually resists stripping of the binder. Coarse grained rocks possess numerous flat and smooth faces of large minerals and are noticeably more inclined to strip than the medium to fine grained types.

Stripping is less of a problem on low volume roads particularly in urban areas with lower speed traffic, however stripping is still a problem at intersections. Because of the importance of stripping in good surfacing performance, no relaxation of the limits in TRH 14 is proposed.

5.3.6 *Asphalt Surfacings*

One of the properties of asphalt that is a factor in its good performance is the high level of quality control. Accordingly no change is proposed in asphalt specifications in order to maintain this performance.

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