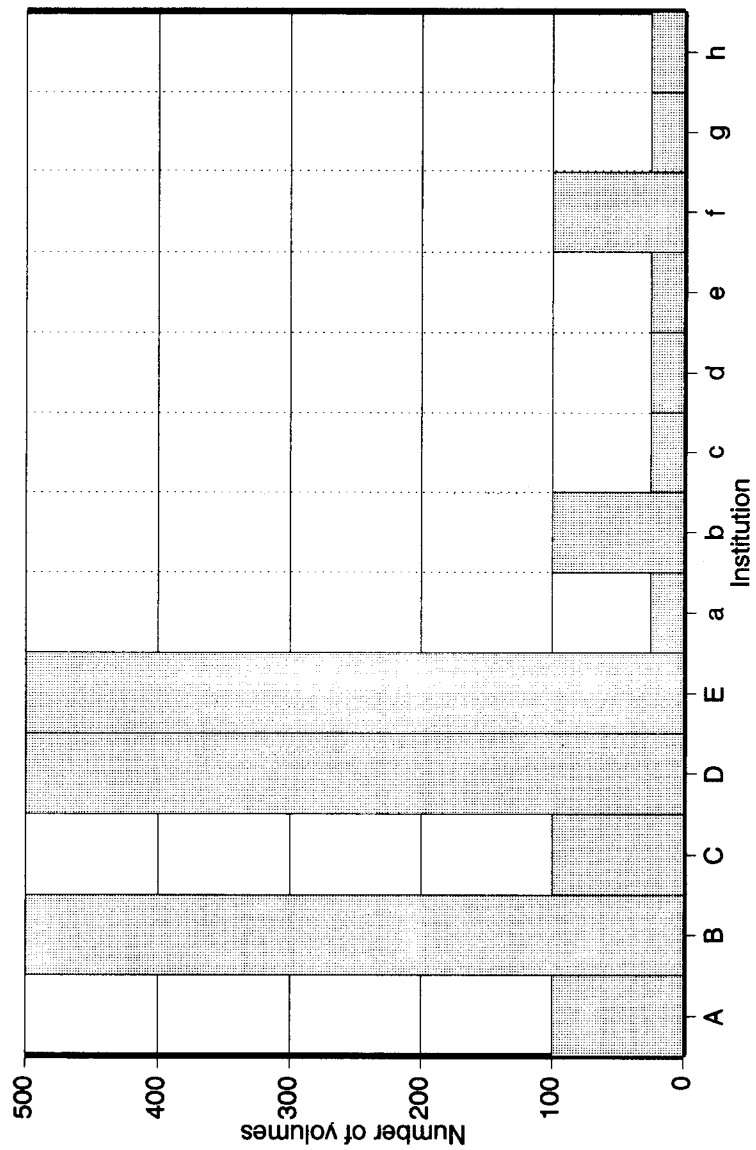

Figure 9 Library resources

BITUMINOUS SURFACINGS FOR LOW VOLUME ROADS IN DEVELOPING AREAS

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Abstract

Specific recommendations on bituminous surfacings for low volume roads in developing urban and rural areas are presented based on the results of extensive field investigations of existing roads, correlated to the variables which affect the life-cycle costs of a chosen surfacing. Variables considered include socio-economic factors, gradient, turning vehicles, maintenance capability, construction quality, surfacing thickness, and drainage. The effect of these variables on surfacing performance in developing areas was found to be overshadowed by the influences of high population stress environments, institutional capacity and varying drainage standards. Surfacings are recommended which are capable of accommodating these new variables. The influences of construction quality and use of labour based construction methods are included in the recommendations. The risk profile, balance of cost between surfacing and pavement structure, and maintenance regime are discussed and the results integrated into a methodology for selecting a cost-effective surfacing.

1 INTRODUCTION

Research into appropriate bituminous surfacings for low volume roads in southern Africa was undertaken from 1987 to 1991 by the Southern African Bitumen and Tar Association (SABITA) through the Council for Scientific and Industrial Research (CSIR). The purpose was to identify which of the commonly used surfacings performed well and cost-effectively under the conditions prevailing in the southern African subcontinent in both rural and urban areas.

The limited literature relevant to developing areas found in various searches meant that the research work had to based on investigating existing roads and their performance histories. The literature on surfacings in developed areas was used to guide this research. The phases encompassed: field investigations, interviews, performance surveys and, finally, financial analysis. The findings for bituminous surfacings have been published in the form of SABITA manuals (1, 2). They have also been incorporated into Department of Transport manuals on appropriat standards for low volume roads (3, 4) which cover all aspects of the road includin pavement structure, materials, geometric standards and drainage requirements.

This paper summarises the main published findings of the research as it applies t developing communities. It also presents new findings from further analysis of th data on the issues of institutional capability, social issues, construction quality labour based construction, and drainage.

2 PREVIOUS APPROACHES TO SURFACING SELECTION

Previous approaches to the selection of bituminous surfacings for developing are have been based on an extension of knowledge and/or experience from develope areas with adjustment for expected conditions in developing areas. Initially th same approach was used in this research until it was found that conditions developing areas were radically different from those in developed areas.

Literature on roads in developing areas of South Africa in the mid to late 198 suggested that asphalt surfacings were probably not economical for basic acce streets. They did not have the fatigue properties necessary to avoid cracking und the higher deflections common to light pavement structures ... such as we expected in developing areas ... while modified binders had great potential ... wi their relatively better fatigue properties. However it was also stated that significa research in this area was needed before definite recommendations could be ma (Netterberg and Paige-Green, 5).

By CAPSA 1989, opinion was that for developing areas, typical low cost surfa treatments like sand seals and single seals could fail early because of low traff volumes in combination with hardening of the bitumen by ultra-violet rays (Hor et al., 6). In other cases the severe loading of even a few heavy vehicles we thought to have highly destructive effects on the surfacings of such low-volum streets (Horak et al., 7). In developing areas, problems of topography were fir noted by Horak et al. (7), where it was stated that steep gradients can facilitat erosion such that certain surfacings can be completely lost.

At the start of the 1990s, the selection of seals for developing areas was st based on cost comparisons, suitability for maintenance (cyclic resurfacing, n institutional capability), availability of aggregate, accommodation of traffic, nois climate, existing pavement surface, texture, and traffic volume (Burger an Nothnagel, 8); which in turn was based on an extension to the South African se design manual (TRH 3, 9). These criteria are all important and valid for roads developed areas (described in detail in Wolff and Visser, 10; and Collura et al., 11 but as this paper will show are not as important in developing areas where oth criteria dominate.

Other approaches have been mainly financial such as the selection of surfacin in Jamaica (Weatherell and Ebrahim, 12). The choice of surface treatment is bas on lifecycle cost, vehicle operating cost and a standard road deterioration mod to give a traffic threshold for four surfacings, from dust palliative to asphalt. Th

approach is not sensitive enough to vary the deterioration model by surfacing type, and so does not adequately incorporate surfacing performance.

3 EXPERIMENTAL WORK

3.1 Design of research

The research consisted of three components. Firstly interviews were held with a wide range of roads engineers and technicians. Secondly field investigations were made into surfacing performance at 98 roads (61 urban and 37 rural) across South Africa. Thirdly cost/benefit analyses were performed for various bituminous surfacings under a comprehensive range of conditions. The research project covered the full range of thin bituminous surfacings ($\leq$ 50mm) from dust palliatives to asphalt, roads in both developing and developed areas, and topography from flat to mountainous (Table 1).

Table 1: Selected indicators of sites sampled

Variable	Range of values		
	Min	mean	max
Climate (I_m)[a]	-37	-2,7	25
Traffic (vpd)	2	160	650
% heavy vehicles	2	10,1	70
Surfacing life (years)	1	7,3	25

Notes a: The environmental classification system which was incorporated is based on temperature, humidity and rainfall, using the Thornthwaite index (Emery, 13). Moisture surplus (wet) areas have a moisture index (I_m) greater than 0, and arid areas have an I_m less than -20.

3.2 Field and laboratory work

The field work was performed in two stages: the first stage was to visit the site, perform various measurements and tests, and take samples for laboratory testing. The field testing and laboratory testing included the dynamic cone penetrometer (DCP; 8kg hammer falling 575mm onto 60° blunt cone), skid resistance, surfacing permeability, basecourse sampling and classification, rut depth, surfacing/base adhesion, gradients, and visual assessment.

The second stage was to revisit each site and perform an inspection by a panel of experienced engineers familiar with surfacing evaluation. The panel had the field and laboratory test results for each section with them during their visit, and made a visual assessment of the performance of each section of road according to TRH 6 (14) and the Transvaal Provincial Administration Pavement Management System forms. This assessment differentiated between surface distress caused by structural or drainage inadequacies, that attributable solely to surfacing deficiencies, and that attributable to the use of substandard materials. Then the panel evaluated surfacing performance to assess its potential life under the prevailing environmental, traffic, pavement and drainage conditions, and to note specific limitations of the surfacing type.

4 ENGINEERING FACTORS AFFECTING SURFACING CHOICE

The engineering knowledge base for surfacing choice was derived from experienc with developed world pavement performance. It was observed during the fieldwor in developing areas that the performance of surfacings was often less tha expected (Wolff and Visser, 10, give a range of surfacing lives for develope areas). It became clear from this, and from numerous discussions with senio engineers and members of industry, that the developed world knowledge base di not adequately make provision for the developing world environment.

Analysis of the results showed that the stresses on the surfacing in the developin world environment came from unexpected sources, and were so large as t overshadow the stresses that are normally experienced in the developed worl environment. Accordingly engineering factors which are important in selectin bituminous surfacings for developed world applications, are relatively less importa in selecting surfacings for the developing world. The factors which had to b considered were those such as maintenance, construction quality, surfacin thickness, pavement strength, turning vehicles, social factors, and drainage. Thes factors are mostly already known, but their importance for surfacing performanc in developing areas was not fully appreciated.

4.1 Institutional capability

The institutional capability of the road authority has a major effect on th performance of the surfacing (indeed of the whole road) over its life. This is le apparent in the developed world where the institutional capabilities are uniform high. But in the developing world, institutional capabilities vary widely. In earli analysis of this research (Emery et al., 15), institutional capability was consider simply in terms of the ability of the road authority to undertake maintenance. Th paradigm shift in the political-institutional axis in South Africa in the early 199 means that institutional capability must be taken beyond just maintenance encompass risk and long term funding.

In the developed world paradigm that South African road authorities operated prior to the 1990s, they were able to operate in a high risk environment and h their thinly surfaced roads together through good management systems a reasonably good maintenance work. This can be seen schematically in Figure which shows the risk levels in relation to time and the pavement serviceabi model. In the developing world paradigm emerging for South Africa in the la half of the 1990s, some road authorities can be expected to have neither capability nor management to continue to operate like this. They must th

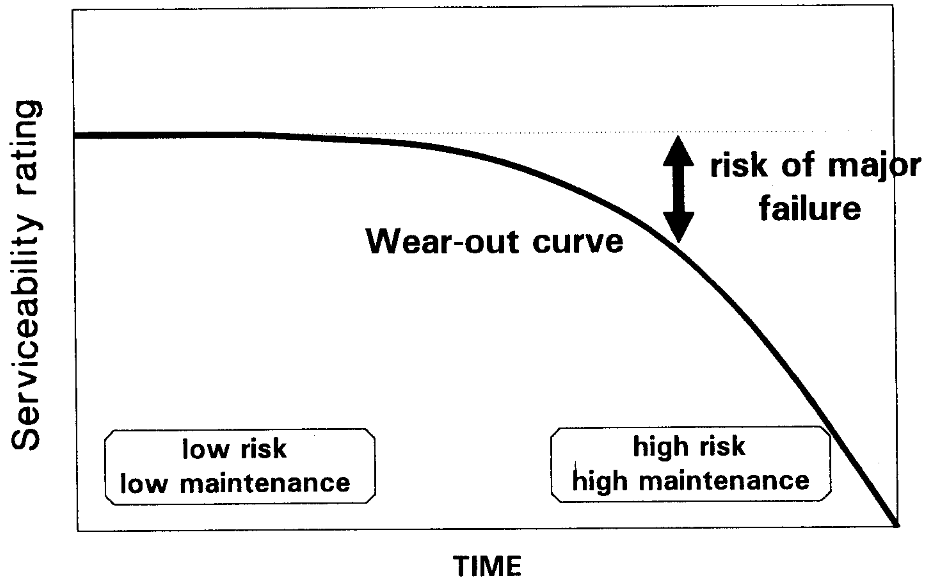

Figure 1 : Risk levels in maintenance

operate on the left hand side of the model, which implies using surfacings of lower risk. This research showed that the surfacings of lower risk are those which are inherently "tougher" and have the ability to limit the spread of damage, such as asphalt or thick slurry.

Under this new paradigm, the developing area road authorities would build for low maintenance by choosing surfacings that do not easily reach the steep part of the deterioration curve.

Allied to this concept is the need to balance the flow of maintenance funds in the road network and keep the roads budget reasonably constant, since the budget and/or the organisation are unlikely to be able to expand or contract quickly.

This is a complex issue, and at this stage, the selection of surfacing according to institutional capability can only be guided by the maintenance capability of the institution. This is inter-related to construction quality, since in areas of nil maintenance it was observed that the inevitable construction quality problems were not repaired. Accordingly only surfacings which are less likely to give construction quality problems should be used in the lower maintenance environments (Table 2).

Table 2 : Choice of surfacing by maintenance capability

Maintenance capability	Definition	Surfacing recommendation
High	Can perform any type of maintenance	any
Medium	Routine maintenance, patching and crack sealing on a regular basis. Typically no maintenance management system[b]	asphalt, Cape Seal, slurry[a], double seal, single seal[d]
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: it is not essential to have a maintenance management system, but its presence indicates a certain level of capability
- c: this is sensitive to construction quality
- d: rural roads only

4.2 Gradient

Gradient can affect the performance of the surfacing by causing either shoving o water damage. Shoving occurs when the bituminous surfacing slips across th basecourse, and for this reason shoving limits are applicable only to the firs surfacing on a road. Second and subsequent surfacings were not observed to sli unless the first surfacing was already slipping, probably due to adequate interloc between surfacings. Shoving is affected by the basecourse smoothness: a roug basecourse is more resistant to shoving than a smooth one. A stabilized fin graded basecourse is sensitive to shoving, and this is accentuated on small radiu curves and with heavy vehicles.

Water damage is the other problem with steep gradients, where water flowin along the bituminous surfacing causes erosion and damage. There is probably maximum water velocity for each type of surfacing before the surfacing ge damaged due to stone plucking and scour, but such water velocity limits are n yet defined, and gradient was used as an indication of water velocity to give limi for surfacings. The gradient does not take into account stormwater design catchpit layout and thus maximum water capacity of each section of road, but is a reasonable approximation at the present state-of-the-art. The gradient lin was observed to vary with the suspended solids in the stormwater, and with a hi level of suspended soils there was observable abrasion at relatively moderate wa velocities. In areas with poor street cleaning (developing world environment), t soil wash concentrated the water flow into channels on the surfacing and dama was done to the surfacing at relatively shallow gradient vectors.

Table 3 : Choice of surfacing for gradient

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

Notes:
- a: not on stabilised basecourse
- b: not if channelling of water flow expected due to soil wash; common in developing areas
- 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 developing areas

The recommendations given in Table 3 are additive to Table 2, so that a single negative in either table is enough to disqualify a surfacing. The performance of modified binders on steep gradients was observed at several sites: there was a slight reduction in loss of stone, little difference in loss of binder, and no difference in overall damage due to water and soil wash; accordingly no difference in recommendation could be made for modified binders.

4.3 Pavement structure

It is known that the performance of the surfacing depends to an extent on the surface deflection of the flexible pavement and in turn on the pavement strength and structure (Horta, 16). As the surface deflects, the elasticity of the surfacing copes with the bending stresses. The elasticity of the surfacing is related to free binder, surface area, binder type, age and adhesion. The more flexible surfacings can accommodate higher deflections before fatigue failure; modified binders improve the ability of the surfacing to accommodate higher deflections. The less flexible surfacings are not able to accommodate high deflection and they perform poorly on weak pavements. There is a minimum level of pavement strength, and a reduction in standard below that leads to early failure.

The underlying pavement structure had less of an effect on the performance of surfacings on low volume roads in developing areas than expected. This is probably because the influence of the other factors dominate, but is also because for low volume roads, very light pavement structures can often be used. For example, the lightest structural designs in the new Department of Transport low volume road catalogue (3) provide for basecourse materials with a soaked CBR 25. These designs were developed mechanistically using the S-N design method and data from the Heavy Vehicle Simulator (Wolff et al., 17). In New Zealand, laborat testing on basecourse materials only exhibited shallow shear failure with soa CBRs below 50 (Dunlop, 18).

4.4 Intersections and turning vehicles

When the road is subject to turning heavy vehicles, the thinner surfacings ca damaged due to scuffing as expected (Pidwerbesky and Pollard, 19). Vari recommendations are made in SABITA Manual 10 (1), and typically in develop areas, if the chosen surfacing for the road is inadequate, the intersections wo be treated as a special case with localised overlays.

5 SOCIAL FACTORS AFFECTING SURFACING CHOICE

5.1 Social environment

During the fieldwork, it was observed that surfacings in upper socio-economic cl areas appeared to perform better than those in lower socio-economic class ar and surfacings in lightly populated areas appeared to perform better than thos densely populated areas. It was clear that socio-economic factors were import Factor analysis was used to extract underlying relationships in all the collec data, and four distinct social environments were identified for low volu bituminous surfacings in South Africa:

- developed world, high standard pavements,
- developed world, lower standard pavements,
- developing world, and
- wet/hilly (both developing and developed worlds).

The developing world environment was characterised by urban housing, with low socio-economic class, dense housing, stormwater carried on surfacing, usua kerbs, little or no maintenance capability. This difference between developed a developing social environments explained the problems with previous approach to the selection of surfacings, using extrapolations of the developed wor knowledge base. Once this difference had been identified, it was also possible put all the other findings into a rational framework.

5.2 Habitat

The road plays an important part in defining the habitat. In urban areas it forms pa of the built environment, and since it represents most of the open space availab in developing areas, then it materially defines the quality of the habitat (Cameron 20). The effect of the road on the developing urban habitat was clearly observ in the fieldwork. In some cases, adjacent suburbs of similar socio-economic cla and housing density would have different surfacings on their roads. This differen in surfacing led to a clear difference in perception of the quality of life by the pan

The areas with asphalt roads were perceived to have a higher quality of life tha

those with stone seals. Factors such as the provision of kerbing, sidewalks, provision of adjacent parks, width of road, maintenance level, and cleanliness were similar between the areas compared, and so were discounted as influencing the preference. It was thought that this observation may be due to a cultural bias on behalf of the panel, and this was explored further by informal interviews with local residents during the inspections. In the interviews, there was a clear preference expressed for asphalt roads over stone seal surfacings.

As an important sub-set of habitat, it was observed that certain surfacings were better suited to informal children's games such as hopscotch. The asphalts, sand asphalts, and to a lesser extent the slurries and possibly the Cape Seals were better in this regard. No evidence of games (chalk marks, soccer goals) were seen on any of the stone seals. Since the road forms a large part of the play areas in developing urban areas, the choice of surfacing can be used to affect the quality of habitat.

5.3 House construction

In urban areas, most of the pavement loading taken by a low volume road is during the house construction phase; in the first 20% of its life, the road can be subjected to 80% of its loading. The traditional solution has been to build the roads to a gravel standard before house construction, and then repair and surface after house construction is complete.

This option is often not available in developing areas. Firstly the pace and/or organization of development may be such that the roads must be contractually completed before house construction commences. Secondly, it was observed that house construction can continue for many years after initial occupation. This will be especially true in areas which are intended for self-help projects, where it is likely that house improvement will continue for many years.

Therefore an appropriate surfacing is usually one which can accommodate house construction traffic. Even though the pavement structure may have been designed for the construction traffic, the surfacing must be able to limit the spread of damage from house construction traffic. This is especially important where the maintenance capability is low, and in areas where house construction will continue after the roads have been surfaced. The tougher surfacings such as asphalt are preferred.

5.4 Water reticulation

The type of water reticulation was observed to have an effect on the performance of the surfacing. In low cost housing areas, it is common to have communal standpipes and it is normal to carry these water services along the road reserve with the water standpipes adjacent to the road. Although each standpipe usually runs into a pit, they were often observed to be blocked by the residents to better use the water for washing clothes. The maintenance on the standpipes is often poor and leaking taps are common. It was common to observe water continuously running onto the road from these standpipes, and this was a significant cause of damage to the surfacing. A second problem is the detergents used in washin clothes cause marked deterioration of the bitumen; it was even observed that the caused deterioration of the concrete pits. At one site the deterioration in asph was measured at 5mm in 2 years.

In situations where communal standpipes exist, surfacings that can resist the effe of continued running water are recommended, such as thicker asphalt surfacing (30mm where 25mm would have been specified). The thicker surfacing is probab more impervious, but its main function is to provide greater wear thickness.

6 CONSTRUCTION FACTORS AFFECTING SURFACING CHOICE

6.1 Construction Quality

Construction affects the choice of surfacing, both in terms of quality and al institutional capability for maintenance. In areas of high maintenance capabilit construction problems (such as a streaky nozzle in a seal) can be tolerated becau the maintenance capability is adequate to repair the damage before it spread Under these conditions, the surfacing usually lasts the full term of its expected lif In areas where the maintenance capability is low, even minor constructio problems can cause the surfacing to fail prematurely.

In the fieldwork, a number of problems were observed with quality of constructio which had led to reduced performance of the surfacing. It was found th construction problems with the surfacing had affected surfacing life at 31.9% o all sites, and construction problems with the underlying pavement had affecte surfacing life adversely at 19.1% of all sites. There are surfacings that will perfor better than others in an environment where the construction quality of th surfacing or pavement is reduced from current standards.

6.1.1 Poor surfacing construction

The effect of poor surfacing construction on surfacing life varied with the type o surfacing (Figure 2). The thinner surfacings were more sensitive and the actu occurrence of problems was higher than expected (Chi square testing; statisticall significant with Chi = 19,65; df. = 11; significance = 0,05).

The thinner surfacings such as sand seals and single seals cannot be recommende for use in developing areas if there will be construction problems, which is simil to the recommendations made earlier on the choice of surfacing for maintenanc Asphalt has a particular advantage over other surfacings in that the quality o material and laying is usually high due to plant control.

6.1.2 Pavements

Construction quality of the pavement was also observed to affect the performanc of surfacings, in terms of defects such as a loose layer at the top of th basecourse, poor compaction and/or substandard materials leading to rutting an subsequent cracking of the surfacing, excess large stone in the basecourse, an

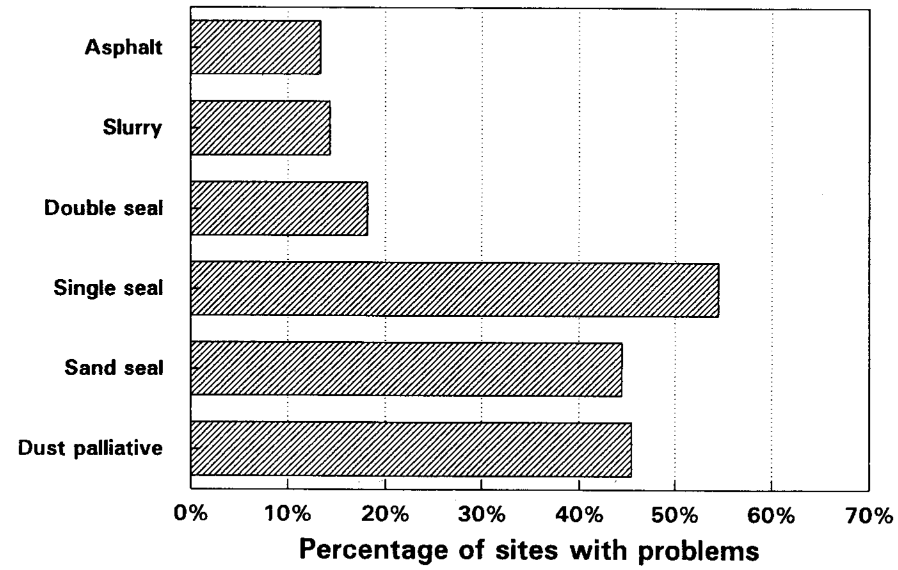

Figure 2 : Surfacing construction problems

basecourse unevenness (similar to the problems discussed by Mandigo et al, 21).

The performance of the surfacings was related to rut depth as expected, with all surfacings, and particularly asphalt, lasting longer on pavements with shallower ruts (Table 4).

Other construction problems were an excessive proportion of large stones in the basecourse and an uneven surface of the basecourse before sealing. The presence of excess large stone in the basecourse reduced surfacing life by an average of 3 years (statistically significant, t = -2,30; probability = 0,023). The thinner surfacings (single seals, sand seals, and dust palliatives) were most affected. An uneven basecourse surface prior to sealing can result in ponding of the bitumen in depressions, and subsequent bleeding, while on the ridges the lack of bitumen can lead to aggregate loss.

Table 4 : Effect of rut depth on surfacing life

Average site rut depth (mm)	Probable life: all surfacings (years)	Probable life: asphalt (years)
0 - 5	8,3	13,9
6 - 10	6,5	9,0
11 - 15	4,5	7,0
16+	4,1	(none recorded)

Although slurries were generally less affected by construction quality than seals, an uneven basecourse meant that the initial layer of slurry could be as thin as 1-2mm over the high spots, which led to early ravelling. It was therefore recommended that thin single layer slurry not be used as an initial surfacing, and a thick (10-15mm) slurry be applied in two layers.

6.2 Labour based construction

6.2.1 Existing surfacings

The issue of construction quality is also tied to the use of labour based construction in developing areas. The South African engineering profession is taking a number of initiatives to develop labour based construction, and surfacings are one such application (Emery et al., 22). Construction using labour based methods does raise the issue of quality. Although there are training programmes being developed and appropriate technologies suited to this type of construction, there is still a possibility that some projects will be built to lower standards.

The choice of surfacing for labour based construction depends on the environment that the road is in. In the developing world environment, the choice is wide because maintenance can be expected to remedy shortfalls in construction. In the developing world though, construction quality problems and lack of maintenance are such that few surfacings can be recommended for labour based construction. Since hot asphalt is not suited to labour based construction of new layers (SABITA Manual 11, 23), then only thick slurry and the Cape Seal remain as a surfacing choice amongst existing surfacing types.

6.2.2 Product Performance Guarantee

The very limited choice of surfacings imposed by the problems of labour based construction quality and institutional maintenance capability in developing areas necessitate a fresh approach to the selection of surfacing.

The traditional response to concerns over construction and early maintenance problems has been to ask for a contractor's guarantee. This in turn raised concerns about the financial stability of the contractor and his ability to provide guarantees, which meant that only the largest contractors could provide these. The use of

guarantees therefore acts as another entry barrier to the emerging contractor, and as such could not be supported for labour based construction.

Instead the Product Performance Guarantee (PPGS) approach is recommended, whereby the performance of a surfacing is guaranteed by its supplier. The supplier has the technical resources to develop suitable products, to provide suitable training in their application, and the financial resources to guarantee their performance. This keeps labour based construction accessible to the emerging entrepreneur, and provides the elements of technical and financial support that they need.

6.3 Drainage

The quality of surface water drainage was another factor affecting the performance of surfacings; the related effect of water erosion has been discussed in section 4.2. Two main types of surface water drainage were observed: urban drainage which was characterised by boxed in construction, (usually) with kerbs, and with water carried longitudinally along the surfacing to a stormwater drain inlet; and rural drainage which was characterised by shoulders and water running off the surface transversely and into the veld. Both types could be found in both of urban and rural population areas.

6.2.1 Incidence of drainage problems

In the fieldwork, surfacing life was seen to be adversely affected by drainage at 33% of sites in developing areas. There was a tendency for the surfacing life to be related to the quality of drainage. Surfacings on roads with good drainage had an average of 2 years more life than roads with fair or poor drainage. Where urban drainage was provided, there was a general tendency for the surfacing life to increase as the provision of drainage elements increased from:

- no drainage (mean surfacing life = 6.1 years; typically no kerbs or catchpits, but boxed-in construction because the road was depressed relative to its surroundings), through
- limited (mean = 6.2 years: kerbs but no or few catchpits, and water was carried for considerable distances along the kerb), to
- adequate (mean = 8.1 years; kerbs and sufficient catchpits connecting generally to underground stormwater drainage, but occasionally in hilly areas to a concrete channel leading away from the road).

However this trend for increased life with improved drainage was countered by the problem of blocked stormwater drains in developing areas, which was common. Where maintenance is poor, catchpits can stay blocked for several years or more. This increases the amount of water being carried by the road in an urban drainage situation and leads to problems of surfacing scour where it would not normally have been expected.

Thus although the provision of adequate kerb and catchpit drainage structures is important where urban stormwater systems are to be used, if there is no maintenance or street cleaning it is likely that the catchpits will become blocked time and their benefit nullified. In a holistic sense, a stronger surfacing such asphalt in conjunction with limited stormwater drainage such as partial kerbing m cost less than a weaker surfacing in conjunction with full kerbing, catchpits a piping in the developing areas, and still perform as well.

7 COSTS FACTORS AFFECTING SURFACING CHOICE

After surfacings have been selected according to the factors discussed above, th selection of the most cost-effective surfacing can be made based on lifecycle co This process is discussed briefly in this paper since it is well covered elsewh (such as SABITA Manual 10, 1).

The surfacing with the lowest lifecycle cost is generally chosen, but issues su as risk profile, construction cost and life may influence the final decision. Th lifecycle cost of the surfacing is found by considering all the costs over the analys period, and discounting those to give present worth of costs. Several methods a available to easily analyse lifecycle costs:

- simplified graphical method presented in SABITA Manual 10, along with dat tables of costs and surfacing lives (SABITA, 1),
- annualized cost basis (Vos, 24),
- SURF economic analysis programme can be used (SABITA, 25), as well a other economic analysis programmes such as CB-Roads.

8 SUMMARY

1 The choice of surfacings for developing urban and rural areas depends on engineering and socio-economic factors such as institutional capability for maintenance, gradient, social factors, construction quality, and the possibility of labour based methods of construction. The recommendations for low volume roads in developing areas are summarised in Table 5.

2 The limited choice of surfacings for labour based construction in developing areas necessitate a fresh approach to the selection of surfacing. The Product Performance Guarantee approach is recommended for labour based construction, whereby the life of specific surfacings is guaranteed by the supplier.

3 The choice of surfacing for developing urban areas should be made in the holistic sense with reference to the other services provided. The overall development cost can be minimised by balancing all elements of the engineering services. For example, a project having the elements of roads with a thick bituminous surfacing, minimal stormwater drainage and communal water reticulation may be more cost effective than a project having the elements of roads with a thin bituminous surfacing, good stormwater drainage, and water reticulation to individual properties.

Table 5 : Recommended surfacings for developing communities

Surfacing type	Suitability for labour based construction	Urban environment		Rural environment	
		No maintenance capability	Steep gradient	Wet climate or bad drainage	Intersect-ion, turning trucks
Dust palliative	good	no	no	no	no
Single seal[a]	fair	no	no	yes	no
Thick slurry[b]	very good	yes	no	yes	yes
Double seal	fair	yes[c]	no	yes	yes[d]
Cape Seal[b]	very good	yes	yes[e]	yes	yes
Asphalt[b]	fair[f]	yes	yes[g]	yes	yes

Notes: a: with or without modified binder; b: popular smooth township surfacing
c: only if contractor's guarantee or PPGS; d: needs fogspray and sand blinding
e: maximum suggested gradient 10%; f: skill required; good for maintenance
g: maximum suggested gradient 16%

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