THE OPTIMUM USE OF NATURAL MATERIALS FOR LIGHTLY TRAFFICKED ROADS IN DEVELOPING COUNTRIES

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The planning, construction and maintenance of lightly trafficked roads are discussed, with particular reference to the optimal use of local materials and resources. Attention is drawn to the importance of terrain evaluation techniques for improved road location and construction material surveys. The importance of an intimate knowledge and appreciation of local conditions and terrain for optimum serviceability is stressed. Foreign aid often covers only the planning and construction phases of development and loses interest during the maintenance after completion. This aspect is of particular importance to the financing institutions to expand the export of expertise and equipment for maintenance. The importance of, and examples illustrating procedures to promote labour intensiveness in highway construction in developing countries is mentioned. Examples of materials standards for gravel surfaced lightly trafficked roads, and the experience on which they are based, as well as the novel applications of certain natural resources are discussed. Geometric standards and drainage applications that have been found to be particularly practical are highlighted. Approximate cost estimates are included for the various grades of roads discussed.

In most countries in the world, and especially in Africa, trade routes have been established over the centuries. These routes form the basic backbone to the infrastructure as such, and should be considered as a fixed system.

Industrial and agricultural development, as well as the creation of new towns and villages, and the change from a subsistence-economy to a market economy requires encouragement through the provision of an infrastructure, consisting mainly of a tertiary road network, to germinate economic advance.

The obtaining of untied capital funds for developing countries poses problems, and consequently it is essential that the available capital resources be used in the most appropriate socio-economic manner. Road development funds which are provided in the form of "package deals" with constricting conditions are not in the best interest of developing countries; they do not lead to self development of the inhabitants of the countries concerned since they are normally conditional upon the use of expertise and equipment from the highly developed donor country.

The optimum use of local labour forces, and of local materials and construction techniques is of prime importance in the development of the infrastructural system. It is also essential that adequately trained personnel and suitable resources be developed during the course of construction so that continued maintenance of the facilities can be effected. All too often the mistake is made of providing over sophisticated facilities which quickly deteriorate due to inadequate and ill-advised maintenance. Since the roads provided as the tertiary network for developing countries generally develop into major routes, and also since they normally generate heavy axle loadings (trucks and buses) rather than the lighter loading associated with the extensive use of cars, it is essential that these roads be designed so as to easily permit later upgrading, with minimum disruption to traffic both geometrically and structurally, into arterial facilities.

For this reason stabilisation of the pavement layers using in-situ, or nearby occurring natural gravels is from a cost benefit viewpoint normally the best approach, since these layers will then form an ideal subbase for the heavier pavements which will follow with time.

Since the geological history and road building conditions in many of the world's developing countries in South America and Africa is very similar to that of South Africa, and also because South Africa has during the last 30 to 40 years experienced the socio-economic conditions now pertaining to these countries, it is considered that South African experience in respect of the development of a system of low cost roads will be of considerable benefit.

Planning

Terrain Evaluation for Location and Design

In order to ensure that from both geotechnical and materials usage aspects the proposed road is located in the optimum economic position, it is essential that terrain evaluation studies be carried out. The terrain over which the proposed road is to be constructed is generally variable, but the variables are the results of recognisable geological processes, where the interaction between geology, climate and time produces a myriad of landscapes, all of which are interpretable in terms of materials properties.

The basic objective of terrain evaluation is to communicate the relevant materials terrain data to the design engineer and consequently only those attributes relevant to the purpose in hand are evaluated and presented in a form intelligible to the engineer.

The actual requirements vary according to the project, but are covered broadly by the following:

1. location of construction materials,
2. assessment of centre line in-situ materials,
3. assessment of relative quantities and distribution of hard and soft materials,
4. definition of drainage and slope stability problems,
5. definition of areas of sub-surface moisture and erosion problems,
6. definition of areas of expansive or collapsible soils,
7. definition of climatic and weather conditions.

As many of these criteria can only be qualitatively described at the early design stage during which the evaluation of the terrain occurs, it is essential that the design engineer possesses a deep sympathy and understanding of the native geology and of the influence of local geological processes upon the terrain.

Terrain evaluation procedures generally lean heavily on air photo interpretation and it has been found in South Africa that the amount of information obtained from interpretation, and the degree of reliance that can be placed on the information so produced, is proportional to the degree of the interpreter's experience beyond his basic training, and also to the extent of confirmatory field work undertaken.

In addition the degree of communication between the interpreter and the design engineer has an effect upon the success of the work. Because of terrain evaluation's essentially practical origin in South Africa, it has been found that from the design engineer's viewpoint only limited detail regarding the terrain attributes is necessary in the early stages of a project, and that as the project progresses, different, and more detailed information becomes necessary. A continual channel of communication between the engineer and the interpreter is thus essential.

Complete integrity is required on the part of the interpreter and it is his duty to inform the engineer of possible weaknesses in the information, which may lie either in the lack of sufficient evidence on which to base his supposition, in his own inability to adequately interpret the photography, or in the lack of clarity as to what the engineer requires.

A mutual understanding of the requirements and limitations of the method is essential.

Road geotechnical engineering is an art - which depends for a large measure for its success upon the exercising of sound judgement; and sound judgement comes from long and tried experience, based on acute observation.

Of nothing is this more true than in the field of geotechnical engineering and it is in this aspect of the project where the study of, and decisions based on an appreciation of ground conditions can have major economic consequences that there should be a combined effort with mutually accepted responsibilities between the terrain evaluator and the highway engineer.

Optimum Procedures for Prospecting Road Building Materials

About seventy percent of the cost of road construction is associated with the use of materials. This is especially true for low cost roads where it becomes economically essential that all available sources are located and taken into account for design purposes. It is also important that the search for construction materials be undertaken on a logical basis and not as is often the case, in a haphazard random fashion.

The use of air-photo interpretation has long since been recognised as an aid in the search for construction materials. In addition the establishment of data banks for the storage of data pertaining to road materials usage for particular region has been encouraged, e.g.,

"It is desirable to establish a permanent exchange of 'know-how' and information between developed and developing countries with a view to the adaptation and utilization of project techniques by the latter countries, particularly as regards terrain evaluation, use of computers and automatic drawing of road projects as well as the establishment of road data banks and the gathering of geological data" (1).

During the last 8 years a system for the storage and retrieval of information pertaining to the occurrence of road building materials as well as its uses, including problems and construction hazards, has been operated in South Africa as an aid to materials prospecting. The procedure is based on the extrapolation of data from previously prospected areas to new areas with similar physiography.

The more important soil-forming factors which are considered responsible over a period of time for the technical properties of any material or soil class are the natural condition i.e. parent material, climate and relief. If any of these conditions change the materials types and problems change as well; on the other hand, one may expect the same technical properties in materials which are found in different localities but have the same parameters. Such a group of related materials has been termed a material analogue and is defined as "a number of material classes with the same parent rock, climate and relief". (2)

Consequently the standard references indicated below have been introduced for the coding of material data and the description for storage and retrieval when required, of material analogues:

1. Parent rock, described in terms of litho-stratigraphy as applicable, and according to the legend of the 1:1000 000 geological map.
2. Weathering, based on the 30 year mean annual rainfall.

3. The relief of the area.

The general principle described above is not sufficient however to provide a field team with directives in their search for materials and a further reference is required indicating where materials with specific engineering properties might be located within an area of the same material analogue. It has been found that the most acceptable and practical reference is an indication of the relevant land surface forms. The relevant land form has therefore been chosen as a sub-unit for materials data banking. It is described with respect to surface shape and is defined as a term which describes the surface form of the locality of road construction materials reasonably uniform properties or soil classes.

Information regarding the properties of construction materials is coded as the probability of locating suitable materials within any particular analogue. It is thus possible to conduct the search for road building materials in a logical fashion and at a saving in cost, both for the time spent in prospecting and more especially because most usable sources are located.

Design and Construction Standards

It is of importance, from an economic viewpoint that a flexible approach be adopted towards the setting of design and construction standards for low cost roads, whilst at the same time recognising that geometric standards will remain for the life of the road, which may be considerable, since the initial tertiary roads will develop into the future main communication links of the country.

In addition local knowledge regarding the performance of pavements using the naturally occurring materials, as well as the construction and maintenance capabilities of the local populace, must be assimilated in determining construction specifications. Various aspects should be kept in mind when making decisions in this respect. They include, inter-alia, topography, geology, drainage, traffic and subgrade characteristics together with other aspects such as the socio-economic climate, prospects for obtaining future finance and maintenance capabilities.

The original network of National Roads for South Africa constructed in the late thirties and during the forties has provided very good service, and in many parts is still doing so following many reseals, nominal widening, the addition of climbing lanes and the application of thin bituminous overlays. Based on this experience over 40 to 50 years the following categories in the development process are suggested for low cost roads in developing countries.

1. Graded and shaped roads (in-situ materials)
2. Graded and shaped gravel roads (imported natural gravel)
3. Bitumen surfaced, natural and stabilised, gravel roads.

Typical Design Standards and Applications

The following considerations must be taken into account in formulating design proposals:

Administrative.
1. Economic considerations.
2. Alignment and services (land use).
3. Construction planning.
4. Axle loadings.

Traffic.
1. Data sources
2. Growth projections
3. Functional classification

Climate.
1. Rainfall and run-off
2. Temperature extremes

Geometrics.
1. Design speed
2. Horizontal, and especially vertical alignment.

Availability of Natural Road Building Materials
1. Data collection procedures
2. Special problems (eg swelling clays, swamps, shifting sand dunes)
3. Treatment of problem areas.
4. Treatment of problems and low quality materials.
5. Evaluating existing road foundations
6. Treatment of existing road foundations where problems occur
7. Pavement design

Drainage.
1. Type of culverts
2. Surface drainage
3. Subsurface drainage
4. Prevention of ponding

Graded and Shaped Soil Roads (in-situ materials)

Design Considerations. This is the first formal step in forming a road from the common veld-track, and it is important for it to comply with the following basic requirements:

1. It should follow the shortest possible route, using the most effective and economical alignment. Consideration can be given to a so-called watershed alignment in order to limit drainage structures. Particular attention should be paid to the fixing of the alignment to alleviate false rise and excessive gradients since this appreciably affects traffic capacities, particularly in situations where the percentage of heavy vehicles is expected to be large.
2. Considerations for drainage and reasonable all weather trafficability should be made.
3. Gravel should be placed only in difficult or rough sections (usually over pipe culverts).
4. Light traffic: not more than 30 vpd.

Construction. Construction of these roads is straightforward and the equipment required can be anything from a mule-grader or an ox cart to the latest equipment available. Hand labour can form an important phase in the construction of these roads. Construction costs can, depending on circumstances and equipment used, vary from a few hundred dollars per kilometre to about 3 000 dollars per kilometre. The local populace and their inherent skills should be used to the maximum extent and as much recource as possible should be had to handwork.

Maintenance. Maintenance will be dependant on the volume and type of traffic as well as the climate (seasonal). Occasional shaping with a grader - often by request of the user - seems to be the most economic solution. In the sandy conditions found in South West Africa (Namibia) a so called sand track grader has been found to be particularly useful in straightening the winding furrows in the road caused by the passage of vehicles.

In some instances, the maintenance and construction of these roads is left to the users or a system of subsidized maintenance is adopted. In the Orange Free State, a province of the Republic of South Africa, \$325 000 and \$360 000 were spent in the fiscal years 1970/71 and 1971/72 respectively on approximately 25 000 km of tertiary roads, ie about 12 dollars per kilometre per annum (3).

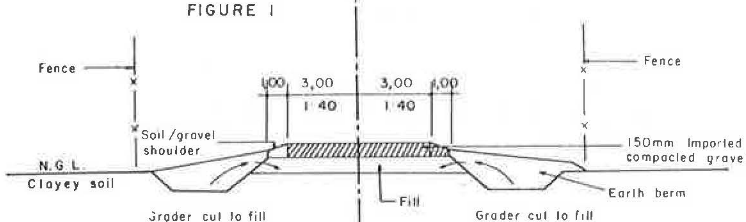
Shaped and Graded Gravel Roads

Roads in this category provide an important service and can link smaller rural communities or tie into the major road network serving the area. Unpaved roads remain an important part of the South African road scene: in 1974, 143163 km (77 percent) of the Republic's rural road network was unpaved, while in Rhodesia 26322 km (78 percent), and in South West Africa 28815 km (90 percent) remain unpaved (4).

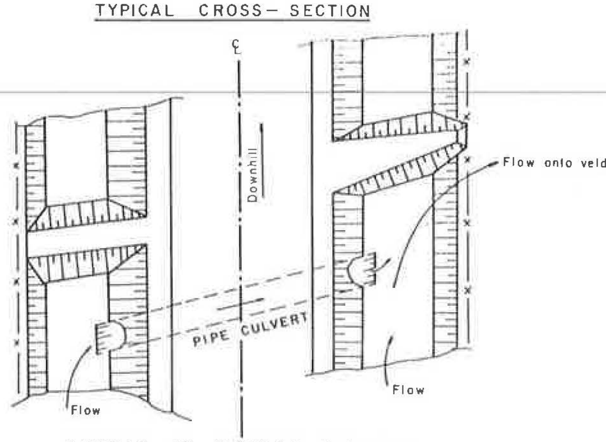
Design Considerations.

Traffic volume	:	50 - 150 vehicles per day.
Design speed	:	80 - 90 kilometres per hour, depending on terrain.
Gravel wearing course	:	5 to 7 m wide, 150 mm compacted thickness.
Crossfall	:	1 in 40.
Shoulder width	:	1 metre minimum (fill material).
Materials		
Fill	:	in-situ materials mostly from side drains or sources as near as possible.
Gravel wearing course	:	material and compaction standards to be controlled, and specified as detailed below.

FIGURE I



TYPICAL CROSS-SECTION



DETAILS OF SURFACE DRAINAGE

Construction. Fill material is obtained from sources as near as possible to the road, generally from within the proclaimed road reserve. The latter method also facilitates drainage of the road. It is advisable and economical to allow construction equipment and traffic to compact the fill prior to placing of the gravel wearing course. Often the earthworks will have been constructed and used by traffic as a lower category road. The so-called 'Dig, load and haul' contracts for placing of the gravel wearing course have been carried out with great success by the provincial roads authorities in Natal and the Orange free State, two provinces of the Republic of South Africa.

Maintenance. Depending on the type and volume of traffic, the life of the gravel wearing course is greatly influenced by the regularity of grader maintenance and patching with gravel in places where the wearing course becomes thin.

An important factor is the replenishing of the fines in the wearing course from the shoulders or sides of the road, where a good grader operator will always leave a windrow for this purpose.

It has been found that dust settles onto the veld next to an average gravel road at a rate of 32 kg per hectare per month, creating an environmental hazard for crops and stock (wool sheep) next to such roads (5). In South Africa the potential dangers of thick clouds of dust from traffic is well known and create a limit to the volume of traffic that can be handled on these gravel roads, particularly in dry climates.

The life expectancy of roads in this category before major maintenance is required, can vary from 2 to 7 years with traffic volumes of about 200 to 50 vpd respectively. The first gravel wearing course usually has a shorter life owing to consolidation and compaction under traffic, and it has been found that a second course added after 2 to 3 years considerably increases the life of the road.

Costs. Approximately 500 - 600 dollars per kilometre can be spent annually on the maintenance of a secondary road; construction costs vary from 5 000 to 12 000 dollars per kilometre with construction units consisting of one or two graders, medium bulldozer, front end loader, and 6 to 8 tip trucks, Compaction equipment is limited to the absolute minimum or where conditions necessitate special attention. Production can reach up to 10 km of completed gravel road per month using a small construction unit.

Selection of Materials for the Wearing Course

The selection of materials for gravel road construction is predicated on a basis of experience rather than structural pavement design concepts and the criteria are related to rate of loss of gravel and the ability to permit the safe passage of traffic in wet weather. An investigation into the capabilities of various wearing course materials, used over many thousands of kilometres and related to the more common road materials tests has led to the following standards being derived for materials used as wearing courses 150 mm thick, compacted to an in-situ density of 95% of the Modified AASHTO effort maximum density, and constructed directly over a prepared subgrade of local in-situ materials (6):

Abrasion. One of the most important criteria has been found to be the resistence to abrasion measured as the loss after 500 revolutions in the Los Angeles Abrasion Machine. In order to provide a reasonably smooth ride in dry weather, and at the same time not to cut up in wet weather, experience has shown that a value between 30% and 60% provides the best results. Materials with a value of less than 30% generally do not provide sufficient fines to meet grading requirements.

Strength. The California Bearing Ratio value should not be less than 20 when determined at the in-situ density.

Atterberg Limits. The following limits are recommended:

Lower Liquid Limit : 20 - 35 (ideally near 30)
Plasticity Index : 5 - 15

It has been found that in the drier regions of Southern Africa, a plasticity index as high as 22 has given satisfactory results especially in controlling corrugations. The rainy season is usually of relatively short duration and slipperyness does not create undue problems. Relaxations of this nature can also be considered when pedogenic materials such as calcretes are used.

Grading. The following grading envelopes shown in Table 1 (after 95% Mod AASHTO compaction effort) have been found to be suitable for gravels: (Sand Clay mixtures do not necessarily have to meet these envelopes but should comply with the other requirements).

TABLE 1 : GRADING REQUIREMENTS FOR NATURAL GRAVEL WEARING COURSE MATERIALS

Sieve Size	Percentage Passing by Mass		
	37,5 mm max size	19,0 mm max size	13,2 mm max size
37,5 mm	100		
19,0 mm	70 - 100	100	
13,2 mm	60 - 85	75 - 100	100
4,75 mm	40 - 60	50 - 75	60 - 100
2,00 mm	30 - 50	35 - 60	45 - 75
0,425 mm	15 - 40	18 - 45	25 - 50
0,075 mm	7 - 30	7 - 30	7 - 30

The grading of material should run parallel to the limits of the relative grading envelope which applies to material subjected to the 95% Mod. AASHTO compactive effort and 4 days soaking. When the grading of the material is too coarse and lies outside the envelopes correction of the deficiency in fines by the blending in of a suitable binder from the in-situ earthworks is often of assistance.

Performance. Table 2 indicates the behaviour tendency of wearing course materials.

TABLE 2 : PERFORMANCE PROPERTIES OF NATURAL GRAVEL WEARING COURSE MATERIALS

Performance	Lower Liquid Limit	Plasticity Index	Coarse plus Coarse fine sand content	% clay
Corrugates	less than 20	-	greater than 55	-
Dusty when Dry	less than 20	-	less than 30	-
Ravels when Dry	less than 20	less than 6	-	less than 6
Potholes when Wet	greater than 35	-	less than 30	-
Slippery when Wet	-	greater than 15	-	-
Cuts up when Wet	-	-	less than 25	greater than 10

In general the following characteristics apply to the gravels more commonly used in South Africa:

Dolerites	: High coarse sand content	- Tend to corrugate
	Low coarse sand content	- Tend to pothole and become slippery
Laterites (Ferricretes)	: Low Plasticity Index	- Tend to corrugate
	High Plasticity Index	- Tend to pothole
Sandstones	: Low plasticity Index	- corrugate and erode easily
	High plasticity Index	- Tendency to pothole
Shales	: Low plasticity Index	- If soft - dusty
	High plasticity Index	- Tend to pothole

Blending of Natural Materials

Blending of naturally occurring materials can be highly beneficial in improving strength and maintenance free life. In the semi-arid regions of Southern Africa natural gravels tend to be low in fines content and with plasticity indices of around 10. This combination of properties is not desirable for gravel wearing courses since it leads to a tendency to corrugate. If such a gravel is blended with a sandy clay soil (15 to 20% by mass) a much more substantial wearing course results.

On the other hand where naturally occurring gravel deposits are at a premium it has been found that blending (5 to 20% by mass) of natural gravel with sandy soils improves compactability dramatically.

Bituminous Surfaced Roads

The next stage, usually dictated by traffic growth and general development of a region, is the upgrading of gravel roads into roads with a bituminous surfaced pavement, constructed with sufficient structural capacity to carry the increasing traffic loads.

The additional costs required to upgrade a natural gravel wearing course road into a bituminous surface road as described below is of the order of fifteen to twenty thousand dollars per kilometre.

The philosophy proposed for developing countries is that such roads should be constructed using equipment which is as simple as possible, and which in addition can be used for other purposes, such as agriculture. Consequently as much use as possible should be made of equipment such as disc harrows and trucks, both of which are able to play their part in the other sectors of the economy.

There should be as little recourse as possible to sophisticated operations such as crushing of rock to conform to the tight gradings commonly specified for crushed stone base, or for the multi-stage crushing operations required to produce good quality aggregate for surface treatments.

By the time it becomes necessary to provide a bituminous surfacing to the pavements the existing gravel roads will generally have been subjected to traffic and the environment for a number of seasons. Areas of water seepage will have been identified and rectified and a stable ground water regime will have been established. In addition most of the settlement in embankments will have taken place and soft spots in the subgrade will have been repaired. The subgrade which is one of the most important factors influencing pavement performance will by now have "bedded down".

Recognising the great economic advantages in respect of performance attendant upon providing a degree of stiffness in the pavement by means of cementitious stabilisation, practice in respect of structural road improvement in South Africa has generally been to stabilise the top 150 mm of the existing wearing course materials on gravel roads using either lime or cement, as a first step in the upgrading of the pavement. The most appropriate equipment for the adequate mixing in of the stabilising agent is the disc harrow, drawn by a sufficiently powerful tractor to operate at the speed required to turn the material under the discs.

Assuming that the wearing course material conforms to the standards previously given, CBR values in excess of 60 percent should easily be attained by the addition of 3 to 4 percent by mass of either lime or cement, the agent used depending upon the plasticity of the wearing course material. For plasticity indices of the order of 8 or more lime is preferable because of the greater time available to complete the mixing and compaction process.

It is common to differentiate between two classes of composition of traffic in determining the necessity or otherwise for additional pavement layers. Where traffic consists predominantly of motor cars it would generally be sufficient to immediately provide a surfacing to the stabilised wearing course. However the more normal case in rural areas is where traffic consists largely of heavy vehicles, such as buses and agricultural haulage vehicles. In such instances it is advisable to provide an additional 150 mm layer of stabilised base material - particularly in low lying areas or areas of poor subsoil drainage.

Pavement Standards. For stabilised base materials the following standards after stabilisation are considered appropriate:

Minimum CBR	: 80 at 95% mod AASHTO (or 0,75 MPa, Unconfined Compression Strength)
Maximum Plasticity Index	: 6
Maximum Linear Shrinkage	: 3
Grading	: A grading envelope is not considered necessary for stabilised layers.

For unstabilised base materials the following standards should be sought:

Grading : Minimum grading modulus 1,5

$$\left(GM = \frac{\%\text{ ret on 2 mm}+0{,}425+0{,}075}{100}\right)$$

Plasticity Index:	Not greater than 12 (pedogenic materials 15)
Minimum CBR :	For traffic consisting mainly heavy vehicles: 60 - 70 percent. For traffic consisting mainly of motor cars: 50 - 60 percent.

The above standards may be relaxed when subgrades with a CBR value in excess of 25 are encountered.

When two layers of stabilised material are provided, the lower layer should have a minimum CBR value of 35 to 45 percent.

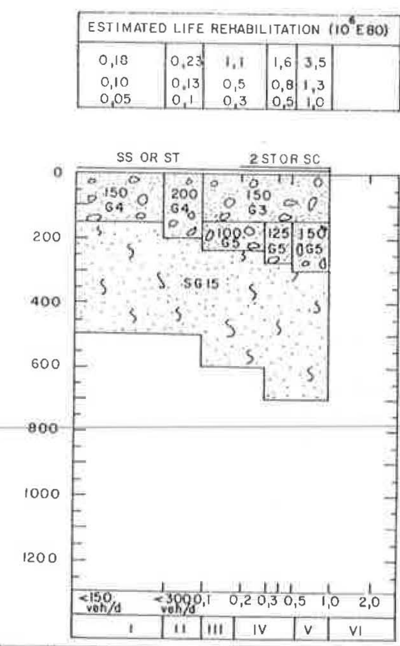
Appropriate surfacing widths are 5,5 to 7,0 metres, with unsurfaced shoulder widths of 0,5 to 1,5 metres. Generally, the shoulder material would not be stabilised and should conform of the standards given for wearing course materials.

An example of a catalogue type design as used in South Africa is shown in Figure 2 (7).

CATALOGUE DRAFT TRH 4 (1978)

FIG. 18(n)	SURFACING : BASE : SUBBASE :	SURFACE TREATMENT GRAVEL G3 OR G5 GRAVEL G5 OR G7	STANDARD C

EXPECTED MODE OF DISTRESS DEFORMATION (IN INITIAL AND REHABILITATE PAVEMENTS)



Symbol	Code	Material	Abbreviated specifications
	G3	Gravels including modified and processed gravels	PI ⊅ 6, CBR ≮ 80
	G5		PI ⊅ 10, % passing 2 mm ⊁ 30, CBR ≮ 45
	G7	Selected gravel	PI ⊅ 12, CBR ≮ 20

FIGURE 2

Bituminous Sand Seal Surfacings

Once traffic volumes on gravel surfaced roads increase, it becomes essential for economical maintenance and safety to have an all weather surfacing. Sand seal surface treatments have found wide application in many parts of Southern Africa and this type of treatment has proved itself over many years of usage over many thousands of kilometres.

A sand seal consists of a cutback bitumen, emulsion, or tar tack coat, and a suitably graded sand applied to a base course with or without a prime coat. The use of a prime coat depends on the type and quality of gravel used as well as traffic volumes.

It must be understood that with a sand seal the actual surface of the base forms the contact surface with the traffic. If the availability of good quality gravel is a problem or only available at great cost, because of long hauls, modifying the top 75 mm of the base by adding a good quality natural gravel or crushed aggregate to "reinforce" the top of the base prior to applying a seal coat is recommended.

Where good quality natural quartzitic sand is available, a sand seal presents an extremely economical solution to a surfaced road for light traffic and can safely be used for traffic volumes of the order of 300 vehicles per day to 500 vehicles per day in drier climates. It is essential to note that sand seal treatment is particularly dependant on the quality of the base course and will fail disastrously when -

1. the base is of a poor standard,
2. the road foundation is poorly drained and,
3. if the road has to take a substantial volume of heavy truck traffic at any stage.

Prior to spraying the tack coat a prime coat consisting of tar or cutback bitumen may be applied to improve the quality of the seal, sprayed at approximately 1,00 litres per square metre. A tack coat, consisting of an emulsion or cutback bitumen, may be used sprayed at 1,5 to 2 litres per square metre.

The sand can be applied manually with spades from a truck or by using the conventional push type chip spreader modified to allow a uniform sand carpet to be spread onto the road surface. The sand can be over applied in order to create a layer of sand of 3 - 5 mm in thickness on top of the base. If no prime coat is used allowance must be made for the tack coat to establish cohesion with the base surface with initial penetration, and an over application of the sand will tend to retard or stop this bond to the base. Each layer of sand must be spread at approximately 170 square metres per cubic metre. Grading requirements for sand are shown in Table 3.

TABLE 3 : SAND SPECIFICATION FOR SAND SEAL SURFACINGS

Sieve Size	Cumulative percentage by mass through sieve
6,7 mm	100
1,18 mm	40 - 65
600 um	10 - 35
300 um	0 - 15
150 um	0 - 2

Initial rolling by means of a 5 ton pneumatic roller is advisable, however if a roller is not available a lightly loaded tip truck, immediately behind the sand spreader is essential for setting the sand in the tack coat.

It is recommended that the excess sand whipped off by traffic be broomed back once or twice, particularly if bleeding is encountered. After a period of say 3 months it is recommended that a second seal be applied to rectify any deficiencies shown by the initial seal coat.

The construction of a "thickened edge", roughly 50 mm deep and 80 mm wide cut into the base and filled with clean (screened) natural gravel, graded 7 mm to 2 mm and saturated with bituminous binder creates an effective cut-off to moisture that may enter the base from the natural gravel shoulder.

The estimated life between reseals, before general surface deterioration, potholing and edge ravelling sets in, is between 4 and 5 years. The cost of a sand seal treatment has been found to be in the region of one and a half dollars per square metre.

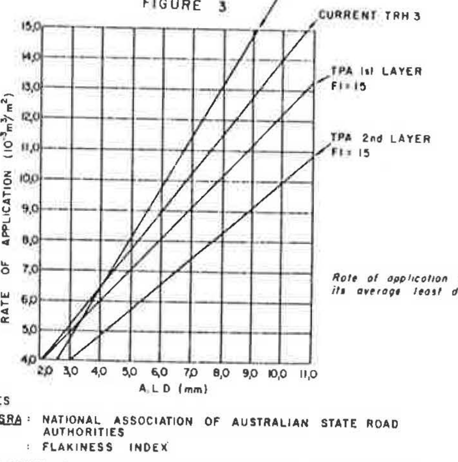
Bituminous Surface Treatments using crushed or natural Rock

Although bituminous surface treatments (generally referred to as "chip and spray" treatments) are not generally considered for this category of road, mention is made of them because suitably crushed or screened rock may be available as bye-products of other engineering activities. In some instances a lack of suitable sand may dictate the use of imported rock chips.

This process is the most common surface treatment for primary roads in Southern Africa and has been developed to a high degree of sophistication. If considered for a lightly trafficked road however, a so-called "single seal" will be applied on the primed base (as for sand seal) sprayed with a first spray of bitumen (penetration grade, cut back or emulsion) followed by 7 mm or 13,2 mm chips and a second application of binder.

The maximum amount of stone that can be retained, is contained in the single layer that comes in contact with the binder film; any over application of stone is whipped off and may be a hazard to traffic (windscreen breakages resulting). The rate of binder application must be related to the average least dimension (ALD) of the stone. It is common practice in South Africa to split the binder application by applying half the initial spray prior to the spreading of the stone chips and then spraying the remainder as a seal coat. This results in much improved stone retention. Figures 3 and 4 may be used for design purposes (8).

FIGURE 3



Rate of application of stone related to its average least dimension (A.L.D.)

NOTES

NAASRA : NATIONAL ASSOCIATION OF AUSTRALIAN STATE ROAD AUTHORITIES

FI : FLAKINESS INDEX

THE LINES ON THIS GRAPH REPRESENT THE DESIGN USED BY THE VARIOUS AUTHORITIES MENTIONED AND AS SUCH INDICATE THE UPPER AND LOWER LIMITS OF STONE APPLICATION RATE THE CURRENT TRH 3 IS THE ONE RECOMMENDED FOR USE

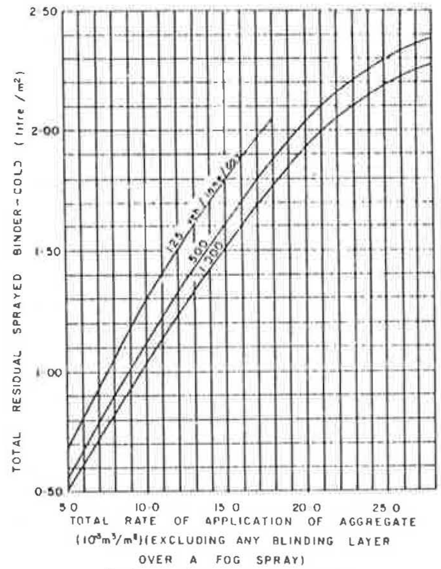


FIGURE 4

Total rate of application of binder for single and multiple surface treatments with stone

Drainage of Lightly Trafficked Roads

The reduced geometric standards generally associated with low cost roads allow better utilisation to be made of watershed alignments and in this way minimise the number of drainage structures required as well as reducing the necessity for surface drainage facilities. The watershed is also normally located on the better class materials and this approach therefore has the added advantage of a resulting better subgrade condition.

The process of shaping the road, using the in-situ materials within the road reserve to provide adequate drainage has resulted in improved performance of many kilometres of roads in Rhodesia and South Africa.

Careful consideration should be given to the sophistication of the structures used for the type of road. It has been found that the local manufacture of concrete pipes is advantageous and preferable to box culverts, and much easier to install.

Causeways or semi-low level bridge structures render roads servicable for the greater part of the year provided that flood levels are calculated to allow fordable water depths over the structures for average type vehicles (approximately 450 mm). Another approach, especially in flat marshy or vlei areas, with only the odd seasonal flood, but with permanent slow flowing water, is to provide a battery of concrete pipes adjacent to a fairly long (approximately 100 m) coarse gravel causeway at a slightly lower-level, with grouted stone pitching, particularly on the down stream face.

Special Problems, Techniques and Materials

It is on projects in this category that engineering judgement and ingenuity is challenged with each road providing its own host of special problems; this underlines the fact that the designer must have an intimate knowledge of local or similar conditions.

Damage to Roads caused by Soluble Salts

In the construction of low cost roads, it is desirable that the most economical use of materials and particularly of water sources in arid conditions be made. Soluble salts in the natural gravels and free water is common in many areas of Southern Africa and is often deleterious to bituminous binders if used for thin seal coats.

Netterberg and Maton reported to the Sixth Regional Conference for Africa and Soil Mechanics and Foundation Engineering in 1975, (9), that damage due to soluble salts had been experienced on at least 16 road construction jobs in South Africa during the past 10 years and that similar problems have also been reported from Botswana and South West Africa (Namibia).

The earlier symptoms of future distress generally occur during or soon after construction and take the form of powdering of the surface of the newly compacted base or of the prime layer itself and/or the deposition of whitish salt in blisters, cracks on the surfacing or along the edge of the surfacing. In the most severe cases heaving and cracking of the surfacing occurs and the whole base may become loose.

Damage can be prevented by limiting the content of very soluble salt, either by identification through testing, or in certain cases by the addition of high calcium content lime. The three most important factors affecting the occurrence of salt damage appear to be:

1. the presence of soluble salts in the base, subbase or subgrade,
2. the length of time an unprimed or primed base is left unsurfaced,
3. the permeability of the surfacing.

High calcium lime treatment should only be used when the salts present in a material are known and furthermore this action appears necessary only if the pH is less than 6,0 and the total soluble salt content is more than 0,2 per cent.

Sea water has been used successfully in the coastal regions of South West Africa for base compaction and reasonable success has been attained with an early application of the bituminous seal coat (within two weeks). Generally however the use of sea water for compaction should be restricted to layers deeper than 0,5 metre below the surfacing.

The Use of Calcretes in Road Foundations

The occurrence of pedogenic rock and in particular calcretes, is common to many countries in the world and Southern Africa is fortunate in having a variety of types occurring over an extremely wide area. In the RSA calcretes are the third most commonly used road building material (10). Calcretes vary from a fine powdery substance to crushable boulders and can be classified into 6 basic types, easily recognised in the field by untrained personnel, viz, calcified soils, powder calcretes, nodular calcretes, honeycomb calcretes, hardpan calcretes and boulder calcretes (10).

Prospecting Methods

Air-photo interpretation is a very useful preliminary tool, because calcarious deposits usually show up well. Another method is infra red aerial photography because the hygroscopic moisture content of calcarious materials is higher than that of the surrounding ground. (Borne out by the fact that small burrowing animals usually dig their holes in these sources - cooler). Ground checking of aerial photography is essential in order to ascertain the quality of the source. For this purpose a valuable tool has been developed by a road inspector (see fig 5).

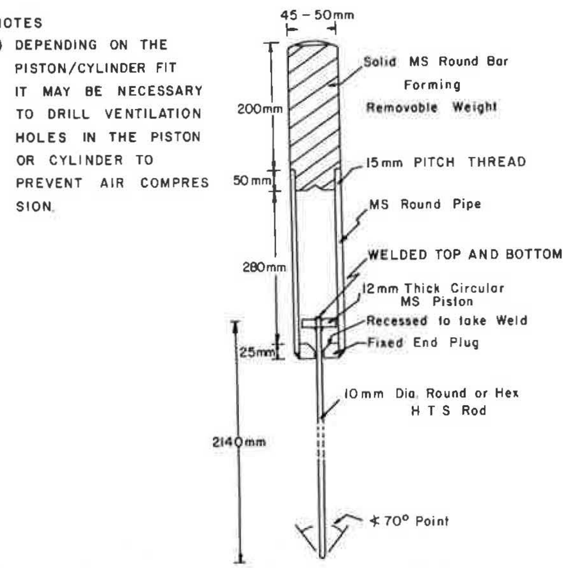


FIGURE 5

RAPID CALCRETE PROBING DEVICE

The tool is simply hammered into the ground to its full reach or to refusal and then withdrawn. Any calcrete encountered will stick to the paint and with practice the quality can be deduced. This probe is about ten times faster than any probe or auger in these conditions.

Engineering Properties of Calcretes

Particle strength of calcretes is usually low and normal grading analysis must be regarded as unreliable. The normal Atterberg-limits of soils must also be applied with extreme care, because practice has shown that calcretes with PI's as high as 15 - 20 can still be used as natural base courses for highly trafficked roads in arid areas.

Two other simple field tests have been devised and reported by Netterberg (10) i.e. the Aggregate Pliers Test that can be used by any field worker using a pair of normal pliers and good judgement in order to establish an approximate 10% FACT value. Similarly softer calcretes can be crushed by the worker's fingers - Aggregate Finger Value (AFC).

It is also well known that a substantial increase in strength of calcareous layers is experienced with time, ascribed to self-cementation.

The successful uses of calcrete in road foundation layerwork have been proven over many years in Southern Africa. In many instances the material used would not comply with the usual AASHTO, British and South African standards for the particular application, however, perfectly satisfactory flexible bases for light and medium trafficked surfaced roads under relatively thin seal coats have been constructed. In the light of these findings it seems reasonable to relax certain materials standards in order to provide a more economically locally suited facility.

Conclusion

The secondary and tertiary legs of the road infra-structure in many developing countries are often neglected thus impeding development and the national economy. In order to utilise natural materials as well as manpower to its fullest possible extent, knowledge of local conditions is essential.

This has the effect of reducing costs to a minimum and consequently the dependance of developing countries. Donor countries offering this aid generally have well developed economies and infrastructural facilities, hence appropriate expertise is not always available within these countries. In such instances it is advisable to consult with countries who have recently passed through this phase of development.

Acknowledgements

Approval to publish this paper has been given by the Secretary for Transport and is gratefully acknowledged. The use of the information from the Provincial Roads Departments of Natal and Orange Free State Provinces, is also acknowledged.

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