MOZAMBIQUE FEEDER ROADS PROJECT: Proposals For Labour-Based Surfacing Trials

by H R Smith, W G Ford, A C Edwards and P A K Greening

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Prepared for: Department For International Development

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MOZAMBIQUE FEEDER ROADS PROJECT:
PROPOSALS FOR LABOUR-BASED SURFACING TRIALS

1. INTRODUCTION

TRL has been approached by DFID to provide Technical assistance to the Mozambique Feeder Roads Project in the Zambezia province of Mozambique. The purpose of this technical assistance is to develop and test a range of bituminous surfacing technologies, which can be applied, using labour-based construction techniques. The purpose of this report is to set out the methodology for implementation of a series of demonstration trials and to report on a preliminary visit carried out by TRL personnel in June 2000. The specific objectives of the visit were to:

- Confirm the project feasibility.
- Hold discussions with local and national organisations, supervising consultants and contractors on various aspects of the project implementation.
- Investigate availability of materials, equipment, suitable contractors and labour.
- Select suitable sections of road for construction of trials.
- Modify proposals and refine the cost estimates.

Three sites have been identified as suitable for the trials and sources of aggregates have been located. Equipment needed and labour requirements for construction have been detailed and the associated costs collated. A full visit report is contained in Appendix A.

The feeder roads project in Zambezia is being carried out on behalf of the Provincial Directorate of Public Works and Housing (DPOPH) and the Provincial Roads Department (DEP) whilst the supervising consultant is Scot Wilson Consulting Engineers.

The proposed trials will be carried out in full consultation and collaboration with these organisations and other local stakeholders. Discussions have also been held at the national level with ANE. Based on the costs given in Tables 12-16 and with the proviso that some material and equipment costs are estimates the construction of the trials will be £39712.

2. BACKGROUND

Roads in rural Africa are vital to the socio-economic well being of communities in these areas by providing access to schools, clinics, jobs, markets, neighbouring communities and the higher order road network. Therefore, whilst these roads tend to carry relatively low levels of traffic, they play an important role in contributing to poverty alleviation, social and economic development and the facilitation of schemes aimed at improving rural livelihoods.

The focus on road provision in rural areas is moving away from the conventional concept of benefits from reduced vehicle operating costs to that of providing all weather access. When access is treated as a priority (i.e. to schools, clinics, markets etc), it is likely that there will be an increased focus on localised improvement options. If these ‘spot improvement’ works are to be carried out, then the conventional equipment based approach becomes prohibitively expensive and cumbersome for the small sections of road to be tackled. However, this can create opportunities for locally based small contractors using labour-based technologies.

Earth and gravel roads are particularly susceptible to environmental damage. Often, just short sections of road are affected but these can have a serious impact on passability, especially during the wet season, thus reducing the benefits for rural communities, which they were designed to provide. Conversely, spot improvements targeted at problem sections of rural road networks can give large benefit/cost ratios.

These spot improvements can take many forms, including the surfacing of sections of road that are likely to require recurrent maintenance. Low–cost sealing as an option for spot improvement works can be carried out by labour–based techniques. Much of the equipment required for the bituminous surfacing is part of the standard plant used by small contractors in the construction of rural roads. Any additional equipment that may be required is relatively cheap and within the range of the capital investment expected by small–scale contractors.

In recent years, labour–based methods have also been seen as an important route to allow the entry of emerging contractors into the road sector. The main reason for the success of this approach is that a much lower level of investment is required by labour–based contractors than for more equipment intensive operations. This has enabled contractors to enter the roads sector at different levels ranging from petty contracting for routine maintenance to periodic maintenance, rehabilitation and even larger construction projects. With the thrust towards decentralisation, it is also important that the urban and rural authorities have a contracting capacity that can operate at the local level without incurring large mobilisation costs for relatively small road works. This is particularly relevant to the construction and maintenance of the relatively short lengths of surfaced roads for which many of these local authorities are now responsible.

As unemployment continues to grow within the region and the developing world generally, the use of local resources becomes increasingly attractive not only in financial terms but also in social terms. By adopting labour–based methods, temporary employment can be offered to people in rural areas that are generally far from other work opportunities. The development of locally based (district and province level) contractors can assist in spreading the employment opportunities into all areas of a country, and provide capacity at the local level for the implementation of road maintenance and improvement works. This is particularly important as the emphasis shifts away from road construction towards maintaining existing road investments. This inevitably results in less new construction work being undertaken and an increase in the need for maintenance and repair works.

In Mozambique much of the rural road infrastructure was destroyed or fell into disrepair in the period following independence and the subsequent war. As part of the rebuilding process, DFIDCA are funding a rehabilitation programme of over 800 kms feeder roads in Zambezia province. One of the objectives in the programme is the training of local contractors in labour – based techniques for the rehabilitation and maintenance of unpaved roads. This objective has been successfully achieved with contractors being trained under the programme.

Programmes such as this are making a substantial contribution to building local capacity, transferring technology and increasing local employment opportunities.

One of the identified risks for ensuring the long-term viability of these small contractors is that they have a relatively narrow skills base and are therefore extremely vulnerable to any discontinuities in the funding for road works. Opportunities for work are likely to be restricted if contractors have limited skills. Therefore, if these contractors are to remain viable, it is important to widen their skills base so that they can diversify their operations when work is scarce. Although the skills described in this paper are still linked predominantly to roads sector operations, they will contribute to widening the skill base of small-scale contractors and will provide opportunities for some diversification into other sectors. Typical examples would be small areas in schools, clinics, roads in small municipalities, rural district roads, roads in villages, car parking areas etc.

3. PRELIMINARY VISIT

Contact in Mozambique was made with Mr D Geilinger of Scott Wilson Consulting Engineers representing DFID for the Feeder Road Project based at Quelimane. With the assistance of Mr Geilinger TRL were able to identify three sites, at Mocuba, Ile and Forquia, which would be suitable locations for the surfacing trials.

Sources of local aggregates to be used in the construction have been located and samples taken for laboratory testing to assess their suitability. TRL visited the local DEP materials testing laboratory in Mocuba where Mr Artur, the Senior Materials Engineer, has offered the necessary testing facilities that may be required during the construction phase of the trials. The ancillary equipment necessary for construction of the trials was found in Quelimane and unit equipment prices have been identified.

TRL propose that a section of the surfacing trials will be allocated to ANE, the Mozambique Road Authority. This will enable them to have the opportunity to construct an alternative local surface treatment alongside the proposed surfacings. Subsequently TRL met Mr Pedro Carvalho, a Consultant to ANE, who has expressed interest in the project and has experience with emulsion sand stabilisation surfacings. Scott Wilson will assign a contractor to carry out the construction phase with TRL providing site supervision. Although it was not possible during the visit to discuss the project with local contractors, it is proposed that during the construction phase a Workshop will be conducted at Scott Wilson's office in Quelimane. This will provide an opportunity to disseminate low volume labour-based technology to the local contractors and provincial road authorities and would involve presentations by TRL and local consultants. Part of the workshop programme would include a site visit during the construction of the surfacing trials.

Bitumen and bitumen emulsions are not readily available in Mozambique, and are imported from South Africa. Mr Carvalho has offered his assistance in procuring the necessary bitumens required for the project.

4. OBJECTIVES

The principal objectives of the surfacing trials are to:

- raise awareness of labour–based surfacing technology.
- increase the skills base of small–scale contractors.
- establish viable methods of constructing bituminous surfacings in locations where mechanised construction equipment and good quality road building materials are not readily available.
- To demonstrate the construction of recognised types of bituminous surfacings using locally available materials and labour – based construction methods.
- To extend currently technologies to allow the use of a wider range of materials and techniques in the production of effective bituminous surfacings.

It is proposed that trials of bituminous surfacings be constructed on the feeder roads project to provide an option of placing a durable surfacing at locations where the cost of maintenance interventions would normally be excessive.

Sites where labour–based bituminous surfacings may be appropriate include the following;

- Steep gradients where run–off can cause erosion and deep gullies.
- Areas where the soils/gravels are of poor quality.
- Approaches to culverts and bridges.
- Sections of road through villages.
- Sharp bends where traffic rapidly erodes the earth/gravel surfacing.
- Peri–urban areas (particularly informal settlements).

- Low-lying areas prone to occasional flooding.

5. TYPES OF BITUMINOUS SURFACINGS

The main thrust of the trials is to show how locally available materials and low-cost labour-bases construction techniques can be used in bituminous surfacings. However, the chances of success will be increased if the surfacings can be designed and constructed with reference to established principles.

Bituminous surfacings which can be regarded as being of relatively low cost and most likely to be adaptable to construction by labour based methods include;

- Otta seals.
- Sand stabilisation
- Sand seals.
- Penetration macadam.
- Pre-mixed material.

If bituminous binders are used then purpose made equipment to heat and spread this bitumen, is desirable on the grounds of safety. In the absence of such equipment great care must be taken to ensure safe working on site.

5.1 OTTA SEALS

This type of surfacing has been constructed on a number of roads in Southern Africa and elsewhere. Construction requires the spreading of a film of bitumen on a prepared roadbase, which is normally left unprimed, followed by the application of a thin layer of gravel. Pneumatic tyred rollers usually roll the gravel or, if necessary, a laden truck so that the bitumen is 'worked up' through the gravel until the layer has the appearance of a dense bituminous surfacing. If the expected traffic is very light then the Otta seal *must* be rolled extensively.

The Otta seal specification uses gravel aggregate conforming to three alternative gradings combined with an MC 3000 bitumen. The construction process would involve heating the bitumen to about 150C. It is considered that this would be dangerous given the low technology that would be available in general in Mozambique. An alternative would be to use a 150-200 pen based bitumen emulsion, which can be applied at ambient temperature thus reducing safety hazards. Local gravel aggregates are available at all three sites but the grading only conforms to a dense material (see Table 1 below). Ideally for Otta seals, the material will conform to an open graded specification but since it is not possible to locate this material the alternative is omit this treatment from the trial. However as the project is partly research based it would be of interest to attempt using the in-situ available gravel.

Only one source of gravel is available and therefore, it is proposed two single Otta seals will be constructed, one single Otta without priming and another where the roadbase is primed.

Table 1 Gravel gradings for Otta seal

	Specification				
Sieve	Open graded	Med graded	Dense graded	Sample 1	Sample 2
19mm	100	100	100	100	100
16mm	80-100	84-100	93-100		
13.2mm	52-82	68-94	84-100	99.6	98.2
9.5mm	36-58	44-73	70-98	98.6	95.2
6.7mm	20-40	29-54	54-80		
4.75mm	10-30	19-42	44-70	72.7	63
2.00mm	0-8	3-18	20-48	25.2	25.3
1.18mm	0-5	1-14	15-38	18	18.5
0.425mm	0-2	0-6	7-25	8.7	7.2
0.075mm	0-1	0-2	3-10	1.7	0.8

5.2 SAND SEALS

These seals are normally constructed in a similar manner to surface dressings but are cheaper, if sand is readily available, and may be more tolerant to variations in materials and application rates. Sand seals are usually less durable than surface dressings and the restrictions regarding choice of bitumen are the same as for surface dressings. Sand seals can be constructed using emulsion and provision for an emulsion–based sand seal has been made in these trials. The treatment uses a sand conforming to a grading specification with a K1-60 bitumen emulsion. It can be seen from Table 2 that the sources of sand available are much finer than is specified. However, as stated for the Otta seals, it is worth experimenting as this is the only type of sand locally available in the area.

Table 2 Gradings for sand seals

Sieve	Specification	Sample 1	Sample 2	Sample 3
6.7mm	100	100	100	100
1.18mm	40-65	99.5	99.2	81.8
0.600mm	10-35	86.5	64.0	51.8
0.300mm	0-15	24.6	7.8	29.9
0.075mm	0-2	0.8	0.2	5.9

5.3 SAND STABILISATION

The original proposals suggested that a section of the surfacing trials will be allocated to ANE to enable them to try a locally developed treatment. Interest has been expressed by ANE who are considering using sand stabilisation. The construction of this surfacing would be under the control of ANE.

5.4 PENETRATION MACADAM

This material is described in BS434 (BSI, 1984) and the recommended procedures given in the British Standard will be applied as far as possible for the trials. After trafficking this type of surfacing is effectively similar to asphalt. It is constructed to be at least 50mm thick and is very robust compared to seal coats. This type of surfacing is, therefore, likely to be the best solution for sites where traffic and road geometry is severe. The cost of this surfacing will be relatively high because screened crushed rock aggregate is required in the standard specification together with a high rate of application of bitumen. However, cold emulsion is suitable for this process.

Crushed aggregate is normally used because this material helps to generate a stable, interlocking layer after it has been compacted. Uncrushed gravel materials can be screened for use in such a layer if the aggregate particles have some surface texture and traffic is light. Suitable aggregates can also be produced by hand-knapping if necessary.

The proportions of aggregate of different nominal sizes required for a 50mm thick layer are;

60% of 40mm nominal single sized stone.
30% of 28mm nominal single sized stone.
10% of 14 to 20mm nominal single sized stone.

It would be best to build a full-grout layer which will require 5.5 to 7 litres (residual bitumen content normally between 3 – 4 litres per square metre) of CRS-2 bitumen emulsion. Heating is not needed and watering cans can be used for application if they are fitted with suitable multi-holed distribution spouts. These will be fabricated on site.

The finished macadam is normally surfaced with a single surface dressing after a period of trafficking. However, for these trials it may be preferable to complete the layer immediately and a decision would be made on site to choose the most appropriate method of sealing the penetration macadam. It may, for instance, be appropriate to use a sand seal depending upon the appearance of the macadam.

Local won crushed rock aggregate is available at Mocuba. The extraction and sizing of this aggregate is highly labour based where the material is reduced by hand knapping, i.e. breaking down with the use of small hammers. The required sizes of aggregate can be obtained using this method and it is estimated that the local quarry will supply the quantities within a period of two weeks.

5.5 PREMIXED GRAVEL MACADAM

Gravel aggregate can be mixed with an anionic emulsion either by hand or in a small drum mixer such as a portable cement mixer with the aggregate gravel specification the same as the Otta seal. Contractors are in possession of portable mixers and manufacturing of this material will pose no particular problems. After mixing, the material will be spread on a primed roadbase and rolled in the same way as an Otta seal. The surfacing would be comparable to an 'Otta' seal and will be produced using bitumen emulsion.

6. METHODOLOGY

6.1 CONSTRUCTION.

It is intended that trials are constructed on short sections to determine the most suitable solutions for different conditions and materials and it will be important to construct some trials on difficult sites to prove the effectiveness of the surfacing materials. However, it is assumed that it will be important to treat the trials as a training programme and not simply as demonstrations. In this context it will be appropriate to construct the first sections on an 'easy' site to establish good working procedures. The most likely timing of the construction phase would be between August and October 2000. This would allow time to refine the proposals, procure materials and equipment and complete construction before the on set of the rains.

6.2 PERFORMANCE MONITORING.

The trials are intended to be a combination of a demonstration of existing surfacing techniques and an investigation of alternative materials and techniques suited to labour–based methods of road construction.

Recommendations related to construction techniques will be able to be reported following construction of the trials. A full assessment of the effectiveness of the completed trial sections can only be made after a period of monitoring. In order to make the monitoring and performance assessments as effective as possible, it will be essential to observe and record details of the quality of construction work. Locations of obvious variations in material quality or quantities of bitumen will be particularly important.

During visits to monitor the performance, the trial sections will be assessed in terms of:

- traffic carried
- deformation if there are obvious wheelpaths
- cracking and other visible defects
- richness of the surfacing
- details of any loss of aggregate from the surfacing, and
- any other factors which help to explain performance.

No allowance has been made in this proposal for the cost of performance monitoring. It will, be possible to make a provisional estimate on comparative performance by assessing the condition of the sections at periods of 3 months, 6 months and 12 months following construction. The cost of these monitoring visits will depend on the number of sections but is provisionally estimated at £8000. It may be possible to include some of these visits in the post evaluation of the feeder road project, which is due to end in March 2001 but with the agreement of the Deputy Chief Engineering Advisor, they could be funded through the Appropriate Surfacings for Low Volume Roads KAR programme.

7. EMULSIONS FOR SURFACING TRIALS

Emulsions are convenient to use but cationic grades 'break' quickly and need heating to about 75ºC for spraying by distributor. They would also need to be heated for spreading with simple applicators. CRS65 is easy to use without heating. For some aggregates the cationic emulsions have some worthwhile advantages in terms of bitumen adhesion. For pre-mixing gravel and bitumen a stable grade, slow breaking emulsion (SS60 or CSS60) is usually the most appropriate binder. The emulsions to be used in the trials will be of various types and grades. The types and grades required are shown in Table 3.

Table 3. Emulsions

Type	Grade SABS
Slow-setting Anionic	SS60
Rapid-setting Cationic	CRS65
Slow-setting Cationic	CSS60
Invert emulsion prime	MSP1

Bituminous binders supplied in 200 litre drums will be the most convenient for the trials. It is preferable that cutback bitumens such as MC30 (for priming roadbases) are supplied already blended. Alternatively an invert emulsion MSP1 may be used.

8. TRIAL SITES

The surfacing trials will be constructed at three separate sites.

The first site is situated in Mocuba, 125 Km north of Quelimane. This site is flat and is currently a gravel road. As the main trial site, it will incorporate all five proposed surfacing treatments.

A second site, some 100 Km north of Mocuba is situated at Ile. The road is currently gravel and is on a gradient. This would be an ideal site to determine the affect and problems a steep gradient would give during construction. In particular, since bitumen emulsions will be used, it may be difficult to keep the emulsion from draining downhill. The two treatments suggested for this site are penetration macadam and pre-mixed material. Scott Wilsons have expressed concern that if two sections of 25m are constructed part way down the slope there may be subsequent problems with drainage. It is therefore suggested that the full slope length will be covered with two sections, each of 75m. As the treatments would be waterproof no problems are foreseen with surface water drainage during the wet season. There would however be additional costs involved in construction of the increased section lengths.

The third site is located near Forquia, 60Km south of Mocuba and 60Km north east of Quelimane. The terrain is flat and the road is a sand track. It is proposed to lay two 25m sections of sand stabilised and Otta seal treatments.

9. EXPERIMENTAL MATRIX

9.1 EMULSIONS

The proposed sections for each of the sites are given in Tables 4 – 6. A summary of the emulsions required is given in Table 7.

Table 4 Mocuba (Flat, gravel)

Surfacing	Sections	Length	Binder	Aggregate
Otta seal (unprimed)	1	25m	CSS60	Local gravel
Otta seal (primed)	1	25m	MC30 or MSP1 CSS60	Local gravel
Sand stabilisation	1	25m		Local sand
Sand seal (single, primed)	1	25m	MC30 or MSP1 SS60	Local sand
Sand seal (double, primed)	1	25m	MC30 or MSP1 SS60	Local sand
Penetration Macadam (unprimed)	1	25m	CRS65	Local Crushed Rock
Premix Macadam (primed)	1	25m	MC30 or MSP1 SS60 or CSS60	Local gravel

Table 5 Ile (Incline, gravel)

Surfacing	Sections	Length	Binder	Aggregate
Penetration Macadam (unprimed)	1	75m	CRS65	Mocuba Crushed Rock
Premix Macadam (primed)	1	75m	MC30 or MSP1 SS60 or CSS60	Mocuba gravel

Table 6 Forquia (Flat, sand)

Surfacing	Sections	Length	Binder	Aggregate
Sand stabilisation	1	25m		Local sand
Otta seal (primed)	1	25m	MC30 or MSP1 CSS60	Local gravel

Table 7 Bitumen emulsions required for trials

Surfacing	Primer	Emulsion
Otta seal	316 L of MC30 or MSP1	1280 L of CSS60
Sand seal	300 L of MC30 or MSP1	675L of SS60
Sand stabilisation		
Penetration Macadam	-	3416 L of CRS65
Premix Macadam	244 L of MC30 or MSP1	2980 L of SS60 or CSS60

9.2 AGGREGATE MATERIAL AND QUANTITIES

The types, quantities and application spread rates of various aggregates at each trial site are given in Tables 8 –10. Table 11 gives the total quantities required.

Table 8 Mocuba (width 6m)

Aggregate	Sections	Area m^2	Application m^3/m^2	Total m^3
Gravel	3 x 25m	450	.015	6.75
Sand single	1 x 25m	150	.005	0.75
Sand double	1 x 25m	150	.01	1.5
Sand Stab	1 x 25m	150	.05	7.5
Crushed Rock	1 x 25m	150	.05	7.5

Table 9 Ile (width 4.5m)

Aggregate	Sections	Area m^2	Application m^3/m^2	Total m^3
Gravel	1 x 75m	337.5	.015	5.1
Crushed Rock	1 x 75m	337.5	.05	16.9

Table 10 Forquia (width 4.5m)

Aggregate	Sections	Area m^2	Application m^3/m^2	Total m^3
Gravel	1 x 25m	112.5	.015	1.7
Sand stab	1 x 25m	112.5	.05	5.6

Table 11 Summary of aggregates required for trials

Aggregate	Total m^3
Gravel	13.6
Sand	15.4
Crushed Rock	24.4

10. CONSTRUCTION COSTS

The costs of the materials, labour, equipment and supervision of the construction of the trials are given in Tables 12 – 16. With the proviso of the costs of binders are estimates, the total costs of the trials is £39712.

Table 12 Aggregate costs

Aggregate	Amount (m^3)	Cost 20US$/$m^3$	Transport 10US$/5$m^3$
Gravel	15	Free	30
Sand	20	Free	40
Crushed Rock	30	600	60
	Total	730 US$	£487

Table 13 Bituminous prime and emulsion costs

Surfacing	Primer	Cost £	Emulsion	Cost £
Otta seal	316 L MC30/ MSP1	Based on UK prices plus 33% for transport and import from South Africa	1280 L CSS60	Based on UK prices plus 33% for transport and import from South Africa
Sand seal	300 L MC30/ MSP1		675 L SS60	
Sand stabilisation			(?) SS60	
Penetration Macadam	-		3416 L CRS65	
Premix Macadam	244 L MC30/ MSP1		2980 L CSS60	
Total	860L (1000)	£400	8351L (8400)	£2960

Table 14 Ancillary equipment required for construction of the trials

Procedure	**Details**		**Item of equipment**	**No. required**
Transportation	For staff, bitumen and equipment	SW	Truck Personnel carrier	2 trucks 1 for supervising personnel
Winning aggregates	Crushed rock	Site	Bought in	
	Gravel	Site	Excavation and transport From end loader and truck or tractor trailer or; Pick axes and shovels	20 of each
	Screens	SW	Weld suitable reinforcing wire	2 each of 4 mesh sizes, 1x1.5m
Roadbase preparation	Scarifying Compaction	Q	Pickaxes Rakes Hand rammers Water supply	See above 5 4 1 bowser
Spreading bitumen	Weighing	Q	50kg weigh scales	1
	Sprayer	SW	Hand pump with lance	1
	Cans	Q	Calibrated containers Large metal watering cans with long metal dispenser on spout Squeeges	 12 5
	Clearing blockages	UK	Gas blow torch	2 + 2 refills
Mixing	Mixing emulsion/gravel	SW	Concrete mixer or Tractor and harrow	2 mixers or 1 set
Spreading aggregate	-	Q	Wheel barrow	8
	Loading and spreading	Q	Shovels	See above
Compaction	Roller	SW	Tandem roller + Loaded truck	1 roller and 2 trucks (see item transport)
Road sweeping	-	Q	Brooms	24
Cleaning equipment	Cloths and solvent	Q	Kerosene solvent	20 litres-
Miscellaneous	Small items	Q		-
		SW	Measuring tape	1 x 30m
		UK	String line	1 large ball of strong string
		Q	Domestic hand brushes	5
		UK	Sample containers for bitumen	4
		UK	Heat resistant gloves	12 pairs
		UK	Sample bags for aggregate	30
		SW	Marker pegs	10
Safety	-	UK	Medical kit (especially for burns)	1
		SW	Fire extinguishers	2 (suitable for bitumen fires)
	-			
	Cooling	SW	Water drum, hand spraying pump	1 of each

SW Scot Wilson
UK TRL
Q Quelimane
Site Local

Ancillary equipment required for construction has been estimated at 2500US$; £1666.

Table 15 Local Labour

Site	Construction time days	Local labour costs(US$)
Mocuba	8	240
Ile	8	240
Forquia	4	120
Total	20	600 £400

1 person day will cost 2US$ for local labour. It is anticipated that 15 people would be required per day during the construction phase. The labour construction costs for each site is given in table 15.

Table 16 TRL supervisory staff (UK based)

( ) days	Flight	Travel	Site preparation	Meeting	Construction	Report	Subs. £30/day
Staff days @ £604/day	£1833	£2416 (4)	-	£604 (1)	£9060 (15)	£4228 (7)	£600
Staff days @ £459/day	£1833	£1836 (4)	£2295 (5)	£459 (1)	£6885 (15)	-	£750
Total	£3666	£4252	£2295	£1063	£15945	£4228	£1350
Total	£32799						

Provision of a contingency for miscellaneous expenditure is estimated to be £1000.

11. PERSONNEL

The TRL team will comprise Mr H R Smith, Mr P A K Greening and Mr A C Edwards. CV's are given in Appendix B.

Mr H R Smith, will primarily be responsible for the design of the surfacings and supervision of the construction of the trials

Mr P A K Greening, will be responsible for liaison with ANE, Scot Wilson Consultants and local small contractors.

Mr A C Edwards, will be responsible for the preparation of the trial site locations prior to construction and also in supervision of the construction of the trials.

As an additional input, Mr C Overby, the Norwegian Road Research Laboratory specialist in Otta Seals and low cost roads, will also contribute advice. This input will be funded through the DFID KAR project on 'Appropriate Surfacings for Low Volume Roads'.

12. REFERENCES

BSI (1984) Bitumen road emulsions (anionic and cationic). Part 2. Code of practice for use of bitumen road emulsions. BS 434: Part 2:1984. (British Standards Institution).

APPENDIX A.

Transport Research Laboratory

International Development
Visit Report No. 1263

Country: Name:	Mozambique PAK Greening and AC Edwards	DFID code R 7470
Dates:	25 June – 3 July 2000	

Objectives: To confirm the feasibility of a project to investigate the use of bituminous surfacings to improve durability and reduce maintenance costs of low volume labour-based roads. The feasibility study will form the basis of a separate report as set out in the TOR for the project.

Background: DFID and other donors are funding road infrastructure projects in rural areas of Africa as part of the effort to alleviate poverty. Many of these roads are being constructed by labour-intensive methods using local personnel. One of the aims of these projects is to promote an improved environment and capacity for sustainable development by training indigenous contractors in labour-based technology. These earth and gravel roads are susceptible to accelerated environmental deterioration in the wet season and spot improvements by surfacing short sections of road most at risk will reduce maintenance inputs. In many African countries the responsibility for the rural road network is being devolved to rural district councils, which has resulted in these authorities being responsible for relatively short sections of paved roads, which can easily be maintained by labour-based methods. There is also an increasing demand for the surfacing of roads through villages, in peri-urban areas and in informal settlements, all of which can be carried out by labour-based methods.
TRL are involved in the development of technology suitable for the surfacing of low-volume roads by labour with the aims of reducing maintenance costs, increasing opportunities for labour-based maintenance and increasing the skills base of small-scale contractors. DFID are supporting the development of this technology through a KAR project and through the Feeder Roads Project in the Zambezia province of Mozambique. DFID have agreed that sections of these project roads can be used to demonstrate and research methods of surfacing by labour-based methods.

Outcome:
Contact in Mozambique was made with Mr D Geilinger of Scott Wilson, Consulting Engineers representing DFID for the Feeder Road Project based at Quelimane. With the assistance of Mr Geilinger, a number of sites were visited and three sites were provisionally identified (Mocuba, Ile and Forquia) following discussions with the project engineers. Sources of local aggregates to be used in the construction have been located and samples taken for laboratory testing to assess their suitability. The Senior Materials Engineer, Mr Artur, has offered testing facilities at the local DEP materials testing laboratory in Mocuba during the construction phase of the trials.

The ancillary equipment necessary for construction of the trials was found to be available in Quelimane and equipment prices have been identified.
The trials and provisionally selected sites were also discussed with Mr Carvalho, a materials specialist consultant to ANE, who is expected to play a significant advisory role in the construction of the trials. As a result of these discussions, the composition of the trials combine a number of surfacing treatments proposed by TRL and ANE, who are also developing technology for the stabilisation of sands with bitumen emulsion using labour-based techniques. The sites and surfacing treatments in the trials have been selected to cover the range of materials, surfacing techniques, site conditions and construction methods, which can most easily be adopted by local small-scale contractors.
Bitumen and bitumen emulsions are not readily available in Mozambique and these materials are currently imported from South Africa. However Mr Carvalho has offered his assistance in procuring the necessary bitumens required for the project.
A contractor will be identified to carry out the construction phase of the trials. Although it was not possible to discuss the project with the contractors during this visit, it is proposed that a workshop will be held in Quelimane during the construction phase. This will provide an opportunity for contractors and other potential stakeholders to discuss the objectives and technical aspects of the project. Subject to his availability Mr Carvalho has agreed to participate in the workshop. Part of the workshop programme would include a site visit during the construction of the surfacing trials.

The Project programme and visit was discussed by telephone with Julia Compton the Livelihoods Field Engineer stationed at BHC in Maputo.

TRL gratefully acknowledges the assistance and advice given by the staff of Scott Wilson, DEP and ANE during the visit.

Key People met:
Mr D Geilinger, Scott Wilson Consulting Engineers, Quelimane.
Mr P Carvalho, Consultant for ANE, Maputo.
Mr M Worth, Head of Mechanical Workshops, Scott Wilson, Mocuba.
Mr A Ndikumagenge, Scott Wilson Field Engineer, Mocuba
Mr G Artur, DEP Senior Materials Engineer, Mocuba.

Signed: *Name & signature*

Date

Circulation for visit report

1. Director of International Division, TRL
2. Head of International Business Development, TRL
3. Group Manager Infrastructure 1, TRL
4. Group Manager Infrastructure 2, TRL
5. PAK Greening, Co-Project Manager, TRL, Harare, Zimbabwe
6. WG Ford, Co-Project Manager, TRL
7. PWD Roberts, Deputy Engineering Advisor, DFID
8. J Hyde, Central Africa Desk, DFID
9. S Stoneman, TRL

APPENDIX B.

SURNAME	FORENAMES	AGE
SMITH	Harry Robert	60

DEGREES etc

HNC, Civil Engineering, Reading College of Technology, 1969
MPhil (Eng), (Kolbuszewski Prize) - University of Birmingham, 1989
Fellow of the Institution of Highways and Transportation

POSTS HELD (with dates)

1992-present	**Project Manager and Principal Investigator** of DFID Technology Development and Research (TDR) and advisory projects for the design and strengthening of paved roads in developing countries and the development of bituminous surfacings for tropical climates.
1991-present	**Project Manager** for the pavement evaluation and asphalt design and bituminous materials projects in Bahrain, Cyprus, Yemen, Mauritius, Tanzania, Nepal, Nevis, St Lucia and Malawi.
1986-1991	**Principal Investigator** on TRL's TDR programme for DFID concerned with the development and design of durable bituminous surfacings to be used in tropical climates.
1983-1986	**Project Manager** of a cooperative TRL/MOTC research project in Kenya which established the causes of premature ageing, and subsequent cracking, of asphaltic concrete surfacings. Recommendations were made on alternative methods of design and construction that prevented these premature failures.
1976-1983	**Researcher** in the Pavement Engineering Section of the Overseas Centre of TRL.
1973-1976	**Team Leader** with the responsibility for supervising a collaborative TRL/MOTC research project in Kenya that investigated the strengthening effects of both different thicknesses and types of bituminous overlay.
1967-1973	**Researcher** in Pavement Engineering Section of the Overseas Centre of TRL.
1964-1967	**Researcher** in a joint TRL/PWD research programme in Malaysia that improved and developed pavement design procedures for roads constructed in areas of high rainfall.
1959-1964	**Researcher** in the Materials Section of the Overseas Centre of TRL.

RECENT PUBLICATIONS (title and reference)

1. Condition of the Tan-Zam Highway at Kitonga Gorge. Paper to African Roads Congress, 1998. (Co-author)
2. Bituminous surfacings for heavily trafficked roads in tropical climates. Proc. Inst. Civil Engineers, Transport, 1998. (Co-author)
3. The benefits of using chip seals in Malaysia. Second Malaysian Road Conference. Kuala Lumpur, 1996.
4. A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical climates. Overseas Road Note 31, Transport Research Laboratory, 1993. (Co-author)
5. The durability of bituminous overlays and wearing courses. 3rd International Conference on the Bearing Capacity of Roads and Airfields. Trondheim, 1990. (Co-author)
6. Research into the durability of bituminous overlays on wearing courses in tropical environments. MPhil theses, School of Civil Engineering, University of Birmingham, 1989.
7. The performance of a full-scale pavement design experiment in Jamaica. Transportation Research Record 1117. Washington DC, 1987. (Co-author)
8. The design and performance of bituminous overlays in tropical environments. 2nd International Conference on the Bearing Capacity of Roads and Airfields. Plymouth, 1987. (Co-author)

SURNAME	FORENAMES	AGE
GREENING	Percival Anthony Kerton	60

DEGREES etc

BSc in Chemistry and Physics University of Wales, 1962
Member of the Institution of Highways

POSTS HELD (with dates)

1993-present.	**TRL Project Manager** based in Zimbabwe managing three DFID/SIDA funded projects in collaboration with countries of the Southern African Development Community (SADC) related to the cost-effective use of locally available roadbuilding materials.
1993-1996.	**Project Manager** for the TRL project coordinating the input of TRL experts to the SIDA-funded Secondary and Feeder Roads Development Programme in Zimbabwe.
1994-1995.	**Project Manager** for the TRL project investigating the premature failure of a road in Zambia.
1991-1992.	**Principal Investigator** supervising the analysis and reporting of the results of the calcrete research in Botswana.
1991-1992.	**TRL representative** on the Scott Wilson Kirkpatrick team on the Botswana Road Maintenance Study providing pavement evaluation and materials information on the Highway Design and Maintenance Model (HDMIII).
1988-1991.	**Principal Investigator** on the Botswana Calcrete road trials, also researcher, organising workshops in the UK, Lesotho and Botswana on the Road Transport Investment Model.
1983-1987.	**Project Officer and Principal Investigator** based in Botswana managing the joint TRRL/Ministry of Works Research Project.
1982-1983.	**Researcher** into the exploitation of local materials for roadbuilding.
1980-1982.	**Principal Investigator** into the unconventional use of public transport in the UK in connection with proposed deregulation.
1976-1980.	**Researcher** into the options for the management of recreational traffic in the UK.
1973-1976.	**Researcher** collating the data analysis and reporting of the DFID-funded TRRL East African Hydrological Drainage Project.
1968-1973.	**Project Officer** based in Kenya supervising the TRRL East African Drainage Project in Kenya, Tanzania and Uganda.
1966-1968.	Researcher in a team investigating the low-temperature effects of roads in the UK and the effects of high temperatures in the topics.
1962-1966.	Research Fellow with the UK Atomic Energy investigating commercial uses of semiconducting materials.

RECENT PUBLICATIONS (title and reference)

1. Calcrete in road bases in the Kalahari region of southern Africa. TRL Project Report PR/ORC/081/96 (co-author J Rolt)
2. Collaborative technology development and research on highway engineering materials in southern Africa. TRL Project Report PR/OSC/054/94. (co-author C S Gourley).
3. Evaluation of weak aggregates for surface dressing low-volume roads. Fifth international conference on low-volume roads, 1991. Transportation Research Record, 1291, Vol 2. (co-authors M E Woodbridge and D Newill).
4. The use of calcrete in paved roads in Botswana. Soil mechanics and foundation engineering, 9th Regional Conference for Africa held in Lagos, September 1987. (co-authors T Toole and A V Lionjanga).

SURNAME	FORENAMES	AGE
EDWARDS	Alan Christopher	58

DEGREES etc

HNC	Chemistry, Reading College of Technology, 1969

POSTS HELD (with dates)

1994-present	**TRL Project Manager and Principal Investigator** of a project to investigate the use of Albanian tar sands for use in low cost bituminous road construction. Also on DFID project on dense bituminous surfacings for developing countries. **Principal Investigator on DFID projects:** a) project Dense bituminous surfacings in Developing countries. b) To study the secondary compaction of bituminous materials. c) To investigate the use of Volcanic Ash as a potential source of fine aggregate for bituminous mixes in the Philippines. **Principal Investigator** on EU project for a study of bitumen and bituminous mixes for road pavements in Kenya.
1993-1994	**TRL representative and bitumen specialist** based at the Institute of Road Engineering in Indonesia responsible for DFID funded collaborative research programme to evaluate the mix properties of bituminous overlays.
1991-1993	**TRL Researcher** for the Department's Technology Development and Research (TDR) and advisory projects in the development of bituminous surfacings for tropical climates.
1978-1989	**TRL Researcher** in a DOT research programme that assessed the quality of recycled wearing course materials in both the Remix and Repave in-situ construction processes.
1968-1978	**TRL Researcher** in a DOT research programme in which accelerated curing procedures were developed for the quality control of fresh concrete.
1961-1968	**TRL Researcher** responsible for the bituminous materials testing in a DOT research programme that established appropriate specification for bituminous pavements with respect to different levels of traffic loading.

RECENT PUBLICATIONS (title and reference)

1. The use of volcanic ash in bituminous mixes. TRL PR OSC/138/98. (Co-author)
2. Recycling of bituminous materials: feasibility study. TRL PR OSC/117/97.
3. A study of Bitumen and Bituminous mixes for pavements in Kenya. TRL PR OSC/657/96. (Co-author)
4. Investigation of Albanian tar sands – Stage 1 and 2. TRL PR OSC/542/95 and OSC/547/95.
5. A laboratory management scheme (LMS) for the asphalt testing facility at the Indonesian Institute of Road Engineering. IRE-TRL Project Report. Bandung, 1993.
6. A study of compaction levels in Indonesian asphaltic mixes. IRE Research Report 11.060.TJ.92. Bandung, 1992. (Co-author)
7. Assessment of the performance of off-site recycled bituminous material. TRRL RR 305, 1991. (co-author)
8. Recycled asphalt wearing courses. TRRL RR 225, 1989. (Co-author)
9. Measurements of the quality of a pavement reconstructed using recycled material. TRRL: Materials Memorandum 147, 1986. (Co-author)