







# Development of Design Standards for Low-Volume Roads in Ethiopia AFCAP/ETH/005/A

Otta Seal Demonstration project: Combel Village, Tulubolo-Kela Road Construction and Workshop Report Report No. CPR1614

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Launched in June 2008 and managed by Crown Agents, the five year-long, UK government (DFID) funded project, supports research and knowledge sharing between participating countries to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources.

The programme is currently active in Ethiopia, Kenya, Ghana, Malawi, Mozambique, Tanzania, Zambia, South Africa, Democratic Republic of Congo and South Sudan and is developing relationships with a number of other countries and regional organisations across Africa.

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## **1** Background

The Ethiopian Road Authority (ERA) has included demonstration projects on the use of Otta seal surfacing under the Africa Community Access Programme (AFCAP). This type of seal is an alternative to the more commonly used chip seal and other more conventional surface treatments. The main project objectives in Ethiopia were to demonstrate Otta seal technology and to research the use of locally available materials.

Two sections of the road network were identified for inclusion in the demonstration project. One section 1900 metres in length was located at Combel village along the Tulubulo – Kela road and the other section 3000 metres long was located in the village of Gerado on the Combolcha – Mekaneselam road. This report deals with the construction of the section at Combel.

### 1.1 **Project objectives**

The demonstration project had three objectives:

- 1. Demonstrate an Otta seal using aggregate that is within the prescribed grading and strength requirements
- 2. Demonstrate the use of locally available natural gravel (decomposed weathered basalt and volcanic cinder aggregate) that might perform satisfactorily although outside the specified aggregate requirements.
- 3. Demonstrate that waste fines from crushing (crusher dust) could be used as a sand seal.

## 2 Site Location

The Tulubola – Kela road through the Combel village is situated south of Addis Ababa, 37 km from Tulubolo – along the Tulubolo – Kela road. One of the reasons for this location was that it was relatively close to the capital Addis Ababa and that the sources of aggregate used were relatively close to the project site. Bitumen was hauled from the Tiya heating plant, 69 km along Alemegena – Butajira road. Figure 1 shows the location of the demonstration project.

The village location was selected in order to demonstrate the potential benefits of using the technique to improve rural roads including roads through rural residential areas. The benefits of sealing these roads include improved all-weather access to facilities within the village as well as the significant environmental benefits from reduced dust pollution compared with the existing gravel road.

#### Figure 1 Location of the project area



#### 2.1 **Topography and cross section**

The demonstration section itself is 1900 m in length. Transition zones of 75 metres at the start of the section and 34 metres at the end were also constructed. The first 200 metres are located on relatively flat terrain. The following 900 metres includes an uphill gradient of between 3% and 5% in the direction towards the village with a relatively flat section through Combel village itself up to the end of the trial.

The road width varied between 5.00 and 7.00 metres. The maximum sealed road width was 6.30 metres. The side drainage has been adequately improved throughout the entire section.

## **3** Pavement Design

The pavement was designed on the basis of the ERA's "Design Standards for Low Volume: Part B 2011".

#### **3.1 Existing road and materials**

A simple classified traffic count was carried out. The design traffic estimated over a period of 15 years is shown in Table 3.1 in which a summary of laboratory and field results are also given.

A key note from the table is the fact that the design chart requires a G65 base layer on top of a G30 sub-base layer each of 125mm thickness. It was not possible to find natural gravel within the project

site that met the materials strength and plasticity requirements in the design charts. The choice of materials was moving a crusher near the site so that the harder 'fresh' basalt could be used a s base course,, hauling crushed stone base from an established source more than 130km away, or using the available weathered basalt.

Field tests using the Dynamic Cone Penetrometer (DCP) on the existing wearing course showed that the lowest in-situ CBR was 120% and the average thickness of gravel was 170mm. The soaked CBR of the weathered basalt proposed for use as base course was only 45% but its strength at optimum moisture content (OMC) and specified density was 65%.

#### 3.1 **Pavement design for Otta seal**

Based on the measurements taken on the existing road, it was considered appropriate to construct a 200mm layer of weathered basalt base course on top of the existing wearing course, which would act as a sub-base and met the strength requirements for sub-base materials in the design chart.

#### Table 3.1 Pavement Design Parameters

		Estimated	
Commercial Vehicles (ADT)	Two-way ADT	ESA/vehicle	ESA/day
Large Bus	24	1.0	24.0
Medium Trucks	8	2.5	20.0
Heavy Trucks	4	5.0	20.0
Sum			64.0
ESAs/Day in one direction			32.0
Design MESA (15 yrs, 5% growth)			0.04
Design Class			LV 2
Laboratory Results			Others
Subgrade CBR (4-day soaked, Mod AASHTO)	15	S5	PI = 22
Existing Gravel Wearing Course CBR (%)	44	G45	PI = 23
Proposed Base Material CBR (%)	45*; 65**	G45	PI = 20
Proposed Base Material	MDD = $2.26g/cm^{3}$	OMC = 8%	
*soaked at OMC **at OMC			
Field Tests			
	()	Thickness	
Existing Layer	CBR (%)	(mm)	Class
Gravel Wearing Course CBR	120	170	G80
Design Chart Requirement (S5, LV2)	Thickness (mm)	Strength Class	Others
			PI<15,
			PM<400,
Base Layer	125	G65	Grading "B"
Sub-base Layer	125	G30	

**Pavement Design Parameters** 

There is clearly a risk involved in using weathered basalt materials due to their susceptibility to damage from moisture ingress but the costs of extracting and hauling conventional materials that fully met the specifications for base course were prohibitive. The perceived risks were reduced by the decision to use a double seal and to seal the carriageway right up to the side drains. It is expected that this will reduce the possibility of the ingress of moisture and of any subsequent deleterious effects to the performance of the basalt base and sub-base. On areas of flat geometry

where there is a possibility of ponding of storm water, it is proposed that the side drains should be lined.

#### 3.2 **Construction of the pavement layers**

In the latest ERA Design Manual, the recommended standard for roads in villages is that the carriageway should be 9.3m wide. The existing carriageway was 5.5m wide but at this location, there were various constraining influences which limited widening of the carriageway and ERA recommended a maximum design paved width of 6.3m which was used throughout the trial section. During construction, the existing road was widened to a nominal width of 7metres by a benching technique with material from the borrow pit used for construction of the base. The edge of the road was then trimmed on both left and right hand sides to form the side drains. The existing carriageway was then scarified to 150mm depth and re-compacted.

The weathered basalt base material was imported from borrow pit, which was located 7km from the site, spread 250mm thick on the finished sub-base to 2.5% camber and compacted to a thickness of approximately 200mm. The material before compaction had a significant quantity of oversize material which broke down upon compaction.

The rainy season began in July 2012, before construction of the base was completed, and work was suspended. The rains continued for a period of more than 3months. The major detrimental effect of the rains was soaking of the base course and washing out the fines from the base material. When construction resumed, it was clear that considerable damage to the base had occurred. The base was scarified, patched and extra material added where required. Fine material was added under vibration compaction. The remedial works took place in January 2013. Further re-compaction was also required on some sections following the remedial work on the base. As a consequence of the rains and the re-working of the base, some smoothness and tightness of the base was lost. This necessitated some sections of the carriageway being re-cut and the final road width varied between 5m and 7m. The final base compaction densities before sealing are shown in the Table 3.2.

Chainage	Test Location	Relative compaction (% of MDD)
39.125	CL	99
38.950	LHS	100
38.775	RHS	95
38.6	CL	100
38.425	LHS	95
38.25	RHS	100
38.075	CL	99
37.9	LHS	96
37.725	RHS	97
37.55	CL	99
37.375	LHS	98

Table 3.2 Base compaction Base Compaction

#### 3.3 **Primed base layer**

The gravel road base layer of weathered basalt road base was primed with MC 30 at an application rate of +/-  $1.0 \text{ l/m}^2$  about a week before the sealing operation started.

The primed base was in a general satisfactory condition but segregation in the base material in localised areas left the base rather open in general from chainage 0 to 600 metres. The binder application rates for the surfacing were slightly increased in these areas to allow for this. From chainage 600 - 1000 metres, the base was very dense and hard. At the end of the section chainage 1000 - 1900 metres the base had become somewhat loose and areas with lamination and had to be improved prior to sealing. Figure 2 shows two photographs of the primed base.

#### Figure 2 Coarse base and dense base layers after priming





#### 3.4 **Layout of the demonstration project**

The demonstration project comprises of four sections of various length using the following different types of aggregate and bitumen viscosity.

All sections will eventually have a double seal, which will be applied 3 months after completion of the first seal. This is to ensure that all the volatile oils (solvent) have evaporated prior to the second seal being applied. If the volatile oils trapped are between the two seals, then the result will be heavy bleeding and instability of the seal. The layout of the demonstration project through Combel village is shown in Appendix A.

#### 3.5 **Properties of the aggregate**

The demonstration project used four types of aggregate:

- Plant crushed from Awash quarry "hard" fresh rock basalt.
- Crusher dust < 5.0 mm from Awash quarry.
- Decomposed basalt labour screened from project road.
- Volcanic cinder gravel screened by labour to produce the required grading.

## 4 Surfacing aggregate

The recommended grading limits and other commonly-used key aggregate properties for an Otta seal are shown in Figure 3.

Figure 3recommended aggregate properties for an Otta seal



AADT	Best suited grading
Less than 100	"Open"
100 - 1000	"Medium"
More than 1000	"Dense"

Aggregate strength requirements	Vehicles per day at the time of construction		BS Test Designation
	< 100	>100	i.
Min Dry 10% FACT	90 k N	110 k N	BC 812
Min WetDry strength atto	0,60	0.75	00 012

Water absorbency max. 4%. PI max. 10. Flakiness Index for crushed aggregate 30

## 4.1 Crushed rock aggregate

The aggregate produced from crushed rock was obtained from the quarry at Awash. The parent rock was "hard" fresh rock basalt. Three size fractions ( $\frac{3}{4}$ ",  $\frac{3}{8}$ " and < 5.0 mm) were produced at the quarry, hauled to site and mixed at site in the proportions of 2 + 2 + 1, respectively, to produce the required grading. The resulting grading and other key properties are shown in figure 4.





The grading of the above material follows the "medium" grading in the Otta seal Design Guide, although the material is somewhat gap-graded because the fraction between 6,7mm and 4mm is missing. The other key properties are well within the requirements such (e.g. PI of 9, Flakiness of 15, 10% FACT dry as high as 300kN and a wet/dry value of 0.87. Water absoption is low at 1,0%.

### 4.2 Crusher dust

The crusher dust is the fine fraction (< 5mm) produced at the crusher. It is alaso often referred to as crusher –waste. The grading curve for the crusher dust is shown in Figure .





#### 4.3 Weathered basalt

The source of the weathered basalt used for the base as surfacing aggregate was located approximately 5 km south of the demonstration project along the same road as the trial section. The aggregate was screened using labour-based techniques in order to remove oversize (> 19 mm) and fines. During the screening process some of the screens broke and as a result about 10 - 15% oversize were included. The grading and other key properties as shown in figure 6.





The grading follows the "open" grading, slightly gap-graded between the fractions 16 - 13 mm. The PI is as high as 20 and is in fact the double of what is recommended. The water absorption is 4% and is on borderline of what is recommended. The 10% FACT dry value is 170 kN and is within the strength requirement of 90 kN, however the wet/dry ratio of 0.35 is only ½ of the 0.75 requirement.

#### 4.4 Volcanic Cinder aggregate

Volcanic Cinder aggregate is abundant in the project area and in other places within the country. The aggregate can easily be extracted and screened by labour to remove oversize and fines from the bulk sample.

The source was about 46 km west of the demonstration project. Figure 7 shows the grading and other key properties for the cinder aggregate.



Figure 7 Grading curve for volcanic cinder gravel (screened) including other key properties

The grading follows the "dense" grading down to about the 2 mm sieve, then follows a much finer grading (about 10 %) than the recommended Otta seal grading requirements. The fraction passing the 0.075 mm sieve is 22%, which is more than double than the recommended value. The other key properties such as a PI of 13 is higher than the recommended value (10). The 10% FACT dry is as low as 39 (requirement 90) but the wet/dry ratio is 0.85. The most challenging parameter is the high water absorption value of 13%.

## **5 CONSTRUCTION OF THE OTTA SEAL / SAND SEAL**

#### 5.1 Introduction

The sealing work was carried out by an ERA Emergency Works Unit, using the following equipment:

- Bitumen distributor (6000 l capacity).
- Self-proppelled chip-spreader.
- 2 tipper trucks (capacity 9 m<sup>3</sup>)
- Pneumatic roller (12 tons)
- Steel roller (8 tons)
- Front-end loader.
- Wheel barrows, brooms and shovels incl. an adequate number of labours.

The primed base was protected by a diversion and watchmen patrolled the primed area in order to keep livestock, the hooves of which picked up the bitumen-based prime leaving 'dimples' of unpromed base material. The aggregate to be used were stockpiled on site adjacent to the road. The sealing operation took place between the 30<sup>th</sup> of January and 8<sup>th</sup> of February 2013.

#### 5.2 **Type of binder and spraying**

Two types of binders were used. The base binder bitumen was MC 3000 and a quantity was cut back to MC 800 viscosity by adding 15% by volume of MC 30 used for priming. Cutting-back was carried out on site. The bitumen hot spray rates ranged from  $1.1 - 3.9 \text{ l/m}^2$ .

The binder application rates were initially increased from the original design values by  $0.1 - 0.2 \text{ l/m}^2$  due to the coaresness of the base and the amount of fines in the aggregate which appeared to be significantly different from the results obtained in the laboratory.

The bitumen distributor did not have a dip stick to measure the volume in the disributor tank which is normally used as a check on volume delivered and hence the spray rate. Consequently the spray rate was controlled using a low speed gauge on the dashboard. This made it very difficult for the driver to maintain an accurate speed whilst at the same time ensuring that the vehicle followed the required spray line. Hence, the actual spray rates produced were rather erratic and adjustments had to be made on a regular basis as the rate of spray was checked after each run using trays placed on the road prior to spraying the binder. The laboratory personel weighed the trays and calculated the actual binder spray rate applied by the distributor.

Prior to the daily sealing operations. the nozzels of the bitumen distributer where checked on site as shown in Figure 8.

#### Figure 8 Checking the spray bar nozzles prior to spraying of binder





The actual binder spray rates for each "spray pull" for each sub-section of the trial is given for the sand seal, cinder gravel, weathered bassalt, in Table 5.1, Table 5.2, Table 5.3 and Table 5.4 respecitively and for both the right hand side (RHS) and left hand side (LHS) of the road.

Table 5.1 Binder spra	y rates for the sand seal	section 0 – 100 m,	including transition zone.
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RHS Chainage (m)	Type of seal	Binder used	Bitumen distributor	Actual spray	Comments
enaniage (iii)		6666	Speed	1000 (108/1112)	
Minus 0 - 74			0.8	0.90	Transistion zone. Crusher
	Sand seal				dust applied by labours
0-40	(crusher dust)	MC 3000	1.15	1.69	Crusher dust applied by
40 - 100			0,.9	1.47	labour
LHS Chainage (m)					

Minus 0 - 74			0.8	1.11	Transistion zone
0 – 50	Sand seal	MC 3000	NA	1.08	Crusher dust applied by
	(crusher dust)				labour
50 - 100			0.8	1.07	Crusher dust applied by
					labour

#### Table 5.2 Actual binder spray rates for the section 100m to 300m using screened volcanic cinder aggregate

RHS Chainage	Type of seal	Binder used	Bitumen distributor	Actual spray	Comments
(m)		6506	Speed	1000 (108/1112)	
100 - 190	Otta seal,		1.8	2.77	Bitumen flowing on the
	cinder	MC 800			primed base
190 - 300	aggregate		1.9	3.90	
LHS					
Chainage					
(m)					
100 - 210	Otta seal,		1,7	2.2	
210 - 300	cinder	MC 800	1.7	2.04	
	aggregate				

#### Table 5.3 Actual spray rates for the section 300m to 600m using screened weathered basalt

RHS Chainage (m)	Type of seal	Binder used	Bitumen distributor Speed	Actual spray rate (kg/m2)	Comments
300 - 400	Otta seal,		18	2.20 *	* Not measured in tray
	screened	MC 800			
400 - 500	weathered		18	2.20*	* Not measured in tray
500 - 600	basalt	MC 3000	17	1.94	Aggregate applied by labour
LHS					
Chainage					
(m)					
300 - 400	Otta seal,		18	1.90	Longitudinal joint no
400 - 500	screened	MC 800	18	1.96	overlap in short places
500 - 600	weathered	MC 3000	18	2.20	Aggregate applied by labour
	basalt				

#### Table 5.4 Actual binder spray rates for the section 600m to 1900m and 34m transition zone using crushed basalt

RHS Chainage (m)	Type of seal	Binder used	Bitumen distributor Speed	Actual spray rate (kg/m2)	Comments
600 -710			15	2.18	
710 - 810			14	1.89	
810 - 860			14	1.88	
860 -960			14	1.80	
960 - 1060			14	2.00	
1060 - 1160				1.90 *	* Not measured in tray
1160 - 1270			14	1.90	
1270 - 1400			16	2.56 ?	
1400 - 1530	Otta seal,	MC3000	14	1.60 *	* Not measured in tray
	crushed hard				Aggregate applied by labour
1530 - 1580	basalt			2.06	

1580 - 1630			1.85	
1630 - 1680		16	2.06	Aggregate applied by labour
1680 - 1730		16	2.20	
1730 – 1780		16	2.06	
1780 - 1900		16	2.20	
1900 - 1934			2.20 *	* Not measured in tray
				Aggregate applied by labour

LHS Chainage	Type of seal	Binder used	Bitumen distributor	Actual spray rate (kg/m2)	Comments
(m)			Speed		
600 - 700			1,8	2.56	
700 -800			17	2.42	
800 - 860			16	2.26	
860 - 960			15	2.70	
960 - 1060	Otta seal,		15	2.28	
1060 - 1160	crushed hard	MC 3000	14	1.56	
1160 - 1260	basalt		16	1.78	
1260 - 1360			15	1.70 *	* Not measured in tray
1360 - 1460			14	1.54	
1460 - 1560			15	1.70	
1560 - 1660			16	1.89	
1660 - 1760			16	1.90 *	* Not measured in tray
1760 - 1860			16	1.90	
1860 - 1900			16	1.90 *	* Not measured in tray
1900 - 1934				1.90 *	* Not measured in tray

Paper was laid between each start and stop position of the distributor in order to achieve straight transverse joints as shown in Figure 9.

#### Figure 9 Paper laid to achieve straight transverse joints



#### 5.3 Aggregate application

The aggregate was pre-stockpiled in the site camp and before loading the aggregate into the tipper trucks, the front-end loader "aired" the aggregate in order to remove as much dust as possible. This entailed tipping the aggregate from a height above stockpile to allow the wind to blow away excess dust as shown in figure 10.

Figure 10 The front-end loader "airing" the aggregate in order to remove dust



The aggregate application was carrried out by a self-propelled chip spreader which applied the aggregate evenly. However, due to two breakdowns some section of the medium hard natural decomposed basalt aggregate and the hard basalt aggregate had to be applied by the use of labour. This worked effectively but the spray length of the sections had to be reduced to about 50 metres in length to enable the aggregate to be applied when the binder was still hot. Also, for the sand seal section the crusher dust had to be spread by labour as the minimum opening for the chip spreader was too big for crusher dust.

The application rate of all the four types of aggregate was on the high side (about  $25 \text{ l/m}^2$  or even more) because of the relatively high rate of binder applied due to the difficulty of controlling the distributor spray rates. In fact, most of the entire length of the demonstration section was rechipped with aggregate due to the high binder spray rates in order to avoid excessive bleeding during the rolling operation. Figure 11 shows the self-propelled chip-spreader in operation and the spreading of aggregate by the use of labours.

Figure 11 Self-propelled chipspreader in operation and the sprading of aggregate by the use of labour.



#### Rolling during construction and after

The rolling during the construction and after was carried out using a 12 tonne pneumatic roller, a 5 tonne steel roller and the two tipper trucks fully loaded with aggregate (capacity 9 m<sup>3</sup>). The rolling was carefully supervised so the entire width of the surfacing and all sections in the trial received adequate rolling. After completion of the sealing operations the entire length of the trial (1000 – 1800) received three days of full rolling using the same equipment,

except for the cinder aggregate which received only two passes of the steel to avoid the the weak aggregate was crushed down.

Figure 12 shows rolling with a loaded tipper truck and the pnumatic roller immediately after the chip-spreader



Figure 12 Rolling in progress by the use of both a pneumatic roller and the loaded tipper truck.



#### 5.4 Weather condition during construction

The weather conditions during the sealing operations were mainly sunny and partly cloudy with temperatures ranging between  $17 - 23 \text{ C}^{\circ}$ . However, strong wind prevailed all times and on Saturday  $2^{nd}$  February rain started in the late of the afternoon and the sealing operation had to be suspended.

## **6 CONSTRUCTION CONSTRAINTS**

#### 6.1 General

This section highlights some of the problems that occurred during the construction of the Otta seals.

#### 6.1.1 Bitumen distributor.

The most significant part was the hauling of bitumen and the inaccuracy of the spray rates from the bitumen distributor. The haulage of bitumen from Tiya 69 km from Alemgena – Butajira road took more the 5 hours each way for the bitumen distrubutor and as a result the sealing operation could not take place every day causing significant dealys. This also caused problems when sealing operations took place as the bitumen had to be heated to spray temperatures from early in the morning and as this took time very seldom the sealing operations took place before 1300 in the afternoon.

The inaccuracy of the bitumen spray rates also caused far too much bitumen for a number sections as seen in the tables 1 - 4. This was partly due to the fact the bitumen operator had difficulties in maintaing the set speed accuratly and at the same time looking at the bitumen spray line. The situation improved when placing a person inside the bitumen distributor assisting the operator keep constant speed.

#### 6.1.2 Aggregate.

The crushed basalt and natural weathered basalt contained too much oversize aggregate and may cause potholes at an early stage as the bitumen may not hold the oversize aggregate. The breakdown of the chip-spreader at two locations and the fact that the aggrgate opening was too

open for the crusher dust caused minor problems as the aggregate was applied by the use of labour and, the bitumen "pull" had to be reduced to 50 metres instead of 100 metres.

#### 6.1.3 Sealing operations.

Construction of the the seal was generally well executed, given that this surfacing technique is new to Ethiopia. Following a slow start in which the constuction team were trained in the various activities, which understandably required close supervision, the whole operation proceeded without any major problems.

# 7 CONSIDERATIONS FOR APPLICATION OF THE SECOND SEAL

The second seal is planned to be placed after a minimum period of 12 weeks allowing the volatile oil (solvent) to evaporate. During this period, dislodged aggregate (first 4 - 5 weeks) can be broomed back in order to ensure a fully matured Otta seal and sand seal. Thereafter all the loose aggrgate can be broomed off.

Prior to construct the second seal all aggregates need to be stockpiled at site and covered with tarpaulins in order to keep the aggregate dry in the case of rain.

Obviously, all defects in the first seal must be repaired prior to the construction of the second seal. All bituminous repair work should be completed at least 3-4 week before sealing operations take place.

The experience with the bitumen distributor giving very high spray rates for the first seal requires serious consideration for the second seal and the second seal spray rates need to be adjusted based on a visula assessment after the seal has been in service for 12 weeks.

The side drains/ditch on the flat area in the village from 0+900 metres to 1+500 metres need to be lined to protect the weathered basalt since water is likely to pond in these areas. Scour checks need to be constructed in the drains on the steep sections to minimise erosion..

## 8 WORKSHOP AND FIELD VISIT

#### 8.1 Introduction

The construction of the trial presented an opportunity to promote the Otta seal concept and a oneday workshop was held to discuss the trial with local stakeholders (ERA engineers, Consultants and Contractors) on the 4<sup>th</sup> February 2013 at Dreamliner Hotel in Addis Ababa. The workshop was attended by 34 participants.

#### 8.2 **Purpose and Scope**

The pupose and scope of the workshop and the field visit to the project site the following day were to promote the Otta seal concept and in general terms providing a better understanding of following aspects regarding application of an Otta seal:

- 1 An Overview of gravel roads vs Sealed roads
- 2 Various types of Surface Treatments
- 3 What is the Otta Seal including the economic aspects

- 4 How to Design and Construct an Otta Seal
  - The Condition of the road to be sealed.
  - Materials on site.
  - Plant / Equipment / tools.
  - The Design of the Otta Seal
  - Construction.
  - Quality Assurance.
  - o "After Care"
  - Reporting.

Slides from the power point presentation are shown in Appendix B.

#### 8.3 Field visit

On the field visit, the workshop articipants travelled to the demonstration site in the village of Combel. At the borrow pit nearby to the village, the participants were able to observe the full production process for the decomposed basalt aggregate. This included excavation, primary screening, secondary screening, transportation and stockpiling and demonstrated the process of using Otta Seal aggregate obtained by screening the material that had also been used for constructing the base course.

At the village, they were able to observe the construction of the Otta Seal using MC3000 binder and the decomposed basalt aggregate. The process of cutting back MC3000 with MC30 to obtain MC800 that was used to construct the Cinder Gravel Otta Seal was also demonstrated.

## **9 Provisional cost estimates for Combel**

The aggregates used for the project were:

- 1) Crushed Stone Aggregate from Awash Crusher plant, located 130km from the site
- 2) Crusher Sand (Crusher Dust) from the same plant in 1)
- 3) Cinder gravels obtained from 60km from the site
- 4) Decomposed Basalt obtained from 7km from the site

#### 9.1 **Distortion of costs**

An attempt has been made to assess the relative costs but it is very difficult to estimate costs on small scale research projects and there are no benefits from "economies of scale". The mobilisation costs are a much higher component of the total costs than in larger projects. For instance if a Dozer is transported by a low-bed truck to stockpile material for 300m of road, the unit cost would be much higher than when the same machine is used to stockpile material for say 10km of road.

Furthermore, materials may be resourced and hauled from further afield because they need to be included in the research rather than because they are the most economic source of available material.

Because of factors such as these, the equipment mobilisation and materials stockpiling cost was excluded from the rate build up and instead a mark-up of 15% was added to the material cost as an alternative.

For aggregates 1) and 2) which were purchased from a crusher plant, the purchase cost, haulage cost (fuel) and a mark-up of 15% for truck wear and tear, crew, handling and storage were used to build the rates.

The Emergency Works Unit which carried out the construction is part of ERA and some of the cost components which would normally be assigned to a contract by a contractor do not apply in this case or are not easily quantifiable. The mark-up of 15% was used as an estimate of the actual costs.

For natural aggregates 3) and 4), the cost of simple tools, labour for screening and haulage costs were used to build the rates. A mark-up of 15% for truck wear and tear, crew, handling and storage were used to build the rates. The cost of heavy plant to produce the natural materials have been excluded and assumed to be part of the cost of producing the base material. This is because the screened natural aggregates used for Otta Seals and the materials for the base course were sourced from the same borrow pit using the same equipment.

#### 9.2 Estimated costs

The cost estimates are presented in the Table 9.1 below:

Material	Aggregate	Unit Cost	Design application rate of Bitumen	Prime - Cost (De	+ Bitumen sign)	Aggregate (Design)	Cost	Otta Seal Cost	or Surfacing
	Birr/m <sup>3</sup>	US\$/m³	Litres/m <sup>2</sup>	Birr/m	US\$/m²	Birr/m <sup>2</sup>	US\$/m²	Birr/m <sup>2</sup>	US\$/m²
Crushed Stone Aggregate	597	31.4	1.8	89	4.7	11	0.6	100	5.3
Crusher Sand (Crusher Dust)	651 411*	34.3 21.6*	1.1	67	3.5	8	0.4	75	3.9
Cinder Gravels	376	19.8	2.3	105	5.5	7	0.4	112	5.9
Decomposed Basalt	238	12.5	2.0	95	5.0	5	0.3	100	5.3

\* factored at 0.63 as a ratio of application rate of Sand to Otta seal aggregate for comparison

#### 9.3 Discussion of cost estimates

The costs of crushed aggregates obtained from blasted rock are usually significantly higher than the cost of natural aggregates (extracted and screened). The two advantages of the aggregate component of this type of seal is that (a) a larger fraction of the crusher output can be used than for a chip seal when using a crushed rock source and (b) the ability to use screened locally available (weaker) aggregate.

The relative bitumen/asphalt costs are the opposite of the aggregate costs in that these costs are higher for natural aggregates than crushed rock. This is because the natural aggregates demand higher quantities of binder than the crushed aggregates. The extra demand occurs as a result of the dense grading and relatively high absorption of natural aggregates compared to the medium grading and low absorption of the crushed aggregates. However, the cost of the increased application rate of binder compared, for example with a chip spray, is offset by the additional life-cycle benefits from increased durability.

However costs are distorted on small-scale research projects as is evident from Table 9.1.

As a result of these factors, the costs of both crushed aggregates and natural aggregates all tend to a central value of between US\$5.3 and US\$5.9 (excluding contractor's mark-up for overheads and profits) per square metre of the surfacing.

The crusher sand seal is cheapest and ideal for very low volume roads although not very durable as a single seal, especially on a relatively weak base.

#### 9.4 **Final remarks on costs**

The aggregate from the crusher plant appears to be unusually expensive, especially since crusher sand is the most expensive material from the plant. This could be a result of the plant spreading its running costs uniformly over all aggregate sizes. It is known, for example, that 1.0m<sup>3</sup> of blasted rock produces about 0.75m<sup>3</sup> of aggregate that can be used for an Otta Seal but 1m<sup>3</sup> of blasted rock produces only about 0.3m<sup>3</sup> useful aggregate for Double Bituminous Surface Treatment which uses single sized aggregates. Therefore for a large-scale project, it is cheaper per volume of output to produce aggregate from a crushing plant for Otta Seals than for conventional bituminous surfacing.

The cinder gravel was hauled unscreened from the borrow pit, which is an unusual practice. The screening was then carried out on site. This meant that an additional cost was incurred in hauling "waste" material. The gravel was hauled from a source 60km away compared to the decomposed basalt for which the haul distance was 7km. If both the cinder gravel and basalt had been located at a similar distance, the cost of the cinder would be cheaper because of the ease of extraction and screening.

Blasting and crushing rock is expensive and at a certain haul distance it will also become uneconomic to transport crushed stone aggregate or even mobilise a crusher plant near the construction site. The exploitation of natural aggregates for rural road construction is usually much more economical, especially if the same material can be used for both base course and can be screened for use surfacing aggregate in an Otta seal and is clearly cheaper than crushed aggregate as well as creating employment in both material extraction and screening.

The initial construction costs of Otta Seals may be higher than that of some other bituminous surface treatments but the life cycle costs of Otta Seals can be up to 40% lower due to their increased durability. Also, the technique has significant potential for using labour-based technology with

relatively low mobilisation costs and is, therefore, ideally suited for spot improvement/targeted interventions such through villages or problem sections on the rural road network.

# **10** Prevailing problems with mainstreaming Otta seal technology.

A major problem in the construction of Otta seals is that they are not yet mainstreamed in most of the LIC countries in which it has been demonstrated and almost every project continues to be, in effect, a research/demonstration project using different materials in a different environment. This leads to a situation where quantities are varied on site with external expert advice, which is not a sustainable option in terms of local use.

Another related problem is that significant variations are carried out on site and the items in the Bill of Quantities produced on the basis of the Guideline often to need to be changed during construction so that both the quantities of materials and the associated costs may no longer apply. Whilst this is not particularly important for small-scale research/demonstration projects, such changes could have more serious implications in full-scale projects. It is important for a consultant to be confident in a design based on the Guideline and a contractor to be confident about the prices in the BoQ.

The situation is further exacerbated by the Guideline document being outdated, not reflecting current knowledge, experience gained in various developing countries nor the wide range of materials that are currently candidate materials for use in Otta seals. It needs to give far more comprehensive guidance to be of use to local practitioners. Whilst it is recognised that a certain amount of engineering judgement may be necessary in many projects and that the document is a Guideline rather than a manual, it should contain sufficient guidance to enable experienced engineers to construct the seal relatively unaided. In its current form, it clearly falls short in providing the required guidance.

Therefore, if the technique is to be more widely used, there is an urgent need for the Guideline to be updated.

## Appendix A

Layout of test sections

## Layout of the Demonstration/Research sections

6.3													
37+32	5			37+9		LAGE, width 6,	30m				39	9+330	
1	75m	20	00m	300m	50	)0m			830m				
-65	0	100	200	300	600	800	1100	1200	1400	1600	1900		1930
Doub	le	Double											
Crush	er	Otta Sea	I	Double Otta Seal									
Sand S	Seal	Cinder a	ggr.	Natural aggregate	Crusher Sar	nd Cover Seal		Double Otta	a Seal Crushed Ag	gregate		Trans	ition
Trans	ition												
					Single Otta	Seal Crushed							
					Aggr	regate							

## Appendix B

**Workshop Presentations** 







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Type of scal	Typical range of service life (years
Sand Seal	2-4
Slurry Seal	2.6
Single Chip Seal	4.6
Double Sand Seal	6-9
Double Chip Scat	7-10
Single Onta Scal + Sand Scal	8-10
Cupe Scal (13mm + single sturry)	8-10
Cupe Scal (19mm + deathle slurry)	10-14
Double Otta Sead	12-16



	28.2	



An Otta Seal is formed by placing graded aggregate on a relatively thick film of comparatively soft binders which, on rolling and trafficking, can work its way upwards through the aggregate interstices.









Difference between Otta/Sand seal and Chip seal

Sawtiewi Onution NATURAL SIMPLE

MECHIA

annihitati 💭

















Anginegate type and quantity,
Anginegate type and quantity.
Anginegate specialing, water absorption and strongth properties.
Progress appropriate balancing zets for cutring back, indicators are strong to the special particular.

and the second

The following must be checked as early as possible p surfacing operations:

Bitumen type and quantity, carti
Paraffin and engine oil quantity.





int must be on site, and in go

six - 6 of each.



a) The Condition of the road to be sealed. b) Materials on site. c) Plant / Equipment / tools.

e) Construction. f) Quality Assurance. g) "After Care" h) Reporting.

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a) The Condition of the road to be sealed. b) Plant / Equipment / tools. c) The Design of the Otta Seal / Sand seal. d) Construction. e) Quality Assurance. f) "After Care"

trans.