AFCAP

Development of Pavement Design Standards for Low-Volume Roads in Ethiopia

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Combolcha Otta Seal Demonstration Site: Construction Report
CPR 1613

A. Otto

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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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Combolcha Otta Seal demonstration site is the second site to be constructed in Ethiopia after Combel in Tulubolo.

This site features Otta Seal on both a primed and un-primed road bases. Two sections on this demonstration site will feature Double Otta Seal while another two sections will feature Otta Seal with a Sand Cover Seal.

This report describes the construction of the first seal.

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1 Introduction

1.1 Background

The Ethiopian Road Authority (ERA) included projects that demonstrate Otta seal technology to surface rural roads as part of its participation the Africa Community Access Programme Project (AFCAP). The Otta seal is an alternative to the more commonly used chip seal or other types of conventional surface treatments. The main objective was to demonstrate the potential for using this technology as a durable cost-effective surfacing option using local contractors and good quality gravel that satisfied the aggregate properties required as stated in NPRA Publication no. 93. Other aggregates used in the programme did not fully meet the requirements but were incorporated as part of ERA’s research programme to exploit the use of locally available materials in road construction.

Two sections where identified for the demonstration. One section on the Tulubolo – Kela road through the village of Combel (1900 metres) and another in the village of Gerado on the Combolcha - Mekaneselam road (2900 metres). This construction report deals with the construction in Gerado village.

2 Demonstration Site

2.1 Introduction

Combolcha town is situated about 376km North of Addis Ababa City and about 25km South-East of the town of Dessie. The demonstration site is located in Gerado village, which is 8km along the Combolcha – Mekaneselam road and 20km from the turnoff on the Combolcha – Dessie Road. The site location is shown on the map in Figure 2-1.

Aggregate for the Otta Seal Construction was obtained from Mitikolo Quarry Plant – 30km from site. Bitumen for the works was heated at a site 30km from the construction site at the heating plant opposite Wollo University Campus.

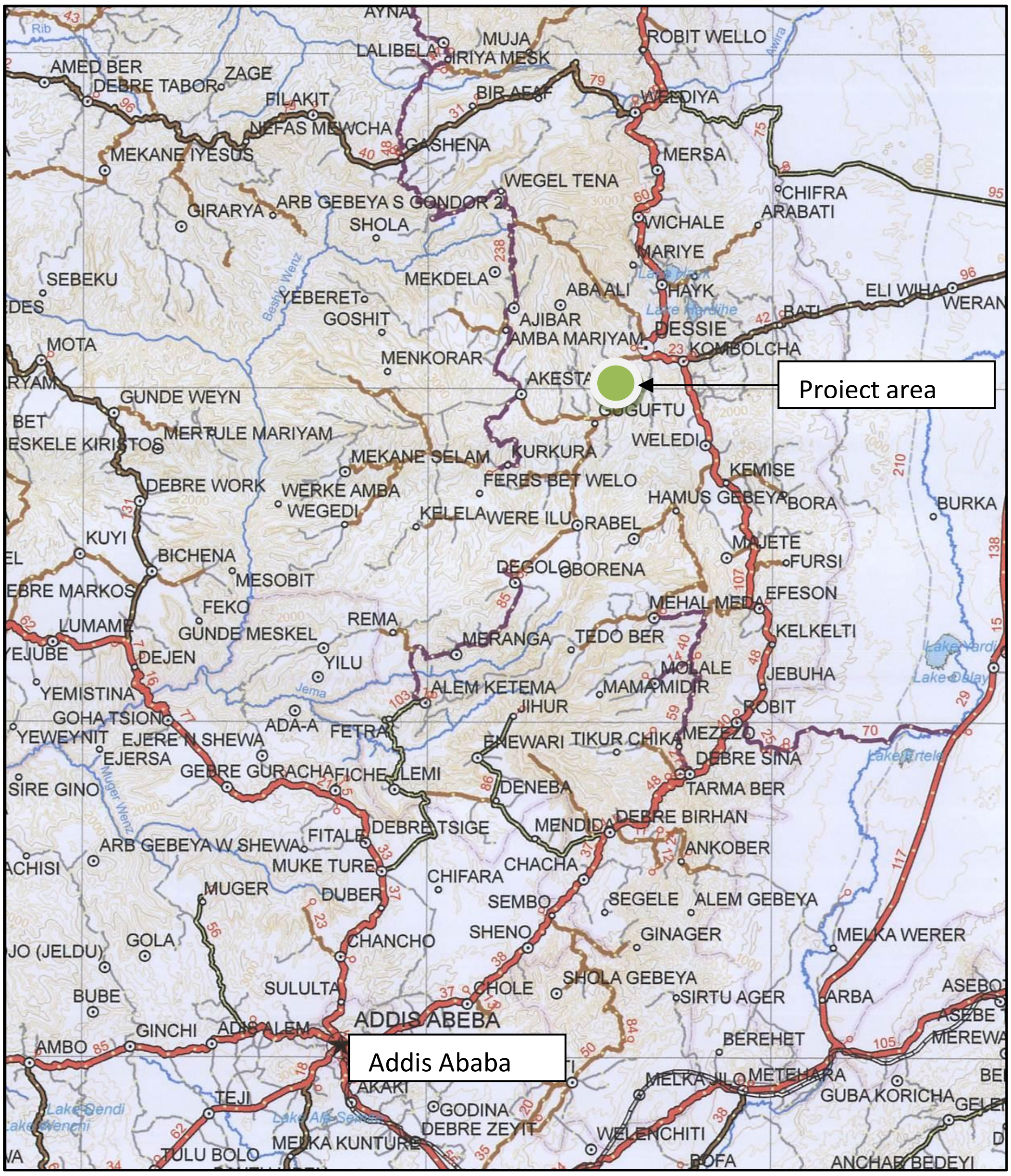

Figure 2-1 Location of the demonstration site

The aim was to demonstrate the benefits of using this technology for surfacing rural roads. These benefits include the health and environmental benefits from a reduction in traffic-generated dust from the existing gravel road together with the usual economic and social benefits that accrue from upgrading unpaved roads.

2.2 Topography and cross section

The demonstration section is 2900 m long and includes a transition zone of 100m at the start of the sections. The first 600m has a gradient of about 5%, followed by 900m of gradient about 3%. The next section undulates with a gradient of not more than 2% for 1200m. The last 200m is very steep with a gradient of around 7%. The existing road width varies between 9.4 – 10.0m and the maximum width of the road width after sealing was 9.7m on curves.

The existing side drainage is generally adequate for most of the section except for 300m at the beginning that will require scour checks.

2.3 Design of the pavement

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

A simple classified traffic count was carried out and Table 2.1 shows the design traffic estimated over a period of 15 years. Shown in Table 2-2 is a summary of materials properties obtained from laboratory and field results.

The existing pavement on the road was constructed in 2011 as part of a new gravel road that comprised 275mm of Sub-base course, and 150mm of wearing course material according to the construction records. However, field tests carried out one year later showed 330mm of Upper Gravel Wearing Course on top of 300mm of Lower Gravel Wearing Course.

Table 2-1 Traffic Characteristics

Commercial Vehicles (ADT)	**Two-way ADT**	**Estimated ESA/vehicle***	**ESA/day**
Large Bus	16	1.0	16.0
Medium Trucks	30	2.7	81.0
Heavy Trucks	16	5.0	80.0
Total			**177.0**
ESAs/Day in one direction			89.0
Design MESA (15 yrs, 5% growth)			0.41
Design Class			LV 4

* Estimated from ERA LVR Manuals Part B: 2011

Table 2-2 Materials properties

Laboratory Results	**Property/ Values**	**Class/Value**	**Others**
Subgrade CBR (4-day soaked, Mod AASHTO)	11	S4	PI = 20
Existing Gravel Wearing Course CBR (%)	82	CBR 80%	PI = 12
Proposed Base Material	MDD = 1.86g/cm^3	OMC = 13%	
Field Tests			
Layer	**DCP CBR (%) – 10th lower percentile**	**Thickness (mm)**	**Class**
Existing Gravel Wearing Course	110	330	**G80**
Lower Gravel Wearing Course	104	300	**G80**
Subgrade	34		
Design Chart Requirement (S4, LV4)	**Thickness (mm)**	**Strength Class**	**Others**
Base Layer	175	G65	PI<9, PM<200, Grading "B"
Sub-base Layer	200	G30	

The laboratory results in Table 2-2 show that the existing pavement was adequate to carry the design traffic. Moreover, the field DCP results show a high mean in-situ value of CBR (120%) by DCP measured in transition between wet and dry seasons (late September 2011) and high pavement thickness (up to 600mm).

At the time of investigation, the traffic was low - about 80 vehicles per day; consisting mainly of light trucks and medium buses. An estimate of the number of heavy vehicles (as shown in Table 2-1 above) was recorded and used to check the pavement design suitability. However during the project planning and inception stage, the Universal Rural Roads Access Program (URRAP) opened up roads to at least 23 Woredas along the road corridor. This led to an increase of up to 260 vehicles per day, including a large number of mini-buses. The increase in heavy vehicles is still within the estimated design axle loading.

However, in the coming year this road is due to be sealed with a Double Bituminous Surface Treatment (DBST) and will serve as a shorter link between Combolcha and Bahir Dar City. This is likely to result in a significant increase in the number of heavy vehicles. If this increase in loading is large, it may reduce the design life and lead to increased rut depths. If there is a significant increase in loading, then the road may need an asphalt concrete overlay at some point in the future.

The gradation of the existing wearing course aggregate is shown in Figure 2-2 and falls partially outside the specifications for both the high volume and low volume roads. The wearing course (used as base course) has a plasticity index (PI) of 12 which is significantly above the value of 9 recommended in ERA 2011 Low Volume Roads Manual Part B. This means in practice the base must be kept on the drier side of the material OMC through the use of sealed shoulders as was the case. Based on the strength exhibited in the laboratory and in the field, it was decided to use the material despite the marginal grading. The only work recommended to be done to the existing road was scarifying, re-shaping and re-compaction.

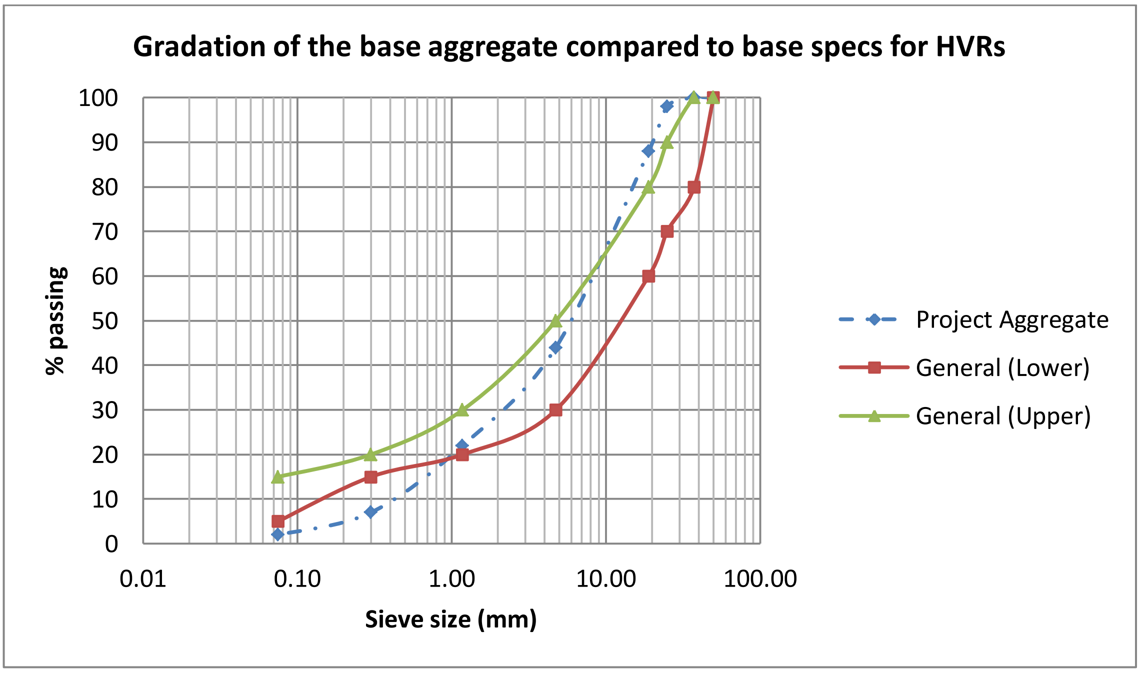

Figure 2-2 Gradation of the base material used in comparison with ERA Draft HVR Manual 2011

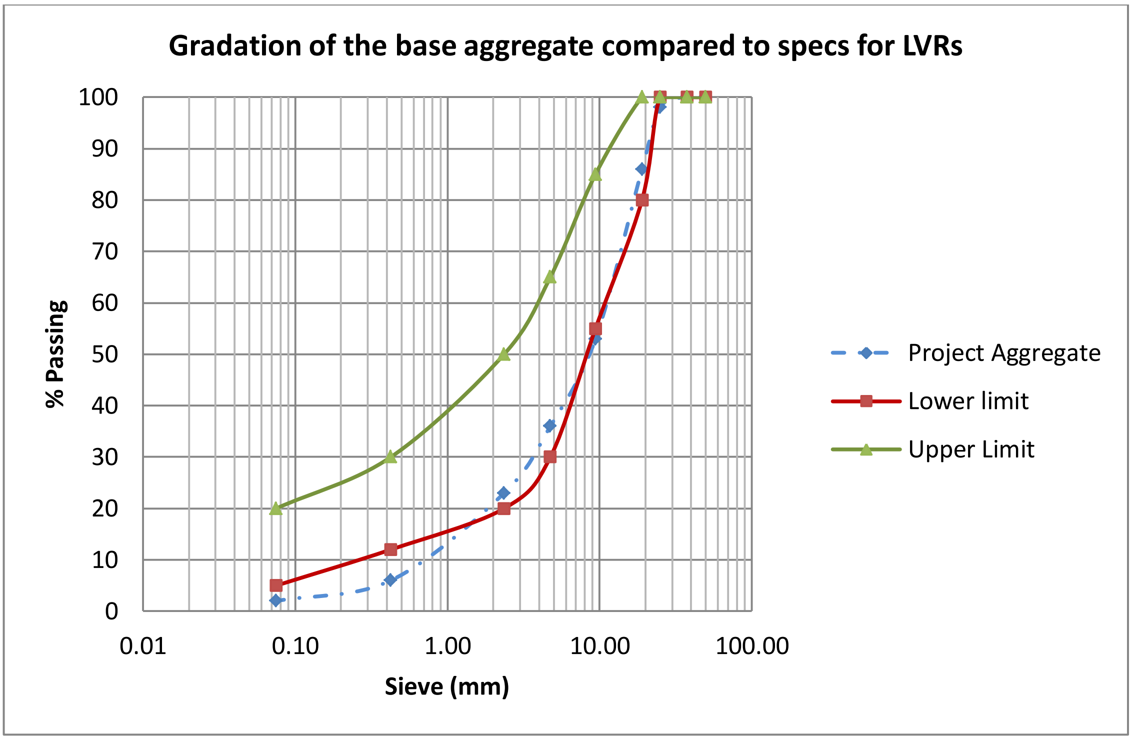

Figure 2-3 Gradation of the base materials used; in comparison with ERA Draft LVR Manual 2011

2.4 Construction of the pavement layers

In May 2012, approximately 300m of the road was scarified, re-shaped and re-compacted. When it was realised that the surfacing works could not start before the rainy season, the work was suspended. In January 2013, the road was re-constructed and a selection of the compaction densities is shown in Table 2-3.

Table 2-3 A selection of compaction densities

Chainage	Test Location	Relative compaction (% of MDD)
8+060	CL	100
8+180	LHS	102
8+360	LHS	99
8+560	RHS	98
8+760	CL	102
8+960	LHS	102
9+200	RHS	100

However, the surfacing works could not start immediately and with the increased traffic volume, a significant quantity of gravel was lost on some sections. Corrections were done in February and March 2013. Some of the initial smoothness and regularity could not be regained without complete re-construction of the base which was not carried out because further extensive re-working of the material would compromise the material quality.

Surfacing works were carried out on the corrected base in the months of February and March 2013.

2.5 Priming the base layer

Of the 2900m demonstration length, 1500m from 8+000 to 9+500 was primed at a rate of 1.0 l/m^2 using MC30. The second half of the demonstration from 9+500 to 10+900 was not primed. This section was designed to demonstrate that an Otta seal can be constructed on an un-primed base with the low viscosity cut-back bitumen acting as both binder and prime.

Problems were experienced with the binder distributor and half width of the road section from 8+000 to 9+000 on the left hand side was primed with labour-based technology using as hand lance to spray the binder. The binder distributor was used on the remaining primed section.

2.6 Layout of the demonstration project

The demonstration project comprises 100m transition section at the beginning and four sections of 700m length each as shown in Appendix A.

The first layer of the whole demonstration section comprised an Otta Seal using a medium graded aggregate of nominal maximum size 16mm.

Two sections of 700m length each were constructed on a primed base and the other two were constructed on an un-primed base. The plan for the second seal is that the outer two sections at each end of the trial will receive another Otta Seal layer whereas the inner two sections will receive a cover seal of crusher sand. The second seals will be applied after the volatiles have evaporated and the surfacing is firm, which is expected to take 2 to 3 months from the completion of construction of the first seal.

3 The Aggregate Used

3.1 Introduction

The aggregate used for the Otta Seal layer and that which will be used for the second seal (including the crusher sand) is basalt with hints of what appears to be andesite and tuff. The bulk density of the aggregate is 1352 kg/m^3. The properties of the aggregate are discussed in the sections below.

3.2 Properties of the aggregate and design of the Otta Seal

The properties of the aggregate used for the first Otta Seal layer are shown in Table 3-1.

Table 3-1 Properties of the Otta Seal Aggregate

Parameter	Value	Recommended Max. (NPRA Guide No 93)
PI on 425µm	**5.2**	10
Water Absorption	**5%**	2%
Flakiness Index	**21**	30
Fines Content	**0.6**	10%
10%FACT (Dry)	**197**	110
10% (Wet/Dry Ratio)	**0.87**	0.75

Water absorption more than 2%!

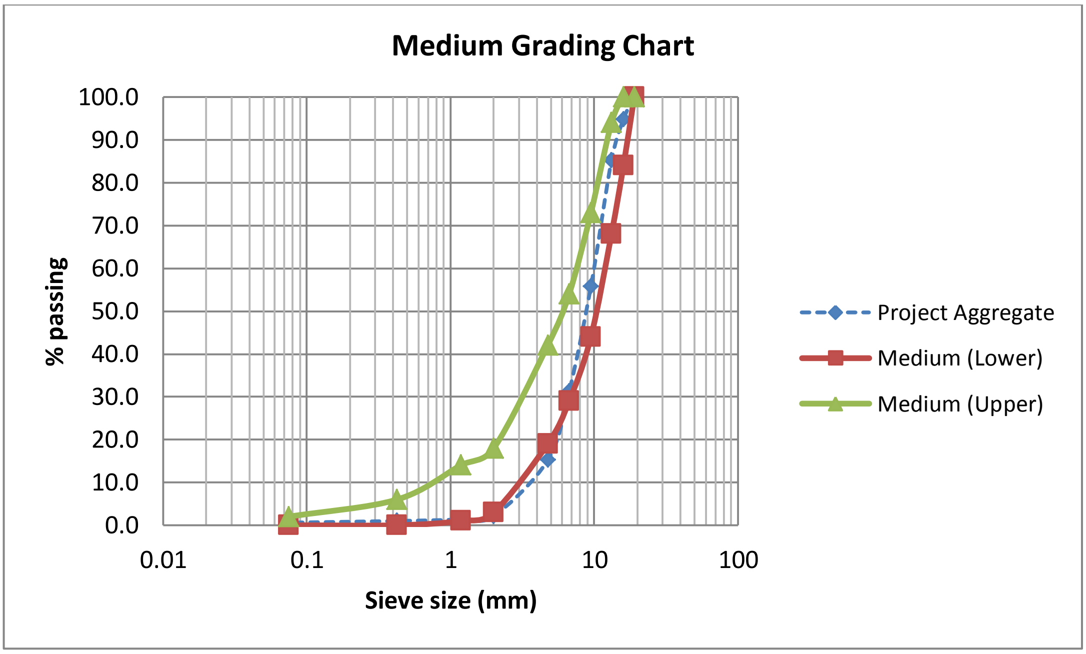

Figure 3-1 Grading of the Otta Seal aggregate

The design binder spraying rates (using the aggregate properties) from NPRA guideline number 93, were MC 3000 at 1.8 l/m^2 on the primed section and MC 800 at 2.0 l/m^2 on the un-primed section. MC 800 was chosen on the un-primed base section because it has a higher penetration than MC 3000 and acts as both prime and binder.

The design guideline (NPRA guideline number 93) recommends an application rate for medium graded aggregates of 13-16 l/m^2, it was however decided that 22 l/m^2 be used – with the understanding that any excess aggregate will be broomed, collected and used in the second seal. This was to minimise any risk of bleeding.

For the sections in the second seal, the Otta seal sections will use aggregate passing the 16mm screen down to the fine fraction (will not be screened on 5mm) and for the crusher sand, the fraction passing the 5mm screen down will be used.

4 Construction of the Otta Seal

4.1 Introduction

The sealing work was carried by the Combolcha District branch of the Ethiopian Roads Construction Corporation (ERCC). Eight supervision personnel, ten equipment operators/drivers and their assistants (10) and twenty labourers were involved in the construction process. A stand-by mechanic was also available on site.

The following items of equipment were used for the construction:

- 2 Bitumen distributors (6000 l capacity).
- 1 Self-proppelled chip-spreader.
- 3 Tipper trucks (capacity 9 m^3)
- 1 Pneumatic roller (24 tonne)
- 1 Steel roller (10 tonne)
- 1 Front-end loader.
- 1 Water bowser

- 1 Motor grader
- 1 Mechanical broom.
- Wheel barrows, brooms, shovels and other minor tools were also used .

Providing a diversion would have proved too expensive and disruptive because the village is highly populated with houses close to the road and the back of the village is heavily farmed. It was therefore decided to construct half of the road width (of a manageable length) at a time while the other half was used by traffic. This caused significant disruption to the work since some drivers did not respect the cordoned-off work area. Managing non-motorised traffic (pedestrians, livestock etc) was challenging, especially on market days.

The sealing operation took place between the 21st February 2013 and 23rd March 2013.

4.2 Types of binder and spraying

Two types of binders were used, namely MC 3000 and MC 800. The MC800 was produced from MC 3000 cut back with 10% by volume using kerosene. This cutting back was carried out at site but away from the village centre. The MC 3000 was used in the primed base section whereas the MC 800 binder was used in the un-primed base section as previously stated.

The binder application rates were initially increased by 0.2 l/m^2 due to the coaresness of the base. Therefore the target application rates were MC 3000 at 2.0 l/m^2 on the primed section and MC 800 at 2.2 l/m^2 on the un-primed section.

Prior to each spraying pull, the nozzles of the bitumen distributor were checked at site as shown in Figure 4-1.

Figure 4-1 Checking of the nozzles prior to sealing operations and spraying of binder

A summary of the spray rates achieved on site is shown in

Table 4-1. The design spray rates were achieved in most cases.

Table 4-1 Binder types and spray rates

Chainage	LHS application rate (l/m^2)	RHS application rate (l/m^2)	Binder used	Bitumen distributor Speed (m/min)	Desired application rate (l/m^2)	Comments
8+000 – 9+300	1.01	1.02	MC 30	90	1.0	Prime. Whirling spray jets distributor used.
8+000 – 8+600	2.03	2.02	MC 3000	135	2.0	
8+600 – 9+300	2.06	2.05	MC 3000	130	2.0	
9+500 – 10+00	2.48	*	MC 800	105	2.2	* Not measured
9+700 – 10+300	*	2.05	MC 800	110	2.2	* Not measured
10+300 – 10+800	2.23	2.08	MC 800	110	2.2	

In all cases, joint paper was used to ensure a good overlap and straight joints. A labourer and a supervisor were specifically assigned to supervise these tasks.

Figure 4-2 shows paper laid for each start and stop for the distributor in order to achieve straight transverse joints.

Figure 4-2 Paper used to achieve straight transverse joints

4.3 Aggregate applications

The aggregate was pre-stockpiled in a borrow-pit 5km from the sections. The pit was being used for another project by the contractor. The advantages of this arrangement were good security and maximised the use of the front-end loader.

The aggregate application was carrried out by a self-propelled chip spreader which applied the aggregate quite evenly. The rates of application are shown in Table 4-2. In most cases re-chipping was done at a rate of 6 l/m² to make up for deficient application of aggregate in the first run. Re-chipping was done either immediately or the following day if work was done late in the evening. Figure 4-3 shows the chip spreader in operation – note the amount of dust acceptable for Otta Seals but not acceptable for other bituminous surfacings.

Table 4-2 Aggregate application rates

Chainage	LHS application rate (l/m²)	RHS application rate (l/m²)	Re-chipping rate (l/m²)	Desired application rate (l/m²)
8+000 – 8+600	13.90	*	6.0	22.0
8+600 – 9+300	12.85	*	6.0	22.0
9+500 – 10+00	19.79	*	*	22.0
9+700 – 10+300	*	15.43	6.0	22.0
10+300 – 10+800	15.96	14.69	6.0	22.0
10+800 – 10+880	17.17	*	*	22.0

Figure 4-3 Self-propelled chipspreader in operation

4.4 Rolling during construction and after

The rolling during construction and afterwards was carried out using a 24 tonne pneumatic roller followed closely behind by a 10 tonne steel roller in non-vibratory mode – as shown in Figure 4-4. The rolling was carefully supervised so that the entire width of the surfacing and all sections received adequate rolling.

After completion of the sealing operations, the entire section received three days of rolling at slow speed (less than 10km/hr) by the pneumatic roller. The steel roller also stayed on site to roll and flatten out the longitudinal joints.

Figure 4-4 Rolling in progress by the use of both a pneumatic roller and the loaded tipper truck

4.5 Weather condition during construction

The weather condition during the sealing operations was sunny and partly cloudy with air temperatures estimated at between 18 – 25 C^o. However, while surfacing the section from 10+000 to 10+400, on two separate days there was a threat of rain and the air temperature dropped significantly. Light rain fell during the night but after initial rolling had been completed.

The rains also meant that the aggregate used between sections 9+500 to 9+700 and the left hand side of 10+200 to 10+300 was damp due to inadequate covering of the stockpile.

5 Construction Constraints Experienced

5.1 General

This section highlights constraints that were experienced during the sealing operations.

5.1.1 Bitumen distributors

The performance of surfacing on sealed roads is highly sensitive to construction practice and on the condition of the construction equipment used.

Initially, there were problems with the bitumen distributors that were provided for the work. A total of 3 distributors were tried and each distributor suffered at least one of the problems below.

- Inability to spray adequate binder quantity
- No low-speed tachometer
- Faulty spray bar height adjustment mechanism
- Frequent full blocking or partial blocking of the spray nozzles
- Non-functional hand lance
- Inability to suck the binder
- Inability to circulate the binder while heating

Fortunately after about 30% of the work had been done, a good functioning distributor was acquired with an electronic tachometer but with an inabilty to suck binder. Another distributor was therefore used to suck and deliver the binder to the distributor used for spraying.

5.1.2 Aggregate.

The aggregate sizes were excellent and on most occasions completely dry. However a brief spell of rain meant that the aggregate used between sections 9+500 to 9+700 and the left hand side of 10+200 to 10+300 was damp due to insufficient covering of the aggregate stockpile. If a second seal is not applied as planned, then there is a risk that this could lead to stripping as a result of poor aggregate-bitumen adhesion thus affecting the subsequent performance of the surfacing.

5.1.3 Sealing operations.

Initially it was quite difficult co-ordinate team activities, particularly in ensuring that the “surfacing train” followed immediately behind the bitumen distributor. This was compunded by the problems experienced with the initial bitumen distributors.

However after the distributor issues had been resolved, the team became very efficient executing their tasks and understood the principle behind the Otta Seal technology.

5.1.4 Traffic management

Owing to the fact that there was no traffic diversion as discussed earlier, vehicles often strayed into the work areas disturbing the fresh surfacing. Vehicles did not obey the speed limit and “flying stones” signs posted.

An attempt was made to use traffic police to manage the traffic but there was no success in controlling the speeds.

Heavy trucks often stepped on barrier blocks punching them into the fresh surfacing. Also on a few occasions, oversize stones from the side drains were scattered onto the fresh surfacing and were occasionally being punched into the surfacing. Both of these problems are potential causes of potholing. These areas will have to be checked and corrected before the second seal is placed.

With the first seal now down, the traffic management for the next seal will be much easier.

6 Considerations for the second seal

6.1 Items to consider

The second seal is planned to take place after it is deemed that sufficient volatiles (solvent) have evaporated from the first seal and the seal has firmly set. This period usually occurs between 2 to 3 months which is sufficient time to allow the volatiles to evaporate..

A risk may have to be taken to apply the second seal slightly earlier than 3 months to minimise the risk of wet weather damage to the first seal. In a normal season, the rainy season could be expected to start almost exactly 3 months after the first seal was completed. This could mean that there would be no time to construct the second seal until after the rainy season. In this situation, the concern is that heavy traffic may damage the first seal significantly during the rainy season.

During the first 4 – 5 weeks, aggregate dislodged by traffic will be broomed back in order to ensure a fully matured Otta seal. Thereafter all the loose aggregate can be broomed, collected and if still of acceptable grading, can be mixed into the stockpile for the second seal.

Prior to constructing the second seal, all aggregate will need to be stockpiled at site and coverd with tarpaulins in order to keep the aggregate dry in the case of rain.

All equipment that was faulty during the construction of the first seal should be repaired and serviced together with all other equipment well in advance before construction of the second seal starts. This especially applies to the heating plant and the bitumen distributors.

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.

On the slopes, scour checks should be constructed to minimise erosion damage to the side drains.

7 Workshop and Field Visit

7.1 Introduction

A one-day workshop was held by ERA on the 21st March 2013 at the Sunny Side Hotel in Combolcha to demonstrate Otta seal technology, to promote the project and the Otta seal concept to stakeholders (ERA engineers, Consultants and Contractors). This was followed by a day on site which included a practical demonstration in which an Otta Seal was constructed on a primed base and an un-primed base. The demonstration included the techinque of cutting-back bitumen on site.

7.2 Purpose and Scope

The pupose and scope of the workshop and the following field visit to the project site were to promote the Otta seal concept and provide participanmts better understanding of the technique.

The following items were included in the workshop presengtations:

1 - An Overview of the gravel roads vs Sealed roads
2 - Various types of Surface Treatments
3 - What is the Otta Seal including the economy
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.
- "After Care"
- Reporting.

7.3 Outcome

Participants at the workshop were enthusiastic and asked many questions. The field visit was especially successful with particiants asking many questions. The cutting back operation was also a new experience for many participants.

The workshop participants were asked to complete a short questionnaire after the workshop. Sixteen responses were received, and these are summarised in Appendix B. The response was very positive, with all particpants indicating that the workshop was useful and that the knowledge they had gained on the design and construction of Otta Seals would be of benefit to Ethiopia. About half of the participants felt that the workshop was too short.

APPENDIX A

Layout of the demonstration section

8+000	GERADO VILLAGE, width 9.40m - 9.70m								10+900	
0	100		800		1500		2200		2900	m
Double Otta Transition zone bitumen	Double Otta Seal using hard aggregate		Single Otta Seal (hard aggregate) with crusher sand cover seal		Single Otta Seal (hard aggregate) with crusher sand cover seal		Double Otta Seal using hard aggregate			
	Double Otta Seal using hard aggregate		Single Otta Seal (hard aggregate) with crusher sand cover seal		Single Otta Seal (hard aggregate) with crusher sand cover seal		Double Otta Seal using hard aggregate			
Prime	Prime	Prime	Prime	Prime	No prime	No prime	No prime	No prime		

APPENDIX B

Workshop Feedback

1 Your education:

University degree	14	88%
College Diploma	2	13%
Secondary School	0	0%

2 Your experience in road management, design, construction or maintenance:

Less than 5 years	12	75%
5 to 10 years	3	19%
More than 10 years	1	6%

3 Your Employment

Central government	14	88%
Regional government	0	0%
Consultant	0	0%
Contractor	2	13%

4 Was this 2 day workshop:

Too short	7	44%
Too long	0	0%
About the right length	9	56%

5 Were the presentations:

Too short	7	44%
Too long	0	0%
About the right length	9	56%

6 Were the discussion periods:

Too short	8	50%
Too long	0	0%
About the right length	8	50%

7 Was the presented material:

Too complicated	0	0%
Too simple	5	31%
About right	11	69%

8 What did you like about the workshop?

- Site demonstration.
- Having theory and practical in same workshop.
- Otta seal hs economic benefits over other seals.
- The workshop was good for ERCC (government contractor company) and the country
- Gave me more information about Otta Seals, which I had no information on before.
- Otta seals allow cost minimisation by using local materials.
- Technology is appropriate to developing countries.
- I would like similar workshops to be held for other types of road contraction works.
- Workshop provided information about Otta Seals which give good performance and durability and not very difficult to construct.
- The content of the workshop and the presentations were very good.
- The presentation was clear and precise.
- Otta seal is cost effective and can be designed for any type of aggregate.

9 What did you dislike about the workshop?

- The discussion time with the presenters was too short.
- Absence of a detailed outline and programme - not distriubuted at the beginning of the workshop.
- Presentation and demonstration photos should be given in soft copy so they can be distributed.
- Too short- not complete.
- The practical workshop time was not comfortable because it was at lunch time; better if it was at 8am.
- Participants should have hard hats on site.