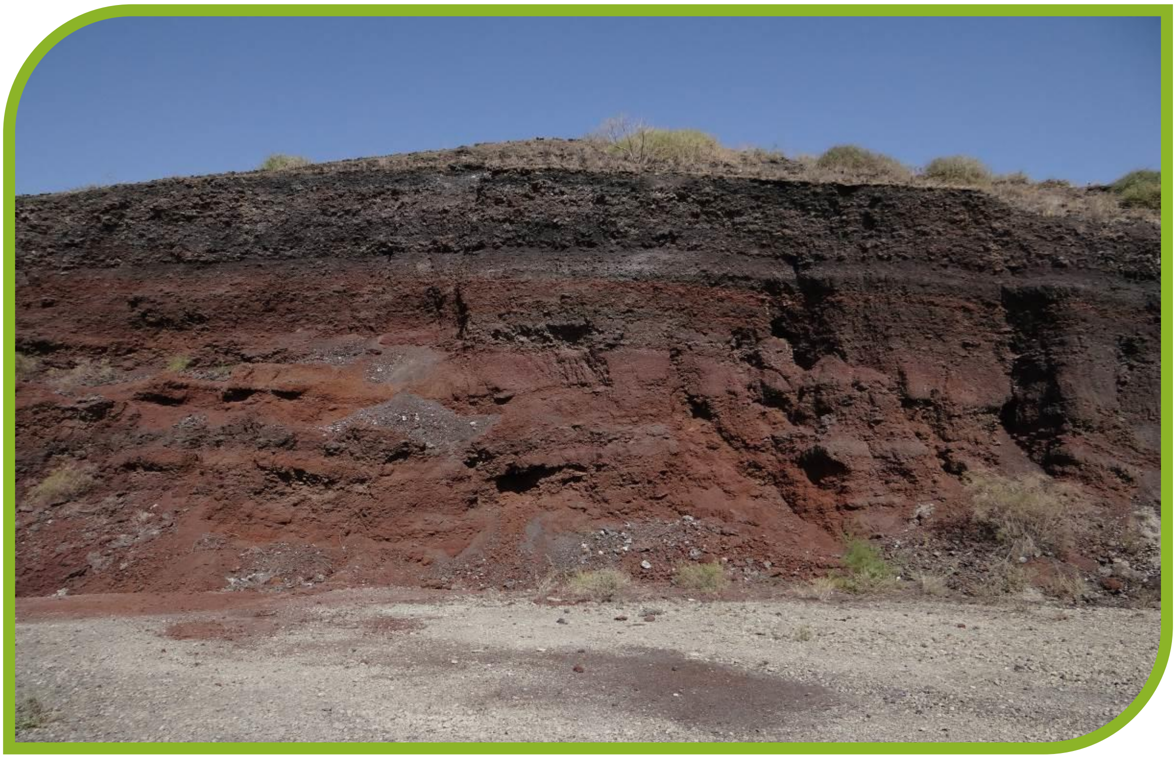
Investigation of the Use of Cinder Gravels in Pavement Layers for low-Volume Roads

Progress Report No 1



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Abstract

This Progress Report summarises progress made on the Project during March-May 2016. The Inception Report was finalised during this period and a programme of fieldwork carried out at various locations along the margins of the Rift Valley south and east of Addis Ababa. This fieldwork involved trial pit investigations and sampling of scoriaceous and non-scoriaceous gravels used in pavement construction at two sites on the Addis Ababa to Butajira Road and a programme of sampling at borrow areas on the margins of the Rift Valley south, southwest and east of Addis Ababa. A total of 22 borrow pits were inspected and sampled. Samples were taken from a total of 37 sites within the borrow areas and transported back to the ERA Kality laboratory for testing. As of the end of May testing had commenced on samples taken from the Addis Ababa-Butajira road and one of the borrow pits.

Key words

Low Volume Roads, Guideline, Pavement Layers, Scoria, Cinder gravels, Ethiopia

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Acronyms, Units and Currencies

AFCAP	Africa Community Access Partnership
ERA	Ethiopian Roads Authority
LVR	Low Volume Roads
LVSR	Low Volume Sealed Roads
RRC	Road Research Centre
TRL	Transport Research Laboratory
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)

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1 Introduction

This Progress Report No 1 covers the period March to May 2016. During early March a draft Inception Report was submitted and was finalised at the end of April. The structure of the project is described in this Inception Report and this Progress Report should be read in conjunction with it. No description is provided in this Progress Report of the discussions held with ERA during project Inception.

2 Summary of activities undertaken during this Period

The main activities undertaken during this Period are listed below:

1) sampling of road pavement materials at two sections along the Addis Ababa to Butajira road, where the sub-base material comprises scoriaceous ('cinder') materials and weathered basalt respectively
2) geological inspection and sampling in existing borrow areas around Butajira, Hawassa, Dodola, Bishoftu, Tuludimptu, Adama, Tulubolo and Metahara.
3) commencement of a programme of laboratory testing on the retrieved samples.
4) discussions with consultants on the Addis Ababa – Adama Expressway who have used scoria extensively as a replacement material for the subgrade and as a capping layer.

These activities are described in Sections 3-5 below.

3 Field investigations along the Alemgena – Butajira road

The Alemgena -Butajira road is the oldest road known to possess a scoria ('cinder') sub-base and to have carried more than 1 million equivalent standard axles. What makes this road even more suitable for study is the fact that about half its length has been constructed with a scoria sub-base whilst in the other half a weathered basalt has been used for the sub-base (very common in Ethiopia). The full length of the road has a crushed stone base. The two sub-base materials possess different engineering and geological properties. It is therefore useful to investigate the engineering properties of the two sub-base materials on this road and compare their performance. Two sections were selected for performance measurement and sampling. A scoria sub-base section and a weathered basalt section were selected at chainages 44+000 to 45+000, and chainages 70+000 to 71+000 respectively. Rutting was measured, a traffic classification count made, and sub-base samples were taken for laboratory testing.
The team has requested other performance measurement data collected by the ERA Road Network Management Division since its construction to be made available. This data is expected to be provided by mid-July.

4 Geological inspection and sampling at existing borrow areas to the south and southeast of Addis Ababa

4.1 Geological outline of locations and materials

There are several scoria ('cinder') cones located along the margins of the Rift Valley. Their locations are controlled by the main fault structures that define the margins of the Rift Valley and their distributions are therefore approximately linear. These cones are geologically very young, with the majority likely to have formed during the early Pleistocene Period of the Quaternary and the Mio-Pliocene Period of the Tertiary.

Many of these cones have been opened up for materials extraction. Discussion on site with borrow pit operators indicates that extracted materials are being used for:

- sub-base and wearing course for municipal gravel roads, and ‘gravel’ surfacing for URRAP roads
- manufacture of hollow blocks (breeze blocks) for building construction
- subgrade replacement prior to the construction of raft foundations for buildings.

Excavated faces in these borrow pits reveal volcanic materials that vary immensely in their composition. Scoria (‘cinder’) cones, by definition, are composed predominantly of pyroclastic materials that vary in size from ash to blocks or ‘bombs’. Layering of these materials is usual, with the layering varying between well-defined and well-sorted to poorly-defined and poorly sorted materials.

The following types of materials have, so far, been identified:

- ash (<2mm) – usually light grey or dark grey to black in colour and non-plastic
- weathered ash and scoria, yellow brown in colour and usually slightly plastic
- ‘cinder’ gravel (fine to coarse), dark grey to black in colour and either without or with very little vesiculation
- Scoriaceous clasts (scoria) that vary in size from fine gravel to cobbles and occasional boulders. The colour of these clasts is also highly variable and reflects composition, but mostly degree of weathering. Grey scoria ‘gravel’ weathers to reddish brown with a significant reduction in strength in the process
- Non scoriaceous clasts, both lithic (country rock) and basaltic (magma)
- Blocks and bombs of scoriaceous basalt, mostly sub-rounded and found occasionally to very occasionally in almost all deposits
- ‘spatters’ of scoriaceous basalt, usually elongated and discontinuous, aligned approximately with the overall depositional structure, and usually ropy in texture
- Discrete flows of lava, usually less than 1m in thickness, often displaying ropy lava texture and occurring within the pyroclastic sequence
- Discrete flows of lava, usually up to 2m in thickness, capping the pyroclastic sequence
- Welded and sintered materials, fused by heat
- Welded materials, fused by iron oxide precipitation upon chemical weathering in the post-formation deposit
- Occasional intruded basalt or andesite, assumed to have been intruded along faults caused by post-depositional tectonic movements.

Most borrow areas contain a wide range of some, or all, of these materials, which vary in terms of their size, colour, strength, shape and composition. Seams of approximately homogeneous material are often less than 2m thick and, in the finer grained deposits, individual bed thicknesses can be 10 mm or less. This poses significant issues for both characterisation (see below) and sampling (Section 4.2).

Unlike more conventional borrow areas, the high variability in materials exposed in most of the borrow pits makes it extremely difficult to characterise them visually. The variability is highest with depth, i.e. between beds and, from an engineering geological perspective, it is impossible to summarise this range. The procedure adopted therefore has been to identify locations where both ‘typical’ and strongest materials are exposed and provide a description of their colour, grain size, apparent density and apparent strength. Another issue relating to the observation and description of materials is access. Some borrow pits are several tens of metres deep and with sub-vertical cut slope angles access on foot is both impracticable and dangerous in many cases.

Table 1 provides a summary of the locations that were inspected, together with the number of samples extracted from each for laboratory testing.

Table 1: Location of borrow areas investigated and samples obtained for testing

Location Number	Location Description	Site No.	Number of Sample Bags	Location Coordinates
1	Alemgena-Butajira road 122km from Addis Ababa	1	3	438925 / 904439
		2	2	438848 / 904167
		3	2	438913 / 904440
2	Alemgena-Butajira road 30km from Addis Ababa	1	2	462330 / 978155
		2	2	Cut slope closest to road
3	Butajira - Zway road km 6 from junction	1	3	437310 / 901285
		2	2	437268 / 901189
		3	1	
4	Butajira - Hossana road 2km from Butajira	1	3	432042 / 895488
		2	2	Opposite side of pit to site 1
5	Butajira - Hossana road Km7.5 from Butajira	1	2	429064 / 891320
		2	3	
6	Tulubolo North	1	3	401900 / 974047
		2	3	
7	Tulubolo South	1	3	414722 / 955767
		2	2	
		3	1	
8	Hawassa	1	4	444591 / 780598
9	Hawassa	1	4	443911 / 776512
		2	2	
10	Hawassa (Rubbish dump)	1	2	445940 / 778241
11	Dodola	1	4	529599 / 800549
		2	1	
12	Dodola	1	4	540358 / 799821
		2	1	
13	Dodola	1	4	490564 / 778928
		2	4	
14	Adama-Dira	1	4	536528 / 913537
15	Adama – Dira	1	2	535374 / 933089
16	Adama – Dira	1	4	533575 / 937332
17	Adama – Dira	1	4	532500/938460
18	Adama – Dira	1	2	532334 / 938481
		2	2	532334/938481
19	Bishoftu	1	4	502495 / 970384
20	Bishoftu	1	4	507806 / 970503
21	Bishoftu	1	4	503632 / 967979
22	Tuludimptu	1	4	479478 / 979044

4.2 Sampling

The high variability in exposed materials described above poses an issue for representative sampling. A decision was made at the commencement of the sampling programme to sample what appeared to be the strongest materials exposed, although in some cases more than one sample was taken to give an indication of variability. Furthermore, wherever materials displaying a degree of plasticity were observed, samples were taken to determine properties for blending purposes. The final results of the lab testing will need to be viewed in the light of the fact that samples may not be representative of the bulk of materials contained in any one borrow pit. Instead, they may be representative of the stronger materials exposed.

For course-grained samples, either three or four 30 kg sample bags were obtained. For fine-grained samples with some apparent plasticity, usually one 30 kg sample was taken. These sample bags were labelled on the outside with permanent marker and a form was included inside the bag describing location number, site number, date taken, material description, number of bags etc.

Samples were taken back to the ERA compound in Kality each evening, with the exception of those taken from locations in Hawassa and Dodola, which were stored in ERA's Sheshamane compound for later transport to Kality by ERA.

5 Laboratory testing

A set of procedures for laboratory testing was discussed and given to ERA prior to the commencement of laboratory testing. These procedures are reproduced here in Annex A.

A schedule of tests was prepared and given to ERA. Testing of samples will be carried out according to AASHTO specified procedures.

For scoria without apparent plasticity, the following tests were scheduled:

- MDD/OMC
- 3-Point CBR (10, 30, 65 Blows)
- Drying Back CBR, 0.75OMC, OMC, 4-day Soak
- Particle Size Distribution of specimens after 3-point CBR tests (all sieve sizes) - wet sieving
- Liquid Limit on < 75 µm sieve (after CBR and PSD tests) – the cone method is not available at RRC
- Plastic Limit on < 75 µm sieve (after CBR and PSD tests)
- Modified Aggregate Impact Value (15 blows)
- Water absorption
- Particle Density

For scoria with some apparent plasticity the following tests were scheduled:

- MDD/OMC
- 3-Point CBR (10, 30, 65 blows)
- Drying Back CBR, 0.75OMC, OMC, 4-day Soak
- Particle Size Distribution of specimens after 3-point CBR tests (all sieve sizes) - wet sieving

- Liquid Limit on < 425 µm sieve (after CBR and PSD tests)
- Plastic Limit on < 425 µm sieve (after CBR and PSD tests)
- Bar Linear Shrinkage
- Modified Aggregate Impact Value (15 blows)
- Water absorption
- Particle Density

For single-sized gravelly (10 mm max.) samples the following tests were scheduled:

- Ten Percent Fines Value (14 mm - 10 mm or 9.5 mm - 6.3 mm)
- Particle Size Distribution
- Loose Density
- Water Absorption
- Sand Equivalent Test/ Hydrometer Dispersion
- Organic Content

For plastic materials used for blending, the following tests were scheduled:

- Particle Size Distribution (All sieve sizes) - wet sieving
- Liquid Limit on < 425 µm sieve
- Plastic Limit on < 425 µm sieve
- Bar Linear Shrinkage

As of the end of May 2016, laboratory testing had progressed on samples taken from the sub-base investigations along the Addis Ababa-Butajira road and at Location 6 (Table 1).

6 Technical and project planning issues during this Period

6.1 Logistical arrangements and programming

The fieldwork undertaken during this Period has been intensive. ERA has made available a 4-wheel drive vehicle with drivers and diesel has been provided from ERA resources. There have been some delays in obtaining fuel on occasions, but generally the logistical support provided by ERA has worked well. The fieldwork has run according to programme. The laboratory testing, however, is significantly behind schedule.

A second field visit by the TRL team was scheduled to commence during the third week of May but problems in obtaining visas has meant that this second visit cannot commence until early June.

ERA was asked to write to the Ethiopian Mapping Agency requesting copies of stereo aerial photographs and a budget for this was agreed with the PMU. This request was not sent during this Period and will need to be actioned early during the next Period.

6.2 Staffing

There have been no staffing issues during this Period. ERA has mobilised a counterpart engineer (Hailu Teshome) who has taken part in, and contributed significantly to, the majority of the fieldwork.

7 Issues to take forward to the next Period

The intention is to complete the second phase of fieldwork during the next Period. This will involve visiting existing and potential borrow areas in the general vicinity of Bahir Dar and Kobo-Mekele. This will also involve additional sampling.

A large number of bulk samples has been collected from 37 sites as shown in Table 1, and there are still more samples to be collected from other areas. Therefore, there are concerns that the laboratory cannot complete the testing of the samples within the project programme. It is expected that the RRC will prepare a schedule for the testing programme and hence it will become clearer whether or not it is realistic to expect laboratory testing to be completed within the proposed time frame.

The request for stereo aerial photographs will need to be finalised and sent to the Ethiopian Mapping Agency along with a final list of required locations.

Significant progress will need to be made in the laboratory testing programme as the results are required in order to progress other elements of the research and to make up for the lost time.

Annex A: Procedures for Laboratory Testing

The following set of procedures was given to ERA.

1 Procedure for tests to produce CBR vs Moisture Relationship (Materials intended for use as base course)

1.1 Preparatory Note

a) Close supervision by a dedicated technician to the procedure is essential for reliable results to be achieved.
b) Accurate and proper labelling of specimens and samples must be maintained at all times.
c) CBR tests shall be conducted at the top and bottom of the mould.
d) After testing the top, immediately cover with cling film to minimise moisture loss, turn the specimen over and test the bottom of the specimen.
e) After CBR testing of both the top and bottom of the specimens, immediately take samples for moisture content test from the top and bottom 50 mm of the CBR specimen.
f) A balance capable of weighing moulds to a high accuracy is required
g) The values determined in the procedures below will give the information required to produce plots of CBR vs M/C.
h) After drying back, the values of CBR may require the use of a higher-rated proving ring.

1.2 Sample Preparation and Testing

1. Air-dry the bulk material for 2 days.
2. Pass the bulk material repeatedly through a riffle box to ensure uniform mixing of the material and to obtain a representative sample.
3. Oven-dry approximately 25 kg of the material at (60°C) in preparation for MDD/OMC testing. The oven-drying should last about 16-24 hrs.
4. Carry out determination of MDD and OMC by the AASHTO T180-01 method. That is 5 layers, 56 blows per layer. Specimen should be re-used.
5. Screen the bulk material through the 20 mm sieve to obtain specimens for CBR testing.
6. Prepare 3 specimens for 3-point CBR testing (all specimens moulded at OMC) moulds for preparation of CBR specimens.
    a. Carryout 3-point CBR testing at 4-days soak.
    b. Conduct wash gradation analysis to determine the particle size distribution after CBR testing on each of the 3 specimens.
    c. Conduct Atterberg limits tests thereafter.
    d. Compute the number of blows required to obtain 98% MDD compaction at OMC.
7. Oven-dry approximately 18 kg of the material at (60°C) in preparation for CBR testing at 98% MDD. The oven-drying should last about 16-24 hrs.
    a. Prepare 3 specimens moulded at OMC and compacted at 98% MDD.
    b. Select Specimen 1 and carry out CBR test at the top and the bottom of the specimen (at OMC).

c. Select Specimen 2, soak for 4 days (measure swell), carryout CBR testing at the top of each specimen, and determine the moisture content from the top 50 mm of each specimen as specified in section 1.1.
d. Select Specimen 3 and allow it to air-dry to 75% of OMC. A spreadsheet has been provided for calculation of the mass of the mould + specimen at this moisture content. After the drying is complete, then wrap the specimen tightly in cling film and allow the moisture to equilibrate in the specimen for 4 days. At the completion of the equilibration, carryout CBR testing at the top and bottom of each specimen and determination of moisture content from the top and bottom 50 mm of each specimen as described in section 1.1 above.

2 Blending of cinder gravel with plastic material

2.1 General

The presence of material with plasticity in a gravel matrix serves two main purposes:

1. It provides the binding forces necessary to achieve stability during compaction and use.
2. When the material dries back, the suction forces provide extra cohesion and hence greater strength (CBR).
3. It provides a degree of impermeability for the lower layers.

After testing and characterisation of the individual materials, they will be blended according to the ratios in Section 2.3. The blends' MDD/OMC shall be determined, then the 3-point CBR specimens shall be prepared, soaked and tested. Wet sieving and Atterberg Limit tests shall be performed on each specimen after CBR testing.

2.2 Blending philosophy

Some cinder gravels are non-plastic in nature; they therefore require blending with materials to add a degree of plasticity to the material.

For cinders intended for use as sub-base materials, the target shall be to have material that has moderate plasticity so as to protect the subgrade. The target CBR should be between 30 – 60%.

For base purposes, the target is to achieve a high CBR, as long as the MDD of the mix is greater than 1500 kg/m^3 (1975 study) with minimal PI required mostly for compaction purpose (low plasticity materials are less sensitive to moisture variation).

2.3 Blending procedure

1 Mix two portions of the blend in the ratios Cinder: Plastic Material; 80:20 and 90: 10 by mass.
2 Determine the MDD and OMC of each of the two portions (specimens may be re-used).
3 For each of the mix portions, prepare three specimens for 3-point CBR testing (10, 30, 65 blows).
4 Soak the 3 specimens of each mix portion for 4-days and test the CBR.
5 For the mix portion containing 20% plastic material, conduct wet sieve analysis of the 3 specimens. Thereafter conduct Atterberg limit tests.
6 For the mix portion containing 10% plastic material, produce more of the blended material and test as described in section 1.2 steps 5 to 14.