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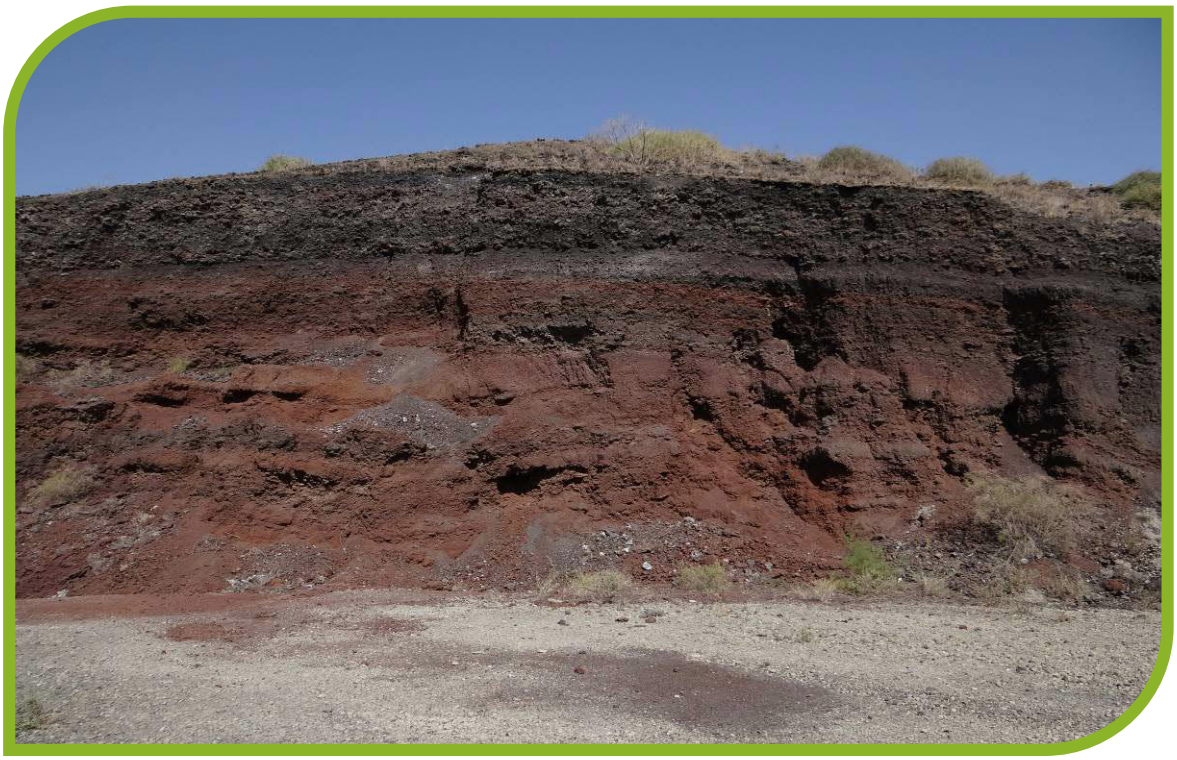
Investigation of the Use of Cinder Gravels in Pavement Layers for Low-Volume Roads

Progress Report No 2



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Abstract

This Progress Report summarises progress made on the Project during May - August 2016. The laboratory testing procedure was revised during this period to reflected the nature in which cinder occurs in the field. Field visits, inspection and sampling were carried out in the area surrounding Bahir Dar, Injibara and Kessa. A priority testing list was also prepared during this period. Laboratory testing commenced during this period and a total of 5 out of 16 priority locations have now been tested. Additional samples were collected from the Butajira area to make up for shortfalls during initial sampling. During initial sampling, it was not possible to transport in one go the large bulk of samples required for laboratory testing. Samples from the southern area (Hawassa, Assela-Dodola, and Shashemene) were transported to RRC Kality since they are the next to be tested. A request for quotation for stereo aerial photographs from the Ethiopia Mapping Agency has been made, samples of the photographs have been obtained and they will be studied by the Team Leader in his next visit. Due to government regulations, the sample photographs cannot be taken out of Ethiopia.

Key words

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

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 2 covers the period May-August 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) Revision of the laboratory test procedures (see Appendix A) to make better utilisation of the available laboratory facilities.
2) Sampling around the areas of Bahir Dar and Injibara, using potential sites identified from Google earth.
3) A visit to the western Rift Valley between Kobe and Mekelle to ground truth possible sources identified from Google earth imagery
4) A priority testing list was prepared to ensure that the most important sites are tested by the end of the project (see Appendix B). In conjunction with this, a laboratory testing schedule was prepared by the RRC (see Appendix C). The schedule is being used to carry out the tests.
5) Supplementary samples from the Butajira area were taken by the counterparts and delivered to the RRC test laboratory at Kality.
6) Samples from the southern area of Hawassa, Assela-Dodola and Shashemene were delivered to the Kality RRC.
7) Stereo aerial photographs were procured from the Ethiopia Mapping Agency.

These activities are described in Sections 3-8 below.

3 Revision of the laboratory testing procedures

The initial laboratory test procedure assumed that all cinder would be blended. The procedure has been revised (see Appendix A) to take into account the fact that suitable blending material may not be available within the vicinity of the cinder source and therefore its neat properties should be assessed before blending is carried out. In case the neat properties are suitable for use, then there will not be a need to blend the material.
Moreover in certain rare circumstances the cinder contains plastic fines. The revised procedure also investigates this phenomenon.
Within some cinder deposits, fine-grained material (sand-silt) exists. The revised procedures investigate the properties of this fine-grained material for potential inclusion in pavement layers. It is known that this material is used locally in the production of hollow blocks.

4 Geological inspection and sampling at existing borrow areas around Bahir Dar, Injibara and Kessa

In June 2016, the team worked in the areas around Bahir Dar and Injibara (south-west of Bahir Dar) using an interpretation of potential sites from Google earth imagery. A number of existing borrow-pits and potential sources were inspected and samples were taken from the locations shown in Table 1 below.
The area around Injibara and Kessa possesses a large number of sources, many of which have not yet been opened or extensively utilised. On this note the government of Ethiopia needs to strengthen the process of designation and proper borrow-pit management in order to ensure sustainable use of cinder and other materials.

Table 1: Location of borrow areas where samples were obtained for testing

Location Number	Location Description	Site No.	Number of Sample Bags	Location Coordinates
23	Debanki	1	3	0320320/ 1281922
		2	1	0320312/ 1282006
		3	1	
24	Wogelisa	1	4	0312415/ 1284977
25	Injibara	1	2	0275369/1210482
		2	4	0275369/1210482
26	Gondar Rd	1	2	0331954/ 1287559
		2	4	0331924/ 1287518
		3	4	0331823/ 1287581
27	Kunzila	1	4	0283614/ 1310784
28	Injibara	1	4	0264625/ 1209960
29	Injibara	1	4	0273401/ 1210056
30	Kessa	1	2	0277418/ 1206098

Because of the far distance of these locations from Addis Ababa, four sample bags were often taken to avoid going back to the field for supplementary samples during laboratory testing.

The samples (39 bags) have been stored at the Bahir Dar Section Depot of the Debre Markos District Road Network Management Directorate and are awaiting transport to Kality by ERA for testing. On this note, the ERA Road Research centre (RRC) is urged to once again request Debre Markos or Gonder districts to assist in transporting the samples to Addis Ababa.

5 Geological inspection at the Kobo – Mekelle area

In the same round of visits, the areas around Maichew, Mohoni, Kobo and Mekelle were inspected. Unfortunately, these areas yielded no sources of cinder. An interpretation of Google earth imagery led to the identification of several potential sources on the western side of the Rift Valley between Kobo and Mekelle. Some of these were visited by the team in June, but those that were accessible did not yield cinder materials. Several cinder cones are evident on the imagery further east and, from the imagery, they do not appear to have been utilised as material sources. Unfortunately, they could not be visited by the team as they are located within a restricted zone.

6 Priority testing list

The time available until the completion of the project and the rate of progress with the testing to date may not be sufficient to complete the testing of all samples collected from the field. For this reason, the team has thought it wise to produce a list of samples from prioritised locations in order to maximise the geographical, and strength and plasticity ranges of the samples. The list is included in Appendix B and includes 16 locations (26 sites). It should be noted that this is significantly less than the 30 locations (49 sites) for sample testing envisaged in the Consultant's technical proposal.

In conjunction with this, a laboratory testing schedule was prepared by the RRC (see Appendix C). The schedule is being used to carry out the tests. The schedule is a working schedule and may need to be modified to suit the outcome of the testing as it proceeds. A progress/update measured against this schedule will be presented in the next progress

report due at the beginning of December 2016. Currently 5 out of the 16 locations have been tested albeit with some few remaining tests per location.

7 Supplementary samples from Butajira area

During initial sampling in the areas around Addis Ababa, transport of bulk samples was an issue, given the limited number of samples transportable back to Addis Ababa each day in the vehicle. From a sampling point of view, it was required to transport up to 18 bags in each day trip; but this would not be safe given the capacity of the field vehicle. It was therefore decided that since the locations are close to Addis Ababa, supplementary samples would be taken during laboratory testing. In July, these supplements were taken from the Butajira area by the counterparts from the RRC. Once the heavy rains stop, supplementary samples will be taken from the Tulubolo area. Samples from the Bishoftu, Adama and Awash areas are generally sufficient, as are those from Hawasa, Shashemene and Bahir Dar.

8 Samples from the southern areas of Hawassa, Assela-Dodola, and Shashemene area

The samples were taken in April 2016 and stored at the Shashemene District Road Network Management Directorate. In August 2016, these samples (30 bags) were transported to RRC Kality for testing.

9 Stereo aerial photographs

A letter requesting a quotation for a set of photographs from various cinder areas was submitted to the Ethiopian Mapping Agency by ERA on the 4th July 2016. On the 29th August 2016, the agency provided samples of the photographs in order to check they have been prepared correctly.

Unfortunately due to Ethiopia government regulations, these photographs cannot be taken out of the country. Therefore the team leader will analyse them in the next visit and acquire any supplementary photographs if necessary.

10 Laboratory testing

According to the programme at the inception stage, laboratory testing was to start in April 2016 and finish in mid-November 2016. However, the start of testing was delayed due to a number of issues. Testing of the priority samples began in June and is expected to be completed by mid-December 2016.

This reduced programme for testing is progressing well in light of the challenges being faced concerning frequent equipment breakdown. By way of illustration, sub-base samples from the Alemgena – Butajira road have been tested and the results are shown in Table 2 and Figure 1.

Table 2: Comparison of test results of sub-base materials on Alemgena – Butajira road

Property	Weathered Basalt Sub-base	Cinder Sub-base
MDD (g/cc)	2.0	1.6
OMC (%)	11.2	21
CBR @ 95% MDD 4-days Soak (%)	32	15
Swell in CBR mould (%)	0.41	0.02
Liquid Limit (%)	50.4	50.4
Plasticity Index (%)	30.3	25.9
Shrinkage Limit (%)	2.9	10.4
Specific Gravity (g/cc)	2.7	2.0
Bulk Gravity (g/cc)	2.6	1.7
Water Absorption (%)	4.6	15.1

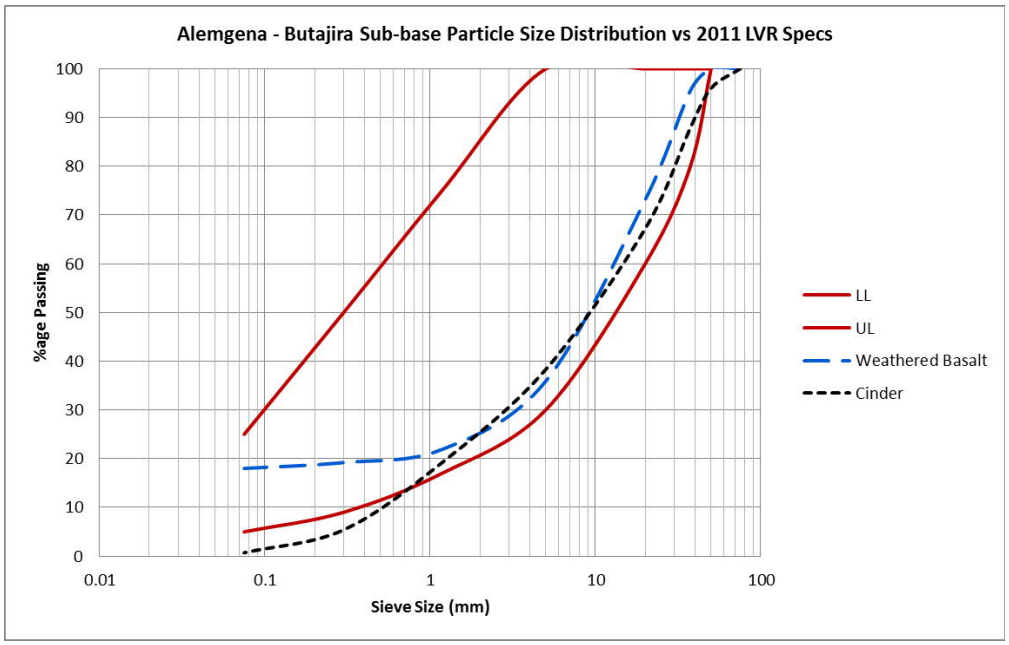

Figure 1: Particle size distribution of sub-base materials along Alemgena – Butajira road

Typical test results of the materials sampled from borrow-pits are shown in Table 3 and Figure 2. In this case the results represent Location 5 situated along Butajira – Hossana Road. Performance results were requested from the Road Network Management Directorate but the results obtained were not detailed enough. A further request has been made for more detailed results.

Table 3: Typical test results of blended cinder from Location 5

Property	Neat Cinder	Blending Material	90% Cinder +10% blending material	80% Cinder +20% blending material
MDD - Specimen not re-used (g/cc)	NR	NR	1.5	1.6
OMC - Specimen not re-used (%)	NR	NR	13.5	14
MDD - Specimen re-used (g/cc)	1.77	NR	1.77	1.8
OMC - Specimen re-used (%)	14.7	NR	16.4	15
CBR @ 100% MDD 4-days Soak (%)	NR	NR	16	17
CBR @ 100% MDD @ OMC (%)	83	NR	24	35
CBR @ 100% MDD @ 0.75*OMC (%)	NR	NR	30	NR
LL	NP	50	NP	30
PI (425 µm)	NP	28	NP	13
PI (75 µm)	NP	NR	NR	NR
Specific Gravity (g/cc)	2.1	NR	NR	NR
Bulk Gravity (g/cc)	1.9	NR	NR	NR
Water Absorption (%)	11	NR	NR	NR
AIV (%)	39	NR	NR	NR

Notes:
NR – Not Required

NP – Non-Plastic

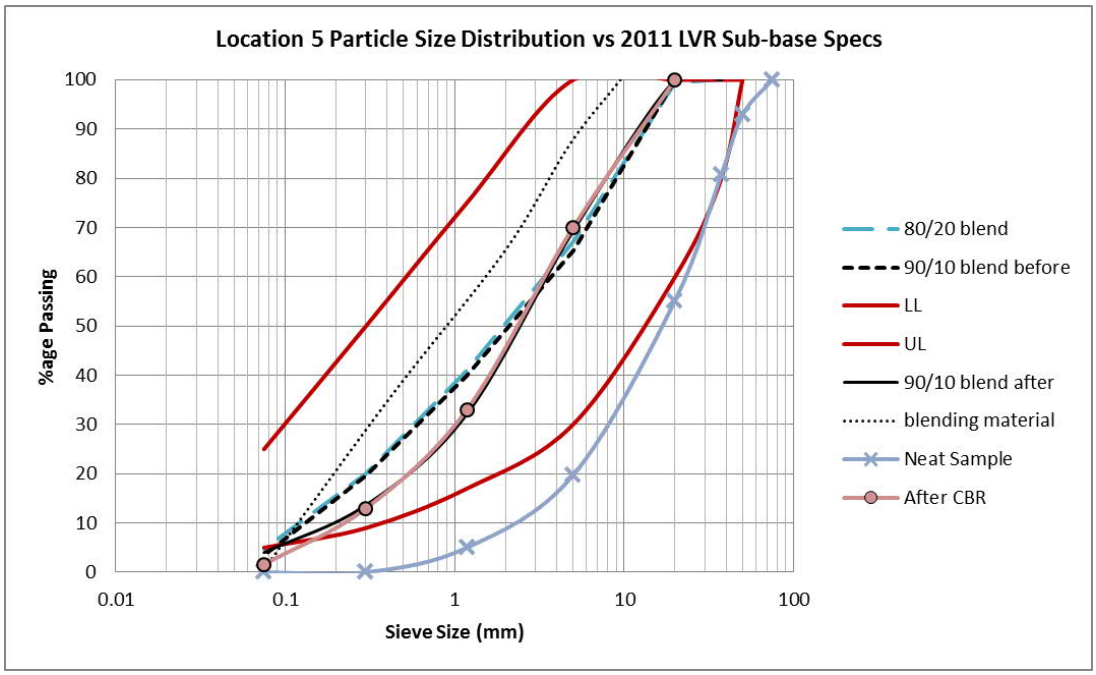

Figure 2: Particle size distribution of blended cinder from Location 5

11 Technical and project planning issues during this Period

The fieldwork undertaken during this Period has been intensive. ERA has made available a 4-wheel drive vehicle with drivers and fuel. There have been some delays in obtaining fuel on occasions, but generally the logistical support provided by ERA has worked well and all ERA staff assigned to the project have worked extremely hard and contributed significantly. The fieldwork has run according to programme. The laboratory testing, however, is significantly behind schedule due to throughput constraints within the RRC laboratory. It is hoped that the RRC will be able to test the samples from the 16 prioritised locations in a timely manner to allow the project to be completed within the contract timeframe. However, an extension to the programme will be required if samples from all 30 locations are to be tested and the project is to proceed as originally intended.

12 Issues to take forward to the next Period

A large number of samples (39) bags are still stored in Bahir Dar. These need to be transported to Addis Ababa for testing. The RRC should expedite the process of transporting these samples if the laboratory testing schedule is not to be impeded.

The stereo aerial photographs will need to be analysed from Ethiopia. If the Ethiopian Mapping Agency or University of Addis Ababa cannot provide a proper stereoscope, then the team leader will need to bring one from the UK which could result in customs clearance issues. The RRC counterparts are therefore requested to check with the Ethiopian Mapping Agency or University of Addis Ababa to determine if either has a desktop stereoscope that can be used.

Significantly improved 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 is the revised procedures given to the RRC.

1 Procedure for testing cinder for use in pavement layers

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 Characterisation of Non-plastic Cinder Using MDD and CBR

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 dry sieving (PSD analysis) of the sample.
5. Confirm that the sample is non-plastic on the 425µm sieve. (If the sample is non-plastic then proceed to step 6, otherwise go to section 1.5).
6. 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.
7. Each time a specimen is prepared and weighed, measure the CBR at the top of the specimen.
8. Description of whether the specimen retains its shape or collapses after removal from the mould (after extracting from the CBR specimens).
9. At the completion of the determination of the MDD and OMC, use the specimen to conduct wet sieving (PSD) analysis.
10. Determine the Atterberg Limits on the 75 µm sieve using material screened from step 9 (if the quantity of fines passing the 75 µm is sufficient, otherwise make a qualitative observation).

1.3 Characterisation of Cinder Using Particle Strength Tests (for material category 1, 2, and 3)

1. Prepare 2 specimens and conduct Modified Aggregate Impact Value (15 blows) tests.
2. Prepare 2 specimens and conduct Particle Density/Specific Gravity and Water Absorption Tests.
3. If sufficient quantities of the material exist then conduct 10% FACT determination.
4. Further, if a sufficient quantity of the material exists then conduct LAAV test.

1.4 Blending of Non-plastic Cinder Gravel with Plastic Material

1. If the category 1 material was delivered with blending material category 4 from the same location, then the tests in this section apply, otherwise do not conduct further tests on category 1.
2. Conduct wet sieve analysis and determine the Atterberg limits of the blending material, category 4.
3. Air-dry all bulk materials for 2 days.
4. Pass the air-dried bulk material repeatedly through a riffle box to ensure uniform mixing of the material and to obtain a representative sample.
5. Oven-dry approximately 25 kg of the material at (60°C) in preparation for MDD/OMC/CBR testing. The oven-drying should last about 16-24 hrs.
6. Mix two portions of the blend in the ratios Cinder: Plastic Material; 80:20 and 90: 10 by mass.
7. Determine the MDD and OMC of each of the two portions by the method of re-using the specimen.
8. Each time a specimen is prepared and weighed, measure the CBR at the top of the specimen.
9. After completion of the MDD/OMC/CBR tests, conduct wet sieve analysis and Atterberg limit tests (material passing 425 µm) on the specimens extracted from the mould.
10. Again Determine the MDD and OMC of each of the two portions, but by the method of NOT re-using the specimen.
11. For the 90:10 mix portion, prepare 3 specimens for CBR testing; moulded at the MDD/OMC determined by the method in step 10; 5 layers, 56 blows/layer. For the 80:20 mix portion prepare only two specimens for testing CBR at OMC and at 4-days soaked conditions.

    a. Select Specimen 1 and carry out CBR test at the top and the bottom of the specimen (at OMC).
    b. 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.
    c. Conduct wet sieve analysis and Atterberg limit tests of specimens 1 and 2 combined.
    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.

1.5 Characterisation of Cinder that evidently contains plastic material

1. Confirm that the material is category 2 by determining the Atterberg limit tests on the portion of the material passing 425 µm sieve.
2. Air-dry the bulk material for 2 days.
3. Pass the air-dried bulk material repeatedly through a riffle box to ensure uniform mixing of the material and to obtain a representative sample.
4. Oven-dry approximately 25 kg of the material at (60°C) in preparation for MDD/OMC/CBR testing. The oven-drying should last about 16-24 hrs.

5. Determine the MDD and OMC of the material by the method of re-using the specimen.
6. Each time a specimen is prepared and weighed, measure the CBR at the top of the specimen.
7. After completion of the MDD/OMC/CBR tests, conduct wet sieve analysis on the specimen extracted from the mould.
8. Determine the MDD and OMC again but by the method of NOT re-using the specimen.
9. Prepare 3 specimens for CBR testing; moulded at the MDD/OMC determined by the method in step 8; 5 layers, 56 blows/layer.

    a. Select Specimen 1 and carry out CBR test at the top and the bottom of the specimen (at OMC).
    b. 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.
    c. Conduct wet sieve analysis and Atterberg limit tests of specimens 1 and 2 combined.
    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.

Annex B: Priority testing list

Area	Location No.	Town	Number of Sites Present	No. of Bags	Remarks	GPS Coordinates (UTM system) Zone 37P for Ethiopia (Easting/Northing)
Addis Ababa	5	Butajira-Hossana	2	Site 1-Cat 4-2bags. Site 2-Cat 1-3bags.	1 of the sites contains material to be used for blending	429064 / 891320
	6	Tulubolo	2	Site 1-Cat 2-3bags. Site 2-Cat 2-3bags.		401900 / 974047
	19	Bishoftu	1	Site 1-Cat 1-4bags.		502495 / 970384
	3	Butajira-Zway	3 combined to 2	Site 1-Cat 2-3bags. Site 2/3-Cat 1-2bags.	Material from Site 3 is the same as Site 2, therefore combine them to form 1 sample	437310 / 901285 (Site 1), 437268 / 901189 (Site 2)
	17	Adama -Dira	1	Site 1-Cat 1-4bags.		532500/ 938460
	7	Tulubolo	3	Site 1-Cat 1-3bags. Site 2-Cat 3-2bags. Site 3-Cat 4-1bag.	1 of the sites contains material to be used for blending.	414722 / 955767
Hawassa	8	Hawassa	1	Site 1-Cat 1-4bags.		444591 / 780598
	11	Dodola-Assela	2	Site 1-Cat 1-4bags. Site 2-Cat 4-1bag.	1 of the sites contains material to be used for blending	529599 / 800549
	13	Dodola-Shashemene	2	Site 1-Cat 2-4bags. Site 2-Cat 2-4bags.		490564 / 778928
Bahir Dar	23	Bahir Dar	3	Site 1-Cat 1-3bags. Site 2-Cat 4-1bag. Site 3-Cat 5-1bag.	1 of the sites contains material to be used for blending. Site 3 is Category 5 - strength test only.	0320320/ 1281922 (Site 1), 0320312/ 1282006 (Site 2)
	24	Bahir Dar	1	Site 1-Cat 1-4bags.		0312415/ 1284977
	25	Injibara	2	Site 1-Cat 4-2bags. Site 2-Cat 1-4bags.	1 of the sites contains material to be used for blending	0275369/1210482
	27	Kunzila	1	Site 1-Cat 1-4bags.		0283614/ 1310784
To follow Immediately after Priority Tests						
	14	Adama - Dira	1	Site 1-Cat 1-4bags.		536528 / 913537
	21	Bishoftu	1	Site 1-Cat 1-4bags.		503632 / 967979
	30	Kessa	1	Site 1-Cat 5-2bags.	Strength tests only	0277418/ 1206098

Annex C: Laboratory Testing Schedule

This is attached as an Electronic File due to large paper size required.