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

Final Inception Report

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Abstract

This inception Report summarises the finding of an Inception Visit to Ethiopia in February 2016 as part of the cinder gravel research project. Discussions were held with the Ethiopian Roads Authority (ERA) during this visit and it was agreed that the responsibilities will be shared in accordance with the TOR. ERA will provide 2 researchers, facilities for workshops, local transport and laboratory testing facilities, with TRL paying the costs of travel, accommodation for the international team and local counterparts when outside of Addis Ababa. Meetings were also held with the Geological Survey of Ethiopia, Addis Ababa University and the Addis Ababa – Adama expressway contractor. Visits were made to existing cinder gravel borrow sites to examine the geological and engineering composition of materials. Agreements have been made with ERA over the requirements of the sampling and testing programme and a revised project programme has been devised accordingly.

Key words

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

Acknowledgements

Ethiopian Roads Authority
Geological Survey of Ethiopia
Addis Ababa University
China Communications Construction Company

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

The contract between Cardno Emerging Markets and the Transport Research Laboratory (TRL) for the project entitled ETH2058A: Investigation of the use of cinder gravels in pavement layers of Low-Volume Roads was signed on 21/01/2016. The principal objective of the project is to carry out research to enable the use of cinder gravels (scoria) in low volume roads to be formalised, by determining the range of engineering properties of cinder gravels, evaluating their performance in road pavements already constructed in Ethiopia and thereby developing specifications for their use in future road construction. By doing so, significant cost savings should accrue.

The programme for the research is 18 months and project activities commenced with the mobilisation of the research team to Ethiopia on 18 February 2016 for the Project Inception Visit. This Inception Report describes the activities undertaken during this inception visit, provides a summary and review of previous work on the subject, describes the technical approach to be adopted, provides an updated programme of research and identifies the tasks required to deliver the project. It has been finalised following comments provided by ERA on the draft version.

2 Description and objectives of the assignment

The principal objective of this project is to improve the understanding of the properties and natural variability of cinder gravels in relation to their use as pavement construction materials in low volume roads. The outcome of this work will be the production of a guidance document covering the selection, processing and application of cinder gravels and a dataset of existing and potential future sources.

To achieve this objective in 18 months it is important that a targeted programme of field investigations, sampling and testing is implemented. This requires the commitment of the TRL and Ethiopian Roads Authority (ERA) team members and the mobilisation of project resources and facilities in a timely manner (Section 6).

3 Responsibilities

Transport Research Laboratory will be responsible for:

- **Provision of technical assistance by the TRL team of experts**. Capacity building and knowledge exchange are important components of ReCAP. In this project, the aim will be to combine the international experience of the TRL experts with the local knowledge of counterpart staff to achieve the best possible project outcome.
- **Overall management of the project in collaboration with the Road Research Centre management and staff**. Whilst the overall management of the project rests with TRL, it is recognised that this is a collaborative effort with ERA and requires close cooperation between the TRL team and RRC management and staff.
- **Remote sensing and desk study**. An examination of available imagery will be undertaken to determine prospective site information for ground surveys. Desk studies will include a continuous review of relevant local and international studies. Selection of sites for investigation will be carried out in collaboration with the RRC.
- **Provision of accommodation for two RRC counterpart staff and two drivers during fieldwork outside of Addis Ababa**. This is intended to ensure continuing out-of-hours discussion with counterpart engineers when the teams are on site and overcome any problems related to the cost of accommodation for the local staff.
- **The development of sampling and testing strategies**. Testing will be mainly carried out in accordance with normal RRC practice although some modification

and additional testing may be required in order to fulfil the research objectives. These changes will be discussed with local counterpart personnel and laboratory staff will be fully informed of the reasons for such changes and will be trained, if necessary, in any new procedures.

- **Analysis of results**. This will be done in close collaboration with counterpart researchers.
- **Production of reports and guidelines**. Full recognition will be given to the role of counterpart staff, who will be included as authors in reports and papers as appropriate.

Ethiopian Roads Authority / Road Research Centre will be responsible for:

- Facilitation and providing all necessary documentation and support to assist the consultant in obtaining entry visas to Ethiopia.
- Provision of a full-time dedicated engineer and the assistance of lab technicians as required to take responsibility for the ERA commitments. Provision of vehicles with drivers and fuel for site visits.
- Provision of per diems for RRC staff for field visits.
- At existing and prospective borrow pits; excavating, taking of samples, bagging and delivery to the testing laboratory.
- Testing samples according to the schedule and programme of tests from TRL and in accordance with international standards and quality control. As stated above, the modification to existing test methods used by RRC and additional testing might be required. The counterpart engineers will be fully informed of the reasons for any changes and the laboratory technicians trained accordingly.
- Facilitation of trial pit investigations of pavement materials along the Alemgena – Butajira road; including organising traffic management, conducting tests as specified, excavation of trial pits, taking and bagging samples, and delivery to the testing laboratory.
- Facilitation of access to as-built records for roads constructed with cinder gravel. The liaison with contractors, universities and other stakeholders, which has already begun in the inception phase, will continue throughout the duration of the project.
- Introductory letters to stakeholders and contractors who may be able to supply information and liaison, where advanced testing is required, such as at the Geological Survey of Ethiopia.
- Provision of facilities in Kality for training and dissemination workshops.
- Provision of office space and WiFi access (by dongle if possible) in Kality for the project team.

4 Methodology for achieving the objectives

4.1 Activities

The Methodology applied to achieving the objectives comprises the following:

- Review of previous work (literature review).
- Identification and location of existing sources of cinder gravels, including the characterisation of material sources in engineering geological terms.
- Identification of potential new sources of cinder gravels.
- Field inspections and investigations of sections of road where cinder gravels have been used previously to assess composition, strength and performance.
- Development of a sampling strategy that allows representative sampling of the range of cinder gravels potentially usable in road construction.

- Scheduling and implementation of laboratory tests, principally CBRs, grading and Atterberg Limits, on recovered samples.
- Analysis of laboratory results.
- Development of guidelines for using cinder gravels more widely in future road construction in the region.
- Organisation of a dissemination workshop.

4.2 Review of previous work

Until around the 1980's there was little difference throughout Africa in the recommendations for the use of materials in the construction of road structures between surfaced roads carrying low levels of traffic and those carrying much higher traffic volumes. Many manuals governing all aspects of road provision in these countries were often based on European or American practice, specifications and standards, which related to the available materials in these countries. Crushed stone was the recommended standard for road base material and when other materials, such as natural gravels were used, the minimum acceptable requirements for strength (CBR) and plasticity (PI) were 80% and 6 respectively. Furthermore, the designs did not include any provision for environmental factors, which for low volume roads has been shown as a major influence on pavement performance (Greening and Gourley, 1999). This approach resulted in high construction costs, of which a large component was haulage, especially in areas where conventional materials that met these requirements were unavailable. These factors contributed to constraining investment in low-volume surfaced roads in many African countries.

In recent years the emphasis has changed to developing specifications and standards which are appropriate to local conditions and a life-cycle approach to investments in rural roads, which has resulted in increased provision of sealed roads in these areas.

Research into the properties of locally available materials, which were previously thought unsuitable for road construction, has led to their increased use with a significant reduction in costs. There are a number of examples where this approach has led to the increased use of such materials. Just a few examples of this research in Africa are: calcretes (Greening and Rolt, 1996), laterites (Grace 1991, Gourley and Greening 1997, Pinard, Netterberg and Paige-Green, 2014) and weathered basalt (Pinard and Jakalas, 1987).

Cinder gravels fall into the group of materials which would previously have been considered as of 'marginal' quality but have a clear potential for road construction, especially in the pavement structure and surfacing of low volume roads. Their use requires that the location of deposits in relation to prospective road projects can be identified, their engineering properties investigated so that the various material types can be classified and guidelines made available for their use. These are the main objectives of the research project.

Some research has already been carried out in Ethiopia to explore the potential use of cinder gravels in road construction. A collaborative project by ERA and TRL (UK) was carried out to investigate the location and properties of cinders as early as the mid 1970's. A final project report was issued by ERA in 1979. Subsequently, papers were presented which contained technical details of the materials investigated and the performance of the trials (Newill and Kassaye, 1980, Newill, Robinson and Kassaye, 1987).

The materials tested showed a wide range in their engineering properties with the coarse fraction dominating in most samples and as-dug material rarely lying within the recommended grading limits, usually due to this lack of fines. The cinder was blended with about 10% fine material to obtain the required grading. The grading of the blended and compacted material for the base course from the trial section fits best in Envelope A-20 mm of the ERA 2011 LVR Manual. This is shown in Figure 1.

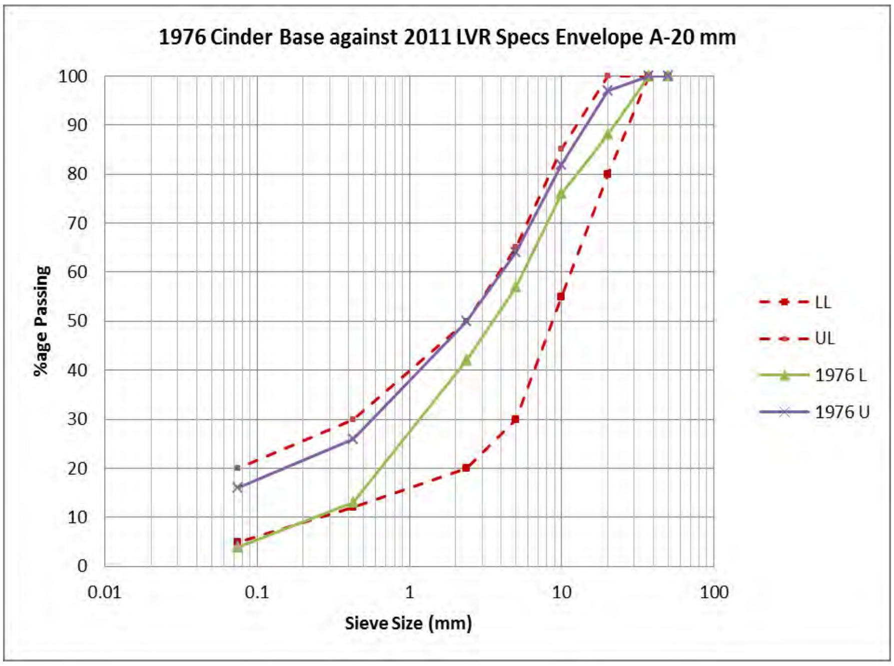


Figure 1: Comparison of 1976 cinder base grading to the ERA 2011 LVR Manual requirements

This study did not discuss the properties of the sub-base in detail. The comparison of the grading to the ERA 2011 LVR Manual requirements for sub-base is shown in Figure 2.

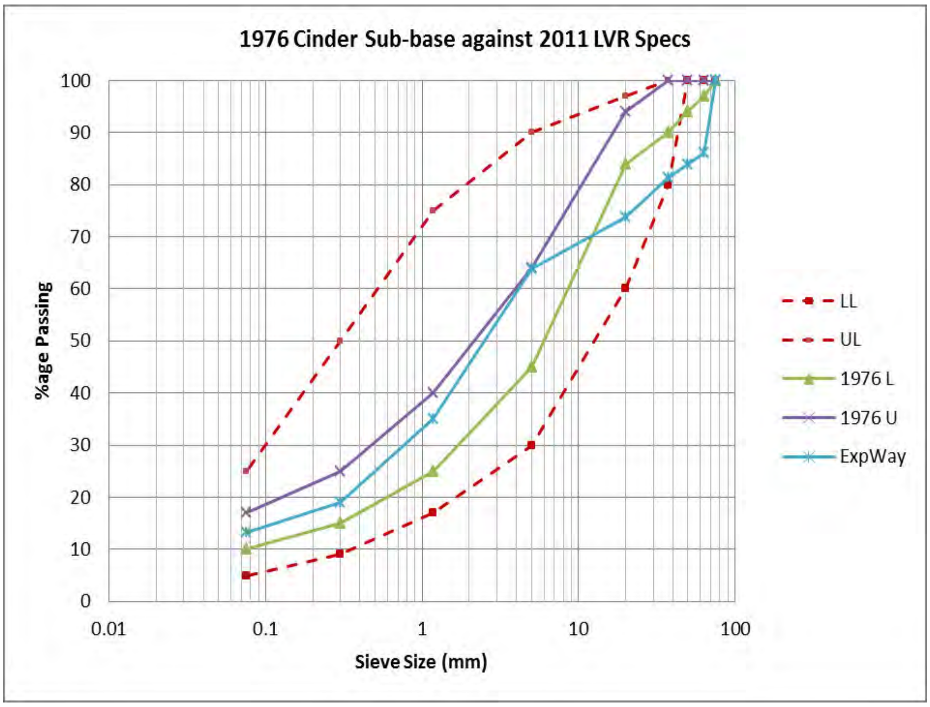


Figure 2: Comparison of 1976 cinder sub-base grading to the ERA 2011 LVR Manual requirements

The grading shows particle sizes larger than the recommended in the ERA 2011 LVR Manual. Based on the outcomes of the study, the envelope for cinder gravels may be widened.

The modified aggregate impact value test (AIV) was used to assess particle strength with results varying between 46 and 177 (It is proposed that the AIV test, which is less likely to break down larger particles, will also be used in the current project). Little change in particle strength was observed after soaking in water.

The revised testing procedures used also gave an indication of the potential breakdown of material using various types of compaction and the resulting impact on maximum dry density (MDD) and the California Bearing Ratio (CBR). The results from this and later projects will be analysed and taken into account in designing the testing programme for the current project. Blending of materials was carried out as part of the study with resulting improvement of dry density (1410-1900 kg/m^3) and CBR values of up to 80 percent being recorded with the BS Heavy standard of compaction.

One important conclusion from this work in the context of the current project was that it is important to select materials from below the weathered zone, which can extend to a depth of 2 metres.

Trials were also constructed to test the in-service performance of a selection of cinder gravels (Newill et al, 1987). Labour-based technology was used to construct the trials, although a grader was available to spread the materials. Compaction was left to traffic and not surprisingly, the highest in-situ densities were recorded in the wheel-tracks. Changes in grading were also observed after trafficking.

The surfaced sections in the trials were monitored over a period of 7 years and the results led to recommendations by TRL that some of the cinder gravel materials could be used as road base for traffic levels up to 3 million esa (Cook and Gourley, 2002). The project was affected by changes in the security situation in the country which resulted in curtailment of monitoring activities and the results of this research appear not to have found their way into documentation governing road provision in Ethiopia. The trial sections were visited in 2004 by a team from TRL and ERA who described the performance as satisfactory. No report for the visit is available. Based on that visit, the estimated traffic carried by the sections is up to 2.6 million equivalent standard axles.

Various research projects have since been carried out on these materials for possible use in pavement structures, primarily through the use of mechanical and/or chemical stabilisation. These projects have reported various strength gains. For example, Alemayehu (2002) reported a gain in CBR from 34% to 56% for a cinder gravel modified with 12% clay with a corresponding increase in density at standard compaction. Addition of 3% and 5% cement to the clay-modified material yielded 14-day cured CBR values in excess of 100% and 28-day UCS values of 2.73Mpa and 3.91MPa for 3% and 5% respectively. However, and perhaps of greater significance in terms of low-volume road construction, was that a CBR value on the unmodified material of 83% was recorded at the higher (modified) level of compaction.

(Berhanu, 2009) reported 28-day strengths from the addition of 3% cement of a UCS of up to 4MPa. Similar work has been carried out internationally with the aim of exploiting the finer ash component of volcanic material. Work done in China (Chen, 2013) reported similar 28-day strengths and values as high as 10 MPa being achieved after 360 days.

Perhaps the most recent work in Ethiopia has been carried out on the impact of modifying cinder material with ash and lime as part of research for an MSc thesis (Hadera, 2015). He found that for the cinder studied, the addition of 22% of fines achieved a maximum dry density of 1.58 g/cc whilst the material for the most part remained within the recommended grading limits. The modified material also gave 4-day soaked CBR values of up to 170%.

Whilst strength benefits clearly accrue from chemical stabilisation with lime and/or cement, using the materials in their ‘natural’ state can be considerably more cost-effective and is therefore the preferred option for low-volume road construction. So perhaps of greater significance in the context of low volume road design is that significant improvements in grading can be obtained from blending the coarse and fine fractions in proportions that improve both strength and stability. This has been reported by a number of researchers in Ethiopia (e.g. Berhanu 2009, Eshete, 2011). The mix proportion will depend on the type of cinder being modified and typical values of the amount of added fines are between 12% and 22%.

In a recent collaborative research project carried out between ERA and TRL under the African Community Access Programme (AFCAP), cinder gravels were also used in an Otta seal surfacing trial in the village of Combel (Overby and Otto, 2014).

4.3 Existing cinder gravel sources and geological characterisation of the material

In geological terms cinder is 'coarse scoriae erupted from volcanoes'. It comprises vesicular clasts of either basalt or andesite lava omitted from volcanoes during explosive eruptions. Explosive volcanic eruptions give rise to deposited materials that range from ash, and other fine grained materials, through ignimbrite, pumice, scoria (cinder), pyroclastic tuffs, breccia and lapilli, scoriaceous basalt, rhyolite, trachyte and basalt and andesite lava.

The Rift Valley of Ethiopia contains 60 volcanoes that are thought to have erupted in the last 10,000 years and there are several eruptive events that have occurred during the recent historical past. Cinder cones of Miocene-Pliocene age occur extensively in the Rift valley of Ethiopia and a number of these have been exploited for construction materials. Visits were made to selected extraction sites during the Inception phase (Section 5) and a plan will be prepared to visit other borrow areas during the course of the fieldwork. Although cinder cones are predominantly associated with the extensional tectonics of the Rift Valley, they are not confined to the Rift Valley; others also occur in association with magmatic extrusions along Rift-parallel faults. Although the study areas have yet to be confirmed in detail, it is envisaged that these will include cinder cones and related deposits in the vicinity of:

- Debre Zeit/Addis – Adama Expressway
- Metahara/Fantale
- Butajira
- Hawassa
- Hosana
- East of Mekele
- Bahir Dar.

The field visits made during the Inception phase provided an interesting insight into the range of materials exposed in some of the exiting borrow areas. The scoria (cinder) is commonly gravel and cobble-sized (occasionally boulder-sized) and can occur as an amorphous (structureless) mass of welded clasts or as a stratified deposit, often with a fines content. In the case of the former coarse gravel and cobble-sized clasts can be welded together with voids in between, making it fairly easy to break up by manual excavation. Alternatively, there can be a range of clast sizes that result in a dense 'conglomerate' that is extremely difficult to penetrate. Individual clasts are usually quite hard, regardless of how loose or dense the deposit might be.

The research carried out in the early part of the programme will allow an engineering geological classification of the various materials to be developed in order to aid prospecting and scheduling of potential end uses. This classification will be developed during the field visits to the study areas listed above (currently scheduled for April 2016 (Section 6.1).

4.4 Identification of potential sources of cinder gravels

Based largely on the outcome of 4.3 above, Google earth and other imagery, where necessary, will be used to help identify additional sources. Visits will be made to these locations to identify any exposures and to collect samples where possible. The suitability of these potential sources will need to be investigated and confirmed by ERA as a separate exercise.

4.5 Field investigations of sections of road where cinder gravels have been used previously

During the inception visit, it was identified that half of the road length from Alemgena to Butajira has a cinder gravel sub-base. The road has been in existence for more than 13 years without any major defects, and thus offers an opportunity to investigate the characteristics of cinder gravels suitable for use as sub-base material. Rut depths shall be measured and any cracks recorded. Trial pits will be excavated and samples of the pavement layers tested in the laboratory for characteristics. The subgrade will also be studied. The section from km 45 to km 46 will be studied to ascertain the performance and characteristics of the cinder sub-base, whereas the section from km 70 to km 71 will be studied as a control section.

A visit will be made to the Awash – Melkasa – Bekojo – Assela road to try and locate any remnants of the 1975-1979 sections. If any are identified, then the cinder gravels will be sampled and tested so as to compare the terminal properties with that at the time of construction.

The Otta Seal section in the village of Combel on Tulubolo – Kela road will be investigated to assess the level of abrasion of the cinder gravel used in the surfacing and thus ascertain the suitability of cinders from the Kela borrow pit and other similar materials for use in surfacing.

In addition to this, the “ash-type”/ ”sandy” material found close to some borrow pits will be evaluated for its possible use in Sand Seals.

4.6 Development of a sampling strategy that allows representative sampling of the range of cinder gravels potentially usable in road construction

The intention is to develop a sampling strategy that will commence during the field visits to the study areas. This strategy will aim to collect representative samples of the main materials types in sufficient numbers to allow the range, average and standard deviation of test results to be determined.

Evidence from the visits made to 6 locations during the launch/inception phase has already shown that the range of materials properties can be expected to be wide. Therefore, a major challenge will be to collect and test a range of samples that are reasonably representative within the allocated project period. The approach used will be to collect samples at most of the sites visited and then prioritise the testing programme for the samples which cover the required range. In this way, guidance can be given on the possible use of these materials in various pavement structures.

Samples will be collected from sites at locations selected from the list given in Section 4.3, and transported to the laboratory at Kality.

4.7 Laboratory testing

The samples will be subjected to the standard engineering tests for soils and aggregates (Grading. Atterberg limits, density, CBR, AIV, etc) to determine the properties of the cinder gravels and fine ash materials selected. Provision has also been made in the contract for additional specialised testing such as X-ray diffraction, if required.

One of the important features of the testing programme will be the determination of the strength /moisture sensitivity of the cinder and blended materials. This is important to be able to give guidance from the results of the research on the use of these materials in the upper pavement layers. Measures such as shoulder sealing or improved drainage measures, if deemed necessary, can extend their usage and reduce risks.

A procedure will be developed for this additional testing and counterpart engineers and laboratory technicians will be trained in its application.

A schedule for the sampling and testing that can be accommodated by the RRC laboratory within the time constraints of the project, (possibly with additional support from outside agencies/laboratories) will be prepared and agreed with ERA.

The testing programme is a key element of the project and any resource constraints encountered at the Kality laboratory (e.g. availability of moulds) will invariably impact on the number of samples that can be tested within the available time. It is recommended that the RRC urgently acquires CBR moulds from completed road construction projects, Alemgena Training Centre and any other sources.

4.8 Analysis of laboratory results

The results of the laboratory testing will be subjected to continuous review by TRL and counterpart engineers to ensure that the tests are being carried out as prescribed and that the results obtained are within the expected limits. The analysis of the results will be carried out in accordance with the research matrix and with the full involvement of counterpart staff so that this component of capacity building in the project is achieved.

4.9 Development of guidelines for using cinder gravels more widely in future road construction in the region

This will be the main output of the project. It will take into account all previous work and the findings of the project activities outlined above. It will include potential new sources of materials in map and tabular format and will provide recommendations for the use of cinder gravels in various fill and pavements layers for low volume roads.

4.10 Familiarisation and dissemination workshops

During the early phase of the project a workshop will be organised at ERA's research facility to familiarise ERA staff with the objectives of the project and how these objectives will be accomplished. It will be necessary for ERA counterpart staff to play an active role in this workshop, including laboratory technicians, so that all personnel involved in the project are fully aware of the need for close quality control and a commitment to programme.

A workshop will be organised towards the end of the research project to discuss and disseminate the results and to explain the Guidelines.

5 Inception visit

The TRL team, comprising Dr Gareth Hearn as Team Leader/Research Specialist, Andrew Otto as Senior Researcher/Materials Specialist and Tony Greening as Low Volume Roads Specialist, visited Ethiopia between 18 February and 29 February 2016. During this period introductory meetings were held with ERA and other relevant parties and visits were made to the field to observe existing borrow areas. These activities are outlined below.

5.1 Meetings

A familiarisation meeting was held between TRL staff and ERA at the ERA research centre at Kality on 19 February 2016. The Minutes of this meeting are provided in Annex A. During this meeting, the approach to the research was discussed and the facilities required to carry out the required laboratory testing were agreed. ERA confirmed that three counterpart staff would be provided, including an engineer/technician who would be responsible for all laboratory testing.

The Project Launch Meeting was held on 23 February 2016 at ERA Central Office in Addis Ababa. This meeting was attended by the TRL team, ERA (headed by Ato Mohammed Abdulrahman, Deputy Director General) and Nkululeko Leta (AFCAP Regional Technical Manager). The Minutes of this meeting are provided in Annex A. Ato Mohammed confirmed ERA's commitment to the project and requested details of the roles and tasks ERA was required to fulfil. These were discussed in outline and are described in Section 6.

On the 26 February 2016 Dr Hearn held a meeting with Genet Assefa of the Geological Survey of Ethiopia (GSE) to discuss their engineering geological mapping and reporting datasets. Copies of engineering geological maps and reports were purchased for the study areas listed in Section 4 and it was agreed that TRL and the GSE would remain in close contact during the progress of the research project. An introductory discussion was also held with Prof Gezahegn of the Geology Department, Addis Ababa University, and a further meeting will be held during the April 2016 visit to discuss sources of data.

On 25 February a meeting was held with the Addis – Adama Expressway contractor. The contractor confirmed that cinder gravel was blended (3 parts cinder gravel to 1 part plastic soil) to get a 4-day soaked CBR of 58% at 93% MDD. This is in agreement with results obtained from cinder gravels in Modjo (60%) in the 1975-1979 trials (ERA/TRL 1979). For fill material, the required CBR is 20%; this material therefore more than meets CBR requirements for this purpose.

5.2 Site Visits

Site visits were made to existing cinder gravel borrow areas close to the northern end of the Addis – Adama Expressway, at Metahara, Alemgena and two others close to Butajira. Notes and photographs describing these site visits are given in Annex B.

6 Programme, staffing, responsibilities and deliverables

6.1 Programme

Error! Reference source not found. shows the revised programme based on the discussions and findings of the Inception visit. The completion of project activities in accordance with this programme will require both TRL and ERA to execute their responsibilities in a timely manner.

6.2 Staffing

Transport Research Laboratory: The team members listed in Section 5 will continue on the project until its completion.

Ethiopian Roads Authority: Ato Alemayehu Endale and Deribachew Mezgebu are confirmed as ERA project counterpart staff. In addition, another engineer (Hailu Teshome) will also be dedicated to the successful completion of ERA tasks throughout the project programme.

6.3 Deliverables

The Guidelines on the use of cinder gravels and other related materials for low volume road construction materials will form the main deliverable. Supporting information will comprise maps of existing and potential future borrow-pits within the study areas and tabular data of location summaries.

7 Conclusions

Previous studies have shown that non-plastic cinder gravels require blending with clayey-material (often located close to cinder borrow pits) to facilitate compaction and grading. Although the addition of plastic fines provides these improvements, excessive use of fines may result in shrinkage cracking and increased moisture sensitivity. This study will endeavour to include recommendations for the limits of proportions of the plastic material to be used to minimise these risks. Non-plastic fines have also been located near several cinder borrow-pits. These are currently used as "sand" in the production of concrete blocks. Their influence in a three-way blend (cinder-"sand"-clayey material) will also be investigated.

It is also known that clayey cinder gravels exist in a borrow pit north-west of Tulubolo, and if similar deposits exist elsewhere, it may eliminate the need for blending non-plastic cinder. The characteristics of the cinder from this deposit will be investigated and if any identifying features that can help in remote-sensing are found then similar deposits will be located. If this kind of cinder is not suitable for use as sub-base or base, it may be suitable as fill and subgrade replacement without the need for blending.

The characteristics of any cinder gravels investigated will be compared to those of the 1975-1979 study and to the requirements of the 2011 ERA LVR Manual. A crucial step will be in fitting the grading of the sources to the various base course envelopes.

The 1975-1979 study base grading did not fit well in Envelope A-37.5 mm due to breakdown during compaction, this study will investigate approaches that may be used to achieve this grading. Alternative compaction methods other than use of pneumatic rollers (not easily available to small scale contractors for extended periods of time) will also be proposed.

The review of previous work has shown that the grading envelope for cinder sub-base needs to be wider than that recommended in the 2011 ERA LVR Manual. The study of Alemgena – Butajira sub-base will add data regarding cinders used in sub-bases.

The Otta Seal section in the village of Combel on Tulubolo – Kela road will be investigated to assess the level of abrasion of the cinder gravel used in the surfacing and thus ascertain the suitability of cinders from the Kela borrow pit and other similar for use in surfacing.

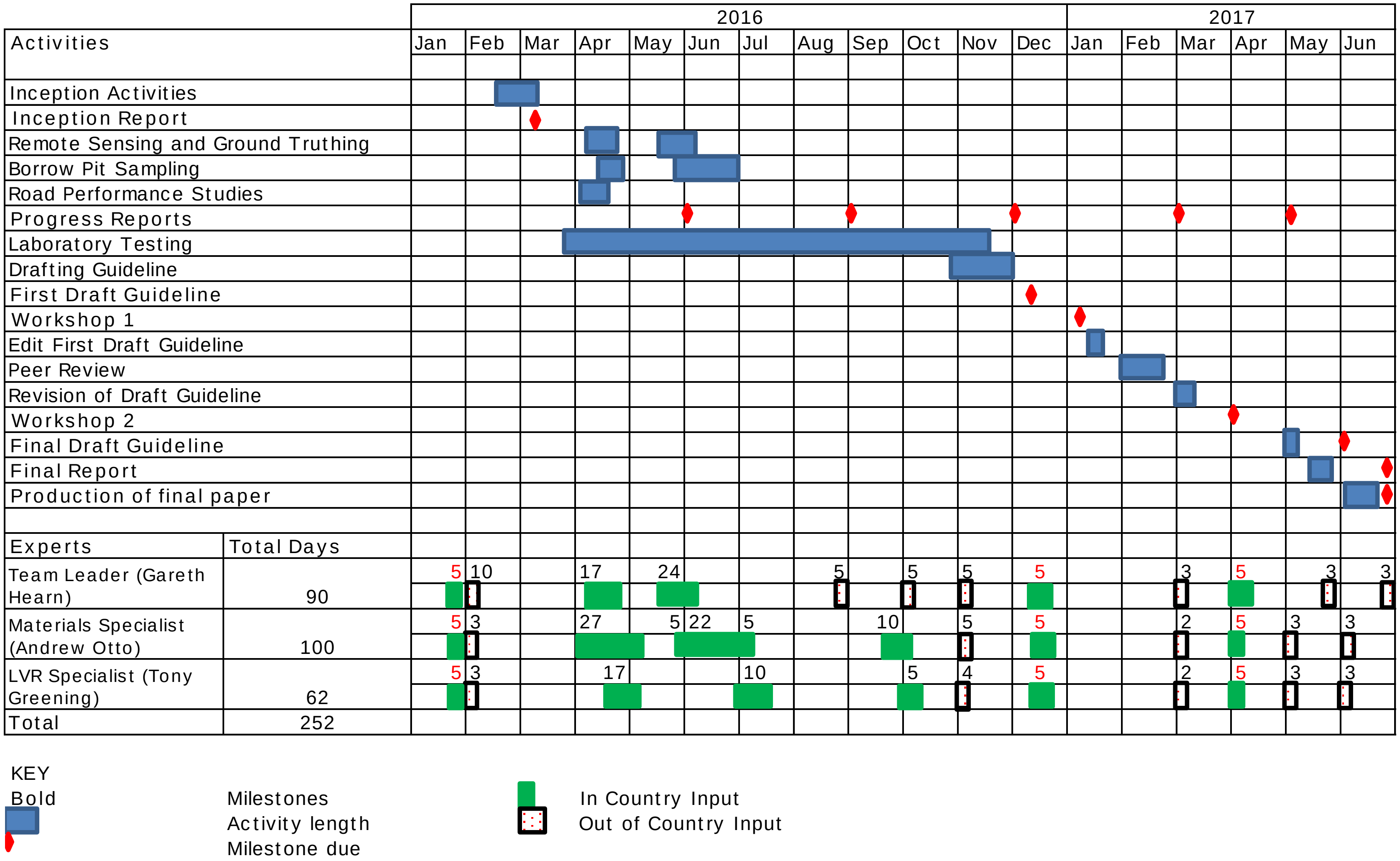
In addition to this, the "ash-type"/ "sandy" material found close to some borrow pits will be evaluated for its possible use in Sand Seals.

Results obtained from the Addis Ababa – Adama Expressway contractor shows that the strength of the cinder gravels (after blending) used is above requirements for fill and capping layer and thus will more than serve as sub-base material for use in low-volume roads.

The cinder gravel research project should form an important contribution to the cost-effective construction of low volume roads in Ethiopia. Discussions with ERA during the Inception phase confirm their full commitment to the project, and consequently TRL looks forward to delivering a valuable set of guidelines for future practice.

Figure 3: Project Schedule

ETH2058A: Investigation of the Use of Cinder Gravels in Pavement Layers of Low Volume Roads



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Annex A: Minutes of Meetings

A.1 Familiarisation Meeting

Minutes of familiarisation meeting: ETH2058A: Investigation of the use of cinder gravels in pavement layers of Low-Volume Roads
Date: Friday 19/02/2016
Location: RRC Offices, Kality
Time: 15:10 – 16:05hrs

Attendance

Name	**Organisation**
Alemayehu Endale	Director – Road Research Centre (RRC)
Deribachew Mezgebu	Team Leader – Highway Research, (RRC)
Gareth Hearn	Project Team Leader/Research Specialist – TRL UK Ltd
Andrew Otto	Materials Specialist – TRL UK Ltd
Tony Greening	LVR Specialist – TRL UK Ltd

Item	**Details**	**Attributed to/Action/Etc**
	<u>Agenda</u> 1. Introduction 2. Week's Programme 3. Long-term Programme 4. Logistical arrangements 5. Visas	ALL
1.0	Introduction: The project partners from TRL were introduced. Gareth Hearn – Team Leader, Andrew Otto – Materials Specialist, Tony Greening – LVR Specialist. The project objectives were explained, particularly the need to characterise cinder gravels for use in pavement layers of LVRS. The application of geological and remote-sensing techniques to identify sources that meet engineering requirements.	GH
2.0	Week's Programme:	AO

	The plan is to visit cinder borrow pits along Alemgena – Butajira road, and at Tulubolo on Saturday; then borrow pits along Addis – Adama Expressway on the Sunday. Depending on the arrival of Eng. Leta, the launch meeting is planned for either Monday 22nd Feb or Tuesday 23rd Feb. After this, the rest of the week will be spent visiting institutions (Geological Survey of Ethiopia, ERCC), Consultant and Contractor of the Expressway, and writing of the inception report. It was agreed that the Expressway contractor/consultant should have important information on the use of cinder gravels. ERA to assist in providing introductions	
3.0	Long-term Programme:	
3.1	The programme period of 18 months is quite short considering the amount of work that is involved; especially laboratory testing. Therefore the need for strong commitment of the laboratory team and counterparts.	TG
3.2	Requested clarification of the 18 months scope of the project.	DM
3.3	Clarification: Cinders are located mostly along the rift-valley and central areas of Ethiopia.	AE
3.4	Clarification: The report from the 1979 study has indicated areas where cinders occur in general including around Lake Bahir Dar and towards Gonder. This study will try to use remote-sensing to locate other potential sources.	AO
4.0	Logistical Arrangements:	
4.1	ERA to provide dedicated full time counterparts, vehicles for fieldwork, laboratory testing, and fieldwork. TRL will provide accommodation during trips outside Addis Ababa when prospecting and sampling begins. This is limited to two counterparts and two drivers.	AO
4.2	The Counterparts will be Ato Alemayehu Endale, Ato Deribachew Mezgebu, and one other researcher to be appointed.	AE
4.3	Most laboratory tests will be conducted at the RRC laboratory in Kality. It was stressed that there will be extensive CBR testing at varying moisture contents	AE

4.4	The counterparts will do everything in their power to ensure the programme is on schedule. The counterparts are fully committed and dedicated.	AE
4.5	Requested for introductory letter to approach government institutions, universities, and private sector consultants and contractors. ERA also agreed to contact the Regional Road Authorities to determine whether they are using cinder gravels	GH
4.6	Letters will be provided although TRL can contact the stakeholders directly.	AE
4.7	Advised that the field trip planned for Saturday should be along the expressway and towards Metahara.	AE
5.0	Visas:	
5.1	The Consultant partners only got single-entry visas for this trip despite asking for multiple-entry visas. Multiple-entry visas save time and money, especially since the consultant partners are involved in countries within the region. This would permit several entries without the need to travel back to home countries and wait for weeks for the visa to be issued. The approval list from the immigrations department in Addis Ababa was for single-entry. This could be the reason why the London embassy issued single-entry visas.	GH
5.2	Spoke to the embassy in London, and they said they are able to issue multiple-entry visas if they got the right request.	GH
5.3	Requested for RRC to visit and speak to the immigrations office in Addis Ababa about the issue so as to ensure that the next time a visa request is sent, a multiple-entry visa is issued by the embassy in London.	AO
5.4	Will request the Administrator at the RRC to do that.	AE
5.5	Should start the visa process for the next trip.	GH
5.6	TRL should send the request letter immediately.	AE
5.7	Will ensure letter is prepared by next week.	AO
	END	

Prepared by Andrew Otto

A.2 Launch Meeting

Minutes of launch meeting: ETH2058A: Investigation of the use of cinder gravels in pavement layers of Low-Volume Roads
Date: Tuesday 23/02/2016
Location: ERA Headquarters, Lagahar
Time: 08:45 – 09:45hrs

Attendance

Name	**Organisation**
Ato Mohammed Abdulrahman	ERA Deputy Director General - Operations
Nkululeko Leta	AfCAP Regional Technical Manager
Ato Alemayehu Endale	Director – Road Research Centre (RRC)
Ato Deribachew Mezgebu	Team Leader – Highway Research, (RRC)
Gareth Hearn	Project Team Leader/Research Specialist – TRL UK Ltd
Andrew Otto	Materials Specialist – TRL UK Ltd
Tony Greening	LVR Specialist – TRL UK Ltd

Item	**Details**	**Attributed to/Action/Etc**
	<u>Agenda</u> 1. Introduction 2. General discussion 3. Logistical arrangements 4. AOB	ALL
1.0	Introduction: All Attendants introduced themselves.	ALL
2.0	General discussions:	
2.1	Said he had been briefed about the project. Stressed that the project offered direct benefits to ERA in use of local materials and reducing costs. He noted that ERA was not engaged contractually in the project, ERA wanted to assist as much as possible and requested to know the objectives and major project	MA

	milestones.	
2.2	The role of the Regional Technical Manager is to manage AfCAP projects in partner countries.	NL
2.3	Partner countries identify projects, key objectives and needs through a scoping study, which may or may not be AfCAP-sponsored. AfCAP facilitates the formulation of the projects (concept notes, ToR) and subsequent procurement of technical assistance. Stressed that partnership with participating countries is AfCAP approach to enhance uptake and embedment of research findings.	NL
2.4	Currently AfCAP is in partnership with ERA for finalisation of low–volume roads manuals project that is on-going, as well as formulation of other pipeline projects.	NL
2.5	Investigation of the use of cinders is the new project now being launched in the meeting. The broad aim is to improve access through cost-effective use of local materials. Cinders are abundant in Ethiopia.	NL
2.6	Other projects for Ethiopia coming online.	NL
2.7	Happy that the contract for the cinders project has been signed, and fieldwork and desk study have started.	NL
2.8	Other issues relating to the project will be discussed during the inception phase or later.	NL
2.9	Regarding capacity building, AfCAP has a different approach to traditional technical assistance: The partner country owns the project whilst AfCAP provides technical assistance through experts to fill the knowledge gap. The partner countries should therefore run the project, not the experts.	NL
2.10	ERA has shown commitment as before; and he is happy that counterparts have been appointed immediately.	NL
2.11	The view is that ERA is doing the project whilst assisted by experts.	NL
2.12	Assured the attendants that ERA will be committed to fulfil their responsibilities under the project.	MA
2.13	It is an opportunity for ERA counterparts to interact with the experts. There is an overall goal of reducing road construction costs and projects such as this should be able to assist.	MA

2.14	Both the process and the outputs of the project are important to ERA.	MA
2.15	Requested the Team Leader to explain the main tasks of the project.	MA
2.16	There is a need to know the performance of cinders, identify sources of cinders, and what each source is best used for in road construction.	GH
2.17	There is a need to define the properties of cinders in a way that they can be used with confidence.	GH
2.18	The project will build on previous work by TRL and ERA in the 1970s.	GH
2.19	Potential sources will be sampled and tested, and recommendations for using each kind of source will be made.	GH
2.20	Over the years since the 1970s, new knowledge on the performance of low-volume roads has been gained. This project will enable us to apply the new knowledge to the use of cinders. There has been a long history of research in ERA which is very good background for this project	TG
2.21	There is a need to identify and classify the various kinds of cinders available in Ethiopia. A document for the use of these cinders will be produced.	GH
2.22	There is a need to assist countries that have taken their own initiative in research, particularly with capacity building and mentoring of personnel.	TG
2.23	That is the desired approach. This assistance provides knowledge both in research management and actual technical knowledge.	AM
2.24	The end product is very important in reducing construction costs in Ethiopia. Therefore it is necessary to put the knowledge in the right context.	AM
2.25	The project has a tight schedule of only 18 months and it is intensely involving. Therefore it is important that the RRC counterparts get ready to commit a lot effort and resources to the project.	GH
2.26	Requested the Materials Specialist to make any additional comments.	AM

2.27	The project will use knowledge from the 1979 study, knowledge from the work done by Ethiopian researchers on cinders, sampling and testing to produce a consolidated guideline for the use of cinders. The capacity building especially remote-sensing will be very useful to the RRC counterparts in identifying future sources of cinders once the existing sources are depleted. URRAP should also benefit Much work on the use of cinder gravels has been done already in Ethiopia but it is available in pockets and needed to be collated.	AO
2.28	Requested the Regional Technical Manager for a memorandum of understanding that defines what is expected of ERA, of AFCAP and of the consultant.	AE
2.29	It is not normal practice under AfCAP to have a MoU for each project. Some AfCAP partner countries prefer a general MOU with AFCAP for the entire duration of the programme, which is then reinforced in each project ToR with appropriate and specific responsibilities of each party. The inception report will add more detail to these responsibilities. For example, whether transportation entails personnel, and materials.	NL
2.30	There is a need for close contact and interaction to ensure the project proceeds successfully according to programme	AM
2.31	For the time-being, let us follow the approach explained by the AfCAP Regional Technical Manager. ERA will discuss internally, and if need be, then a revised MoU will be requested.	AM
2.32	Transportation, laboratory facilities, technicians and counterparts will be made available for the project. The Team Leader should let ERA know in case of anything.	AM
2.33	The inception report will include details of logistics required.	Agreed by ALL
2.34	Regarding the existing broad and general MoU between AfCAP and participating countries, does ERA need the original MoU to be updated?	NL
2.35	For now include responsibilities in the inception report as suggested. On the need to update the MoU, ERA will have an internal discussion before getting back to AfCAP.	AM
3.0	Logistical Issues:	

3.1	Process of getting visas is getting more and more difficult. It requires about two weeks to process from Ethiopia and up to two weeks to apply in the country embassies.	NL
3.2	Will take this as an issue and discuss with the government. It is currently on ERA's agenda. It will be addressed, and will advise on the outcome	AM
3.3	The issue, the immigrations office says, is temporary and will soon revert to as it was before – 3 months multiple-entry visas. Advised that consultant should send request letter two weeks before intended travel.	AE
3.4	Advised that the request letter from the consultant to ERA should be submitted at least 1 month before intended date of travel.	NL
3.5	Clarified that the embassy in London is willing to give multiple-entry visas as long as the immigrations office in Addis requests so.	GH
4.0	AOB:	
4.1	Requested on a formal communication (letter) on commencement of the project.	AM. NL to provide within 1 week.
4.2	Happy on the commencement of the project and for the presence of the experts.	AM.
4.3	A vehicle has been dedicated for the project personnel and office space has been allowed at the RRC for the project use.	AE.
	END	

Prepared by Andrew Otto

Annex B: Field Visit Reports

Field Visit: Addis-Ababa – Adama Expressway to Metehara

B.1 Start of Expressway

The first borrow pit visited was at the beginning of the expressway at Tuludimptu (UTM 0479149/0979075, 8°51’24”/38°48’36”). The cinder material in the pit ranged from very hard (could not be broken by hammer) to boulders/lumps that could easily be broken down by hammer to particles of about 5 mm in size. The material is mostly reddish-brown in colour. The sides of the borrow pit indicate that the material was extracted by an excavator.

The softer material was used in the expressway as improved subgrade, fill, and capping. This material (in the borrow pit) appeared to be mostly single-sized particles of about 5 mm. Such material would not under normal circumstances be used as sub-base or base material even on low-volume roads; on the basis of it having too high a fines content. However, the particles have rough surfaces and could result in higher than expected CBR values that meet low-volume road requirements. This will only be confirmed by testing. Moreover the material appears to be non-plastic and free draining, and thus is not expected to lose strength significantly when soaked. If this is true then the recommended grading range would be different from that for other materials.

If the neat strength is not adequate for use in upper pavement layers, blending with locally available slightly plastic soil will be investigated.

Figure 4: Side of the borrow pit worked by excavator

Figure 5: Small concretionary particles

Several other cinder borrow pits are located along the expressway and will be visited at a later date.
Additional photographs are contained below.

B.2 Metahara Lava field (probably scoriaceous lava)

This is a large expanse of boulder-size-but-joined-together material, easily observed from Northing 8°50'17" and Easting 39°43'17". The field extends for several kilometres. The boulders cannot be broken by hammer, nor separated easily form one another say by dozer. Reports are that several dozers have lost rippers when they attempted this. It is believed that a combination of pneumatic hammer drill, dozer, and loaders can be used to extract the material for crushing and use in high volume roads. This may save on the cost of drilling and blasting alternative sources.

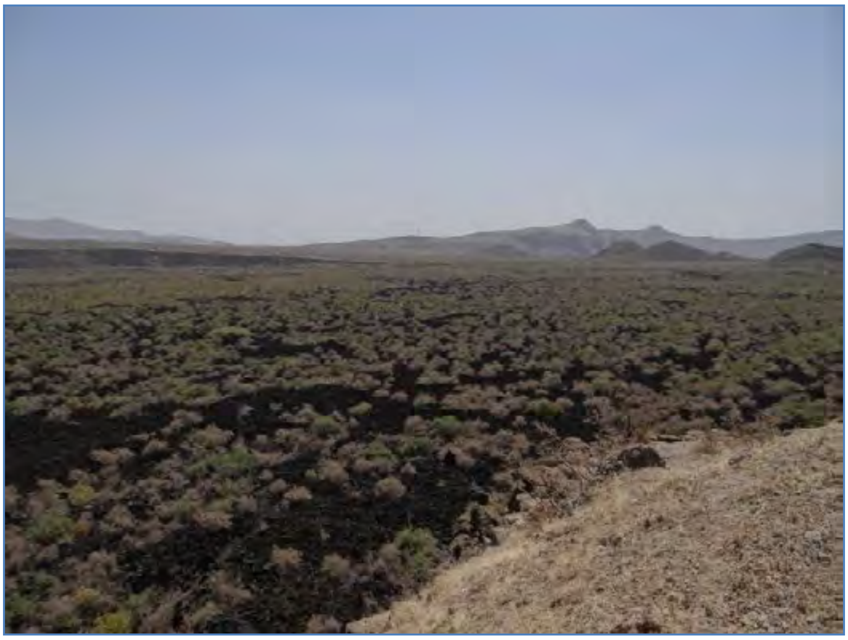


Figure 6: Volcanic lava (black) field near Metahara

B.3 Grey-black cinder cone near Metahara (Metahara 1)

This cone is located at about Northing 8°50'31" and Easting 39°42'50" (UTM 0578568/977414). The cone has not been exploited. Around the base, loose particles ranging from gravel up to boulder-size are scattered about. The particles a very hard, moderately dense and very difficult to break by hammer. This could be the reason why this cone has not been exploited. It may not be easy to extract material from such cones, thus rendering them difficult for use in low-volume roads.

Just opposite this cone is a deposit of pumice-like material, very light and easily crushed; even by shoe heel. It is said that the material is used for making hollow blocks. This type of material may be exploited and used for blending and improving grading of other cinders or other materials lacking in fines. It is believed that upon compaction of the blend, the pumice like material would break down to produce fines.

Figure 7: Grey-black cinder cone with very hard particles

Figure 8: Boulder of very hard grey-black-coloured cinder

Additional photographs are contained below.

B.4 Another grey-black cinder cone (Metahara 2)

This cone is located at about Northing 8°49’41” and Easting 39°42’36” (UTM 0578027/0976043) - within 2 km of the cone in Section B.3. However, the particles/boulders are of relatively low density and are much softer and easily crushed by hammer. Perhaps this kind of material could also be used to improve the grading of other cinders lacking in fines as described for the pumice-like material in Section B.3.

Figure 9: Grey-black cinder cone with soft particles

Figure 10: Close up of grey-black cinders with soft particles

Additional photographs are contained below.

B.5 Cinder dome with variable materials (Metahara 3)

This dome is located within a kilometre of the cone in Section B.4 at about Northing 8°50'3" and Easting 39°42'37" (UTM 0578113/976600). The materials range from grey-black to reddish-brown. The materials are in distinct layers, grey-black on top of the reddish-brown layer. Most of the material particles in this borrow pit are soft, regardless of the colour. Again the materials could possibly be used to improve the grading of other cinders lacking in fines. The range in colour does not appear to reflect a range in strength.

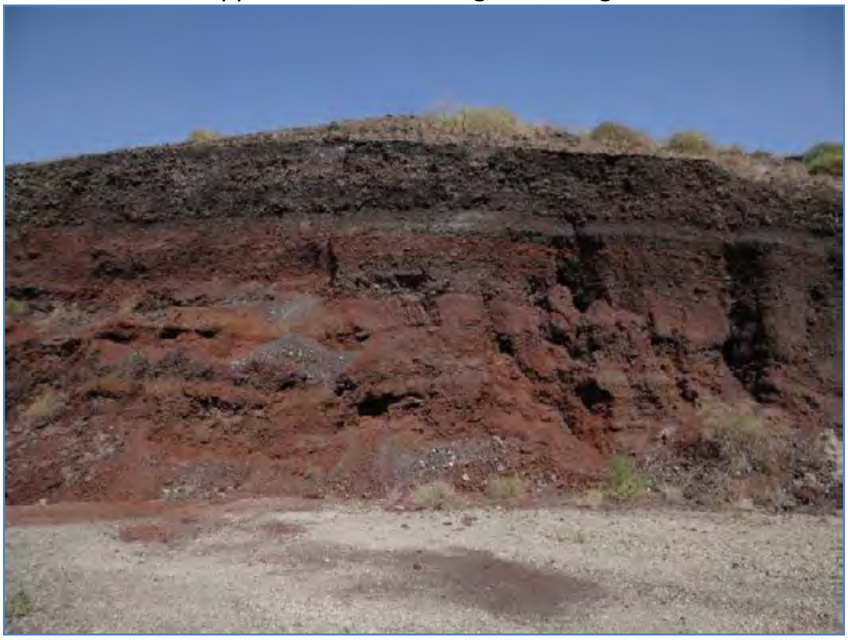


Figure 11: Cinder dome with two distinct layers

Additional photographs are contained below.

B.6 Conclusions from this trip

From this trip the following tentative conclusions can be drawn:

1. There is a need to collect cinder materials test data and work methods from the contractor and consultant of the Addis - Adama Expressway to see if the cinders used here could be used in upper pavement layers of low-volume roads.
2. Anecdotally, the strength of the cinder gravels is not dependent on colour, but this should be investigated further. The sources located here could be used to investigate this.
3. The softer cinders could be used to improve the grading of cinders and other materials lacking in fines. The harder non-plastic cinders could be blended with this or with slightly plastic locally available subgrade material.
4. The materials exposed in these cinder cones and related deposits appear to vary significantly in their engineering properties over short distances. This requires further investigation in order to be able to assist in the development of a predictive tool.

Additional Photographs

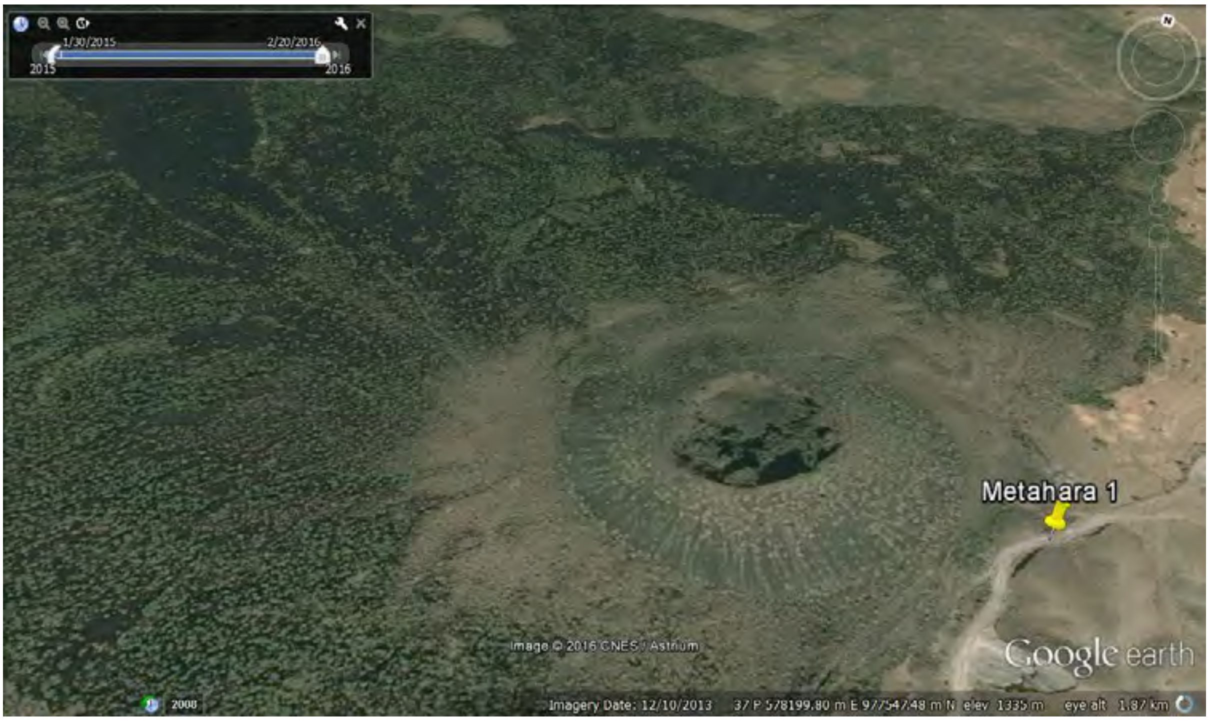
Tuludimptu

Distinct layering of cinder and possibly ash (grey)

Coarsely-bedded 'cinder gravel'

Aerial view of the Tuludimptu borrow pit

Metahara 1



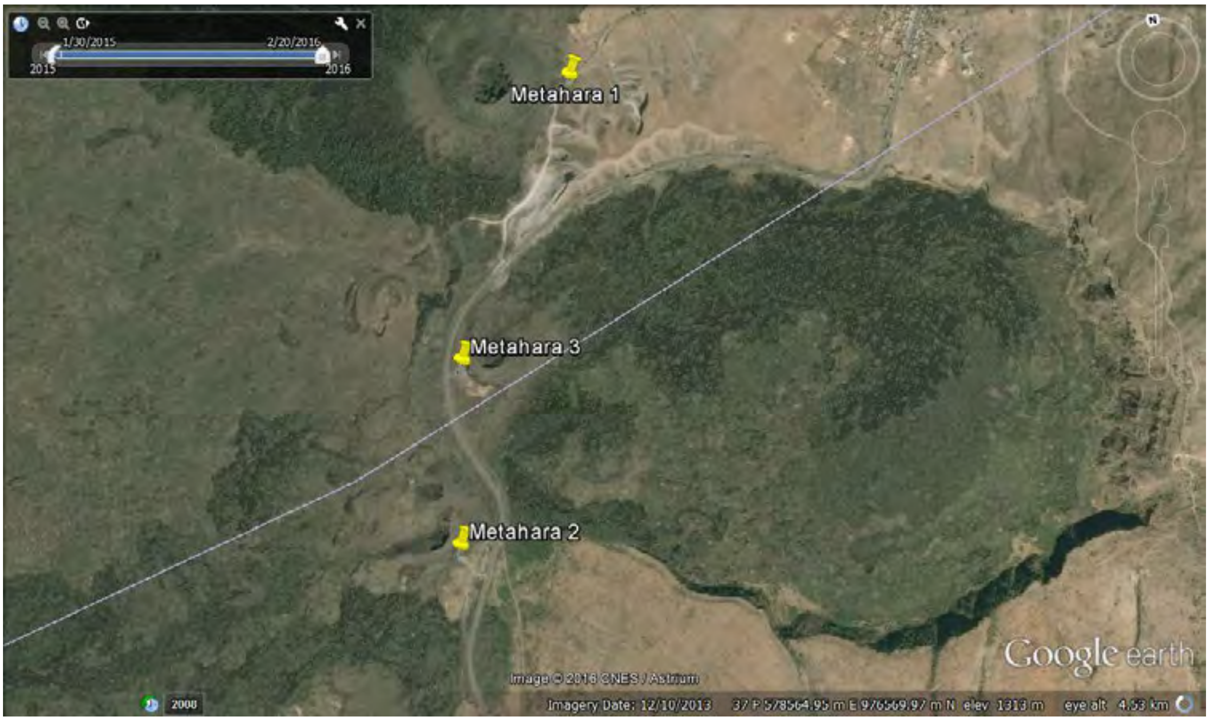
Perspective view of the "Metahara 1" cone


Pumice-like deposits, coarsely stratified

Metahara 2

Voided deposit of cinder bombs, fines probably washed out in groundwater

Metahara Borrow Pits



Aerial view of Metahara borrow pits

Field Visit: Alemgena – Butajira – Ziway Road

B.7 Alemgena Borrow Pit

The borrow pit is approximately 10m deep and is located between km 29 and km 30 along Addis Ababa - Butajira Road, coordinates UTM 0462330/0978155. The borrow pit appears, from Google earth, to be located some distance to the south from an ancient volcano.

Geological materials description

There are essentially three broad types of material exposed in this borrow pit:

1) Extremely hard/very strong purplish-red welded cinder gravel that cannot be broken or penetrated under heavy hammer blow. This material is located in the 'core' of the borrow pit and is effectively and is amorphous and non-stratified
2) Strong to very strong dense cinder gravels and cobbles with coarse stratification forming the upper portion of the 'core' of the borrow area. This material can be broken with a geological hammer, is reddish brown and contains some silt. Its face is slickensides in places, probably due to the smear of the excavator bucket. The stratification is moderately dipping away from the road, probably towards the
3) Loose to medium dense, friable and well-stratified fine – medium cinder gravels and cobbles with some fines content located on the western periphery of the borrow pit, close to the road. Beds are dipping (apparent dip 30-40^{o}) with a sense of dip towards the west, i.e. not consistent with the location of the possible source volcano to the north. This material is stratigraphically above the strong welded material that forms the 'core' of the borrow pit (Materials 1 and 2).

Construction materials description

The cinder in the borrow pit ranged from moderately hard to hard concretionary particles of about 10 mm. Other larger particles were also present. The cinder appeared to possess some plasticity. The cinder is mostly reddish-brown in colour. The sides of the borrow pit indicate that the cinder was extracted by both a dozer and an excavator. There is no room to expand the borrow pit further, due to settlements. At the edges of the borrow pit, weathered material was present. This can be used to blend the cinder to improve its grading and strength. The material from this borrow pit was apparently used as sub-base material on a section of the Alemgena – Butajira road.

Since this material was used as sub-base on this high volume road, it should possess the characteristics that make it suitable for use in the base layer of low-volume roads, either neat or blended.

Figure 12: Side of the borrow pit worked by dozer

Figure 13: Weathered material at the edge of the borrow pit

Additional photographs and Google earth images are provided below.

B.8 Kela Borrow Pit

The borrow pit is located between km 122 and km 124, coordinates UTM 0438925/0904439. The borrow pit seems to be located to the east of an ancient volcano. The cinder deposit here is large and has been exploited to a small extent only.

Geological materials description

The material comprises reddish brown strong to very strong nodular gravels and cobbles forming an unstratified loose to medium dense deposit. The deposit is voided and the clasts appear coarser grained towards the base of the excavation and finer towards the top.

At the base of the borrow pit, the particles are hard and when carefully extracted by excavator sounds as if we had an excavator, the material sizes range from about 70 mm down to 5 mm.

The material is generally non-plastic and has been used for Otta Seal surfacing trial at village of Combel on Tulubolo – Kela Road.

Towards the top of the borrow pit, the particles are of similar size but the main difference is that there is evidence of weathered and fine material. With standard compaction, this material should be suitable for use as sub-base (grading and strength) material. With heavy vibratory compaction, the material should be suitable (grading and strength) for use as base course material.

Figure 14: Borrow pit at lower level (non-plastic)

Figure 15: Borrow pit at upper end (some plasticity)

B.9 Mascan Borrow Pit (Butajira – Ziway Road)

This is a large borrow pit located about 2 km to the north east, left, at about 5 km along the Butajira – Ziway road, coordinates UTM 0437340/0901296. The cinder deposit here is large and has been exploited to a small extent only. The borrow area is located on what appears to be the margin of an old volcanic crater. From the Google earth image this is quite evident and there are similar but much smaller cones to the southwest.

Geological materials description

Two areas were inspected. The first was in the excavated face that forms part of the outside of the apparent crater. This material is a stratified deposit of loose strong to very strong gravels and cobbles. Further to the south west is a stratified deposit of black/dark grey loose coarse sand to medium gravel.

Construction materials description

Materials are granular, easily extracted by excavator or dozer. The particles are generally about 20 mm. The particles range from medium strength to hard. The material appeared to be non-plastic.

At the edge of the dome/cone is a large quantity of “ash-type” material. The granules are about maximum size 10 mm. The material appears to be generally non plastic. It is currently being exploited for use in making hollow blocks and concrete. It is perhaps used as “sand” filler. The potential for use of this material as sand seal will be investigated.

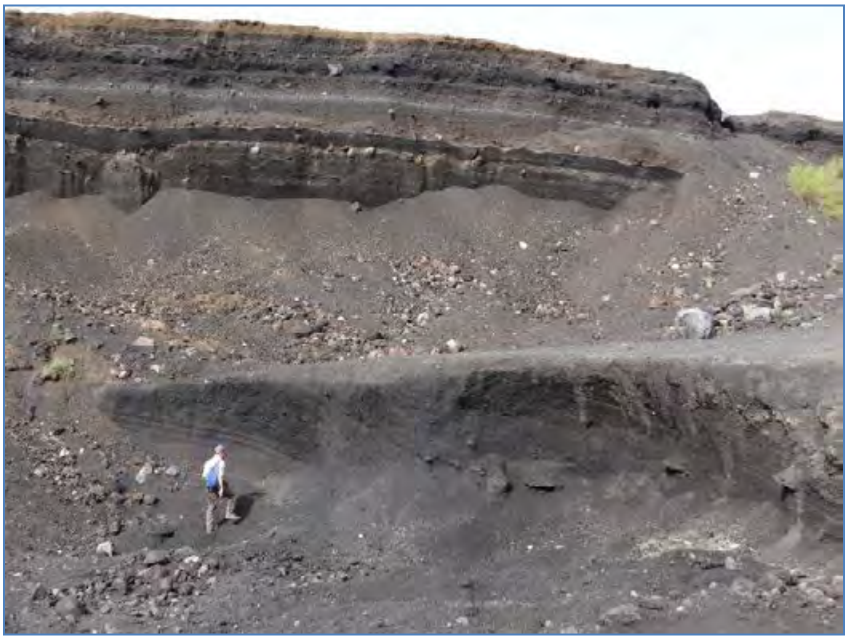


Figure 16: "Ash-type" material at the edge of the dome/cone

Figure 17: Granular cinder material

B.10 Performance evaluation of cinders used in the sub-base

As pointed out earlier, cinder material from the borrow pit at Alemgena has been used in the sub-base of Alemgena – Butajira road. The current road pavement has been in use for more than 13 years but does not show any major defects. We will compare the performance of this section of road with that of another similar control section where other sub-base material has been used.

The cinder study section is proposed to be located between km 45 and km 46. The control section is proposed to be located between km 70 and km 71.

Additional Photographs

Alemgena Borrow Pit

Material 1: Welded cinder gravel

Material 2: stratified, dense, cinder gravel

Material 3: Well-stratified, loose fine to medium cinder gravel

Material 2: stratification

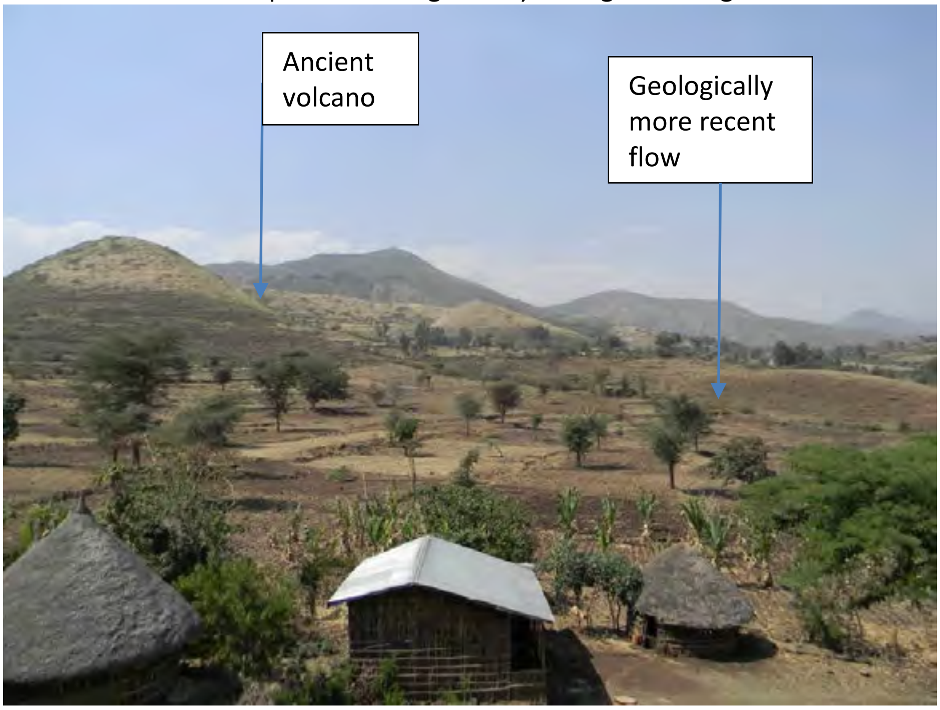
Material 3: Dip of stratification

View approx. west, looking down-dip at Material 3 in the far excavation
with boulders of Material 1 in the middle ground

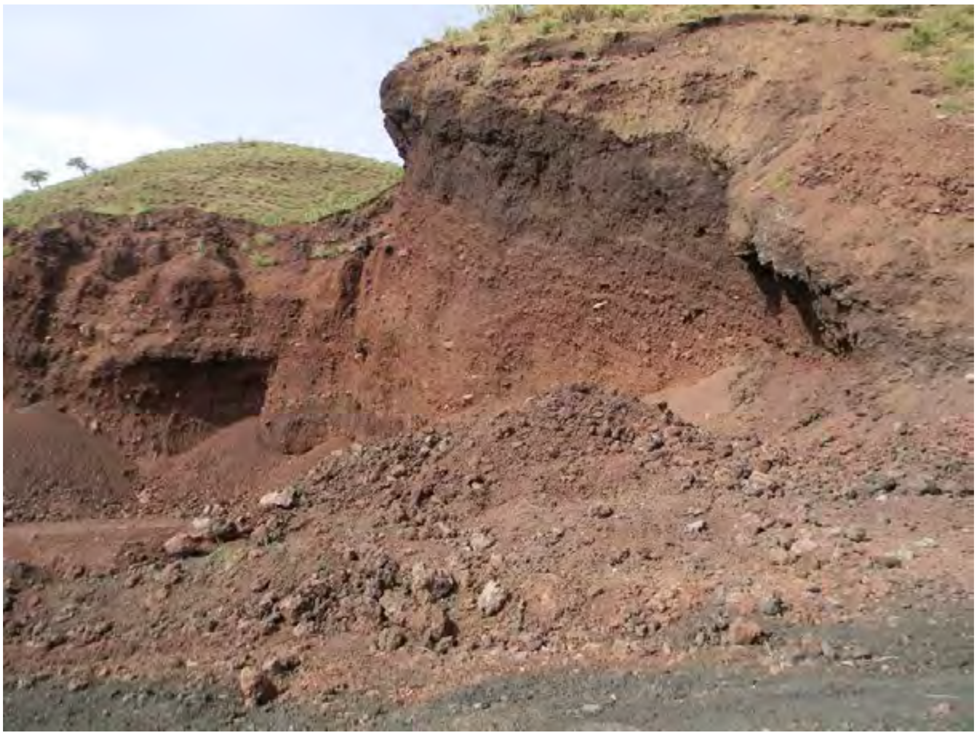
Alemgena borrow area and possible source volcano to the north

Kela

Voided deposit of strong to very strong nodular gravel



Mascan



Stratified deposit of loose gravels and cobbles

Clasts of strong to very strong material within a loose deposit

Some fines content can be identified as well as a loose structure

Stratification

Fine grained, well stratified deposit

Borrow area on the edge of the crater with other cones to the southwest