Cinder Gravels Workshop at the iTRARR Conference-Mombasa, Kenya, - June 2018

Workshop Report

Institution: TRL Ltd

ReCAP Reference number: ETH2058A

June 2018

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Cover photo: ReCAP sponsored delegates at the conference

Quality assurance and review table

Version	Author(s)	Reviewer(s)	Date
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		N Leta H Nkwanga C Visser	21 June 2018
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		N Leta	26 June 2018

ReCAP Database Details: Investigation of the Use of Cinder Gravels in Pavement Layers for Low-Volume Roads

Reference No:	ETH2058A	Location	Mombasa, KENYA
Source of Proposal	RECAP	Procurement Method	RESTRICTED TENDER
Theme	INFRASTRUCTURE	Sub-Theme	MATERIALS
Lead Implementation Organisation	TRL Ltd	Partner Organisation	ETHIOPIAN ROADS AUTHORITY, ROADS RESEARCH CENTRE
Total Approved Budget	£26,762.3	Total Used Budget	
Start Date	09th April 2018	End Date	30th July 2018
Report Due Date	15th July 2018	Date Received	19th June 2018

Contents

Tables and Figures

Abstract

This report provides a brief overview of the presentations made by A Otto and G Hearn at the iTRARR conference 2018 in Mombasa, Kenya. These presentations concerned the AfCAP-funded research undertaken on the use of cinder gravel in the low volume road sector in Ethiopia between January 2016 and February 2018.

Key words

iTRARR, Conference, Mombasa, Kenya, Cinder gravels, Ethiopia, workshop

Acknowledgements

iTRARR organising committee for provision of a dedicated time slot for the workshop and organising workshop logistics.

Acronyms, Units and Currencies

iTRARR	International Transport and Road Research
AfCAP	Africa Community Access Partnership
ReCAP	Research for Community Access Partnership
CBR	California Bearing Ratio
ERA	Ethiopian Roads Authority
MTRD	Materials Testing & Research Division
KRB	Kenyan Roads Board
TRL	Transport Research Laboratory
XRF	X-Ray Fluorescence
XRD	X-Ray Diffraction

Executive summary

The 2nd international Transport and Road Research (iTRARR) conference was held at the Sarova Whitesands Hotel, Mombasa Kenya from 11th June to 14th June 2018. Registration of delegates and briefing of presenters was conducted on 11th June 2018. Plenary and breakout sessions were held on 12th, 13th and 14th of June. Four site visits were also organised on the afternoon of 13th June 2018. The conference was attended by 396 delegates from 17 countries. The conference was officially opened by Mr. James Macharia the Cabinet Administrative Secretary, Ministry of Infrastructure, Housing and Urban Development. He also officiated at the closure.

The AfCAP cinder gravel workshop was held in a breakout session at 17:45 hrs to 19:00 hrs on the 12th June 2018. Five topics covering the testing and use of cinder gravels were presented. These topics were: introduction to the project, geological background, investigation techniques, testing, use, and quality control, and sustainable use. The workshop was attended by an estimated 40 delegates. A number of questions were raised by the participants and addressed by the presenters. Many delegates gave positive reviews of the workshop. There is an indication from delegates from Kenya and Uganda to carry out similar research on the cinder gravels that occur in their countries.

The next iTRARR conference is scheduled to take place in 2020.

1 Introduction

The International Transport and Road Research (iTRARR) conference was co-organised by Kenya Roads Board (KRB) and the Materials Testing and Research Division (MTRD) of the Ministry of Transport & Infrastructure of Kenya.

The conference was held at the Sarova Whitesands Hotel, Mombasa, Kenya from 11th June to 14th June 2018. Registration of delegates and briefing of presenters was conducted on 11th June 2018. Plenary and breakout sessions were held on 12th, 13th and 14th of June. Four site visits were also held on the afternoon of 13th June 2018. The conference was attended by 396 delegates from 17 countries.

The conference was officially opened by Mr. James Macharia the Cabinet Administrative Secretary, Ministry of Infrastructure, Housing and Urban Development. He also officiated at the closure.

The next iTRARR conference is scheduled to take place in 2020.

This report describes the conduct and outcome of the cinder gravels workshop that formed part of the breakout sessions during the conference.

The conference secretariat will produce conference proceedings/ report, which will include all papers submitted and speeches made by dignitaries. These will be posted on the Kenya Roads Board website (www.krb.go.ke) for reference.

2 The plenary sessions

Four main plenary sessions were held over the 3 days of the conference. A number of presentations were made covering road network monitoring, intermodal transport planning in the region, innovative pavement designs and integrated transport planning.

3 Breakout sessions

There were three concurrent breakout sessions on Day 1, one on intelligent transport solutions, another on innovations in transport, and the third on guidelines for testing and use of cinder gravels in road pavements.

4 The cinder gravels workshop

4.1 Introduction

The cinder gravel workshop was held on Day 2 of the conference, which was on Tuesday 12th June 2018, from 17:45 hrs to 19:00 hrs. During the workshop, another two breakout sessions were held concurrently in adjacent rooms - one on intelligent transport solutions and the other on innovations in transport.

The main aim of the cinder gravels workshop was to create awareness amongst delegates about the processes necessary to successfully use cinder materials and other marginal materials in low-volume road construction. The session was chaired by Eng. Joachim Mbarua, the iTRARR Technical Committee Chair. The session was attended by an estimated 40 delegates.

The expected learning outcomes of the delegates were:

1. Understand the procedures for sampling and testing cinder gravels for use in different pavement layers and as subgrade replacement
2. Understand and appreciate the rigour in quality control required in using cinder materials in different pavement applications
3. Understand the potential role of XRF and XRD testing
4. Extend the knowledge acquired to the use of cinder gravels in their respective countries

5. Extend the techniques acquired to the use of other marginal materials in their countries
6. Appreciate the importance of setting up Long-Term Pavement Performance sections.

4.2 Presentations

The presentations covered the topics shown in Table 1 PowerPoint slides of the presentations are provided in Annex 2.

Table 1 Topics presented at the workshop

Presentation No.	Topic	Presented by
1	Introduction to the project	Andrew Otto
2	Geological background	Dr. Gareth Hearn
3	Investigation techniques	Dr. Gareth Hearn
4	Testing, use and quality control	Andrew Otto
5	Sustainable use	Dr. Gareth Hearn
6	Questions and discussions	All

4.3 Questions and comments raised

At the formulation stage of the workshop methodology, it was planned that after each presentation, delegates would be given the opportunity to ask one or two questions and then ask more questions taken during the 'questions and discussions' session. However, when this approach was tried, delegates were asking pre-emptive questions on issues that were to be covered in subsequent presentations. Because of this, the approach was changed so that all questions were asked during the 'questions and discussions' session. This approach was being used in all the conference plenary sessions, so delegates did not find any problem with it. The questions raised and the answers given were as follows:

Q1: Are cinder gravels volcanic or are they some other kind of rock?

Response: Cinder gravels are volcanic rocks. The actual composition can vary depending on the characteristics of the magma and its post-eruption evolution and deposition. Note this question was asked after Presentation 1.

Q2: Most volcanic materials are plastic in nature why not cinder gravels?

Response: Volcanic rocks are generally non-plastic until they have undergone weathering/decomposition. Note this question was asked after Presentation 1.

Q3: What are the maximum dry densities and CBRs of the cinder gravels?

Response: The properties will vary significantly from source to source or even from within the same source. In the Ethiopia study, maximum dry density ranged from 1.4 to 2.1 gm/cc and CBR from 18% to 148%. Details of values and other tests can be found in the Guideline and Project Final Report that can be downloaded from the ReCAP website.

Q4: Why are cinder gravels plastic on the BS cone penetrometer test and non-plastic when tested by the Casagrande apparatus?

Response: In the Casagrande method, when conducting the liquid limit test, the specimens collapse immediately after making the groove, before subjecting it to any blows; whereas with the penetrometer method, there will always be a reading of liquid limit.

Q5: Was any cost analysis done on the use of cinder gravels?

Response: It is estimated that the initial cost will be about 30% to 70% of the cost of using crushed stone or other difficult-to-extract weathered gravel. The actual costs should be evaluated on a project-by-project basis since haulage distance matters. It could be cheaper, for example, to crush rock located about 1 km from a project site than to haul cinder gravel from 100 km. Regarding life-cycle costs, the longest study has been for a period of 7 years. Although the road (Awash Melkasa – Assela road) is known to have performed well for over 25 years, no systematic reports were made beyond 7 years thus preventing the opportunity for a life-cycle cost analysis. This issue emphasises the importance of long term pavement performance monitoring.

Q6: What is the life expectancy of roads constructed using cinder gravels?

Response: The longest study has been for a period of 7 years for the material used in the roadbase. The road is judged to have performed well for over 25 years and carried about 3 million standard axles. Again, this issue emphasises the importance of long term pavement performance monitoring. In the sub-base, it is known that cinder-gravels have performed satisfactorily for more than 14 years and carried more than 2.7 million standard axles.

Q7: What are other types of materials that can be used for low volume sealed roads?

Response: Generally, a lot of other materials can be used for low volume sealed roads, for example lateritic gravels, river bed gravels, weathered basalts, and weathered granites.

Q8: In Kenya, some cinder gravels have been seen in areas outside the Rift Valley, what could be the reason for this?

Response: There may be Rift-parallel faults along which the magma has risen. Magma will follow geological structures, such as faults to find its way to the surface.

Q9: Given the variability in the materials, do we need to do another study in Kenya?

Response: It is certainly a good idea to do that. As a start, you can compare the specific gravities and water absorptions of the cinder gravels in Kenya with those from the Ethiopia study. Strength tests such as the Aggregate Impact Value will also be very valuable for comparison. It is also very important to compare the results of the X-Ray Fluorescence and X-Ray Diffraction.

Our study has given a good indication of the range of geological and engineering variability. A material that may be weak geologically could be proven to be fit for purpose in a low volume road context, depending on application and treatment.

Comments

C2: A source of cinder gravel has been noted in Meru near one of the proposed research sections soon to be constructed. There is a possibility of including it in the trial.

Response: This presents a good opportunity and it should be explored even on an adjacent or nearby stretch of road from the main research sections.

C3: In Tanzania, other than the Kilimanjaro region, there is a likely source of cinder gravel in the Mbeya region.

Response: It is certainly possible that it could occur in that location since it represents the southern part of the rift valley that continues northwards to western Uganda. It would be helpful if photographs can be taken.

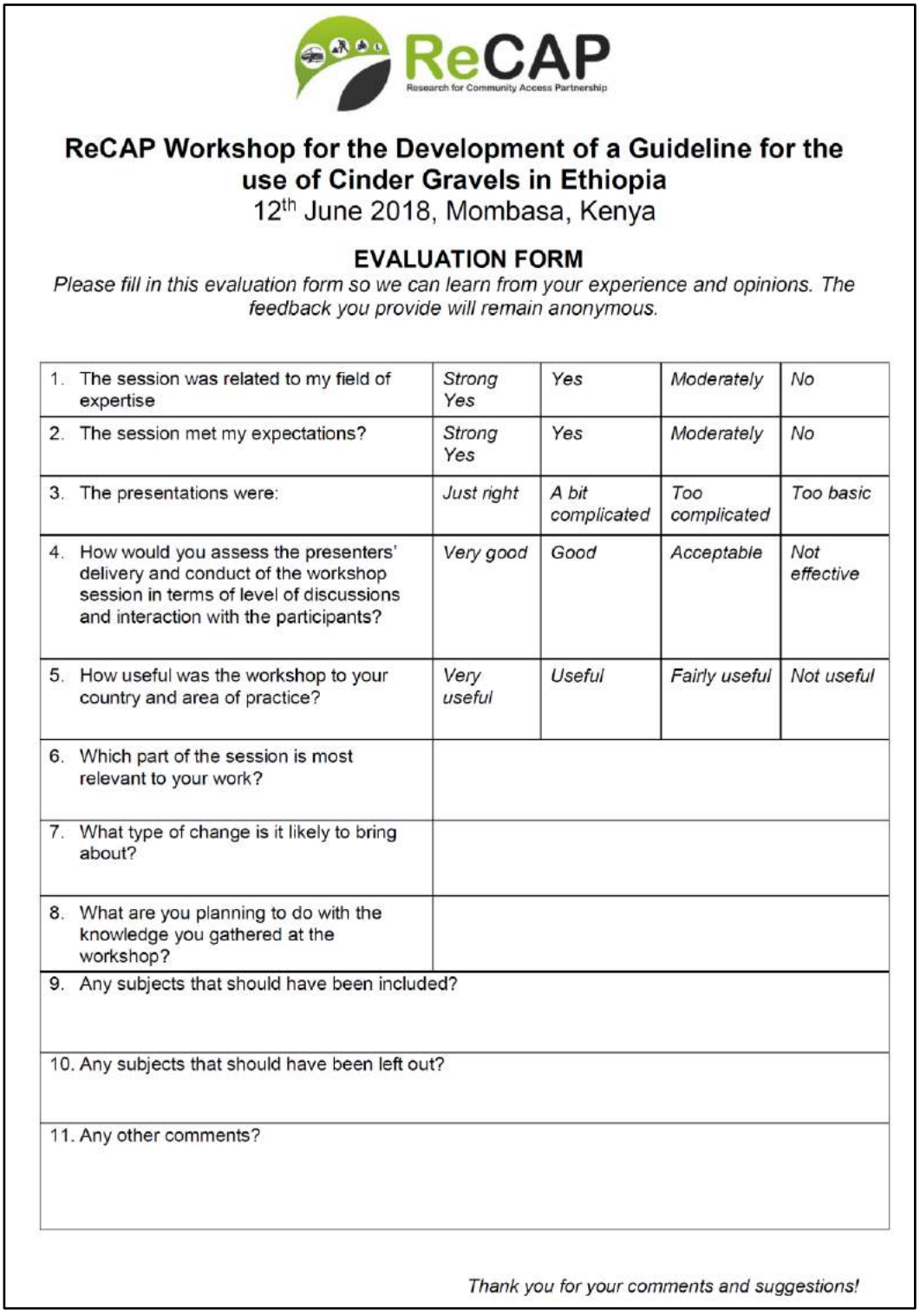
4.4 Challenges faced

At proposal stage, the planned duration of the workshop was 1 hour 45 minutes. During the conference preparation, the allocated time was reduced to 1 hour 30 minutes (14:00 – 15:30 hrs), and finally to 1 hour 15 minutes (16:15-17:30 hrs) a few days before the conference. On the conference day, the workshop was rescheduled to start at 17:45 hrs to 19:00 hrs. The reduction in time meant that two proposed presentations on X-Ray Fluorescence and X-Ray Diffraction Analysis, and on Monitoring of Long Term Pavement Performance sections had to be excluded. Lastly, the counterparts from Ethiopia were unable to attend; therefore, their responsibilities had to be shared by the two presenters.

4.5 Feedback from delegates

A questionnaire (Figure 1) was distributed to delegates immediately prior to the Cinder Gravel workshop. The questionnaire is reproduced below. A total of 36 returns were received. The handwriting on one of the returns was so poor that it was largely illegible. All delegates filled out Questions 1-6, though several left the space for answers to Questions 7-11 blank, and there was only 1 answer provided for Question 10 that unfortunately concerned a misinterpretation of the question. The responses and review of responses to Questions 7-11 have been included in Annex 1.

Figure 1 Workshop evaluation form



ReCAP
Research for Community Access Partnership

ReCAP Workshop for the Development of a Guideline for the use of Cinder Gravels in Ethiopia
12th June 2018, Mombasa, Kenya

EVALUATION FORM

Please fill in this evaluation form so we can learn from your experience and opinions. The feedback you provide will remain anonymous.

1. The session was related to my field of expertise	*Strong Yes*	*Yes*	*Moderately*	*No*
2. The session met my expectations?	*Strong Yes*	*Yes*	*Moderately*	*No*
3. The presentations were:	*Just right*	*A bit complicated*	*Too complicated*	*Too basic*
4. How would you assess the presenters' delivery and conduct of the workshop session in terms of level of discussions and interaction with the participants?	*Very good*	*Good*	*Acceptable*	*Not effective*
5. How useful was the workshop to your country and area of practice?	*Very useful*	*Useful*	*Fairly useful*	*Not useful*
6. Which part of the session is most relevant to your work?				
7. What type of change is it likely to bring about?				
8. What are you planning to do with the knowledge you gathered at the workshop?				
9. Any subjects that should have been included?				
10. Any subjects that should have been left out?				
11. Any other comments?				

Thank you for your comments and suggestions!

4.5.1 Questions 1 to 5

The responses to Questions 1 to 5 are summarised in Table 2 below.

Over 85% of delegates considered the contents of the workshop to be relevant to their field of expertise (Question 1). The session met the expectations of 97% of the audience (Question 2), though 14% described their expectations as having been 'moderately' met. The presentations themselves were considered to be 'just right' by almost 90% of the audience, an outcome that is consistent with the comments provided under Question 11 (see below). Question 4 is aligned with Question 3, with 97% of delegates describing the

presentations as either 'good' or 'very good'. Finally, 86% found the workshop to be either useful or very useful, with the majority falling into the latter category.

Table 2 Analysis of responses on Questions 1-5

1. The session was related to my field of expertise	*Strong Yes*	*Yes*	*Moderately*	*No*
	41.7%	44.4%	11.1%	2.8%
2. The session met my expectations?	*Strong Yes*	*Yes*	*Moderately*	*No*
	27.8%	55.6%	13.9%	2.7%
3. The presentations were:	*Just right*	*A bit complicated*	*Too complicated*	*Too basic*
	83.9%	13.9%	2.8%	0%
4. How would you assess the presenters' delivery and conduct of the workshop session in terms of level of discussions and interaction with the participants?	*Very good*	*Good*	*Acceptable*	*Not effective*
	47.2%	50%	2.8%	0%
5. How useful was the workshop to your country and area of practice?	*Very useful*	*Useful*	*Fairly useful*	*Not useful*
	58.3%	27.8%	13.9%	0%

4.5.2 Question 6

Which part of the session is most relevant to your work?

All 36 delegates responded to this question. The analysis to the responses is shown in Table 3. Seven considered that the entire session was relevant to their work, while a further 7 considered testing of materials and discussion of tests results to be most relevant to them. Three considered testing and sustainable use of cinder gravels to be particularly relevant. The remainder cited various elements of the presentations as being most relevant, and these included topics of research, investigation and the use of cinder gravel as a potentially viable alternative material. Only two participants made specific reference to geology as being relevant to their work. Nevertheless, the audience was entirely engaged during the geological and sampling presentations. Delegates also appreciated the importance of sustainable use of cinder gravel materials, and appeared to concur when the issues over environmental protection and conservation were raised.

Table 3 Analysis of responses to Question 6

Answers to Question 6 – Which part of the session is most relevant to your work?	Number of returns with this approx. answer
All parts	7
Testing and results	7
Sustainable use of cinder gravel	5

Testing and sustainable use of cinder gravel	3
Testing of the cinder gravel and its use in construction	2
Rock formations and geology	2
Sampling and testing	1
Cinder gravel	1
Gravelling by contractors	1
Investigation	1
Use of cinder gravel in low volume roads	1
Research findings on cinder gravel and application in road construction	1
Development of a country-specific guideline for Kenya	1
Cinder gravel as an alternative construction material	1
Further testing of marginal materials to establish suitability	1
Use of cinder gravel as an alternative construction material	1

Note: it is not possible to group all responses into subject categories, such as 'testing and results', as many contain unique comments on specific subjects. This applies to the written responses given to all questions (Qs 6 to 11).

4.6 Conclusions and recommendations from the workshop

The workshop achieved its main aim and the expected learning outcomes were realised. For future workshops organised as part of a conference, we recommend that ReCAP obtain a firm commitment on the exact dates and time.

The workshop was attended by 36 delegates and was a success. The workshop was able to get the main issues across to the delegates. These issues relate to material variability, marginality, and usage sustainability; the delegates appeared very appreciative of this. There was a high level of interest in the subject among delegates and, from their questionnaire returns, they appeared very keen to pursue the use of cinder gravels in their own working environment. They were aware that further investigations and testing are required, including the use of pilot studies to demonstrate and monitor performance.

Given the level of interest in the subject, it is recommended that ReCAP considers a similar study in Kenya, Tanzania, or Uganda. The study could be done in one of the three countries and counterparts from the other two could travel to participate in key activities.

Annex 1 Analysis of questionnaire feedback

It is not possible to group all responses into subject categories, such as 'testing and results', as many contain unique comments on specific subjects. This applies to the written responses given to all questions (Qs 6 to 11).

Q7. What type of change is it likely to bring about?

Generally, the answers to this question were centred on the opportunities for cost savings in road construction through reduced haulage costs if cinder materials are available locally. It is clear from the responses that the delegates intend to examine the potential use of cinder gravels, as lower cost alternatives to conventional materials.

Answers to Question 7	Number of returns with this approx. answer
We can use the cinder gravel thereby reduce costs where other gravels are distant	5
Positive	2
Better planning of projects and less depletion of gravel sources	2
The use of cinder gravel in my country	2
Time was too short – *NB this is a misinterpretation of the question*	2
Understanding the chips placed as blacktop on the road	1
Exposes options on the use of cinder gravels	1
Recommended materials for low volume roads in Kenya and the region	1
Research improvement	1
My understanding of cinder gravel	1
Greater use of the material in pavement construction	1
Sustainability of road construction	1
Construction of more roads in my country where conventional materials are limited	1
I am thinking of applying the knowledge gained	1
Interesting information, useful in cases of material scarcity	1
Available of alternative materials	1
Use of locally available material	1
I will now henceforth follow (*look for*) material sources	1
Quality (*control*) and (*selection of the*) right material for use	1
Allow for research for alternative materials	1
Help in extraction	1
Improve pavement materials for low volume roads	1
The way road (*construction*) materials are sourced and used	1
Reduce over-reliance on conventional materials	1
Exploration of new alternatives of gravel for construction	1
Need to carry out further research on locally available material yet to be exploited	1
A shift in assessing availability and practicability of use of cinder gravel in Kenya	1
Open-minded considerations	1

Q8. What are you planning to do with the knowledge you gathered at the workshop?

From the responses, delegates intend to examine how the use of cinder gravel can be applied in their own working environment, following investigation and testing. Two engineers (presumed to be from Kenya) stated they would try to convince their respective road authority to adopt the use of cinder gravels while another said they would consider using it as a trial project in Uganda. The responses, in general, indicate that the delegates are aware that research and trialling will be necessary before the material can become formally adopted as a potential alternative to conventional sources.

Answers to Question 8	Number of returns with this approx. answer
Carry out further research on the use of cinder gravel	7
For personal understanding and sharing with my colleagues/junior engineers	5
Implement it within my construction sites	3
Use it as the basis to understand more about cinder gravel	1
Research and teaching at university and industrial collaboration	1
Formulation of a project on the use of cinder gravel in S Western Uganda	1
Share with others in our field and advise them to apply it as I also intend to apply it	1
Application of the knowledge gained to do further study in my country	1
To do more research in my country about cinder gravel and convince road authority to use it	1
Review standards for low volume roads in the use of cinder gravel in Kenya	1
Examine the possibility of its use in concrete	1
Focus more on the properties of cinder gravel	1
Apply to residents (*meaning unclear*)	1
Use cinder gravel if available	1
Try out alternative materials after testing them	1
Use as a ReCAP project in implementation	1
Food for thought	1
Do more research on the suitability of cinder gravels and apply it to local roads in my country	1
Advise the authorities for its adoption	1

Q9. Any subjects that should have been included?

From the table below it is evident that most delegates would like to receive information about the cost-benefits of using cinder gravel over conventional materials, and the applications in which cinder gravel can form a suitable alternative to conventional materials. They appreciate that there will need to be a programme of investigation, testing and piloting before the use of cinder gravels can be formalised. Many of the subjects of interest are already covered in the ERA guideline.

Answer to Question 9	Number of returns

	with this approx. answer
Cost analysis, including comparison with alternatives	7
Cement stabilisation	2
Research should have been linked to a pilot project	1
Non-CBR-based testing of cinder gravels	1
Concrete	1
More properties of cinder materials for road surfacing material suitability	1
Sample roads constructed (*from cinder gravel*) and describe their design	1
Comparison of various gravels in Kenya	1
Full disclosure of LCCA (*meaning not clear*)	1
More on the testing and performance of materials in low volume roads	1
How cinder gravel binds with bitumen and other binders	1
Further interpretation of test results for certain parameters using different methods	1
Problems faced during research	1
Comparison with other materials used for the same purpose	1
Most suitable method of testing cinder gravel to meet the required standards for use as pavement material, e.g. stabilisation and blending	1
The challenges associated with it	1

Q10. Any subjects that should have been left out?

There were no suggestions in response to this question, other than one misinterpretation, indicating that the contents of the presentations were judged to be entirely relevant to the subject.

Answers to Question 10	Number of returns with this approx. answer
Comparison with other available gravel material – *NB this is a misinterpretation of the question*	1

Q11. Any other comments?

Responses to this question were very favourable in terms of the quality and delivery of the research and the presentations. Delegates indicate that they would like to have similar work carried out in Kenya and Tanzania.

Answers to Question 11	Number of returns with this approx. answer
Good research, well done, good topic and great presentation, well presented – I understood the topic, excellent and commendable work	11
Need for more time to discuss the material in detail	1
The presentations should be given in Tanzania where there is likely availability of this	1

material	
Investigations should be carried out to identify cinder gravel sources in all developed (*developing?*) countries of Africa. This will be useful for low volume roads	1
Can a similar project be carried out in the Rift Valley of Kenya or Kerio Valley?	1
More training and workshops and alternative case studies	1
I appreciate the knowledge learned	1
I appreciate the efforts and the documentary is useful	1
A good research area for Kenya	1
This is very technical, I am at policy level	1
Comparison of performance of cinder gravels with other gravels, e.g. lateritic or quartzitic gravels	1

Annex 2 Presentation PowerPoints

Use of Cinder Gravels in LVR Pavements Workshop June 2018

Presented by: Andrew Otto

TRL

Introduction

Objectives of the Workshop

Sharing approaches and knowledge

- Share with you the process of development of the Guideline so that you could adopt/adapt this Guideline or develop you own along similar lines
- Extend the knowledge and processes to the development and use of other materials in your respective countries
- Appreciate the rigour required in the successful use of marginal materials
- Understand the importance of setting up and monitoring of LTPP sections

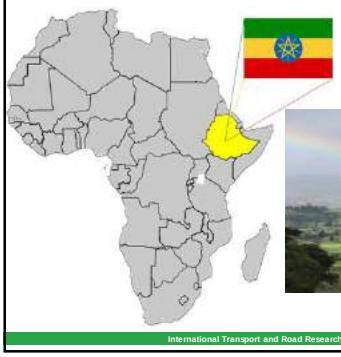
Workshop Timetable

Our timetable will be as follows:

Topic	Presenter	Duration (mins)
Introduction to the project	Andrew Otto	10
Geological background	Dr. Gareth Hearn	10
Investigation techniques	Dr. Gareth Hearn	10
Testing, use and quality control	Andrew Otto	25
XRF and XRD Analysis	Dr. Gareth Hearn	10
Sustainable use	Dr. Gareth Hearn	10
Importance of LTPP sections	Andrew Otto	10
Questions and Discussions	All	20

Ethiopia

A project was carried out in Ethiopia on the use of cinder gravels



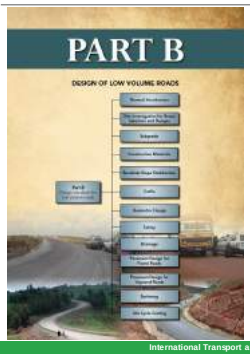
Ethiopia Road Network

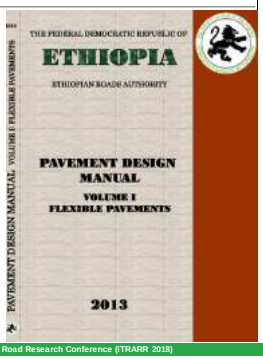
A massive programme – URRAP

- RSDP launched in 1997 (15 years but extended)
- Federal Road Network length = 28,699 km (2018)
- District and community road network length > 110,000 km
- Construction of 72,000 km of rural roads were planned through the Universal Rural Roads Access Programme (URRAP) 2010 – to date; 57,075 km so far done
- Vision of 201,750 km (excludes URRAP) by 2028 (2020 EC)

Inputs into Road Development

Manuals for planning, provision, and preservation (maintenance)





Inputs into Road Development

The importance of research

Inputs into Road Development

The importance of research

Inputs into Road Development

Continuous monitoring of research sections

Why Cinder Gravels

Abundance and ease of extraction compared to other materials

- The abundance of cinder gravels in Ethiopia
- The need/demand for a rapid road network expansion especially in the rural areas
- The ease of extraction of cinder gravels compared to other gravels

Why a Guideline for Cinder Gravels

A very different material

- Cinder gravels very different from other natural gravels
  - Highly variable within the same source
  - Breakdown considerably in handling and compaction
  - Highly vesicular
  - Mostly non-plastic
- Development of Ethiopian Roads Authority Low Volume Roads Manual
- Need to assess how to meet recommendations in the Manual and areas where deviations from the Manual is warranted (given the nature of the cinder gravels)

The Project Team

In action

The Guideline

- Developed through Literature review, re-analysis of information from previous and ongoing projects, field and laboratory investigations

Content of the Guideline

Main Chapters

1. Introduction	9. Cinder Gravels as Gravel Wearing Courses
2. Pyroclastic Materials	10. Processing of Cinder Gravels
3. Future Extraction	11. Other Uses of Cinder Gravels
4. Engineering Properties of Cinder Gravels	12. Recommendations
5. Cinder Gravels for Subgrade Replacement and Capping	13. Appendices
6. Cinder Gravels for Sub-base Layer	
7. Cinder Gravels for Roadbase Layer	
8. Cinder Gravels for Bituminous Surfacings	

Introduction to the Project

Thank you all!

Supported by: ReCAP Research for Community Access Partnership, UKaid from the British people

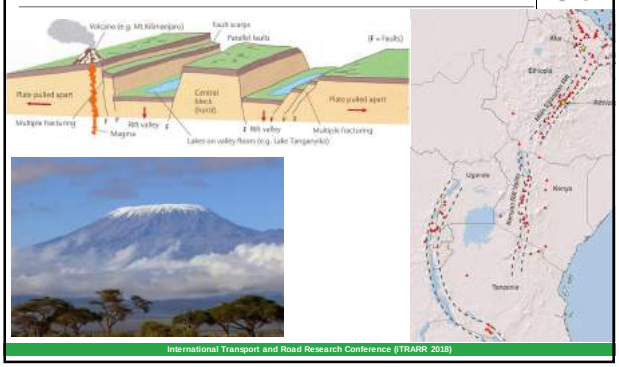
Use of Cinder Gravels in LVR Pavements Workshop June 2018

Presented by: Dr. Gareth Hearn

Geological Background

Geological Background

The East African Rift and distribution of the main volcanoes



Geological Background

Formation of Cinder Gravel

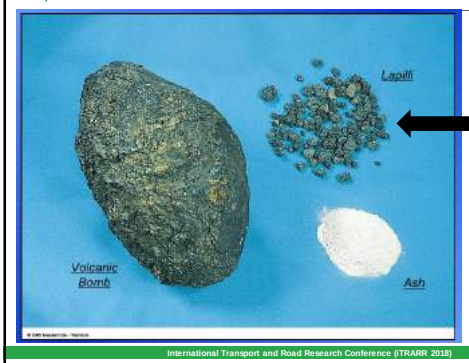
Volcanic eruptions result in a wide range of volcanic products:

- Lava
- Pyroclastic material (tephra)

Tephra
- Ash (<2mm)
- **Lapilli (2-64mm)**
- Bombs & blocks (>64mm)

Geological Background

Tephra



Cinder gravel size range

Geological Background

Broad classification of volcanic products - lavas/lapilli

- Felsic – acidic, high in SiO_2, including light-coloured rhyolites, andesites, low-density pumice, obsidian, volcanic glass – high viscosity
- Mafic – basic, rich in plagioclase, olivine & iron, dark-coloured basaltic lavas, basaltic scoria (cinder 'gravel') – lower viscosity

First 3 Images: courtesy geology.com

Geological Background

Basaltic scoria – cinder 'gravel'

- Highly vesiculated
- Low-moderately vesiculated

Increasing strength

Geological Background

What controls vesicularity?

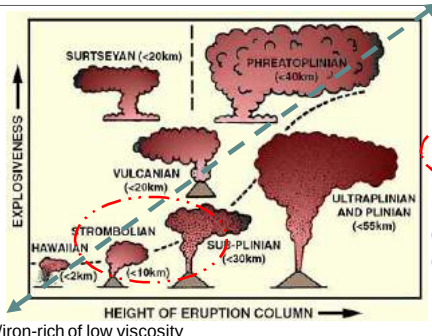
As magma rises towards the Earth's surface:

- Confining pressure reduces
- Volatile gases come out of solution to form bubbles
- Bubbles are either retained in the magma as it ascends or separate to form large gas 'pockets'
- The magma fragments as it explodes from the vent, creating pyroclastic material with varying bubble contents
- Bubble content may change as the lapilli mix with gases in the plume
- Cooling and solidification create vesiculated lapilli structure where gases have been unable to escape its mass

Geological Background

Eruptive types

Felsic/silica-rich of high viscosity

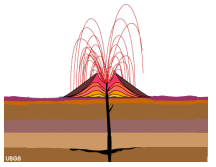


Most cinder cones

Mafic/iron-rich of low viscosity

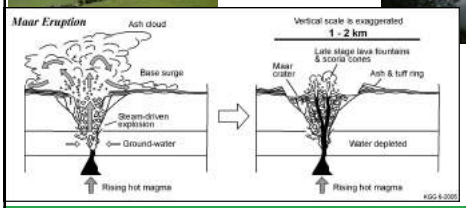
Geological Background

Anatomy of a typical cinder cone



Geological Background

Common variant on the cinder cones: Maars



Geological Background

Some regional observations

Marsabit, Kenya

There are 180 cinder cones and 22 maars in Marsabit, Kenya

There are 40 cinder cones at Bufumbira, Uganda

Ol Doinyo Lengai, Tanzania

Geological Background

Thank you for your attention!

Supported by: ReCAP Research for Community Access Partnership UKaid from the British people

Use of Cinder Gravels in LVR Pavements Workshop June 2018

Presented by: Dr. Gareth Hearn

TRL

Investigation Techniques

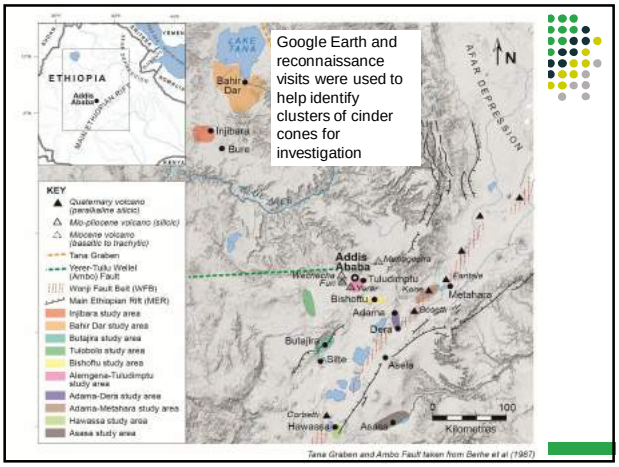
Investigation Techniques

Sampling purpose

1. To combine and compare engineering geological assessments of material strength with CBR and AIV/MAIV data from recovered samples

2. To use the CBR, AIV/MAIV & other lab test data to develop engineering guidelines for the use of cinder gravels in LVRs

3. To analyse the geochemistry of the samples, using X-Ray Diffraction (XRD) & X-Ray Fluorescence (XRF), to identify any geographical trends

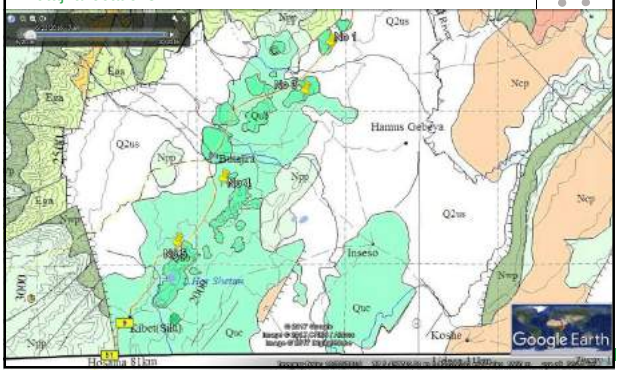


Google Earth and reconnaissance visits were used to help identify clusters of cinder cones for investigation

Tana Graben and Ambo Fault taken from Berhe et al (1987)

Investigation Techniques

Butajira locations



Investigation Techniques

Wide range of stratigraphy, particle size, strength and consistency

Investigation Techniques

Investigation and sampling procedure -1

- Qualitative assessment and description of the range of materials exposed in each location, subject to access and H&S limitations
- Selection of the apparent strongest materials for sampling
- Selection (in some cases) of fine-grained (usually weathered horizon) materials for potential blending purposes
- Removal of samples and transport to the ERA laboratory in Addis Ababa
- Use of the portable AIV device for trial purposes

Investigation Techniques

Investigation and sampling procedure -2

Each sample required 3 x 30 kg bags, due to the volume of testing

Investigation Techniques

Use of the portable AIV device

Investigation Techniques

Findings of the field investigations -1

- A small number of cones were composed of predominantly one material type, in terms of size, shape and vesicularity – commonly this material was over-size and weak
- A large number of cones were comprised of well-bedded sequences of ash, gravel and cobble/boulder-sized materials – commonly some of these materials were among the strongest
- There was usually such high variability of material in each cone that representative sampling was impracticable

Investigation Techniques

Findings of the field investigations -2

- Samples from Injibara, Asasa, Butajira and, to a lesser extent, Bishoftu were generally stronger, both in terms of average and maximum field strength, with lowest variability.
- Samples from Hawasa were found to be the weakest
- Samples from Injibara had the lowest vesicularity, while those from Hawasa the highest
- The lowest AIV values (highest strength) were found in samples from Injibara and Bahir Dar, while the highest values (lowest) strength were for samples from Hawasa

Cluster Area	No of Locations	Field Strength							Aggregate Impact Value (AIV)%			Bulk Specific Gravity (gm/cm³)	
		Average	Rank Average	Variability	Rank Variability	Rank (highest Average + lowest Variability)	Maximum	Rank Maximum	Range	Average	Rank Average	Average	Rank Average
Butajira	4	Mod	5	Low	1	4			37-39	38	5	1.85	1
Alemgena-Tuludimptu	5	Mod	5	High	6	7	High	1	37-47	42	8	1.69	5
Tulubolo	2	Mod-High	1	Mod	3	2			38-40	39	7	1.76	4
Hawassa	3	Low-Mod	8	Mod	3	6	Low-Mod	9	44-62	51	9	1.50	9
Asasa	4	Mod-High	1	Mod	3	2	High	1	25-54	37	4	1.80	8
Adama-Dera	6	Low-Mod	8	High	6	9	Low-High	8	17-50	35	2	1.67	6
Bishoftu	13	Mod-High	1	High	6	5	Low-High, mostly High	6	9-71	38	5	1.77	3
Bahir Dar	6	Mod	5	High	6	7			23-47	32	1	1.63	7
Injibara	8	Mod-High	1	Low-Mod	2	1	High	1	25-45	36	3	1.78	2
Adama-Metahara	5	Low-Mod		Mod-High			Low-High						

Investigation Techniques

Field strength versus landform type

Pyroclastic landform	Field strength based on BS5930		
	Low	Moderate	High
Pyroclastic ridge or flow feature extending from cinder cone or volcano	80%	20%	0%
Dome – low-amplitude, mostly circular raised ground with shallow side slopes	50%	25%	25%
Well-defined, steep-sided, cone, with or without crater	11%	48%	41%
Maar	28.5%	28.5%	43%

Investigation Techniques

Thank you for your attention!

Supported by:

Use of Cinder Gravels in LVR Pavements Workshop June 2018

Presented by: Andrew Otto

Testing, use, and quality control

Laboratory Tests

Main tests conducted

- Aggregate Impact Value
- Maximum Dry Density
- California Bearing Ratio
- Particle Size Distribution
- Atterberg Limits
- Specific Gravity and Water Absorption
- XRF and XRD Analysis

Laboratory Tests

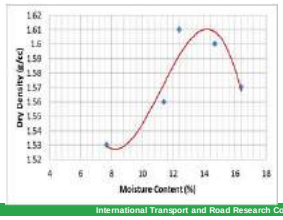
Aggregate Impact Value

- Carried out according to BS812 Part 112:1990
- Important because it measures the resistance to breakdown of the particles
- Aggregates passing 14 mm and retained on 10 mm
- Sieve on 2.36 mm sieve after hammering
- AIV = (mass passing 2.36 mm/mass of sample)*100
- A wide variation of strengths noted

Laboratory Tests

Maximum Dry Density

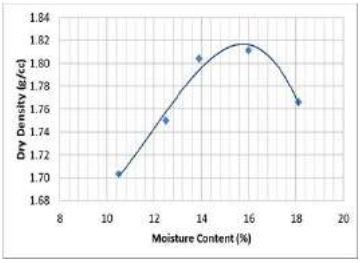
- Carried out according to AASHTO T180-D
- Many times indeterminate results for neat cinders



Laboratory Tests

Maximum Dry Density

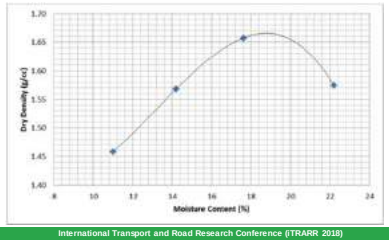
- By re-using one specimen at different moisture contents, better curves are obtained



Laboratory Tests

Maximum Dry Density

- For cinder gravels containing plastic fines or those blended with fines, no need to re-use the specimen.
- Sometimes re-using the specimen results in higher CBRs



Laboratory Tests

California Bearing Ratio

Tests carried out using the AASHTO T-193 test method

- Tests on neat cinder gravels should be treated as a method of initial selection for blending
- Neat CBRs may be applicable where lateral restraints exist or for material for subgrade replacement
- A wide range of results between different locations
- Range between 18 to 148%, average 65%

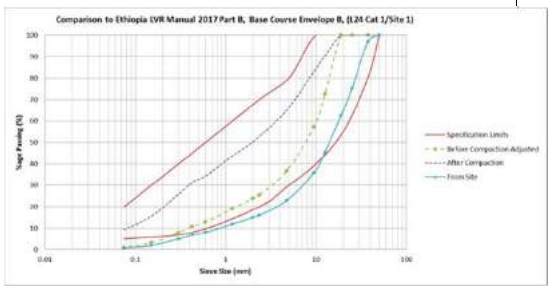
Laboratory Tests

Particle Size Distribution

- Carried out according to AASHTO T11 and T27 methods
- In situ large variety of particle sizes are present from sand to boulder fractions
- In the lab sizes handled usually passing 75 mm

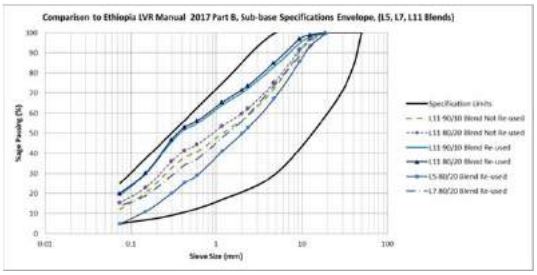
Laboratory Tests

Particle Size Distribution



Laboratory Tests

Particle Size Distribution



Laboratory Tests

Atterberg Limits

- By AASHTO-T89 and T90, Casagrande apparatus
- Cinder gravels mostly non-plastic BUT…
- In some locations cinder gravels occur in a matrix of plastic fines

Location	Site	LL	PI	% Passing 425 µm sieve	Plasticity Modulus
Location 6	S1	74	39	8	312
	S2	66	41	14	574
Location 13	S1	47	21	23	483
	S2	47	26	36	936

Laboratory Tests

Atterberg Limits

- By using the penetrometer method, a number of sources shows plasticity

Location	LL	PI	%age Passing 425µm sieve	Plasticity Modulus
Red Ash at km 31+000 Addis-Adama Expressway	43	13	31	404

Source: ELE

- Results on the sample by Casagrande apparatus is non-plastic

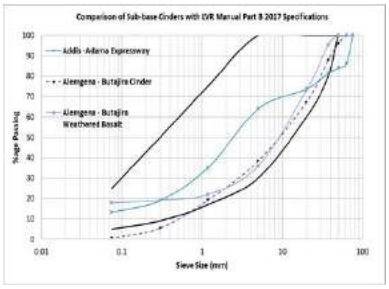
Laboratory Tests

Water Absorption and Specific Gravity

- Carried out according to ASTM C127 test method
- Water absorption: Average 13%, range 5-33%
- Apparent Specific Gravity: Average 2.14 gm/cc, range: 1.57-2.62 gm/cc
- Saturated Surface Dry Gravity: Average 1.91 g/cc, range: 1.45-2.44 gm/cc
- Bulk Specific Gravity 1.17-2.33 gm/cc

Samples from the road

Maximum particle sizes greater than 75 mm



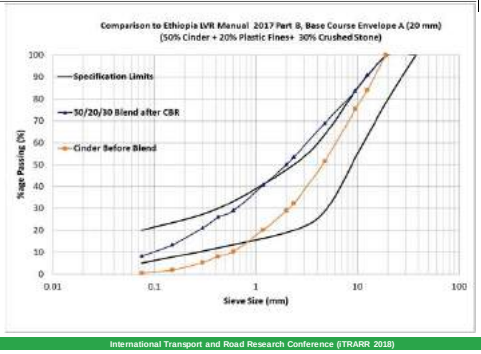
Samples from some roads

Other properties (for 2.7 MESA, 14+ years)

Property	Weathered Basalt Sub-base	Blended Cinder Sub-base	LVR Specification
Soaked CBR (97%)	32	15	Min 30%
LL	50	50	Max 45
PI	18	26	Max 12
PM	*342*	*208*	*720*
Linear Shrinkage (%)	6	10	Max 6
Water Absorption (%)	4.6	15.1	-

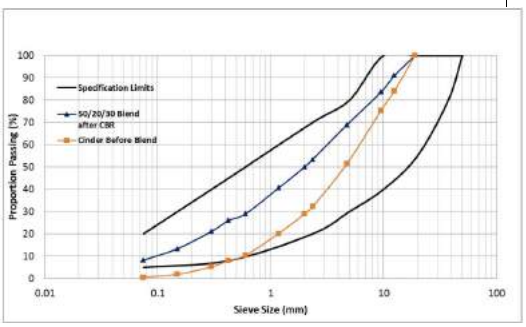
Roadbase PSD requirement

Envelope A difficult to achieve: required for (0.5-1.0 MESA) & S2



Roadbase PSD requirement

Envelope B (applicable up to 0.5 MESA) is achieved adequately



Construction Quality Control

Very important for marginal materials

- Batching/ stockpiling in manageable sizes at extraction – variability – allows downgrading of manageable quantities
- Preliminary testing of batches
- Trial sections at the beginning of projects approx. 200 m (like we do for AC)
- Main aim of trial section is to establish blending proportions, and construction/compaction sequence to meet specifications determined in the lab

Construction Quality Control

Very important for marginal materials

- Take density measurements – at least 10 number
- Material from density holes – check layer thickness, particle size distribution, and Atterberg limits (changes with breakdown)
- If not satisfactory, then adjust blend proportions, and or compaction level or sequence
- Determine over-compaction level if material in the laboratory shows a reduction in quality from over-compaction

Final Remarks

How does this help Ethiopia?

- Better understand the location and occurrence of different qualities of cinder gravels
- Make better use of the cinder gravel by better understanding its properties and improving its performance
- Inspire confidence in the specification and use of this abundant material
- Cheaper provision of LVSRs (no need to haul large quantities of crushed stone over long distances)
- Counterparts have been empowered to carry out further research on this and other materials

Final Remarks

How you can apply this in your country

- Identify any cinder gravel sources in your country
- Estimate the abundance of the material
- If you don't have cinder gravels in your country, apply similar principles for the study of your marginal materials
- Compare the results with your design standards
- Build experimental sections/ pilot projects
- Apply results from experimental sections and use the material appropriately

Testing, use, and quality control

Thank you all!

Supported by: ReCAP UKaid

Use of Cinder Gravels in LVR Pavements Workshop June 2018

Presented by: Dr. Gareth Hearn

Sustainable Use

Sustainable Use

Key issues

- Environmental approval and compliance regarding site selection, operation and restoration
- Methods of extraction
- Materials management – stockpiling for multiple end-use
- Abide by Health & Safety regulations
- Work all borrow areas before opening new ones
- Proper restoration

Dedicated planning controls are required and must be adhered to

Sustainable Use

Safeguard high-value landscapes & sites of scientific interest

Liaise fully with the:
Geological Survey
Environmental Protection Agency
Other planning and regulatory authorities

Sustainable Use

Ensure existing and new borrow pits are mined correctly

Correct

Incorrect

Sustainable Use

Materials management for multiple end-use

- Cinder gravel has multiple uses, including as:
  - Subgrade replacement and fill
  - Pavement layers for LVRs
  - Blending material, i.e. non-expansive fines
  - Surfacing for tracks and residential/commercial access
  - Aggregate in light-weight concrete
  - Aggregate for hollow blocks

- Cinder gravel borrow pits may contain:
  - Oversize material
  - Material too variable for screening
  - Material too weak for intended use
  - Material too strong for intended use, e.g. welded material
- Unsuitable materials must be stockpiled for later use

Sustainable Use

Conform with health and safety in the work place

Incorrect

Incorrect

Sustainable Use

Management and restoration

- Sequenced excavations to maximise material usage
- Benched excavations to maximise access, maximise material usage and maximise slope stability
- Drainage control
- Stockpiling of topsoil and temporarily unusable materials for reuse
- Development, application and compliance with H&S and environmental protection plans
- Restoration and return to productive land use

Sustainable Use

Thank you for your attention!

Pyroclastic art, Ethiopia, sculptor not known

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