THE USE OF NATURAL POZZOLLAN TO STABILIZE CINDER GRAVEL FOR A ROAD BASE (ALONG MODJO-ZIWAY ROUTE)

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In road construction using locally available materials plays a significant role in cost and time saving of road construction projects. Cinder gravel is abundantly available in different parts of Ethiopia. However, its use has been for too limited purposes due to its light weight, rough surfaces and high porosity. In this study two types of Natural Pozzolanas were collected from Ziway Area in order to stabilize cinder gravel for a road base. One was Pumice (coarser) and the other was volcanic ash (Pumicite). Pozzollanicity test was conducted on both samples using strength activity index test. For the Pumice the strength activity index value was 89.17% while for the volcanic ash (Pumicite) it was 76.43%. Since the volcanic ash (Pumicite) satisfies the minimum requirement for pozzollanicity and is finer, it was used as a stabilizer. From the unconfined compression test conducted on two specimens of the volcanic ash (Pumicite), the average UCS value increases from 84.65 kPa to 266.63kPa for 3 and 7 curing days, respectively. The cinder gravel was blended with 0, 4, 8, 12, 16, 20, and 24% by mass of volcanic ash (Pumicite). Compaction, California Bearing Ratio, Gradation, Atterberg limit, Los Angeles Abrasion, Aggregate Crushing Value, Ten Percent Fines Value, Absorption and Specific gravity tests were conducted in the laboratory.

From the laboratory test results of moisture content vs. density relationship, it has been observed that the optimum amount of natural pozzollana (volcanic ash) is 20% by mass proportion at a density of 1.76g/cc. For the optimum blending proportion; the range of soaked CBR increases from 98% to 245% whereas for the unsoaked condition the CBR increases from 118% to 307%, for 0 to 28 days curing.

Key Words: CBR, Cinder Gravel, Compaction, Natural Pozzollana, Unconfined Compression

INTRODUCTION

Cinder is a volcanic, non-cohesive and weak gravel material which is widely available in the main rift valley of Ethiopia. Volcanic cinders are pyroclastic materials associated with recent volcanic activity. They occur in characteristically straight sided cone-shaped hills which frequently have large concave depressions in their tops or sides where mixtures of solids and gases were released during the formation of the cone. Cinders vary in color, often within the same cone and may be red, brown, grey or black. The cinder particles also vary in size from large irregularly shaped lumps 0.5m in diameter to sand and silt sizes. In some cones, however, particles may be more uniform with the largest size not

exceeding 30mm in diameter. Other characteristic features of cinder are their light weight, their rough vascular surface and their high porosity. Usually they are weak enough to be crushed under the heel [2]. An advantage as a road construction material is the relative ease with which they can be dug from the quarry: a mechanical shovel or hand tools are usually adequate for their extraction although, occasionally, a bulldozer may be required to open up a working face [2]. But cinder gravels are deficient of fine material, as a result of this, they are porous materials with nonconformity to conventional gradations for subbase and road base and they are difficult to compact. Previous researches have been conducted on cinder gravels jointly by Ethiopian Transport Construction Authority and Road research laboratory (UK) to devise a specification to use as a road construction material for light traffic roads [6]. Recent researches conducted to improve the prop-

erty of cinder gravel to use as road construction material include; stabilizing cinder gravel heavy trafficked base course [3], blending cinder gravel with fine grained soil to use as a sub base material (The case of Butajira-Gubre Road) [7], blending cinder gravel with coarse aggregate and fine grained soil for road sub base on the area Addis Ababa- Adama [4] and Stabilization of cinder gravel with cement and clay[2].

In this research cinder gravel has been stabilized using natural Pozzollana (volcanic ash) from samples collected between Modjo and Ziway. Grading, Atterberg limits, absorption, specific gravity, compaction, California Bearing Ratio and unconfined compressive strength tests have been conducted in the laboratory. Then strength tests have been conducted on the stabilized material to check the improvement in the compaction characteristics of cinder gravel and to check its conformity with ERA's standard technical specification for road base and recommended as a proper blending proportion for use as a road base material.

MATERIALS AND LABORATORY INVESTIGATIONS

In this study, natural cinder gravel samples were investigated from Modjo, and the natural pozzollanas were collected from Ziway area, near Bulbula River. The natural cinder gravel was prepared for various tests after repeated quartering using sample splitter riffle box and studied in laboratories at Addis Ababa University and at Ethiopian Roads Authority Road Research laboratory. In the presentation throughout the paper, the samples are designated by Modjo and Ziway respectively.

Figure 1 and Figure 2 depicts the gradation curves of the samples before and after compaction of the natural cinder gravel with ERA gradation specification limits for naturally occurring granular base, respectively. The gradation of cinder obtained is generally coarser. However, in both cases the gradation is almost within the specification limits except that the samples are deficient in fines before compaction and coarse particles are finer than the desirable limits after compaction because cinder particles break down during compaction due to their weak strength.

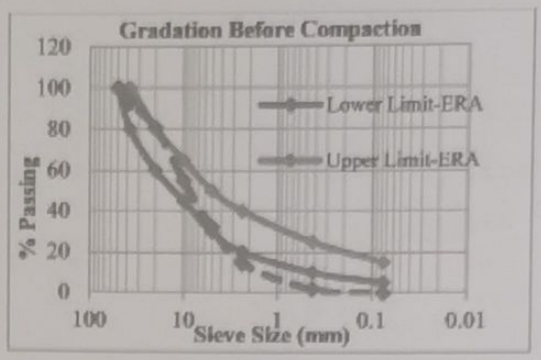


Figure 1 Gradation before Compaction

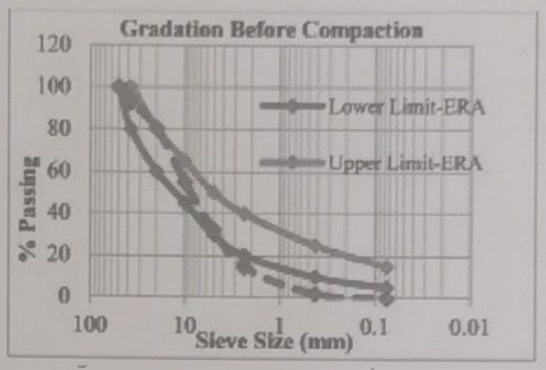


Table 1 Characterization of the Natural Cinder gravel used for the study

Type of Test	Required Limits	Test Results
Los Angeles Abrasion	<45%	48.88%
Aggregate Crushing value	>50kN	50.77%
Ten Percent Fines Value	>50kN	32.13kN
Aggregate Impact Value	<35%	42.68%
Specific Gravity	2.5-3.0	2.62
Water Absorption	1.0-2.0	12.97%
Modified Proctor	-	OMC=5.55% MDD=1.57g/cc
CBR	-	59%

From the descriptive test results shown in table 1, once can see that cinder gravel is weak in resistance to abrasion, crushing and impact because of its high water absorption potential and due to its high porosity. The CBR value is inadequate for use as a road base.

From the plot of gradation before compaction of the natural cinder gravel, one can see that cinder is short of fine material; as a result, needs stabilization by adding finer material in order to improve its gradation.

During sampling, two types of natural pozzolana were collected from Ziway area. Both materials were tested for pozzollanicity using the strength activity index test. From the test result the coarser one exhibited relatively higher SAI values whereas the volcanic ashpumicite exhibited lower SAI value but is above the minimum requirement for pozzollanicity and is finer at its natural state. For this reason it was chosen as a stabilizer. The volcanic ash/Pumicite has a specific gravity of 2.4 which is relatively lower than that of the cinder gravel which is due to the fineness of the minerals present in it. Atterberg limit result showed that the material is a non-plastic material. Descriptive test results conducted on the natural pozzolana are presented in Table 2

Table 2 Characterization of the Natural Pozzollana

Type of Test	Required Limits	Test Results
Strength Activity Index Pumice-Coarser Volcanic Ash/Pumicite	 >75%	 89.17% 76.43%
Specific Gravity	>2.3	2.4
Unconfined Compression Strength 3 days curing 7 days curing	-	 86.43kPa 266.73kPa
Plasticity Index	0 - 6	0
Standard Proctor	-	OMC=38.82% MDD=1.13g/cc

A maximum dry density of 1.13g/cc at an optimum moisture content of 38.82%, which was obtained from standard proctor, was used to prepare four samples of UCS in order to observe the role of curing in the strength development. The samples were covered with a soft paper and sprinkled with water and penetrated on the 3rd and 7th day Unconfined compression strength test conducted showed an increment in average UCS values for 3 to 7 day curing. This indicates that the material is pozzollanic and undergoes cementation as curing times is given.

EXPERIMENTAL INVESTIGATIONS

To attain the objective of improving the compaction property of the cinder gravel and ultimately the strength, compaction method was used to obtain the optimum blending proportion. Modified proctor test was conducted for 4, 8, 12, 16, 20, and 24% by mass proportion. From the test result, the optimum moisture content and the maximum dry density increases up to 20% but the maximum dry density decreases and the corresponding optimum moisture content increase at 24% by mass proportion.as tabulated in table 3 and presented in Figure 3.

Table 3 Determination of MDD & OMC For different Volcanic Ash/ Pumicite percentage

% Volcanic Ash/pumicite	MDD (g/cc)	OMC (%)
0	1.57	5.55
4	1.58	13.61
8	1.60	14.55
12	1.65	15.45
16	1.72	16.23
20	1.76	13.01
24	1.70	18.10

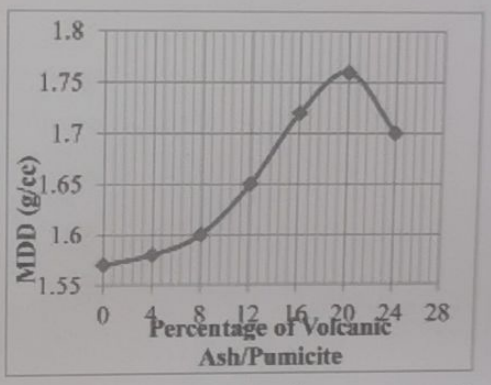


Figure 3 Variation of MDD with percentage of Volcanic Ash/Pumicite

From Figure 3 of the Modified compaction at variable blending proportions, one can see that the optimum blending proportion to be 20% by mass proportion. In order to cure the stabilized material air curing technique was used. Air cure technique is used to stabilize samples by gradual moisture content reduction, instead of the usual water curing technique or water submergence method which has been a common practice for past experiments [1]. In the air curing method the

specimens were prepared and wrapped in a polyethylene film and stored in a controlled environmental condition for the specified curing period, i.e. zero, three, seven, fourteen and twenty eight curing days. For this optimum blending proportion strength test, i.e. California bearing ratio test was conducted by giving zero, three, seven, fourteen and twenty eight air curing days for the soaked and unsoaked condition. After air curing, the samples prepared for the soaked condition were immersed in water for four days before penetration.

RESULTS AND DISCUSSION

Table 4 shows the CBR values for the soaked and unsoaked condition for zero, three, seven, fourteen and twenty eight curing days at the optimum i.e. at 20% volcanic ash content.

Table 4 Determination of CBR for different Curing times for the 20% Volcanic Ash/pumicite

Air Curing Time (Days)	CBR	
	Soaked	Unsoaked
0	98	118
3	128	165
7	178	210
14	181	221
28	245	307

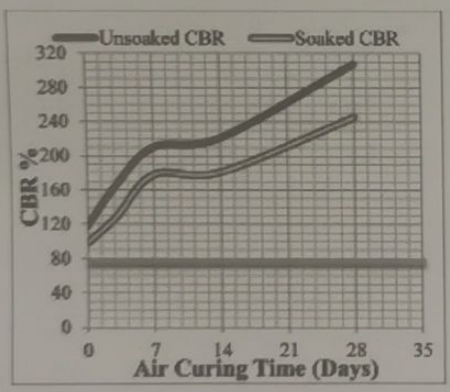


Figure 4 CBR vs. Air Curing time plot for Soaked/ Unsoaked Condition

From the CBR vs. Curing time plot for Soaked/ Unsoaked Condition shown in Figure 4, one can see that the CBR value increased for both conditions linearly and that soaking has decreased the CBR for all air curing days. The plot of the CBR vs. curing time showed higher values of CBR. By introducing 20% of the volcanic ash/Pumicite the CBR value of the cinder was improved from 59%to 98%.Table 4 shows the CBR values for the soaked and unsoaked condition for varying air curing days at the optimum i.e. at 20% volcanic ash content. It shows that the range of soaked CBR increases from 98% to 245% whereas for the unsoaked condition the CBR increases from 118% and 307%, for 0 to 28 days air curing period.

Figure 5 Cured and penetrated CBR Sample during Extraction (Left) and after Extraction (Right)



The picture presented Figure 5 shows how the cured and penetrated sample is stable and intact during extraction and after penetration. It shows that the penetrated sample was stable without disintegration which indicates that pozzollanic reaction was taking place during the curing period. The increase in strength along with the curing period is attributed to the fact that the material used as a stabilizer i.e. the volcanic ash/pumicite exhibits pozzollanic or cementation property. The plot also shows that seven to fourteen curing days was not sufficient time for reaction to take place for the soaked and unsoaked condition. But for the other curing periods the reaction time was sufficient as shown from higher CBR values for both conditions.

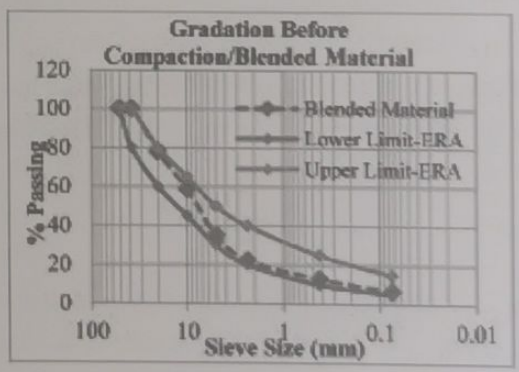


Figure 6 Gradation before compaction of the blended material

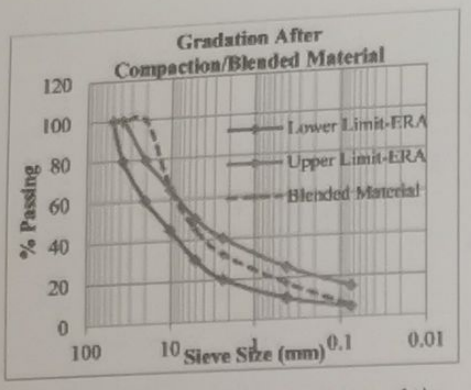


Figure 7 Gradation after compaction of the blended material

From the gradation curves forw the optimum blending proportion shown in Figures 6 and 7; one can see that the gradation before compaction falls within ERA specification Limit. For the coarser sieves, particularly sieve No.10 and above the percentage retained is small which makes it closer to ERA's specification upper limit for the naturally occurring granular base. For Sieves less than N.10 addition of 20% volcanic ash has improved the gradation of the natural cinder gravel by filling up its deficiency of fine material as was observed from the gradation curve of the natural cinder gravel.

From the gradation after compaction plot of the optimum blending proportion, the curve falls out of ERA specification limit starting from sieve No. 10 and above. This is due to the modified compaction effort used and the weak resistance to crushing of the aggregates of cinder gravel. Under laboratory conditions, the grading parameter falls outside of the limits set by ERA specifications. The grading of a material is used as an indicative measure of a material's capability to achieve a desired performance. Hence, the laboratory testing demonstrated that the stabilized material still achieved the strength requirements without having the correct grading then this should not be seen as a reason for rejection.

CONCLUSIONS

Although Cinder gravel is abundantly available in Ethiopia, it had not been widely used as a road construction material because of its failure to meet specification requirements. This study attempted to use Natural Pozzollana to stabilize Cinder gravel for a road base. The under listed conclusions are made from this study work:

- The gradation after compaction shows significant breakdown of Coarser cinder gravel particles.
- The blended road base material has no plasticity characteristics and the plastic product and the plastic modulus is zero.
- The property of cinder gravel is improved when blended with Natural Pozzollana, i.e. volcanic ash/pumicite.
- From the maximum dry density vs. percentage volcanic ash/pumicite plot, the optimum amount of Natural Pozzollana is 20%.
- The Volcanic Ash/Pumicite exhibits Pozzollanic property as shown from the physical tests i.e. Strength Activity Index and Unconfined Compression Strength tests.
- The Unconfined Compression Strength of the volcanic Ash/Pumicite increases significantly for 7 days when compared to 3 days while covered with a soft paper and sprinkled with water.
- Soaking has decreased the CBR for 0, 3, 7, 14 and 28 curing days when compared with the Unsoaked CBR value.
- The minimum soaked CBR is 98% at 4 days soaking and the peak soaked CBR value is 245% at 28 days for the optimum blending proportion.
- The blended material, i.e. 80% cinder gravel with 20% volcanic ash/pumicite could be used as a road base material.
- The rate of increment of CBR for the soaked condition is lower when compared to that of the unsoaked condition.
- The gradation before compaction of the optimum blending proportion falls within ERA specification limit.

- Curing plays an important role in the strength development of the blended material.

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