

STABILIZATION OF GRANULAR VOLCANIC ASH IN SANA'A AREA

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Abstract

This paper presents the findings of compaction and strength characteristics of a Granular Volcanic Ash from Sana'a city center, which was mixed with various percentages of two binders to form a stabilized material namely; fine soil and Portland cement. The study showed a significant improvement of the Volcanic Ash properties. The maximum dry density and California bearing ration (CBR) were considerably increased by addition of stabilizers at different rates for different binder contents. Optimum fine soil content for the maximum dry density and CBR is determined. A relationship between the optimum moisture content and the binder combination content for different fine soil percentages was established.

Keywords: Volcanic ash, California bearing ratio, Ordinary Portland cement, Maximum dry density, Fine soil.

1. Introduction

Soil stabilization is the alteration of one or more properties by mechanical or chemical means to create an improved soil material possessing the desired engineering performance. In stabilization, the main properties concerned are strength, compaction characteristics, durability and volume stability.

In the interest of economy, using the locally available materials is one of the main requirements in minimization of construction cost. Natural granular volcanic ash is available in large quantities at many parts and locations of Yemen and in particular at Sana'a city. It is usually used as a pavement courses or filling materials regardless of the lack in scientific information and studies concerning its engineering properties. This material is a cohesionless granular soil in nature contains very little or no fine material. In this regard the properties of the stabilized

Nomenclatures

C_c	Coefficient of curvature
C_u	Coefficient of uniformity
G_s	Specific gravity of solid
$L.L$	Liquid limit, %
$P.I$	Plasticity index, %
w	Moisture content, %

Greek Symbols

γ_d	Dry unit weight, kN/m ³
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cohesionless soil depend on many factors such as soil gradation, nature of stabilizer, stabilizer content, compaction and curing conditions [1-9]. In general, the strength and compaction characteristics of cement stabilized materials are increased with the stabilizer content, curing period and temperature [2, 5, 7, 10-13].

The present study concentrates on the investigation of Granular Volcanic Ash stabilized with various percentages of cement before and after mixing it with different percentages of a fine soil as a gradation improving agent and binder. Effect of cement and fine soil on the strength measured by California bearing ration (CBR), and compaction characteristics of the granular volcanic ash were studied.

2. Experimental Procedure

2.1. Materials

2.1.1. Granular volcanic ash

Granular volcanic ash was chosen from Sana'a city center area. It is available in surface layers of loose and un-cemented nature at a depth varies from 0.5 m to several meters. Gradation of the material differs from location to location, having a maximum size of about 25 mm with very little or no fine materials, finer than # 200 sieve. Chemical analysis and some of the index properties are given in Tables 1 and 2 respectively, the grain size distribution curve is shown in Fig. 1.

2.1.2. Fine soil

Fine soil is taken from Shamlan at Sana'a city center area is used as a binder and to correct the Granular Ash gradation. It is a light brown colored soil taken from a depth of 1.0-1.50 m below the ground surface. The gradation and some index properties are shown in Fig. 1 and Table 2 respectively.

Table 1. Chemical Analysis of Ash.

Parameters	SiO ₂	Al ₂ O ₃	Fe ₂ O	CaO
Percentage (%)	68.53	14.32	9.45	5.89

Table 2. Properties of Ash and Fine Soil.

Characteristics	Ash	Fine soil
Specific Gravity, G_s	2.23 *	2.71
Liquid Limit, $L.L$	N.P	38 %
Plasticity Index, $P.I$	N.P	15 %
Passing #200 Sieve	0.7 %	96 %
Clay Content	Non	13 %
Organic Matter	Nil	0.1%
Sulphate Content	Nil	Nil
Unified Classification System	GP	CL
AASHTO Classification System	A-1-a	A-4
Coefficient of Uniformity, C_u	10.6	-
Coefficient of Curvature, C_c	0.24	-
Wearing Percentage	56	-

* - The weighted average of fraction finer and coarser than # 4.

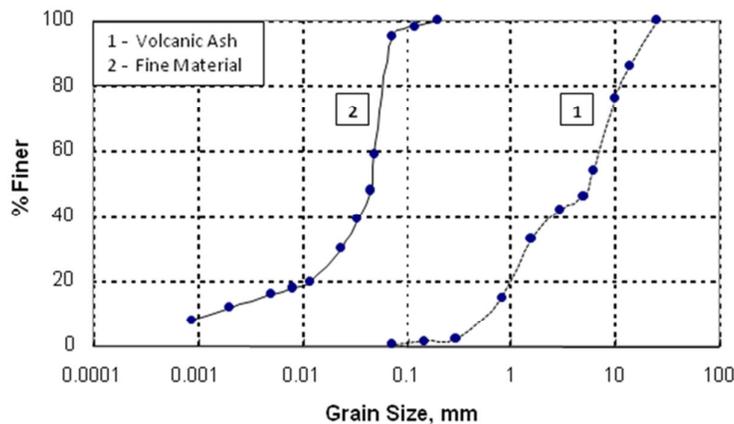


Fig. 1. Grain Size Distribution of Ash and Fine Material.

2.1.3. Cement

Ordinary Portland cement was used for treatment of the granular volcanic ash before and after its gradation correction.

2.2. Design of binders

Two binders were used; fine soil and Ordinary Portland Cement. Twenty mixtures were used in such a way to show the effect of each binder and combination of both at different mixing ratios. The fine soil contents used were 0%, 10%, 17%, 24%, and 31% with cement content of 0%, 3%, 6% and 9%. Since using the cement for the stabilization of Ash showed unsatisfactory results concerning the strength due to the soil nature (cohesionless or very little or no fine soil-poorly

graded), therefore it was decided to improve the gradation of the Granular Ash by mixing it with a fine soil as a binder prior to cement stabilization process.

2.3. Preparation of compaction and CBR specimens

The Granular Ash was prepared for the different mixtures in accordance with ASTM D1557-2000 [14] and ASTM D558-2011 [15]. Modified compactive effort was used for the different mixtures, and the process of mixing and compaction was performed within a time of less than 40 minutes after water addition to avoid any strength loss [1].

The stabilized compacted specimens of the various mixtures were cured at their molding water content for four days at the laboratory temperature ($21 \pm 2^\circ\text{C}$) before testing.

2.4. Strength tests

The California bearing ratio (CBR) tests were carried out to determine the specimens strength after completion of the curing period for all mixture compacted specimens.

3. Results and Discussion

The index properties of the Granular Volcanic Ash indicated that it is of a cohesionless soil nature with a low specific gravity. A low Maximum dry density and CBR were obtained for this material. Therefore the Ash was treated with a various percentages of cement to improve its properties namely; 3, 6, and 9%. Addition of cement up to 9% gave relatively low results of dry density and CBR of the stabilized material as shown in Fig. 2, and a higher percentage of cement is required to obtain a satisfactory result which is predicted as 25%. It is considered to be uneconomical quantity.

Fine soils of various percentages were added as a binder and to improve the Ash gradation in order to reduce the amount of cement required for stabilization. A fine content of 10, 17, 24 and 31% were mixed with the Ash in combination with cement percentages to determine the optimum fine content for different cement percentages.

3.1. Compaction characteristics

Figures 2 to 6 show the relation between the dry densities (γ_d), and molding water content (w) for the Ash mixed with 0, 10, 17, 24 and 31% of fine soil respectively, stabilized with various cement content. In general it can be seen that both the increase in dry density with the molding water content (slope of the curve) at the dry side of the optimum moisture content, and the decrease at the wet side of the optimum moisture content reduce and becomes less pronounced as the cement content increases, it is valid for all mixtures of different fine contents separately. This indicated that the densities of the mixture becomes are less sensitive to water addition as the cement content increases. This may be attributed to the filling of the voids between the ash particles by cement as a fine material, and increasing the fills resulting in a reduction in the water sensitivity [2]. Similar relationships were found by Kwon et al. [7] and by Yoon and Abu-Farsakh [16].

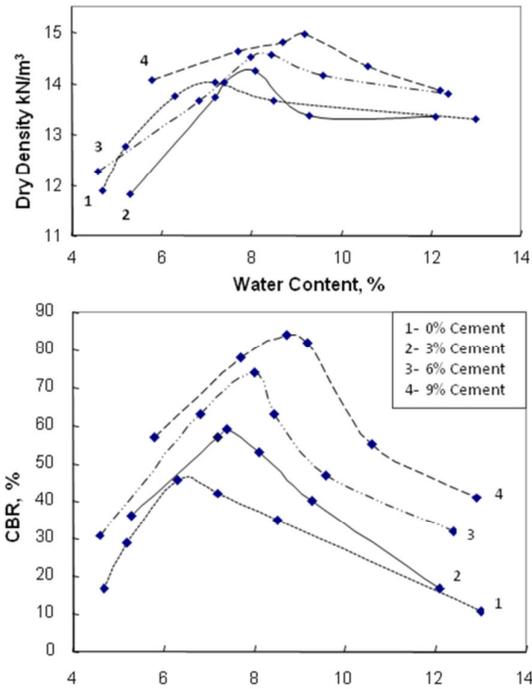


Fig. 2. Compaction and CBR Characteristics of (Ash + 0% Fine) Stabilized with Various Cement Percentages.

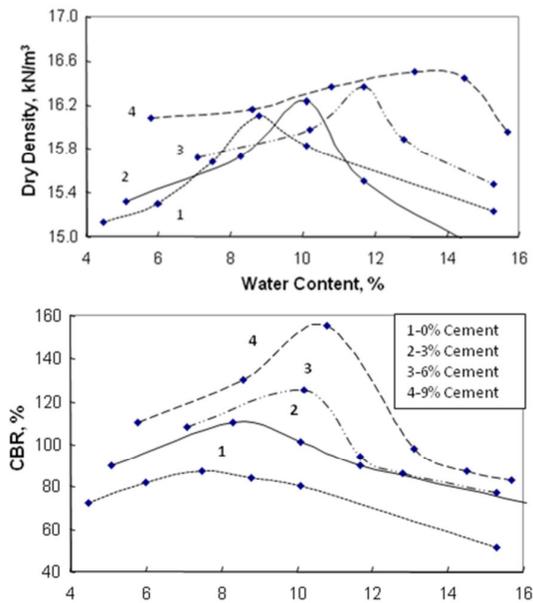


Fig. 3. Compaction and CBR Characteristics of (Ash + 10% Fine) Stabilized with Various Cement Percentages.

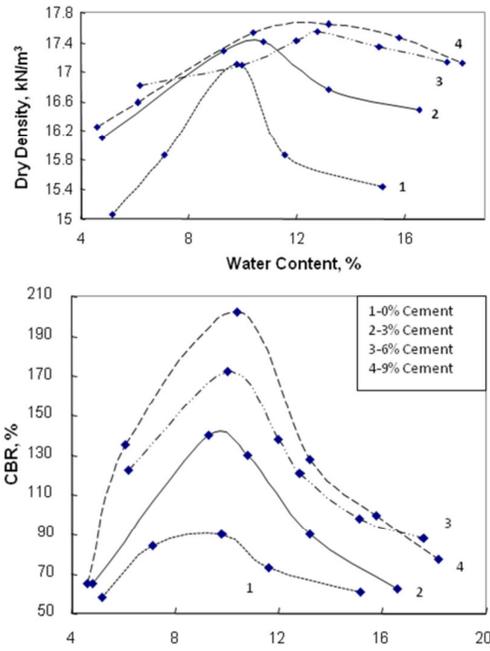


Fig. 4. Compaction and CBR Characteristics of (Ash + 17% Fine) Stabilized with Various Cement Percentages.

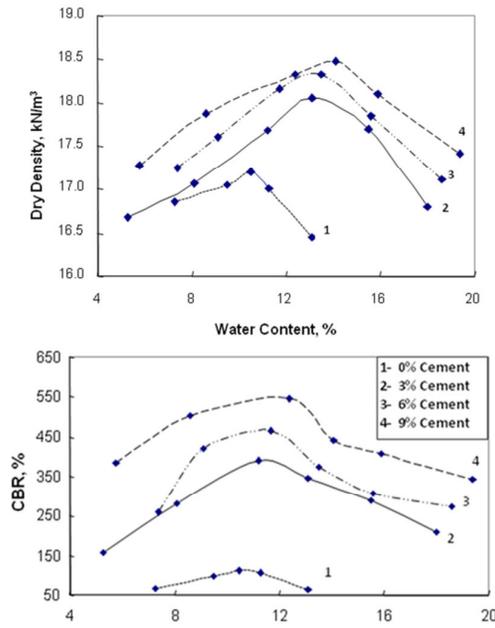


Fig. 5. Compaction and CBR Characteristics of (Ash + 24% Fine) Stabilized with Various Cement Percentages.

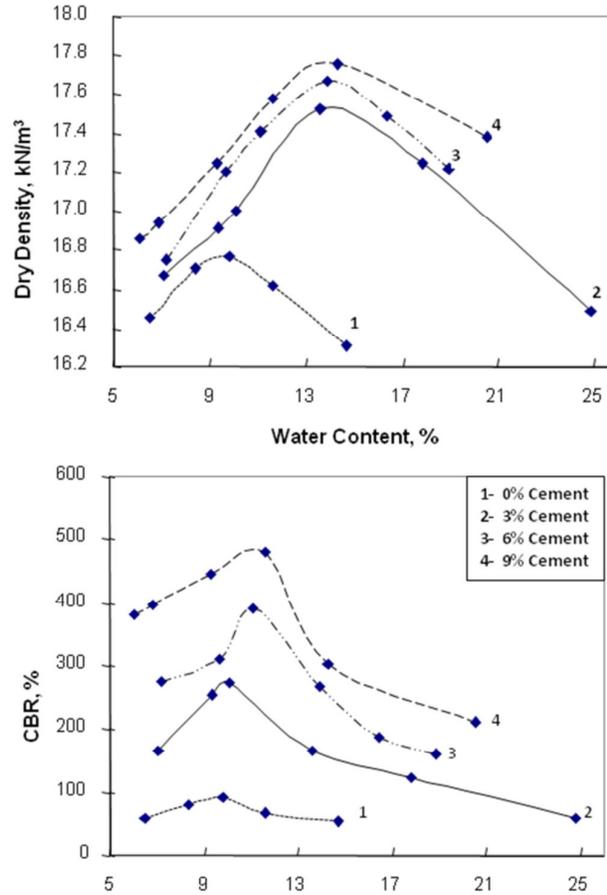


Fig. 6. Compaction and CBR Characteristics of (Ash + 31% Fine) Stabilized with Various Cement Percentages.

3.1.1. Effect of fine soil content

The effect of fine soil on the maximum dry density of untreated mixtures and those treated with 3, 6 and 9% of cement shown in Fig. 7. It can be seen that the maximum dry density increases with the fine content up to a certain value after which starts to decrease. Rate of increase of maximum dry density is lowered with the addition of percentages fine soil content. These behaviors are similar for the mixtures stabilized with the various cement contents. The optimum fine content is shown to be 24% for untreated and all treated ashes. Addition of fine soil fills the voids between the ash particles to increase the maximum dry density, while in case of percent more than the optimum it resulted in changing the material gradation toward a uniform soil nature which showing a reduction in density. Similar behaviors were shown by Kwon et al. [7].

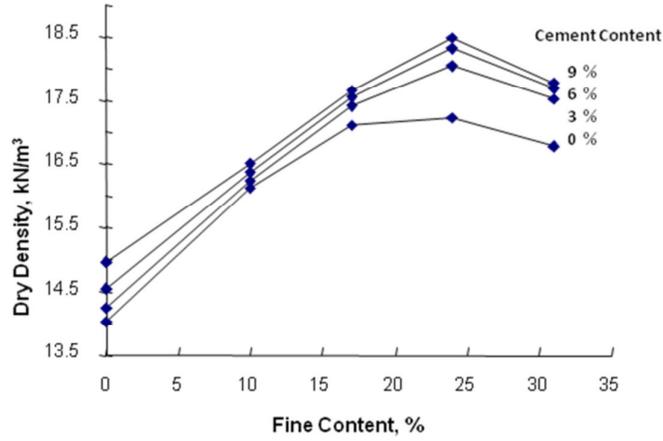


Fig. 7. Effect of Fine Material on the Maximum Dry Density of Stabilized Ash with Various Cement Contents.

3.1.2. Effect of cement content

Figure 8 indicated that in general; the maximum dry density increases linearly with the cement content, but at slightly different rates for different mixtures. This is due to a higher specific gravity of cement than those of ash and fine soil. Yoon and Abu-Farsakh [16] obtained similar relations.

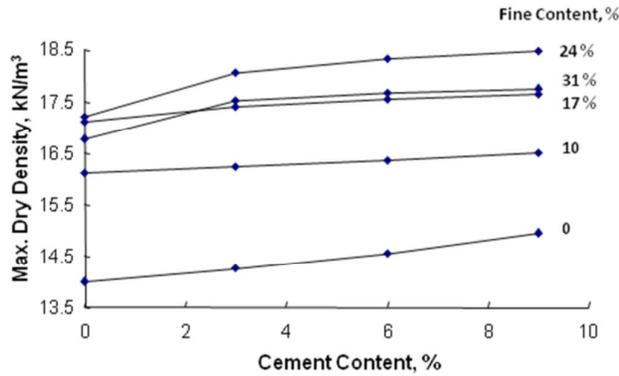


Fig. 8. Effect of Cement on the Maximum Dry Density of Stabilized Ash for Various Fine Contents.

3.2. Strength (CBR) characteristics

The relationships between the CBR and molding water content for ash mixed with 0, 10, 17, 24 and 31% of fine soil are shown in Figs. 2, 3, 4, 5 and 6 respectively.

In general; these behaviors are similar to the compaction curves of the same conditions. A similar behavior was concluded by Yoon and Abu-Farsakh [16] and by Kenai et al. [17].

3.2.1. Effect of fine soil content

The main objective of mixing the fine soil with ash was to improve the ash gradation and provide cohesion. Figure 9 shows an increase in fine soil content causes increase of CBR with accelerated rate up to certain value after which CBR starts to decrease. Similar behavior obtained for mixtures stabilized with different percentages of cement. The optimum fine content value is determined to be 24% for all mixtures although showing a different maximum CBR. Increasing CBR with fine soil is due to filling the voids between ash particles and increasing the density up to optimum value of fine soil after which decreases density and CBR correspondingly. Similar behavior was found by Layla and Ali [18] and by Kwon et al. [7].

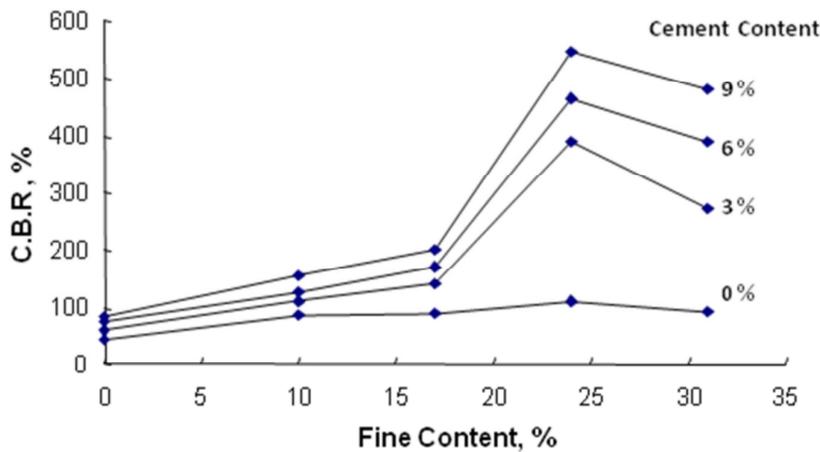


Fig. 9. Effect of Fine Material on the Max. C.B.R. of Stabilized Ash with Various Cement Contents.

3.2.2. Effect of cement content

The maximum CBR increases linearly with cement content for the mixtures having 0, 10 and 17% of fine soil as shown in Fig. 10. In case of 31% and 24% fine content mixture rate of increasing lowers for higher cement contents. This is due to the presence of a higher fine content which needs an increased percentage of cement.

Values of CBR up to 550 can be obtained for the stabilized Ash with 9% cement at the optimum fine content since the recommended CBR value for the cement stabilized road sub-base and base is 200 [2]. These results are with agreement with Yoon and Abu-Farsakh [16] and Kenai et al. [17].

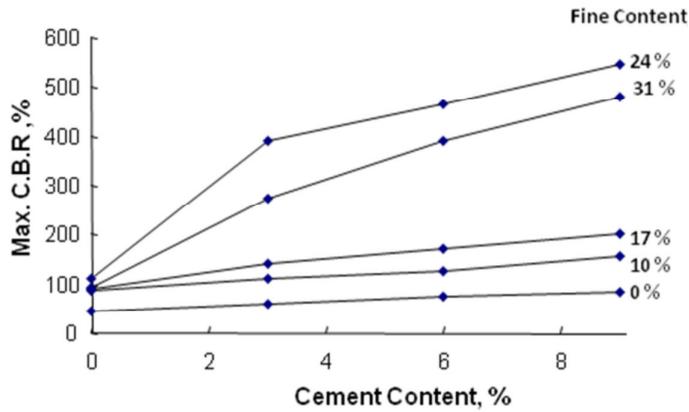


Fig. 10. Effect of Cement on the Maximum CBR of Stabilized Ash for Various Fine Contents.

The overall effect of (Cement + Fine Materials) content on the optimum moisture content of the stabilized ash for various fine contents is shown in Fig. 11.

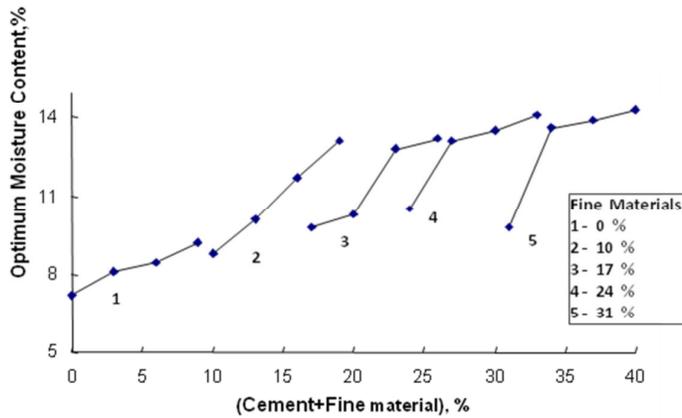


Fig. 11. Effect of (Cement + Fine Materials) Content on the Optimum Moisture Content of the Stabilized Ash for Various Fine Contents.

4. Conclusions

From this study the following conclusions can be drawn:

- The granular volcanic ash can be stabilized with cement successfully after improving its gradation by fine soil.
- The optimum fine content for maximum dry density and CBR for various fine contents is found to be 24%.

- The maximum dry density for mixtures of different fine contents increases linearly with cement content.
- The CBR increases linearly with the cement content for various fine contents.
- The content of the binders' combination (fine soil + cement) is direct proportional to the optimum moisture content for mixtures of different fine contents.
- A compaction and CBR results of a stabilized granular volcanic ash can be used for different engineering uses and in particular for road courses.

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