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AN EXPERIMENTAL STUDY OF THE SHEAR STRENGTH CHARACTERISTICS OF MARBLE DUST TREATED CLAYEY SOIL

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ABSTRACT

Soil treatment has commonly resorted in order to improve the strength, stiffness properties of road foundations, embankments & to reduce swelling potential of clayey soils. Therefore, chemical stabilization of soft clayey soils is essential. This paper deals with the study of variation of the shear strength parameters of clayey soil with different proportion of waste marble dust. Samples were prepared by uniformly mixing marble dust as 0,2,4,6,8 and 10% in the soil by its dry weight. The index properties and engineering properties were studied of untreated and treated soil samples. The parameters investigated include grain size distribution, consistency limits, compaction characteristics and triaxial shear parameters. The results highlighted the improvements in strength characteristics of marble dust treated clayey soil. Therefore, the study reinforces the concept of utilizing marble dust in clayey soils as much as possible in view of the site-specific requirements in order to decrease environmental pollution.

Keywords: Clayey soil; marble dust; consistency limits; triaxial shear characteristics.

I. INTRODUCTION

Soil stability is one of the important topics in the geotechnical engineering practices. Clayey soil is the type of soil that exhibits generally undesirable engineering properties. They tend to have low shear strengths upon wetting and other physical disturbances. Due to frequent failure of the soil on sloppy or leveled ground can be costly in the terms of life and property.To improve soils, various soil stabilization methods have been taken into consideration.Chemical stabilization is one of the widely used method. It involves mixing chemical additives with natural soils to remove moisture and improve strength properties of the soil. Generally, the role of the stabilizing agent in the treatment process is either reinforcing of the bonds between the particles or filling of the pore spaces.

This paper offers an attempt to study the effect of waste marble dust on the shear strength characteristics of clayey soil. In India, about 6 million tonnes of waste from marble industries are being released from marble cutting, polishing, processing, and grinding.Rajasthan alone accounts for almost 95% of the total marble produced in the country and can be considered as the world largest marble deposits. There are about 4000 marble mines in Rajasthan and about 70% of the processing wastes are being disposed locally. The marble dust is usually dumped on the riverbeds and this possesses a major environmental concern. In the dry season,the marble dust dangles in the air, flies and deposits on vegetation and crop. All these significantly affect the environment and local ecosystem. The marble dust disposed in the riverbed and around the production facilities causes a reduction in porosity and permeability of the topsoil and results in water logging. Further, the fine particles result in poor fertility of the soil due to increase in alkalinity. Attempts are being made to utilize marble wastes in different applications like road construction, and asphalt aggregates, cement and other building materials (Pappu *et al.*, 2006).

Strength development of clayey soil is a method of improvements of geotechnical properties of soil. For the present study, laboratory experiments were conducted on marble dust treated soil samples. 2, 4, 6, 8 & 10% marble dust was added to clayey soil. Proctor characteristics, consistency limits and triaxialshear parameters were followed as per Indian Standard Code.

II. OBJECTIVES

The objectives of the study are:

1. To investigate the use of marble dust as stabilizer and enhancer in the geotechnical behaviour of the clayey soils.
2. To explore optimum utilization of marble dust in such soils for two-fold advantage; one as reiterated above and second to solve the solid waste disposal problem of this waste material.
3. To have an insight into the effect of curing time on strength parameters of the soil mixed with marble dust.

III. MATERIALS AND METHODOLOGY

A. Materials

1. Soil

The soil used in this study was collected from a site situated in Sitarganj, Uttarakhand, India. The soil was sampled after removing the top layer of 50 centimeters. Laboratory tests were conducted to classify the soil. The particle size distribution of soil is shown in Fig. 1. The engineering properties of soil are summarized in Table-1.

Table 1. Physical properties of soil

. No.	Properties	Value
1.	Specific Gravity of Soil	2.53
2.	**Consistency Limits (%)**	
	Liquid Limit	27
	Plastic Limit	12
	Plasticity Index	15
3.	**Compaction Characteristics**	
	Optimum Moisture Content (%)	13
	Maximum Dry Density (kN/m^3)	17.71
4.	**Grain Size Distribution (%)**	
	Gravel	0.00
	Sand	7.56
	Silt	80.52
	Clay	11.92
5.	**Triaxial Shear Parameters**	
	Cohesion (kN/m^2)	19.86
	Angle of Internal Friction (degree)	17.49

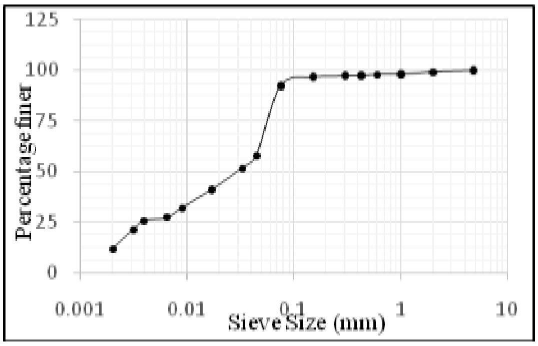

Fig. 1 Particle size distribution of soil

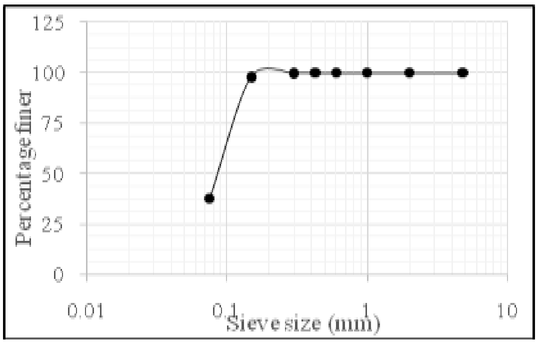

Fig. 2 Particle size distribution of waste marble dust

2. Waste Marble Dust

The marble dust was collected from the local market of Kishangarh in Ajmer, Rajasthan (India).The percentage of marble dust added to the soil was 0-10% at the increment of 2%. The mixing of soil, waste marble dust and water was done manually in a sample tray. The particle size distribution of marble dust is presented in Figure 2. A typical composition of marble dust is summarized in Table 2.

Table 2. Chemical composition of Waste Marble Dust (*After Saygili, 2005)

Elements	*Marble Dust (%)
SiO_2	0.02300
Al_2O_3	0.00380
TiO_2	0.00034
Fe_2O_3	0.00014
CaO	55.5600
MgO	0.26000
Na_2O	0.30100
K_2O	0.03700
SO_4	-
P_2O_5	0.07300
MnO	0.00210
LOI	42.4800

B. Methodology

A series of laboratory tests consisting of standard Proctor compaction, consistency limits and triaxial shear were performed on the untreated and treated soil. The percentage of marble dust added to the soil was 0-10% at the increment of 2%. The mixing was done by hand and the mixture is allowed to cure overnight in airtight polythenes for proper blending.

1. Compaction Tests

The method given in the IS: 2720 (Part-7) was used to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of soil. Tests were performed on treated and untreated soil. The data obtained from compaction tests were further used in making of triaxial shear samples.

2. Consistency Limits

Liquid limit, plastic limit and plasticity index of untreated and treated soil with marble dust were determined according to the IS: 2720 (Part-5).

3. Triaxial Shear Tests

The unconsolidated undrained (UU) triaxial tests were conducted on soil and soil mixed with marble dust as per IS: 2720 (Part-11).

IV. RESULTS & DISCUSSION

C. Compaction Characteristics

Figs. 3 to 5 highlight the trends of optimum moisture content (OMC) and maximum dry density (MDD)with increasing percentages of marble dust. The values of MDD and OMC are summarized in Table 3. These results revealed that in initial cases the addition of marble dust increased the OMC but decreased the MDD.

The initial drop in MDD is thought to result from the flocculated and agglomerated clay particles (caused by the cation exchange reaction) occupying larger spaces, thus increasing the volume of voids and consequently reducing the weight-volume ratio. The smaller increase in density with 10% marble dust may be due to the replacement of soil particles in a given volume by particles of marble dust of comparatively higher specific gravity (2.78).

On the other hand, the increasing OMC with increasing marble dust content is thought to result from the increasing desire for water (as marble dust content increases), as more water is requiredfor the formation of the lime-like product$Ca(OH)_2$, and dissociation of this product into$Ca^{2+}$and OH^{-}ions, in order to supply more Cafor the cation exchange reaction.

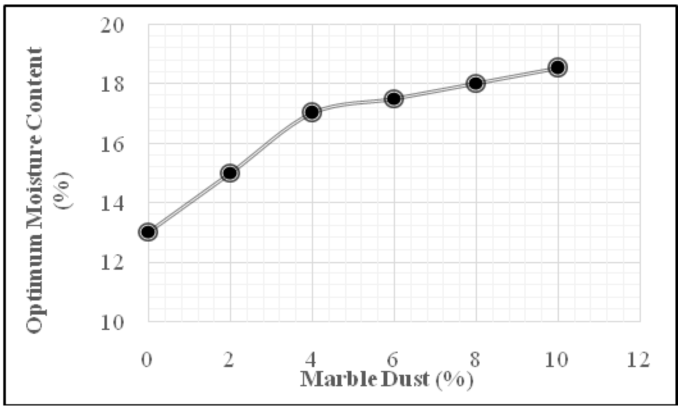

Fig. 3. Variation of Proctor characteristics with marble dust contents

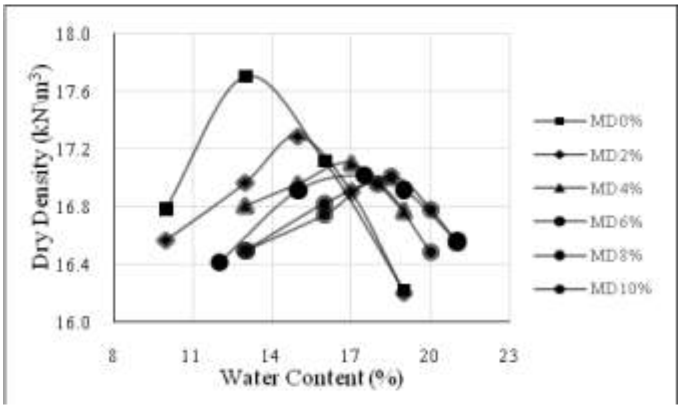

Fig. 4. Variation of OMC with marble dust contents

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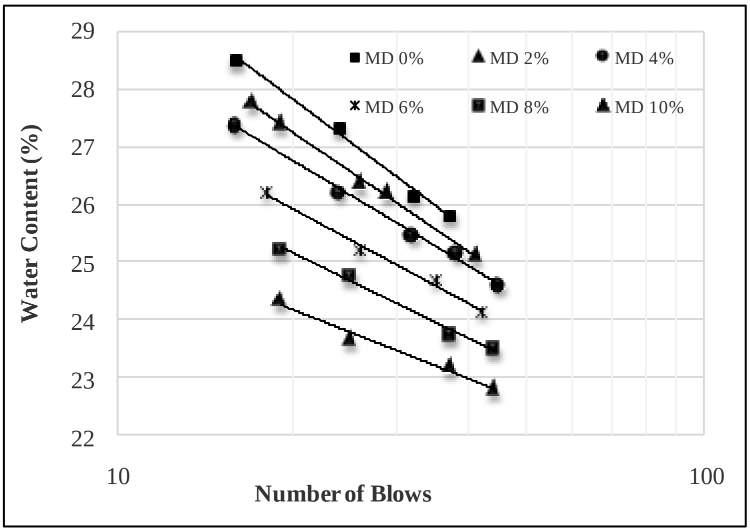

Fig. 5. Variation of MDD with marble dust contents

Table 3. Variation of MDD and OMC with percentages of marble dust

Marble Dust (%)	MDD (kN/m^3)	OMC (%)
0	17.71	13
2	17.29	15
4	17.10	17
6	17.02	17.5
8	16.96	18
10	17.01	18.5

D. Consistency Limits

The flow curves for both untreated and treated soils are presented in Fig. 6. The variation of consistency limits and plasticity index is presented in Table 5.

The results showed that liquid limit decreased from 27.06% to 23.79% while plastic limit increased from

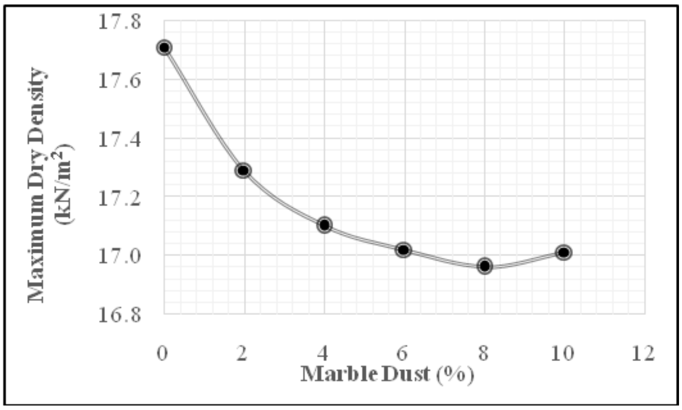

Fig. 6. Variation of liquid limits with marble dust contents

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11.76% to 14.19% with the addition of marble dust. Also, the plasticity index was reduced from 15.30% to 9.60%. The decrease in plasticity index indicates an improvement in the workability of the soil.

The decrease in liquid limit is thought to result due to the decrease in interparticle repulsion. As the repulsion is decreased, the particles become free to move at lower water content or lower interparticle distance.

Table 4. Variation of consistency limits with marble dust contents

Marble Dust (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	27.06	11.76	15.30
2	26.57	12.39	14.18
4	26.15	12.65	13.50
6	25.40	13.10	12.30
8	24.66	13.70	10.96
10	23.79	14.19	09.60

E. Triaxial Shear Parameters

Fig. 7 shows the variation of modified shear parameters. The angle of internal friction increased with the increase in marble content. The angle of internal friction increased from 17.49^o to 28.24^o, but the cohesion decreased from 19.86 kPa to 14.88 kPa. These findings confirm previous results of Saygili, 2015.

The decrease in cohesion is thought to be resulted from the reduction of clay content and due to shifting of grain size towards the coarser side. The reduction in clay-size particles is due to the flocculation and coagulation. The increase in internal friction is assumed due to ongoing marble dust-clay reaction which modifies the pore size distribution by filling them with cementitious products.

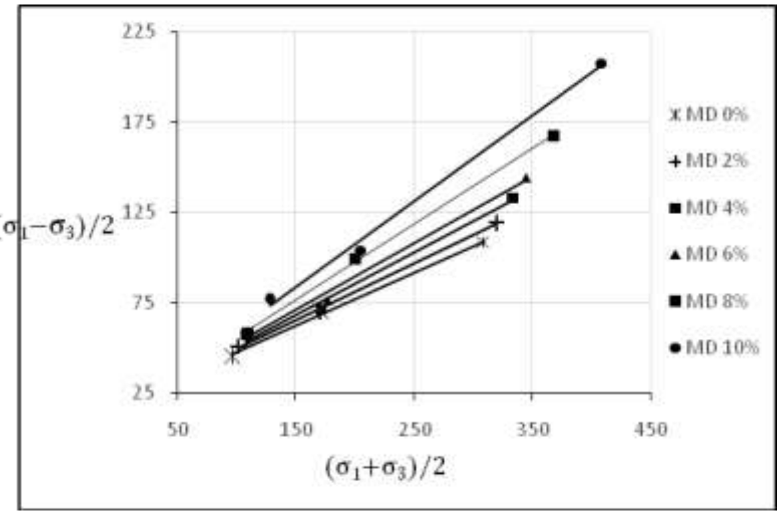

Fig. 7. Variation of modified shear parameters with marble dust contents

Table 5. Variation of shear parameters with marble dust contents

S. No.	Modified Failure Parameters		Triaxial Shear Parameters	
Marble Dust (%)	d	Ψ	c	ϕ
0	18.954	16.28	19.86	17.49
2	18.107	17.49	19.07	18.36
4	17.020	18.99	18.12	20.13
6	16.044	20.24	17.26	21.63
8	14.540	22.67	16.00	24.70
10	13.108	25.33	14.88	28.24

V.CONCLUSIONS

The following conclusions are drawn based on the results obtained.

1. The marble waste added to the specimens reduced the liquid limit and plasticity index of soil and increased their plastic limits.
2. The general assessment of compaction characteristics showed that marble dust addition decreased the maximum dry density of the samples. It also increased the optimum moisture content of treated soils.
3. The Triaxial shear results showed that the cohesion decreased while the angle of internal friction increased with the increase in marble dust.

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