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Sustainable Utilization of waste Marble Dust as a Chemical Stabilizer in Expansive Soils

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Abstract: This study investigates the use of waste marble dust in the improvement of geotechnical properties of expansive soils. Laboratory tests were undertaken to evaluate the behavior of waste marble dust on the physical & mechanical characteristics of expansive soils. Marble dust was added to the soil from 0-10% at the rate of 2% increment by weight of dry soil. Particle size distribution, compaction characteristics, consistency limits& California bearing ratio tests were performed on untreated and treated samples. The results showed that the expansive soil can be successfully stabilized by adding marble dust. This shows that utilizing marble dust in expansive soils is a new utilization area and will decrease environmental pollution.
Keywords: waste marble dust; expansive soil; California bearing ratio.

I. INTRODUCTION

Expansive soil is one of the problematic soil faced by many geotechnical engineers in the field. The expansive soil is known to cause severe damage to structures that are founded on it. Expansive soils are the soils which expand when the moisture content of the soil is increased and shrink when the moisture content of soil is reduced. The soil is generally dry because in such places, the water table is quite low. During rainy season, they becomes wet and get expanded resulting in severe damage. The damages may occur to buildings, roadways, pipelines and other structures founded on such soil if proper preventive measures are not adoptive.The expansiveness of soil is mainly due to its mineralogical composition. The clay mineral montmorillonite mainly attribute the swell-shrink phenomenon to the soil. The swell of montmorillonite occurs due to the weak bond between the stacks of sheet forming mineral. The basic structural unit consists of a alumina sheet sandwitched between two silica sheets. The two successive structural units are joined together by a link between oxygen ions of the two silica sheets. The link is due to natural attraction for the cations in the intervening space and due to the Vandar Waal forces. The negatively charged surfaces of the silica sheet attract water to the space between two structural units. This results in an expansion of the mineral (Arora, 2008).The behavior of soil also depends on the Atterberg limits. When the soil's natural moisture level is near the liquid limit (LL), the soils exhibit low strength and when the moisture content is near the Plastic limit (PL), greater strength results.The swelling behaviour of soil is also depicted by its specific surface area (SSA) and cation exchange capacity (CEC). The swelling increases with increase in SSA and CEC.This study offers an attempt to sustainably utilize the waste marble dust in expansive soil as admixture. In India, about 6 MT 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 is being disposed locally. The marble dust is usually dumped on the riverbeds and this possesses a major environmental concern. In dry season, the marble dust dangles in the air, flies and deposits on vegetation and crop. All these significantly affect the environment and local ecosystems. The marble dust disposed in the riverbed and around the production facilities causes reduction in porosity and permeability of the topsoil and results in water logging. Further, 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).

II. OBJECTIVE

The main aim of theresearch is to effectively stabilize the expansive soil by the use of waste marble dust. Some of the other objectives of study are listed below.

A. To investigate the use of marble dust as stabilizer and enhancer in geotechnical behaviour of expansive soils.
B. 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.

C. To look into and compare cost considerations for improving the behaviour of expansive soils mixing it with marble dust (an industrial waste) in place of conventional materials.

III. EXPERIMENTAL INVESTIGATION

A. Material Used

1) *Soil:*The soil used in this study was collected from a site near 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 distributionof soil is shown in Fig. 1. The engineering properties of clayey soil are summarized in Table 1.

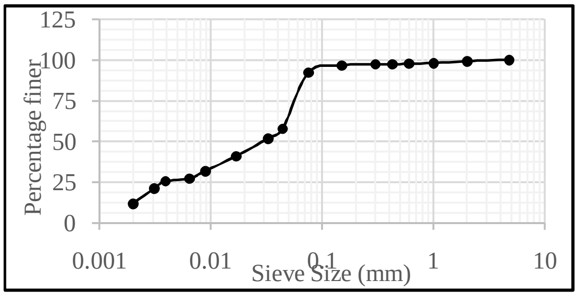

Fig. 1. Particle size distribution of studied soil

Table1. Physical characteristics of Soil

S. No.	Properties	Value
1)	Specific Gravity of Soil	2.53
2)	Atterberg Limits (%)	
i.	Liquid Limit	27
ii.	Plastic Limit	12
iii.	Plasticity Index	15
3)	Compaction Characteristics	
i.	Optimum Moisture Content (%)	13
ii.	Maximum Dry Density (kN/m^3)	17.71
4)	Grain Size Distribution (%)	
i.	Gravel	0.00
ii.	Sand	7.56
iii.	Silt	80.52
iv.	Clay	11.92
5)	Differential Free Swell (%)	40
6)	IS Classification	CL
7)	California Bearing Ratio (%)	
	Soaked	2.16
	Unsoaked	6.67

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2) *Marble Dust:* The marble dust was collected from marble cutting industry in Ajmer, Rajasthan, India. The mixing of soil, waste marble dust and water was done manually in a sample tray. The following tests were carried out to assess the effect of marble dust on soil: particle size distribution, specific gravity, Atterberg limits, standard Proctor test and California bearing ratio.After finding Atterberg limits, it was found out that marble dust is non plastic material. The specific gravity of marble dust was estimated as 2.78. The particle size distribution of marble dust is presented in Fig. 2. A typical chemical composition of marble dust is summarized in Table 2.

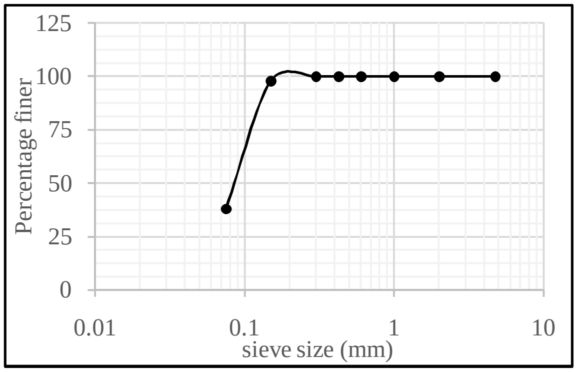

Fig.2. Particle size distribution of WMD

Table2. Chemical composition of WMD (* 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. *Laboratory Tests*

A series of laboratory tests consisting of standard Proctor compaction, consistency limits and California bearing ratio tests were performed on the untreated and treated soil samples. 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 air tight 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 was further used in making California bearing ratio tests samples.

II. RESULTS AND DISCUSSION

A. *Compaction Characteristics*

Figs. 3 and 4 highlight the trends of maximum dry density (MDD) and optimum moisture content (OMC) 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

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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.

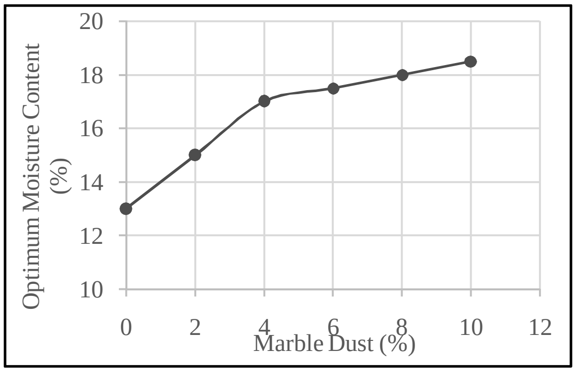

Fig.3. Variation of MDD with percentages of marble dust.

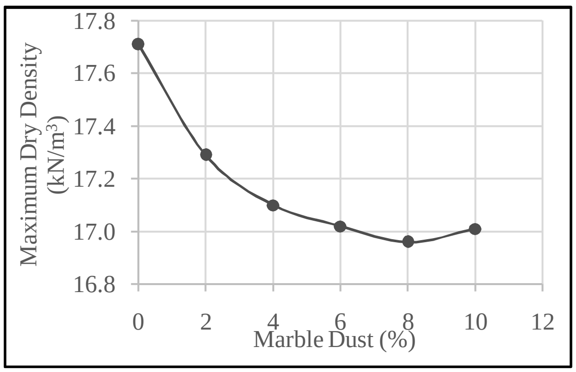

Fig. 4.Variation of OMC with percentages of marble dust.

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

B. Consistency Limits

The flow curves for both untreated and treated soils are presented in Fig. 5.

The results showed that liquid limit decreased from 27.06% to 23.79% while plastic limit increased from 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 values of consistency limits with different proportions of marble dust are indicated in Table 4.

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

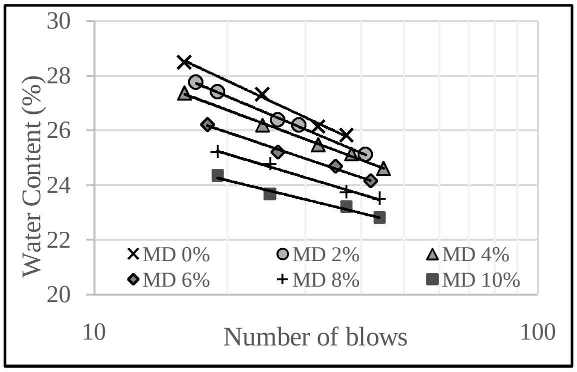

Fig. 5 Variation of flow curves with percentages of marble dust.

Table4. Variation of consistency limits with percentages of marble dust

Mix	Consistency Limits (%)		
	Liquid Limit	Plastic Limit	Plasticity Index
Soil + 0% MD	27.06	11.76	15.30
Soil + 2% MD	26.57	12.39	14.18
Soil + 4% MD	26.15	12.65	13.50
Soil + 6% MD	25.40	13.10	12.30
Soil + 8% MD	24.66	13.70	10.96
Soil+10% MD	23.79	14.19	9.60

C. California Bearing Ratio

Table 5 shows the CBR values of soil treated with different percentages of marble dust. The soaked values were also calculated after immersing the samples into water for 96 hours. The maximum value of CBR was recorded when soil was mixed with 8% marble dust. The values of unsoaked and soaked CBR are plotted in Figs. 6 and 7.

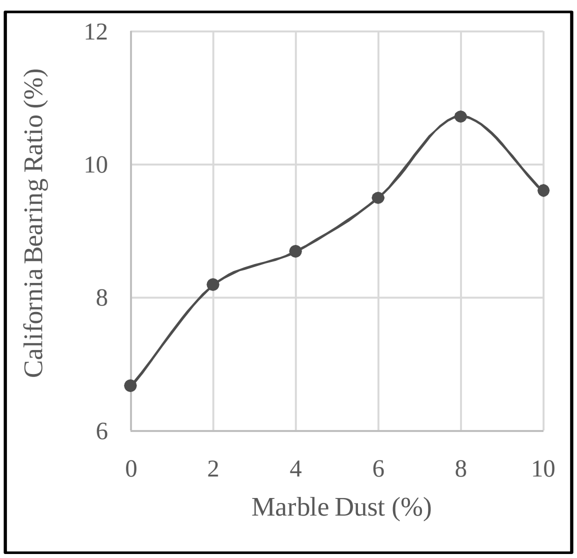

Fig. 6. Variation of unsoaked CBR with percentages of marble dust

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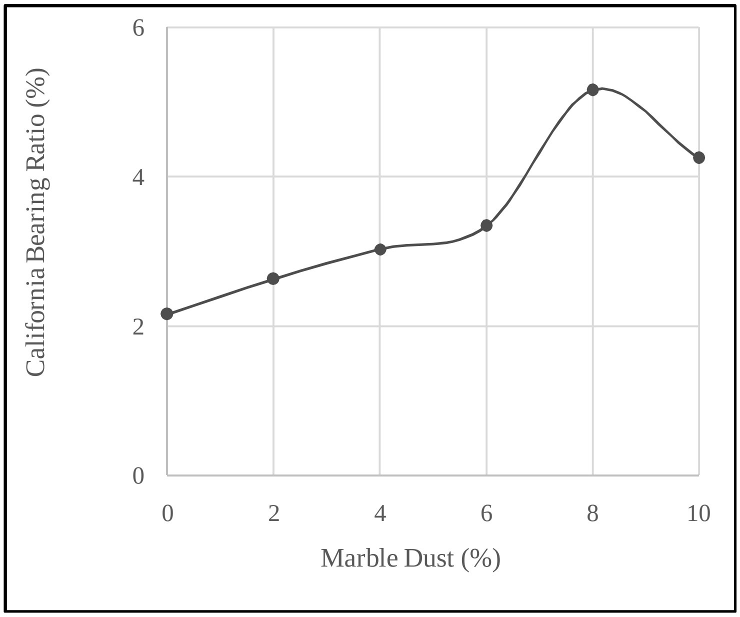

Fig. 7.Variation of soaked CBR with percentages of marble dust.

Table 5. Variation of CBR with percentages of marble dust

Marble Dust (%)	CBR (%)	
	Unsoaked	Soaked
0	6.67	2.16
2	8.19	2.63
4	8.69	3.03
6	9.5	3.34
8	10.72	5.16
10	9.60	4.25

III. CONCLUSIONS

The following conclusions are drawn based on the results obtained.

A. The evidence from this study points towards the improvement of clayey soil stabilized with marble dust, a waste product resulting from the quarrying and crushing of marble. Improvements are in the form of increase in California bearing ratio.

B. The findings from compaction tests indicate that maximum dry density is reduced with increased marble dust content. This is attributed due to the aggregation and flocculation of particles as a result of the reaction between marble dust and soil. The aggregated and flocculated particles occupies larger spaces, increasing the volume of void and consequently reducing the weight-volume ratio.

C. The increasing demand of water with increasing marble dust content is thought to result from the increasing desire for water, 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.

D. The addition of marble dust improved the CBR values. The improvement is more significant with increasing curing time. The stages of attainment of strength is thought to be similar to soil-lime mixture; that is, an immediate cation exchange reaction followed by a time dependent pozzolanicreaction, during which strength is developed. The reduction in CBR of the soils when the marble dust content exceeds the 8□□optimum value suggests that the excess marble dust is not used up in the marble dust–soil reaction. This implies that further addition of marble dust beyond that percentage is undesirable.

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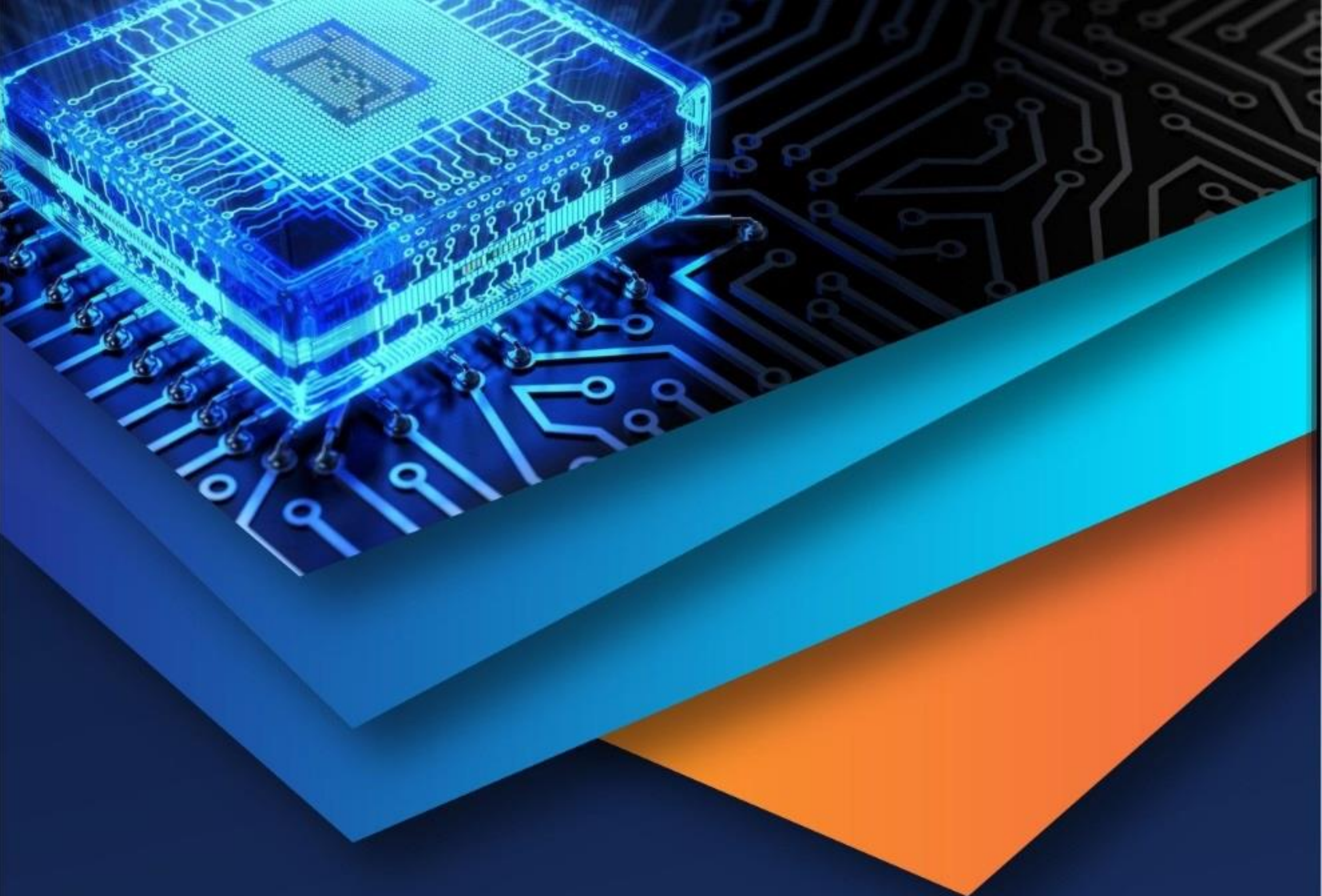

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