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Enhancement of engineering characteristics by use of marble slurry in Udaipur region

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ABSTRACT : : Marble powder is an excellent material for mechanical stabilization of cohesive soil. For proving this, various engineering tests were conducted with different soil samples of Udaipur region. Tested sample gave satisfactory results.

KEY WORDS : Marble dust, Soil, Stabilization, CBR value, Permeability

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Rajasthan is known as mineral majestic state as it produces more than 90 types of minerals and rocks. Marble – generally a white based elegant looking stone, geologically a thermally metamorphosed rock belonging mainly to precambrian rock formations of Rajasthan. It is spread over in 16 belts in 15 districts of the Rajasthan state. As a result, number of marble quarries as well as processing units has significantly grown up in last few years.

Marble industry is producing huge amount of powdered marble waste. The marble slurry waste generated during processing of marble can be estimated as about 10per cent of the total marble quarried. The waste produced is very fine but non-plastic and almost well graded. The particle size of powdered waste depends upon the strength of marble, the type of cutter or grinder and the pressure applied during cutting and grinding.

Large pieces of marble waste can be used as a stabilizer in embankment or pavement material or waste marble dust can be used as additives in some industries (paper, cement, ceramic etc.). But, only small portion of the waste marble products is utilized economically.

Some materials when used separately may not provide desired properties but when combined together, may produce satisfactory material. These methods of combining different materials range from preparation of soil aggregate mixture and simple compaction to application of admixtures, to thermal and electro-kinetic methods. The degree of stability depends upon shear strength which in turn, is a function of type and condition of soil.

The above method of stabilization will prove economical as the by product derived from extraction, sawing, polishing and water treatment of marble will be put to reuse. Recycling of this by product is a crucial demand by environmental laws in agreement with concept of sustainable development. In this study, the suitability of waste marble dust as a stabilizer for soil appears in Udaipur and Rajsamand region was investigated.

The mixture of cohesive and non cohesive soils, produce stable soil. The stabilization techniques which ensure stability without the addition of any foreign matter are termed as 'mechanical stabilization'. The marble powder although being non-plastic contains an appreciable amount of colloidal fraction that forms a gel which significantly reduces permeability and increases strength. Various researches made to investigate the effect on various engineering properties after addition of marble dust to soil. Some of them are reviewed. Joulani (2012) investigated the effect of stone powder on strength, compaction and CBR properties of fine grained soil. The variables of research were two additives and three percentages (10, 20 and 30%). The direct shear, compaction and CBR tests were conducted on soil by adding a specific percentage (10, 20 and 30%) of stone powder by weight of soil and mixed it with optimum moisture content obtained from compaction test without soaking or curing the specimen.

Sarkar *et al.* (2012) carried out a study on characteristics of pond ashes mixed with marble dust and various properties were investigated. In California bearing ratio test, firstly soaked CBR tests were conducted on pond ash alone. The CBR values obtained were 12.2, 10.4 and 13.2 per cent for Badarpur, Dadri and Rajghat pond ashes, respectively. After that it was observed that addition of marble dust in pond ash increases CBR value. CBR value increases linearly with increase in marble dust per cent. Misra *et al.* (2010) carried out work to study for bulk utilization of marble slurry dust (MSD) in soil stabilization during road construction. From Rajsamand district, Rajasthan (India), soil sample was collected from construction site at Sirola to Kucholi Road and MSD from site at Moonlight Marbles. From this study it was concluded that effect of mixing MSD (up to 40%) with soil resulted in minor changes in plasticity of soil but load bearing capacity (CBR test) of soil was improved. Dust made the soil slightly cohesive and resulted in better compaction. Unconfined compressive strength of soil with MSD was also improved CRRI, the researchers constructed a sub-grade layer and embankment using marble dust, a road stretch was constructed at Rajsamand district, Rajasthan and was under evaluation for three monsoon seasons.

The potential of marble dust as stabilizing additive to expansive soil was evaluated by Agarwal *et al.* (2011). The soil sample were prepared by replacing natural clay by 10 per cent bentonite to make it more expansive and then marble dust was added to prepare the samples from 0-30 per cent at an interval of 5 per cent (by weight).

Sabat *et al.* (2005) it stated that rice husk ash cannot be used alone for stabilization of soil due to lack of cementations properties (Haji Ali *et al.*, 1992). So it is used along with a binder like lime, cement, lime sludge, calcium chloride for stabilization of soil. This method is also described in Muntohar (1999), Haji *et al.* (1992), Rama Krishna and Kumar (2006), Basha *et al.* (2003), Chandra *et al.* (2005) and Sharma *et al.* (2008). The effect of marble dust on compaction, UCS soaked CBR, swelling pressure and durability characteristics of an expansive soil stabilized with optimum percentage of rice husk ash was studied.

Eskioglou (1996) evaluated the effectiveness of marble dust as a soil stabilizer. The study revealed that the geotechnical parameters of forest soils are improved substantially by the addition of marble dust. Significant PI reductions occurred with MD treatment, particularly for high PI soils. A research work was undertaken by Firat *et al.* (2012) in which it was observed that on addition of marble dust in two different soil samples increased the value of void ratio of the soil structure thus, increasing the permeability of the soils. The value of CBR values for saturated medium plasticity soil and low plasticity soil sample increased by 75 and 1 per cent, respectively. For unsaturated sample maximum CBR value was obtained at addition of 15per cent of marble dust. In a thesis submitted by Onur Baser (2009) it was observed that liquid limit of soil sample decreased as the stabilizer percentage increased. Decrease in liquid limit of soil sample was in the order of 18 per cent by minimum addition of stabilizers. The maximum reduction was 33.4 per cent for waste dolomite marble dust added sample. Plastic limit of soil sample increased as the stabilizer percentage increased. Increase in plastic limit of soil sample.

METHODOLOGY

The purpose of this study was to investigate the effects on available soil samples by addition of waste marble dust. The effects were studied by taking measurements of Atterberg's limits, shear strength, CBR value and permeability.

Material :

For this study, three soil samples were collected from Ayad village, Kanpur village and Fatehpura area of the Udaipur region. The samples were taken from a depth of 0.3-0.9m below the ground. Each sample was dried and passed through IS sieve 4.75 mm before usage and named S_1, S_2 and S_3, respectively. Waste marble dust was collected from Kelwa village in Udaipur district. It was passed through IS sieve 75μm before using it for preparing samples. Particle size of collected soil and marble dust samples are given in the Table A.

Table A : Particle sizes of various sample and marble dust

IS sieve	Particle passing per cent			
	Sample 1	Sample 2	Sample 3	Marble dust
12.5 mm	92.80	89.53	91.33	100.0
2.38 mm	70.19	62.67	55.67	100.0
.075 mm	36.74	14.47	5.07	88.0

Preparations of test samples :

Each sample was prepared by addition of waste marble dust to soil samples (S_1, S_2 and S_3) at a different percentage level and predetermined percentage of stabilizer varying from 0 to 30 per cent at an interval of 10 per cent (by dry weight of the sample).

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Sample properties without marble dust :

Atterberg limits :

To determine the index property Atterberg limit test and hydrometer test were performed according to IS 2720-part V and IV (1985), respectively. Soil properties and its classification as per unified soil classification system (USCS) are given in the Table 1. The test results are plotted on plasticity chart as shown in Fig. 1.

Table 1 : Atterberg limits and classification of soil samples without marble dust

Sample	L.L. (%)	P.L. (%)	P.I. (%)	Behaviour	S.L. (%)	UCSC
S_1	29.90	18.66	11.24	Medium plasticity	26.94	CL
S_2	28.26	21.36	6.90	Low plasticity	19.30	CL+ML
S_3	50.70	20.00	30.70	High plasticity	21.90	MH or OH

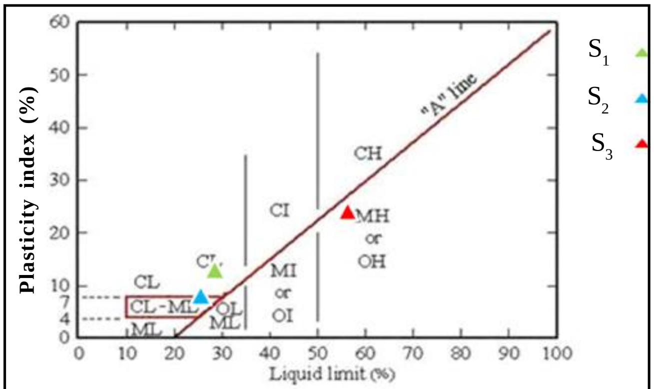

Fig. 1 : Classification of soil samples on USCS plasticity chart

The general trend obtained was decreased in liquid limit with increase in marble dust percentage. On the other hand, plastic limit of all soil samples goes on increasing with increase in marble dust percentage. As a result, plasticity index of each sample decreased with increase in marble dust percentage.

According to USCS, sample 1 comes under clay group with low plasticity. Addition of marble dust increased the silt fraction in the soil, thus, reducing both the plasticity index and liquid limit. The shrinkage limit decreased with increase in marble dust percentage.

Sample 2 comes under clay + silt group with low plasticity. In this case also, plasticity index and liquid limit both decreased with increase in marble dust percentage. Shrinkage limit increases with increased in marble dust percentage.

Sample 3 comes under silt or organic silt with high plasticity. Plasticity index and liquid limit decreased with increase in marble dust percentage in soil. It showed good compaction characteristics on addition of 30 per cent marble dust in it since the PI reduced to 18.30 per cent (near about 16). Shrinkage limit increased with increase in marble dust percentage.

Maximum dry density (MDD) and optimum moisture content (OMC) :

Maximum dry density and optimum moisture content were obtained by performing standard proctor test and results are tabulated in Table 2 along with the graph as shown in Fig. 2, 3 and 4. For sample 1, MDD and OMC both decreased with increase in marble dust percentage. On addition of 30 per cent MD, maximum dry density thus maximum compaction was achieved at only 8 per cent of water (by weight of sample).

For sample 2, from the values obtained from standard proctor test MDD increased very slightly while OMC remained constant with increase in marble dust percentage.

For sample 3, minimum MDD and maximum OMC were obtained on addition of 20 per cent marble dust. From the results of compaction test, it can be deduced that addition of 305 of marble dust will give satisfying compaction at 10 per cent of OMC.

Table 2 : Standard proctor test results

Sample	MDD (g/cm^3)	OMC (%)
S_1	1.945	7
S_2	2.047	10
S_3	1.745	9

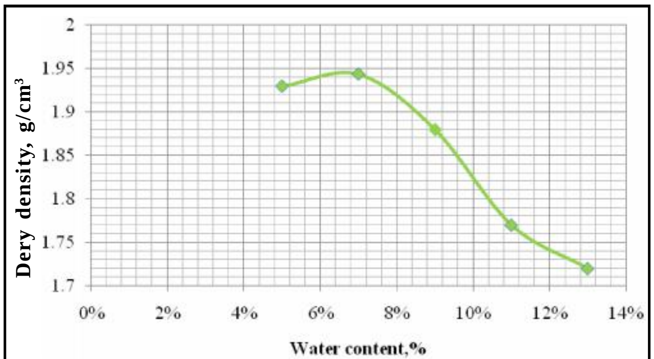

Fig. 2 : Compaction curve for sample 1

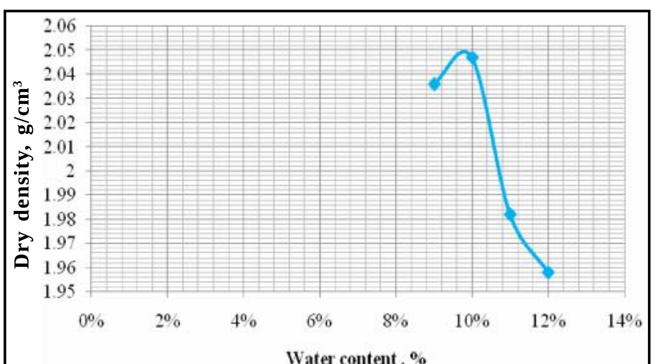

Fig. 3 : Compaction curve for sample 2

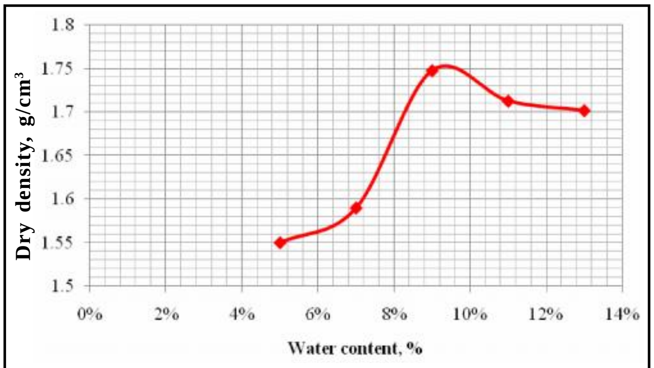

Fig. 4 : Compaction curve for sample 3

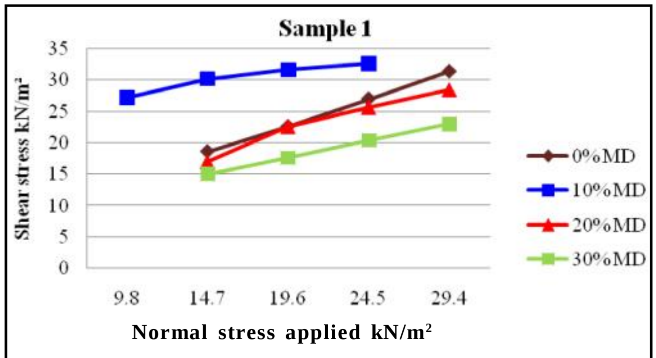

Fig. 5 : Shear stress v/s normal stresses applied for S_1 with different marble per cent

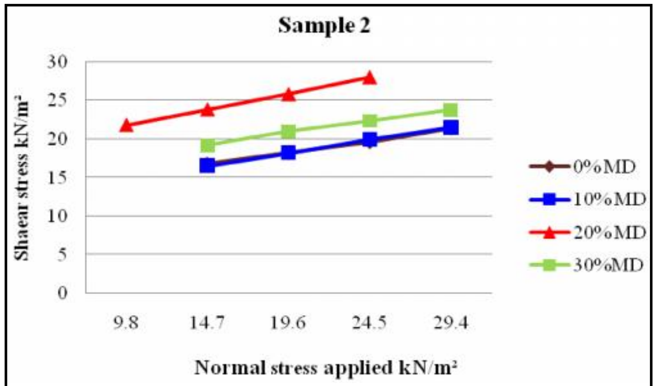

Fig. 6 : Shear stress v/s normal stresses applied for S_2 with different marble per cent

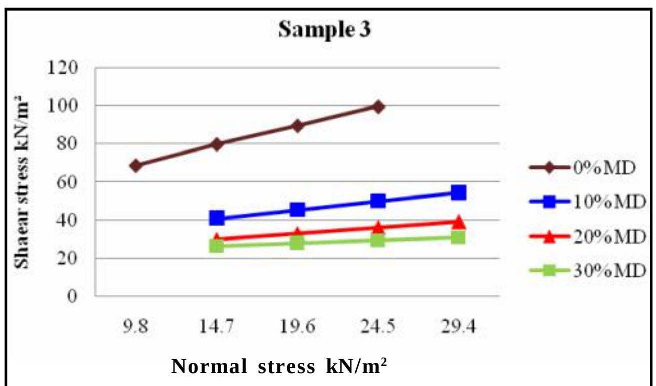

Fig. 7 : Shear stress v/s normal stresses applied for S_3 with different marble per cent

Shear characteristics :

Shear properties of soil samples were obtained by performing direct shear test. Results obtained are tabulated (Table 3). Angle of frictional resistance and cohesion was obtained by plotting the results on graph as shown in Fig. 5, 6 and 7. In case of sample 1, it was observed that with increase in percentage of marble dust (10, 20 and 30%), angle of friction (Φ) became constant while the cohesion value (c) decreased. Thus, shear strength decreased due to decrease in cohesive forces being highest at 10 per cent MD. In case of sample 2, similar trend was followed by angle of friction (Φ) but cohesion (c) increased with increase in percentage of marble dust in soil sample. In case of sample 3, both the value of angle of friction (Φ) and cohesion (c) decreased on increase in percentage of marble dust in soil sample.

Table 3 : Direct shear test results

Sample	Normal stress applied (kN/m²)	Corresponding shear stress (kN/m²)	Angle of frictional resistance Φ (degree)	Cohesion c (kN/m²)
S_1	14.7	18.6	42°	5.6
	19.6	22.6		
	24.5	27.0		
	29.4	31.4		
S_2	14.7	16.8	16°	12.6
	19.6	18.2		
	24.5	19.6		
	29.4	22.4		
S_3	9.8	68.6	45°	64.2
	14.7	79.8		
	19.6	89.6		
	24.5	99.6		

The CBR values and permeability co-efficient :

Properties like CBR value and permeability were also obtained by performing CBR test and constant head permeability test, respectively. Results obtained are shown in Table 4 and Fig. 8, 9 and 10. The optimum amount of marble dust in sample 2 at which maximum CBR value obtained was 10 per cent. For sample 1 and sample 3 optimum amount of marble dust obtained as shown by test results was 20 per cent. It was observed that for all samples permeability co-efficient decreased with increase in marble dust percentage. From the values of co-efficient of permeability it was deduced that sample 1 and sample 2 soil are semi-pervious in nature while sample 3 soil comes under impervious category.

Table 4 : CBR values and co-efficient of permeability of samples

Sample	CBR value	Co-efficient of permeability, k (cm/sec)	Classification on basis of permeability
S_1	4.21	2.17×10^{-5}	Semi-pervious
S_2	2.16	3.55×10^{-5}	Semi-pervious
S_3	2.53	6.36×10^{-6}	Non-pervious

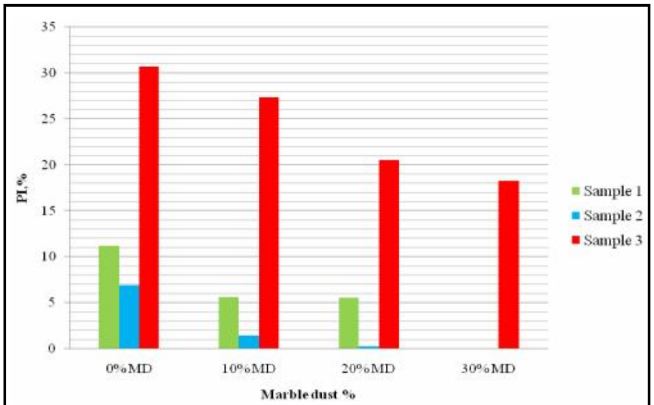

Fig. 8 : Variation in PI with MD per cent for different samples

CBR value :

Test results for CBR value are shown Table 5 and a comparative chart are plotted showing the variation of CBR value with MD per cent in Fig. 9 and 10.

Table 5 : CBR values variation with increase in MD Per cent

Sample	MD Per cent	CBR value
1	0	4.21
	10	4.96
	20	5.75
	30	4.90
2	0	2.16
	10	5.17
	20	3.25
	30	0.56
3	0	2.53
	10	3.30
	20	5.05
	30	2.68

Conclusion :

It was observed that the plasticity index and liquid limit decreased while the shrinkage limit increased with increase in the marble dust percentage in the soil sample. MDD and OMC

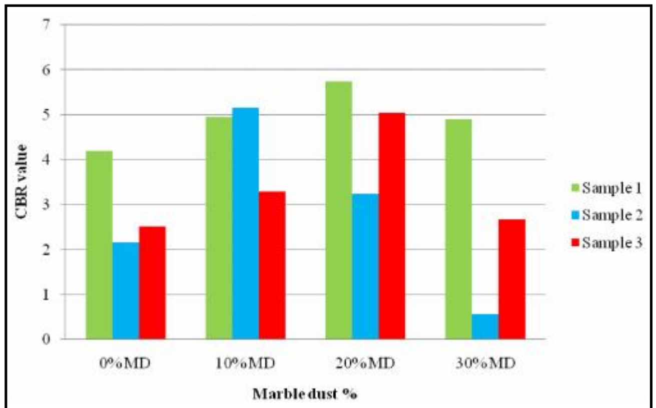

Fig. 9 : Variation in CBR value of samples with increase in MD per cent

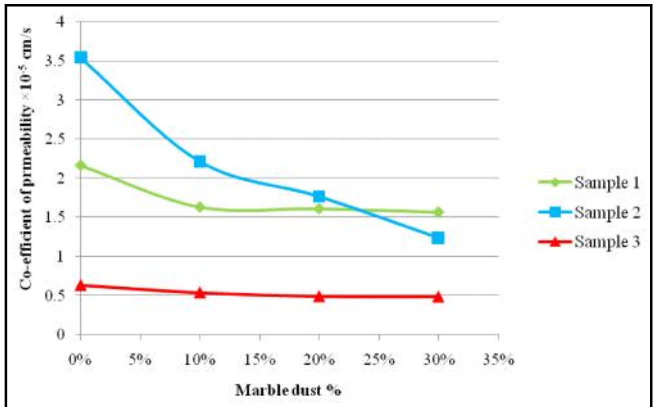

Fig. 10 : Decrease in co-efficient of permeability with increase in MD per cent

both decreased with increases in marble dust percentage. From CBR test, the optimum percentage of marble dust was found 10 per cent for S_2 and 20 per cent for S_1 and S_3.

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