Enhancement of Shear strength and California Bearing Ratio of Cohesive Soil by Inclusion of Marble Slurry in Udaipur & Rajsamand Region

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***Abstract*-Marble powder is an excellent material for mechanical stabilization of cohesive soil. A test was conducted for studying the outcomes of various engineering such as CBR values and shear strength when the marble slurry is mixed with different soil samples. It was found that addition of marble slurry at the rate of 20% in soil can improve the soil stability. Hence from the study, Marble slurry can be recommended for road and embankment construction. Use of marble slurry with soil can be a sustainable solution for its disposal.**

Key words: Marble Dust, Soil, Stabilization, CBR value, Shear Strength.

I. INTRODUCTION

Soil Stabilization is a needful component for improving soil strength and increasing resistance to softening by water through bonding of available local soil for mass construction.A massive earth work is necessary for filling the sides of the road. In the past few years, utilization of by-product and industrial solid wastes has been the focus of many researchers (Tara et. al. 2010). For construction of road, various type of by-productwas recommended as construction material.

Rajasthan is full of non-homogeneity and anisotropy of soil masses. The production of building stones is one of the important earning sources in the State of Rajasthan. Lime stone, marble stones are the main produce of the Aravalihills. The potential of stone industry is very large and this region contains mainly cohesive and cohesion less soil mass, rest is fragments of 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 quantities of powder as marble waste. The waste produced during cutting and grinding of marble is commonly known as marble slurry which is very fine but non-plastic and almost well graded. The particle size of the powdered waste depends on the strength of marble, the type of the cutter or grinder and the pressure applied during cutting and grinding. Hard marble and low cutting pressure produces finer particles and vice-versa. The marble powder although non plastic contains an appreciable colloidal fraction that forms a gel which significantly reduces the permeability and allows deformation without cracking which is desirable for any non permeable structure.

The mixture of non-cohesive and cohesive soils, produce stable soils. Hauser(1956) describes colloids as the particles smaller than 0.001 mm. Every mineral can be transformed into the colloidal state by simply grinding it. The colloidal fraction of the admixture, to soil can be imagined as a colloidal coating on the surfaces of the coarser soil particles. In the construction of earth dam, sub grade of roads and embankment, the property of colloidal particles to adsorb to a certain degree, some quantities of water and to expand, attracts the interest of soil and earth work engineers.

Khan (2005) suggested thatby addition of only 10% of marble waste, almost 100% increase in the CBR value and 23% increase in unconfined compressive strength was achieved for un-soaked condition. The plasticity index reduces by 48%. Nabil Al.Joulani (2012) concluded that addition of 30% of stone power increases angle of internal friction (ϕ) by about 50%, significant increase in CBR value and reduction in cohesion by about 64%. Misraet. al. (2010) indicatedthat 20-30% marble slurry dust in soil mass can replace sub- grade preparation. Load bearing capacity (CBR test) of soil improved with addition of marble slurry dust (MSD) up to 20% dust made soil slightly cohesive and resulted in better compaction of pavement layers. Sabat and Nanda (2011) studied effect of marble dust on strength and durability of rice husk ash stabilized expansive soils. The soaked CBR of rice husk ash stabilized expansive soil increased up to 20% by addition of marble dust. A.K Misra et al (2010) represents the result of changes in MDD by increase in percentageof marble dust with three different soil samples.

Large pieces of marble waste can be used as a stabilizer in embankment or road construction. 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.Marble dust, if used separately may not provide desired properties but when combined together, it may produce satisfactory material. The degree of stability of soil cum marble dust mixture is depending upon shear strength which is a function of types and conditions of soil. A test was undertaken to study the enhancement of engineering properties of soil mixed with varying level of marble dust.

II.MATERIAL AND METHOD

It was aimed to mix, marble slurry which is available in abundance in the adjoining area from where soil samples were collected. Procedure followed for carrying out the experiment is shown in Table.1. Three soil samples wereobtained at the depth range of 1.0-1.5m from ground surface from various places of Udaipur and Rajsamand Districts, Rajasthan.Geotechnical properties of the soil samples were determined as shown in Table.2. Two different samples of marble slurry were obtained from following industrial locations andphysio-chemical properties were determined, shown in Table.3.

1. Village Kelwa Dist. Rajsamand sample A.
2. Village Rishabdev District Udaipur sample B.

Table.1. Test procedure

1.	Sample collection	After collecting soil from site, it was brought to laboratory, the dry soil samples were prepared as per IS 2720 part I(1983) similarly marble slurry sample from gang Saw, & brought in the laboratory.
2.	Moisture content determination	As per 1S 2720 part 2 (1973), water content of soil samples and marble slurry sample were determined.
3.	Specific Gravity	The specific gravity of soil samples & marble slurry determined as per IS part 3(1980) and RILEM recommendation (1983)
4.	Particle size Distribution	Grain size analysis of soil specimen, determine for classification of soil as per IS.2720 (part 4) (1985) Grain size analysis of marble slurry also conducted in similar way.
5.	Shear Strength	The direct shear test on soil, marble slurry and soil MSD mixes were done as per IS 2720 part (13) 1986, to determine cohesion (c) and angle of internal friction (Ø) in un- drained condition, the test was conducted at constant rate of strain. To determine shear strength characteristics of soil mixes with MS, in terms of Mohr coulomb total strength parameters, namely cohesion (C) and angle of internal friction (Ø).
6.	Compaction Characteristics	Standard proctor test, the test performed on soil, Marble slurry dust and all mixes as per test program ,according to IS 2720 (Part 7) 1980
7.	California Bearing Ratio	CBR test performed on soil, marble slurry dust (M.S.D) and MSD mixes as per IS 2720 (part16) 1987 as CBR value corresponding to a penetration of 5mm exceeded that for 2.5mm, the was repeated and the reported result of bearing ratio are corresponding to 5mm penetration.

Table.2. Geotechnical Properties of soil masses [Sample 1, Sample 2, Sample 3]

S. No.	Properties	Source of Soil Mass from		
		Soil sample 1 (from Sakrawas)	**Soil sample 2 (from Bedwas)**	**Soil sample 3 (from Banoda)**
1.	Fine sand size (0.475-0.075)	37.5%	24%	29.5%
2.	Silt size (.075-.002mm)	42%	50%	52%
3.	Co- efficient of uniformity (Cu)	51.6	43.3	50.8
4.	Co- efficient of Curvature (Cc)	4.35	0.233	1.96
5.	specific Gravity	2.62	2.66	2.61
6.	Plastic Limit (%)	56.2	59.1	47.6
7.	Maximum Dry Density	1.74	1.78	1.79
8.	Optimum Moisture Content (%)	16.64	20.7	14.54
9.	C.B.R. Value (%) Un-Soaked Soaked	1.2 0.82	3.10 1.14	2.33 0.94
10.	Cohesion (kg/cm^2)	0.404	0.560	0.440
11	Angle of internal friction(°)	4.41	6.33	10.5

III.RESULT AND DISCUSSION

Variation in strength parameters of soil by Marble slurry mix

(a) Shear strength parameters **:**

Resistance developed in soil mass against shearing force is termed as Shear Strength, Cohesion (c) and Angle of Internal Friction (ϕ) as shear parameters. Both Parameters have been find out by Direct Shear test as per IS 2720(Part XIII).This test was performed on all soil samples passing 1.18mm IS sieve with respective marble slurry as per mentioned in Test Programme. Test were carried out with a strain controlled shear apparatus at strain rate of 1.25mm/min to determine failure stress and both shear parameters cohesion (c) and angle of internal friction(ϕ).Figure 1&2 shows value of 'c' and ϕ with different percentage of marble slurry dust in soil.

The X-axis (abscissa) being percentage of MS, Y-axis (Ordinate) contain friction angle (Degree), curve is a straight line variation, there is steep increase in value of friction angle above 20% MS, below this percentage there is increase in value of internal friction but slow increase is observed. This can be understand as gradation effect in soil mix due to marble slurry particles, which are of angular shape, low Plasticity Index (P.I.) make it favorable by mixing in soil mass.

Table.3. Geotechnical Properties of Marble Slurry Powder [Sample A & Sample B]

S.No	Property	Value
Sample A (Kelwa)		
1.	Specific Gravity	2.61
2	Liquid limit(%)	32
3	Plastic limit(%)	N.P.
4	Shrinkage Limit	14.0
5	Co efficient of UniformityC_u	68
6	Co efficient of curvature C_c	2.56
2.	Max, Dry Density (g/c.c.)	1.38gm/cc
3.	Optimum Moisture Content (%)	17.5%
4.	Cohesion(Kg/cm2)	N.P.
5.	Angle of internal friction(°)	35.4
6	C.B.R.(Un Soaked)	2.54
7	Coefficient of permeability k (cm/sec)	5.70×10^{-8}
Sample B (Rishabdev)		
1.	Specific Gravity	2.65
2	Liquid limit(%)	29.8
3	Plastic limit(%)	N.P.
4	Shrinkage Limit	12.9
5	Co efficient of Uniformity C_u	60
6	Co efficient of curvature C_c	2.86
2.	Max, Dry Density	1.46gm/cc
3.	Optimum Moisture Content	18.1%
4.	Cohesion(Kg/cm^2)	N.P.
5.	Angle of internal friction	39.2^0
6	C.B.R.(Un Soaked)	3.4
7	Coefficient of permeability k (cm/sec)	6.90×10^{-8}

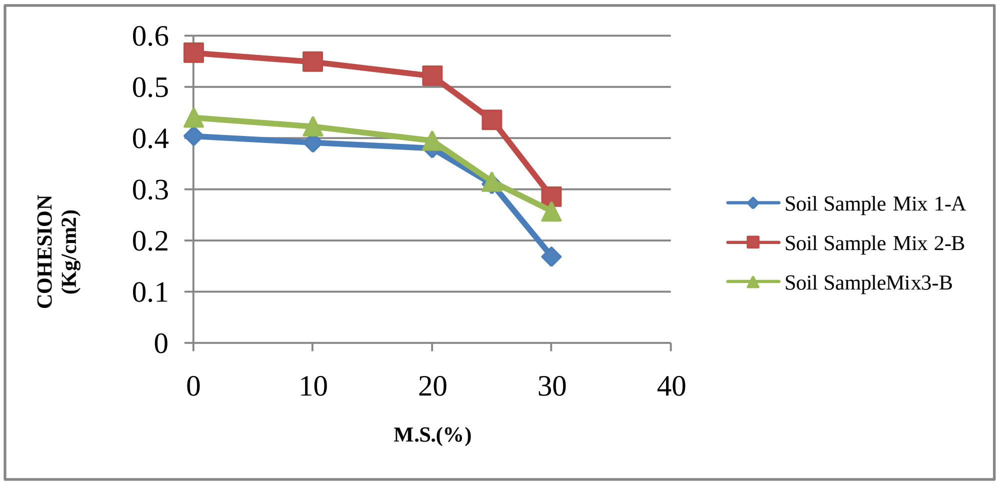

Fig.1 Variation in Cohesion (c) with different percentage of marble slurry, soil mix.1-A,2-B and 3-B

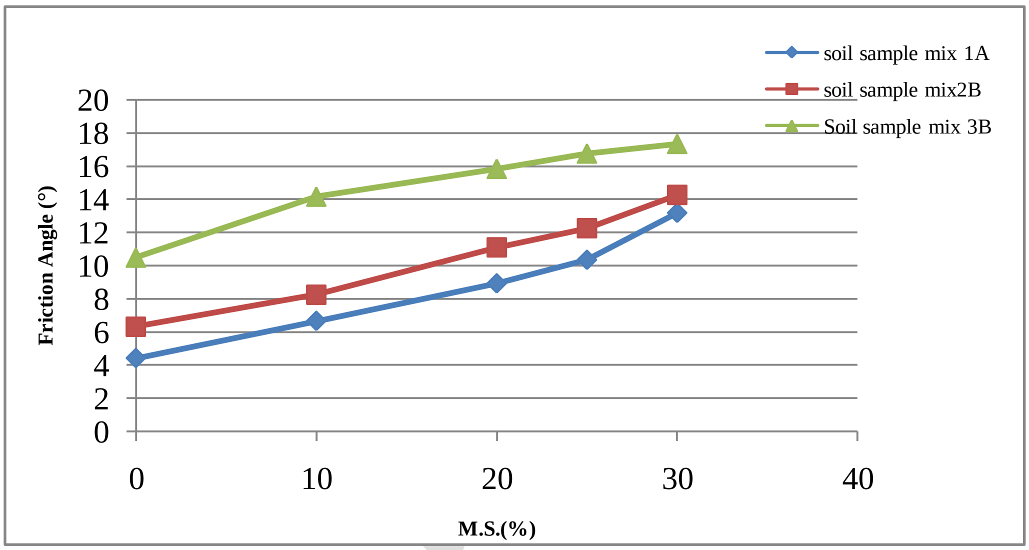

Fig.2 Variation in FrictionAngle **(ϕ)**with different percentage of marble slurry & soil.1-A,2-B and 3-B

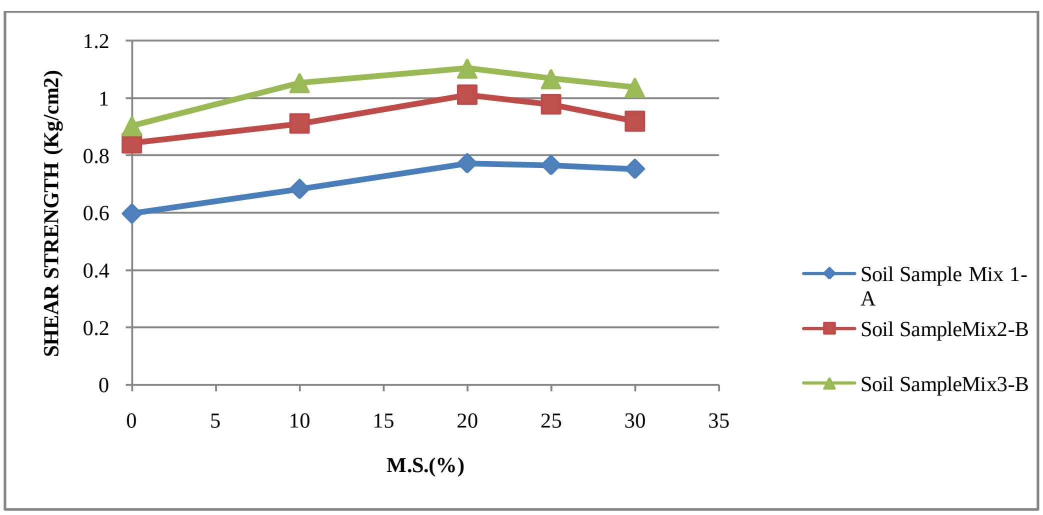

Fig.3 Variation in Shear Strengthwith different percentage of marble slurry, soil mix.1-A,2-B and 3-B

Shear strength of the soil samples were also measured at the varying level of marble slurry. It was found that 29.34% increment in shear strength at 20% M.S. in soil mix sample 1-A whereas at the same time 19.94% & 22.19% increment was found in shear strength for soil sample 2-B and 3-B respectively. The improvement in shear strength is attributed due to risein the value of angle of friction. It was found that as the value of cohesion (c) is falling down,shear strength first rising upto a critical point and after that it starts decreases. This characteristicdepends on the soil properties.

The shear strength envelop can be described by Mohr-Coulomb failure theory, utilized for calculating shear strength $s = \tau = c + \sigma \tan\phi$ for an instant value of soil particles, below 5m to ground surface, taking water table position 2m below, bulk unit weight 1.70 g/cc. The increase (enhanced) value of shear strength for all three tested soil is shown is Table 4to 6.

Table. 4: Enhancement of shear strength in soil sample 1, mix 1-A

S. No.	MSD	Cohesion (c)	Angle of internal (ϕ)	Shear Strength	Increase in Shear
	%	kg/cm^2	Degree	kg/cm^2	%
1	0	0.404	4.41	0.5968	-
2	10	0.391	6.65	0.6824	14.35
3	20	0.380	8.91	0.7719	29.34
4	25	0.311	10.33	0.7656	28.29
5	30	0.168	13.16	0.7525	26.08

Table.5: Enhancement of shear strength in soil sample 2, mix 2-B

S. No.	MSD	Cohesion (c)	Angle of internal (ϕ)	Shear Strength	Increase in Shear
	%	kg/cm^2	Degree	kg/cm^2	%
1	0	0.566	6.33	0.8432	-
2	10	0.549	8.25	0.9114	8.09
3	20	0.521	11.1	1.0114	19.94
4	25	0.435	12.26	0.9782	16.01
5	30	0.285	14.25	0.9199	9.08

Table. 6:Enhancement of shear strength in soil sample 3, mix 3-B

S. No.	MSD	Cohesion (c)	Angle of internal (ϕ)	Shear Strength	Increase in Shear
	%	kg/cm^2	Degree	kg/cm^2	%
1	0	0.440	10.5	0.9033	-
2	10	0.423	14.16	1.0523	16.62
3	20	0.395	15.83	1.1038	22.19
4	25	0.315	16.75	1.0672	18.14
5	30	0.257	17.33	1.037	14.78

b) Influence of marble slurry on CBR Value

To evaluate a sub grade or sub base material for pavement design, California Bearing Ratio (CBR) characteristic plays an important role. Deformation of soil specimen, predominantly shear in nature, CBR value can be regarded as indirect movement of strength. CBR measured as per is 2720 Part 16,1987.Theresults are shown in Fig. 4 to Fig. 6 and in Table.7 in un-soaked and soaked condition. From the Table.7, it can be observed that value of CBR under un-soaked conditionis ranging from 1.20 to 5.35, 3.10 to 5.55 and 2.33 to 4.10 which lie inmoderate range. Value of soaked CBR is quite less due to submergence in water for 48 days. There is rapid increase of CBR value under un-socked condition up to 20-25% inM.S. mixed soil sample 1 and mixed 1-A. CBR under un-soakedcondition is increasing up to 345.83% at 25% MS where asunder soaked condition, it was increased upto 179.2%.For soil sample 2 and 3, mix 2-B and 3-B,the rises in the CBR value is 146.77 and 75.96% respectively for un-soaked condition at 20% M.S. and after this value there is drop in CBR and this drop is quite rapid.For soaked condition, the CBR value increases for the same soil sample is 96.84% and 118.18% respectively. A non dimensional parameter, which is the ratio of CBR value of marble mixed soil over pure soil is termed as California Bearing Ratio Index (CBRI) for soaked and un-soaked conditions hasbeen measured with the help of CBR values. It is shown in Table 8 and Fig.7 and Fig.8.

Table.7. Variation in CBR value by increasing MS % in pure soil

S. No.	MS (%)	Soil Sample		Soil Sample 2		Soil Sample 3	
		Mix 1-A		Mix 2-B		Mix 3-B	
		Un-soaked	Soaked	Un-soaked	Soaked	Un-soaked	Soaked
1	0	1.20	0.82	3.10	0.95	2.33	0.55
2	10	2.20	0.97	4.85	1.35	3.25	0.87
3	20	4.10	1.28	7.65	1.87	4.10	1.20
4	25	5.35	1.47	5.55	0.98	3.85	1.0
5	30	3.80	0.97	3.90	0.57	2.65	0.49

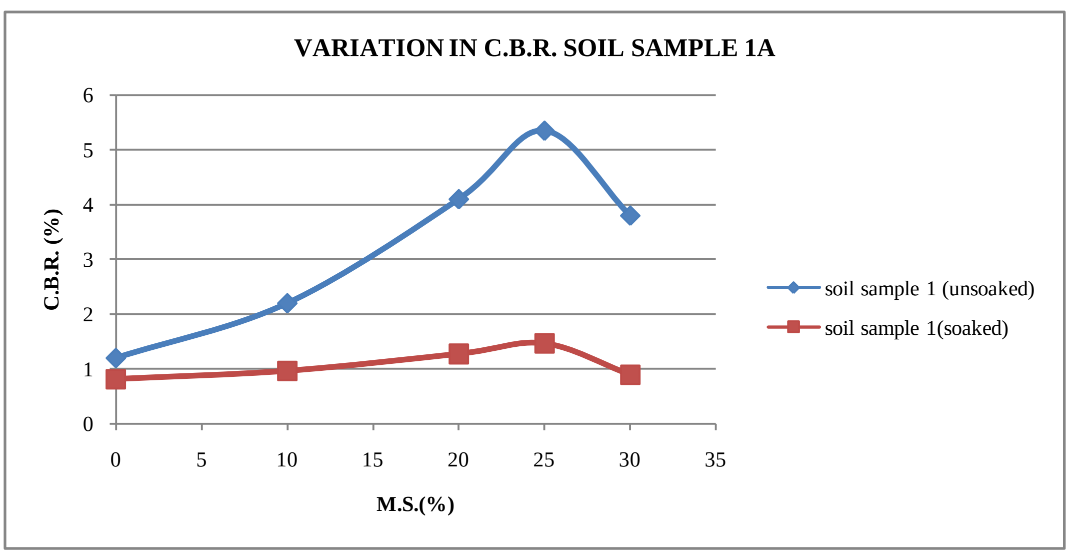

Fig.4. Variation in C.B.R.Value with different percentage of marble slurry, soil mix. 1-A

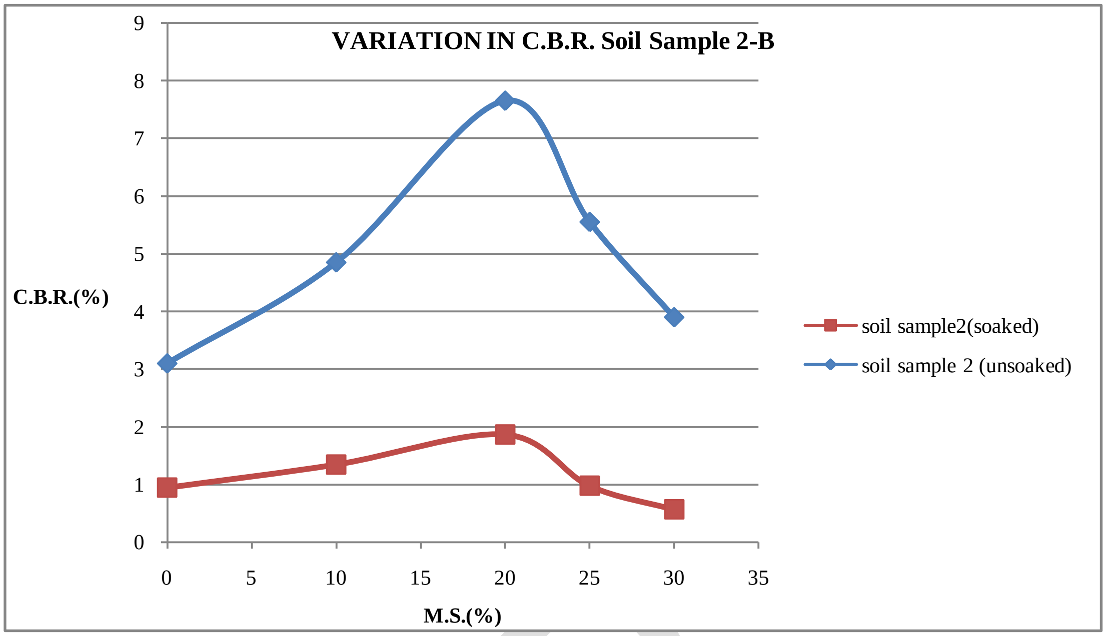

Fig.5. Variation in C.B.R.Value with different percentage of marble slurry, soil mix. 2-B

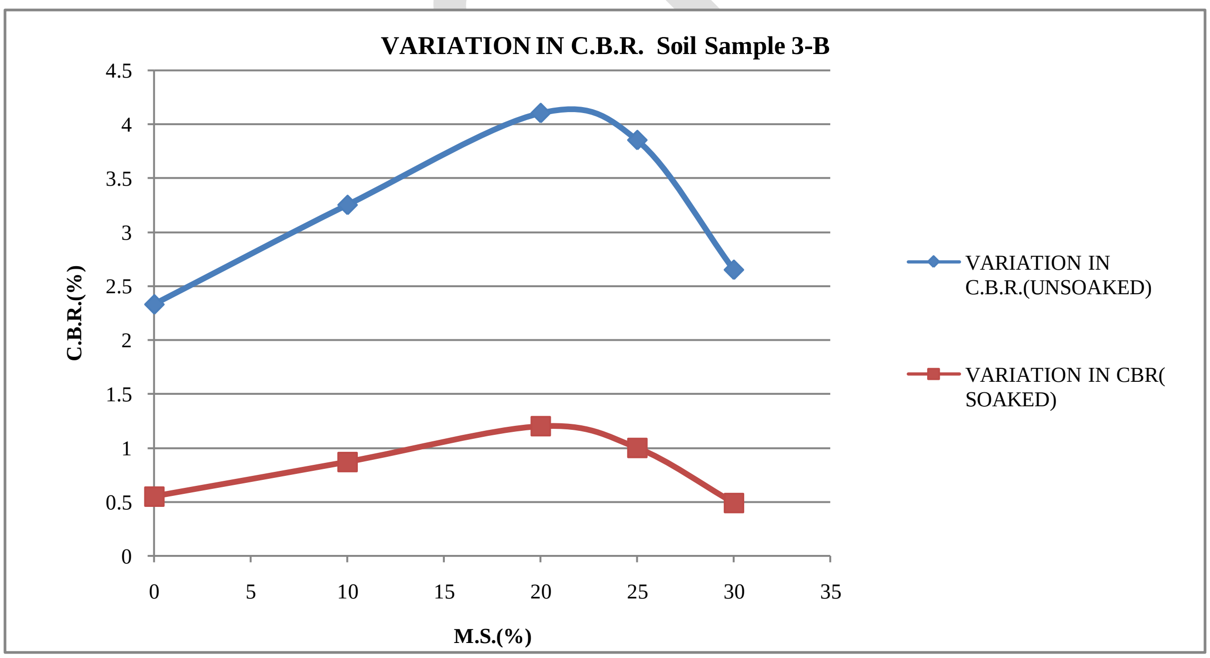

Fig.6. Variation in C.B.R.Value with different percentage of marble slurry, soil mix. 3-B

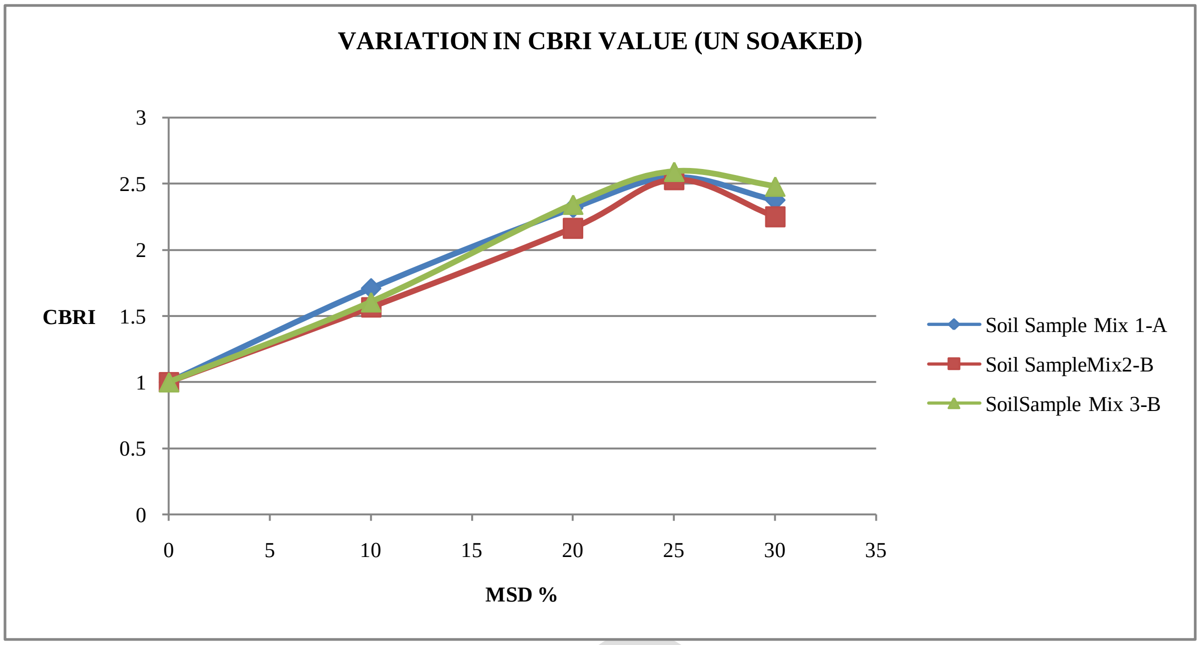

Fig.7 Variation in CBRIValue(Un soaked) with different percentage of marble slurryin all three test soil

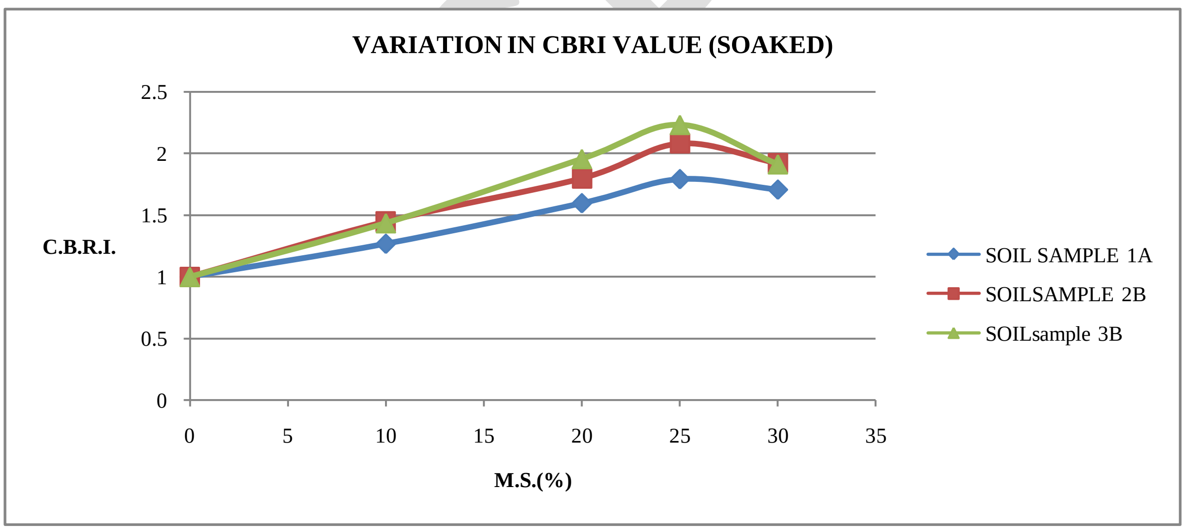

Fig.8 Variation in CBRI(Soaked)Value with different percentage of marble slurryin all three test soil

Table.8: Enhancement of CBR in terms of CBRI by addition of MS (%) in pure soil

S. No.	MS (%)	Soil Sample Mix 1-A		Soil Sample 2 Mix 2-B		Soil Sample 3 Mix 3-B	
		Un-soaked	Soaked	Un-soaked	Soaked	Un-soaked	Soaked
1	0	1.0	1.0	1.0	1.0	1.0	1.0
2	10	1.883	1.183	1.56	1.421	1.394	1.58
3	20	3.416	1.524	2.467	1.968	1.76	2.18
4	25	4.458	1.792	1.79	1.03	1.652	1.818
5	30	3.167	1.09	1.258	0.6	1.137	0.890

CONCLUSION

A substantial amount of waste material like marble dust, which is generated from marble industry,causes hazardous effect to the lands and environment. A test was conducted to study the change in engineering properties like C.B.R. values and Shear Strength of cohesive soil by addition of marble slurry. From the study, it was found that addition of marble slurry at the rate of 20% in soil can improve its engineering properties (Sarkar et.al). The soil stabilized by marble dust can be utilized in the construction of canal lining, pavement structures and foundation.

Few generalized conclusion are summarized below

1. Shear strength parameters modify by the inclusion of marble slurry in soil mass. Cohesion intercept (c) continuously decreases by adding marble slurry in soil mass, cohesion reduces rapidly at 20-25% of marble slurry.
2. Angle of internal friction (Ø) increases continuously by increase of marble slurry fraction, this depends on type of marble slurry and soil mass also.Both value of cohesion and internal friction improves the shear resistance of soil mass. It is at peak at 20% of marble slurry mix.
3. C.B.R. characteristics is greatly influenced by mixing of marble slurry in the soil sample .The increase in C.B.R. is at peak for the marble slurry fraction at 20-25 % .The increase in un-soaked C.B.R. value is more than soaked C.B.R. value for the same soil mass and marble slurry mix.
4. The value of CBRI is being increased by inclusion of marble slurry in all three soil samples which indicates enhancement of soil characteristics used in design of roadpavements

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