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Enhancing Engineering Properties of Soil by Using Marble Waste

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Abstract - The marble industry in Rajasthan, India, generates substantial amounts of waste, primarily in the form of marble dust, due to its significant growth in marble extraction and processing. This study investigates the potential of utilizing marble dust as a stabilizing agent for soil, with a focus on its effectiveness in enhancing soil properties for construction applications. Conducted in the Udaipur region, this research aims to assess the feasibility of marble dust in soil stabilization by evaluating its impact on key geotechnical properties. A series of experiments were carried out to analyze the influence of marble dust on soil characteristics, including water content, specific gravity, density, liquid limit, shear strength, and California Bearing Ratio (CBR). The study tested soil samples with varying percentages of marble dust (0%, 10%, and 20%) and compared these results to baseline data. Key findings include a significant increase in specific gravity, density, and unit weight of the soil with add of marble dust, indicating improved soil compaction and load-bearing capacity. Additionally, the marble dust was found to enhance the shear strength and CBR values of the soil, suggesting better stability and durability for construction purposes. However, the study also identified some drawbacks, such as increased soil alkalinity and potential environmental impacts, which need to be addressed. Overall, the results demonstrate that marble dust can be an effective and sustainable soil stabilizer, offering both economic and environmental benefits. The research concludes that marble dust has the potential to contribute positively to soil stabilization practices, but further investigation into long-term effects and environmental implications is recommended.

Keywords* - *CBR values, Geotechnical, Marble dust, Soil, Stabilizing, Sustainable

I INTRODUCTION

Rajasthan, known as the mineral majestic state, produces over 90 types of minerals & rocks. Among these, marble, a thermally metamorphosed rock primarily from the Precambrian formations, is highly prized. Marble extraction and processing have surged, resulting in a concomitant increase in marble waste. Typically, this waste is disposed of in open lands or forests, raising environmental concerns. This study focuses on the feasibility of using marble dust waste to stabilize soils, thereby mitigating environmental impact and promoting sustainable development.

II LITERATURE REVIEW

[1] Hitesh Bansal and Gurtej Singh Sidhu (2016) conducted a study where waste marble dust was mixed into soil at varying percentages, ranging from 10% to 30% in 10% increments. The study found that as the percentage of marble dust increased from 0% to 30%, the liquid limit decreased from 31.70% to 25%, and the plasticity index

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ranged from 17.69% to 19.26%. Additionally, the optimum moisture content (OMC) of the clay reduced from 18% to 14.10%, while the maximum dry density increased from 1.738 gm/cc to 1.884 gm/cc. The CBR value also improved, rising from 2.46% to 6.07%.

[2] S. Flrat et al. conducted research to study the influence of marble dust on CBR values, swelling, and permeability of soil. Their findings revealed that the addition of marble dust to two different soil samples increased the void ratio, thereby enhancing the soil's permeability. CBR values for saturated medium plasticity & low plasticity soils increased by 75% and 1%, respectively. For unsaturated soils, the maximum CBR value was achieved with 15% marble dust. Furthermore, the swelling ratio was significantly reduced in soil samples containing 15% marble dust. They were about 0.4% and 0.9% for medium plasticity and low plasticity soil respectively.

[3] **Effect on plasticity index, maximum dry density, CBR values and UCS**

To showcase the technology developed at CRRI, researchers constructed on sub-grade layer and embankment using marble dust. A road stretch was built in Rajsamand district, Rajasthan, and monitored over three monsoon seasons for evaluation. The site selected for the demonstration did not have low-lying areas, so an embankment was constructed in a confined, cut condition using 100% marble dust to study its settlement behavior under prevailing load and environmental conditions. The demonstration stretch consisted of 150M length of control sections on either side of test specimen, 150M length of embankment in cutting prepared with 100% marble dust dust and 450M length of sub grade prepared by mixing in-situ soil and optimum quantity of MSD. From the above study, it was found that the load bearing capacity (CBR) of soils improved with addition of MSD up to 25%. The Amberi and Kesariaji soils, which had a low CBR values, it improved even with 35% dust. The unconfined compressive strength of soils also improved as a result of addition of 15%-25% MSD.

III Methods of Soil Stabilization

Stabilization: Blending and mixing materials with soil to enhance its properties.

Mechanical Stabilization: Achieved through compaction to produce interlocking of soil-aggregate particles, forming a dense mass.

Chemical Admixture Stabilization: Involves mixing soil with chemical additives to improve volume stability, strength, permeability, and durability. Common admixtures include lime, cement, fly ash, and marble dust

Stabilization with Marble Dust

Advantages:

- Cost-effective and readily available.
- Enhances strength in concrete and bricks.
- Reduces construction costs by replacing conventional materials.

Disadvantages:

- Increases soil alkalinity and affects plant growth.
- Potential health hazards from airborne marble dust.
- Reduces soil fertility and can lead to slip accidents.

Extensive research has demonstrated the effectiveness of using marble dust in soil stabilization. The high lime (CaO) content in marble dust contributes significantly to its stabilizing properties.

IV Experimental Worke

Table 1: Water Content of soil sample (0% Marble waste)

Sample	Container Weight (gm)	Container +Wet Soil (gm)	Container +Dry Soil (gm)	Weight of Water (gm)	Weight of Dry Soil (gm)	Water Content (%)
T.H-1	15.36	62.308	54.103	8.205	38.743	21.178
T.H-2	15.11	64.640	55.908	8.732	40.798	21.40
T.H-3	14.95	62.991	54.580	8.411	39.630	21.22

Average Water Content: 21.266%

Table 2: Specific Gravity (0% Marble waste)

Pycnometer Weight (M1) (gm)	Pycnometer + Soil (M2) (gm)	Pycnometer + Water + Soil (M3) (gm)	Pycnometer + Water (M4) (gm)	Specific Gravity (G)
600	800	1580	1480	2.0

Table 3: Unit weight by Core Cutter method (0% Marble waste)

Mass of Core Cutter without Dolly (gm)	Core Cutter + Wet Soil (gm)	Mass of Wet Soil (gm)	Volume of Core Cutter (cm³)	Density (gm/cm³)	Unit Weight (KN/m³)
960	2800	1840	1021	1.8	17.68

Table 4: Sieve Analysis (0% Marble waste)

IS Sieve No.	Particle Size (mm)	Mass of Soil Retained (gm)	% Retained	Cumulative % Retained	% Finer
100mm	100	0	0	0	100
63mm	63	0	0	0	100

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20mm	20	36	3.6	3.6	96.4
10mm	10	140	14	17.6	82.4
4.75mm	4.75	162	16.2	33.8	66.2
2mm	2	185	18.5	52.3	47.7
1mm	1	271	27.1	79.4	20.6
600 mic.	0.6	45	4.5	83.9	16.1
300 mic.	0.3	12	1.2	85.1	14.9
150 mic.	0.15	31	3.1	88.2	15.8
75 mic.	0.075	9	0.9	89.1	10.9

Table 5: Proctor Test (0 % Marble waste)

Sample	T.H1	T.H2	T.H3	T.H4	T.H5	T.H6
Weight of Mould + Compacted Soil (gm)	10320	10440	10480	10540	10580	10540
Compacted Soil (gm)	1800	1920	1960	2020	2060	2020
Density (gm/cm³)	1.82	1.94	1.98	2.04	2.08	2.04
Dry Density (gm/cm³)	1.67	1.75	1.76	1.78	1.79	1.73

Table-6: Water Content:

Sample	T.H1	T.H2	T.H3	T.H4	T.H5	T.H6
Container + Wet Soil (gm)	50.87	45.10	53.58	53.12	59.02	64.14
Container + Dry Soil (gm)	48.6	42.23	50.18	49.64	54.19	58.36
Weight of Solid (gm)	24.82	26.235	27.15	23.34	29.57	32.23
Weight of Water (gm)	2.27	2.87	3.4	3.48	4.83	5.78
Water Content (%)	9.10	10.9	12.5	14.9	16.3	17.9

Table 7: Liquid Limit

Sample No.	W (%)	No. of Blows	Container + Wet Sample (gm)	Container + Dry Sample (gm)	Weight of Solid (Wd) (gm)	Weight of Water (Ww) (gm)	Water Content (%)
T.H-1	30	26	25.62	24.52	10.26	1.1	10.72
T.H-2	33	11	29.80	26.52	14.69	3.28	22.32
T.H-3	34	06	24.63	22.40	9.68	2.23	23.03

Liquid Limit = 18.69

Specific Gravity (G):

Table 8: Specific Gravity of Sample with 10% Marble Dust

Pycnometer Weight (M1) (gm)	**Pycnometer + Soil (M2) (gm)**	**Pycnometer + Water + Soil (M3) (gm)**	**Pycnometer + Water (M4) (gm)**	**Specific Gravity (G)**
615	**845**	**1610**	**1473**	**2.47**

Table 9: Specific Gravity of Sample with 20% Marble Dust

Pycnometer Weight (M1) (gm)	Pycnometer + Soil (M2) (gm)	Pycnometer + Water + Soil (M3) (gm)	Pycnometer + Water (M4) (gm)	Specific Gravity (G)
615	873	1666	1473	3.69

Table 10: Proctor Test Results of Sample with 10% Marble Dust

Sample	T.H1	T.H2	T.H3	T.H4	T.H5	T.H6
Weight of Mould + Compacted Soil (gm)	10420	10480	10600	10620	10560	10540
Compacted Soil (gm)	1900	1960	2080	2100	2040	2020
Density (gm/cm³)	1.92	1.98	2.10	2.12	2.06	2.04
Dry Density (gm/cm³)	1.73	1.75	1.84	1.83	1.76	1.72

Water Content:

Sample	T.H1	T.H2	T.H3	T.H4	T.H5	T.H6
Container + Wet Soil (gm)	41.74	44.03	45.60	50.83	47.90	43.58
Container + Dry Soil (gm)	39.84	41.2	42.5	46.10	43.13	39.19
Weight of Solid (gm)	17.56	21.77	22.52	29.98	27.69	23.76
Weight of Water (gm)	1.9	2.83	3.1	4.73	4.77	4.39
Water Content (%)	10.8	13.0	13.8	15.8	17.2	18.5

Table 11: Proctor Test of Sample with 20 % Marble Dust

Sample	**TTH1**	**TTH2**	**TTH3**	**TTH4**	**TTH5**	**TTH6**
Weight of Mould + Compacted Soil (gm)	**10400**	**10440**	**10560**	**10620**	**10620**	**10660**
Compacted Soil (gm)	**1880**	**1920**	**2040**	**2100**	**2100**	**2140**
Density (gm/cm³)	**1.91**	**1.94**	**2.06**	**2.12**	**2.12**	**2.16**
Dry Density	**1.82**	**1.83**	**1.89**	**1.91**	**1.9**	**1.89**

Water Content:

Sample	TTH1	TTH2	TTH3	TTH4	TTH5	TTH6
Container + Wet Soil	42.07	48.45	48.39	55.85	37.65	50.79

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(gm)						
Container + Dry Soil (gm)	40.88	46.38	52.98	52.98	35.4	47
Weight of Solid (gm)	25.18	31.5	26.66	26.66	19.4	27.56
Weight of Water (gm)	1.19	2.07	2.87	2.87	2.25	3.79
Water Content (%)	4.7	6.6	10.8	10.8	11.6	13.75

Liquid Limit with Marble Dust

Table 12: Liquid Limit of Sample with 10% Marble Dust

Sample No.	W (%)	No. of Blows	Container +Wet Sample (gm)	Container +Dry Sample (gm)	Weight of Solid (Wd) (gm)	Weight of Water (Ww) (gm)	Water Content (%)
TH1	27	40	32.58	30.74	8.46	1.84	21.7
TH2	32	36	38.90	35.05	15.62	3.85	24.6
TH3	34	34	33.76	31.02	11.04	2.74	24.8
TH4	36	18	36.20	32.19	16.07	3.83	23.8
TH5	38	14	26.38	24.12	8.69	2.26	26.0

Liquid Limit (WL) = 24.4%

Table 13: Liquid Limit of Sample with 20% Marble Dust

Sample No.	W (%)	No. of Blows	Container + Wet Sample (gm)	Container +Dry Sample (gm)	Weight of Solid (Wd) (gm)	Weight of Water (Ww) (gm)	Water Content (%)
TH1	27	42	38.70	35.90	12.12	2.8	23.1
TH2	31	37	29.81	27.10	11.10	2.71	24.4
TH3	33	23	37.75	34.80	11.77	2.95	25.6

Table 14: Shear Test (0% Marble dust)

Sample	Normal Stress (kPa)	Shear Stress (kPa)
T.H-1	100	46
T.H-2	200	83
T.H-3	300	115

Table 15: Shear Test (Sample with 10% Marble Dust)

Sample	Normal Stress (kPa)	Shear Stress (kPa)
T.H-1	100	52
T.H-2	200	94.5
T.H-3	300	135.5

Table 16: Shear Test (Sample with 20% Marble Dust)

Sample	Normal Stress (kPa)	Shear Stress (kPa)
T.H-1	100	55.5
T.H-2	200	104
T.H-3	300	148.2

Table 17: CBR Test (Sample with 0% Marble dust)

Penetration (mm)	Load (kg)	CBR (%)
2.5	1375	5.3
5.0	2055	4.8

Table 18: CBR Test Results (Sample with 10% Marble Dust)

Penetration (mm)	Load (kg)	CBR (%)
2.5	1530	6.12
5.0	2280	5.5

Table 19: CBR Test (Sample with 20% Marble Dust)

Penetration (mm)	Load (kg)	CBR (%)
2.5	1700	6.79
5.0	2550	5.98

V RESULT & DISCUSSION

In this section, we will discuss the results obtained by the various tests conducted on the soil samples with and without the addition of marble dust.

Water Content

The water content tests show that the average water content of the soil samples without marble dust is approximately 21.266%. When marble dust is added to the soil samples in percentages of 10% and 20%, the water content tends to decrease. This indicates that the addition of marble dust improves the soil's capacity to retain less water, making it more suitable for construction purposes where lower water content is preferred.

Specific Gravity

The specific gravity of the soil samples increased with the addition of marble dust. The specific gravity for the soil sample without marble dust was found to be 2.00, while the specific gravity for the samples with 10% and 20% marble dust were 2.47 and 3.69, respectively. This increase in specific gravity indicates that marble dust makes the soil denser and more compact, which can enhance its load-bearing capacity.

Particle Size Distribution

The sieve analysis results showed that the soil samples had a significant amount of fine particles, with a notable percentage passing through the smaller sieves. The addition of marble dust did not significantly alter the particle size distribution, indicating that the dust particles are well

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incorporated into the soil matrix without segregating.

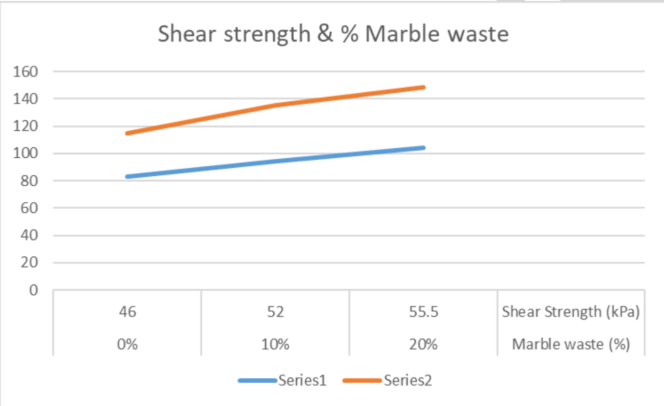
Proctor Test (MDD)

The Proctor test results indicate that the maximum dry density of the soil increases with the add of marble dust. For the soil sample without marble dust, the maximum dry density was found to be around 1.79 gm/cm³. With 10% marble dust, the maximum dry density ranged from 11.89 gm/cm³, and for 20% marble dust, is 1.91 gm/cm³. This shows that marble dust enhances the soil's compaction characteristics, making it more suitable for construction purposes.

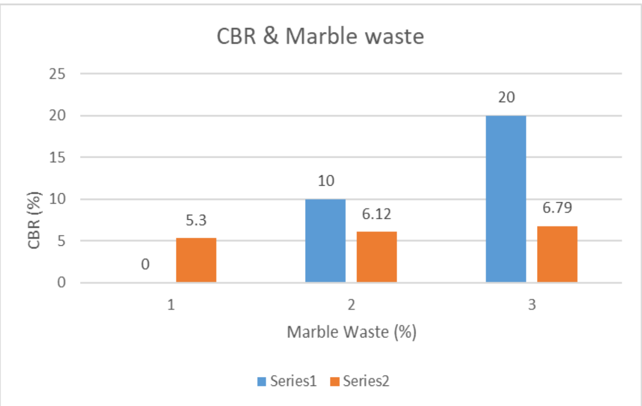
Liquid Limit

The liquid limit of the soil samples also increased with the addition of marble dust. For the soil sample without marble dust, the liquid limit was 18.69%. With 10% marble dust, the liquid limit increased to 24.4%, and with 20% marble dust, it further increased to 25.0%. This increase in liquid limit indicates that soil becomes more plastic and workable with the addition of marble dust.

Shear strength and % Marble waste



CBR & % of Marble waste



VI Conclusion

From the tests conducted, it is evident that the addition of marble dust to soil samples has a significant impact on their geotechnical properties. The specific gravity, density, and unit weight of the soil increase with the addition of marble dust, making it more compact and suitable for construction purposes.

Overall, the results suggest that marble dust can be an effective soil stabilizer, enhancing the soil's properties and making it more suitable for use in construction projects. Further studies could be conducted to explore the long-term effects of marble dust on soil properties and its potential environmental impact.

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