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Economical Study on Safety of Earthen Embankments by Use of Marble Slurry

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ABSTRACT

Marble slurry wastes are available widespread in Rajasthan as by-product of industrial process. Generally these wastes pollute and damage the environment due to sawing and polishing processes. This waste can be used for making an earthen embankment. For this, three samples of soil and two samples of marble dust from different places were collected. The marble slurry was mixed with soil sample at a ratio of 0-30%. Factor of safety and CBR properties were observed of each sample. From the several experiments, 25% mixed marble dust based soil sample is approved for building of road embankments.

Key words: Marble slurry, stability test, embankment, factor of safety, C.B.R.

INTRODUCTION

Waste management is a fundamental component to any manufacturing or production enterprise. It is estimated that there are million tons of marble waste are produced in each year. Although a portion of this waste may be utilized on-site such as for excavation pit refill [1]. Marble waste use as a material is a very important environmental management tool for achieving sustainable development. On the other hand, recycling waste without properly based scientific research and development can result in environmental problems greater than the waste itself. Marble waste from quarry operations can be unsafe and environmentally detrimental. In India, million tons of wastes from marble industries are being released from marble cutting, polishing, processing and grinding.

Marble is the second largest quarried stone in Rajasthan. There are around 4000 marble mines and 1100 marble processing units spread over 16 district of Rajasthan. All these generate a huge quantity of marble dust (5-6 MT) in the form of slurry during cutting and processing of marble stone. On an average, cutting of 25 mm marble block results in 5 mm thick waste (~20%) known as marble slurry. Marble slurry is a semi liquid substance containing high percentage of very fine particles and water used as coolant during sawing and polishing. The waste is approximately 20% of total marble handled. The major environmental concern is the disposal of this by product. The marble cutting industries are dumping the marble dust in any nearby pit or vacant spaces near their unit, although notified areas have been marked for dumping. This leads to serious environmental problems like dust pollution and occupation of vast areas of land, especially after the slurry dries up. This also contaminates the underground water reservoirs [2]. Palaniappan et.al. (2009) [3] had studied the stabilizing effect of marble dust on engineering properties of expansive soil and has found varied success. Marble power is an excellent material for mechanical stabilization of cohesive soils.

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 [1&4].

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 byproduct 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 (waste marble dust) as a stabilizer for soil appears in Udaipur and Rajsamand region was investigated. This study presents work carried out at Department of Civil Engineering, College of Technology and Engineering, Udaipur on embankment design, methodology adopted for construction, performance evaluation, economy achieved etc. for utilization of marble dust slurry.

REVIEW OF LITERATURE

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 below.

Joulani et. al. (2012) [5] 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) [6] 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 % 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%.

Misra et al. (2010) [7] 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 MarblesFrom 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. The soil sample were prepared by replacing natural clay by 10% bentonite to make it more expansive and then marble dust was added to prepare the samples from 0-30% at an interval of 5% (by weight).

Sabat et. al. it was stated that Rice husk ash cannot be used alone for stabilization of soil due to lack of cementations properties (Haji Ali et al., 1992) [8]. 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 et. al. (2000) [9], Haji et al. (1992) [8], Basha et al. (2003) [10], Chandra et al. (2005) [11] and Sharma et al. (2008) [12]. 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.

MATERIAL AND LABORATORY STUDIES

Three soil samples and two marble slurry samples obtained from various places within Udaipur and Rajsamand Districts of Rajasthan. These samples are adopted for the research work, enlisted below:
Soil sample location

a) Sample 1- Sakrawas, District Rajsamand
b) Sample 2- Bedwas, District Udaipur
c) Sample 3- Banoda, District Udaipur

Areas from where the marble dust was collected are mentioned as under;

a) Sample A, village Kelwa, District Rajsamand
b) Sample B, village Rishabdev, District Udaipur

These soil samples were collected from open space in the above rural area at the depth range of 0.6-1.0m from ground surface. Various geotechnical properties such as particle size distribution, liquid limit, plastic limit, shrinkage limit, specific gravity, maximum dry density and optimum moisture content have been determined (Table 1).

It was aimed to mix marble slurry with the locally available soil samples. Chemical composition of each marble slurry sample was performed at laboratory of Department of Mines and Geology, Udaipur.

Table-1 Geotechnical Properties of Soil Masses

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	0.08	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

Slope Stability Analysis:

Slope/w model formed with the help of slope geometry soil properties. Geo- slope is one of powerful tools for analysis, include the use of finite element computed pore-water pressure and stresses in a stability analysis. The software Geo-Studio (slope/w) used to find out lowest value of factor of safety [27] [28].

Factor of safety (F.O.S.) is calculated by Bishop and Morgenstern Price methods (Table 3 and 4) with variable side slope 1:1,1:1.5,1:2 at varying marble slurry percentage 0%,10%,20%,25% and 30 % mix with all three collected soil for 3m and 6m height of Embankment. The study took helps of Software Geo–Studio 2012 (slope/w). Data of M.D.D., cohesion and angle of internal friction of soil mix were used for study.

Table -2 Sample Mixture

Slope	Sample Mixture	Percentage of marble slurry in sample
1:1 1:1.5 1:2	Soil sample 1 + Marble Slurry A **(Mix.1-A)**	0%,10%20%,25%,30%
1:1 1:1.5 1:2	Soil sample 2 + Marble Slurry B **(Mix.2-B)**	0%,10%20%,25%,30%
1:1 1:1.5 1:2	Soil sample 3 + Marble Slurry B **(Mix.3-B)**	0%,10%20%,25%,30%

Table -3 Factor of Safety for all three Soil Mixes at Different Marble Slurry Percentage at Embankment Height 3m

Side Slope 1:1

S. No.	M.S. (%)	Soil Mix 1 – A		Soil Mix 2 – B		Soil Mix 3 B	
		Bishop	Morg. P.	Bishop	Morg. P.	Bishop	Morg. P.
1	0	4.833	5.336	6.314	6.411	5.483	5.678
2	10	4.801	5.260	6.143	6.206	5.25	5.294
3	20	4.704	4.846	5.894	5.970	4.863	4.95
4	25	3.98	4.252	5.237	5.265	4.115	4.245
5	30	2.452	2.53	3.677	3.793	3.525	3.636

Side Slope 1:1.5

S. No.	M.S. (%)	Soil Mix 1 – A		Soil Mix 2 – B		Soil Mix 3 B	
		Bishop	Morg. P.	Bishop	Morg. P.	Bishop	Morg. P.
1	0	5.716	5.922	6.717	6.723	6.258	6.271
2	10	5.592	5.782	6.526	6.532	6.096	6.091
3	20	5.488	5.663	6.32	6.323	5.704	5.814
4	25	4.786	4.788	6.043	6.051	4.825	4.941
5	30	2.89	2.94	4.312	4.416	4.131	4.228

Side Slope 1:2

S. No.	M.S. (%)	Soil Mix 1 – A		Soil Mix 2 – B		Soil Mix 3 B	
		Bishop	Morg. P.	Bishop	Morg. P.	Bishop	Morg. P.
1	0	6.592	6.649	7.011	7.498	6.696	6.891
2	10	6.392	6.561	6.813	7.289	6.512	6.709
3	20	6.355	6.435	6.61	7.030	6.279	6.421
4	25	5.403	5.451	6.453	6.651	5.645	5.649
5	30	3.371	3.373	5.036	5.046	4.845	4.846

Table-4 Factor of Safety for all three soil mixes at different marble slurry percentage at Embankment Height 6m

Side Slope 1 : 1

S. No.	M.S. (%)	Soil Mix 1 – A		Soil Mix 2 – B		Soil Mix 3 B	
		Bishop	Morg. P.	Bishop	Morg. P.	Bishop	Morg. P.
1	0	2.47	2.506	3.265	3.284	2.854	2.904
2	10	2.466	2.502	3.205	3.228	2.845	2.875
3	20	2.465	2.500	3.12	3.144	2.681	2.757
4	25	2.14	2.189	2.792	2.85	2.329	2.334
5	30	1.438	1.439	2.007	2.072	2.045	2.047

Side Slope 1:1.5

S. No.	M.S. (%)	Soil Mix 1 – A		Soil Mix 2 – B		Soil Mix 3 B	
		Bishop	Morg. P.	Bishop	Morg. P.	Bishop	Morg. P.
1	0	2.948	3.075	3.747	3.748	3.447	3.497
2	10	2.947	3.062	3.667	3.671	3.418	3.453
3	20	2.942	3.060	3.568	3.578	3.25	3.328
4	25	2.569	2.659	3.361	3.402	2.825	2.909
5	30	1.742	1.811	2.504	2.577	2.478	2.569

Side Slope 1:2

S. No.	M.S. (%)	Soil Mix 1 – A		Soil Mix 2 – B		Soil Mix 3 B	
		Bishop	Morg. P.	Bishop	Morg. P.	Bishop	Morg. P.
1	0	3.443	3.515	3.981	3.997	3.792	3.826
2	10	3.459	3.509	3.893	3.902	3.735	3.761
3	20	3.444	3.506	3.801	3.807	3.617	3.635
4	25	3.012	3.056	3.684	3.715	3.264	3.356
5	30	2.017	2.096	2.870	2.972	2.865	2.97

California Bearing Ratio (C.B.R.)

California Bearing Ratio measured as per is 2720 Part 16, 1987. The result has been shown in Table -5. The procedure has been followed under unsoaked and soaked condition with all three soil sample mixed with marble slurry. Percentage of marble slurry is varying from 0% to 30%. Value of C.B.R. under unsoaked condition ranging from 1.20% to 3.06%, 3.10% to 7.84% and 2.33% to 6.04% that is not very high. This is due to fine fraction clay percentage available in the soil mass. Value of soaked C.B.R. is quite less due to submergence in water for 48 hours. There is a rapid increase of CBR value up to 25% marble slurry under mix 1-A under un soaked condition and socked condition.

Table -5 Variation in C.B.R. Value by Increasing M.S. % in all Three Soil Samples

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	1.20	0.82	3.10	1.14	2.33	0.94
2	10	2.05	1.04	4.85	1.65	3.74	1.35
3	20	2.78	1.31	6.71	2.05	5.46	1.84
4	25	3.06	1.47	7.84	2.38	6.04	2.10
5	30	2.85	1.40	6.98	2.19	5.78	1.80

Economics of marble slurry Embankment

Marble slurry yielding highest C.B.R at 25% content in the soil samples Mix 2-B. Reduction in cross sectional area by steepening of side slope of the embankment till F.O.S remains above critical safer line.

An Embankment for a single lane requiring 3.75m top width and keeping allowance for shoulders, taking 4m top width, similarly for two lane 8m top width have been analyzed with C.B.R. value of pure soil mass of each soil sample and soil sample mixed with appropriate marble slurry. Table -6 shows C.B.R. value and thickness of embankment in respect to reduction in thickness of pavement due to benefit achieved by increased C.B.R. of different soil samples and soil mixes with marble slurry.

Table -6 Thickness of Earth Work in Embankments for Pure Soil and Soil Mixed with 25% Marble Slurry in all Three Test Soil Mix

S. No.	Soil/ Soil mix	C.B.R. %	Thickness of pavement (cm)	Thickness of Embankment (cm)
1	Pure Soil 1	1.2	60	300
2	Soil mix.1-A	3.0	50	290
3	Pure Soil 2	3.1	50	300
4	Soil mix. 2-B	7.84	28	287
5	Pure Soil 3	2.33	57	300
6	Soil mix.3-B	6.04	34	277

C.B.R. Design chart with curve D have been used for determination of pavement thickness. The thickness of embankment height is taken as 3 meter for each pure soil. Reduction in pavement thickness and steepening of slope by use of soil mix with marble slurry, this consideration reduces a lot of earth work magnitude. Table -7 shows Earth work requires for a 1 km. long embankment for different side slope of 1:1.5 and 1:0.6 for a single lane and double lane road of 4m and 8m top width.

Table -7 Earth Work in Embankment including Pavement Thickness for Pure Soil and Soil Mixed with Marble Slurry for 1 km. Long Single Lane and Double Lane Road Work

S.No.	Soil/Soil mix.	Earth work in Embankment (m^3)			
		Single lane		Double lane	
		Side slope 1:1.5	Side slope 1:0.6	Side slope 1:1.5	Side slope 1:0.6
1	Pure soil 1/2/3	25500	17400	37500	29400
2	Soil mix 1-A	24215	16646	35815	28246
3	Soil mix 2-B	22712	15757	33832	26877
4	Soil mix 3-B	22589	15683	33655	26763

Cost of pure soil made road embankment in single lane of 1 Km long is Rs.43.98 Lacks. It reduces to Rs 41.77 Lacks by mixing 25% marble slurry in soil sample 1. Similar cost reduction for other soil samples and for two lanes has also been shown in Table.8. It is cleared that reduction in cost due to increased C.B.R. over pure soil. 6% to 12% cost benefit is achieved in single lane whereas 5% to 11% cost benefit is being achieved in double lane.

Table -8 Cost of Earth Work and Cost Reduction Ratio due to Mixing of Marble Slurry in Embankment with Side Slope 1:1.5, for 1 Km Long Single Lane and Double Lane Road Work

S. No.	Soil/Soil mix	Cost of Earth work and Cost reduction ratio in Embankment			
		Single lane		Double lane	
		Cost Rs. (Lacks)	Cost reduction ratio	Cost Rs. (Lacks)	Cost reduction ratio
1	Pure soil 1/2/3	43.98	1	64.68	1
2	Soil mix 1-A	41.77	0.94	61.78	0.95
3	Soil mix 2-B	39.17	0.89	58.36	0.90
4	Soil mix 3-B	38.96	0.88	58.05	0.89

Table -9 shows cost of embankment (in lacks) and cost reduction ratio combined with increased C.B.R. and reduction in cross section by steepening of side slope up to a safe limit by inclusion of marble slurry. Cost benefit ratio increased tremendously as combined effect of reduction in cross section and increased value of C.B.R. from 35% to 41% in single lane and 25% to 31%for double lane. On an average nearly 30% cost saving is being achieved.

Table - 9 Cost of Earth Work and Cost Benefit Ratio Due to Mixing of Marble Slurry with Reduction in Cross Section by Steepening of Side Slope in Embankment, with Side Slope 1:1.5, for 1 Km Long Single Lane and Double Lane Road Work

S.No.	Soil/Soil mix	Cost of Earth work and Cost reduction ratio in Embankment			
		Single lane		Double lane	
		Cost Rs. (Lacks)	Cost reduction ratio	Cost Rs. (Lacks)	Cost reduction ratio
1	Pure soil 1/2/3	43.98	1	64.68	1
2	Soil mix 1-A	28.71	0.65	48.72	0.75
3	Soil mix 2-B	27.18	0.61	46.36	0.71
4	Soil mix 3-B	27.05	0.61	46.16	0.71

CONCLUSION

The following conclusions are made-

- The embankment made from such stabilized soil at different M.S. ratio have been tested for slope stability analysis keeping other variable constant and it is found safe up to 25% marble slurry. Factor of safety is calculated by software Geo-Studio with two different methods i.e. Bishop and Morgenstern Price. It was found that Bishop Method leads lower value in compare to Morgenstern Price.
- The factor of safety predominately varies on type of Soil and Marble Slurry percentage.
- Embankment made of similar soil and marble slurry F.O.S. is depending on the steepness of slope as well on height of embankment. The factor of safety for 3m height of embankment ranging from 6.31to 3.67 (Slope 1:1) to 7.01 to 5.03 (slope 1:2). Similarly for 6m height of embankment ranging from 2.47 to 1.43 (Slope 1:1) to 3.44 to 2.01(slope 1:2) steeper to flatter slope for the same soil and M.S. mix from 0 to 30 % . Factor of safety reduces as steepness of sides and height of embankment increases.

- Marble slurry yielding highest C.B.R at 25% content in all soil marble mixture.
- Cost of road embankment reduces with inclusion of marble slurry, this is achieved by enhancement in C.B.R. as well improvement in stability of slope, and approximately 6% to8% cost reduces as enhancement in C.B.R. only.

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