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STUDY ON EFFECTS OF STABILIZATION ON EXPANSIVE SOILS USING MARBLE DUST WASTE

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ABSTRACT

The aim is to improve the engineering properties of black cotton soil such that the pavement to be built on such type of soil can efficiently withstand to the applied loads. The main objective of this research is to investigate the possibility of utilizing waste marble dust in stabilizing problematic soils (especially swelling clays).Such soils swell when given an access to water and shrink when they dry out. Several attempts are being made to control the swell-shrink behaviour of these soils. Soil stabilization using chemical admixtures is the oldest and most widespread method of ground improvement. In this study waste marble dust, by-products of marble industry were used for stabilization of expansive soils. To achieve, higher strength, chemical stabilization such as addition of lime or other chemical additives are also used to increase the strength of the BC soils. Use of geo-synthetics is also another way of increasing strength. At last it was also found that engineering properties of black cotton soil substantially improved by addition of marble dust in different proportions from 1% to 4%.

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INRODUCTION

Soil stabilization may be defined as the alteration or preservation of one or more soil properties to improve the engineering characteristics and performance of a soil. Stabilization, in a broad sense, incorporates the various methods employed for modifying the properties of a soil to improve its engineering performance. Soil stabilization refers to the procedure in which a industrial by product, cementing material, or other chemical materials are added to a natural soil to improve one or more of its properties. One may achieve stabilization by mechanically mixing the natural soil and stabilizing material together so as to achieve a homogeneous mixture or by adding stabilizing material to an undisturbed soil deposit and obtaining interaction by letting it permeate through soil voids. Soil stabilizing additives are used to improve the properties of less-desirable rood soils. When used these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion and serve as cementing and water proofing agents. A difficult problem in civil engineering works exists when the sub-grade is found to be clay soil. Soils having high clay content have the tendency to swell when their moisture content is allowed to increase.

SOIL STABILIZATION

Soil stabilization is one of the oldest and most widespread techniques among the ground improvement methods because construction on soft ground is a main problem in civil engineering. If the ground is untreated, it is not good enough for the construction, and the bearing capacity or slope failure may occur because of insufficient soil strength.

Stabilized soil is, in general, a composite material that results from a combination and optimization of properties in individual constituent materials. Well-established techniques of soil stabilization are often used to obtain geotechnical materials improved through the addition into soil of such cementing agents.

The solution of refining these soils in-situ by stabilization often becomes handy, as this has the insinuation of natural resource conservation, reduction in energy usage and carbon dioxide release and increased cost efficiency.

Many binder materials possess hardening applications which could potentially be used for the stabilization of soils. Soils with high water content stabilized by traditional mixtures have been commonly used for the construction purpose to enhance bearing capacity, reduce settlement, control shrinking and swelling, and reduce permeability. Although such traditionally chemical stabilizers have been economically attractive, from an environmental point of view, it is more prudent to consider industrial by-products for soil stabilization that are most cost-effective, and not affecting the surrounding soil and groundwater ecology upon treatment. Nevertheless, there are some negative effects of using some of these materials in soil stabilization.

Soil Stabilization Methods

In road construction projects, soil or gravelly material is used as the road main body in pavement layers. To have required strength against tensile stresses and strains spectrum, the soil used for constructing pavement should have special specification. Through soil stabilization, unbound materials can be stabilized with cementations materials (cement, lime, fly ash, bitumen or combination of these). The stabilized soil materials have a higher strength, lower permeability and lower compressibility than the native soil. The method can be achieved in two ways, namely;

1) In situ stabilization and
2) Ex - situ stabilization.
Some stabilization techniques are listed below
A. Mechanical Stabilization
B. Stabilization by using different types admixes
1) Lime Stabilization
2) Cement Stabilization
3) Chemical Stabilization
4) Fly ash Stabilization
5) Rice Husk ash Stabilization
6) Bituminous Stabilization
7) Thermal Stabilization
8) Electrical Stabilization
9) Stabilization by Geo-textile and Fabrics
10) Recycled and Waste Products etc.

PRINCIPLES OF SOIL STABILIZATION

Natural soil is both a complex and variable material. Yet because of its universal availability and its low cost winning it offers great opportunities for skillful use as an engineering material. Not uncommonly, however the soil at any particular locality is unsuited, wholly or partially, to the requirements of the construction engineer. A basic decision must therefore be made whether to (Pannu, 2016):
a) Accept the site material as it is and design to standards sufficient to meet the restrictions imposed by its existing quality.

b) Remove the site material and replace with a superior material.

c) Alter the properties of existing soil so as to create a new site material capable of better meeting the requirements of the task in hand.

METHODOLOGY

COLLECTION OF SAMPLE

Site Data

Proposed site for implementation of this work and sample collected is under MPRRDA, PMGSY (Pradhan mantri gram sadakyojna) road at sehora district Jabalpur. The soil sample collected from the site and its properties are as follows:

PAVEMENT DESIGN:
Traffic Volume data
Traffic Volume data of 2017 at 12/0 km.

Source: R&B department data.
- No of commercial vehicles/day are 8,800.
- No of non-commercial vehicles/day are 14,045.
- Iron tire vehicles/day is 205.
- Bullock carts/day is 163.
- Total traffic volume in PCU/day is 50,200.
- Total traffic intensity factor in tones are 1,14,079.

Fig.1 Site Condition

Soil data

As a part of this investigation, the expansive black cotton soil was acquired from the site Sehora, Jabalpur, Madhya pradesh. The black cotton soil thus obtained was carried to the laboratory in sacks.A small amount of soil was taken, sieved through 4.75 mm sieve, weighed, and air-dried before weighing again to determine the natural moisture content of the same. The various geotechnical properties of the procured soil are as follow

Table- 1 Properties of Soil Sample.

Sl. No.	Properties	Code referred	Value
1.	Soil Classification	IS SOIL CLASSIFICATION	Cohesive
2.	Specific Gravity	IS 2720 (Part 3/Sec 1) - 1980	2.74
3.	Liquid Limit	IS 2720 (Part 5) - 1985	62.5%
4.	Plastic Limit	IS 2720 (Part 5) - 1985	25.51%
5.	Plasticity Index	IS 2720 (Part 5) - 1985	39.49%
6.	Shrinkage Limit	IS 2720 (Part 6) -: 1972	17.37%
7.	Gravel %	IS 2720 (Part 4):1985	0.20%
8.	Sand %	IS 2720 (Part 4):1985	27.80%
9.	Fines(Clay/Silt) %	IS 2720 (Part 4):1985	72%

10.	Free Swell Index	IS 2720 (Part 40) - 1977	60%
11.	Natural Moisture Content	IS 2720 (Part 2) - 1973	7.28%
12.	Optimum Moisture Content (OMC)	IS 2720 (Part 7) - 1980	22.65%
13.	Maximum Dry Density (MDD)	IS 2720 (Part 7) - 1980	1.52 gm/cc

MATERIALS USED

Marble Dust Sample

Marble or real marble is a metamorphic rock that consists predominantly of calcite and dolomite. Marble may be considered as metamorphosed limestone (i.e. limestone which has been fully re-crystallized and hardened under hydrothermal conditions). In this study waste dolomitic marble dust was used. The production of fine particles (<2 mm) while cutting marble is one of the major problems for the marble industry. When 1 m^3 marble block is cut into 2 cm thick slabs, the proportion of fine particle production is approximately 25 %. While cutting of marble blocks water is used as cooler. But, the fine particles can be easily dispersed after losing humidity, under atmospheric conditions, such as wind and rain. Thus, fine particles can cause more pollution than other forms of marble waste.

METHODOLOGY ADOPTED

To evaluate the effects of marble dust as stabilizing additive in expansive soils, series of testswhere conducted with content of marble dust in the expansive soil was varied in values of 1.0% to 4.0% by dry weight of the total quantity taken of soil sample. The Indian Standard codes were followed during the conduction of the following experiments:

1. Standard proctor test – IS: 2720 (Part 7) – 1980

Fig.2 performing standard proctor test

2. Unconfined compressive strength (UCS) test – IS:2720 (Part 10) – 1991

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Fig.3 Performing U.C.S. sample specimen and mould

3. California bearing ratio (CBR) test – IS: 2720 (Part 16) – 1987

Fig.4 Performing Test of CBR soil specimen

4. Free swell index test – IS:2720 (Part 40) – 1977
5. Liquid & Plastic limit test – IS: 2720 (Part 5) – 1985

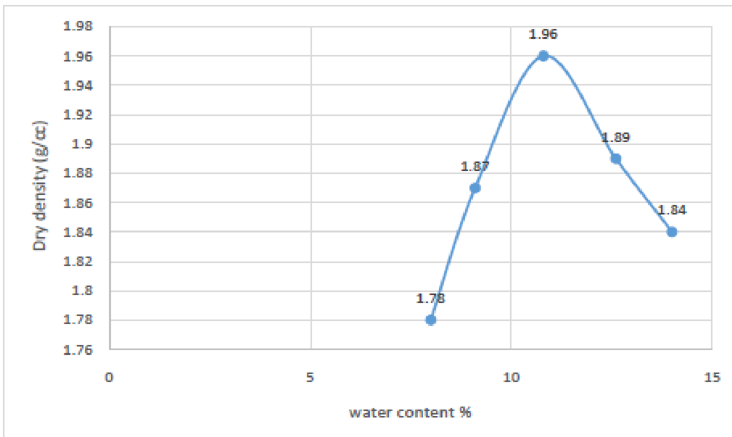
Fig.5 Liquid limit-apparatus & tools

RESULT AND DISCUSSION

STANDARD PROCTOR TEST RESULTS & GRAPH

Table 1 Standard proctor test for soil sample adding marble dust in different ratio

Volume of Mould (cc)	Weight of mould W_1 (g)	Wt. of mould + compacted soil W_2 (g)	Wt. of compacted soil $W=W_2-W_1$ (g)	Bulk density $Y_b=W/V$ (g/cc)	Water Content %	Dry Density $Y_d=Y_b/1+w.c$ (g/cc)
1000	4810	6726	1916	1.92	8	1.78
1000	4810	6850	2040	2.04	9.1	1.87
1000	4810	6960	2150	2.15	10.8	1.96
1000	4810	6940	2130	2.13	12.6	1.89
1000	4810	6850	2240	2.24	14	1.84

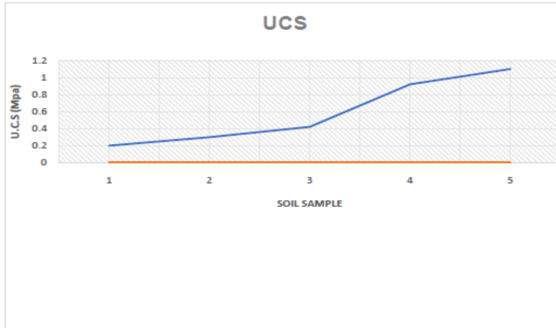


Graph 4.1 Standard proctor test

UNCONFINED COMPRESSIVE STRENGTH (UCS) TEST FOR SOIL – MARBLE MIXTURE

Table 2 Unconfined Compressive Strength Test of Soil

Unconfined Compressive Strength Test of Soil Sample(Mpa)					
Soil Sample	soil accumulated	added 1% marble dust	added 2% marble dust	added 3% marble dust	added 4% marble dust
Mpa	0.2	0.3	0.42	0.92	1.1



Graph 2 Unconfined Compressive Strength Test

(a) UN-SOAKED SOIL SAMPLE CALIFORNIA BEARING RATIO (CBR) TEST FOR SOIL – MARBLE DUST

Table 3 Un-soaked CBR test for expansive soil + 1% marble dust

Sl. No.	Plunger penetration (mm)	Dial gauge readings	Applied load (kg)	CBR stress (kg/cm^2)	Standard load intensity (kg/cm^2)	CBR intensity $(\% age)$
1	0	2	4.94	0.25		
2	0.5	5	12.36	0.63		
3	1	14	34.59	1.76		
4	1.5	23	56.83	2.90		
5	2	33	81.54	4.16		
6	2.5	41	101.31	5.16	70	7.37
7	3	48	118.61	6.04		
8	3.5	55	135.91	6.93		
9	4	61	150.73	7.68		
10	4.5	66	163.09	8.31		
11	5	71	175.44	8.94	105	8.51
12	5.5	75	185.33	9.44		
13	6	79	195.21	9.95		
14	6.5	82	202.62	10.32		
15	7	86	212.51	10.83		
16	7.5	89	219.92	11.21	134	8.36
17	8	90	222.39	11.33		
18	8.5	91	224.86	11.46		
19	9	91	224.86	11.46		

Table 4 Un-soaked CBR test for expansive soil + 2% marble dust

Sl. No.	Plunger penetration (mm)	Dial gauge readings	Applied load (kg)	CBR stress (kg/cm^2)	Standard load intensity (kg/cm^2)	CBR intensity (% age)
1	0	2	4.94	0.25		
2	0.5	7	17.30	0.88		
3	1	17	42.01	2.13		
4	1.5	28	69.19	3.51		
5	2	38	93.90	4.77		
6	2.5	46	113.67	5.77	70	8.25
7	3	52	128.49	6.53		
8	3.5	58	143.32	7.28		
9	4	63	155.67	7.91		
10	4.5	68	168.03	8.53		
11	5	72	177.91	9.04	105	8.61
12	5.5	76	187.80	9.54		
13	6	80	197.68	10.04		
14	6.5	83	205.09	10.42		
15	7	86	212.51	10.79		
16	7.5	89	219.92	11.17	134	8.34
17	8	91	224.86	11.42		
18	8.5	93	229.80	11.67		
19	9	94	232.27	11.80		
20	9.5	94	232.27	11.80		
21	10	94	232.27	11.80	162	7.28

Table 5 Un-soaked CBR test for expansive soil + 3% marble dust

Sl. No.	Plunger penetration (mm)	Dial gauge readings	Applied load (kg)	CBR stress (kg/cm^2)	Standard load intensity (kg/cm^2)	CBR intensity (% age)
1	0	3	7.41	0.37		
2	0.5	9	22.24	1.13		
3	1	19	46.95	2.39		
4	1.5	29	71.66	3.65		
5	2	37	91.42	4.66		
6	2.5	52	128.49	6.54	70	9.35
7	3	57	140.84	7.17		
8	3.5	65	160.61	8.18		
9	4	71	175.44	8.94		
10	4.5	77	190.26	9.69		
11	5	83	205.09	10.45	105	9.95
12	5.5	86	212.50	10.82		
13	6	89	219.92	11.20		
14	6.5	91	224.86	11.45		
15	7	92	227.33	11.58		
16	7.5	93	229.80	11.71	134	8.73
17	8	94	232.27	11.83		
18	8.5	94	232.27	11.83		

Table 6 Un-soaked CBR test for expansive soil + 4% marble dust

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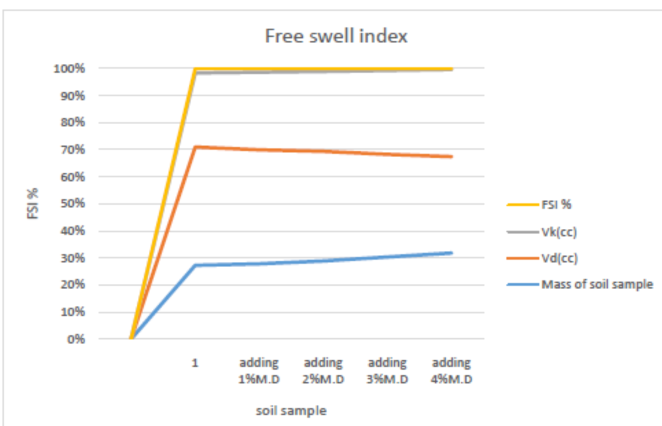
Sl. No.	Plunger penetration (mm)	Dial gauge readings	Applied load (kg)	CBR stress (kg/cm^2)	Standard load intensity (kg/cm^2)	CBR intensity $(\% age)$
1	0	4	9.88	0.49		
2	0.5	10	24.71	1.23		
3	1	28	69.19	3.45		
4	1.5	44	108.72	5.43		
5	2	52	128.49	6.42		
6	2.5	59	145.79	7.28	70	10.40
7	3	66	163.08	8.14		
8	3.5	72	177.91	8.88		
9	4	78	192.74	9.63		
10	4.5	83	205.09	10.24		
11	5	90	222.39	11.11	105	10.58
12	5.5	95	234.74	11.72		
13	6	98	242.16	12.09		
14	6.5	100	247.10	12.34		

FREE SWELL INDEX

Table 7 Free swell index

Free swell index					
sample No.	1	adding 1%M.D	adding 2%M.D	adding 3%M.D	adding 4%M.D
Mass of soil sample	10	10	10	10	10
Vd(cc)	16	15.1	14	12.5	11.2
Vk(cc)	10	10.3	10.2	10.2	10.1
FSI %	60%	46.60%	37.25%	22.54%	10.89%

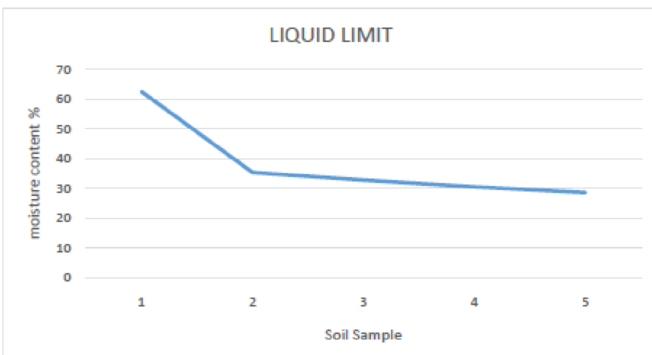


Graph 3 Free Swell Index

LIQUID LIMIT TEST

Table 8 Liquid Limit Test Result

Liquid Limit Test						
Description	**Unit**	**Liquid Limit**				
Container no.	No.	1	2	3	4	5
Soil Sample	Type	soil accumulated	adding 1% marble dust	adding 2% marble dust	adding 3% marble dust	adding 4% marble dust
No. of Blows	No.	25	25	25	25	25
Wt. of container W1	gm	20.1	20.18	21.37	24.28	20.42
Wt . Of wet soil +Container W2	gm	50	38.24	36.1	40.14	39.58
Wt. of dry soil +Container W3	gm	38.5	33.52	32.46	36.43	35.32
Wt . Of water W4=(W2-W3)	gm	11.5	4.72	3.64	37.1	4.26
Wt. of Dry soil W5=(W3-W1)	gm	18.4	13.34	11.09	12.15	14.9
Moisture Content=(W4/W5)*100	%	62.5	35.38	32.82	30.52	28.59



Graph 4 Liquid Limit Test

CONCLUSION

Based on the results of tests conducted stabilization on expansive soil with different proportion of marble dustcontent of 1%, 2%, 3%, 4%, by dry weight of the soil. Under the study, the following conclusions are drawn.

1) Soil sample under study stabilized with different percent of marble dust waste those results in decrease in optimum moisture content by 20%.

2) The maximum dry density of expansive soil under study increased by 0.43% with increase in proportion from 1% to 4% of marble dust.

3) The unconfined compressive strength of soil mix increased by 0.9%significantly with marble dustas stabilizer.

4) Soil stabilization with the help of marble dust results in increment of C.B.R value of soil by 0.04%.

5) Stabilization by adding marble dust as stabilizer it was found that liquid limit decreased by 33% by adding minimum stabilizer.
6) Soil stabilization of expansive soil with the help of marble dust mix proportion of 1% to 4% results in decrease of plastic limit by 13%.
7) Free swell ratio decreased upto5.5times for expansive soil sample with increasing marble dust as stabilizer from 1% to 4%.

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