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Soil Improvement By Using Waste Marble Powder And Chemical Additives

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Abstract:- Soil stabilization is the process of making the existing natural soil strong enough to carry the wheel load of the various vehicles and to keep the sub grade free from the moisture content that can damage the pavement. Soil stabilization can be achieved by various methods such as mechanical method, soil - fly ash stabilization, soil - cement stabilization, soil – lime stabilization and chemical stabilization. This study is focused on to identify the soil mixture, laboratory investigations for finding the initial engineering property for classification of sub-grade soil. Also to determine the engineering characteristics of soil with additives to find whether it is viable for use in terms of economically, suitability and environmentally. The main testing is carried out to compare the strength and characteristic of expansive soil before and after treating with different concentration of additives.

I. INTRODUCTION

An economy of country is dependent upon many factors, among which transportation network is one of the main factors. For a country to be stable and developed it needs a good, safe, economic and efficient transportation network. Transportation network may consist of mode of transportations such as railways, roadways, airways and waterways. Among all the modes of transportation, roadways is one of the most commonly used mode in daily life as it provides door to door service from origin to destination for passengers or freight. For the purpose of management and administration, roads in India are divided in to the following five categories.

- National Highway (NH)
- State Highway (SH)
- Major District Road (MDR)
- Other District Road (ODR)
- Village Road (VR)

India is currently confronted with the tremendous test of safeguarding and upgrading the transportation framework, these require the interest of new material to enhance the security of soils. There are industrial and mechanical waste materials which can be contaminating the earth; however in the event that used for sub-grade, it enhances the quality of the soil, in this way decreasing the expense of development of the street. In this condition important to enhance the treatment of soil stabilization. The state of Minnesota and many counties throughout Minnesota, along with other entities throughout the Midwest, are using a variety of stabilization techniques for various materials used in road construction. Such methods appear to improve constructability and lead to increased performance and reduced maintenance.

While a number of studies in the past have investigated such stabilization efforts (including materials and techniques, relative increases in strength and/or stiffness, etc.) no overall quantification and summary of the effects of material stabilization have been brought forward with recommendations of parameters to be used for the design purposes. Cost effective roads are very important for economic growth in any country. There is an immediate need to identify new materials to improve the road structure and to expand the road network. Commonly used materials are fast depleting and this has led to an increase in the cost of construction.

Stabilized soils can often be adequate for airfields, traffic pavements, and parking and storage areas where an all-weather surface is required, yet traffic does not justify a higher-strength pavement. Surface treatments are also used to provide dust control. The most widely recognized form of stabilization is compaction, which improves the mechanical stability of virtually any soil. However, compaction alone is often not enough.

Stabilization is the process of blending and mixing materials with a soil to improve the soil's strength and durability. The process may include blending soils to achieve a desired gradation or mixing commercially available additives that may alter the gradation, change the strength and durability, or act as a binder to cement the soil.

II. LITERATURE REVIEW

Sharma (2015) has studied stabilized artificial soil samples were obtained by adding 5, 10, 15, 20, and 25 % of marble slurry and then the effect of waste type on the consistency limits and compaction parameters of the samples were examined. The following conclusion was drawn from the result of the laboratory tests. The addition of the marble dust to the soil reduces the clay contents and thus increases in the percentage of coarser particles. It reduces the liquid limit, raises the shrinkage limit and decrease in the plasticity index of the soil and thus swelling percentage. By curing the sample, the rate of swell and swelling percentage decreased. Therefore expansive soil can be replaced by marble dust for reducing the swelling up to 20% to 25 % because there is not much difference in swelling potential and rate of swell up to adding of 25 % marble dust.

Chavahan &Bhole (2014) have studied Compressive strength increases with increase of marble powder. Compressive strength increases with 30% replacement and also 45%, 50% replacement by sand. The maximum 28 days split tensile strength was obtained with 45%marble powder replaced with fine aggregate. We have put forth a simple step to minimize the costs for construction with usage of marble powder which is freely or cheaply available; more importantly. We have also stepped into a realm of saving the environmental pollution by cement production; being our main objective as Civil Engineers. Marble slurry utilization in black cotton soil is one of the best ways to improve soil properties and to protect the environment up to some extent from the harmful effects of disposal of marble slurry in land and water.

Devesh (2015) has studied experimental investigation conducted on optimum marble dust replacement with sand. After cutting and sawing marbles, in large amount of marble slurry produce. This marble slurry disposed to open land area, it make land pollution and harmful to land. In road construction it can use as substitute of fine aggregate, it good binding property and give enough strength to concrete.
Specific gravity of sand 2.58 and marble dust's 3.06, thus specific gravity of marble dust is more than sand. Sand has more water content then marble dust. So for preparing concrete mix marble dust require more water to add. Initial setting time of cement was found 45-50 minute. In slump test workability of marble dust-concrete was determined, as amount of marble dust increased slump value also decreased as compare to normal cement concrete. For desired slump value for workability add more water added. In compressive strength test on harden concrete cube, it was found as amount of marble dust increased compressive strength decrease but it has enough compressive strength as require for construction. Up to 50% fine aggregate can replaced with sand.

Kavas &Olgun et al. (2007) have studied the general effect of marble dustand crushed bricks is to retard the setting time of the cement. The replacement of PC by MD and CB influences significantly the strength of the mortar. The strength of the mortar containing waste materials was lower than that of the control mortar. Depending of the CB resource, the incorporation of MD and CB results in an enhanced flexural strength compared to the PC mortar containing MD. The cement containing waste material demands higher water content than Portland cement. The production of cement containing MD and CB seems to be very challenging, due to satisfactory properties of the blended cement as well as the low cost and the availability of MD and CB in Turkey.

Ali, Khan& Shah et al. (2014) have studied Unified Soil Classification System (USCS), The Bannu soil classified as CH group. Stabilization of soil by using industrial waste such as marble dust and bagasse ash is successfully improving the poor properties of expansive soil. Marble dust and bagasse ash are available locally in large quantity, thus it is an economical way of soil stabilization. Marble dust and bagasse ash are directly disposed of into the river which affect the aquatic life and are already burden on our natural environment. Thus it is Best alternative to utilize these wastes for the improvement of local expansive soil. Addition of 4%, 8% and 12% marble dust and bagasse ash are led to reduce the liquid limits, plastic limits, plasticity index and expansive index. Thus increasing in marble dust and bagasse ash reduce the index properties of expansive soil. Addition of 12% marble dust reduce soil uplift pressure from 9.02psi to 5.56psi where as 12% bagasse ash reduce soil uplift pressure from 9.02 psi to 4.72psi which shows that bagasse ash is more effective in decreasing the soil uplift pressure. Dry density of expansive soil also increase with the addition of marble dust and Bagasse ash and remain maximum approximately at 8% addition but again decline with the addition of 12% marble dust and bagasse ash.

Saygili (2015) has studied of clay samples having varied activity levels are improved substantially by the addition of waste marble dust. High plasticity samples (K3B7) showed better performance in direct shear and swelling tests, low plasticity samples (K7B3) showed better performance in unconfined compressive strength tests. All these property changes have their origin in the modification caused by the marble dust-clay reactions in the structure and texture of the treated samples. These properties change with curing time and samples gain performance with the pozzolanic reactions.

Based on the experimental results obtained from this study, finding new utilization areas for waste marble dust (by-product) will decrease environmental pollution and by utilizing these waste materials in problematic soils have great contribution to the economy and conservation of resources. Besides that, usage of waste marble dust in improving problematic soils (especially swelling) will be an alternative and economic method in highly active clayey zones.

III. LABORATORY TEST AND ANALYSIS

Laboratory Tests for Soil (As per Indian Standards)

To identify the engineering properties as per Indian Standard provision, various tests were performed which are enlisted as follows.

- Determination of Grain Size Analysis (IS: 2720 (Part IV) – 1985)
- Determination of Liquid & Plastic Limit (IS: 2720 (Part V) – 1986)
- Determination of Free Swell Index of Soils (IS: 2720 (Part XL) – 1977)
- Laboratory Determination of California Bearing Ratio (IS: 2720 (Part XVI) – 1987)
- Determination of Unconfined Compressive Strength (IS: 2720 (Part X) – 1991)

A) Soil Classification, FSI & Atterberg's Limit

IS: 1498 – 1970 describes the Indian Standard on Classification and Identification of soils for general engineering purposes. To determine the classification of soil, data for gradation, Atterberg's limits are required which were performed in the laboratory as per Indian Standards. Following are the results for the given soil.

Table 1: Soil Classification, FSI & Atterberg's Limit

Soil	Grain Size Distribution			Atterberg's Limit			Free Swell Index (FSI)	IS Classification
	Gravel (%)	Sand (%)	Silt/Clay (%)	L. L (%)	P. L. (%)	P. I. (%)		
Clay Soil	1	27	72	43.20	22.175	21.025	50%	CI

Table 2: LL, PL and Free Swell Index for Clay Soil + Marble Powder

Materials	Liquid Limit	Plastic Limit	Plasticity Index	Free Swell Index
Clay soil + 20 % Marble Powder	31.3	19.725	11.57	34.44
Clay soil + 30 % Marble Powder	27.6	16.4	11.2	32.81
Clay soil + 40 % Marble Powder	25	15.34	9.66	30.77
Clay soil + 60 % Marble Powder	23.5	19.15	4.35	29.28

Table 3: Free Swell Index For Soil Sample

Free Swell Index				
Mass of Dry Soil	**Volume of Soil In water**	**Volume of Soil In kerosene**	**% Free Swell Index**	**Avg. FSI**
10	50	10	50	50
10	50	10	50	

Table 4: Result for CBR Test for Clay Soil + 40%Marble Powder + 0.002 % Terassil

Result for CBR Test Clay Soil					
Sample Condition : Remolded at OMC & MDD					
Test Condition : Soaked **Soaking for 96 Hours, 7 Day, 14 Day, 21 Day, 28 Day**					
Penetration Rate : 1.25 mm/minute **Surcharge Weight :** 10.0 kg					
Penetration (mm)	**Load (kg) 96 Hours**	**Load (kg) 7 Day**	**Load (kg) 14 Day**	**Load (kg) 21 Day**	**Load (kg) 28 Day**
0.5	44.252	53.102	64.165	79.654	92.929
1.0	67.484	79.653	98.460	116.162	136.074
1.5	94.035	110.63	139.393	146.031	171.476
2.0	119.480	141.606	164.839	179.220	204.665
2.5	141.606	178.114	209.090	219.047	248.917
4.0	190.283	215.728	246.704	258.874	297.594
5.0	226.791	248.917	271.043	297.594	330.783
7.5	285.425	297.594	316.401	345.165	342.953
10.0	307.551	329.677	359.547	384.992	379.460
12.5	315.295	356.228	392.736	415.968	448.051

Table 5: Result for UCS Test for Clay Soil + 40% Marble powder

Axial Deformation (mm)	**Compressive Stress (KPa)**	**Compressive Stress (KPa) 3 Day**	**Compressive Stress (KPa) 7 Day**	**Compressive Stress (KPa) 14 Day**	**Compressive Stress (KPa) 21 Day**	**Compressive Stress (KPa) 28 Day**
0	0	0	0	0	0	0
0.5	12.920	33.592	37.468	40.052	24.548	47.805
1	17.968	50.055	65.456	62.890	33.370	68.023
1.5	21.673	65.020	82.868	80.319	47.171	95.617
2	26.593	74.714	96.242	91.177	62.051	115.238
2.5	28.929	84.272	100.624	99.366	71.694	127.038
3	31.230	88.695	104.936	103.686	84.948	143.662
3.5	32.257	93.051	107.940	107.940	93.051	161.289
4	33.267	93.641	110.891	112.123	99.802	171.265
4.5	35.483	94.214	112.568	116.238	106.450	181.087
5	37.665	94.771	114.211	117.856	110.566	184.683
5.5	38.606	**95.310**	114.613	**118.233**	113.407	187.001
6	**39.530**	94.634	**114.998**	117.394	**113.800**	**188.070**
6.5	39.248	93.958	114.177	115.367	112.988	186.728
7	38.966	93.282	113.356	113.356	112.175	185.385
7.5	37.511	91.434	112.534	112.534	111.362	182.869
8	36.237	90.767	111.713	110.549	109.386	181.534
8.5	36.963	90.098	109.735	109.735	108.580	179.042
9	35.543	89.432	108.923	108.923	105.484	176.571

IV. THICKNESS DESIGN AND COST

A) Thickness Design of Flexible Pavement as Per IRC: 37 – 2001 & IRC: 37 – 2012

Thickness Design for Clay Soil

Data for pavement design are given below and from that design of flexible pavement can be done. For Clay soil soak CBR value is 2.09%

Data:

- State Highway (2 Lane)
- Design Traffic (A) = 1000 CVPD
- Lane Distribution Factor (D) = 50 percent (Two Lane Single Carriageway Road)
- Vehicle Damage Factor (F) = 4.5 (Plain Terrain)
- Design Life (n) = 15 years
- Annual Growth Rate (r) = 7.5 percent (Assumed)
- Width = 10.5 + 10.5 m (Considering only single side i.e. 10.5 m)
- Design Soak CBR = 2.09% (obtained)

Design Calculations:
Cumulative no. of standard axle load

$$N = \frac{365 \text{ x } [(1+r)^n - 1]}{r} \text{ x A x D x F}$$

$$N = \frac{365 \text{ x } [(1+0.05)^{15} - 1]}{0.05} \text{ x } 1000 \text{ x } 0.50 \text{ x } 4.5$$

$$N = 17.72 \text{ msa} = 18 \text{ msa}$$

Now, for 2.09% CBR and 18 msa traffic, thickness design is calculated as per IRC: 37 – 2012, pg.26. After interpretation for 18 msa traffic Pavement composition is shown below.

Thickness Design for Soil + Marble Powder
Soaked CBR test is carried out in the laboratory as per Indian Standard, which is 4.68% for 4 days & 6.08% for 28 days for Clay & Marble dust (30%) mixture. So, while designing for Clay + Marble dust 4 & 7 is used to determine the thickness of flexible pavement. For plate 4 & 7 CBR value is 6% and 9 & 10% respectively. Now, for 6% and 9 & 10% CBR and 18 msa traffic, thickness design is calculated as per IRC: 37 – 2012, pg.27, 28. Pavement composition is shown below.

Total Pavement Thickness for Clay Soil + Marble Powder
After 4 days,

- Total Pavement Thickness = 690 mm
- Pavement Composition
  I. Granular Sub base = 300 mm
  II. Granular Base Course = 250 mm = 125 mm +125 mm
  III. Dense Bound Macadam = 100 mm
  IV. Bituminous Course = 40 mm

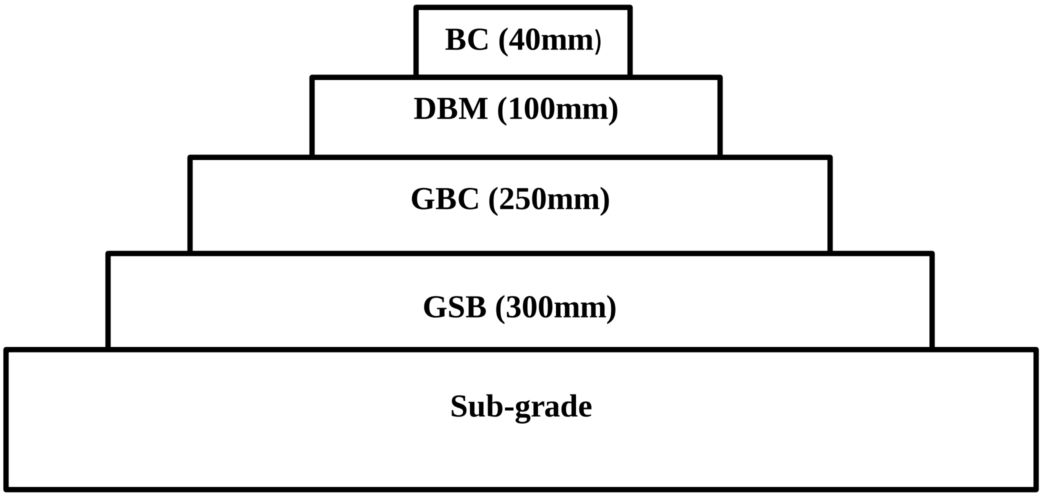

Fig. 1: Composition of layers for Clay + Marble dust

After 28 days,

- Total Pavement Thickness = 655 mm
- Pavement Composition

I. Granular Sub base = 260mm
II. Granular Base Course = 250 mm = 125 mm +125 mm
III. Dense Bound Macadam = 105 mm
IV. Bituminous Course = 40 mm

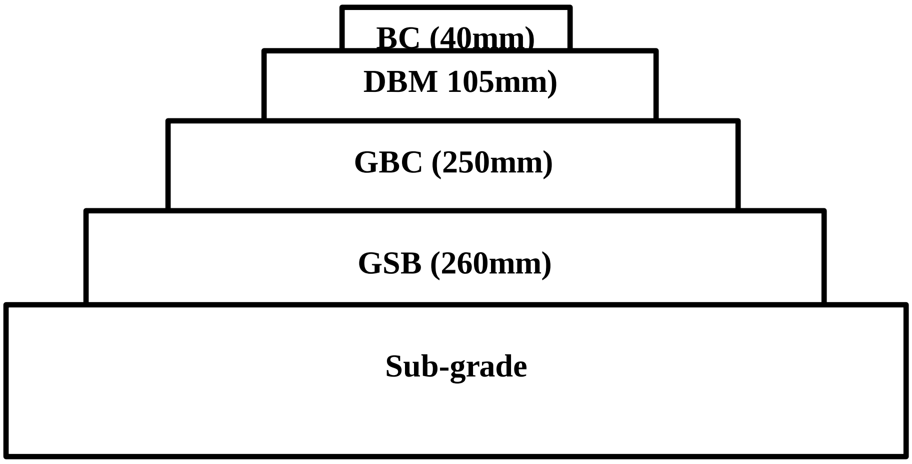

Fig 2: Composition of layers for Clay + Marble Powder

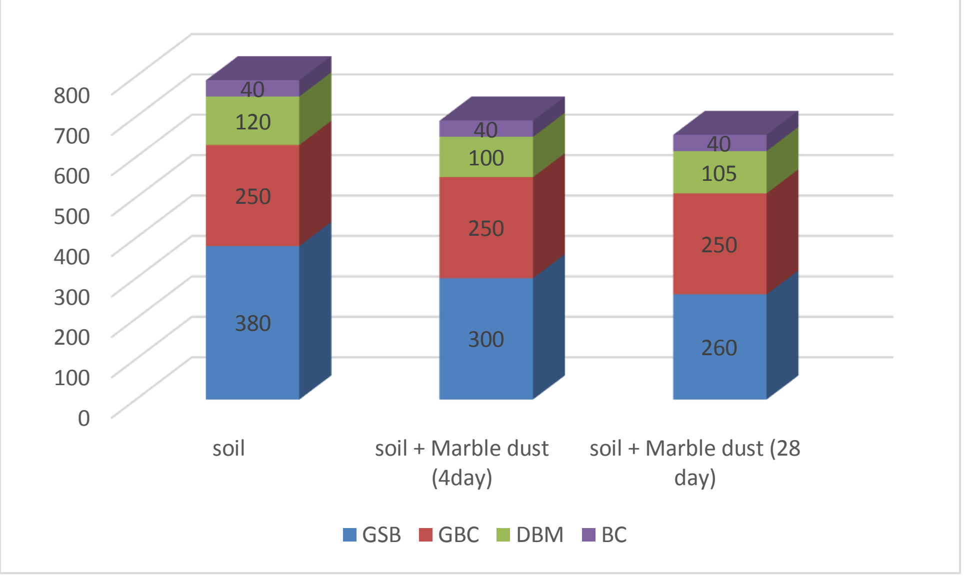

Fig 3: Comparison of Thickness layers with and without additives

CONSTRUCTION COST

Initial cost is generally the major factor in deciding the type of the pavement design. Generally the construction cost is based on tender pricing. It is assumed that the initial cost reflects correct design and the best workmanship of required quality. Here the Rate is taken from NH Standard Data Book (Road & Bridge) 2013.

Quantity for Clay Soil (1 km)

- GSB = 380 mm (200 mm GSB I + 180 mm GSB II)
  Now, width = 7m & length = 1000 m

Quantity for GSB I = 0.200 * 7 * 1000 = 1400m^3
Quantity for GSB II = 0.180 * 7 * 1000 = 1260m^3

- GBC = 250 mm (125 mm WBM + 125 mm WMM)
  Quantity for WBM = 0.125 * 7 * 1000 = 875m^3
  Quantity for WMM = 0.125 * 7 * 1000 = 875m^3
- Quantity for Prime Coat = 7* 1000 = 7000m^2
- Quantity for DBM = 0.093 * 7 * 1000 = 651 m^3
- Quantity for BC = 0.040 * 7* 1000 = 280m^3

Table 6: Cost Analysis for Clay Soil

Item No.	Item Name	Total Quantity	Unit	Rate Rs.	Total cost Rs.
1	GSB I	1400	Cum	989	1384600
2	GSB II	1260	Cum	999	1258740
3	WBM	875	Cum	1036	906500
4	WMM	875	Cum	1330	1163750
5	Prime Coat	7000	Sq. m	35	245000
6	DBM	651	Cum	7398	4816098
7	BC	280	Cum	8493	2378040
Total Amount Rs.					12152728

Quantity for Clay soil + Marble dust (1 km)

- GSB = 300 mm (180 mm GSB I + 120 mm GSB II)
  Now, width = 7 m & length = 1000 m
  Quantity for GSB I = 0.180 * 7 * 1000 = 1260 m^3
  Quantity for GSB II = 0.120 * 7 * 1000 = 840 m^3
- GBC = 250 mm (125 mm WBM + 125 mm WMM)
  Quantity for WBM = 0.125 * 7 * 1000 = 875m^3
  Quantity for WMM = 0.125 * 7 * 1000 = 875m^3
- Quantity for Prime Coat = 7 * 1000 = 7000m^2
- Quantity for DBM = 0.068 * 7 * 1000 = 476 m^3
- Quantity for BC = 0.040 * 7 * 1000 = 280 m

Table 7: Cost Analysis for Clay Soil + Marble dust

Item No.	Item Name	Total Quantity	Unit	Rate Rs.	Total cost Rs.
1	GSB I	1260	Cum	989	1246140
2	GSB II	840	Cum	999	839160
3	WBM	875	Cum	1036	906500
4	WMM	875	Cum	1330	1163750
5	Prime Coat	7000	Sq. m	35	245000
6	DBM	476	Cum	7398	3521448
7	BC	280	Cum	8493	2378040
Total Amount Rs.					10300638

Table 8: Summary of Cost Analysis

Sr. No.	Materials	Cost (Rs.)
1	Clay Soil	12152728
2	Clay Soil + Marble dust	10300638

V. CONCLUSION

Untreated Soil

1. The soil selected comes out to be Clay soil i.e., Intermediate Plastic Clayey soil (CI) soil.
2. Atterberg's Limits of natural soil are: Liquid Limit is 43.20, Plastic Limit is 22.175 and Plasticity Index is 21.025. Free Swell Index of CH soil is 50%.
3. The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are 10.16 and 1.89 respectively.
4. The average value of California Bearing Ratio (CBR) for 0 Day and 7 Day of natural soil comes out to be 2.09% and 2.09% respectively, which is very weak for pavement construction.
5. Unconfined Compressive Strength (UCS) of 0, 3, and 7 days untreated CI soil is found out as 29.733, 89.49, and 105.39 KPa respectively.

Clay Soil + 40% Marble Powder

1. Liquid Limit and Plastic Limit is 25 and 15.34 respectively. Plastic Index is 9.66.
2. The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are 7 and 2.13 respectively.
3. The average value of California Bearing Ratio (CBR) for 0 and 7 days natural soil comes out to be 10.65% and 11.79% respectively.
4. Unconfined Compressive Strength (UCS) of 0, 3, and 7 days untreated CI soil is found out as 39.53KPa, 95.31KPa and 114.998KPa respectively.

Clay Soil + 40% Marble Powder + 0.002 % Terrasil

1. Liquid Limit and Plastic Limit is 25.95 and 16.175 respectively. Plastic Index is 9.775.
2. The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are 2.18 and 8.75 respectively.
3. The average value of California Bearing Ratio (CBR) for 3 and 7 days natural soil comes out to be 11.036% and 13.001% respectively.
4. Unconfined Compressive Strength (UCS) of 1, 3, and 7 days untreated CI soil is found out as 40.728KPa, 99.631KPa and 116.196KPa respectively.

The unconfined compressive strength and the California bearing ratio of the clay soil increases by stabilizing the soil with Marble powder. It is one of admixture out of remaining admixture like stone dust, fly ash, rice husk, polymers, Portland cement, lime and ionic stabilizers. We can say it is a little bit of effective in using Marble powder as admixtures when compared with other stabilizing agents.

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