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AN INVESTIGATION ON THE EFFICACY OF MARBLE DUST POWDER FOR STRENGTHENING THE MARINE CLAY IN FLEXIBLE PAVEMENTS SUBGRADE

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Abstract - *The great compressibility and low shear strength of Marine Clays present a number of challenges to construction and economic activities. Therefore, investigations to enhance the Geotechnical qualities of Marine Clays that make up extensive sections of coastal line have become of prime importance in recent decades. Although, there have been some systematic studies on compressibility features, very few attempts have been made to research the shear strength components of Marine Clay and the creation of methods to enhance it. The present work details the study carried out on Kakinada Marine Clay to investigate the efficiency of Marble Dust Powder(MDP) in varying proportions to increase the geotechnical characteristics and obtain optimum percentage of admixture with marine clay. In this study laboratory tests such as Atterberg's limits, Modified Proctor Compaction test, CBR test and Cyclic Plate Load test were carried out for treated and untreated marine clay. The study showed the enhancement of the strength of Marine Clay with Marble Dust Powder.*

***Key Words*: Marine Clay, Sub Grade, Marble Dust Powder (MDP), Stabilization, Optimum Moisture Content (OMC), California Bearing Ratio (CBR)**

1. INTRODUCTION

Soil stabilization have emerged as predominant importance in recent years. With the onset of urbanization and the ensuing search for the increasing amounts of habitable land, it became imperative that vast tracts of Marine Clays, previously thought to be in-habitable, have to be reclaimed and developed. The Marine Clays have high shrinkage and swelling behaviour when exposed to water during the monsoon that changes their density. In the summer, the soil shrinks owing to evaporation of water, and hardens due to increasing density, and loses its natural properties as depth increases. The seasonal variations in the ground water profile that cause changes in moisture content are what cause the volumetric deformation.

The evolution of traffic patterns and subgrade conditions, the measures and stabilization techniques to necessitate sustainable construction techniques of pavements is essential. There have been numerous issues with embankments and deep cuttings for both railways and highways, as well as settlement of structures built on foundations made of these soils. These concerns make stabilization of Marine Clay inevitable. Stabilization is carried out using various stabilizing materials such as Lime, Cement etc. The alternate use of stabilizing materials such as detritus obtained during mining or construction activities have been increasing. Effective use of construction waste has been a major logistical and environmental issue in large scale activities. Worthwhile Utilization of Construction and industrial waste materials is the best way of disposal. Marble Dust is obtained during trimming, smoothing and grinding of marble stone. Waste marble dust which is waste obtained from marble industry is used as stabilizer. Marble dust constitutes of 40% of total marble handled. The research conducted here studied at how adding Marble Dust Powder to Marine Clay affected its properties.

The purpose of this work is to investigate ways to increase the strength attributes of Marine clay. Marble dust is blended with untreated soil in a various proportions to achieve the ideal admixture level needed for soil stability. the present experimental study has been taken up by adding Marble Dust Powder to Marine Clay. For both untreated and treated Marine Clay, laboratory tests like the Atterberg limit, compaction test and CBR test are conducted as part of this comparative study. Therefore, the investigation learned and the data produced could be applied to the pavement sub grade and foundations of offshore structures as well.

2. OBJECTIVES OF THE STUDY

Do not number text heads-the template will do that for you. The objectives of the present experimental study are

- To determine the properties of the Marine Clay.
- To examine the effectiveness of Marble Dust in enhancing the strength parameters of Marine clay.
- To investigate the performance of the treated Marine Clay as a subgrade material for flexible pavements under cyclic pressures.

3. MATERIALS USED

3.1 MARINE CLAY

The Marine Clay was obtained from Kakinada Sea Ports Limited in Kakinada at a depth of between 0.3 and 1.0 metres. On the eastern coast of India stands the port city of Kakinada. According to geotechnical engineers, any of the already employed methods for improving the ground must be applied to alter how these deposits behave.

Fig 1. Marine Clay

3.2 MARBLE DUST POWDER (MDP)

Marble is a non-foliated metamorphic rock composed of re-crystallized carbonate minerals, most commonly calcite ortodolomite. Geologists use the "marble" to refer the metamorphosed limestone; however stone masons use term more broadly to encompass un-metamorphosed limestone. The Marble Dust Powder was collected from Astra Chemicals Private Limited, Chennai, India.

S.No	Constituent Elements	Content
1	Silica (SiO_2)	1.138%
2	Alumina(Al_2O_3)	0.23%
3	Ferric Oxide(Fe_2O_3)	0.09%
4	Calcium Oxide(CaO)	45.18%
5	Calcium Carbonate($CaCO_3$)	8.850%
6	Magnesium Oxide(MgO)	0.20%
7	Magnesium Carbonate($MgCO_3$)	0.42%
8	Sulphur (SO_3)	0.01%
9	Phosphorus (P_2O_5)	0.01%
10	Loss On Ignition	43.60%

Table-1 Chemical Composition of MDP

Source Aastra Chemicals

Fig 2 Marble Dust Powder

S. No	Property	Value
1	Physical State	Fine Powder
2	Odour	Odorless
3	Appearance	Free Flowing
4	Color	Natural White
5	Pack Density	1.100 g/ml
6	Ph(5% Solution)	6
7	Specific Gravity	2.7
8	Moisture Content(%)	0.40
9	Oil Absorption(%)	18.2
10	Particle size	325 Mesh

Table-2 Physical Properties of MDP

Source : Aastra Chemicals

4. VARIABLES TAKEN FOR THE STUDY

The study is carried out on Marine clay; marine clay treated with Marble dust (MD) and Marine Clay with optimum of Marble Dust Powder treated in the following percentages. Marble Dust Powder (MDP) was varied in percentages of 10%, 15%,20% and 25% by weight of marine clay throughout the experiment. In order to increase the CBR of Marine Clay treated with Marble Dust Powder.

5. LITERATRE REVIEW

Dr.D.Koteswara Rao , Ch Srikanth (2019) studied "An experimental study on the performance of the Marine Clay stabilized with seashell powder and sodium silicate as a sub-grade for the flexible pavements". It was observed from laboratory test results that the CBR value of the Marine Clay has been improved by 233.4% on addition of 18% seashell powder and CBR value of this treated the Marine Clay has been improved further 499.03% by addition of 1% sodium silicate when compared with untreated the Marine Clay.

Harish Parimi et al. (2018) studied "A Modern and Experimental Study on stabilization of Marine Clay by using

coir fibre for Foundation". It was observed from laboratory test results that the overall deformations at ultimate load carrying capacity of the treated model foundation bed at OMC have lowered by 45.0% when compared to the untreated Marine Clay.

The results of a laboratory plate load test revealed that the treated marine clay at OMC has a higher ultimate load bearing capacity than the untreated marine clay, increasing by 142.49%.

Julia Rachel (2020) studied "A Study on the Effect of Polypropylene Fibre on Jarofix-Stabilised Cochin Marine Clay". It was observed from laboratory test results that the liquid limit was discovered to decrease regardless of the amount of jarofix added. The uncontaminated marine clay's CBR value was 0.88% for dry conditions and 0.74% for wet conditions before being enhanced by 290% and 300%, respectively. It was discovered that the CBR value increases continuously as the percentage of jarofix rises to 30% and then falls with further addition. In tests using jarofix and synthetic fibres with the addition of and 480% for damp conditions, 30% was chosen as the ideal percentage.

Najwa Wasif Jassim, Hanan Adnan Hassan (2022),studied Utilization of waste marble powder as sustainable stabilization materials for subgrade layer. The plasticity index decreased by about 22% with the increase in the MD content from 0% to 12%. The results also indicate that using 9% MD reveal further increase in the plasticity index.The maximum dry density MDD of the treated soil mixture increased, whereas the optimum moisture content OMC of the mixture decreased by about 14%, 26% respectively as adding MD to the soil mixture from 0% to 15%.

Ramoo Ram, Ravi Kant Pareek,observed the effect of Marble Dust on Soil Properties 2018,It reduces the liquid limit, shrinkage limit and increase in the plasticity index of the soil and reduce the swelling percentage because of change in gradation of clayey soil by mixing marble dust..As compared to untreated soil, the percentage increase in OMC at 15% addition of Marble dust is 22.39% due to change in plasticity index and liquid limit. The optimum results were found when soil was stabilized with 15% marble dust. The CBR value is increased from 2.36% to 14.86%.Above results of CBR test and MDD of soil with 20% marble shows that the CBR results of this soil is good enough to construction for medium traffic volume roads. So we can utilize more marble waste in stabilization process.

6. TESTS CONDUCTED

6.1 Differential Free Swell Index

Free swell index, is the volume increase of soil caused by being submerged in water in absence of any external forces for a period of 24 hours. it is conducted as per IS 2720 (Part XL)-1977. The free swell index of the soil helps in identifying the swelling potential of the soil.

$$\text{Free swell index (\%)} = \frac{V_d - V_k}{V_k} * 100$$

V_d = Soil specimen volume after immersing 24 hours in distilled water.

V_k = Soil specimen volume after immersing 24 hours in Kerosene.

6.2 Atterberg's Limits

Consistency limits sometimes referred to as Atterberg's limit, are the water contents at which soils transform from one condition to another. The Liquid Limit, Plastic Limit and thereby the Plasticity Index were determined using Casagrande's apparatus as per the procedures laid down in IS: 2720 part 5 (1985).

6.3 Modified Proctor Compaction Test

Modified proctor compaction test used for the determination of Optimum Moisture Content and Maximum Dry Density**.** It was conducted as per IS: 2720 part-10 (1983).

6.4 California Bearing Ratio Test

Test specimen is prepared by mixing of Marble Dust Powder in different percentages by the dry weight of soil and MDP was mixed thoroughly with equivalent dry unit weight and optimum moisture content which is obtained from proctor test. Mixed soil sample is placed in five layers in CBR mould having dimensions of 150mm diameter and 175mm height and each layer is compacted by 55 blows. The prepared soil sample is soaked for four days.The loads necessary for 2.5mm and 5.0mm penetration were noted and higher value is considered.

$$\text{CBR (\%)} = \frac{\text{Penetration load}}{\text{Standard load}} * 100$$

6.5 Laboratory Plate Load Using Model Tank

Cyclic Plate Load Test is a field or laboratory test for determining the ultimate load carrying under an applied load. These tests were carried out on flexible pavements systems in a circular steel tank of a diameter of 60cm . The loading was done through a circular metal plate of 10cm diameter laid on the subbase course in a model flexible pavement system. The steel tank was placed on the pedestal of the compression testing machine. Two dial gauges of least count 0.01 mm were arranged on opposite sides for obtaining the deformations. A 5 Ton capacity hydraulic jack was placed on the loading frame . Cyclic load tests were carried out at OMC state corresponding to tire pressures of 500,560,630,700 and 1000 kPa. Each pressure increment

was applied until there was no significant change in deformation between the consecutive cycles. The testing was further continued till the occurrence of failure of the model pavement to record the ultimate load. These tests were carried out at OMC for all the model flexible pavements.

7. RESULTS AND DISCUSSIONS

7.1 Values Obtained from various tests of Untreated Marine Clay

S.No	Description		Value
1	Natural Moisture Content (%)		91.87
2	Particle Size Distribution	Gravel (%)	0%
		Sand (%)	9.0
		Silt (%)	42.0
		Clay (%)	49.0
3	Specific Gravity		2.51
4	Differential Free Swell Index (%)		82.0
5	Liquid Limit (%)		68.91
6	Plastic Limit (%)		31.02
7	Plasticity Index (%)		37.89
8	Soil Classification		CH
9	Maximum Dry Density (g/cc)		1.410
10	Optimum Moisture Content (%)		33.81
11	CBR (%)		0.86

Table 3 Properties of Untreated Marine Clay

7.2 Differential free Swell Index of Marine Clay Treated with various proportions of Marble Dust Powder

S.No	Mix Proportion	DFS (%)
1	100 % Marine Clay	82
2	90 % MC+ 10 % MDP	70
3	85 % MC+ 15 % MDP	60
4	80 % MC + 20 % MDP	45
5	75 % MC + 25 % MDP	40

Table-4 Differential free Swell Index of Marine Clay treated with various proportions of Marble Dust Powder

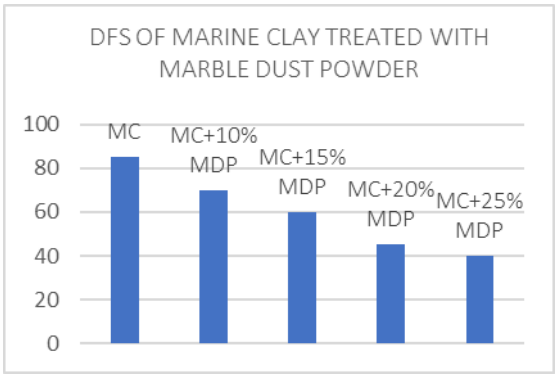

Chart -1: Differential free Swell Index of Marine Clay treated with various proportions of MDP

From the above table and figure it is observed that the differential free swell index of the marine clay decreases with increasing the percentage of marble Dust Powder. The DFS value decreases from 82 to 66 when Marble Dust Powder content is increased from 0 to 20 %.

7.3 Atterberg limits of Marine Clay Treated with various Proportions of Marble Dust Powder

S.No	Mix Proportion	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	100 %MC	68.91	31.02	37.89
2	90 % MC+10 % MDP	58.56	27.8	30.76
3	85 % MC+15 % MDP	54.13	28.92	25.21
4	80 % MC+20 % MDP	51.8	29.27	22.53
5	75 % MC+25 % MDP	48.05	30.86	17.19

Table-5 Atterberg limits of Marine Clay treated with various proportions of MDP

The results of Atterberg's limit values on the marine clay with different percentages of Marble Dust Powder are shown in the above table and figure. From the figure the following conclusions were made.

The liquid limit of the marine clay decreases with increasing the percentage of marble Dust Powder. The Liquid limit value decreases from 68.91 % to 48.05 % when Marble Dust Powder content is increased from 0 to 25 %.

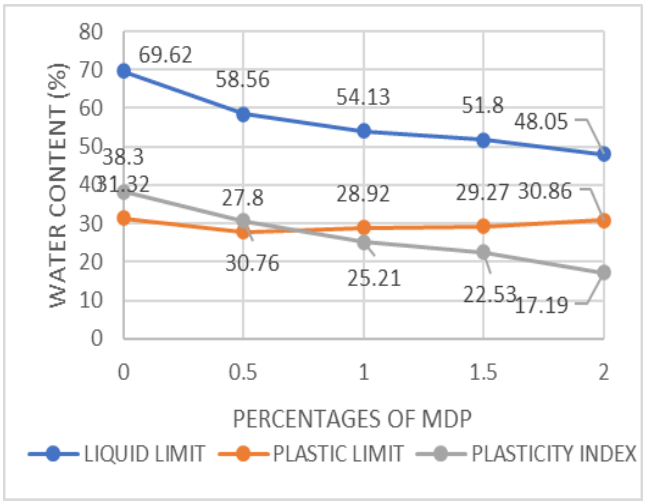

Chart -2: Atterberg Limits of Marine Clay treated with various Proportions of Marble Dust Powder

The Plastic limit of the marine clay decreased initially at 10% of Marble dust powder content after that it increases with increasing the percentage of marble Dust Powder.

The Plasticity Index of the marine clay decreases with increasing the percentage of marble Dust Powder. The Plasticity Index value decreases from 37.89 % to 17.19 % when Marble Dust Powder content is increased from 0 to 25 %.

7.4 Optimum Moisture Content and Maximum Dry Density of Marine Clay treated with various proportions of Marble Dust Powder

S.No	Mix Proportion	Optimum Moisture Content (%)	Maximum Dry Density (g/cc)
1	100% (MC)	33.81	1.41
2	90% MC + 10% MDP	30.07	1.5405
3	85% MC + 15% MDP	25.48	1.709
4	80% MC+ 20% MDP	21.66	1.791
5	75% MC + 25% MDP	18.96	1.74

Table-5 OMC and MDD of Marine Clay treated with various Proportions of Marble Dust Powder

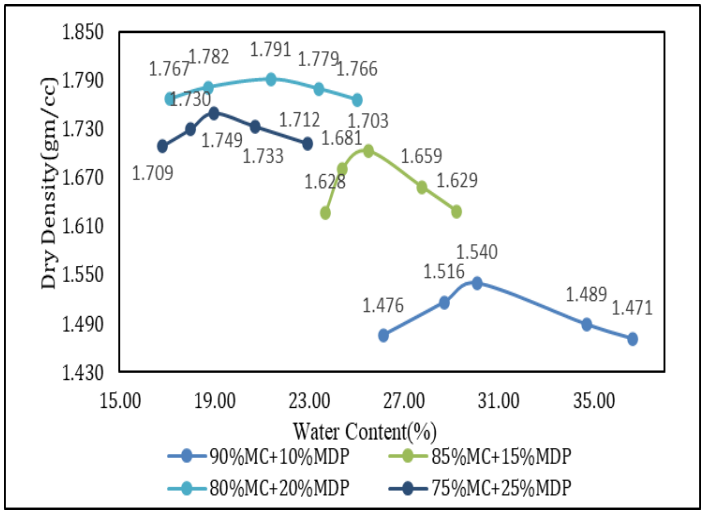

Chart -3: OMC and MDD of Marine Clay treated with various Proportions of Marble Dust Powder

From the above table and graphs its clearly observed that the Maximum Dry Density of the Marine Clay is increases with Increasing the amount of Marble Dust Powder. The MDD value increases from 1.41 % to 1.791 % when Marble Dust Powder content is increased from 0 to 20 %. The Optimum Moisture Content of the Marine Clay is decreases with increasing the amount of Marble Dust Powder. The OMC decreases from 33.12 % to 21.66 % when Marble Dust Powder content is increased from 0 to 20 % and then decrease is observed from 20% to 25%.

7.6 California Beating Ratio Values of Marine Clay treated with various proportions of Marble Dust Powder

S.No	Mix Proportion	CBR (%)
1	100% MC	0.86
2	95% MC + 10% MDP	1.34
3	90% MC + 15% MDP	2.59
4	85% MC + 20% MDP	3.67
5	80% MC + 25% MDP	1.88

Table – 6 CBR of Marine Clay treated with various Proportions of Marble Dust Powder

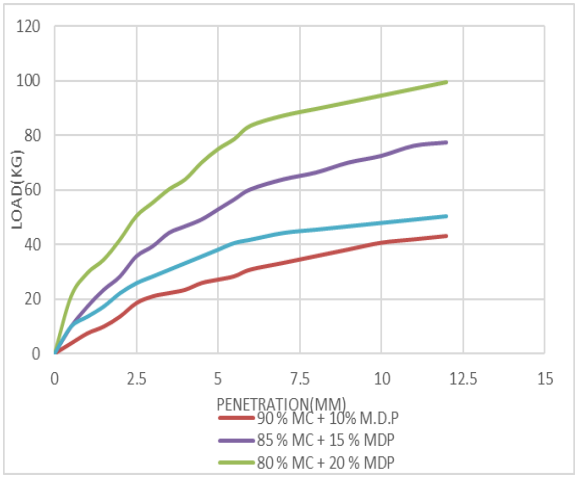

Chart-7 Composite CBR Values of Marine Clay treated with various proportions of Marble Dust Powder

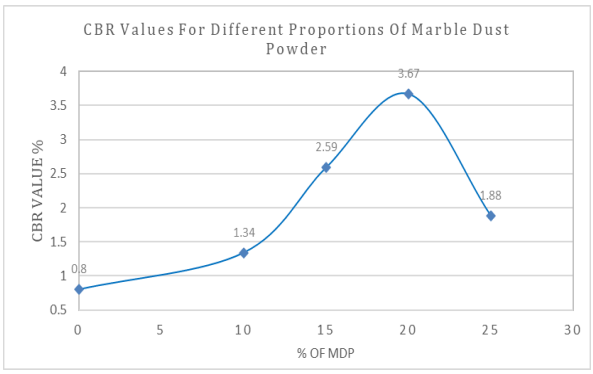

Chart-8 CBR Values of Marine Clay treated with various proportions of Marble Dust Powder

From the above table and graphs it's clearly observed that the CBR Value of the Marine Clay increases with increasing the amount of Marble Dust Powder. The CBR value increases from 0.86 % to 3.67 % when Marble Dust Powder content is increased from 0 to 20 %.

7.7 Laboratory Plate load Test of Untreated Marine Clay and Marine Clay treated with 20% of Marble Dust Powder

S. No	Sub-grade soil	Sub base	Base Course	Ultimate Cyclic Pressure (kPa)	Settlement (mm)
1	100% MC Sub grade flexible pavement	Gravel	WMM -III	630	2.64
2	MC+20% MDP for subgrade flexible pavement	Gravel	WMM -III	1050	2.36

Table-7 Laboratory Plate load Test of Untreated Marine Clay and Marine Clay treated with 20% of Marble Dust Powder

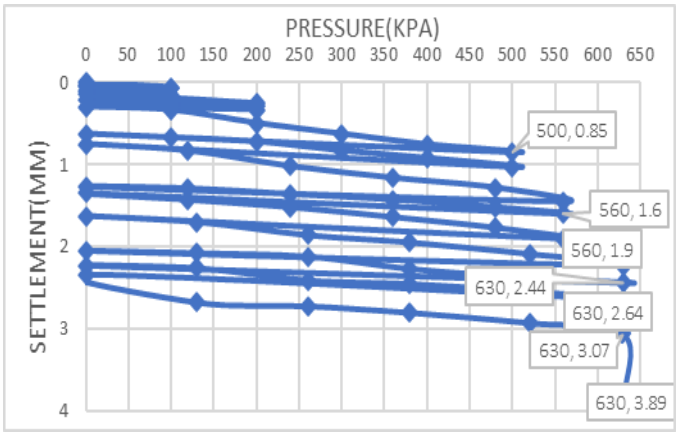

Chart-9 Laboratory Cyclic Plate Load Test Results Of The Untreated Marine Clay For Sub Grade Model Flexible Pavement

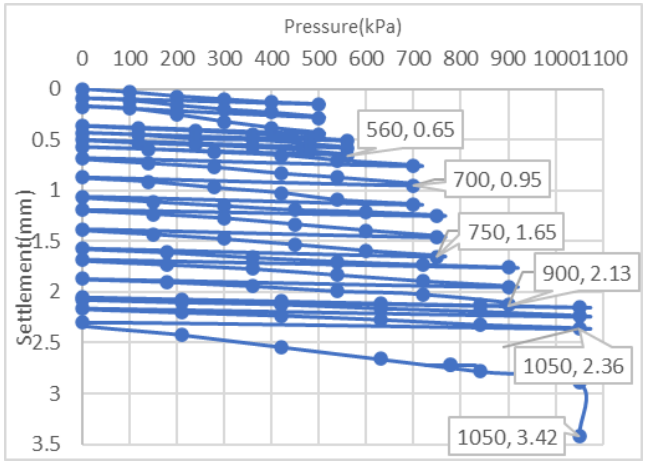

Chart – 10 Laboratory Cyclic Plate Load Test Results Of The Marine Clay Treated With 20% MDP For Sub Grade Model Flexible Pavement

Cyclic Plate Load Test Results of Untreated Marine clay

It was observed from the Chart-9 the Untreated marine clay at OMC for sub graded soil has exhibited the ultimate cyclic load of 630 kN/m² with the deformation of 2.64 mm.

Cyclic Plate Load Test Results of Treated Marine Clay Treated with 20% MDP as subgrade

It was observed from the Figure 4.16 the Marine clay treated with 20% MDP at OMC for sub graded soil has exhibited the ultimate cyclic load of 1050 kN/m² with deformation of 2.36 mm.

8. Conclusions

- It is noticed from the laboratory test results that the Differential Free Swell of Marine Clay has been reduced by 41.17% on the addition of 20% MDP

- It is observed from the laboratory test results that the Liquid limit of Marine Clayhas been decreased by 25.59% on the addition of 20% MDP
- It is observed from the laboratory test results that the Plastic limit of Marine Clay has been increased by 4.9 % on the addition of 20% MDP
- It is observed from the laboratory test results that the Plasticity Index of Marine Clay has been decreased by 41.32 % on the addition of 20% MDP
- It is noticed from the laboratory test results that the OMC of Marine Clay has been decreased by 35.14% on the addition of 20% MDP
- It is noticed from the laboratory test results that the MDD of Marine Clay has been increased by 28.77% on the addition of 20% MDP
- It is observed from the laboratory test results that the CBR of Marine Clay has been increased by 358.75% on the addition of 20% MDP.
- It is noticed from the laboratory investigations of the plate load test results that, the ultimate cyclic pressure of treated Marine Clay with 20% Marble Dust Powder for sub-grade flexible pavement has been improved from 630 kPa to 1050 kPa when compared with untreated Marine Clay.
- It is noticed from the laboratory investigations of the plate load test results that, the total deformation of treated Marine Clay with 20% Marble Dust Powder for subgrade flexible pavement has been improved by 10.60 % when compared with untreated Marine Clay.

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