Effect of Nano Particle (Marble Sludge Powder) on Shear Strength of Soil to Strengthen the Vembakottai Dam

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Abstract

Objectives: A study is carried out to investigate the effect of marble sludge powder on the stabilization of soil and to improve soil properties of an earthen dam at Vembakottai. Methods: Soil samples were collected from different places at Vembakottai dam, while marble sludge powder bought from local market. Marble Sludge powder is the by product from marble pieces and used as a constituent for cement concrete and then stabilize the soil strength. The test revealed as compaction test, unconfined compression test obtained on soil mixed at different proportions of marble sludge powder and cement. Findings: Finally, marble sludge powder can be used to stabilize the soil as sustainable alternative compared to other stabilizers. Marble dust is the best way to achieve sustainable practices and enhance the strength in Vembakottai dam. Basis of experimental work, this research concludes that soil stabilization using cement alone is a very difficult process. Some extra admixtures are used to increase the strength of soil. An admixture which reacts with cement undergone hydration process for that marble sludge powder plays important role in soil stabilization. In this research, better results can be achieved by using marble sludge powder and cement in a ratio of 10:20.

Keywords: Binding Material, Compaction Test, Shear Strength, Stabilization, Sustainable Practices

1. Introduction

Nowadays waste materials are mainly used for the replacement and constituent material in construction practices. Numerous waste products are obtained from agricultural, industrial and domestic purposes. Wastes from all sources pose a threat and cause damage to the environment and human beings. For future considerations, wastes are recycled and reused in a proper manner and also to mitigate the problem created in the environment. Soil stabilization is the important method for changing physical, chemical or biological properties to meet the requirements for engineering purpose to improve the bearing capacity and strengthen the embankment in Vembakottai dam. The main objective of the soil stabilization is to enhance the materials strength and bearing ratio. In past times, it can be done by binding the properties in correct composition for stabilization. But in this study focus on the marble sludge powder as an additive for find out the shear strength in Vembakottai dam. Soil stabilization is defined as the alteration of the soil properties by chemical or physical means in order to enhance the engineering quality of the soil. The main objective of the soil stabilization is to increase the bearing capacity of the soil, its resistance to weathering process and soil permeability. The long term performance of any construction project depends on the stabilization techniques are necessary to ensure the good quality of soil so that it can successfully sustain the load of the superstructure especially in case of soil which are highly active, also it saves a lot of time.
and millions of money when compared to the method of cutting out and replacing the unstable soil. This paper deals with the complete analysis of the improvement of soil properties and its stabilization using lime. Results of a laboratory study undertaken to investigate the effect of marble dust powder on the index properties of black cotton soil. Black cotton soil has a very good capacity and plays a major role in volume change depend upon variations in moisture content. Such expansive soils may need to be improved to make them suitable for construction activities. In this paper explored that to evaluate the feasibility studies using the byproduct of industries as marble dust for soil stabilization.

2. Objectives of this Study

- To use the marble sludge powder as nano particle to strengthen the soil.
- To protect the environment from the pollutant marble sludge powder by effectively using it in the strengthening process.
- To implement this strengthening process in Vembakottai dam.

3. Need for this study

Marble sludge material is a cost effective material which is economical. It eliminates up to 98% of problems associated with soil at the source and very much useful in strengthen and stabilize the soil in dam construction practices. It is environment friendly.

4. Research Methodology

Literature reviewed through the journals, e books and secondary source of information and find out the scope and need of research. Samples as both disturbed and undisturbed samples have been collected near the failure spot canal embankment. These samples undergone laboratory investigation on soil under consideration for check all the properties using proper test machines.

5. Background of Nano Particle

Marble is a metamorphic rock resulting from the transformation of pure limestone considered as a nano particle having their size range between 1 and 100 nanometers which is small in size bit behaves like a full unit depends upon its properties and further, it can be classified upon diameter. Nearly numerous nano particles are available. In this study have chosen marble sludge powder as nano particle which is a byproduct of industrial waste creates an environmental problem to the society all over the world. Marble Sludge Powder (MSP) are discarded in the nearby land and the natural fertility of the soil is spoiled. Due to its property of fineness it could be easily mix with soil mainly for fill the open voids present in the soil and gives perfect soil strength. In this research further test have conducted on combination of soil and marble sludge powder to determine its strength.

Table 1. Chemical properties of marble sludge powder

| S.No | Characteristics     | Result  |
|------|--------------------|---------|
| 1    | Loss on Ignition, % by mass | 3.33    |
| 2    | Silica, % by mass   | 69.21   |
| 3    | Iron, % by mass     | 4.40    |
| 4    | Titanium, % by mass | Nil     |
| 5    | Aluminium, % by mass| 13.48   |
| 6    | Calicum Oxide, % by mass | 8.40 |
| 7    | Magnesium Oxide, % by mass | 0.81 |
| 8    | Available Sodium Oxide, % by mass | 0.26 |
| 9    | Availble Potassium Oxide, % by mass | 0.11 |

5.1 Particle Size Analyzer

The particle size analyzer works on the principle of Dynamic Light Scattering (DLS). In this instrument these measurements taken from 0.3nm to 8micro meter. This analysis can be done by the procedure of 1mg sample is dissolved in acetic acid for half an hour. The solute is kept inside the instrument for analysis. The following values are found from particle size analyzer.

Table 2. Particle size analysis.

| Peak No | S.P. Area Ratio | Mean  | S.D  | Mode  |
|---------|-----------------|-------|------|-------|
| 1       | 1.00            | 12.39 | 11.19| 121.3nm |
| 2       | -               | -     | -    | -     |
| 3       | -               | -     | -    | -     |
| Total   | -               | 12.39 | 11.9n| 121.3nm |
7. Physical Properties of Soil

7.1 Specific Gravity of soil
Specific gravity was determined by using pycnometer. The pycnometer was dried and weighed with its cap (W1). The soil sample was taken into the pycnometer and weighed again (W2). The quantity of water added to the soil and cap was screwed and then shaked well for the purpose of removing entrapped air. Freshly pycnometer was filled with water completely and was dried thoroughly and weighed. Then the values are tabulated for calculation.
Specific gravity of soil = 2.65

7.2 Sieve Analysis
The sieve analysis apparatus is conducted to determine the particle size. Sieve analysis apparatus consists of arranged number of sieve in which weight of each sieve as well as bottom pan to be used in the analysis. Record the weight of dry soil sample and assemble all the sieves in an ascending order. Pour the soil sample from the top of the pan and place the cap. Kept the sample in mechanical shaker and shake for 10 minutes. Remove the shaker and weigh each sieve.
Percentage of gravel = 14%, Percentage of sand = 84%, Cu = 4.4, Cc= 1.71.

7.3 Liquid Limit and Plastic Limit of the Soil
The liquid limit and plastic limit was determined in the laboratory as per IS code. A dried soil sample 120gm was taken out passing through the 425 micro sieve and then mixed with water and paste will come out. Paste was kept in the cup and leveled off using spatula. Grooving tool can be used for groove the middle of the liquid cup. The crank has been rotated about 2 revolutions per second and notes the number of blows and moisture content of the soil. The liquid limit of soil is 24%.
About 20gm of soil passing through 425 micro sieve was mixed thoroughly and was rolled on a glass plate with hand. Mixing and rolling was repeated up to the crumbling stage of until diameter as 3mm. Determination of water content of the crumble portion of threads is called as plastic limit. The plastic limit of the soil is zero, in this proportion of cement and marble sludge powder no threads were formed. i.e. consistency will be zero.

7.4 Shrinkage Limit of the Soil
Shrinkage limit was conducted using shrinkage dish and measured by mercury displacement method as follows:

| S.No | Proportion | SL (%) |
|------|------------|--------|
| C    | MSP        |
| 1    | 10         | 10     | 12 |
| 2    | 20         | 10.5   |
| 3    | 30         | 10     |
| 4    | 20         | 10     | 9.5 |
| 5    | 20         | 10     |
| 6    | 30         | 11     |

7.5 Standard Proctor Compaction Test
This test is mainly used to determine soil compaction properties under the laboratory investigation and then find out the moisture content and relationship between moisture and density of the soil.

| S.No | Proportion | OMC (%) | MDD   |
|------|------------|---------|-------|
| C    | MSP        |
| 1    | 10         | 14      | 1.133 |
| 2    | 20         | 12      | 1.054 |
| 3    | 30         | 14      | 0.987 |
| 4    | 20         | 13      | 1.258 |
| 5    | 20         | 14      | 1.552 |
| 6    | 30         | 16      | 1.826 |

8. Direct Shear Test
Shear box can be used for testing the shear strength of the soil. The shear box is assembles together using the pin. Bottom grid plane is fixed perpendicular to the shear direction in that size of the soil sample is measured in the shear box as 60*60*27mm. The weight of sample calculated for given density. Pins are removed from the shear box and record the observations. Tests were conducted by adding various proportions of marble sludge powder and cement. From that observations shear value will be calculated and plot the graphs using these values. The following values for constant for all proportions:
9. Results and Discussion

The main purpose for determining shear resistance characteristics of soil parameter will be used in the design of the earthen dam and embankment. The advantage of the direct shear test compared to other shear tests are the simple, time consuming and economical and also measure the pore water pressure in undrained conditions. The result shows that failure plane to occur in a specific location alone.

| S.No | Normal load | Deflection dial gauge | Proving ring reading | Normal stress |
|------|-------------|-----------------------|----------------------|---------------|
| 1    | 0.2         | 16                    | 81.2                 | 55.55         |
| 2    | 0.4         | 30                    | 165.3                | 111.11        |
| 3    | 0.6         | 39                    | 245.8                | 166.67        |
| 4    | 0.8         | 49                    | 327.4                | 222.22        |
| 5    | 1           | 58                    | 402.4                | 277.77        |
| 6    | 1.2         | 69                    | 486.6                | 333.33        |
| 7    | 1.4         | 48                    | 541.3                | 388.88        |
| 8    | 1.6         | 89                    | 645.2                | 444.44        |
| 9    | 1.8         | 92                    | 728.5                | 500           |
| 10   | 2           | 110                   | 804.6                | 555.55        |

Direct shear test result for 0-0%:

| Shear Load | 0.3 | 0.6 | 0.9 | 1.2 | 1.5 | 1.8 | 2.1 | 2.4 | 2.7 | 3 |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|
| Shear Stress | 200 | 400 | 600 | 800 | 1000| 1200| 1400| 1600| 1800| 1767 |

Direct shear test result for 10-10%:

| Shear Load | 0.22 | 0.39 | 0.76 | 1.24 | 1.81 | 1.93 | 2.45 | 2.82 | 2.94 | 3.24 |
|------------|------|------|------|------|------|------|------|------|------|------|
| Shear Stress | 146.6| 260 | 506.67| 826.66| 1206.66| 1286.66| 1633.33| 1880 | 1960 | 1860 |

Direct shear test result for 10-20%:

| Shear Load | 0.25 | 0.54 | 0.98 | 1.32 | 1.67 | 1.93 | 2.3 | 2.52 | 2.93 | 3.1 |
|------------|------|------|------|------|------|------|-----|------|------|-----|
| Shear Stress | 166.67| 360 | 653.33| 880 | 1113.33| 1286.66| 1533.33| 1680 | 1953.33| 1933.667 |

Direct shear test result for 10-30%:

| Shear Load | 0.17 | 0.25 | 0.75 | 1.34 | 1.63 | 1.92 | 2.27 | 2.57 | 2.68 | 3.24 |
|------------|------|------|------|------|------|------|------|------|------|-----|
| Shear Stress | 113.33| 166.67| 500 | 893.3 | 1086.67| 1280 | 1513.33| 1713.33| 1786.67| 1710 |

Direct shear test result for 20-10%:

| Shear Load | 0.17 | 0.25 | 0.75 | 1.34 | 1.63 | 1.92 | 2.27 | 2.57 | 2.68 | 3.24 |
|------------|------|------|------|------|------|------|------|------|------|-----|
| Shear Stress | 113.33| 166.67| 500 | 893.3 | 1086.67| 1280 | 1513.33| 1632.52| 1656.32| 1641.2 |

Direct shear test result for 20-20%:

| Shear Load | 0.2 | 0.45 | 0.82 | 1.35 | 1.68 | 1.94 | 2.3 | 2.52 | 2.85 | 3.09 |
|------------|-----|------|------|------|------|------|-----|------|------|-----|
| Shear Stress | 133.33| 300 | 546.67| 900 | 1120 | 1293.33| 1533.33| 1555 | 1567 | 1490 |

Direct shear test result for 20-30%:

| Shear Load | 0.2 | 0.45 | 0.82 | 1.35 | 1.68 | 1.94 | 2.3 | 2.52 | 2.85 | 3.09 |
|------------|-----|------|------|------|------|------|-----|------|------|-----|
| Shear Stress | 133.33| 300 | 546.67| 900 | 1120 | 1293.33| 1312.55| 1385.45| 1415.33| 1455 |
Figure 1. Comparative graph between shear stress vs. normal stress.

10. Conclusion

Basis of experimental work, this research concludes that soil stabilization using cement alone is a very difficult process. Some extra admixtures are used to increase the strength of soil. An admixture which reacts with cement undergone hydration process for that marble sludge powder plays important role in soil stabilization. In this research, better results can be achieved by using marble sludge powder and cement in a ratio of 10:20.

11. References

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