Strengthening of Soil by adding Lime and Glass Fiber as Stabilizing Materials for the Construction of High Rise Buildings

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Abstract. The main aim of this research is to increase the strength properties of the weak soil by using stabilizing materials for the construction of high raised buildings on weak soils. As we all know that the most important thing in construction industry is soil. In this research we are adding stabilizing materials like lime and glass fibers to the weak soil to increase the strength parameters of the soil. The addition of stabilizing materials and admixtures to the soil leads to the increase in the strength parameters of the soil. There are various Infrastructural projects which are constructed on the soil, in many of these cases the black cotton soil is not suitable, because the Black cotton soil is weak in strength and which has low engineering properties. Black cotton soil has more swelling property and high shrinkage nature. To overcome these problems and to improve the engineering properties of the black cotton soil, we are adding Lime and Glass fibers as the stabilizing materials in the weak black cotton soil. The engineering properties like strength, compressibility and bearing capacity of the soil were increased by stabilizing the weak soil these stabilizing materials. This work mainly concentrates on the feasibility of the usage of lime and glass fibers as the stabilizing materials for the black cotton soil. The percentage of Lime and glass Fibers used in black cotton soil varies in different proportions like 2%, 4%, 6%, 8% and 10%. All the necessary tests were conducted to get the results. The properties like Liquid limit, Plastic limit, Compaction characteristics values and Differential free swell index of soil have been studied in this research.

Keywords: stabilization, admixtures, lime, glass fibers, strengthening, black cotton soil, montmorillonite, swelling, expansive.

1. Introduction

For the development of infrastructure, the footings should be strong enough to bear the large loads. For footings to be strong the soil below and around the footings should be strong enough to bear the large amount of loads [1]. The mixture of organic matter, minerals, water, air and some organisms form soils. We have different types of soils available in INDIA e.g. black cotton soils, mountain soils, alluvial soils; laterite soils among all the soils available in India, black cotton soils are very poor in bearing capacity and in engineering properties [2]. The soil in nature is very useful for agricultural and engineering point of view. From an engineering perspective, soil plays a different role in buildings, roads, railways, airports and in other construction works. The strength of the structure depends upon
the type of soil, if the soil has low strength for a particular structure on site, stabilization techniques are needed to increase the strength of the soil [3]. Therefore, before construction of any structure, an engineer must know about the characteristics of the soil below and around the footings, properties as well as the factors affecting their behaviours. Soil stabilization is crucial to ensure soil properties [10]. In this research, lime and glass fibers are used as the strengthening materials for the black cotton soil, because the black cotton soil is not preferable for the construction of high rise buildings due to the presence of montmorillonite in black cotton soils which possesses large swelling and shrinkage when contact with water, as lime and glass fibers provide stabilization of the soil to strengthen the cracking [7]. Adding lime and glass fibers to the soil increases the elasticity modulus and toughness of the soil, which can also change the failure mode of stabilized soil completely from brittle to ductile in nature [9].

2. Materials and Properties

2.1. Black cotton soil

The soils which become sticky when water is added and contract when it is dry condition are known as black cotton soils [11]. Generally these soils contain montmorillonite, which may cause sudden swelling and shrinkage property when it is contacted with water [5]. These swelling and shrinkage properties of the black cotton soil are leads to the decrease of the strength and engineering properties of the soil. The black cotton soils are most preferable for agricultural purposes because of the properties it has like sudden swelling when contact with water but not preferable for the construction of high raised buildings, to overcome that we are stabilizing with the stabilizing materials to improve the strength and engineering properties.

![Figure 1: Black cotton soil](image)

| Table: 1 Black cotton soil properties |
|--------------------------------------|
| **Property**             | **Black cotton soil** |
| Max dry density          | 15.23                |
| Liquid limit (%)         | 63                   |
| Optimum moisture content (%) | 24.31            |
| Plastic limit (%)        | 29                   |
| Specific gravity         | 2.72                 |
| Shrinkage limit (%)      | 13                   |

2.2. Lime

Lime is a multifunctional mineral that can be available in different forms and find application in environmental, metallurgical, architectural and chemical industries [7]. Due to the presence of the high Calcium content in the lime which gives more strength to the soil. The fastest growing lime issued in environmental applications where lime is used in compliance with air, drinking water, wastewater
and solid waste regulations [12]. During the addition of lime in the soil, the clay particles convert natural clay particles as per the requirement such as interlocking metal line structure. Individual clay soil becomes drier and less vulnerable to water content.

**Figure: 2 Lime**

| Property         | Poly propylene |
|------------------|----------------|
| $\text{Al}_2\text{O}_3$ | <1.5          |
| CaO              | >82.4          |
| MgO              | <0.5           |
| Specific gravity | 2.2            |
| $\text{So}_3$    | <0.5           |

2.3. **Glass fibers**

Glass fibres are also called as fibre glass. Glass fibers consist of numerous fine fibers of glass. Glass fibers are the non-crystalline material with a short range network structure [12]. Generally these glass fibers are collected from the waste glass products from the elevation or interior design shops which work on the glass material [4]. The glass fibers act as reinforcement when it is added to the soil as a stabilizing material and it is very strong in tension. Waste glass pieces collected from them and used as a stabilizing material. And it is more economical.

**Figure: 3 Glass Fibers**

| Property            | Glass fiber |
|---------------------|-------------|
| SiO$_2$             | 53.8        |
| Aluminum Oxide      | 27.3        |
| CaO                 | 12.62       |
| Specific Gravity    | 2.31        |
3. Results and Discussion

3.1. Liquid Limit (LL) of Soil Test

This test is carried out to find out the soil liquid limit in accordance with IS: 2720 (Part 5) - 1985. This test is used to find the liquid limit of soil in which the soil behaves like liquid with smaller shear strength [6]. The number of blows utilized to contact the soil sample is noted. The graph is prepared by considering a number of blows towards abscissa and on the ordinates; water content has been taken [8]. The liquid limit is expressed by $W_c$.

| %Lime | %Glass fiber | Liquid Limit % |
|-------|--------------|----------------|
| 0     | 0            | 58             |
| 2     | 1            | 57             |
| 4     | 2            | 56             |
| 6     | 3            | 55             |
| 8     | 4            | 56             |

Figure: 4 Graphical Representation

3.2. Plastic Limit (PL) of Soil Test

This test is made to study the plastic constraints of the soil accordance with IS: 2720 (Part 5) - 1985. It is the value below which the soil behaves like plastic and when rolled into 3 mm diameter yarns begin to collapse [10]. The sample is prepared by passing through 425 µ sieve and water is added to it after that which is rolled with hand on the glass plate at certain diameter it tends to get cracks and deformed after that we can determine its water content with the help of the oven.

Figure: 5 Plastic limit test
Table 5: Variation of Compressive strength values with various percentages of fibers

| %Lime | %Glass fiber | Liquid Limit% |
|-------|--------------|---------------|
| 0     | 0            | 53            |
| 2     | 1            | 52            |
| 4     | 2            | 50            |
| 6     | 3            | 48            |
| 8     | 4            | 51            |

Figure 6: Graphical representation

3.3. Compaction Test

This test was conducted on version soil of 3 Kg sample. Maximum Dry Density (MDD) of the soil can be determined by conducting this test [4]. A sample of 3kg was prepared as per the codal provisions and certain content of water added to it and mixed thoroughly later on the prepared sample is filled in to the mould as layer by layer and each layer tampered with 25 blows by using a tampered rod [6]. The Maximum Dry Density can be achieved by plotting graph between the water content and dry density as abscissa and ordinate respectively. The graph of both the values with lime and glass fibers mixture soil and normal soil are shown below.

Fig: 7 Compaction Test
After conducting the test, the results of the Maximum Dry Density were measured with respect to lime content (%) in the soil. From the above graphical representation, it is determined that Maximum Dry Density increases with increase of lime content in the soil due to the presence of the high amount of calcium in the lime. The highest relative increase in Maximum Dry Density is obtained from 4 % to 6 % of lime content as per the test results. Therefore we also perform a test on 5 % and obtained Maximum Dry Density of about 1.64. Therefore we consider 5 % lime is preferable as a stabilizing material in the soil in order to make structure economical.

| Lime content | MDD  |
|--------------|------|
| 2            | 1.60 |
| 4            | 1.62 |
| 6            | 1.64 |
| 8            | 1.65 |
| 10           | 1.66 |
| 12           | 1.68 |

**Table: 6 Compaction test values**

![Graphical representation of MDD values](image)

**Figure 8:** Graphical representation of MDD values

| Glass fibers | MDD  |
|--------------|------|
| 0.2          | 1.70 |
| 0.4          | 1.71 |
| 0.6          | 1.72 |
| 0.8          | 1.73 |
| 1.0          | 1.71 |
| 1.2          | 1.70 |

**Table: 7 Compaction test values**
Figure 9: Graphical representation of MDD values

After conducting the test, the results of the Maximum Dry Density measured with respect to glass Fiber (%) content in the soil. Also the Maximum Dry Density has been analyzed by mixing 5 % lime with fiber content in different ratio (0.2 %, 0.4%, 0.6%, 0.8%, 1% and 1.2 %). From the experimental investigation, it is clear that Maximum Dry Density increases up to 0.8 % of polypropylene fiber content mixed in the soil after that it starts decreasing due to the presence of the tensile nature of the fibers. Higher is the Maximum Dry Density higher is the strength of the soil.

3.4. Differential Free swell Test

It is used to measure the enhanced volume of soil. It is determined using the equation written below [2]. The test was conducted for both normal soil and mixture of Lime and glass fibers in different percentages in the soil, as per IS code: 2720 part 40. The test sample was prepared as per the codal provisions, the soil which passes through the 425μ sieve and taken in to two jars one contains polar liquid and the other contains non-polar liquid.

\[
\text{Differential Free swell index} \% = \frac{(V_d - V_k)}{V_k} \times 100
\]

\[V_d = \text{Vol. of the soil in distilled water.}\]
\[V_k = \text{Vol. of the soil in kerosene}\]

| Determination number | Parent Soil | Mixed soil |
|----------------------|-------------|------------|
| Mass of dry soil passing 425 μ sieve | 10 | 10 |
| Volume in water after 24 hrs \(V_d\) (cc) | 14 | 13 |
| Volume in kerosene after 24 hrs \(V_k\) (cc) | 10 | 10 |
| Average Free Swell Index | 40% | 30% |

4. Conclusion

From the experimental investigation the below conclusions were drawn.

- It is clear that the glass fibers and lime can be used as stabilizing materials to the stabilization of black cotton soils for the construction of high raised buildings.
- The test results for the normal soil give less than compared to the stabilized soil by the glass fibers and lime powder up to certain % of the adding of these materials.
- Soil Stabilization using Glass fibers is better way to disposal of Glass instead of dumping glass in land. This gives the better strength properties than the normal soil.
- The engineering properties of the black cotton soil get improved up to certain % of glass fibers added as stabilizing material in the soil due to the tensile nature of the glass fibers.
- It is clearly observed that the lime and the waste glass powder are the best stabilizing materials for the soil to increase the strength and the engineering properties of the soil.
- The strength parameters of the soil get improved by adding the lime in the soil due to the presence of the calcium content in the lime.
- By performing experiment at varying percentage of Glass fibers and Lime Powder in the soil, we may concluded that Maximum strength properties of black cotton soil is achieved at 8% of Glass fibers and 10% of Lime Powder in black cotton soil.
- If we add more amount of lime and glass fibers to the soil which leads to the un-economical.

References

[1] Latifi, N., Eisazadeh, A., Marto, A., & Meehan, C. L. (2017). Tropical residual soil stabilization: A powder form material for increasing soil strength. Construction and Building Materials, 147, 827-836.
[2] IS: 2720 (Part 5,40) – 1985, Methods of test for soil, Determination of Liquid limit and Plastic limit of soil, Determination of differential free swell index.
[3] Reddy, V. R., & Krishna, G. R. (2018). Improvement of Soil Characteristics Using Waste (plastic, steel and wood). Journal of Geotechnical Engineering, 4(3), 7-10.
[4] Razvi, S. S., Bhalke, S. B., Wadhav, M. D., Waghe, A. P., & Rathod, D. C. (2018). Soil Stabilization by using Lime. International Journal of Engineering and Management Research (IJEMR), 8(2), 79-86.
[5] Khattab, S. A., Al-Mukhtar, M., & Fleureau, J. M. (2007). Long-term stability characteristics of a lime-treated plastic soil. Journal of materials in civil engineering, 19(4), 358-366.
[6] Loehr, J. E., Bowders, J. J., Owen, J., Sommers, L., & Liew, W. (2000). Stabilization of slopes using recycled plastic pins. Journal of the Transportation Research Board, 1714, 1-8.
[7] Etim, R. K., Eberemu, A. O., & Osinubi, K. J. (2017). Stabilization of black cotton soil with lime and iron ore tailings admixture. Transportation Geotechnics, 10, 85-95.
[8] Harichane, K., Ghrici, M., & Kenai, S. (2018). Stabilization of Algerian clayey soils with natural Pozzolana and lime. Periodica Polytechnica Civil Engineering, 62(1), 1-10.
[9] Wroth, C. P., & Wood, D. M. (1978). The correlation of index properties with some basic engineering properties of soils. Canadian Geotechnical Journal, 15(2), 137-145.
[10] Sofi, A. and Naidu Gopu, G. (2019) ‘Influence of steel fibre, electrical waste copper wire fibre and electrical waste glass fibre on mechanical properties of concrete’, in IOP Conference Series: Materials Science and Engineering. doi: 10.1088/1757-899X/513/1/012023.
[11] Satyam Tiwari & Nisheet Tiwari (2016). Soil stabilization using waste fiber materials. International Journal Of Innovative Technology And Research 4(3), 2927 – 2930.
[12] Elias, T., George, S., Zachariah, A., Suli, S., & PS, S. (2016). Comparative Study of Soil Stabilization Using Human Hair and Lime. International Journal of Scientific & Engineering Research, 7(2).