Effect on CBR Values with Addition of Coir Geotextile and Marble Dust in Silty Sands

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Abstract. The subgrade is the foundation of pavement. The conventional method of replacing weak soil with good soil can cause an increase in the cost of a project. Due to this reason ground improvement techniques are much popular nowadays. The major goal of this research work is to compare California Bearing Ratio (CBR) values of the virgin soil and soil reinforced with coir geotextile in one layer and a combination of two layers at different heights from the top surface of the soil. To see the change in CBR values one layer of coir geotextile was reinforced at three different heights (i.e., H/3; H/2 and 2H/3). After that, the effect on CBR values by reinforcement of combination of two layers of coir geotextile at different heights (i.e., H/3 and H/2; H/2 and 2H/3; and H/3 and 2H/3) from the top surface of the soil was studied. Thereafter, the soil is replaced by various percentages of marble dust ranging from 10% to 25% with an increment of 5% and again CBR values of soil samples reinforced with one layer of coir geotextile and a combination of two layers of geotextile at three different heights were compared with virgin soil. The test results reviewed that the maximum dry density (MDD) decreased and optimum moisture content (OMC) increased with the replacement of marble dust in the soil. The CBR test results specify an enhancement of the value of CBR with the addition of coir geotextile and marble dust. The maximum value of CBR is obtained when one layer of coir geotextile was introduced at the height of H/3 and in the case of a combination of two layers of coir geotextile maximum CBR values is obtained when the coir geotextile was introduced at a height of H/3 and 2H/3 from the top surface of the soil.

1. Introduction
Subgrade acts as the foundation layer of the road. Road performance depends largely on the properties and soil types. A weak subgrade can be problematic for road construction. The replacement of weak soil with good soil makes the project costly. Due to economic reasons, ground improvement techniques are used. These techniques help to improve soil properties like bearing capacity, shear strength, drainage, etc. using ground improvement techniques, we can properly utilize waste materials also. Uses of geotextile are one such ground improvement technique which gains popularity in recent years [1–4].

Currently, the world market production of coconut fibre is approximately 350,000 metric tonnes (MT). However, the top two coconut fibre producers in the world are India and Sri Lanka, which account for about 90% of the globe’s coconut fibre making. The chemical composition of coir fiber includes cellulose 43%, hemicelluloses less than 1%, and lignin 45%. In addition, marble dust is a waste that is formed during marble production. About 25 percent of marble mass is lost in the form of dust while cutting process. Chemically, marble dust consists of about 40 percentage of calcium oxide, 28.35 percentage of silicon dioxide, 17 percentage of magnesium oxide, and a small amount of iron oxide and aluminium oxide. There have been various studies in which natural fiber, Coir geotextile is...
used for ground improvement, marble dust has also been the subject of numerous studies which focused on improving soil properties. There are many applications of geosynthetics in the field of civil engineering. However, some basic and important applications are Reinforcement, Separation, Filtration, Drainage, Stiffening, and Protection [5–7].

Coir geotextile is coming out to be promising alternative technology for soil stabilization. The treatment of poor soil with the use of coir geotextile is coming out to be an economical method. Improvement of soil depends upon the type and method by which coir geotextile is to be used. Using coir fibres, it has been observed that it helps to increase the OMC and decrease MDD. Also, it helps in delaying the failure of the subgrade layer. Shear strength and soil compressive strength are also increased with the help of coir geotextile. When the soil was reinforced with coir geotextile there was an improvement in the behaviour of Stress-strain of the soil. Moreover, the stiffness of soil also improved. If we increase the number of layers of coir geotextiles, then the number of cycles that cause the subgrade to fail increases as a result. Pavement thickness can also be reduced by reinforcing coir geotextile as it improves the strength of the subgrade layer. If we use coir geotextile on the slopes it will minimize the erosion and increase moisture availability and it will also help in the growth of vegetation on the slopes. The value of the CBR of soil intensifies with the help of coir geotextile. Rut failure is one of the main problems in the pavements and it can also be correlated with California Bearing Ratio. CBR value reduces as time passes due to the degradation of coir in soil. Decay of coir in clayey soil with low compressibility is higher than clay with medium compressibility.

The shrinkage and swelling pressure of soil can be reduced by the replacement of stone powder in soil. With the replacement of marble dust in the soil Liquid limit (LL) and plasticity of soil can be decreased. Also, MDD can be reduced by the increment of marble dust in soil. Marble dust also helps increase the alkalinity of soil. Also, the strength of soil can be increased. With the replacement of marble dust in soil, there is an improvement of the CBR value of soil. This paper presents the Geotechnical properties of silty sand which are found in a Taruana village of Haryana state of India and the effect on CBR value with the help of using a single layer and combination of two layers of coir geotextile at different heights. Also, to find out the optimum amount of marble dust replaced in soil, CBR values were observed with the replacement of various percentages of marble dust (10% to 25% with increment of 5%). After that, with the optimum amount of marble dust in soil with one layer and combination of two layers of coir geotextile at different heights in soil, CBR values were also observed. The CBR test is used to assess the effect on soil [8–10].

2. Materials Used

2.1 Soil

The soil, which is used for this research work is taken from Taruana village which is situated near Kalanwali in Sirsa district of Haryana, India. According to the USCS classification of soil, the soil is categorized as Silty Sand (SM). Before testing, the soil in this research work was oven dried for 24 hours. Table 1 lists various properties of soil [11–13].

2.2 Coir Geotextile

The coir geotextile which is used for this study is produced by Terrain Infratech. The name of coir geotextile is NW600, it is a needle-felt machine-produced woven geotextile that is of 100% coconut fiber with consistent thickness with coconut fibers evenly distributed over the entire area of the geotextile with monofilament hope netting. It comes in a standard roll with proper length and width. Coir geotextile was used for reinforcing soil by introducing it in one layer at three different heights i.e., H/3; H/2, and 2H/3 from the top surface of the soil (where H is the height of soil sample) and combination of two layers at different heights i.e., H/3 and H/2; and H/2 and 2H/3; and H/3 and 2H/3. Table 2 list various properties of woven coir geotextile [14–16].
### TABLE 1. Properties of Soil.

| Property          | Value   |
|-------------------|---------|
| Sp. Gravity       | 2.68    |
| LL (%)            | 21.67   |
| PL (%)            | NP      |
| OMC (%)           | 12.2    |
| MDD (gm/cc)       | 1.771   |
| Grain Size Distribution |       |
| Gravels (%)       | 1       |
| Sand (%)          | 58      |
| Clay + Silt (%)   | 41      |
| Unified Soil Classification |       |
| CBR Unsoaked      | 4.81    |
| CBR Soaked        | 2.77    |

### TABLE 2. Properties of Woven Coir Geotextile

| Properties                      | Specifications                  | Test Method                |
|---------------------------------|---------------------------------|----------------------------|
| Description                     | Needle punched coir fiber       | IS 14716                   |
|                                 | with netting on both sides      |                            |
| Mass per Unit Area              | 600gm/m²                        | ASTM D: 5199 - 2012        |
| Thickness                       | 6 mm                            |                            |
| Wide Width tensile Strength Dry| 7.58                            | ASTM D: 4595 - 2011        |
| KN/m (minimum)                  |                                 |                            |
| Permeability at (50 mm WH)      | 235                             | ASTM D:4491-RA             |
| l/m²/sec                        |                                 | 2015                       |
| Standard Roll Length            | 46 m                            |                            |
| Standard Roll width             | 0.6 m                           |                            |

2.3 *Marble Dust*

Marble dust which is used in this research was brought from the marble industry (Shakti Marbles) locate in Bathinda, Punjab, India. Marble dust is white in colour and fine in nature. Its specific gravity is 2.7. Marble dust was used to replace the soil starting from 10% to 25% with an increment of 5%.

3. Experimental Procedure

The soil taken for the samples was excavated from more than 30 cm below the ground to avoid any vegetation. In the laboratory, firstly, the soil was heated at 105°C for 24 hours. Then basic tests like
specific gravity (SG), partial size distribution, and Atterberg limit tests were done. After that, the standard proctor test (SPT) and CBR tests were performed on the soil. In the SPT, the soil was firstly oven-dried at the temperature of 105°C and then soil samples with the addition of varying content of water were made. After that soil was placed and compacted in proctor compaction mould in 3 layers and each layer was compacted with 25 blows using a 2.5 kg hammer. Before the placement of the new layer, the surface of the previous layer was scratched to ensure even distribution of compaction effects across all of the layers. Virgin soil samples were prepared to find out MDD and OMC of soil by SPT. After that, soil samples with the replacement of marble dust of 10%, 15%, 20%, and 25% were made and a standard proctor test was performed.

CBR test is a penetration test for finding out the pavement subgrade strength. For California bearing ratio test, the soil specimen is prepared at MDD. To perform this test, firstly soil is passed through a 4.75 mm I.S. sieve, soil finer than a 4.75 mm I.S. sieve is taken and dried in the oven for 24 hours. OMC is maintained in preparing soil samples. Soil compaction is done with a 4.89 kg hammer in 5 layers with 55 blows per layer. CBR test was performed in unsoaked and 4-day-soaked conditions. Soil sample of virgin soil, soil with one layer of coir geotextile laid at heights of H/3, H/2, and 2H/3 height from the top surface of the soil and the combination of two layers of coir geotextile at heights of H/3 and H/2; H/2 and 2H/3; and H/3 and 2H/3 heights from a top surface of soil were made to perform CBR test (H is the height of the soil sample). Soil samples with replacement of the soil with marble dust of 10%, 15%, 20%, and 25% were also made for the test to find out the optimum amount of marble dust replacement in the soil. After finding the optimum amount of marble dust, soil test samples with one layer and a combination of two layers of coir geotextile at different heights were made with an optimum amount of marble dust in the soil to perform CBR test.

4. Results and Discussion

4.1 Standard Proctor Test

To determine the soil compaction properties, SPT was used to find MDD and OMC. Soil samples of virgin soil and the soil which was replaced by various percentages of marble dust were made for the test. After the test, the OMC for virgin soil was found out to be 12.2% and for soil with which 10% and 15% marble dust was replaced, OMC increased to 16%. But with a 20% replacement of marble dust, the OMC became 15.98%. Further, when marble dust content was increased to 25%, the OMC reduced to 15.5%, which was still higher than virgin soil OMC of 12.2%. With the increment of marble dust content in the soil, the OMC increases due to an increase in the desire for water to form products like lime, Ca(OH)$_2$, and to break this product into OH$^-$ and Ca$^{2+}$ ions so that the cation exchange reaction of Ca$^{2+}$ ions increased. MDD decreased with the increment of marble dust in soil. The MDD of virgin soil was found out to be 1.771 gm/cc whereas when 10% and 15% marble dust was added to the soil, MDD remained the same as MDD of virgin soil. Further, when 20% of marble dust was present in the soil, MDD was reduced to 1.75 gm/cc, and when 25% marble dust was present in the soil, MDD was reduced to 1.745 gm/cc. Initially decrease in dry density is due to an increase in the volume of voids and a constant reduction in the weight water ratio of flocculated clay particles produced by cation exchange reaction. Density may also be decreased due to the difference in specific gravity of marble dust and soil. Variation of MDD and OMC is shown in figure 1.
4.2 California Bearing Ratio Test

The CBR test is used to find out the strength of the soil. Also, it is used for determining the thickness of pavement required. CBR test is done at OMC and MDD. In laboratories, this test is done in both unsoaked and 4-day-soaked conditions. Soil is soaked for four days to make sure that, after wetting and drying, bearing and resisting properties of the soil must be good enough to sustain and resist the applied load. Also, when the soil is under the pavement, alternating drying and wetting occur due to change in climate conditions and variations in the environment. So, to simulate the field condition for the worst situation, a 4-day soaking condition test is to make this same condition during laboratory testing. Subgrade soil is considered good if the soil has high CBR value. The soil which was used for this study had a very low CBR value.

Unsoaked and soaked CBR values of virgin soil came out as 4.81 and 2.77 respectively. When one layer of geotextile was introduced in the soil as reinforcement, the unsoaked and soaked CBR values at H/3 height from the top surface of soil came out to be 9.09 and 6.76, respectively. For coir
geotextile at height of H/2 from top surface came out to be 8.56 and 6.08 and that for coir geotextile at height of 2H/3 from the top surface of the soil was 7.10 and 5.98 respectively. For one layer of coir geotextile, the CBR value was maximum when coir geotextile was at the height of H/3 from the top surface. With the addition of coir geotextiles in soil, tension resistance element introduces in the soil. So, CBR of the soil increases with the addition of coir geotextile. But when we used coir geotextile in a combination of two layers, coir geotextile at height of H/3 and H/2 from top surface values of unsoaked and soaked CBR were 10.85 and 9.68, respectively. Unsoaked and Soaked CBR values for coir Geotextile at height of H/2 and 2H/3 from top surface came out to be 10.17 and 7.88 and that for coir geotextile at height of H/3 and 2H/3 from the top surface of soil came out 12.79 and 10.21, respectively. There was a significant increase in the soaked CBR values, but the difference between the unsoaked CBR values and the soaked CBR values was not much. The value of CBR was highest when coir geotextile was at height of H/3 and 2H/3 from the top surface of the soil. When coir geotextile was in H/2 and H/3 height or H/2 and 2H/3 height from the top surface, the values were less because both the coir geotextile counterbalance each other effect.

CBR tests were also performed with the replacement of marble dust in soil. Unsoaked CBR values of the soil samples with marble dust of 10%, 15%, 20%, and 25% were 7.73, 8.71, 10.85, and 9.82, respectively. Soaked CBR values of soil samples with marble dust of 10%, 15%, 20%, and 25% were 4.96, 5.54, 7.49, and 5.98, respectively. CBR values of soil with marble dust in it were increased until the marble dust was 20% in the soil after that, the CBR value decreases. The increase in CBR with the increase of marble dust in the soil is due to improvement of gradation, increase in compactness of soil and marble dust mixture, and better inter particle b/w particles of soil and marble dust. The decrease of CBR values after the replacement of marble dust of 20% in the soil is due to the poor gradation of soil and marble dust. Based on test results, the optimum amount of marble dust came out to be 20%.

After that 20% of marble dust was used in soil with one layer and a combination of two layers of coir geotextile at different heights. Unsoaked CBR values with 20% marble dust in the soil and coir geotextile at height of H/3, H/2, and 2H/3 height from top of soil surface were 11.72, 11.18, and 10.93, respectively. Soaked CBR values of these samples were 8.34, 7.91, and 7.67, respectively. There was a significant increase in both soaked and unsoaked conditions CBR values of one layer of coir geotextile. Unsoaked CBR values of soil samples, with 20% of marble dust in the soil with a combination of two layers of coir geotextile at height of H/3 and H/2; H/2 and 2H/3; and H/3 and 2H/3 height from the top surface of the soil, were 12.13, 11.74, and 12.91, respectively. Soaked CBR values of these soil samples were 10.19, 8.43, and 10.44, respectively. CBR values of the combination of coir geotextile of two layers in virgin soil and soil having 20 percent of marble dust in it, had very less difference because the reinforcement of coir geotextile can increase CBR value up to a certain limit. Variation of CBR values of different soil samples is as shown in figure 2.
5. Conclusions

This research was done to see the influence of CBR values of coir geotextile and marble dust in soil, SPT, and CBR tests were done in the laboratory. The CBR test was performed in unsoaked and 4 day-soaked conditions with one and two layers of coir geotextile at different heights, with different percentages of marble dust in soil and optimum amount of marble dust and coir geotextile in one and two layers at different heights. The conclusions of this research are:

1. CBR of soil increased when one layer of coir geotextile was introduced in the soil. The maximum value of CBR was achieved when coir geotextile was laid at a height of H/3 from the top surface of the soil.

2. Also, the CBR of soil increased when the combination of two layers of coir geotextile was introduced in the soil at different heights. Maximum CBR of the soil was achieved when the coir geotextiles were laid at a height of H/3 and 2H/3 from the top surface of the soil.

3. When soil is replaced with marble dust, the MDD of the soil decreases, and OMC increases.

4. CBR of the soil increased with the increment of marble dust. The optimum amount of marble dust was found to be 20% in the soil.

5. When one layer of coir geotextile was introduced in the soil with 20% of marble dust in it, the CBR value of the soil increased and maximum CBR value was achieved when the coir geotextile was at a height of H/3 from the top surface of the soil.

6. When a combination of two layers of coir geotextile was used in the soil having the optimum amount of marble dust in it, the CBR values of soil increased and the maximum value of CBR was achieved when the coir geotextiles were at the height of H/3 and 2H/3 from the top surface of the soil.
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