EFFECT OF EPOXY RESIN ON CBR IMPROVEMENT OF SOFT CLAYEY SUBGRADE MIXED WITH COCONUT COIR FIBRES

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Abstract. Road infrastructure is a key factor for the development of an economy. For construction of road pavements, good subgrade soil is a major feature which influences the design, construction and durability of the pavement. Pavements built on soft subgrade soils experience faster degradation due to the low strength and high compressibility of soft soil. Replacement of soft soil with good soil is not sustainable, since it is expensive and also impacts the environment. Stabilization of soft soil is a sustainable alternative which can be used to improve the properties of soft soil in-situ. The use of various additives can improve the properties of soft soils. In this study, the effect of using coconut coir in combination with polymeric resin on the improvement of properties of soft soil is studied. Coconut coir is a waste material which can be used as bio-fibers, but since they are decomposable, are used in combination with polymeric resin. The effect of random percentages of coconut coir along with polymeric resin on the compaction and penetration behaviour of soil is presented.

Keywords. Soft soil, coconut coir fibre, Epoxy resin, Stabilization.

1. Introduction

Pavement service life depends upon the subgrade conditions among many other factors. Subgrade is the bottom most soil layer on which the pavements are constructed. Subgrade should have sufficient strength to bear the traffic loads coming on to it. Soft soils do not have sufficient strength to withstand heavy loads and hence pavements constructed over such soils are subjected to early degradation. Earlier practice of replacing soft soil with good quality soils is not feasible due to the high costs involved in the procurement and transportation of the soil, in addition to the pollution caused during the transportation. The method of treating soft soils at the field itself using additives is called stabilization of soils. In this treatment, the properties of soil are improved by mechanical or chemical means. Over the years various materials have been used for stabilization of weak soils such as clays. A recent trend is to utilize waste materials for modifying soft soils. The advantage of using waste materials in construction includes its low cost involved and a new solution for the waste disposal.

India is one of the leading countries in the production of coconut. Coconut palm is one of the most useful tropical palms and one of the important cottage industries related to coconut palm, is the coir industry. It is estimated that the coir-processing industries in India produce roughly 0.5 million tonnes of coir waste [Leema Peter et al., (2014)] annually. These coir wastes are accumulated along the sides of the production units thus creating environmental solution problems. Open disposal of coir pith into heaps acts as a medium for bacteria growing resulting in poor hygiene of the surrounding areas. A major portion of the coir is utilized as a fuel in domestic stoves which creates air pollution. Also, dumping of coir waste into water bodies like rivers, lakes etc., may affect the life within water bodies. Thus a proper disposal method of coir waste is to be proposed.

Many studies have been conducted relating to the behaviour of soil reinforced with randomly
distributed fibers. Leema Peter et al., (2014) examined the improvement of subgrade characteristics of expansive soil stabilized with coir waste by performing laboratory studies. They concluded that the addition of coir pith and coir fibres combinedly causes a decrease in the Maximum Dry Density (MDD) value and the Optimum Moisture Content (OMC) increases. Mali and Singh (2013) observed that soft soils can be improved with randomly distributed fibers of natural and synthetic types. They proved experimentally that, when loaded, the fibers mobilize tensile resistance, which gives greater strength to the soil. S.Muthu Lakshmi et al., (2018) studied the utilization of coconut coir fiber at different percentages for improving the subgrade strength of clayey sand. From the test results, they observed that on increasing the percentage of coir fiber, OMC is increasing and MDD is decreasing. The Soaked CBR values have also increased. They concluded that use of coir mixed with soil drastically reduces the thickness of subgrade required for pavement construction.

V. Rama Susheel Kumar and J Vikranth (2014) analyzed the characteristics of black cotton soil mixed with fly ash and coconut coir. They concluded that the addition of coconut coir to black cotton soil mixed with Fly ash will result in an increase in compressive strength of more than 200%. M. Mirzababaeia, et al., (2017) studied the effect of fibres and a non-traditional polymer, Poly Vinyl Alcohol (PVA) added in various percentages to soil. They concluded that the addition of fibres and PVA has increased the unconfined compressive strength of soil significantly. R.R Singh & Shelly Mittal (2014) studied the effect of coir fibers mixed with soil on the unconfined compressive strength of soil and the CBR values. They concluded that, addition of 1% fibres to soil gives the optimum UCS and CBR values. Nithin and Sayida (2012) observed the properties of silty sand mixed with fly ash and coir fibres and established that discrete and randomly distributed coir fibres are improving the bearing capacity of soil. Parag M. Chaple et al. (2013), focused on the effect of coir on the bearing capacity and settlement of footing using laboratory model tests on square footings supported on highly compressible clayey soil reinforced with randomly distributed coir fibres. By varying the parameters such as thickness of reinforced layer (B, B/2, B/4) and the coir percentages (0.25%, 0.5%, 0.75% and 1.0%), they concluded that the bearing capacity increases significantly when using coir. The use of natural fibers for ground improvement is often advantageous as they are cheap, locally available and eco-friendly.

2. Materials

2.1. Soil

Soil was obtained from TTD temple construction site in Venkatapalem near Amaravati, Krishna District of Andhra Pradesh, India. Soil was collected about 3m deep below the ground level to avoid top soil and humus content. The colour of the soil is Blackish brown. The geotechnical properties of the soil are listed in Table 1.

2.2 Coconut coir fibre

Coconut coir Fiber is obtained from the husk of coconut and belongs to the group of hard structural fibers. It is the fibrous portion of the coconut extracted mainly from the green nut. Coir extracted consists of rotting the husk in water and removing the organic material binding the fiber. The long bristle fibers are separated from shorter mattress fibers underneath the skin of nut, a process known as wet milling. The coir fiber is elastic enough to twist without breaking and it holds a curl as though permanently waved. The coir is purchased from a local market in Chirala town of Prakasam District, Andhra Pradesh, India. The Diameter of the coir fibres is 0.5mm. The coir is cut into pieces with length varying from 3cm to 5cm.

2.3 Epoxy Resin
Araldite standard epoxy resin is used as additive. The resin was used in addition to mixing of coconut coir fibres with soil. The Resin is readily available in the market.

| Soil Property               | Test Result             |
|-----------------------------|-------------------------|
| Visual Identification       | Blackish Brown Clay    |
| Liquid Limit (%)            | 69.1                    |
| Plastic Limit (%)           | 28.06                   |
| Plasticity Index (%)        | 41.04                   |
| Specific Gravity            | 2.36                    |
| Soil type                   | CH                      |
| Optimum Moisture Content (%)| 16.1                    |
| Maximum Dry Density (g/cc)  | 1.63                    |
| California Bearing Ratio(%) | 2.1 (Soaked)            |

Table 2. Properties of coconut coir fiber

| Property          | Test Result |
|-------------------|-------------|
| Length (cm)       | 3-5         |
| Density (g/cc)    | 1.40        |
| Breaking Elongation (%) | 30%        |
| Diameter (mm)     | 0.3-0.5     |

3. Experimental investigation

The soil was dried in oven at temperatures between 80°C and 105°C, pulverised and then sieved through the 425μ sieve for the consistency limits and 4.75mm sieve for the compaction and CBR tests. The coconut coir fibre were cut into 3-5cm length pieces and separated as single strands. Coconut coir was first added to the soil with different proportions of the total dry weight of soil for the determination of compaction behaviour and CBR test. The coir fibres were added in four proportions, 0.5%, 0.75%, 1.0% and 1.5%. The fibres and soil were hand mixed thoroughly. For each proportion of fibres added, the compaction characteristics were first determined. From the compaction characteristics, the samples were prepared for the CBR test. After determination of the CBR value for soil mixed with fibres, Epoxy resin was added to further improve the soil properties. The epoxy resin was added in two different methods: First by mixing the resin along with the fibres directly in the soil and second by surface application after mixing the fibres with soil. The CBR test was performed on the soil added with fibres and also Epoxy resin.

4. Results and Discussions

The results of experimental investigation on the effect of coconut coir fibres added to soil along with resin are discussed.
4.1. Soil mixed with Coconut coir fibres only

4.1.1. Compaction Characteristics

Compaction tests were carried out on soil mixed with different proportions of coir fibres. Figure 1 shows the variation of maximum dry density (MDD) for different percentages of coir fibre. The optimum moisture content (OMC) was found to be increasing with an increase in the percentage of fibres added to the soil. The OMC obtained from the compaction test was used for preparation of the soil samples for CBR test.

![Variation of MDD with Coir Fibre %](chart)

Figure 1. Variation of Soil MDD with different percentages of Coconut Coir Fibre

4.1.2. California Bearing Ratio (CBR)

CBR of the soil is a measure of the strength of the subgrade material to be used as a highway pavement. Soil mixed with coconut coir fibre shows improvement in CBR value of the soil for various percentages of the fibres. The soaked CBR values for soil mixed with different percentages of coconut coir fibres are shown in Figure 2.

![Variation of CBR in soil with CC fibres %](chart)

Figure 2. Variation of Soil CBR with different percentages of Coconut Coir Fibre

From the above results it can be seen that, the MDD of the soil has decreased with increase in the percentage of Coconut coir fibres. The CBR value has increased with addition of Coconut coir fibres. The highest increase, in percentage, is seen when 1% coconut coir fibre added to soil.
4.2. Soil with Coconut coir fibres and Direct Mixing of Epoxy Resin

In the second phase of the experimental investigation, the soil is tested for compaction and CBR values for addition of coconut coir fibres and also epoxy resin. In this phase, Coconut coir fibres percentage is selected as 1%, since the maximum CBR value is obtained at that percentage. The soil is mixed with 1% coconut coir fibres and epoxy resin. The epoxy resin is mixed in three percentages of 0.5%, 1% and 1.5%.

4.2.1. Compaction Characteristics

The results of the compaction tests carried out on soil mixed with 1% coconut coir fibres and different percentages of epoxy resin is are shown in figure 3.

4.2.2. California Bearing Ratio (CBR)

The soaked CBR values for soil mixed with 1% coconut coir fibres and different percentages of epoxy resin are shown in Figure 4.
Figure 5. Variation of CBR of soil with 1% CC fibre mixed with Epoxy resin %

From the above results it can be seen that, the MDD of the soil with 1% coconut coir fibres has decreased with increase in the percentage of Epoxy Resin added to the soil by mixing. The CBR value has increased lightly but almost remained the same for increase in percentage of epoxy resin mixed with soil.

4.3. Soil with Coconut coir fibres and Surface Application of Epoxy Resin

In the third phase of the experimental investigation, the soil is tested for compaction and CBR values for addition of coconut coir fibres and surface application of epoxy resin. In this phase, Coconut coir fibres percentage is fixed at 1%, since the maximum CBR value is obtained at that percentage. The soil is mixed with 1% coconut coir fibres and the epoxy resin is applied on the surface. The epoxy resin is applied in the same three percentages of 0.5%, 1% and 1.5%.

4.3.1. Compaction Characteristics

The compaction test was not performed since it is not possible to perform compaction on the sample since the epoxy resin is applied on the top surface. Hence, the compaction test was not performed.

4.3.2. California Bearing Ratio (CBR)

The soaked CBR values for soil mixed with 1% coconut coir fibres and different percentages of epoxy resin applied on the surface are shown in Figure 5.

Figure 6. Variation of Soil CBR with 1% CC fibre and Surface Application of Epoxy resin %

From the above results it can be seen that, the CBR value has increased with the increase in the percentage of Epoxy resin applied on the surface of the soil with coconut coir fibres.

4.4. Comparison of CBR values of Soil with Coconut fibres and Direct Mixing Vs Surface Application of Epoxy Resin

The CBR values obtained for Soil with 1% Coconut coir fibres and addition of Epoxy Resin via Direct Mixing and Surface Application are compared. The comparison is shown below in Figure 7.
5. Conclusions

Laboratory experimentation was done on Soft clayey Subgrade soil to improve the properties. coconut coir fibres and epoxy resin were added to soil in various proportions and the compaction and CBR values of the treated and untreated soil were determined. The Epoxy resin was added in two different methods: Direct Mixing with soil and Surface Application. Based on the test results obtained from the experimental program, the following conclusions are made. Based on the above laboratory investigations conducted on the soil, coconut coir and epoxy resin mixes the following conclusion can be drawn

1. Addition of coconut coir fibres increases the Optimum Moisture Content of the soil but decreases the Maximum Dry Density of the soil.
2. Addition of coconut coir fibres increases the CBR value of the soil. The CBR value has increased by 90%, 122%, 146% and 136% respectively for an addition of 0.5%, 0.75%, 1.0% and 1.5% coconut coir fibres to soil. The highest increase in CBR value was observed when 1% coconut coir fibres are added to soil.
3. The Maximum Dry Density values are observed to be decreasing when Epoxy resin is added to soil with coconut fibres by way of Direct Mixing. This can be attributed to the formation of soil balls formed, because of the adhesion properties of the epoxy resin.
4. The CBR value of soil containing 1% coconut coir fibres and different percentages of Epoxy resin added by way of Direct Mixing has almost remained constant. This can also be due to the same reason that the Epoxy resin mixed in soil, forms soil balls and may not be creating bonding between the soil particles. Hence, the CBR value remained same even for an increase in the percentage of Epoxy resin mixed.
5. The CBR value of soil containing 1% coconut coir fibres and different percentages of Epoxy resin added by way of Surface Application has increased. The CBR value has increased by 22%, 35% and 57% respectively for an application of 0.5%, 1% and 1.5% of Epoxy resin on the surface. The highest CBR value was observed when the Epoxy resin applied on the surface is 1.5%
6. From the test results, it can be concluded that Epoxy Resin should be Surface Applied to improve the CBR value rather than Direct Mixing in the soil.
7. The combined improvement of the CBR value for 1% coconut coir fibres and 1.5% Epoxy resin applied on the surface is 286%.
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