Strength Characteristics of Coir Fibers and Fly ash on Soil
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Abstract:
The expansive soils cause cracking and break up of pavements. The problem of disposal of fly ash will also sorted out up to some extent. Attempt is made to mitigate the problems of expansive soil by use of Fly ash and small amount of coir fiber. The soil is mixed with fly ash in varying percentage of 20-80% and properties like Atterbergs limit, free swell index, moisture-density relation and CBR are studied. The optimum value of fly ash content in soil is 30% & is selected for further modification with coir fibers content in the range of 0.5-1.5% with different length 10mm, 20mm, and 30mm. The properties of soil like moisture-density relation, CBR, and UCS are evaluated. The investigation concluded that CBR value of fiber reinforced fly ash soil mix increases with increase in percentage of fiber content and increase of length but UCS value decreased with increase of length.

Keywords: CBR, UCS, fiber reinforced fly ash, coir fiber

1. INTRODUCTION

Road plays a crucial role in the development of country. They are lifeline providing a smooth flow of man and materials. Road pavement in general consist of a relative thin wearing surface built over a base course and sub base course resting on the sub-grade (Compacted or natural). In pavement, Sub grade layer is the bottom most layer underlying the base course or surface course. The sub-grade is normally in-situ soil over which the road is being constructed or it can be a layer of selected material. The top 500mm of the embankment is termed as sub grade Ministry of Road Transport and Highway (MORTH, 2013). Although there is a tendency to look at pavement performance in terms of pavement structures and mix design alone, the sub grade can often be the overriding factor in pavement performance. A sub grade’s performance generally depends on two inter related characteristics i.e. load bearing capacity and volume change. In load bearing capacity the sub grade must be able be support loads that are transmitted from the pavement structure. This load bearing capacity often affected by, degree of compaction, moisture content and soil type. A sub grade that can support a high amount of loading without excessive deformation is considered good. Similarly for volume change most soils undergo some amount of volume when exposed to excessive moisture or freezing conditions. Some soils clay shrink and swell depending upon their moisture content, while soils with excessive fines may be susceptible to frost in freezing areas. Sub grade materials are typically characterized by, first, their resistance to deformation under load which is often termed as material stiffness and, second, their bearing capacity which is the strength. In general more resistant to deformation a sub grade is the more loads it can support before reaching a critical deformation value. Although there are other factors involved when evaluating sub grade materials (such as shrink swell in case of clays and ash), stiffness is most common characterization. Basic sub grade stiffness characterizations commonly used are California Bearing Ratio (CBR) Value, Resistance value and Resilient Modulus (Mₐ₈).b for soft sub grade soils are a common problem in pavement infrastructure in many parts of India. In summer the moisture evaporates quickly causing deep and wide shrinkage cracks to this soft sub-grade soil. In the rainy season water enters the cracks and causes enormous swelling. Highway embankments in such type of soils suffer severe damages, distresses, and the pavement gets disrupted resulting in poor performance and increased maintenance cost. Again clayey soil having plasticity index more than 6 are required to be treated and stabilized before going to be used for construction as per the specification of Ministry of Road Transport & Highway, Government of India. To prevent the structure from such damages, stabilization of soil is required with the stabilizing materials like fly ash, lime, sand, bitumen, cement, rice husk ash etc. The engineering properties of Black Cotton Soil (BC) can significantly be improved with these stabilizing agents.

NEED FOR THE STUDY

As the world, in one side is debating about the adoption of green technology in the construction industry which could contributes towards the sustainable development and on the other side on same time it’s facing the disposal problem of various waste products from the different industries. For example Fly ash from coal burning power plants and coir fiber from the coir industries are such two waste materials. These waste materials have vast applications in civil engineering area in general and in pavement engineering in particular i.e. for strength improvement of different pavement layers and embankments. Further these are having better future scope in other construction sector as these two has been identified as the innovative materials in the list by many agencies or organizations like National Rural Road Development Authority (NRRDA) and Indian Road Congress (IRC) in India. These materials are available abundantly in quantity and should be make use of as environmental friendly and cost effectively in various construction purposes. Further, the coir fiber is naturally biodegradable material and inclusion of fly ash and coir fiber in pavement layers it believed that it will enhance the strength of pavement and ultimately the benefits will be the prolonged for stable pavements with healthy environments. Keeping these in mind, it is felt to study the influence of these materials in highway construction as BC soil as subgrade.
III. OBJECTIVES OF THE STUDY

The present study is aimed to accomplish the following major objectives:

1. To study the behaviour of fly ash in partial replacement in BC soil and estimate the optimum quantity of fly ash for replacement.
2. To use the coir fiber on soil-flyash mix and analyze the effect of the same and decide the optimum content of fiber in terms of quantity and dimensions of the fiber.

IV. METHODOLOGY

Evolving new construction materials to suit various traffic and site conditions for economic and safe design is a challenging task in road construction. Effective utilization of local weak soils by imparting additional strength using stabilization materials enable reduction in construction cost and improved performance for roads. Exploring the feasibility of such materials for Subgrade and embankment stabilization will help the road building sector to evolve a stronger, durable and economic design. With a soft sub grade, it is often impossible to build a stable base course without losing expensive base material into the sub grade which is characterized by California Bearing Ratio (CBR). Such soils like black cotton soils have one or more problems viz., low shear strength, high compressibility, low hydraulic conductivity, swelling and shrinkage and susceptible to frost action etc., and are therefore, associated with problems such as low bearing capacity, high settlement, high seepage loss etc. Coir Geotextiles provide a physical separation and reinforcement layer between the aggregate and the sub-grade soil, to prevent migration of fines and thus preserve the structural thickness of the aggregate by maintaining it clean. Coir Geotextiles are recommended for this function because of the low cost, high coefficient of friction, high elongation, and high coefficient of permeability besides good drape to conform to the contour of the surface. The main focus of the present study is to evaluate the performance of coir fiber in the optimum mixture of fly ash and problematic subgrade soil. This can be achieved by conducting California Bearing Ratio (CBR) test, Unconfined Compression Strength (UCS) tests on soil-fly ash-fiber sample specimens and by doing parametric study for analysing and modelling their behaviour. Road construction over soft subgrade soil is a major issue affecting cost and scheduling of highway projects in regions where soft subgrade are common. The strength of the subgrade is most often expressed in terms of California Bearing Ratio (CBR), which is the ratio of test load to standard load at a specified penetration, by a standard plunger. When soil is stabilised with any admixture additional tests like Unconfined Compression Strength tests, resilient tests need to be evaluated. In India the design of flexible pavement is primarily on the basis of the subgrade CBR (IRC: 37-2001).

**Figure 3.1** flow chart for the Study methodology

<table>
<thead>
<tr>
<th>Materials collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil from NIT Warangal campus</td>
</tr>
<tr>
<td>Fly ash from Ramagundem STPP</td>
</tr>
<tr>
<td>Coir fiber - straight fiber - twisted fiber</td>
</tr>
</tbody>
</table>

| Characteristic properties of soil such as: |
| Sieve analysis |
| Consistency limits |
| Free swelling Index |
| Specific gravity |

| Characteristic properties of fly ash such as: |
| Sieve analysis |
| Consistency limits |
| OMC |

Replacement of soil with different percentages (20, 30, 40, and 50%) of fly ash

Light compaction tests for the various soil-fly ash blend

CBR tests for the various soil-fly ash blend by adding respective OMC of mixes

Proctor compaction of soil-flyash-fiber mix

Results and analysis

Conclusions

Figure 3.1 flow chart for the Study methodology
V. MATERIALS

Black Cotton Soil

Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. This A black cotton soil occurs mostly in the central and western parts and covers approximately 20% of the total area of India (Seehra2007). Because of its high swelling and shrinkage characteristics, the Black cotton soil (BC soils) has been a challenge to the highway engineers. The Black cotton soil is very hard when dry, but loses its strength completely when in wet condition. The roads laid on BC soil bases develop undulations at the road surface due to loss of strength of the subgrade through softening during monsoon. The black color in BC soil is due to the presence of titanium oxide in small concentration. The BC soil has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in color. The physical properties of BC soil vary from place to place. Black cotton soil are made of varying proportions of day minerals like Montmorillonite, illite and Kaolinite, chemicals like iron oxide and calcium carbonate (in the forms of Kankar Nodules) and organic matter like humus (Ramaiah, 2013). Montmorillonite is a predominant mineral of black cotton soils. The swelling and shrinkage behavior of black cotton (BC) soils originate from this mineral. Clay minerals are hydra silicates of aluminum and magnesium. They are made of sheets of silica and alumina stacked one above the other forming sheets like structure with expanding lattice. The structure of the aluminum is by magnesium ions and minerals become chemically active. The mineral has high activity, and has the Base Exchange capacity compared to negative charge in the clay minerals. They attract water molecules and various hydrated cations to the surface causing the soil to increase the volume. Abundance of calcium in black cotton soils to yet another failure. It may be present in the form of saturating ions or as nodules of kankar (CaCO₃). Organic matter in the form of humus makes these soils more plastic and compressible.

Fly ash

Coal is the most easily available fuel for power generation in India. Huge quantities of fly ash are produced as waste by-product of coal combustion. The present annual generation of fly ash is estimated to be about 140 million tonnes. Fly ashes are readily available, cheaper and environmental friendly. There has been a steady progress in utilization of fly ash since 1990 (Mir 2013). Fly Ash is comprised of non-combustible mineral portion of coal. When coal is consumed in power plant, it is first ground to the fineness of powder. Blown into the power plants boiler, the carbon is consumed leaving molten particles rich in silica, alumina and calcium. These particles solidify as microscopic, glassy spheres that collected from the power plant’s exhaust before they can “fly” away hence the product’s name: Ash. Chemically, Fly ash is pozzolana when mixed with lime pozzolans combine to form cementitious compounds. Concrete containing Fly ash becomes stronger, more durable, and more resistant to chemical attack. Among the various waste materials, fly ash has shown better results as subbase material. The previous researchers Kumar et al. 2006, Brown., 1974, Leonards and Bailey 1982), Freitag , 1986 Maher, 1990, Ranjan et al. 1996 and Sear , 2010) have also highlighted the usefulness of fly ash. While coarser fly ash can be used as fill material, the finer ash can be used for replacement of sand and cement in road construction works. Use of fly ash for rural road work has been covered in IRC: SP-20 2002 and Ministry of Rural Road Development (MoRD,2004) and Vittal, (2000).

Fly ash Properties

The physical and chemical properties of fly ash depend upon the type of coal, its grinding and combustion techniques, collection, and disposal systems. It has little cementitious properties compared to lime and cement. Most of the fly ashes belong to secondary binders; these binders cannot produce the desired effect on their own. However, in the presence of a small amount of activator, it can react chemically to form cementitious compound that contributes to improved strength of soft soil. Fly ash reacts with lime in presence of moisture to form cementitious compounds. This is known as pozzolanic activity. The pozzolanic property of fly ash enables it to be used as an alternate binder in place of cement.

Fly ash Use in Roads

Sub-base course can be constructed using pond ash or bottom ash replacing conventionally used morrum. Laboratory and field studies conducted in India and abroad have established that fly ash can be adopted for stabilization of sub-base/base. Fly ashes are cohesion less materials, and therefore non-plastic in nature while soil particles are generally cohesive. Mixing of soil and ash in suitable proportions improves the gradation and plasticity characteristics of the mix, thereby improving the strength. Addition of small amounts of lime greatly improves the strength characteristics of fly ash stabilized layers. 3 to 5 per cent of lime is used depending upon the quality of lime. (The use of stabilized fly ash sub-base/base courses would be particularly attractive in locations where fly ash is easily available and supply of aggregate is expensive.) The proportion 1:2.9 of lime fly ash and morrum or sand has been found to provide the best performance. Fly ash can be utilized for constructing semi-rigid pavements in the form of lime-fly ash concrete, dry lean fly ash concrete. Pavements constructed using these mixes possess higher flexural strength than flexible pavements and hence they are classified as semi-rigid pavements. Fly ash can be used for construction of rigid pavements also by using cement-fly ash concrete, high performance concrete; roller compacted concrete and so on.

Classification of fly ash

According to ASTM C-618 Fly Ash is broadly classified into two major categories: Class F and Class C fly ash. The chief difference between these two classes is the amount of calcium, silica, alumina, and iron content. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

Class F fly ash

The burning of old anthracite and bituminous coal typically produces Class F fly ash which contains less than 10% lime (CaO). Possessing pozzolanic properties, the glassy silica and Alumina of Class “F” Fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively the addition of a chemical activator such as sodium silicate (water glass) to a Class “F” ash can lead to the formation of ageopolymer.
Class C fly ash
Class “C” Fly ash produced from the burning of younger lignite or sub bituminous coal generally contains more than 20% lime (CaO). This type of ash does not require an activator & the contents of Alkali and sulphate (SO₄) is generally higher as compared to the Class “F” Fly ash. Most of the coal burning thermal power plants in India produce the class F type fly ashes.

Table 1. Normal range of chemical composition for fly ash from different coal types

<table>
<thead>
<tr>
<th>Composition</th>
<th>Bituminous</th>
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<th>Lignite</th>
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<tr>
<td>SiO₂</td>
<td>20-60</td>
<td>40-60</td>
<td>15-45</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>5-35</td>
<td>20-30</td>
<td>10-25</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>10-40</td>
<td>4-10</td>
<td>4-15</td>
</tr>
<tr>
<td>CaO</td>
<td>1-12</td>
<td>5-30</td>
<td>15-40</td>
</tr>
<tr>
<td>MgO</td>
<td>0-5</td>
<td>1-6</td>
<td>3-10</td>
</tr>
<tr>
<td>SO₃</td>
<td>0-4</td>
<td>0-2</td>
<td>0-10</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0-4</td>
<td>0-2</td>
<td>0-6</td>
</tr>
<tr>
<td>K₂O</td>
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<td>0-4</td>
<td>0-4</td>
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<td>LOI</td>
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</table>

Fly ash is generally grey in color, abrasive, mostly alkaline, and refractory in nature. Pozzolans, which are siliceous or siliceous and aluminous materials that together with water and calcium hydroxide form cementations products at ambient temperatures, are also admixtures. Fly ash from pulverized coal combustion is categorized as such a pozzolan. Fly ash also contains different essential elements, including both macronutrients P, K, Ca, Mg and micronutrients Zn, Fe, Cu, Mn, B, and Mo for plant growth. The geotechnical properties of fly ash (e.g., specific gravity, permeability, internal angular friction, and consolidation characteristics) make it suitable for use in construction of roads and embankments, structural fill etc. The pozzolanic properties of the ash, including its lime binding capacity makes it useful for the manufacture of cement, building materials concrete and concrete-admixed products. The chemical composition of fly ash like high percentage of silica (60–65%), alumina (25–30%), magnetite, Fe₂O₃ (6–15%) enables its use for the synthesis of zeolite, alum, and precipitated silica. The other important physicochemical characteristics of fly ash, such as bulk density, particle size, porosity, water holding capacity, and surface area makes it suitable for use as an adsorbent. Table 1.1 shows the normal range of chemical composition for fly ash from different coal types (Ahmaruzzaman, 2010).

Coir Fiber
Coir fibre is extracted out of the husk (mesocarp) of a coconut, the fruit of a coconut palm (Cocos nucifera L.) which is grown extensively in tropical countries. Fibres can be extracted from unripe nuts and are then called ‘white coir’, while ‘brown coir’ is extracted after ripening of the coconut. The colour of the fibres depends however also on the coconut palm species, the extraction method and eventually the time between retting and extracting. Coir is also a versatile vegetable fibre extracted from the fibrous husk that surrounds the coconut. The fibres are tough, strong and extremely resistant to fungal and bacterial decomposition, fibre length varies from 0.3 mm to 250 mm but to an average ranges from 100 mm to 200 mm. Coir cross sections are highly elliptical and non uniform with average diameter 0.25 mm. It has high degree of crystalline; spiral angle of the micro fibres ranging between 30° and 40° which imparts greater extensibility compared to other natural fibres. In spite of low cellulose content, coir fibre has a very close fibre structure which account for its better durability compared to other natural fibres (Mesheramal, 2013). Natural geotextiles made of coir; jute, etc. are more preferred to synthetic fibres on account of the fact that the material is environment friendly and ecologically Compatible as it gets degraded with the soil. In an age of growing environmental awareness, synthetic geotextiles have some disadvantages. They are polymeric materials which are not biodegradable and are likely to cause soil pollution. Further their production process cause air and water pollution. Moreover, natural fibres are less costly and easily available in many parts of the world which make it a better choice compared to synthetic fibres. The ability of natural fibres to absorb water and degrade with time is its prime properties that give it an edge over synthetic geotextiles for slope stability applications. Coir geotextiles is a prominent natural fibre geotextiles primarily applicable for Temporary soil reinforcements and erosion control. Coir resembles natural soil in its Capacity to absorb solar radiation. This means that there is no risk of excessive heatingas happens sometimes in the case of synthetics. In application of erosion control, coir geotextiles serve the purpose of protecting the seeds and surface soil from being washed away in the initial stage and the final stability of the slope is attained by the roots of vegetation and soil consolidation.
VI. RESULTS AND DISCUSSIONS

TABLE 2. BASIC PROPERTIES OF SOIL

<table>
<thead>
<tr>
<th>Soil Properties</th>
<th>Test Results</th>
<th>Is Code Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid limit percent</td>
<td>61</td>
<td>IS:2720 (Part V)-1985</td>
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<tr>
<td>Plastic limit percent</td>
<td>21</td>
<td>IS:2720 (Part V)-1965</td>
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<tr>
<td>Plasticity index percent</td>
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<tr>
<td>Specific gravity</td>
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<tr>
<td>OMC percent</td>
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<td>IS:2720 (Part VIII)-1980</td>
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<tr>
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<tr>
<td>Gravel percent</td>
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</tr>
<tr>
<td>Sand percent</td>
<td>27</td>
<td>IS:2720 (Part IV)-1965</td>
</tr>
<tr>
<td>Silt percent</td>
<td>40</td>
<td>IS:2720 (Part IV)-1965</td>
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<tr>
<td>Clay percent</td>
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<td>Soil classification</td>
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<td>Free Swelling Index percent</td>
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<td>IS:2720 (Part 40)-1977</td>
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<tr>
<td>CBR percent (Unsoaked)</td>
<td>3.2</td>
<td>IS:2720 (Part XVI)</td>
</tr>
<tr>
<td>CBR percent (Soaked)</td>
<td>0.73</td>
<td>IS:2720 (Part XVI)</td>
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TABLE 3. PROPERTIES OF FLY ASH

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test results</th>
<th>Is Code Used</th>
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<td>Silt percent</td>
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<td>Clay percent</td>
<td>13</td>
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TABLE 4. PROPERTIES OF SOIL FLY ASH MIXTURE

<table>
<thead>
<tr>
<th>Percent Fly Ash</th>
<th>MDD KN/m³</th>
<th>OMC percent</th>
<th>Unsoaked CBR percent</th>
<th>Soaked CBR (percent)</th>
<th>UCS 7 days</th>
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<tbody>
<tr>
<td>20</td>
<td>16.6</td>
<td>17</td>
<td>5.4</td>
<td>2.8</td>
<td>132</td>
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<td>30</td>
<td>16.9</td>
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TABLE 5. PROPERTIES OF SOIL-FLY ASH-COIR FIBER (STRAIGHT) MIXTURE FOR DIFFERENT LENGTH AND FIBER CONTENT

<table>
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<tr>
<th>Length</th>
<th>Fiber Content Percent</th>
<th>MDD KN/m³</th>
<th>OMC percent</th>
<th>Unsoaked CBR (percent)</th>
<th>Soaked CBR (percent)</th>
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<tbody>
<tr>
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TABLE 6: PROPERTIES OF SOIL-FLY ASH-COIR FIBER (TWISTED) MIXTURE FOR DIFFERENT LENGTH AND FIBER CONTENT

<table>
<thead>
<tr>
<th>Length Mm</th>
<th>Fiber Content</th>
<th>MDD (KN/m²)</th>
<th>OMC (%)</th>
<th>Unsoaked CBR (%)</th>
<th>Soaked CBR (%)</th>
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<tr>
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<td>18</td>
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TABLE 7: UNCONFINED COMPREHENSIVE STRENGTH (UCS) OF SOIL-FLY ASH-COIR FIBER (TWISTED) MIXTURE FOR DIFFERENT LENGTH AND FIBER CONTENT

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<th>Length Mm</th>
<th>UCS (KPa) After Curing Period (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>straight</td>
</tr>
<tr>
<td></td>
<td>twisted</td>
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EFFECT OF FLY ASH ON MDD-OMC

Effect of Coir Fiber on MDD-OMC on Soil-Fly Ash-Fiber Mix

Effect of Straight Coir Fiber Content on CBR of Soil-Fly Ash-Fiber Mix

Effect of Fly ash on CBR
Effect of Straight Coir Fiber Length on CBR of Soil-Fly Ash-Fiber Mix

- Unsoaked and soaked CBR (%)
- Fiber (straight) Length (mm)

<table>
<thead>
<tr>
<th>Fiber Length (mm)</th>
<th>0.5% Unsoaked</th>
<th>0.5% Soaked</th>
<th>1.0% Unsoaked</th>
<th>1.0% Soaked</th>
<th>1.5% Unsoaked</th>
<th>1.5% Soaked</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

Effect of Twisted Coir Fiber Length on CBR of Soil-Fly Ash-Fiber Mix

- Unsoaked and soaked CBR (%)
- Fiber (twisted) Length (mm)

<table>
<thead>
<tr>
<th>Fiber Length (mm)</th>
<th>0.5% Unsoaked</th>
<th>0.5% Soaked</th>
<th>1.0% Unsoaked</th>
<th>1.0% Soaked</th>
<th>1.5% Unsoaked</th>
<th>1.5% Soaked</th>
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<tbody>
<tr>
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</tr>
</tbody>
</table>

Effect of Twisted Coir Fiber Content on CBR of Soil-Fly Ash-Fiber Mix

- Unsoaked and soaked CBR (%)
- Fiber (twisted) content (%)

<table>
<thead>
<tr>
<th>Fiber Content (%)</th>
<th>0.5% Unsoaked</th>
<th>0.5% Soaked</th>
<th>1.0% Unsoaked</th>
<th>1.0% Soaked</th>
<th>1.5% Unsoaked</th>
<th>1.5% Soaked</th>
</tr>
</thead>
<tbody>
<tr>
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<td>6.5</td>
<td>7.0</td>
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<td>8.0</td>
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<td>8.0</td>
<td>8.5</td>
<td>9.0</td>
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</tr>
</tbody>
</table>

Effect of Straight Coir Fiber Content on UCS of Soil-Fly Ash-Fiber Mix

- Unconfined compressive strength (KPa)
- Straight fiber content (%)

<table>
<thead>
<tr>
<th>Fiber Content (%)</th>
<th>10mm, 7 days</th>
<th>10mm, 14 days</th>
<th>10mm, 28 days</th>
<th>20mm, 7 days</th>
<th>20mm, 14 days</th>
<th>20mm, 28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5%</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>250</td>
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</table>

Effect of Twisted Coir Fiber Content on UCS of Soil-Fly Ash-Fiber Mix

- Unconfined compressive strength (KPa)
- Fiber (Twisted) content (%)

<table>
<thead>
<tr>
<th>Fiber Content (%)</th>
<th>10mm un soaked</th>
<th>10mm, 7 days</th>
<th>10mm, 14 days</th>
<th>10mm, 28 days</th>
<th>20mm un soaked</th>
<th>20mm, 7 days</th>
<th>20mm, 14 days</th>
<th>20mm, 28 days</th>
<th>30mm un soaked</th>
<th>30mm, 7 days</th>
<th>30mm, 14 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5%</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
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</tbody>
</table>

Effect of Twisted Coir Fiber Length on UCS of soil-fly ash-fiber mix

- Unconfined compressive strength (KPa)
- Straight fiber length (mm)

<table>
<thead>
<tr>
<th>Fiber Length (mm)</th>
<th>0.5% 7 days</th>
<th>0.5% 14 days</th>
<th>0.5% 28 days</th>
<th>1.0% 7 days</th>
<th>1.0% 14 days</th>
<th>1.0% 28 days</th>
<th>1.5% 7 days</th>
<th>1.5% 14 days</th>
<th>1.5% 28 days</th>
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</thead>
<tbody>
<tr>
<td>10</td>
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</tbody>
</table>

Effect of Twisted Coir Fiber Content on UCS of soil-fly ash-fiber mix

- Unconfined compressive strength (KPa)
- Curing Period (Days)

<table>
<thead>
<tr>
<th>Fiber Content (%)</th>
<th>10mm, 0.5%</th>
<th>10mm, 1.0%</th>
<th>10mm, 1.5%</th>
<th>20mm, 0.5%</th>
<th>20mm, 1.0%</th>
<th>20mm, 1.5%</th>
<th>30mm, 0.5%</th>
<th>30mm, 1.0%</th>
<th>30mm, 1.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5%</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
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<td>200</td>
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<td>1.0%</td>
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<td>240</td>
<td>240</td>
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<td>240</td>
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</tbody>
</table>

Graphs and tables showing the effect of coir fiber length and content on CBR and UCS values.
Variation in UCS for the twisted fiber on fiber content

Effect of Twisted Fiber Length on UCS of Soil-Fly Ash-Fiber Mix.

Effect of Curing period on UCS of Soil-Fly Ash-Fiber Mix

VII. CONCLUSIONS

Based on the study, following conclusions can draw.

- The maximum dry density is found to be 16.7 KN/m³ at 18 percent OMC for 30 percent of Fly ash. CBR value is found to be 3.7 percent for 30 percent content of fly ash in soil which is more than the virgin soil.

- On addition of straight and twisted discrete fibers in soil fly ash mixtures, for different length MDD value decreased.

- CBR value increases with increase in the fiber content and length. UCS value increase with the increase in fiber content but decrease with the increase in length.

- CBR value is found to be 21.9 percent and 6.03 percent for the twisted and straight twisted coir fiber for 1.5 percent and 30mm length when 30% soil is added to the soil.

- UCS value is found to be 450 and 745 for the straight and twisted coir fiber of 30 mm length and 1.5 percent content for the 28 days of curing. Corresponding 7 days UCS values of are 304 kPa and 550 kPa respectively for straight and twisted fiber.

- Therefore, it is concluded that Fly ash alone and Fly ash fiber in BC soil is suitable as the subgrade material in the highways.

VIII. POINTS FOR THE FUTURE WORK

The present study is limited to BC soil, class F fly ash and discrete coir fiber. This can be further extended by adopting as mentioned below:

- By replacement of fly ash by lime, stone dust, sand, cement, rice husk etc.

- By replacing coir fiber by sisal, shredded tyre rubber.

- By replacing the BC soil with other problematic soil.

From the above materials, mixes of different proportions or combinations can be made for improving the soil which may be used for construction of embankment or soil subgrade in highways.

IX. JOURNAL PAPERS


X. ACKNOWLEDGEMENTS

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