INFLUENCE OF CEMENT AND COIR FIBER ON THE MECHANICAL PROPERTIES OF RAMMED EARTH

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Abstract:

Rammed earth, a construction is widely used globally due to its ease of availability of materials and mechanical performance. Stabilization is necessary in rammed earth construction to enhance the binding of the soil particles which in turn increases the mechanical and durability properties of rammed earth. The purpose of this research is to determine the optimum percentage of chemically treated Coir fiber dust and cement for rammed earth. Fibers and cement can be easily integrated into the soil mixture, increasing the wall's strength and durability. Compressive, flexural, and tensile strength tests were performed on the samples, and failure patterns were studied. Cement is varied in percentages of 6%, 9% and 12% and coir fiber dust (0.1, 0.2, 0.3, and 0.4 percent by weight of soil) were added as stabilizer and reinforcement. To assess the optimum strength and durability, it is recommended to utilize 0.2 percent fiber content Coir fiber dust, along with 9 percent cement by weight of soil. It is observed that with the cement and fiber dust incorporation there has been increase in the mechanical properties of rammed earth.

Keywords- Cement Stabilized Rammed Earth (CSRE), Coir Fiber Dust, wet compressive strength, flexural strength.

1. INTRODUCTION

The global demand for housing and construction is always rising, which has led to a major use of natural resources in the form of building materials. Building construction supplies are becoming scarcer and more expensive as a result of this over-exploitation. Understanding the causes of this has led to a change in focus toward the creation of sustainable building materials that use less energy during both the building's construction and operation. One such material that can maximize resource utilization while lowering the carbon impact is stabilized rammed earth.
Soil is one of the most ancient building materials in the world. The two most significant building methods used during the evolution of soil material were rammed earth and adobe masonry. These methods have little embodied carbon and use local materials. There are two types of rammed earth, unstabilized rammed earth and stabilized rammed earth. The most common methods to use fiber-reinforced earth as a building material are adobe, cob & pise[1].
The studies are generally done for double stabilization of rammed earth such as stabilization with lime & fibers. Studies done globally show that a cement content of 5-10% & fiber content of 0.2-0.6% provides the best mechanical properties [2-5]. The length of the fiber strand also has an impact on the mechanical properties. Overall cement stabilization improves strength and durability; however, fibers improve the ductility of rammed earth and can also increase the strength.
There have been a lot of published studies on the impacts of adding fiber stabilization to rammed earth, but not much on the interaction between the fiber and the earth. In earlier studies, it was discovered that adding fibers to rammed earth or composite soils either decreased the unconfined compressive strength [6,7]; or gave a small increase at low-fiber contents [8-11]. The relationship between fiber content and UCS may be influenced by the soil's clay concentration; whereas more sandy soils responded to increasing fiber content with a lower UCS, soils with higher clay contents responded to increased fiber content with a higher UCS, even less has been written about how fibers affect the shear strength of earthen construction materials than the published research on UCS. Cheah et al. (2012) [12] evaluated the shear strengths measured for large rammed earth samples using the traditional triaxial and triplet tests (the latter similar to those used on masonry structures), assuming a straightforward Mohr-Coulomb failure criterion. According to their findings, when a failure occurs through shearing involving fibers, the presence of fibers diminishes apparent cohesiveness but increases the friction angle. However, a more recent study [13] that reports shear box testing on rammed earth samples reinforced with wool fibers did not reach the same conclusion

regarding friction angle. In either case, adding fibers does not seem to inherently increase strength.
All publications that dealt with the linear shrinkage of rammed earth samples found that it decreased with increasing fiber concentration. In many of these publications [7, 11, 14], it is hypothesized that changes in material properties are brought on by incorporated fibers mobilizing more tensile strains. This would aid in evenly dispersing stresses across the entire sample, preventing shrinkage, reducing crack spread, and also resulting in more ductile failures.

In 1999 a study was conducted on composite soil blocks [10] using sisal and coconut fibers sourced in Brazil. The studies comprised 4% of 50 mm long sisal or coconut fibers, and the results revealed an improvement in ductility and an approximate 15% increase in compressive strength for both types of fibers. It was discovered that sisal fibers better absorbed water than coconut fibers. However, neither of the fibers allowed shrinkage cracks to form. Even though the addition of bitumen did not enhance bonding, it did increase ductility. Attom et al. (2009) [15] evaluated the use of two fibers, one natural and the other synthetic (palm yarn and nylon, respectively), ten years after this study. Three distinct types of clay soil from Jordan were used in the study to examine how changes in mechanical behavior were affected by randomly oriented fibers. Five different percentages, ranging from 1-5%, of the mass of solid soil particles were tested. According to the findings, using natural fiber improved the relative UCS more than using synthetic fiber. This shows that natural fibers may be preferable to synthetic fibers for use in soil-based construction materials, while durability with the latter is a concern. An additional issue with stabilizer use is the increased breakdown of fibers brought on by chemical reactions. Studies that simulate the cycles of wetting and drying of fibers [16] in the presence of strong alkalis that can take place during the curing of mortars reveal significant losses in strength first for the fibers and subsequently for the fiber-reinforced mortar. With earthen construction materials, however, this might only be a minor issue because (i) the alkalinity during curing will be lower due to smaller percentage inputs of cement or lime and (ii) the majority of the material will dry uniformly rather than in cycles of wetting-drying.

2. MATERIALS USED

It is important to consider the choice of materials and their properties before performing any tests on specimens consisting of these materials. Materials used in this project were sand, soil, cement, and Coir fiber dust.

Sand

M Sand or Manufactured Sand Artificial sand is made by crushing big, hard stones, mostly granite or rocks. It is used as an alternative for river sand mainly for creating concrete or mortar mix. The M sand used in this project is passed through a 4.75mm sieve and should be free from silt, clay, and other organic particles.

Soil

The Doddaballapur region's suitable red soil, which is abundant in kaolinitic minerals, is preferred for the current investigation as it offers great strength in comparison to other soil minerals. [17]

Cement

The soil sample was stabilized with 53-grade Birla super cement. Cement was used at a 9 percent per dry soil mass proportion for this project. According to IS- 12269(1987), rammed earth must be stabilized with a cement content of at least 6 percent.

Coir fiber dust

Coir fiber dust soaked in neem-based acrylic polymer was used (Fig 2.1). The fibers were soaked in this polymer to make it decay-resistant against the decomposition action of bacteria (Fig 2.2). Fibers were soaked in a 1:2 solution of polymer and water for 24 hours and were then air-dried for about 24 hours. These were then used in different proportions of 0.1%, 0.2%, 0.3% and 0.4%.

Fig 2.1 Coir fiber dust after treatment with neem-based acrylic polymer

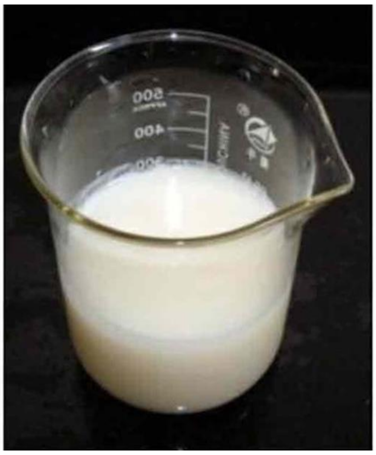

Fig 2.2 Neem-based acrylic polymer

3. Experimental investigation

Particle size distribution:

From the cumulative particle size distribution curve in Fig 3.1, the particle size corresponding to 10% finer materials, D10 was obtained as 0.21mm and similarly, D30, and D60 obtained were 0.521mm and 1.28mm respectively. For the sample chosen, the coefficient of curvature obtained was 6.1 and the uniformity coefficient was found to be 1.01. Hence the soil can be considered as well-graded soil as the obtained results lie in between the given range.

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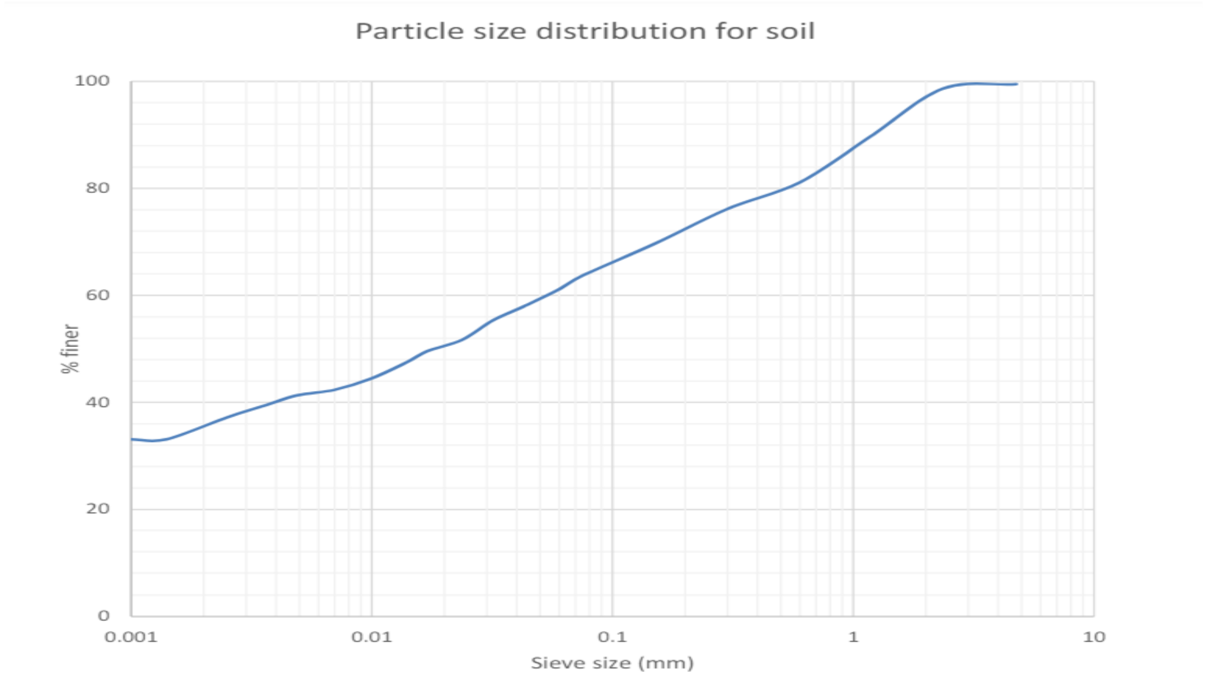


Fig 3.1 Particle Size Distribution Curve for Soil Sample

Atterberg Limits:

Atterberg limit values are tabulated in Table 3.1.

Table 3.1 Atterberg's Limits and Clay content

	Natural soil	Reconstituted soil
Liquid limit	33.31%	30.2%
Plastic limit	19.63%	17.26%
Shrinkage limit	14.18%	12.31
Clay content	33%	13%

OMC and MDD of Soil:

OMC and the corresponding MDD of a sample have to be found from the graph of dry density versus moisture content.

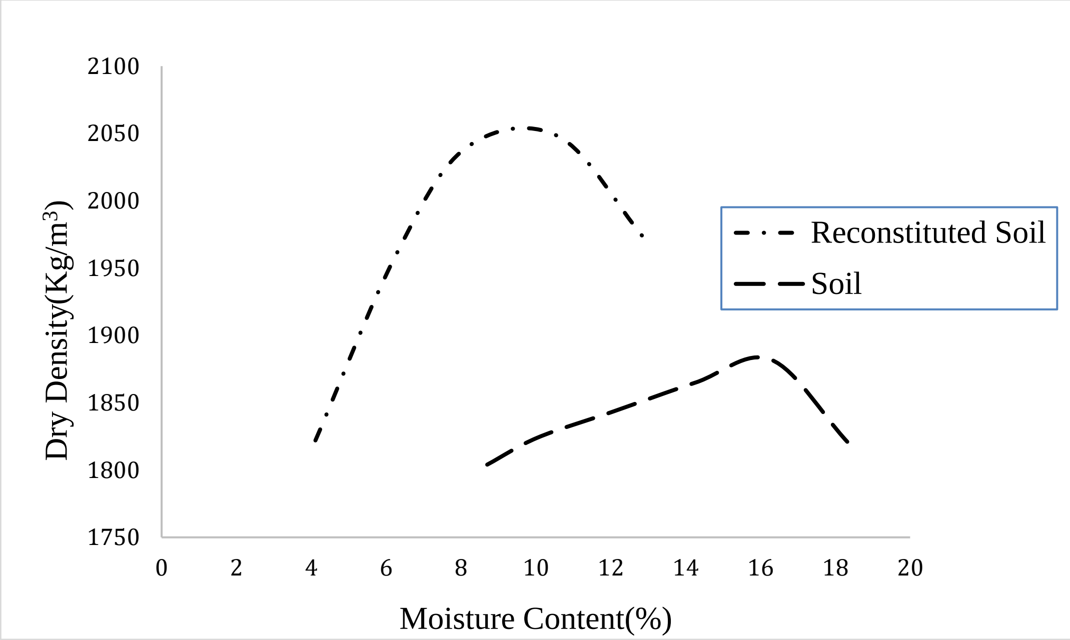


Fig 3.2 Compaction Curve for soil and reconstituted soil

OMC and MDD of Fiber Reinforced Soil:
Reconstituted soil and Coir fibres with 0.1, 0.2%, 0.3%, and 0.4% variation in the mix were combined in a mix design.

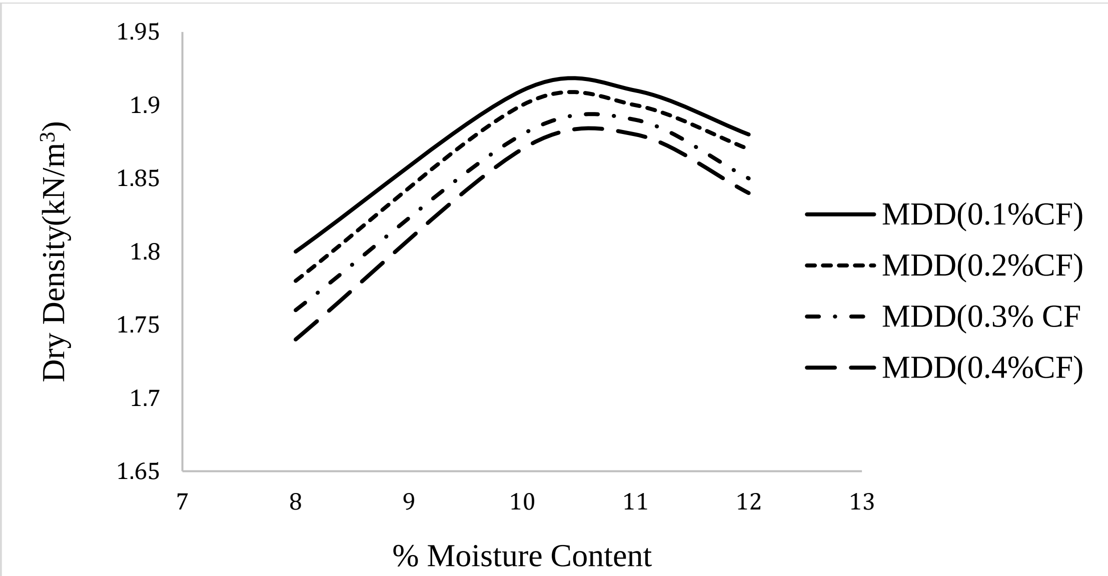


Fig 3.3 Compaction Curve with Coir fiber

Optimum percentage of cement
Cylinders cast with three different cement contents; 6%, 9% and 12% were tested under compressive loading after curing the specimens for 28 day. 7.4MPa, 5.02MPa and 3.5MPa were obtained as the wet compressive strength for the cement contents 6%, 9% and 12% respectively. 6% cement could not be adopted for the field application as it would lead t durability issue; 12% cement which is a very high content acts as a lean concrete affecting the sustainability concern and hence could not be adopted. Hence 9% cement is adopted for the current study.

Cylinders with coir fiber in the ratio 0.1%, 0.2% and 0.3% to the reconstituted soil with 9% cement. The results of the compression test are plotted for coir fibers as shown in Fig 3.4. It is found that a maximum strength of 4.9MPa has been obtained for 0.2% of coir fibre.

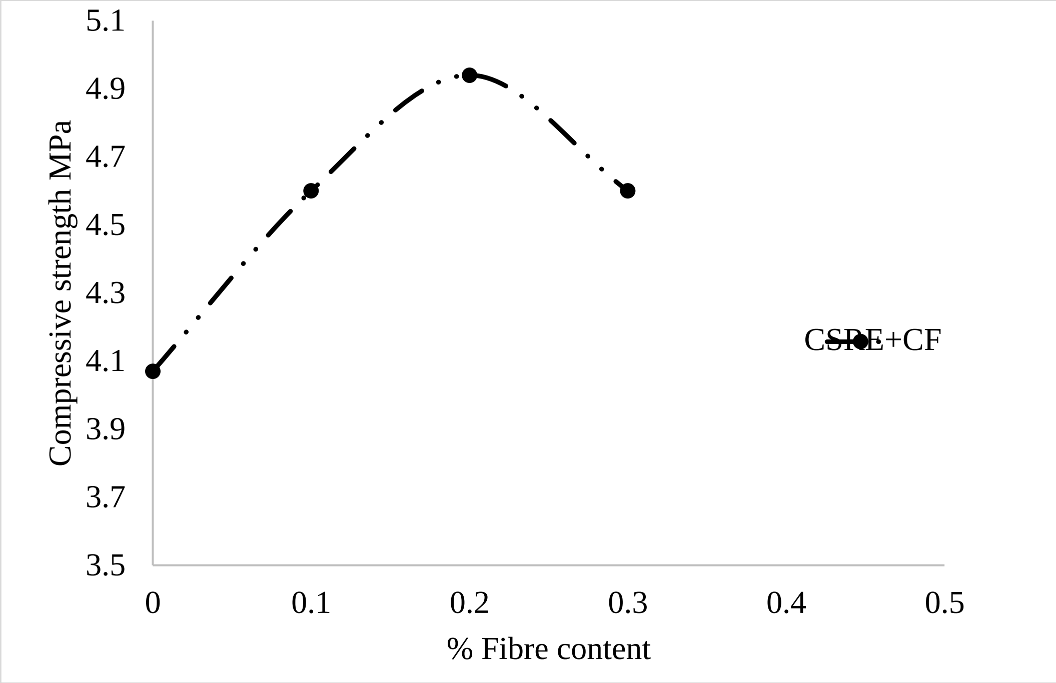
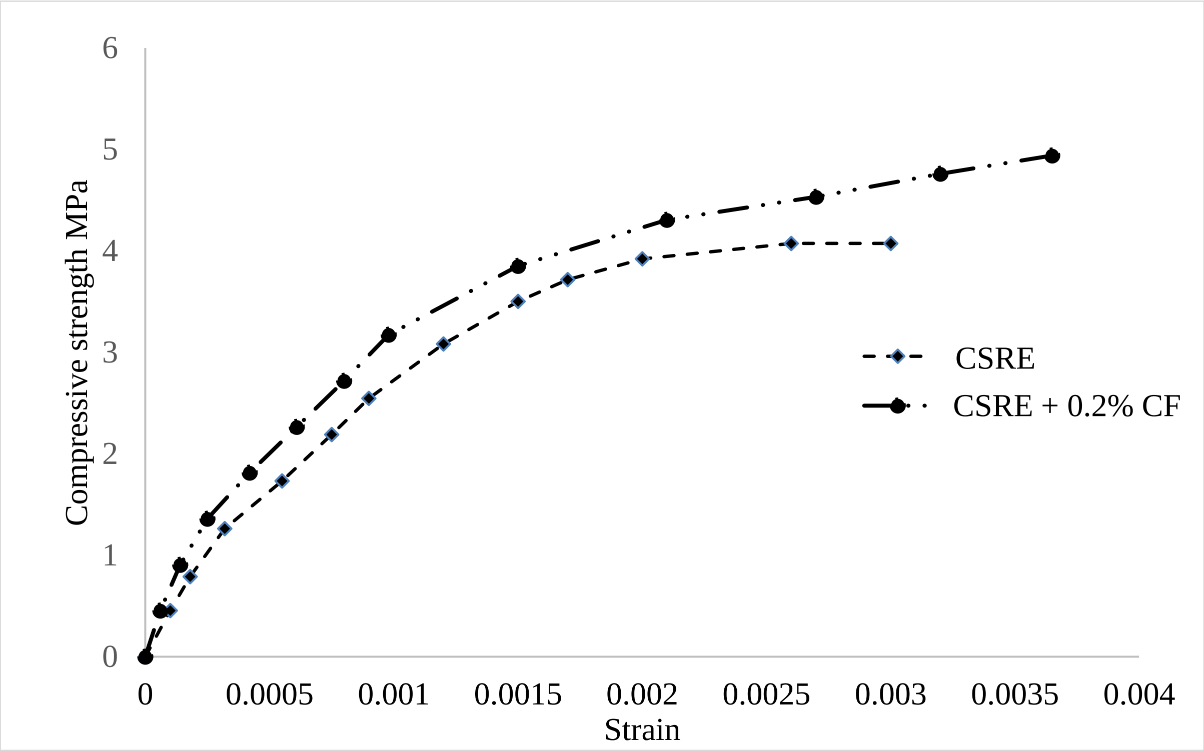


Fig 3.4 Variation in Compressive Strength with fiber content



Split Tensile Strength:

The failure pattern of the sample is as observed in Fig 3.5 where in the fibers bridge the crack developed and keep the rammed earth material together without splitting. The variation of split tensile strength with fiber content in

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percentage is plotted as shown in Fig 3.6 for all fiber variants. It is observed that a split tensile strength of 0.52MPa has been achieved for 0.2% fibre.

Fig 3.5 Failure of the sample under tension

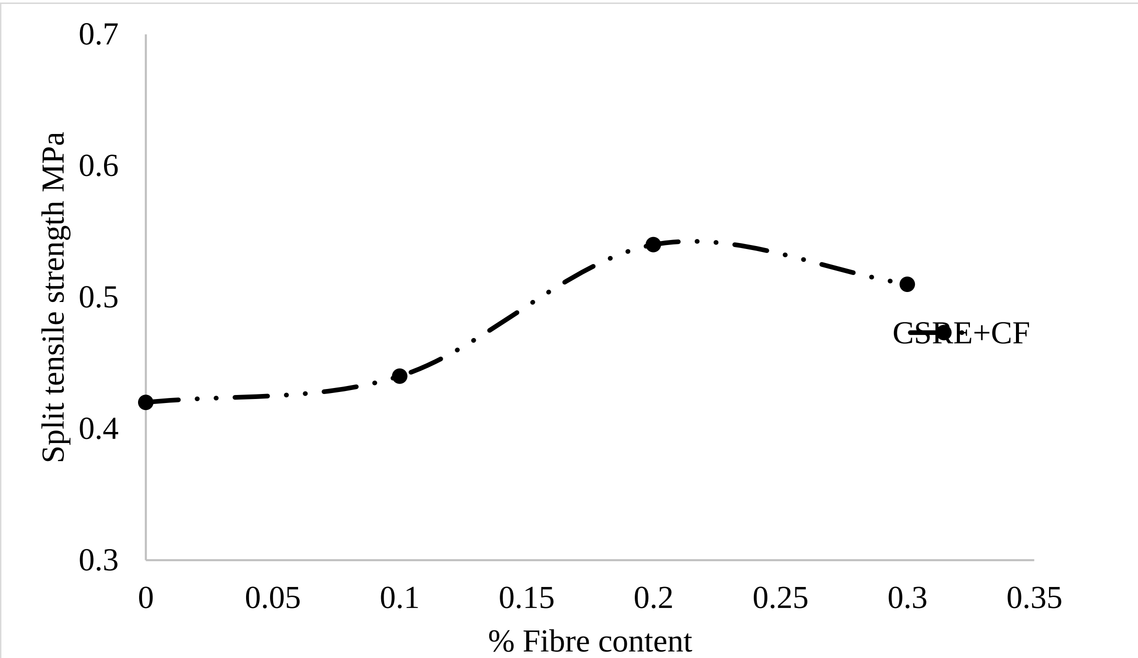

Fig 3.6 Variation of split tensile strength with fiber content

Flexural Strength:

Fig 3.7 shows failure of a beam sample after being subjected to a two-point flexural strength test. For Coir fiber dust 0.2%, fiber content has highest flexural strength and offers the greatest ductility. It is found that the flexural strength of 0.84MPa and 0.8MPa has been observed for the specimen with and without fiber reinforcement

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Fig 3.7 Failure of the sample under flexure

Conclusion:

- Coir fiber is considered to be a sustainable material for rammed earth wall construction because it helps in improving the geotechnical and mechanical properties of rammed earth blocks.
- The maximum compressive strength of 4.8 MPa was obtained for 0.2% coir fiber and 9% CSRE.
- A split tensile strength of 0.55 MPa was obtained for 0.2% coir fiber CSRE.
- A flexure strength of 0.84 MPa and 0.8 MPa was obtained for 0.2% coir fiber CSRE and CSRE respectively.

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