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Influence of treated coir fiber on durability properties of black cotton soil

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ABSTRACT

The particular characteristics of black cotton soil, which prevent it from contributing to a sturdy foundation, are significant. There are therefore two options: either eliminate the current soil and substitute it with non-expanding soil or stabilise the soil to enhance its qualities. There are numerous tools and methods for stabilising soil. One method for enhancing the engineering qualities of expansive soils is soil reinforcement. One of the most economical and environmentally responsible ways to strengthen soil is to use natural fibres. The application of randomly distributed fibre reinforced soil has persuaded researchers to look into further features and scenarios. The objective of the current study is to determine how long coir-reinforced soil can withstand harsh atmospheric conditions. The Coir fibre is a decomposable substance as well, and it tends to deteriorate in harsh environments like contaminated water, leachate, alternate sequences of wetting and drying, freezing and thawing, and so forth. Although the lifespan of coir fiber in soil is predicted to be between 8 and 10 years, However, it may decay quickly as a result of numerous environmental exposures. In the current inquiry, a treatment of fibres is made to try and analyse the durability properties of coir fibre employing this treated fibre in Black cotton soil.

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1. Introduction

The western half and some regions of south India have black cotton soils. Black Cotton soil absorbs moisture when there is moisture present, swell, and lose strength. These soils have a tendency to heave when wet and are compressible in such situations. In dry conditions, black cotton soil shrinks and become cracked. Clay makes up a significant portion of Black Cotton soil; mostly its structure is montmorillonite and is either black or blackish grey in appearance. Geotechnical and highway engineers have had difficulty working with the Black Cotton soil due to its heavy swelling and shrinkage properties. The soil is extremely firm while it is dry, but completely loses its hardness when it is wet (Balasubramaniam, et. al, 1989). The procedure of wetting and drying transfers the soil mass vertically, which leads to pavement failure in the form of settlement, severe depression, cracking, and unevenness. In addition, it produces clods that are challenging to pulverise before being used in road construction. (Holtz and Gibbs, 1956). This presents significant challenges for the road's performance further forward. Additionally, the softened subgrade sometimes heaves into the pavement's higher layers, particularly when the sub-base is made of void-filled stone soling. The road will always fail when damp Black Cotton dirt slowly infiltrates. But because it is readily available and inexpensive, this soil is widely employed in building (Bell, 1988). A few factors that determine how these expansive soils behave include preliminary moisture content, dry density, the amount and kind of clay in the soil, the soil's Atterberg limits, and swell potential. The term "soil stabilisation" refers to any physical, chemical, biological, or combination of these methods that can be used to improve specific characteristics of a typical soil to make it sufficiently serve a projected purpose. Over the past three decades, strength deformation behaviour studies have been conducted on soft soil reinforced with fibre. It is now beyond question that adding fibre to the soil enhances engineering performance in general. Greater extensibility, a minor post-peak strength loss, isotropy in strength, and the absence of weak points are a few of the significant improvements. Recently, fibre mixed soil has been adopted in several nations, and advanced study is being done on many of its unexplored potentials. All types of soil are thought to benefit from fibre reinforced soil (i.e. sand, silt

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and clay). Since a very long time, numerous nations, including India, Bangladesh, and the Philippines, have employed natural materials like jute, coir, sisal, and bamboo as soil reinforcement. The availability and affordability of these materials locally are their main benefits. Due to their biodegradability, they pose no environmental disposal issues (Singh and Bagra, 2013). Therefore, cost effectiveness is made possible by extensive availability. In several underdeveloped nations, the coir fibre sector is very significant. The objective of the current study is to determine how long coir-reinforced soil can withstand harsh atmospheric conditions. In hostile settings such contaminated water, leachate, alternating cycles of wetting and drying, freezing and thawing, etc., the decomposable substance coir fibre also tends to degrade. Although the lifespan of coir fibre in soil is predicted to be between 8 and 10 years, However, it may decay quickly as a result of numerous environmental exposures. In the current inquiry, a treatment of fibres is made to try and analyse the durability properties of coir fibre employing this treated fibre in BC soil.

2. Materials

a) Black cotton soil
b) Coir fibre
c) Acid
d) Leachate

3. Methodology

Wet and dry sieve analysis, Atterberg Limits, Standard Proctor Test, Differential Free Swell Test, Swelling Pressure Test, and California Bearing Ratio(CBR) were used to determine the fundamental properties of black cotton soil. The north Karnataka region provided the soil. Test. Sieve Analysis According to IS 2720 (Part 4)-1985, the soil was submitted to dry and wet sieve studies, and it was classified using IS 1498–1970. The soil's Atterberg Limits were set in accordance with IS 2720 (Part 5)-1985. The Atterberg Limits were used to determine the soil's liquid and plastic limits, which were then used to determine the soil's plasticity index. In line with IS 2720 (Part VII) – 1980, the Common Proctor Test, also known as the Standard Proctor Test, was performed on the soil to ascertain the degree of compaction and water content that would be necessary in the field. We can determine the water content at which the greatest dry density is reached using the test's correlations. Free Swell Differential Test The soil's free swelling index, which was obtained using a differential free swell test, was used by IS 2911 (Part 3)-1980 to calculate the expansiveness of the soil. Cleaning the coir fibres, roughening the surface, covering with water-based epoxy substance, and then sprinkling quartz sand over the wet surface of the fibres will be done to treat the coir fibre and offer a mechanical key. To conduct CBR test, Preparation the mould,weigh the mould with baseplate attached to the nearest 5 g (m2). Measure the internal dimensions to 0.5 mm. Attach the extension collar to the mould and cover the base-plate with a filter paper. Measure the depth of the collar as fitted, and the thickness of the spacer plug or plugs, to 0.1 mm. Divide the prepared quantity of soil into three portions with a mass equal to within 50 g of each other and seal each portion in an airtight container until required for use. Place one portion in the mould and level the surface. Compact to 1/3 the height of the mould in the compression device using suitably marked steel spacer discs to obtain the required depth of sample. The mould is then removed from the compression device and the second portion of the material is added. This is then compressed to give a total sample depth to 2/3 the height of the mould Finally, the remainder of the sample is added and the mould is returned to the compression device until the finished sample is just level with the top of the mould. Care should be taken not to damage the press by attempting to crush the steel mould when the sample is level: always pay close attention to the load gauge. Except for some dense aggregates the force required for compaction should not be very large. On completion of compaction weigh the mould, soil and baseplate to the nearest 5 g (m^3). Unless the sample is to be tested immediately, seal the sample (by screwing on the top plate if appropriate) to prevent loss of moisture. With clay soils or soils in which the air content is less than 5 %, allow the sample to stand for at least 24 h before testing to enable excess pore pressures set up during compression to dissipate. The tests mentioned above are also performed on an unreinforced soil sample as a point of comparison. On a large soil sample with various coir fibre content ratios, a number of studies are conducted. The length of coir fiber considered is 35 mm which is randomly distributed. In the present investigation it is intended to obtain optimal fibre content to improve CBR value along with degradation of coir fibre (Both treated and untreated) under different environmental conditions. In this regard experiments are conducted to obtain the CBR value by keeping fiber volume fraction as variable.

4. Result and discussions

In the soil, the proportions of coir fiber are 0.25 %, 0.50 %, 0.75 %, 1 %, and 1.25 %. Table 1 displays the CBR values of several samples in varying percentages.

As can be seen, both treated and untreated coir fibre soil samples had a maximum of 1 % soaking CBR value. In contrast, a 32.6 % increase in the soaking CBR value is shown when 1 % more coir fibre is added. Effect of fiber percentage on CBR is presented in Fig. 1. For further investigation, BC soil mixed with 1 % of coir fibre. Figs. 2-5

4.1. Alternate soaking and drying in water

Black cotton soil CBR moulds were created with and without 1 % coir fibre. Prepared. 24 h were spent soaking the CBR mould in water, and another 24 were spent drying it in a 500°F oven. For 7, 14, and 28 days, the process of alternately soaking and drying was carried out. The differences in CBR value with coir fibre, treated coir fibre, and normal soil are presented in Table 2 and CBR value decreases with increasing time.

Black cotton soil gains strength in comparison to its initial strength after several alternating cycles of wetting and drying. The amount of alternating wetting and drying cycles enhances bearing capacity, but beyond a certain number of cycles, the rate of rise of bearing capacity sharply declines, resulting in a fall in bearing capacity. For lateritic soil, liquid limit as well as plastic limit are likewise impacted by the cycle of alternate wetness and drying. As alternate wetting and drying cycles number increases, both the liquid limit and the plastic limit individually drop.

Table 1
CBR of B.C. Soil With various proportions of Coir Fiber.

Coir (%) by wt of soil	Soaked CBR for untreated coir	Soaked CBR for treated coir
0.25 %	3.04	3.29
0.50 %	3.21	3.52
0.75 %	3.71	3.75
1 %	3.69	3.82
1.25 %	3.50	3.61

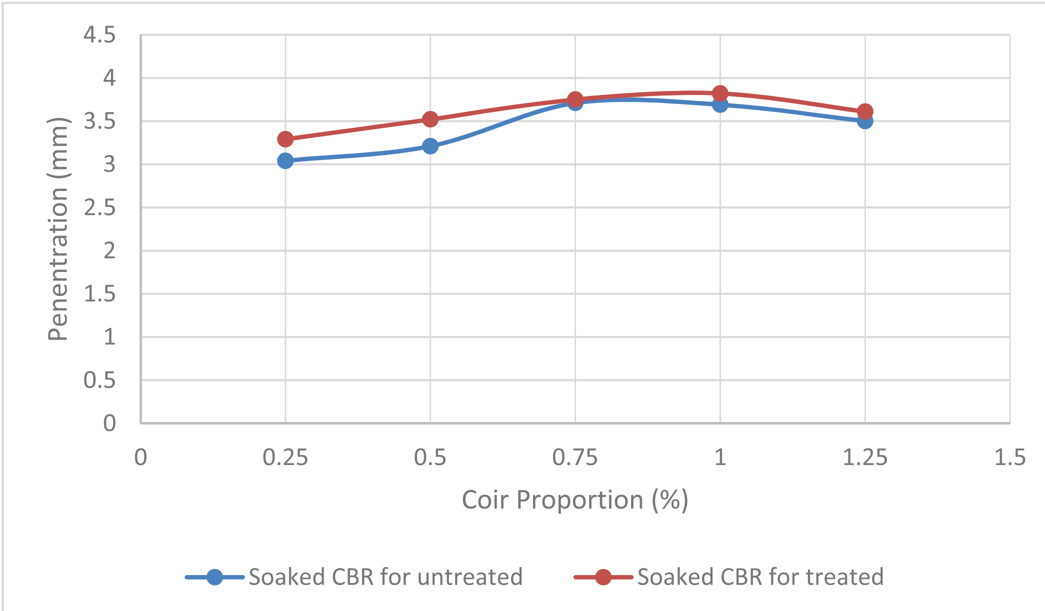

Fig. 1. CBR variation for untreated and treated coir fiber reinforced soil.

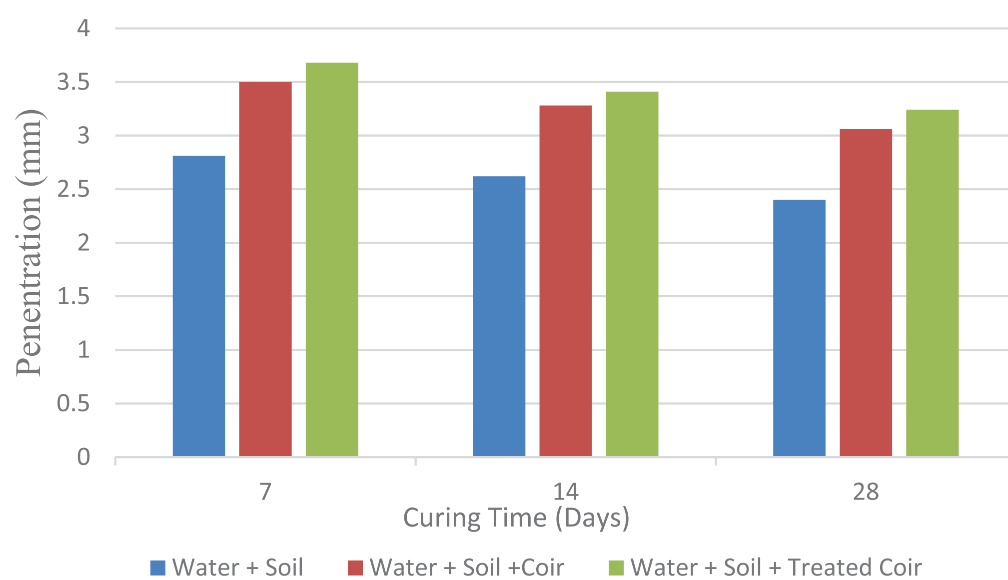

Fig. 2. Variation of CBR for various curing period for Alternate Soaking and Drying in Water.

4.2. Alternate soaking and drying in acid

1 % untreated coir fibre, 1 % coir fibre, and 1 % treated coir fibre were used to prepare the CBR mould of the black cotton soil. The prepared CBR mould was stored in sulphuric acid with 0.6 ml/5l of distil water for 24 h as a soaking solution, and for 24 h at 500 °C as a drying solution. For 7, 14, and 28 days, soaking and drying were alternated. The changes are displayed in Table 3 and indicate that CBR value decreases with increasing time.

The liquid limit for black cotton soil decreased as sulphuric acid content rose. This was typically caused by a decrease in the formed double layer's thickness and a rise in the pore fluid's electrolyte content. This indicates a fall in soil water-holding capacity, an increase in frictional resistance, and a loss of soil cohesiveness. The cation exchange capacity of soils diminishes as acid content rises. The ideal moisture content of soils is declining.

Due to the loss of cohesiveness, unconfined compressive strength has drastically decreased. The CBR value of BC soil declines over time.

4.3. Outcome of alternate wetting and drying in Leachate

1 % untreated coir fibre, 1 % coir fibre, and 1 % treated coir fibre were used to prepare the CBR mould of the black cotton soil. For the purpose of soaking, CBR mould is prepared and kept in leachate for 24 h. An oven temperature of 500C for 24 is maintained for 24 h in order to dry the specimen. For seven days, fourteen days, and twenty-eight days, this alternate soaking and drying process is

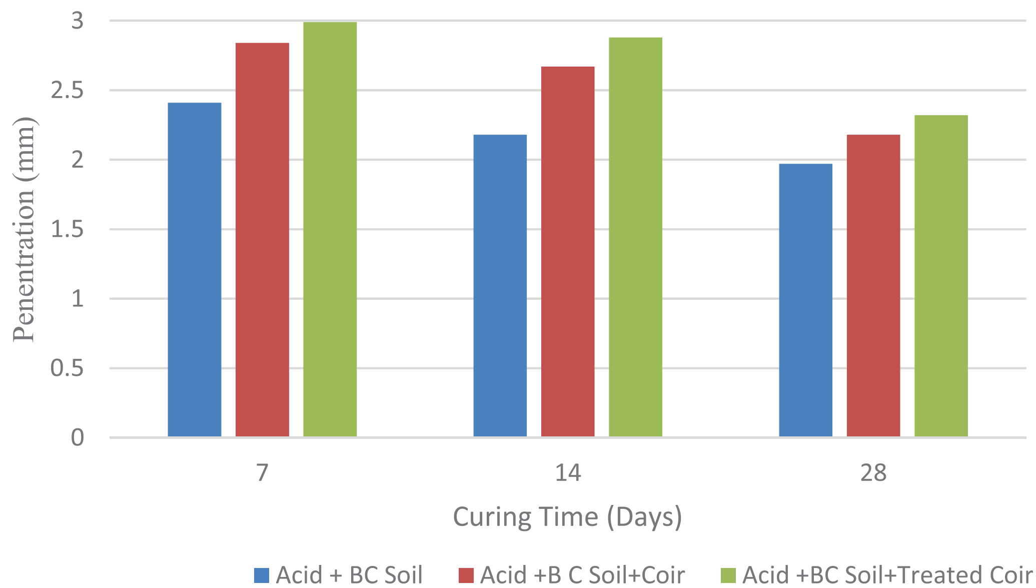

Fig. 3. Variation of CBR for different curing period under Alternative Soaking and Drying in Acid.

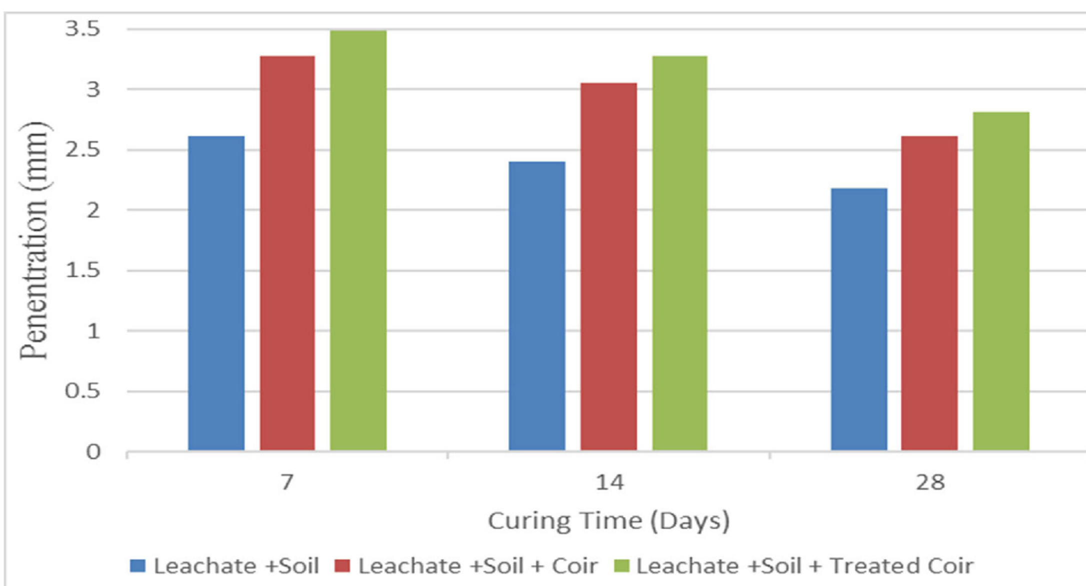

Fig. 4. Variation of CBR for different curing period under Alternate Wetting and Drying in Leachate.

repeated. The variations are seen in Table 4 and the CBR value falls with increasing time.

With a rise in substrate concentration in influent wastewater, coir geotextile medium fibres lose tensile strength. This might be the case because the availability of substrates affects how well bacteria grow. These microbes do, however, degrade the media. The coir geotextile media's tensile strength is also influenced by pH. The quantity of substrates in the influent also affects permittivity. In the pores of the coir geotextile medium, suspended particles may obstruct the influent's capacity to flow through the filter. The coir geotextile medium fibres lose tensile strength due to the substrate concentration in influent wastewater. This might be due to how readily available substrate affects microbial development. However, these bacteria deteriorate the media. The number of substrates in the influent has an impact on permittivity, which in turn has an impact on the strength of the coir geotextile medium under stress. The influent may not be able to flow through the filter if suspended particles in the influent get caught in the pores of the coir geotextile media.

4.4. Result of alternate freezing and thawing

Black cotton soil CBR moulds were created with and without 1 % coir fibre. For the purpose of soaking, CBR mould is prepared and kept in leachate for 24 h. To dry the specimen, an oven temperature of 500C is kept constant for 24 h. For seven days, fourteen days, and twenty-eight days, this alternate soaking and drying process is repeated. The variations are displayed in Table 5 and the CBR value falls with increasing time.

It is evident that unreinforced samples lose more strength after repeated freezing and thawing than stabilised ones. After multiple freeze–thaw cycles, soils that are both loose and dense may achieve the same void ratio. Soils frequently become looser and denser over time. Permeability will rise as a result of the size of

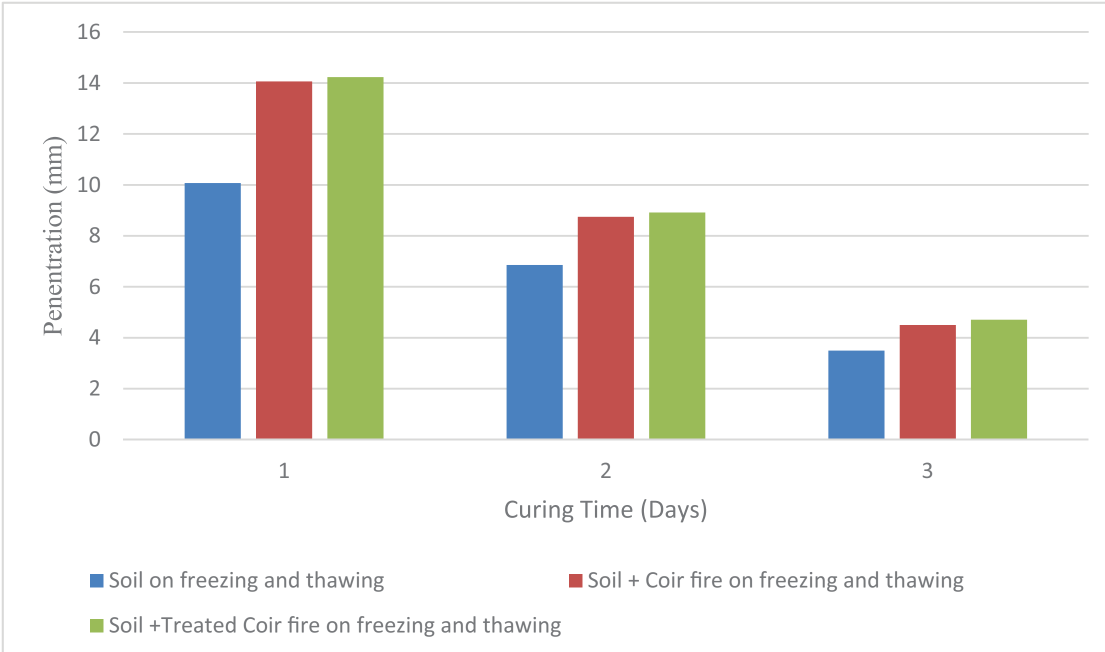

Fig. 5. Variation of CBR for different curing period under Alternate Wetting and Drying in Leachate.

Table 2
CBR of Soil After Alternative Soaking and Drying In Water.

Days	Soil	Soil + Coir	Soil + Treated Coir
7	2.81	3.5	3.68
14	2.62	3.28	3.41
28	2.4	3.06	3.24

Table 3
CBR of B.C. Soil in Acid on Alternate Soaking and Drying.

Time (Days)	Acid + BC Soil	Acid + B C Soil + Coir	Acid + BC Soil + Treated Coir
7	2.41	2.84	2.99
14	2.18	2.67	2.88
28	1.97	2.18	2.32

Table 4
CBR of B.C. Soil After Alternate Soaking and Drying In Leachate.

Time (Days)	Leachate + Soil	Leachate + Soil + Coir	Leachate + Soil + Treated Coir
7	2.62	3.28	3.49
14	2.4	3.06	3.28
28	2.18	2.62	2.81

Table 5
CBR of B.C. Soil on Alternate Freezing and Thawing.

Days	Soil in freezing and thawing	Soil + Coir fiber on freezing and thawing	Soil + Treated Coir fibre on freezing and thawing
7	10.07	14.06	14.23
14	6.86	8.75	8.92
28	3.5	4.5	4.71

the big pores that are still there after ice crystals thaw. The maximum strength of the soil is decreased by these cycles. The interlocking of soil grains is disturbed, and the mechanical characteristics of soil are altered by the separation of soil aggregates brought on by ice lenses made of soil-pure water at temperatures just below 0 °C.

5. Conclusion

Based on the investigation that was done, the following conclusions were drawn.

1. The soaked CBR value of BC soil was 2.81, and it was increased by 31 % by adding 1 % treated coir fibre (by weight).
2. Sulfuric acid decreases both the CBR of BC soil and the tensile strength of coir fibre.
3. Later 28 days, the CBR of stabilised had fallen by 30 % and was less than the original CBR of BC soil. Degradation was worse with alternate wetting and drying in leachate but less severe with acid. Therefore, using treated coir fibre at the landfill site area rather than untreated one is desirable.
4. The CBR of stabilised soil and unstabilized soil was dramatically boosted on alternate freezing and thawing by 269 % and 254 %, respectively, and it gradually lowers over time while remaining at least as high as the original CBR of BC soil. As a result of repeated freezing and thawing, both stabilised soil and unstabilized soil have higher CBR values overall. For stabilisation in cold areas, treated soil reinforced with coir fibre may be used.

Next 14 and 28 days, the CBR was extremely low and plummeted to 29 % and 35 % of the original CBR of BC soil, respectively. The CBR of stabilised soil and unstabilized soil decreases on alternating wetting and drying in acid with time. Therefore, treated coir fibre reinforced soil is more effective than untreated coir reinforced and unreinforced soil in a given situation.

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submitted work.

7. Code availability

Codes are generated by the authors using MATLAB 7.0.

8. Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Sangeetha D. M. and Naveenkumar D. T.. The first draft of the manuscript was written by Sangeetha D. M. and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflicts of interest/Competing interests

The authors have read the Committee on Publication Ethics guidelines and agree to abide by provisions thereof. Availability of data and material: All the required data are generated by the authors using a software code written using MATLAB 7.0.

CRediT authorship contribution statement

R. Sridhar: Conceptualization, Methodology, Software, Writing – review & editing. **H.C. Guruprasad:** Supervision. **D.T. Naveenkumar:** Data curation, Writing – original draft, Visualization, Investigation. **D.M. Sangeetha:** Software, Validation.

Data availability

No data was used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Further reading

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