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Review Paper on Stabilization of Expansive Soil Sub Grade by Reinforcement with Natural Coir Fibre

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Abstract: *Expansive soil covers approximately 20% of land area of Indian subcontinent. These are also called as black soil or Regur. These are formed by the weathering action on parent igneous rock which results in the formation of clay and its recrystallization changing the behaviour of rock from which it is derived. These soils have property of swelling and shrinkage with the change in the moisture content of the soil. Hence pavement surface formed in such soil are unstable and there is possibility of crack formation development of pot holes uneven settlement in their design life. Because of such reason there is need to stabilise the soil by natural or chemical means in order to get a stabilised sub grade for transfer of anticipated wheel loads to the soil. This paper is a review of the stabilization techniques used for expansive soil, also this is summation of conclusions obtained from earlier experiments performed in related topic.*

Keywords: *Expansive soil, Coconut Coir Fibre (CCF), Soil Reinforcement*

I. INTRODUCTION

Expansive or swelling soils, as their name implies, are soils that swell when subjected to moisture. These swelling soils typically contain clay minerals that attract and absorb water. Covering about 15 to 20% of the total land area of the country these dark colour soils show a large change in volume with water content. The dark colour is due to the presence of the compound of iron and aluminium, accumulated humus and colloidal hydrated double ion and aluminium silicate. Prior to building the structure, a soil test of the site should be performed to ensure that the soils are stable and to determine the approximate effect that the soil will have on the structure. With the breakdown of igneous rock through the weathering action leads to the formation of clay, weathering allows re-crystallising the atoms of soil hence changing their behaviour than the parent rock, with the recrystallization Silica Tetrahedron sheet and Aluminium octahedral sheets are formed. It is only the mode of stacking of these sheets, the nature of bonding force and the different metallic ion in the crystal lattice that go to make different clay mineral.

Coir is a tough, mouldable, ordinary fiber available in tremendous amount (World: 0.78 million tons/year; India: 0.16 million tons/year) and is a boundless resource. Coir fiber is manufactured by de husking coconut and confining it from the material of the strong mesocarp by a technique called retting. Retting, may be passed on out at whatever point during the year either in freshwater or saline water, gushing water or stagnant water, significant waters or back waters. The husks are put either in the upstanding position in coir nets or in pits. It has been represented (CSIR 1960) that the retting is quicker in the pre-summer months anyway the shade of the fiber is dim hued. The strands gained from the husks retted in saline water are more grounded and have a predominant concealing (splendid yellow); in fibres got from husks set in new water, the retting is divided realizing same proportion of pith sticking to the fiber. Fibres got from retting in torpid water were seen to be weak. Husks drenched in the back waters and set upstanding in coir nets yielded better quality strands, both to the extent quality and shading for inspecting purposes.

Soil support methods can be categorised into two noteworthy classes:

- 1) In-situ soil reinforcement.
- 2) Built in soil reinforcement.

In the in situ reinforcement method the reinforcement is put in an undisturbed soil to frame a strengthened soil structure. This incorporates the method of soil nailing and soil dowelling. The fortification utilized for in situ structures is typically direct attributable to the technique for establishment.

The idea of soil nailing as metal bars, cylinders, or poles includes the situation of fortifying components in situ at appropriate separations to expand the shear quality of the dirt and to control its relocations during and after uncovering. Also, on account of soil securing, prestressed soil stays are introduced in the ground to fortify the dirt and bolster vertical or slanted unearthings.

In micropiling, little width (around 10–30 cm) heaps are introduced vertically, or in a reticulated way to help unearthings, inclines, and establishments, or to support or retrofitting structures. In all the fortification strategies referenced over, the pressure move between the dirt and the fortifying components, disappointment surface of the strengthening components, strain similarity between the dirt and the support, situation technique for the strengthening component, and the sturdiness and long haul conduct of the fortifying components are the significant variables that choose the viability of these techniques for different structures. In this section, the ground enhancements by utilizing various strategies for soil fortification systems are introduced.

II. LITERATURE REVIEW

- A. Rao et al. (2005) conducted the triaxial tests on sand reinforced with coir fibre. The aim of the experiment was to calculate the strength parameter. The percentage of coir varied was 0.5% and 1%. He concluded that longer fibres were stiffer than the shorter ones. The length of the fibre selected to study the stiffness of fibre was between 150-199 mm (type A1) and with fibre length less than 100 mm (type A2). For experimental work the length of fibre selected was 25mm. It was concluded that deviator stress at the time of failure increases with increase in the fibre content, at the lower value of confining pressures A2 type coir fibre shows higher value of deviator stress as compared to A1 type of fibre. At fibre content of 0.5% coir content A2 type shows higher strength than A1 type and at fibre content of 1% both A1 and A2 type shows near about similar strength when coir fibre was randomly distributed.
- B. Vasudevan and Babu (2008) conducted triaxial test for analysing the influence of coir fibre on strength and stiffness behaviour of soil at various fibre content and at different fibre lengths, diameter and different confining pressure, it was concluded that stress-strain behaviour inclusion of coir fibre has improved by the use of coir fibre thus increasing the value of deviator stress increased up to 3.5 times with percentage inclusion of fibre in soil, the deviator stress increment of soil increases with the diameter of fibre and the maximum value of fibre length being fibre in between 15-25 mm and was also observed that stiffness of soil has increased and immediate settlement was minimized by inclusion of coir fibre in the soil.
- C. Chauhan et al. (2008) studied the effect of inclusion of coir fibre with polypropylene fibre in the silty sand mixed with fly ash. The percentage of fly ash was mixed at 10%, 20%, 30% and 40% of the dry weight of the soil and it was found that the optimum value percentage inclusion of fly ash was 30%. Both the fibres at 0.5%, 1%, 1.5% and 2% by dry weight were used in the study. UCS values increased up to 0.75% making it as an optimum value. Optimum dose of polypropylene fibre optimum dose was found out to be 1% finding from the triaxial tests resulted that the coir fibre exhibit more improvement in shear strength (up to 47.5%) of soil than the synthetic fibre (up to 70%).
- D. Subaida et al. (2009) he reinforced the unpaved road with woven coir geotextile. It was concluded when geotextile was placed at mid- depth of base course there was significant increase in the value bearing capacity, further woven geotextile decreased the permanent vertical deformation when subjected to repeat loading by restraining the lateral spreading of base material. It was concluded that when coir geotextile was placed at sufficient height above the geotextile layer it mobilizes frictional resistance and help to decrease the damage caused to the geotextile due to traffic.
- E. Dasaka and Sumesh (2011) reinforced the soil with the coir fibre at various fibre content and found that unconfined compressive strength increases for fibre content of length and improves ductile behaviour of soil a well-defined failure surface could not be seen due to increased ductile behaviour also peak compressive strength increased at the fibre content of 1.5% and thereafter value compressive strength becomes constant. When triaxial tests were conducted in the Unconsolidated Untrained (UU) condition under the various confining pressure it was concluded that ductility increases with increase in the fibre content and also the cohesion and friction angle was increased at the optimum fibre content of 1.5%.
- F. Dutta et al. (2012) considered the impact of inclusion of coir fiber (15 mm long) in the unconfined compressive state of the soil. For treatment of dry fiber, sodium hydroxide and carbon tetrachloride were used. The sample for the unconfined compressive tests was set up with the fiber percentage inclusion of 0.4%, 0.8% and 1.6%. The axial stress increased from 63.98 kPa to 79.67 kPa was seen when clay was strengthened 0.4% dry fibre and with 1.6% inclusion of dry fibre strands increased up to 114.77 kPa. NaOH treated fiber the optimum value 0.4% axial stress of 81.47 kPa which on expanding the fiber substance to 1.6% raised to 130.03 kPa. Further, when the soil blend was fortified with 0.4% CCl₄ treated filaments, the pinnacle pressure was 70.69 kPa, which again reached to 245.78 kPa when the fiber substance was increased to 1.6%.

- G. Nithin and Sayida (2012) mixed silty sand with fly ash and reinforced it with randomly distributed coir fibre and analysed change in the bearing capacity of the soil. Changing the aspect ratio they varied content of fly ash from 5% to 20% and coir fibre was added in the range of 0.5% to 5%. The unconfined compression test suggested the optimum percentage of fly ash was at proportion of 15% and with 85% of silty sand this was further mixed with different percentage of coir fibre. It was seen that the strength increased up to an optimum value, with further increase in the content of fibre they came very close to each other that caused them to slip over one another and thus the value of strength goes on decreasing beyond that certain value of optimum strength decreasing the unconfined compressive strength. For the aspect ratio of 40 the optimum fibre content of coir came out to be 3%, for the aspect ratio of 80 it was 4% and was 2% for the aspect ratio of 120 and 160.
- H. Kirar et al. (2012) varied the percentage of coir fibre of diameter from 0.1 mm to 0.3 mm and conducted triaxial. It was observed from the study that fibre is more effective at higher shear strain where it increases the shear modulus significantly.
- I. Maliakal and Thiyyakkandi (2013), performed series of consolidated undrained tests were performed with varying fibre content to study the effect of randomly distributed coir fibre on the shear strength of clay having an aspect ratio of 50, 100 and 150 and fibre content of 0.5, 1 and 2%. Of all percentages of coir fibre maximum strength was obtained at the fibre content of 2% and new strength was 1.7 times as compared to unreinforced soil. Further the aspect ratio, the optimum aspect ratio was 150 at which the length of fibre was 36 mm.
- J. Sreekumar and Nair (2013) stabilized lateritic block with help of coir cutting waste as reinforcing material. The lateritic soil which shows high clay content was used in the study and was pre-stabilized with sand and cement, stabilizing with waste coir fibre it was tested for strength and durability. He also stabilized the soil with sand and cement, by preparing block with varying percentages of sand and cement and curing them for 28 days, optimum results were obtained when the sand was 25% and the cement used was 8%. The coir fibre content was varied in 0.5%, 1% and 1.50%. The block of soil-sand-cement-coir was made and tested for the optimum result in the laboratory. After conducting various, it was concluded that bulk density decreases on increasing the coir fibre as it was replaced with lighter coir fibre that resulted in the increase of the total volume of mix. The compressive strength, with coir waste of 0.50% improved upto 19% with respect to the reference block, but on further increasing fibre percentage it starts decreasing. In the case of tensile strength, the fibre content of 0.5% showed 9% increase which starts decreasing beyond the content of 0.5%. Water absorption by the coir fibre at 0.5% coir fibre combination showed comparatively low water absorption than other combination as per Indian standards.
- K. Chaple and Dhattrak (2013) studied effect on laboratory model test on square footing which were supported on compressible clayey soil reinforced with coir fibre which were randomly distributed in soil of coir fibre on bearing capacity and settlement of footing, the percentage selected for test were 0.25%, 0.50%, 0.75% and 1% of coir fibre. It increased the ultimate bearing capacity for reinforced soil with 0.50% coir for 100 mm, 50 mm and 25 mm depth the corresponding values were 425 kN/m², 495 kN/m² and 665 kN/m² respectively which were higher than unreinforced soil having a value of 250 kN/m². The bearing capacity increases only up to a fibre content of 0.50% and there after start decreasing with the further addition of coir fibre in it.
- L. Naveen and Yasaswi (2013) he used a set of natural fibre based polyester composite which consists of coir as a reinforcement and epoxy resin. He developed coir composites and evaluated mechanical properties at varying fraction and length of coir fibre. From the experiments performed it was found that mechanical properties depend upon the volume of fibres in composite and 5% coir fibre showed significant strength than higher fibre content.
- M. Singh and Mittal (2014) investigated the clayey soil with varying the percentages of coir fibre as 0.25%, 0.50%, 0.75% and 1% by weight. A series of unconfined compression test (UCS) and California bearing ratio (CBR) test were conducted in his study. From the study, it was found that there is considerable improvement in compressive strength of the soil reinforced with the coir fibre. Soil with no reinforcement had an unconfined strength of 2.75 kg/cm² which then on adding of fibre increased to a value of 6.33 kg/cm² for coir content of 1% by weight of soil, this increase in value could be because of increase in the shear parameters, it was found difficult to prepare the identical sample beyond 1% of fibre content so, only up to 1% of coir fibre was used in his study. From the CBR tests also it can be stated that the value for both the unsoaked as well as the soaked test has considerably increased on increasing the fibre content in the soil sample, it was noted that the soaked value of CBR has improved to a value of 9.22% from that of 4.75% when 1% coir fibre was included in the soil and also for the unsoaked condition the value has increased from 8.22% to 13.55%. It could be concluded from his study that coir fibre can be utilized successfully in sub base for flexible pavement and also for the rigid pavement.
- N. Kar et al. (2014) to conduct direct shear test with unreinforced and reinforced soil with different values of normal stresses coir fibre of length of 15 mm, 20 mm and 25 mm with the aspect ratio (length\ diameter) being 75, 100 and 125 respectively. The fibre content here was varied from 0.2% to 1.0% at an increment of 0.2%, also the CBR test was also conducted in the same

aspect ratio but the fibre content was varied from 0.2 to 1.6% with the increment of the 0.2%. From the direct shear tests it can be inferred that with increase in normal stresses, peak and residual strength of the reinforced soil increases and this increase was seen up to 0.8% coir content, if the fibre content was increased beyond 0.8%, the value of both peak and residual strength start decreasing irrespective of aspect ratio. The maximum increase in the peak and residual strength was found at 20 mm fibre length. From the CBR tests it was found that up to the fibre content of 1.4% the CBR value increases for all the aspect ratio, and after the fibre content of 1.4% the CBR value starts decreasing, the cause for decrease in the CBR values beyond this fibre content could be because that at higher fibre content the bond between fibre and soil could not be developed properly which causes balling effect and also lead to poor mixing.

- O. Kumar and Vikranth (2014) to contemplate the impact of incorporation of coir fiber for improvement in quality of soil with various rates of coir fiber and fly ash remains they conducted a series of unconfined pressure test (UCS) and California bearing proportion (CBR) test. Fly cinder at 0%, 5%, 10%, 15% and 20% with coir fiber in 0% 0.25%, 0.50%, 0.75% and 1% was utilized in study. From the investigation of CBR tests led by him, one might say that there is an enormous measure of progress of solidarity when coir fiber alongside fly fiery debris is blended in the dirt. The greatest worth was found at fly slag substance of 20% and coir fiber substance of 1%. The expansion in CBR worth was observed to be 285% more than that of unreinforced soil. It was additionally observed that with just fly fiery debris content in the dirt the CBR worth increases about 83%. In the UCS examination likewise colossal measure of progress in quality was seen, again the mix of 20% fly powder and 1% coir fiber was observed to be the ideal, by this mix the measure of increment in the quality of fortified soil when contrasted with unreinforced soil was about 120% and with just fly slag at 20% the UCS worth increments by 66%.
- P. Ramasubbaroa (2014) studied the strength of soil that was reinforced with the incorporation of coir fibre which were covered with kerosene oil and were arbitrarily distributed. The coir strands utilized was in the changed as 0%, 0.5%, 1% and 1.5% by dry load of soil. Water ingestion tests were completed on treated and basic coir fiber which were absorbed water for 1, 2 and 3 days. Different tests completed were compaction test, unconfined pressure test and rigidity test. So as to decide the water adsorption limit of coir fiber, uncoated coir weighing about 10g were inundated in water for 1 day and weight was looked at which came to be 63.7g, bringing about water adsorption of about 537%, if same coir fiber treated with lamp fuel was utilized water assimilation limit was diminished to 364%. Correspondingly, tests were accomplished for 2 and 3 days and it was discovered that 2 days inundation of coir fiber in lamp oil is adequate which decreased water ingestion limit from 537 to 223%. From the compaction tests directed, it was seen that most extreme dry thickness diminishes and OMC increments by the expansion of fiber from 0 to 1.5% because of the supplanting of lighter fiber with the overwhelming soil. By the consequences of UCS tests, we came to realize that dirt strengthened with 1% coir fiber gives the most extreme estimation of UCS and this quality worth abatements with increment in fiber content because of the predominance of fiber to fiber collaboration instead of soil fiber. Rigidity was resolved from part test and it was considered that elasticity was expanded from 64 kPa to 96 kPa expanding by half when soil was strengthened with treated coir fiber at 1% fiber substance.
- Q. Anggraini et al. (2015) studied the effects of coir fibre inclusion on the strength of soft marine clay. The strength assessed were flexural and tensile strength . The selected range of percentage variation of coir fibre was from 0.5% to 1% .It was found that the optimum dosage of coir fibre was 1% that increased the strength of the fibre upto 2.5 times as compared to the unreinforced soil . The tensile strength of reinforced soil was found at 1.5% coir fibre percentage, after which increase in fibre content interlocking and friction mobility of the samples gets reduced.
- R. Soundara and Senthil (2015) compared the inclusion of coir fibre and polypropylene fibre in the clay soil. The fibres were varied as 0.5%, 1% and 1.5% for strength determination.
- S. Abhijith (2015) contemplated the impact of coir fiber to decide CBR value of soil, coir fiber with fluctuating length from 0.5 to 3 cm and with the distinctive rate from 2 to 8% of the weight of the soil was taken for the test. It led to improve CBR quality, to decide the ideal fiber substance and furthermore to find the ideal position of geotextile in the soil subgrade. After the tests, results summarised that the ideal fiber content is 5% of all out weight of the soil with the ideal fiber length of 1.5 cm, perfect position of coir geotextile in the subgrade was observed to be at the highest point of subgrade and end was produced using the examination that geotextile increases the quality of the asphalt.
- T. John and Patel (2015) included coir fiber (of 20 mm, 40 mm and 60 mm long) and coir pith with fly ash and portland cement to improve the performance and stability of swelling soil. For experimentation percentage coir fiber consideration were 0.5, 1, 2, 3 and 4% as for weight of soil ,coir fiber was arbitrarily circulated in the soil . The result of the experimentation revealed that , coir substance is less efficient in reinforcing than the, ideal portion of coir fiber and coir essence to improve CBR and UCS worth was 3% and 2% and 2% and 1.5% separately.

- U. Jayasree et al. (2015) used coir pith and trimmed coir fibres to study the change in the behaviour of soil. For the experimental study, six different percentages of coir pith ranging from 0.5 to 3% were used and short fibre ranged from 0.2 to 1%. After conducting various tests, it was found that swell index reduced by 95% and 92% by adding coir pith and coir fibre respectively also the compression index was reduced by 68 and 94% respectively. It was also seen that the rate of consolidation gets accelerated by the use of coir waste, it was reported that 2% coir pith and 0.6% of coir fibre is best and use of coir waste as reinforcing material to avoid the volume changes in case of expansive soil was recommended.
- V. Yadav and Tiwari (2016) they mixed cement content and coir fibre with clay pond and ash combination. As the water was absorbed by coir fibre, the maximum dry unit weight decreased and OMC increased. The unconfined strength of clay pond mixture at 1% coir fibre, stabilized with 2% cement was 2.55 times more than original and at cement content of 4% and 1% coir fibre the value comes out to be 4.84 times more. The addition of fibre suppresses the crack remarkably. There was a reduction in strength after 1% coir fibre inclusion.
- W. Anggraini et al. (2016) they used Nano-modified coir fibre with ferric hydroxide and aluminium hydroxide to study the shear strength of marine clay treated with lime. Mixing of soil with 1% of modified and unmodified coir fibres was done manually and 5% of lime was added. It was observed that coir fibre increased the tensile strength by 33% and 66% in fibres when they were treated with ferric hydroxide and aluminium hydroxide respectively.
- X. Ayininuola and Oladotun (2016) investigated changes in properties of soil with the inclusion of Coir with the percentages varying from 0.1 to 1.5%. Cohesion values of soil samples increased up to the fibre content of 1.2% and after this fibre content it starts decreasing and the angle of internal friction also increased up to the same fibre content, for the CBR tests on all three soil samples the strength increased up to 1.2% of coir fibre after this value it starts decreasing so making 1.2% of coir fibre as the optimum dose to be mixed in soil.

III. CONCLUSION

From review of above paper we can conclude the following points:

- A. It was found that longer fibres are stiffer. It was concluded that deviator stress increases at the time of failure with increasing fibre content even the lower value of confining pressure.
- B. Concluded that the use of coir fibre improve stress-strain behaviour and increase the deviator stress up to 3.5 times. The deviator stress augmentation of soil increases with the diameter of fibre and the maximum value of fibre length being fibre in between 15-25 mm and was also observed that stiffness of soil increased and immediate settlement was minimized by inclusion of coir fibre in the soil.
- C. Optimum value percentage inclusion of fly ash was found 30% when fibres at 0.5%, 1%, 1.5% and 2% by dry weight were used. UCS values increased up to 0.75%. Optimum dose of polypropylene fibre was found out to be 1%
- D. When coir geotextile was placed at sufficient height above the geotextile layer it mobilizes frictional resistance and help to decrease the damage caused to the geotextile due to traffic.
- E. When triaxial tests were conducted in the Unconsolidated Undrained (UU) condition under the various confining pressure it was concluded that ductility increases with increase in the fibre content and also the cohesion and friction angle was increased at the optimum fibre content of 1.5%.
- F. The unconfined compression test suggested the optimum percentage of fly ash was at proportion of 15% and with 85% of silty sand which was further mixed with different percentage of coir fibre. It was observed that the strength increased up to an optimum value, with increase in fibre content then they came very close to each other which caused them to slip over each another and thus decreasing the value of strength.
- G. It was observed from the study that fibre is more effective at higher shear strain where it increases the shear modulus significantly.
- H. It was concluded that bulk density decreases on increasing the coir fibre as it was replaced with lighter coir fibre that resulted in the increase of the total volume of mix.
- I. The compressive strength, with coir waste improved up to a limit with respect to the reference block, but further increase in fibre percentage caused decline. As for tensile strength, the fibre content of 0.5% reported 9% increase which starts decreasing beyond the content of 0.5
- J. It was found that mechanical properties depend upon the volume of fibres in composite and 5% coir fibre showed significant strength than higher fibre content.

- K. it was found that compressive strength improves for the soil reinforced with the coir fibre. it was found difficult to prepare the identical sample beyond 1% of fibre From the CBR tests also it can be stated that the value for both the unsoaked as well as the soaked test has considerably increased on increasing the fibre content in the soil sample, it was noted that the soaked value of CBR improved to a value of 9.22% from that of 4.75% when 1% coir fibre was included in the soil and also for the unsoaked condition the value has increased from 8.22% to 13.55%. It could be concluded that coir fibre can be utilized successfully in sub base for flexible pavement and also for the rigid pavement.
- L. There is an enormous measure of progress of solidarity when coir fiber alongside fly fiery debris is blended in the dirt. The greatest worth was found at fly slag substance of 20% and coir fiber substance of 1%. The expansion in CBR worth was observed to be 285% more than that of unreinforced soil. It was additionally observed that with just fly fiery debris content in the dirt the CBR worth increases about 83%.In the UCS examination likewise colossal measure of progress in quality was seen, again the mix of 20% fly powder and 1% coir fiber was observed to be the ideal, by this mix the measure of increment in the quality of fortified soil when contrasted with unreinforced soil was about 120% and with just fly slag at 20% the UCS worth increments by 66%.

IV. FUTURE SCOPE

In the studied literature only coir fibre has been used and tested for its effects on various properties of soil, other natural materials too can be tested and examined in varying amounts and different blends so that the effect of different natural materials on varying properties of soil can be understood.

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