Effect of Rice Husk and Nylon Fibre on the CBR and UCS of clayey soil

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Abstract - Soil stabilization is done to improve its engineering performance such as shear strength, compressibility and permeability. Soil stabilization may be physical, chemical, biological or combined methods to meet an engineering purpose. Soft clay is a problematic soil from civil engineering construction point of view. To make them more feasible to construction purposes, numerous materials have been used. In this paper stabilization of clayey soil using Nylon fiber and Rice Husk ash was evaluated. Experiments were conducted on soil treated with Rice Husk ash only and soil treated with both Rice Husk ash and Nylon fiber. The methodology used was first to find out the optimum Rice Husk ash that can be utilized in untreated soil. Further various percentage of Nylon fiber (0.5 and 1.5) was added at various Rice Husk ash percentages (20, 25, and 30) and the optimum was found out. The optimum percentage was obtained from standard proctor test, and the strength was obtained from unconfined compressive strength test and California bearing ratio test. The optimum percentage of Nylon fiber and Rice Husk ash was obtained as 1.5 and 25% by weight of soil, respectively. Result of optimum percentage on unconfined compressive strength, California bearing ratio test and plasticity characteristics of treated soil were determined over a curing period of 1 day and 7 days. The strength of soil stabilized with Nylon fiber and Rice Husk ash was found to be improved, and the strength of treated soil was more in the case of combination of Rice Husk ash and Nylon fiber.

***Key Words*:** Rice Husk, Nylon Fibre, CBR test, UCS test

1. INTRODUCTION

Expansive soils are the soils which have high shrinkage and swelling characteristics and lower strength when it came in contact with water. These soils are very sensitive to variations in water content and show excessive volume changes and has high compressibility. This highly plastic soil may create cracks and damage the construction work done above these type of soils.

In India, expansive soil covers nearly about 20% of the land and includes approximately the entire Deccan Plateau. They are mostly black and reddish brown in colour and are generally found with layer thickness between 0.5 m to 10 m below the surface. Because the expansive soil is prone to volume changes when it came in contact with the water by rain or water table capillary action, it will get expand and may cause lifting of the structures built over it. So, these soils are not suitable for construction works until they are properly stabilized which can increase the low bearing capacity of expansive soils.

In India, nearly 46% of total land is covered by Alluvial soil which is the most important soil type of or country. Other soils such as Black cotton soil, desert soil, laterite soil and marine soil are also the important soil groups of India. The Alluvial soil and the black cotton soil mainly consists of clay which is very fine soil and it's the main constituent of expansive soils and due to the cohesive nature of clay, these soils absorb large amounts of water and show swelling characteristics which create problems such as bulging of soil, low bearing strength of soil, and can cause cracks in the foundation.

Literature Review

Chandrakaran et al. (2021) Experiments were conducted on soil treated with fly ash only and soil treated with both fly ash and nylon fiber. The methodology used was first to find out the optimum fly ash that can be utilized in untreated soil. Further various percentage of nylon fiber (0.25 and 0.5) was added at various fly ash percentages (10, 20, 30 and 40) and the optimum was found out. The optimum percentage was obtained from standard proctor test, and the strength was obtained from unconfined compressive strength test. The optimum percentage of nylon fiber and fly ash was obtained as 0.25 and 20% by weight of soil, respectively. Result of optimum percentage on unconfined compressive strength and plasticity characteristics of treated soil were determined over a curing period of 1 day, 7 days and 28 days. The strength of soil stabilized with nylon fiber and fly ash was found to be improved, and the strength of treated soil was more in the case of combination of fly ash and nylon fiber.

Okonta et al. (2018) In this study, the synergic effects of pre-compression and fiber inclusions, on the mechanical behaviour of lime fly ash stabilised soil were investigated. Randomly distributed 25 mm sisal fibers were mixed with stabilised soil at the contents of 0%, 0.25%, 0.5%, 0.75% and 1% by dry mass of the soil. Both fiber composite and unreinforced soil specimens were subjected to the pre-compression stresses equivalent to 10% and 20% of the strength mobilised by the un-precompressed specimens. The pre-compression stresses were applied after 4 h, 8 h and 24 h of accelerated curing at 40 °C, after which the conditioned specimens were allowed to continue curing under constant conditions. The 7 day strength of the fully cured composites was determined by a series of unconfined compression tests. The results revealed that optimum strength of 3.5 MPa was mobilised by un-precompressed specimens at 0.75% fiber content. Pre-compression with 10% UCS showed maximum strength of 2.8 MPa at 0.25% fiber content whereas 20% UCS indicated optimum strength of 3.04 MPa at 0.25% fiber content.

Rokade et al. (2017) Addition of nylon fibre along with fly ash to measure the change in the strength parameters of black cotton soil. The CBR of the soil was determined by conducting three series of tests. Tests were carried out on the BC soil mixed with varying percentage of fly ash, from 10% to 40% out of which 20% came out to be cptimum. Then, nylon fibre with aspect ratios (length/ diameter) 20, 40, 60 and 80 and fiber contents were varied from 0.25% to 1.5% with 0.25% interval, out of which 0.75% of fibre content is considered as optimum on the basis of MDD and maximum CBR value.

Mahesh et al. (2016) Soil stabilization is used to reduce the permeability and compressibility of the soil mass in earth structures and to increase its shear strength. Soil stabilization is required to increase the bearing capacity of foundation soils. However, the main use of stabilization is to improve the natural soils for the construction of highways and airfields. CBR value is high at 10% lime + 1.5% fiber when compared to the remaining proportions. CBR value for (soil +10% lime) and (soil + 40% lime) is same. CBR gradually increases with increase in fibers upto 2% (soil + 5% lime).

Wang et al. (2016) The Unconfined Compression Strength of expansive soil is very less without the addition of certain additives which can increase their strength. CKD was chosen to add in various proportions. 2,4,6,8,10,12,14,16,18,20% of CKD was the proposed quantity. The UCS value rises till 10% CKD content after that when CKD quantity is further increased, the value of UCS started to decline gradually. Which concluded that 10% is the optimum value of CKD at the curing period of 28 days.

Tiwari et al. (2016) They studied the stabilization of black cotton soil using fly ash and nylon fibre. In their study, they used different combinations of fly ash as 10%, 20%, 30% & 40%. 20% was their optimum value. After which they calculated the optimum value of nylon fibre from various values as0.25%, 0.50%, 0.75%, 1%, 1.5%. From which 0.75% nylon fibre comes to be the optimum. The CBR value of soil+20% fly ash+0.75% fibre was maximum of all other readings. And the MDD was also maximum of this mix proportion.

Phanikumara et al. (2013) This paper presents the swell-consolidation characteristics of remoulded expansive clay specimens reinforced with randomly distributed nylon fibre.In the case of nylon fibre, the length of the fibre (l) was varied at 15 mm and 20 mm. As the diameter of the fibres was 1mm, the aspect ratio of the fibres used was equal to 15 and 20, respectively. The fibre content (fc) used in the testing programme was varied at 0%, 0.05%, 0.1%, 0.15%, 0.2%, 0.25% and 0.3% by the dry weight of the soil. Their result shows that the swell potential (S%) and the vertical swelling pressure also decreased with an increasing fibre content (fc) for a given fibre length. & thesecondary compression decreased with an increasing length of fibre. The value of the secondary consolidation coefficient (Cα) for fibre-reinforced specimens was less than that for the unreinforced specimen.

Ismaiel et al. (2013) This work dealt with a chemical stabilization of an expansive high plastic soil of using cement kiln dust (CKD) and cement kiln dust with lime (CaO) to reduce their swelling and improve their geotechnical properties. Various tests were conducted such as plasticity tests, compaction test, Unconfined Compressive strength test. According to the test results, optimum content of the cement kiln dust was 16% (CKD) & The optimum content of the cement kiln dust with the lime was 14% (CKD) with 3% (Cao).

Kameshwar Rao Tallapragada et al. (2009) their work is undertaken to research the benefits of fiber reinforced subgrade. They used two fibres: nylon fibre and monofilament. The main tests performed were CBR test & UCS test to check the strength. Three proportions were prepared as 0.75%, 1.5% & 2.25%. Their result shows CBR value of Black Cotton soil also increases considerably due to addition of the fibers in soil. From UCS test it was found that Maximum Stress value of soil increases with increasing aspect ratio of nylon fibre.

2. Materials and Methods

Section 2.1 **Rice Husk Ash and Nylon Fibre as stabilizer**

2.1.1 Rice Husk Ash

RHA that has amorphous silica content and large surface area can be produced by combustion of rice husk at controlled temperature . Suitable incinerator/furnace as well as grinding method is required for burning and grinding rice husk in order to obtain good quality ash. The rice husk, also called rice hull, is the coating on a seed or grain of rice. It is formed from hard materials, including silica and lignin, to protect the seed during the growing season. Each kg of milled white rice results in roughly 0.28 kg of rice husk as a by-product of rice production during milling.

2.1.2 Nylon Fibre

Nylon 6 is a polymer developed to reproduce the properties of nylon 66. It is a semi crystalline polyamide. Nylon 6 fibres are tough, possessing high tensile strength, as well as elasticity and lustre and has excellent abrasion resistance. Nylon 6 is generally white but can be dyed to in a solution bath prior to production for different color results.

Nylon fibre is used in soil stabilization to increase the load carrying capacity of soil by the frictional interaction between the soil and the reinforcement and it should be randomly mixed with soil in proper proportions.

Nylon fibre has good elasticity behaviours and it is highly resistant to abrasion and temperature so it can be used in high temperatures also. The aspect ratio of nylon fibre ie. L/D ratio of fibre is the deciding factor for the size that is to be used.

Section 2.2 Methods

The present project can serve as an effective method to uticlize industrial wastes Rice Husk Ash and Nylon Fibre in the construction of low cost rural roads and stabilize the subgrade of pavements where the soil is expansive in nature. These various tests needs to be carried out on samples selected for study:

1.Liquid Limit test and plastic limit test needed to be performed with the help of Cassegrande's Apparatus first on virgin soil and then the various proportions of the mix. The Plasticity Index of the Optimum Mix should be always less than that of virgin soil.

2.Standard Proctor Test is carried out to calculate Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of virgin soil which is then compared to MDD of mix proportions. The MDD of the optimum mix should always be higher than pure soil.

3.California bearing ratio test is conducted to calculate CBR Values at different proportions with material.

4.Unconfined compression strength test is conducted to calculate UCS Values at different proportions with material.

Table -1: Properties of soil used

S.No.	Properties	Result
1.	Liquid limit (%)	48
2.	Plastic limit (%)	26
3.	Plasticity Index (%)	22
4.	Specific Gravity	2.69
5.	Maximum Dry Density (KN/m³)	18.25
6.	Optimum Moisture Content (%)	13.6
7.	Soil Classification	CI
8.	CBR (%)	3.82
9.	UCS (kN/m²)	240

Table -2: Properties of Rice Husk used

S.No	Compound	Value (%)
1	Sio2	87.20
2	Al2O3	0.15
3	Fe2O3	0.16
4	CaO	0.87
5	MgO	0.25
6	So3	0.24
7	K2o	2.94

Table -3: Properties of Nylon fibre used

S.No.	Property	Value
1.	Density	1.14gm/cc
2.	Melting point	215℃
3.	Length(L)	20mm
4.	Specific gravity	0.90
5.	Diameter(D)	0.50mm
6.	Aspect ratio(L/D)	40

Results and Discussion

The soil used in this project was collected from local soil deposits in Jammu. Then the soil is prepared by doing sieveing with 4.75mm sieve, the quantity retaining on 4.75 mm sieve is taken out of the sample soil and the soil passing 4.75mm sieve is over dried with a temperature of 105°C for 24 hours. All the lumps if present in the soil were cleared with hammer.

Tests conducted in the laboratory for different objectives are as follows:

1. Liquid Limit Test (Casagrande's method)
2. Plastic Limite test (Thread method)
3. Standard Proctor test (OMC and MDD)
4. California Bearing Ratio test
5. Unconfined Compression strength test

MIX PROPORTIONS USED

Different proportions of different materials were used in the project work. Rice Husk Ash was 20%,25% & 30% and Nylon fibre used was 1.0%, 1.5%, & 2.0%.

Now, S=Soil, RHA= Rusk Husk Ash, N=Nylon fibre

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EXPERIMENTAL RESULTS

Section 1 Standard Proctor Test

Table no. 4: Results of OMC and MDD for mix proportions of Soil, RHA and Nylon Fibre

SOIL:RHA:NYLON FIBRE	MDD (kN/m³)	OMC (%)
100:0:0	18.25	13.6
74.5:25:0.5	18.10	14.70
74.0:25:1.0	17.65	15.45
73.5:25:1.5	17.27	16.10

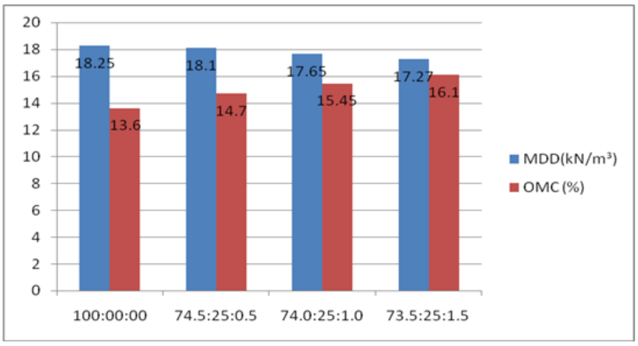

Fig:-1 variations b/w MDD and OMC of RHA, Nylon Fibre & soil with different proportions

Section 2 Unconfined Compression Strength Test

Table no. 5: Results of UCS of Rice Husk Ash and Nylon Fibre Mix with Soil

Clayey Soil :R.H.A: N.F	Curing Period (Days)	UCS (kN/m^2)
100 : 00	7	240.05
74.5:25:0.5	7	285.9
74:25:1.0	7	305.6
73.5:25:1.5	7	323.5

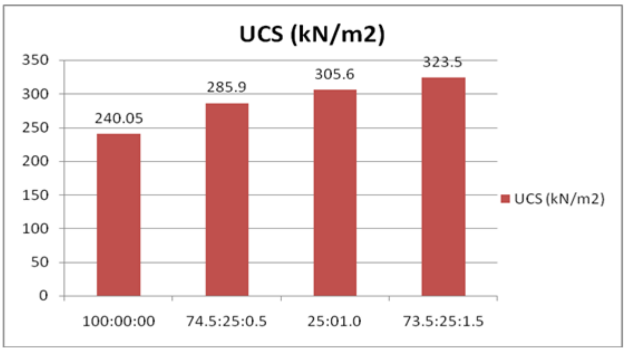

Fig:-2 . UCS Value of Clayey soil of Rice Husk Ash and Nylon Fibre

Section 3 California Bearing Ratio Test

Table no. 6: Results of CBR of Rice Husk Ash and Nylon Fibre Mix with Soil

CS: Cement Kiln Dust: R.F	CBR (%)
100:00:00	3.82
74.5:25:0.5	5.12
74:25:1.0	5.67
73.5:25:1.5	6.10

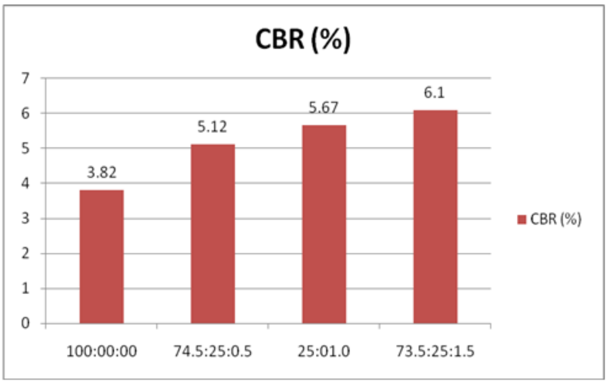

Fig:-3 CBR Percentages of Clayey soil, Rice Husk Ash and Nylon Fibre

DISCUSSIONS

MODIFIED PROCTOR TEST:

There is an also increase of OMC from 14.7 to 16.10% and decrease of MDD from 18.10 to 17.27% when the percentages of Nylon Fibre vary from 1.0%, 1.5% and 2.0% and Rice Husk ash is fixed at 25%.

Specific gravity of Rice Husk Ash is lower than as compared to soil. So MDD is decreased and OMC is increased.
There is an expansion in OMC when the amount of Rice husk ash is expanded. The purpose for of this pozzolanic response of Rice husk powder with soil that needs more water for completion of cation trade response.

With Rice Husk ash kept constant at 25% MDD decreases with an addition of Nylon Fibre content in soil and Rice husk Ash mix. The reason behind of such behavior is Rice Husk Ash is lighter in weight and it has high water absorption properties because of presence of calcium oxide and hence OMC increases with increase of Rice Husk Ash content.

CBR TEST:

Presence of pozzolanic compounds in Rice Husk Ash and CaOH available in soil might be increase the CBR value due to formation of cementitious compounds in soil. Due to excess of Rice Husk Ash in soil ultimately occupies spaces within sample because of this Rice

Husk ash could not be mobilized for the reaction at 25% of Rice Husk ash in soil.

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The CBR value of virgin soil is 3.82 and it increase to 1.59 times when Rice Husk ash 25% and Nylon Fibre 1.5% is added to virgin soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.

UCS TEST:

The expansion in U.C.S. value might be a direct result of the slow advancement of the cementitious mixes in the soil by the response between pozzolanic mixes in Rice Husk ash and CaOH accessible in soil.

The UCS values of virgin soil also improves considerably with expansion of Rice Husk ash 25% and Nylon Fibre 15%. The value increases from 240.05 kN/m² to 323.5 kN/m² with addition of Rice Husk ash and Nylon Fibre.

The reason behind of this when Rice Husk ash and Nylon Fibre comes in contact with
water, pozzolanic reactions takes place during the curing period.

Conclusions

Following conclusions can be inferred on the basis of the experiments performed:

1. From this study it is concluded that Rice Husk Ash is waste product from industries that can be used as stabilizers to clay soil and this would help to solve the conventional problem of disposal of them. .
2. The optimum value of Rice Husk Ash is used for this work was 25 % because of the optimum value of C.B.R. is found at 25% of Rice Husk Ash when added to soil.
3. The C.B.R value increases with increase of Nylon Fibre along with fixed quantity of Rice Husk Ash. It increased 1.59 times from the untreated soil.
4. The optimum value of Nylon Fibre and Rice Husk Ash ash required for soil stabilization is 1.5 % and 25 % by weight of soil respectively.
5. Unconfined compressive strength increases with increase of quantity of Nylon Fibre and with fixed quantity of Rice Husk Ash. The value of Unconfined compressive strength is increased 1.34 times from the untreated soil.

Addition of Rice Husk Ash and Nylon Fibre stabilizer makes the soil mixes durable, low cost and effective for soil improvement. If these two materials are easily available near to the site.

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