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CHARACTERIZATION OF CLAY SOIL REINFORCED WITH HUMAN HAIR FOR PAVEMENT DESIGN

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ABSTRACT

Various techniques are in use to enhance the shear strength parameter of weak soil subgrade for the pavement design. Many of those soil reinforcement techniques use different types of fiber. Human Hair Fiber (HHF) has been used in this work to enhance the shear strength and bearing capacity of weak soil subgrade for pavement construction. Using HHF would also mean sustainable use of waste material. Human hair fiber is a natural biodegradable waste material. However, due to slow degradation it creates health and environmental problems, which instead can be disposed properly in soil subgrade for the pavement construction to increase the soil subgrade properties. Therefore, this study deals with the experimental characterization of clay soil reinforced with HHF. CBR and Triaxial shear tests were performed on these homogeneous, fiber-reinforced clay samples with different percentage of human hair fiber. The results are compared with those of unreinforced clay soil and also with those of previous works.

Keywords: CBR, Human hair fiber, MDD, OMC

I. INTRODUCTION

Admixtures and geogrids are frequently used in practice to stabilize soils and to improve their load carrying capacity. The performance of pavements depends upon the quality of subgrade and subbases. A stable subgrade and properly draining subbase help produce a long-lasting pavement. A high level of spatial uniformity of a subgrade and subbase in terms of key engineering parameters such as shear strength, stiffness, volumetric stability, and permeability is vital for the effective performance of the pavement system. Furthermore, there has been a significant amount of research on stabilization/treatment techniques, including the use of recycled materials, geotextiles, and polymer grids for the design and construction of uniform and stable subgrade and subbase.

In pavement construction the subgrade soil often lack the required bearing capacity. In that condition property of the soil subgrade such as strength and CBR value is to be improved. For that purpose, reinforcement of soil or stabilization of soil can be done using different kind of fibres like steel, glass, synthetic and natural material. Among these human hair fibres (HHF) have been used as a natural fibre to improve the strength and CBR value of weak soil subgrade for the construction of pavement. As human hair is available at very low cost and it has been used easily for reinforcing material that increases the soil properties and also reduces the disposal problem.

Recently soil reinforcement studies were carried out on the stabilization of soft clay using various additives such as lime, cement, synthetic and natural fibres. Wajid Ali Butt, Karan Gupta, Showkat Maqbool Bhat (2014) have investigated on soil subgrade improvement using HHF of various proportion (0, 0.5, 1.0, 1.5, 2, 2.5) in percentage by the weight of soil sample with air dried sample and found that 0.25% of fiber, MDD increases and OMC decreases and finally CBR value increases upto 2% of fiber [1]. Rohin Kaushik (2014) et.al have done the research on " Innovation Technique Improving the CBR value of soil using Human Hair Fiber ", and observed that there was an increase in bearing capacity of soil and hence decrease in the undesirable settlement [2]. A study on bearing capacity of randomly distributed Fiber-reinforced sand fills overlying soft clay was done by Temel Yetimoglu et al. (2004) [3]. Plate load test on Fiber-reinforced soil was studied by C. Consoli et. al. (2003) and the plate load test result showed that the addition of polypropylene fibers significantly improved the behaviour of soil [4]. Mechanical behaviour of a clay soil reinforced with Nylon fibers was studied by A. R. Estabragh et. al. (2011) and he showed that the reinforcement using fibers was found to restrain the volumetric dilation of soil and this leads to increase of excess pore water pressure in undrained conditions and increase in effective shear strength of soil with pressure of fibers [5]. Model for analysis of fiber-reinforcement clayey soil was studied by G.L Babu and Chouskey (2010) and he found that reinforcing the soil with fibers improves the stress-strain response of clayey soils [6]. Strength behaviour of clayey soil reinforced with Human Hair Fiber as a natural fiber was studies by Butt and Jha (2015) and test results revealed that the strength significantly improves with the inclusion of HHF and also prevents the sample from cracking [7]. Study on strength influence mechanism of Fiber-Reinforced expansive soil using Jute was done by Wang Yixian et al. (2016) and it was observed that the cohesion of reinforced specimens increased with increasing of fiber content until fiber content reached a special value after which the cohesion decreased. Fiber content has no particular influence on internal friction of expansive soil [8]. K. Shankar Narayanan and S. Mary Rebekah Sharmila have stabilized the clay soil by doing CBR and UCC test and found the California Bearing Ratio (CBR) of virgin soil sample is 5.41%. With the addition of 1.2% of HHF the CBR value increases to 8.83% .strength of the soil creases to around 56.6% when compared to virgin soil sample. The strength characteristics UCS of virgin soil sample were 125 KN/m2 with addition of 1.2% of HHF the UCS value increased to 209.2 kN/m2. It decreases when adding above 1.2 percentage of HHF [9]. Prakash Patil and Harini H.N has Improved the Subgrade Strength of Soft Soil Using Human Hair Fibers as Reinforcement and found the CBR value at OMC for un-reinforced soil was 2.89% which is increased to 4.82% by the addition of 0.1% of HHF leading to 66.78% increase in strength in soaked condition and from UCS test at OMC, for un-reinforced soil the compressive strength found was 0.35 kg/cm2 which is then increased to 0.59 kg/cm2 showing an increase in strength of 71.3% with addition of 0.1% of HHF [10]. Renju R pillai and Ayothiraman Ramanathan used fiber content on Kaolinite clay with addition of 2.0% fibers by weight and found the unconfined compressive strength increases up to 2 times that of unreinforced soil [11].

The objective of this research is to understand and investigate the variation of strength of clay soil mixed with human hair fibres (HHF). CBR and tri-axial tests were carried out to determine the optimum HHF percentage in

clay soil which gives maximum bearing capacity and shear strength. The CBR test results were used to obtain the reduction in road pavement volume when HHF reinforced clay soil subgrade instead of virgin soil.

1.3 REINFORCED SOIL

The standard fiber-reinforced soil can be defined as soil mass consisting of fiber which enhance in the behaviour of soil composite.

II. EXPERIMENTAL INVESTIGATION

2.1 MATERIAL USED

2.1.1 SOIL

In the present study soil is clayey in nature and having dark brown colour. The soil was collected from Hooghly River in Kolkata region. To investigate the engineering properties of the collected soil laboratory tests have been carried out according to IS methods of testing. Specific Gravity as per IS: 2720 (part 4) – 1985, Particle Size Distribution By Sieving (Grain Size Analysis) as per IS : 2720 (part 4) – 1985, Liquid Limit And Plastic Limit Of Fine Soil By Using Casagrande Apparatus as per IS : 2720(part 5)-1985, Shrinkage Limit of the Soil by IS: 2720(part 6)-1972, maximum dry density and optimum moisture content by standard proctor compaction method as per is 2720-7(1980), unconfined compressive strength as per 2720-10 (1991), Laboratory Determination of California Bearing Ratio (CBR) as per IS : 2720 (Part 16) – 1987.

2.1.2 HUMAN HAIR FIBRES

Human hair is a protein filament (long chain of protein). Its function is to prevent heat loss from person's head. These fibres are solid waste which creates environmental problems due to being non biodegradable in nature. CBR and triaxial test were carried out at different percentage of human hair fibres (0%, 0.5%, 1.0%., 1.5%) by weight of clayey soil and corresponding to the obtained CBR value of reinforced soil with HHF, the thickness of pavement is obtained for the pavement design described in guidelines for the design of flexible pavement (IRC:37-1984).

2.2 RESULT AND ANALYSIS

TABLE-1: Properties of Clay

Properties	Experimental value tested in Soil Mechanics laboratory
Specific gravity	2.66
Plastic limit	22.4 %
Liquid limit	47.7 %
Plasticity index	25.53%

Maximum dry density	1.73 (gm/cc)
Optimum moisture content	23.82%
CBR at OMC	4.92%
Clay content	62.50%
Silt content	33.90%
Sand content	3.60%

TABLE-2: Optimum moisture content (OMC) and maximum dry density (MDD) with varrying percentage of HHF by weight of clayey soil

Human hair fiber % (w/w)	Optimum moisture content % (w/w)	Maximum dry density (gm/cc)
0.0	23.82	1.73
0.5	22.15	1.6217
1.0	21.93	1.6041
1.5	23.17	1.5759

5

TABLE-3: CBR test Results in soaked condition with varrying percentage of HHF by weight of clayey soil

Human hair fiber % (w/w)	CBR Value in %	Thickness of pavement(mm) described in IRC:37-1984
0.0	4.92	484
0.5	6.63	394
1.0	7.70	359
1.5	7.25	372

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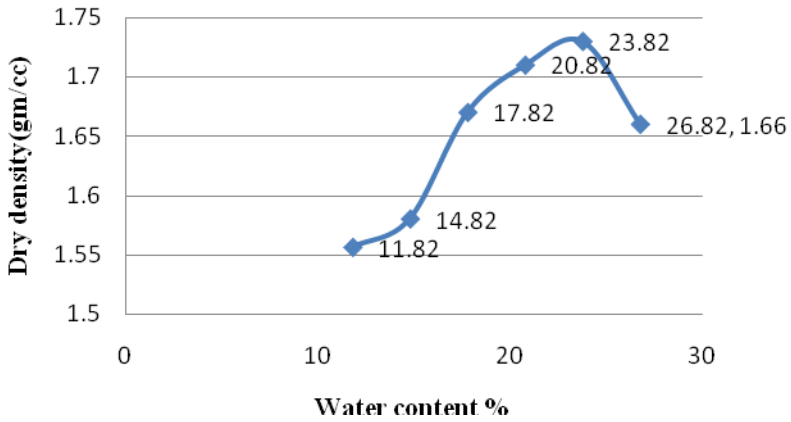

Fig: 1 Plot of moisture content versus dry density in unreinforced soil

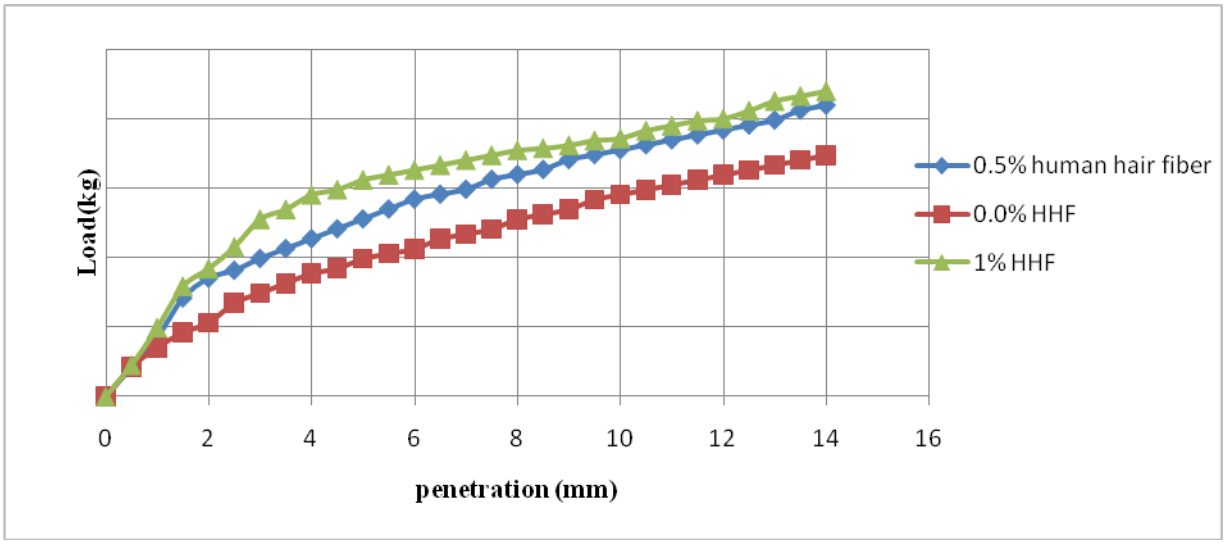

Fig-2: Load penetration curve with different percentage of fiber content

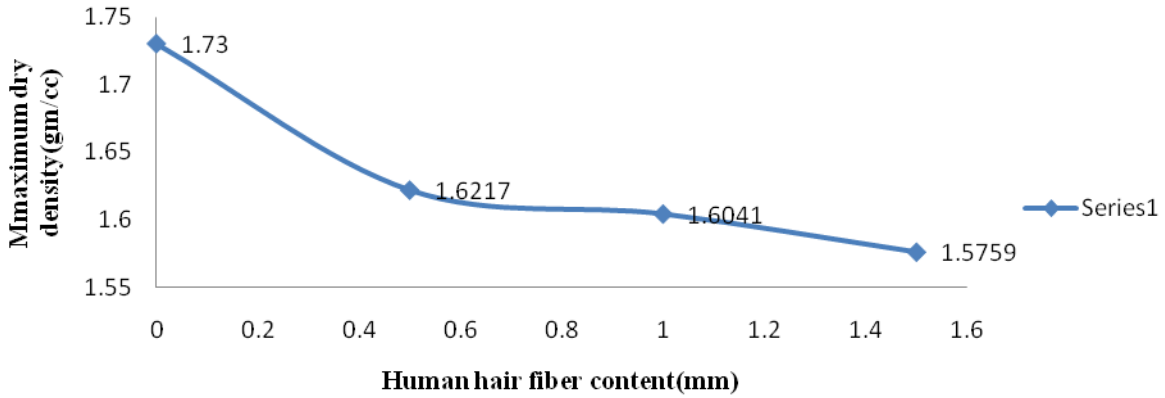

Fig-3: Showing variation of maximum dry density with fiber content

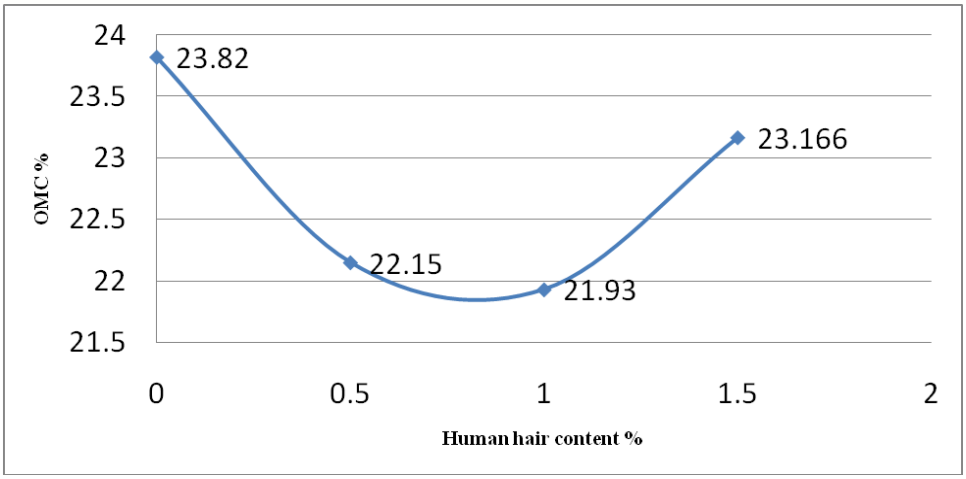

Fig 4: Variation of OMC v/s human hair content in the clay soil

TABLE:-4 Comparison of CBR test results with previous work

Data source(Author)	Max CBR (%)	CBR value of virgin soil (%)	(%)Hair at max CBR	% gain in CBR value
K. Shankar Narayanan et al.(2017) [9]	8.82	5.41	1.2	56.6
Prakash Patil et al.(2016) [10]	4.82	2.89	0.1	66.78
Wajid Ali Butt et al. (2014) [1]	17.21	13.26	2	29.78
This study	7.7	4.92	1	56.5

2.3 PAVEMENT COST ESTIMATION

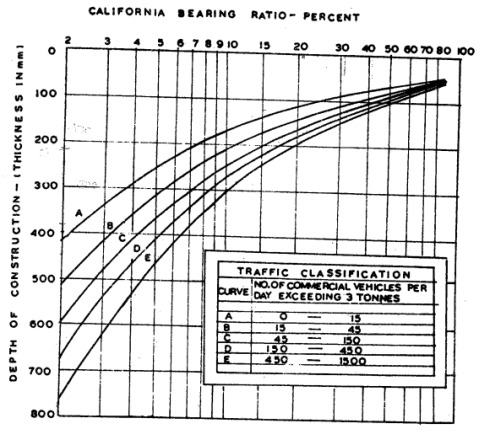

Fig 5: CBR curve for flexible pavement design

Appropriate design for pavement can be chosen for a given 450-1500 vehicle/day traffic and soil strength. Considering 3.5m width of road, for a 1Km of road the volume of the pavement is reduced by 437.5 m^3 as the thickness of pavement decreases for higher CBR value of subgrade as shown in figure 5. The cost of construction of pavement has also got reduced as cost is proportional to volume of pavement.

III. CONCLUSIONS

- MDD initially reduces slightly due to addition of light weight hair fiber and then practically remains same. CBR value increases with inclusion of HHF in clay soil. CBR value of unreinforced clay soil is 4.92 and with the optimum percentage of HHF 1.0% CBR value is 7.70%. At 25 KPa confining pressure Peak stress of unreinforced soil was175.98 KPa and with HHF 1.0% peak stress obtained 200.15 KPa.

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