Study of Fiber-Reinforcement on CBR-Value of Sand

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ABSTRACT

The California Bearing Ratio (CBR) Test is a technique for assessing the strength of soil subgrade/sub-base and base course material for adaptable asphalt. The CBR is a proportion of opposition of a material to infiltration of standard unclogger under controlled thickness and dampness conditions. The viability of consideration of arbitrarily appropriated filaments in sandy soils for further developing the California bearing proportion esteems is explored through a trial examination. The California Bearing Ratio (CBR) Tests were led on fine sand supported with haphazardly dispersed discrete polypropylene and coir strands, under both drenched and unsoaked conditions. The paper portrays the heap infiltration reaction acquired from CBR tests performed on fine sand. The CBR upsides of fine sand increment fundamentally because of consideration of arbitrarily disseminated strands under doused and unsoaked conditions. The expansion in CBR is pretty much as high as 100% because of expansion of 1.5% fiber.

KEYWORDS: CBR, Fiber reinforced soils, Load penetration response, Polypropylene, Soaked, Un-soaked.

INTRODUCTION

Past research has demonstrated that inclusion of fibers significantly improves the engineering response of soils. Gray and Ohashi (1983) studied the mechanics of fiber reinforcement in cohesionless soils and showed that inclusion of fibers increased peak shear strength and ductility of soils under static loads. A number of factors such as fiber content, orientat5ion of fibers with respect to the shear surface, and the elastic modulus of the fiber were found to influence the contribution of the reinforcement to the shear strength. Later work (e.g, Gray and Al Refeai (1986); Masher and Gray (1990); Al Refeai (1991); Maher and Ho (1993), (1994); Consoli et al. (1998a); Montardo (1999); Casagrande (2001); and Michalowski, Cermak (2002), Santoni et al. (2001), Kumar et al. (2003), Gosavi et al. (2004), Gupta (2004), Prabakar et al. (2004), Consoli et al. (2005), Casagrande et al. (2006), Ozkul et al. (2007), Kumar et al. (2007), Sivakumar Babu et al. (2008), Salah Sadek et al. (2010), Hongtao Jiang et al. (2010), Consoli et al. (2011), Yilmaz et al. (2011), Mohanty et al. (2011), Achmad Fauzi et al. (2012), Chacko et al. (2013) and

Trivedi et al. (2013)) has improved understanding of the mechanisms involved and the parameters affecting the behavior of fiber-reinforced soils under static loading conditions. The present work discusses the behavior of a CBR test on soil specimen of fine sand (S) reinforced with randomly distributed discrete polypropylene and coir fibers, under both soaked and unsoaked conditions, when compared to a non reinforced soil specimen under similar conditions.

LABORATORY TESTING PROGRAM AND MATERIAL USED

The soil samples used in the present study were obtained from locally available Jaipur sand. The soil is classified as fine sand according to I.S. Soil Classification System .The table 1 presents the properties of the soil used.

Two different types of fibers, synthetic and natural were used. For synthetic fibers, polypropylene fibers manufactured from high-density polypropylene and polyethylene were taken. It is totally resistant to seawater, acids, alkalies and chemicals. It has high breaking strength and high abrasion resistance as it is less prove to wear ad tear [Setty and Rao (1987), and Rehsi (1988)]. The natural fibers used are coir fibers. These natural fibers are exceptions that they do not deteriorate and exhibit any loss of strength when subjected to an alternate welting and drying in the solutions of sodium hydroxide.

The coir fibers are reported to have good strength and are resistant against biodegradation over a long period of time (Thomson, 1988). Table 2 presents characteristics of fibers.

CBR test were carried out on fine sand (S) reinforced with randomly distributed discrete polypropylene and coir fibers, under both soaked and unsoaked conditions. For soaking, the samples were kept submerged in water for 4 days before testing. The tests were conducted on remolded soil samples prepared at standard Proctor's density and optimum moisture content (IS- 2720-7-1980, Light compaction). Each test was repeated thrice and the average CBR values are reported.

Table 1: Properties of soil used in the investigation

Soil No.	Soil Classification	Specific gravity (G)	Average grain size D_{50} (mm)	Uniformity Coefficient (C_u)	Angle of internal friction ϕ (deg)	MDD kN/m^3	OMC
S	Fine sand (SP)	2.62	.549	2.39	34	16.2	13%

Table 2: Characteristics of fibers used in the investigation*

Fiber type	Diameter (d)	Aspect ratio (l/d)	Specific gravity	Tensile strength	Tensile modulus	Coefficien t of

	mm		G	(kPa)	(kPa)	friction f*
Polypropylene	0.3	50, 75, 100, 125	0.92	1.5×10^5	3×10^6	0.42
Coir	0.2	50,75, 100, 125	0.75	1.00×10^5	2.0×10^6	0.67

*****Properties of fibers have been provided by supplier/manufacturer.

TEST RESULTS AND ANALYSIS

The engineering behavior of the geomaterials studied was examined focusing on the influence of fiber inclusion on load penetration behavior of reinforced/non reinforced sandy soil. The load penetration curve has been plotted for each specimen. Fig. 1shows the typical plots of load- penetration curves for unreinforced fine sand under soaked and unsoaked conditions. Also, Fig. 2 presents the typical plots of load-penetration curves for fine sand reinforced with polypropylene fibers. The CBR values have been calculated for the load corresponding to the penetration of 2.5 mm and 5.0 mm. The higher of these values have been adopted as CBR value (IS-2720-16-1979). Generally the CBR value at 2.5 mm penetration is higher. However, in the present study the CBR values of fiber reinforced sand at 5.0 mm penetration are found to be higher than those at 2.5 mm penetration, under both soaked and unsoaked conditions. This indicates that at larger deformations the fiber reinforcement is more effective in improving the strength of sandy soils by increasing the resistance to penetration. Such a behavior of fiber reinforced sand is consistent with its stress-strain response under triaxial testing (as demonstrated by past research) where the reinforced soil samples do not indicate the failure even more than 20% axial strain: thereby exhibiting greater ductility and marked hardening behavior in the composite material than unreinforced sand, under similar loading conditions. The resisting action of the fibers can be visualized by Figure (3). Where, in situation (a) the plunger pushes down particle C to occupy position in between particles A and B. The fiber resists the downward movement of particle C until slippage between soil and fiber occurs or the fiber fails in tension, resulting into a development of situation (b). Since fibers are extensible in nature, they cannot fail in tension. Thus it is the interaction between soil and fibers which causes the resistance to the penetration of the plunger resulting into higher CBR values.

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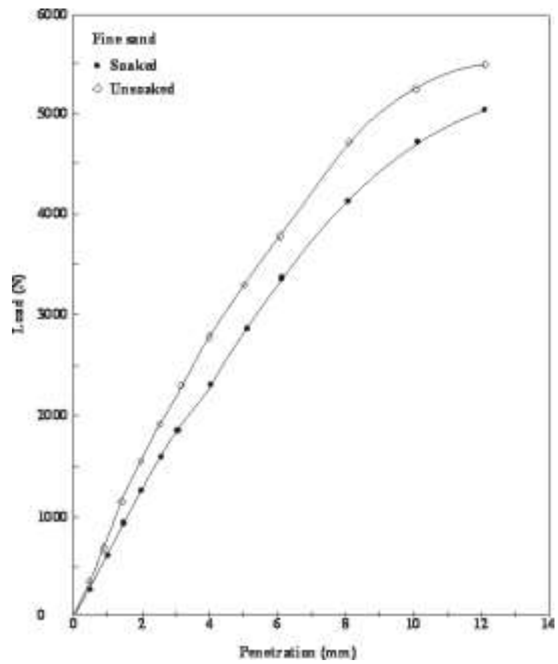

Figure 1: Load-penetration curves for CBR tests on unreinforced fine sand under soaked and unsoaked conditions

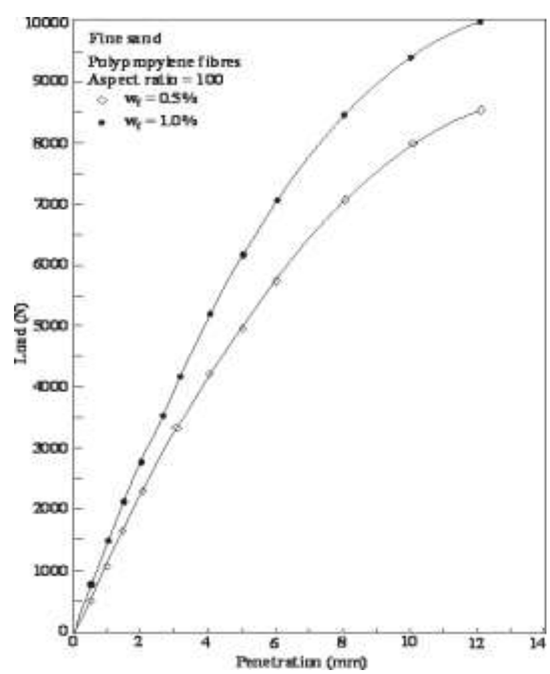

Figure 2: Load-penetration curves for CBR tests on polypropylene fiber-reinforced fine sand under unsoaked condition

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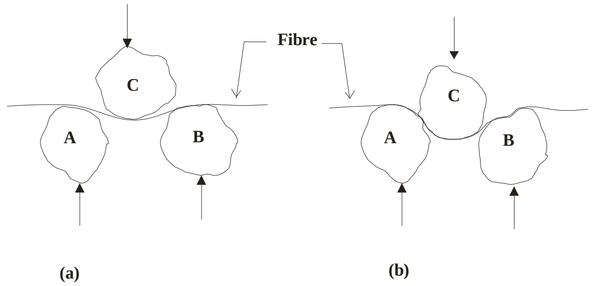

Figure 3: Schematic diagram showing position of fibers; (a) before and (b) after slippage between soil and fiber

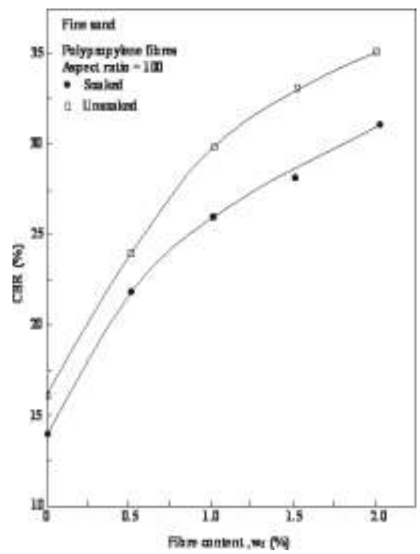

Figure 4: Effect of fiber content on CBR values of polypropylene fiber-reinforced fine sand under soaked and unsoaked conditions

Table 3 presents the results of CBR tests on fiber reinforced fine sand. Comparing the results it can be observed that the inclusion of polypropylene fibers causes significant improvement in CBR values of the sand, under soaked and unsoaked conditions. The CBR values are observed to increase by 47%, 70.5%, 100% and 111.76% of that of the unreinforced sand with 0.5%, 1%, 1.5% and 2% of polypropylene fibers inclusions respectively, under unsoaked condition. The CBR values for soaked condition are improved by 53.3%, 80.0%, 93.33% and 113.3% of that of unreinforced sand, with 0.5%, 1%, 1.5% and 2% fiber content respectively.

Fig. 4 shows the variation of the CBR values of fine sand with percent fiber content. The shape of the curves indicates that the rate of increase in CBR is higher for fiber content of 0.5– 1.0%; beyond which the relative gain in CBR is smaller. The mixing of fibers to soil becomes impractical at fiber content; $w_f > 2\%$.

The CBR values of fiber reinforced sand obtained in the present study may be viewed with respect to its application as soil subgrade/sub-base of the flexible pavement. The components of the flexible pavement are subgrade, sub-base, base and surface course. As per the recommendations of Indian Road Congress (IRC-37, 1984), the sub-base material should have minimum CBR of 20% for cumulative traffic up to 2 million standard axles (msa) and 30% for traffic of greater than 2 msa. OR, if the CBR of the subgrade is more than the minimum requirement for the sub-base (as mentioned above), no sub-base is required. It may be noted that the CBR values of the fiber reinforced sand (Table 3) obtained in the present study meet the requirements for use as a sub-base material. Fiber reinforced sand may be employed as sub-base material in situation where conventional sub-base material (i.e. gravel, moorum, kankar, brick mortar, crushed stone etc.) are not economically viable.

Table 3: California Bearing Ratio values of fiber reinforced fine sand.

Fiber content w_f (%)	California bearing ration (%)		Increase in CBR (%)	
	Unsoaked	Soaked	Unsoaked	Soaked
0.0	17	15	–	–
Polypropylene fibers				
0.5	25	23	47.05	53.33
1.0	29	27	70.5	80.0
1.5	34	29	100.0	93.33
2.0	36	32	111.76	113.3
Coir fibers				
0.5	27	24	58.8	60.0
1.0	32	28	88.2	86.66
1.5	33	31	94.11	106.66

CONCLUSIONS

The following observations and conclusions are made regarding the engineering properties and behavior of propylene fiber-reinforced/nonreinforced specimens of a sandy soil from CBR tests carried out in the laboratory of Malaviya National Institute of Technology, Jaipur, India. The propylene fiber-reinforced specimens showed a marked improvement in CBR values of sandy soils under soaked and unsoaked conditions. The CBR values are observed to increase by 47%, 70.5%, 100% and 111.76% of that of the unreinforced sand with 0.5%, 1%, 1.5% and 2% of polypropylene fibers inclusions respectively, under unsoaked condition. The CBR values for soaked condition are improved by 53.3%, 80.0%, 93.33% and 113.3% of that of unreinforced sand, with 0.5%, 1%, 1.5% and 2% fiber content respectively. Similarly, a significant improvement in CBR values has been observed due to addition of discrete coir fibers to the sand. The rate of increase in CBR is higher for fiber content of 0.5–1.0%; beyond which the relative gain in CBR is smaller. The mixing of fibers to soil becomes impractical at fiber content; w_f > 2%. The CBR test results showed that the addition of polypropylene fibers significantly improved the behavior of soil. A noticeable stiffer response with increasing penetration was observed. This improvement of soil behavior due to fiber addition suggests the potential application of randomly distributed discrete fibers to reinforce soft soil subgrade/sub base under heavy loads for improving the strength which may suffer excessive deformation otherwise. The other areas of applications of randomly distributed fibers technique may be shallow foundations, embankments over weak soils and other earthworks.

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