Some laboratory studies on reinforced soil using Coconut coir mat

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Abstract: Attempts have been made is this paper to determine feasibility of Brahmaputra River sand reinforced by Coconut coir mat in terms of CBR values under soaked and unsoaked conditions in the laboratory for road construction purposes. Coir mats were placed at different depths from top of the mould and CBR values were obtained. CBR values are also determined using different mould-plunger ratios to know the effect of lateral confinement. Further settlement pattern of the same is studied by loading and unloading tests for one cycle only.

Index Terms-reinforced, Coconut coir, CBR values, lateral confinement

Introduction:

Design and construction of pavement on weak subgrade soils pose lots of problems due to low load bearing capacity of soft sub grade, roads causing rut formation under high axel loads of vehicle. Several techniques have been developedto overcome the problem. Among them, soil reinforcement with natural fibre,e.g., and geotextiles is seen to be a promising scope in future. The use of geosynthetic/ geotextiles as reinforcement for soil improvements has been studied by many researchers. Use of coir mats in the form geotextiles as soil reinforcing materials first gained popularity in India because of its long durability and abundance in India. A wide variety of geotextiles ranging 400 to 1400 gm per sqm have been developed by coir Board. However, there is limited literature available where coconut coir mats are used as reinforcing material. Under that circumstance it becomes necessary to improve the bearing resistance of subgrade or to reduce lateral displacement of subgrade by providing earth reinforcement using coconut coil mat.

Mehndirattaetal (1993),Cancellingetal (1996), Aziz &Ramnswami (1994), Rao etal (1996,1999),Army corp of engineers (2003) etc are some of the literature reporting the use of geosynthetics or geotextile materials for pavement design.Sheebhaetal. (2000) observed that the behavior of a clay layer changes from undrained to drained nature with the use of coir felt. Smaller thickness of felt is required for sandy beds to increase resistance. Lyngdoh (2006),observed improvement in bearing capacity of sandy soils reinforced by coconut coir mat by model plate load tests in laboratory.Conducting an experimental study, Abhijit (2015) reported that increased strength of subgrade in terms of CBR values was observed using natural coir fibers as reinforcement .The optimum percentage of coir fibers was found to be five and the ideal position of placing the same was at top.

Since very little literature is available on the use of coconut coir mat as a reinforcing material, Dora(2007) studied the behaviour of this abundant product as a reinforcing element in subgrade soil to investigate the following,

(1) to determine the effect of reinforcement and lateral confinement on CBR values of reinforced soil,

(2) to predict the soaked CBR values of soil from the unsoaked values with the help of a correlation developed in the study and

(3) to segregate the recoverable and non-recoverable components of total settlement of the reinforced soil and compare the values with unreinforced soil

Test Programme:

The test programme consisted of two series. In the first series, the tests conducted are –sieve analysis, Specific gravity, Proctor compaction and California Bearing Ratio tests. The second series of tests for reinforced soil were conducted using coconut coir mat at different depths and different diameters of moulds(D in cm)10,15,20,25,plunger diameter (d =5 cm)and height 175 mm with detachable extension collar 50 mm height and a detachable perforated base plate of 10 mm thick. Table 1 show various tests conducted in the second series of tests.

Table 1: List of Tests on Reinforced Soil Samples

Name of the test	D/d	No. of Test			
		Position of Reinforcement from top surface of samples			
		1 cm	2cm	3.2cm	4.2cm
CBR Test Unoaked & Soaked	2	1	1	1	1
	3	1	1	1	1
	4	1	1	1	1
	5	1	1	1	1
CBR Test with Unsoaked& Unloading	2	1	1	1	1
	3	1	1	1	1
	4	1	1	1	1
	5	1	1	1	1

Sample Preparation:

Optimum moisture content and maximum dry density (determined by Proctor Compaction Preparation of samples for CBR tests both for soaked and unsoaked conditions were done at test). Soils were compacted (statically) with the help of a hydraulic jack of capacity 5 t/cm^2. The reinforced samples were prepared by placing the circular coir mat of the same size of the internal diameter of the mould at the required position from the top surface of the sample. For this purpose, coir mats were cut into circular section to fit the required mould. The soil in the mould was compacted in three layers with proper measurement especially while incorporating the coconut coir geotextile.

Taking the surcharge weight of 5kg for the mould of diameter 15cm as standard, the surcharge weights for the other moulds of 10cm, 20cm and 25cmare calculated and approximately found to be 2.5kg, 10kg and 15kg respectively maintaining constant surcharge pressure (almost) for the different sizes of moulds .

The test procedures followed in experimental study were as per relevant Indian Standard codes.

Test results and interpretation:

The soil sample collected from of the river Brahmaputra bank was tested in the Soil Mechanics laboratory of Assam Engineering College. The obtained grain size distribution of soil is shown in Table 2 .The other properties are : Specific gravity : 2.602 , Optimum moisture content (O.M.C) and maximum dry density (γ_d) are 15 % and 1.63 gm/cc respectively. CBR value of the soil is 5.29% for unoaked condition and 2.46% for soaked condition at optimum moisture content and maximum dry density.

The soil according to Indian Standard Classification falls in the category of poorly graded sand and silt mixture (SP- SM).

Table 2: Grain size distribution of Brahmaputra river sand

Silt & Clay	Sand			Gravel %
% Lessthan0.075 mm	Fine Sand % (0.075-0.425mm)	Medium Sand % (o.425-2.0mm)	Coarse sand % (2.0-4.75)mm	(>4.75mm)

5.948	93.928	0.1	0.024	0

Results of the California Bearing Ratio (CBR) tests:

All CBR tests were conducted at optimum moisture content and maximum dry density. CBR values obtained from Penetration curves drawn from C.B.R. tests results (not shown due to space constrain) for both soaked and unsoaked conditions are listed in Tables 3 .The adopted C.B.R values considered to be the higher of the values corresponding to penetration 2.5mm and 5mm and are marked by * marks shown in the same table.

Table 3: CBR values for different conditions.

D/d ratio-	D/d=2		D/d=3		D/d=4		D/d=5	
Penetration Level	2.5mm	5.0mm	2.5mm	5.0mm	2.5mm	5.0mm	2.5mm	5.0mm
Position of Coir mat from top surface (cm)	Unsoakedspecimen (%)							
No coir mat	15.86%	*18.16%	*5.29%	4.87%	*6.00%	5.57%	3.42%	*3.47%
1	14.34%	*20.49%	7.55%	*9.61%	5.58%	*10.90%	5.48%	*6.36%
2	13.06%	*16.55%	6.64%	*6.99%	4.17%	*6.84%	6.94%	*9.45%
3.2	10.79%	*13.61%	5.80%	*7.18%	5.15%	*6.72%	5.07%	*5.79%
4.2	11.14%	*14.08%	5.26%	*5.83%	4.92%	*5.97%	2.47%	*3.15%
Position of Coir mat from top surface (cm)	Soaked (%)							
No coir mat	8.75%	*10.20%	2.26%	*2.46%	2.54%	*3.16%	2.47%	*2.51%
1	10. Specimen 20%	*14.27%	7.14%	*7.71%	4.63%	*6.90%	3.29%	*4.05%
2	8.69%	*10.82% 2.55%	*2.97%	3.75%	*4.88%	3.52%	*4.42%	
3.2	4.96%	*6.18% 2.04%	*2.53%	2.92%	*3.27%	3.81%	*4.66%	3.2
4.2	2.27%	*3.86% 1.13%	*1.78%	2.58%	*2.64%	2.69%	*3.09%	4.2

The percentage change of CBR value due to coconut coir reinforcement is calculated and listed in Table 4.

Table 4: Percentage change of CBR value with respect to original

Unsoaked Specimen					
D/d	**Unreinforced CBR (%)**	**Percentage change of CBR value w.r.t. unreinforced (%)**			
		at1cm from top	**at 2cm from top**	**at 3.2cm from top**	**at 4.2cm from top**
2	18.16	12.83	-8.87	-25.06	-22.47
3	5.29	81.66	32.14	35.73	10.21
4	6	81.67	14.00	12.00	-0.50

5	3.47	83.29	172.33	66.86	-9.22
Soaked Specimen					
D/d	**Unreinforced CBR (%)**	**Percentage change of CBR value w.r.t. unreinforced (%)**			
		at1cm from top	**at 2cm from top**	**at 3.2cm from top**	**at 4.2cm from top**
2	10.2	39.90	6.08	-39.41	-62.16
3	2.46	213.41	20.73	2.85	-27.64
4	3.16	118.35	54.43	3.48	-16.46
5	2.51	61.35	76.10	85.66	23.11

It is observed from Table 4 that CBR values of the soil have been improved up to 81.67% for unsoaked condition and 213.41% for soaked condition when the position of reinforcement was placed at 1cm from the top surface.

Variation of CBR values with respect to position of reinforcement (unsoaked and soaked conditions)and D/d ratios are shown in Figures.1 a & b and 2 a & b respectively.

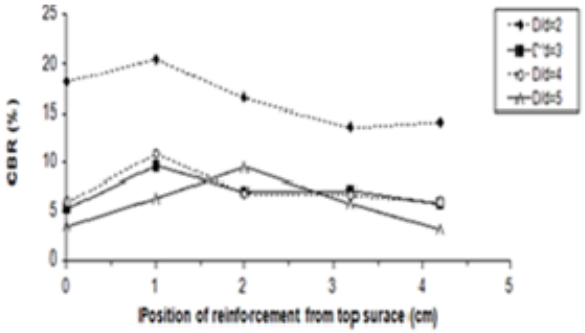
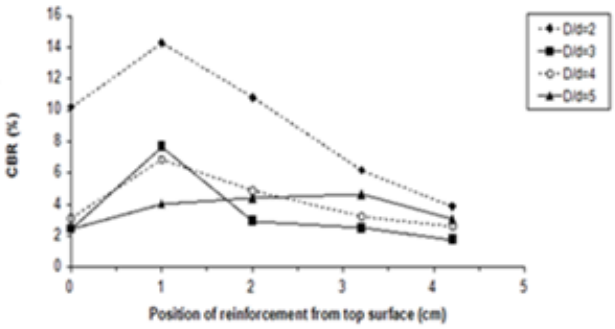


Figure 1a CBR Vs position Reinforcement from top surface of unsoaked specimen



Fifue 1 b CBR Vs position of Reinforcement from top surface for soaked specimen

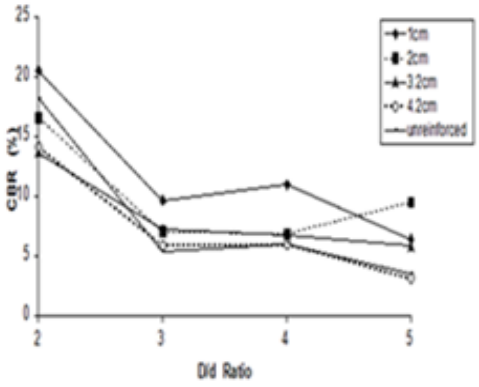


Figure 2 a CBH Vs D/d Ratio eor Unsoaked Specimen

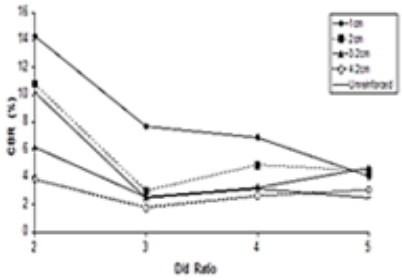


Figure 2 b Vs D/d Ratio for Soaked Specimen

The figures indicate that the best position of reinforcement is at 1 to 2 cm from top of soil surface .Increasing diameter of mould of CBR tests (indicating decreasing confining pressure) is observed to affect the CBR values which tend to decrease with increase in D/d ratios.

Relation between Soaked and Unsoaked CBR.

The relation between CBR values for Soaked and Unsoaked conditions are determined usingRegression analysis according to the concept given by Mehndiratta,(1993) .The relation is shown in Table 5 for different values of D/d and for unreinforced soil .Similarly equations for reinforced soil can be developed.

Table 5: Relation between the soaked and unsoaked CBR values

D/d Ratio	2	3	4	5
R^2 adopted	0.868	0.8338	0.8689	0.6043
Equation adopted	CBR(Soaked) =1.3292x CBR(unsoaked) -12.97	CBR(Soaked) =1.3119x CBR(unsoaked) -5.6669	CBR(Soaked) =0.7881xCBR(unsoaked) -1.5723	CBR(Soaked) =0.2788 x CBR(unsoaked) -2.1724

Results of CBR test with unloading

The performance of coconut coir reinforced soil due to unloading is studied in terms of total settlement and plastic settlement by unloading CBR tests. In this case, CBR tests were carried out, by statically increasing load up to the maximum load with corresponding records of the total settlements (S). Next the load was reduced slowly at the same rate of loading and recording the plastic settlement values (Sp) from the dial gauge readings. It can be considered as cyclic CBR test with one cycle of loading and unloading.

Using results of unloading tests for different D/d ratios ,for unreinforced and reinforced soil at different positions of reinforcement from the top surface and for both soaked and unsoaked conditions ,total settlement(S), plastic settlement i.e. unrecoverable settlement (Sp),and elastic settlement i.e.(recoverable settlement (Se) , corresponding to load on plunger (P)are shown in Tables 6.

It is observed in Table 6 that the load corresponding to maximum total settlement decreases with increase in mould -plunger diameter (D/d) ratio and is of lesser values in cases of soaked conditions than unsoaked condition. For comparison purpose, ratios of total settlement of reinforced soil and unreinforced (TSR) and ratio of plastic settlement of reinforced and unreinforced soil (PSR) for different positions of reinforcement and D/d values are calculated as shown in Table 7.
Tables 6 and7 indicate that plastic settlements are of lesser value for reinforced soil than that of unreinforced soil in all cases except for D/d =2 ; but for soaked condition settlement ratios are greater than 1 both for D/d=2 and 3.
The variation of TSR and PSR with respect to D/d ratios are presented in Figs.3 a , b and 4 a , b for different conditions considered.

Table 6:Total(S), Plastic(Sp) and Elastic(Se) Settlements for a given load & D/d Ratio at Different Positions of reinforcement

Table: 7: Total Settlement ratio (TSR) Plastic Settlement Ratio (PSR)between reinforced and unreinforced soil for different positions of reinforcement and D/d ratios

D/d Ratio	Load on Plunger P (Kg)	Total (S), Plastic (Sp) and Elastic (Se) Settlements for a given load respective to the different moulds.														
		Unsoaked Specimen														
		Unreinforced			Reinforced											
					at1cm from top			at 2cm from top			at 3.2cm from top			at 4.2cm from top		
		S	Sp	Se	S	Sp	Se	S	Sp	Se	S	Sp	Se	S	Sp	Se
2	257.4	4.52	3.25	1.27	5.13	3.58	1.55	6.44	4.48	1.96	7.83	5.59	2.24	5.81	4.7	1.11
3	158.4	9.05	7.7	1.35	7.25	5.34	1.91	6.05	4.44	1.61	6.86	5.36	1.5	8.97	7.5	1.47
4	158.4	12.04	10.55	1.49	8.54	6.6	1.94	8.91	7.07	1.84	10.25	8.11	2.14	11.94	9.2	2.74
5	118.8	12.41	10.83	1.58	5.26	3.73	1.53	5.32	3.67	1.65	9.42	7.47	1.95	8.81	6.76	2.05
Soaked Specimen																
D/d Ratio	**Load on Plunger P (Kg)**	**Total (S), Plastic (Sp) and Elastic (Se) Settlements for a given load respective to the different moulds.**														
		Unreinforced			**Reinforced**											
					at1cm from top			at 2cm from top			at 3.2cm from top			at 4.2cm from top		
		S	**Sp**	**Se**	**S**	**Sp**	**Se**	**S**	**Sp**	**Se**	**S**	**Sp**	**Se**	**S**	**Sp**	**Se**
2	178.2	4.22	3.22	1	5.3	3.23	2.07	7.08	5.53	1.55	8.54	6.67	1.87	8.08	6.73	1.35
3	99	6.24	4.51	1.73	8.08	6.62	1.46	6.61	5.02	1.59	8.17	6.53	1.64	11.7	10.21	1.49
4	79.2	12.29	10.3	1.99	5.17	2.83	2.34	8.01	6.84	1.17	9.47	7.12	2.35	11.83	9.77	2.06
5	59.4	13.56	11.93	1.63	5.65	3.79	1.86	9.8	7.29	2.51	12.29	9.89	2.4	10.37	8.25	2.12

Condition	D/d ratio	Values of TSR * and PSR *							
		Reinforced at 1 cm from top		Reinforced at 2 cm from top		Reinforced at 3. 2 cm from top		Reinforced at 4. 2 cm from top	
		TSR	PSR	TSR	PSR	TSR	PSR	TSR	PSR
Unsoaked	2	1.13	1.1	1.42	1.5	1.73	1.72	1.28	1.45
	3	0.8	0.69	0.67	0.58	0.76	0.69	0.99	0.97
	4	0.71	0.62	0.74	0.67	0.85	0.77	0.99	0.87
	5	0.42	0.34	0.43	0.33	0.76	0.69	0.71	0.62
Soaked	2	1.26	1	1.68	1.72	2.02	2.9	1.91	2.09
	3	1.29	1.47	1.06	1.11	1.3	2.07	1.87	2.26
	4	0.42	0.27	0.65	0.66	0.77	0.69	0.96	0.94
	5	0.42	0.31	0.72	0.61	0.91	0.83	0.76	0.69

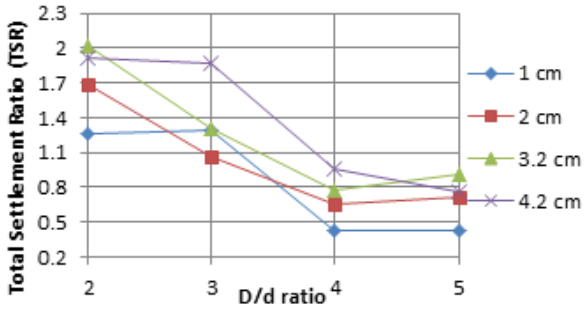


Figure 3 a TSR VS D/d Ratio for unsoaked condition

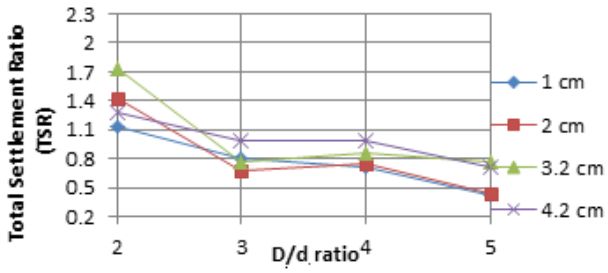


Figure 3 b TSR VS D/d Ratio for soaked condition

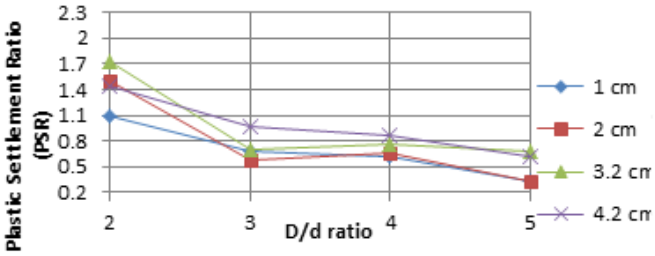


Figure 4 a - PSR VS D/d Ratio for unsoaked condition

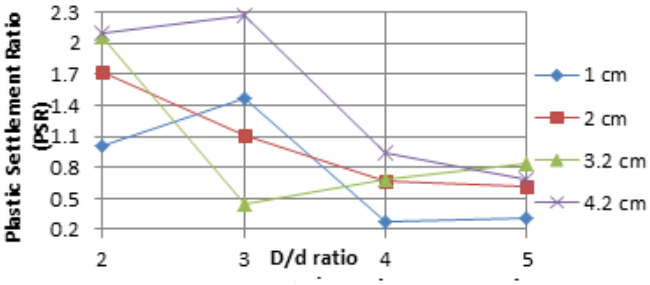


Figure 4 b - PSR VS D/d Ratio for soaked condition

Table 6 indicates that values of Plastic Settlement(SP) decreases with introduction of coconut coir mat reinforcement when D/d ratios are 3 ,4 & 5 while SP increases for D/d =2 for unsoaked condition. Therefore PSR is greater than 1 for D/d ratio is 2 and smaller than 1for D/d ratio is 3,4 or 5(Table7).It may be inferred that settlement ratio depends on D/d ratio as indicated by Table 7 and Figure.4a.But no conclusion can be made from soaked condition test result (Table7&Fig.4b). It may be due to swelling of soil and coir mat in contact with water in soaked condition .Therefore further study is required in this direction.

Conclusion

The conclusions drawn from the study are:

1. The soil sample selected for the study is from the river Brahmaputra with a specific gravity of 2. 602 and has optimum moisture content and maximum dry density 15 % and 1.63 gm/cc respectively. CBR values of the soil are 5.29% for unsoaked condition and 2.46% for soaked condition at optimum moisture content and maximum dry density. The soil according to Indian Standard Classification is poorly graded sand& silt mixtures(SP- SM).

2. The CBR values of the soil have been observed to be increased with addition of coconut coir reinforcement both for soaked and unsoaked conditions showing improvement upto 81.66% for unsoaked condition and 213.41% for soaked condition when the position of reinforcement was placed at 1cm from the top.

3. There exists a good relation between soaked and unsoaked CBR values and it is possible to predict the soaked values from the unsoaked values of both for unreinforced soil and reinforced soil without conducting the soaked tests for this type of soil using the method mentioned.

4. The best position of reinforcement has been found out to be near the loading surface i.e. at 1cm and 2cm for both soaked and unsoaked condition. Position of reinforcement at 3.2 cm from the top is also seen to be effective as compared to the unreinforced soil. Position of reinforcement at 4.2 cm has no positive effect.

5. CBR values decrease with increasing D/d ratio i.e. reduction in lateralconfinement (approaching field conditions). Decrease is seen to be more for the soaked than that for unsoaked condition. The same trend is found for D/d = 2, 3, 4 for both conditions, whereas for D/d = 5 no conclusion can be made.

6. Total Settlement ratio and Plastic Settlement Ratio of the reinforced soil due to CBR loading and unloading tests is seen to be dependent on D/d ratio and position of reinforcement. It may be inferred that effect of reinforcement is dependent on confining condition of subgrade.

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