Study of the Effect of Coir Fibre Reinforcement on the Strength Parameters and CBR Value of Clayey Soil

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***Abstract* - In India as the population of the country gallops towards alarming proportions, the generation of waste has increased. Much attention is not imparted towards the development of methods to dispose or make use of the waste generated in a useful manner. India has large tracks resting on expansive soil covering an area of 0.8 million square meters which is about 20% of total area of India. These expansive soils undergo volumetric changes with change in moisture content, swelling and shrinkage of these soil causes severe damage to the foundations, buildings, roads, retaining structures etc. In recent days it has been investigated that addition of fibres will improve the ductility behavior of soil. Thereby reducing the cracks during the shrinkage. Use of artificial fibres poses the environmental problems, hence natural fibres like coir, jute and wood pulp can be used as a reinforcing material to soil.**

In this project an attempt is made to study the influence of coir fibre reinforcement on compaction and strength properties of expansive soil. Coir fibre is made up of the coarse fibres extracted from the fibrous outer shell of coconuts. The individual fibre cells are narrow and hollow, with thick walls made of cellulose. They are pale when immature but later become hardened and yellowed as a layer lining is deposited on the walls. The main objective of our study is to evaluate the effect of fibre inclusions on strength parameters and CBR value of clay soil. In order to achieve the objectives detailed laboratory tests were conducted on virgin sample and fibre reinforced clay. Tests are performed by varying the fibre content in different proportions so as to achieve optimum fibre content ensuring maximum increase in bearing capacity of the soil.

Key Words: coir fibre,expansive soil,CBR value,virgin soil,strength parameters,laboratory tests,optimum fibre content,bearing capacity,framed structure,fibre reinforced soil,

1. INTRODUCTION

The concept of the reinforced soil with natural fibre materials originated in ancient times. During ancient periods palm fibres, wood, bamboo and animals skin were used for improvement of bricks properties and increase of foundation bearing strength.Nowadays, from natural or vegetable fibres as coir, banana, jute, flax, sisal, pal, reed, bamboo and wood fibres are used for improvement of mechanical properties of soil. These fibres are used for increase of tensile, compression and shear strength of soils (especially on clay soils), to prevent from soil erosion in slope, canals and shoreline.

Most advantageous application of natural fibres in comparison with metal and polymer materials, is that they are pollution free, easily available and cost effective.There are two varieties of coir, brown and white. Brown coir is harvested from fully ripened coconuts. It is thick, strong and has high abrasion resistance. It is typically used in mats, bushes and sacking. Mature brown coir fibre contain more lignin and cellulose than fibres such as flax and cotton, and the fibres are resilient, strong and highly durable but less flexible than flax and cotton. The coir fibre is relatively water-proof and is one of the few natural fibres resistant to damage by salt water.

2 NECESSITY

The necessity arises due to the following challenges in dealing with soft soil construction:

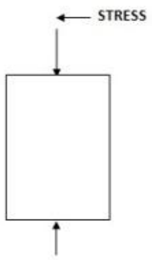
- Costly construction.
- Excessive post construction settlement.
- Instability on excavation and embankment forming.
- Poor bearing capacity.

The main objective of our study is to evaluate the effect of fibre inclusions on strength of parameters and CBR value of clay soil. In order to achieve the objectives a detailed laboratory test were conducted on virgin sample and fibre reinforced clay. Test are performed by varying the fibre content in different proportions (1%, 2% and 3% by weight) with an aspect ratio of 50. The fibre used in our project is coir fibre and tests are performed virgin soil and fibre reinforced soil.The fibre strands are 0.1mm in diameter and length of 5mm is adopted to maintain the aspect ratio of 50. The test result are tabulated and compared.

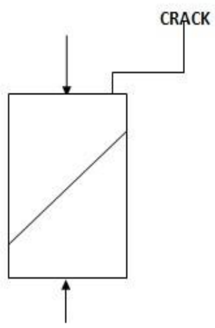
3.MECHANISM OF FIBRE REINFORCED SOIL

The fibre reinforced soil is a composite material ,Made up of soil mixed with fibres at a percentage by volume of the soil. By the introduction of fibres homogeneously throughout the soil, we increase the strength of the bond, there by increasing shear strength. Consider a soil element at equilibrium subjected to the stress as shown in fig.2.1.Such an element will be subjected to both diagnol tension and compression. Since the soil is very weak in tension, it will fail diagonally due to diagonal tension.

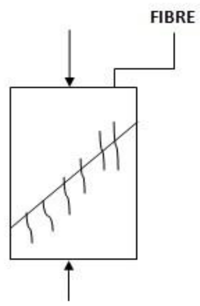
When fibres are introduced into the soil, the fibres will carry the tension and thus carries additional loads. In figures, only the fibres along the failure plane are shown, but the fibres will be spread homogenously throughout the soil.



Soil subjected to axial load



Formation of diagonal crack at failure load



Crack resisted by the others

3. IDENTIFICATION OF PROBLEMATIC SOIL

Table 1

Sample location	V_{WATER} (ml)	$V_{KEROSENE}$ (ml)	Free Swell Index %
OMR road	12	10	20
Kalpakkam	16.5	10	65
Nolambur	14	10.6	32.07
Tambaram	13.4	10.3	30.09

$$SI = \frac{V_{water} - V_{kerosene}}{V_{kerosene}} \times 100$$

Where, V_{water} = volume of water in ml.

$V_{kerosene}$ = volume of kerosene in ml.

Soil samples from four sites were collected. The soil sample from Kalpakkam was found to be having the highest degree of expansion.

Hence it is identified as the most problematic soil. So the site of project is chosen as Kalpakkam.

Table 2 Observation for Index Properties of soil.

CALCULATION	SYMBOL	FORMULA	RESULTS
Differential Free Swell index	DFS	$(V_{WATER} - V_{KEROSENE}) / (V_{KEROSENE}) \times 100$	65
Plasticity Index	I_P	$W_L - W_P$	49%
Liquidity Index	I_L	$W - W_P / I_P$	0.25
Consistency Index	I_C	$W_L - W / I_P$	0.75
Flow Index	I_F	$(W_1 - W_2) / \mathrm{Log}_{10}\, n_2/n_1$	17
Toughness Index	I_T	I_P/I_F	2.88

4. EXPERIMENTAL RESULTS

Based on the test conducted in the laboratory to determine the characteristics of soil . The test results are given below –

1. Differential free swell index 65%

2 . Specific gravity of soil 2.60

3. Water content 35%

4. Liquid limit 72%

5. Plastic limit 23%

6. Plasticity index 0.49

7. Liquidity index 0.25

8. Consistency index 0.75

9. Toughness index 2.88

Based on atterberg's values as well as per BIS soil is classified as clay of high compressibility (CH).

5. SIGNIFICANCE OF TEST RESULTS

The index properties which have been determined enable us to classify the type

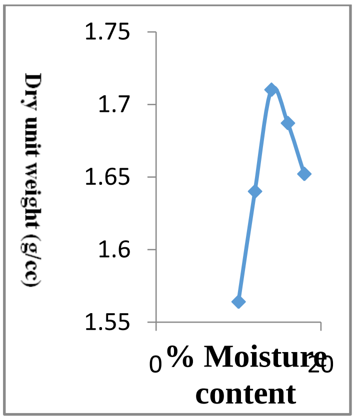
of soil according to IS 1498:1970 which aids in providing suitable design.

1. The calculated value is free swell index is found to be 65% which indicates that soil has very high degree of expansion.
2. The calculated value for plasticity index is 49% which indicates that the soil is highly plastic.
3. The calculated value for liquidity index is 0.25 which indicates that the soil is intermediate between stiff and liquid state condition.
4. The calculated value for consistency index is between 0 and 1 which indicates that consistency of soil is soft.
5. The calculated value for toughness index is 2.88 which indicates that soil is clayey in nature.

6. STANDARD PROCTOR TEST ON VIRGIN SOIL

This test is done to determine the relationship between moisture content and the dry density of soil.Compaction is the process of
densification of soil by reducing air voids.The dry density is the maximum at optimum water content.

S.No.	Moisture content (%)	Weight of mould + wet soil (gm)	Weight of wet soil (gm)	Bulk unit weight(g/cc)	Dry unit weight (g/cc)
1	10	5565	1715	1.72	1.564
2	12	5680	1830	1.839	1.640
3	14	5795	1945	1.95	1.710
4	16	5800	1950	1.958	1.687
5	18	5795	1945	1.950	1.652



A curve is drawn between the water content and dry density to obtain the maximum dry density & the optimum water content.

OUTCOME

From the Stress vs strain curve,the maximum stress gives the unconfined compressive strength (q_u).For $\varphi=0$ condition,the shear strength or cohesion of the soil may be taken to be equal to half the unconfined compressive strength.

$C = q_u/2 = 161.4/2 = 80.7$ kPa.

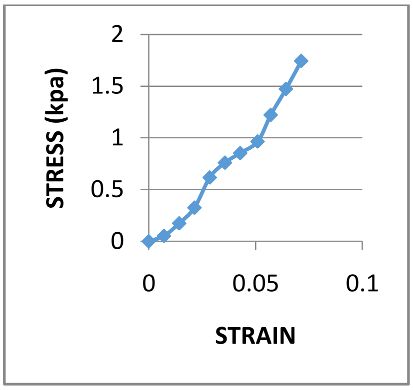
1. Maximum Dry Density = 1.710 g/cc.

2. Optimum Moisture Content = 14%

7.UNCONFINED COMPRESSION TEST ON 1] VIRGIN SOIL

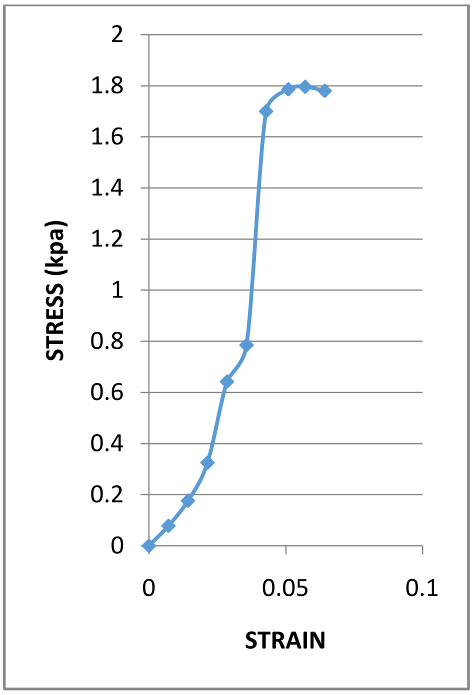
This test is done to quickly evaluate the undraine cohesion. Undisturbed cylindrical specimens(38 mm diameter,76 mm length) of soil is prepared for the test.

S. No.	Dial gauge reading (div)	Deformation (mm)	Proving ring reading (div)	Load (kg)	Strain (1x10⁻³)	Correction area of specimen (cm²)	Stress (kg/cm²)
1	0	0	0	0.00	0	9.62	0
2	50	0.5	0.4	0.49	7.145	9.69	0.052
3	100	1.0	1.6	1.95	14.287	9.76	0.200
4	150	1.5	2.7	3.29	21.423	9.83	0.335
5	200	2.0	4.8	5.86	28.573	9.90	0.591
6	250	2.5	5.8	7.08	35.716	9.98	0.708
7	300	3.0	10	12.20	42.858	10.05	1.214
8	350	3.5	12	14.64	51.0	10.13	1.446
9	400	4.0	13.5	16.47	57.143	10.20	1.614



8. 1 % FIBRE REINFORCED SOIL

Dial gauge reading (div)	Deformation (mm)	Proving ring reading (div)	Load (kg)	Strain (1x10⁻³)	Corrected area of specimen (cm²)	Stress (kg/cm²)
0	0	0	0.00	0	9.62	0
50	0.5	0.60	0.73	7.145	9.69	0.078
100	1.0	1.40	1.71	14.287	9.76	0.176
150	1.5	2.60	3.17	21.423	9.83	0.325
200	2.0	5.20	6.34	28.573	9.90	0.642
250	2.5	6.40	7.81	35.716	9.98	0.783
300	3.0	14.00	17.08	42.858	10.05	1.699
350	3.5	14.80	18.06	51.0	10.13	1.783
400	4.0	15.00	18.30	57.143	10.20	1.795
450	4.5	15.00	18.30	64.286	10.28	1.779
500	5.0	14.60	17.81	71.429	10.36	1.719
550	5.5	13.00	15.86	78.571	10.44	1.519

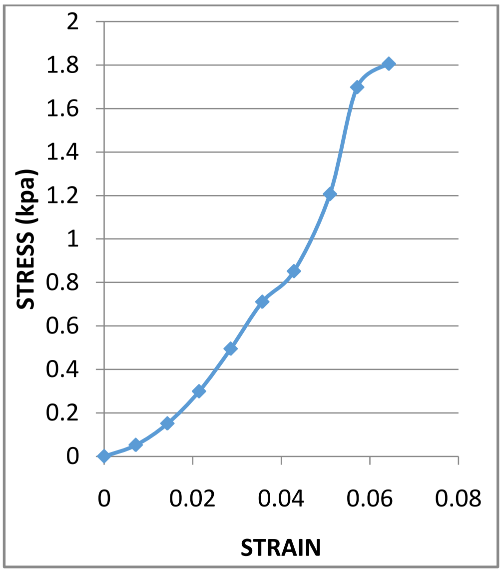


From stress vs strain graph,

C = $q_u/2$ = 179.3/2 =89.65 kPa

9. 2% FIBRE REINFORCED SOIL

Dial gauge reading (div)	Deformation (mm)	Proving ring reading (div)	Load (kg)	Strain (1x10^{-3})	Corrected area of specimen (cm^2)	Stress (kg/cm^2)
0	0	0	0.00	0	9.62	0
50	0.5	0.40	0.49	7.145	9.69	0.052
100	1.0	1.20	1.46	14.287	9.76	0.151
150	1.5	2.40	2.93	21.423	9.83	0.299
200	2.0	4.00	4.83	28.573	9.90	0.495
250	2.5	5.80	7.08	35.716	9.98	0.711
300	3.0	7.00	8.54	42.858	10.05	0.852
350	3.5	10.00	12.20	51.0	10.13	1.207
400	4.0	14.20	17.32	57.143	10.20	1.699
450	4.5	15.20	18.54	64.286	10.28	1.807
500	5.0	15.00	18.30	71.429	10.36	1.766
550	5.5	13.00	15.86	78.571	10.44	1.519

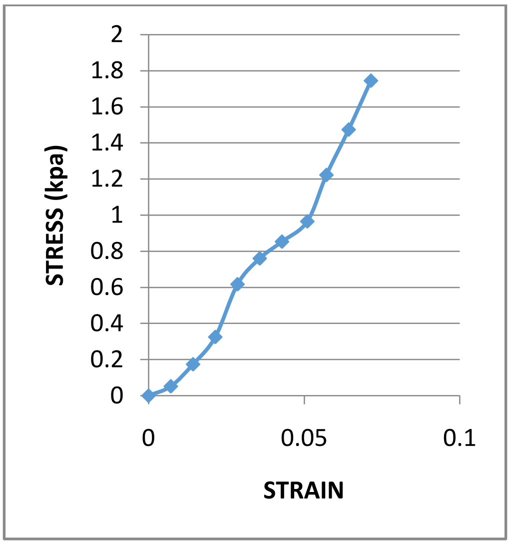


From stress vs strain graph,

C = $q_u/2$ = 180.4/2 =90.2 kPa

10. 3% FIBRE REINFORCED SOIL

S.No.	Dial gauge reading (div)	Deformation (mm)	Proving ring reading (div)	Lod (kg)	Strain (1x10^{-3})	Corrected area of specimen (cm^2)	Stress (kg/cm^2)
1	0	0	0	0.00	0	9.62	0
2	50	0.5	0.40	0.49	7.145	9.69	0.052
3	100	1.0	1.40	1.71	14.287	9.76	0.174
4	150	1.5	2.60	3.17	21.423	9.83	0.325
5	200	2.0	5.00	6.10	28.573	9.90	0.617
6	250	2.5	6.20	7.56	35.716	9.98	0.76
7	300	3.0	7.00	8.54	42.858	10.05	0.853
8	350	3.5	8.00	9.76	51.0	10.13	0.965
9	400	4.0	10.20	12.44	57.143	10.20	1.222
10	450	4.5	12.40	15.13	64.286	10.28	1.473
11	500	5.0	14.80	18.06	71.429	10.36	1.744
12	550	5.5	13.00	15.86	78.571	10.44	1.519

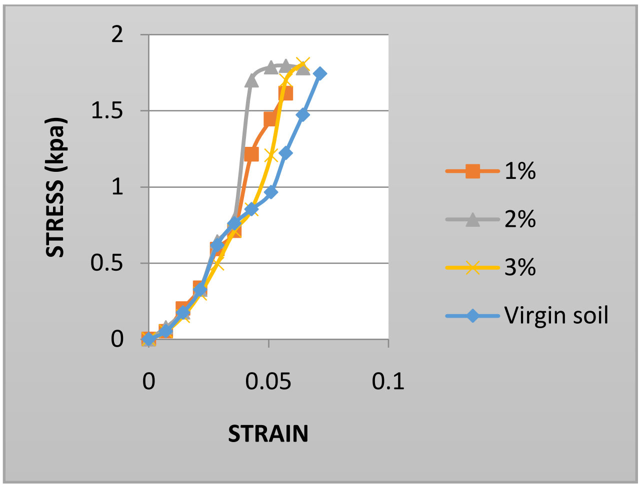


From stress vs strain graph,

$C = q_u/2 = 174.3/2 = 87.15kPa$

11. COMPARATIVE STUDY OF SHEAR STENGTH OF VIRGIN SOIL AND FIBRE REINFORCED SOIL.

S. No.	TESTS	UCC VALUES q_u (kPa)	COHESION C_u (kpa)
1	virgin soil	161.4	80.7
2	virgin soil + 1% of coir fibre	179.3	89.65
3	virgin soil+ 2% of coir fibre	180.4	90.2
4	virgin soil + 3% of coir fibre	174.3	87.15

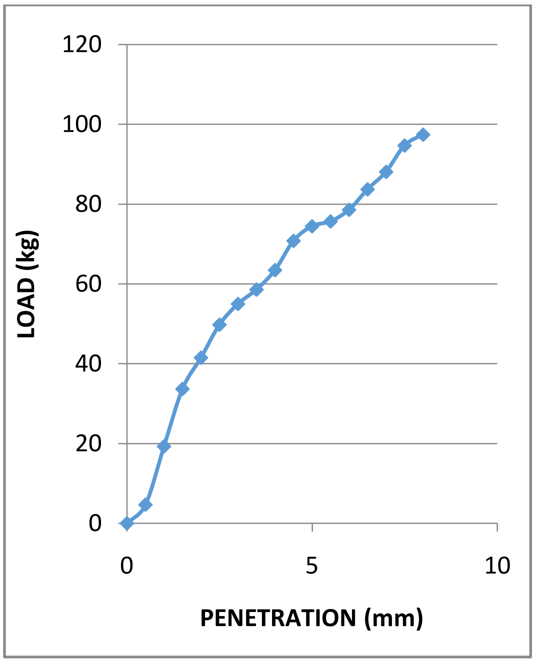


- The shear strength of the soil increases with the increase in fibre content. Upto 2% fibre content, there is a considerable amount of increase in unconfined compressive strength of soil and above 2% there is slight decrease in UCC value.
- The reason might be because of the rough texture of fibres which increases the friction between the particles and holds the soil particles together. Thus it increases the resistance to sliding and deformation of soil sample in the un confined compression test.
- The soil shows small reduction in development of strength at 3 % fibre content, which might be due to the excessive addition of coir fibre. It reduces the optimum density of the soil and hence causes the reduction in shear strength of the soil.
- Therefore we conclude that the coir fibre content of 2% by weight of soil is found to be the optimum coir fibre content for the increment in strength of the poorly graded (clay of high compressibility) clayey soil.

12.CALIFORNIA BEARING RATIO TEST ON VIRGIN SOIL

The penetration resistance of the soil determined using the California bearing ratio test. In the experiment soil specimen prepared at optimum moisture content and tested in CBR value machine for the determination of CBR value of virgin soil and coir reinforced soil. The results obtained were tabulated below.

S.No.	Penetration (mm)	Proving ring reading (div)	Load (kg)
1	0.0	0	0
2	0.5	3.8	4.636
3	1	15.8	19.278
4	1.5	27.6	33.674
5	2.0	34	41.5
6	2.5	40.8	49.779
7	3.0	45.06	54.975
8	3.5	48	58.57
9	4.0	52	63.45
10	4.5	58	70.79
11	5.0	61	74.45
12	5.5	62	75.66

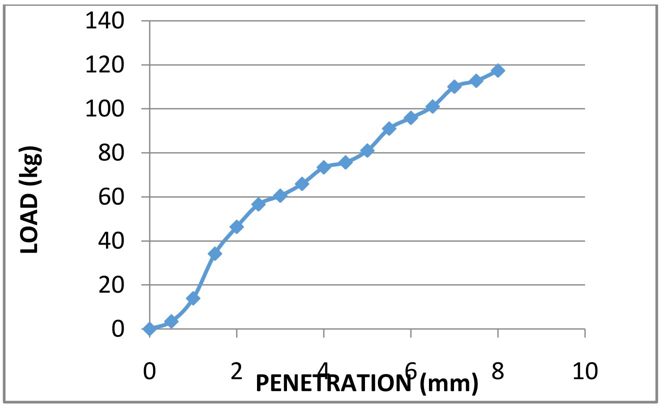


13.RESULTS:

Standard load for 2.5mm penetration = 1370 kg
Standard load for 5.0mm penetration = 2055kg
CBR value corresponding to 2.5mm penetration =(49.779/1370)x100 = 3.63
CBR value corresponding to 5.0mm penetration =(74.45/2055)x100 = 3.62
Hence the CBR value is 3.63.

14. CBR TEST ON 1% FIBRE REINFORCED SOIL

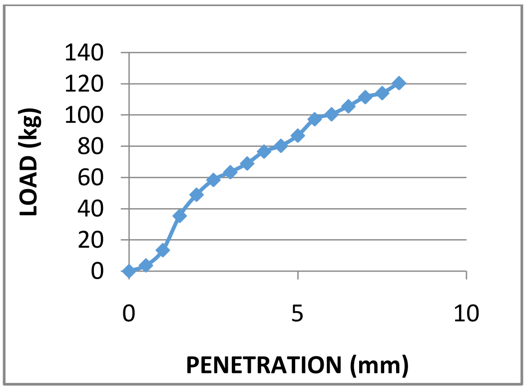
S. No.	Penetration (mm)	Proving ring reading (div)	Load (kg)
2	0.5	2.8	3.436
3	1	10.8	13.916
4	1.5	28	34.19
5	2.0	38	46.38
6	2.5	46.4	56.61
7	3.0	49.6	60.515
8	3.5	54	65.9
9	4.0	60	73.4
10	4.5	62	75.66
11	5.0	66.4	81.028
12	5.5	74.6	91.014



CBR value corresponding to 2.5mm penetration =(56.61/1370)x100 = 4.13
CBR value corresponding to 5.0mm penetration =(81.028/2055)x100 = 3.94
Hence the CBR value is 4.13

15. CBR TEST ON 2% FIBRE REIFORCED SOIL

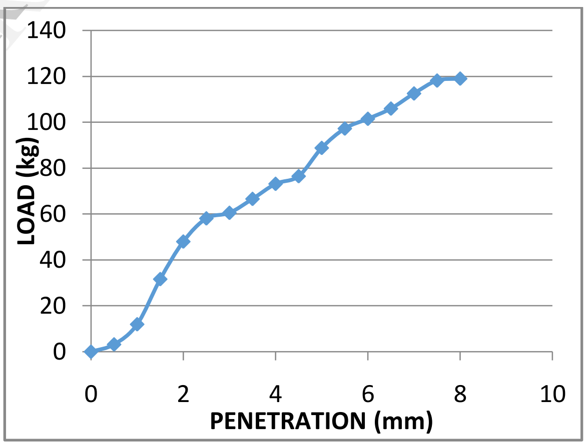
S. No.	Penetration (mm)	Proving ring reading (div)	Load (kg)
1	0.0	0	0
2	0.5	3	3.68
3	1	11	13.45
4	1.5	29	35.4
5	2.0	40	49
6	2.5	48	58.46
7	3.0	52	63.42
8	3.5	56.6	69
9	4.0	62.8	76.63
10	4.5	66.4	80.334
11	5.0	71.2	86.864
12	5.5	79.8	97.352



CBR value corresponding to 2.5mm penetration =(58.46/1370)x100 = 4.27
CBR value corresponding to 5.0mm penetration =(86.864/2055)x100 = 4.23
Hence the CBR value is 4.27

16. CBR TEST ON 3% FIBRE REINFORCED SOIL

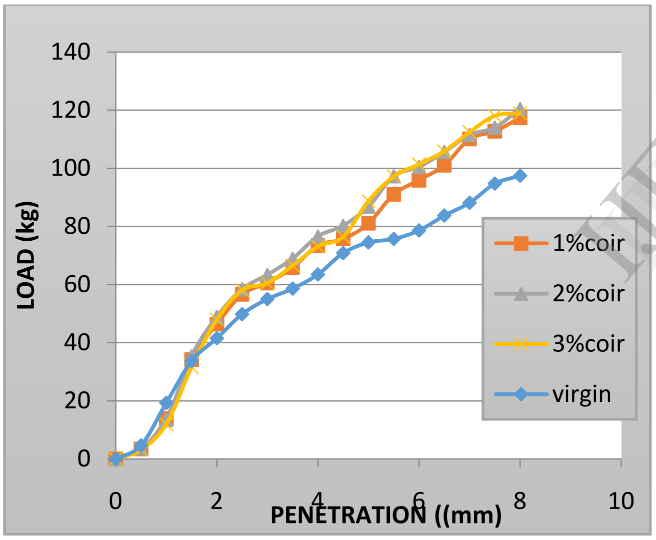
S. No.	Penetration(mm)	Proving ring reading (div)	Load (kg)
1	0.0	0	0
2	0.5	2.6	3.176
3	1	9.8	11.95
4	1.5	26	31.92
5	2.0	39	47.98
6	2.5	47.6	58.072
7	3.0	49.8	60.5
8	3.5	54.8	66.556
9	4.0	60.2	73.124
10	4.5	63	76.46
11	5.0	72.6	85.52
12	5.5	80	97.2



CBR value corresponding to 2.5mm penetration =(58.072/1370)x100 = 4.24
CBR value corresponding to 5.0mm penetration =(85.2/2055)x100 = 4.14
Hence the CBR value is 4.24

17. COMPARATIVE STUDY OF VIRGIN SOIL AND FIBRE REINFORCED SOIL

Penetration (mm)	CBR VALUE			
	Virgin soil	Soil +1% of coir fibre reinforcement	Soil +2% of coir fibre reinforcement	Soil +3% of coir fibre reinforcement
2.5	3.63	4.13	4.27	4.24
5.0	3.62	3.94	4.23	4.14



- The CBR value of the virgin soil is very poor. This value increases with addition of coir fibre up to 2% by weight of soil.
- The increase in penetration resistance of reinforced soil is attributed to increase in interlocking of particles between the fibre elements and bond between fibres and soil particles.
- The optimum fibre content of the soil is found to be 2%. Beyond this range there is no significant increase in the CBR value.

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