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USE OF COIR GEOTEXTILE AND SYNTHETIC FIBRE TO INCREASE THE STRENGTH OF SOIL

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CHAPTER 1

INTRODUCTION

The development of transportation infrastructure is the key to overall development of a country. For countries like India, where resources are limited, the importance of rural / unpaved roads is to be highly emphasized. The subgrade, which is the bottom most layer ofthe pavement, is made up of compacted soil and so also for the highway and railway embankments. The road alignment is decided based on many factors of which one is the availability of good soil along the proposed alignment. In early days, areas having weak soil deposits were avoided while fixing up the alignment. But with scarcity of land and other resources, we do not have the choice of land and hence roads and embankments have to be built on weak soil deposits. These problematic soils have one or more of the short comings viz., low shear strength, high compressibility, low hydraulic conductivity, swelling and shrinkage, susceptibility to frost action etc., and hence are associated with problems such as low bearing capacity, high settlement, high seepage loss, liquefaction during earthquake and instability of foundation excavation. In such cases, it is often impossible to build a stable base course over soft subgrade, without losing expensive base material which penetrates into the soft subgrade soil and hence a ground improvement method has to be resorted to.

Ground improvement is a general term used for the modification of soil to enhance the strength and other engineering properties. There are many methods of ground improvement such as using additives (like cement, lime etc.), compaction (both static and dynamic), thermal stabilization etc. One of the methods, which got momentum in recent years, is the concept of reinforced soil. Though the principle was not clearly enunciated, people have used techniques of reinforcing earth for centuries. With the development in the field of polymer technology, a wide variety of geosynthetic materials have come up. Geosynthetics, both natural and polymeric, establish a family of geomaterials, which are used in a wide variety of civil engineering applications. According to ASTM D4439 (2004) a geosynthetic is defined as "a planar product manufactured from polymeric material, used with soil, rock, earth or other geotechnical related materials, as an integral part of a human made project, structure or system". There are eight types of geosynthetics, namely, geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, geopipes, geofoams and geo composites (Koemer, 2005). These products generally have a long life and do not undergo biological degradation, but are liable to create environmental problems in long run. Geotextiles form one of the largest groups of geosynthetics. Its growth rate in the industry during the past fifteen years has been nothing short of awesome. They are indeed textiles in the traditional sense, consisting mainly of synthetic fibres, though natural fibres are also used for manufacturing. They can be Woven or Non-woven type. There are enormous specific application areas for geotextiles. Even though, the fabric always performs at least one of the five discrete functions. viz., separation, reinforcement, filtration, drainage and moisture barrier (when impregnated). One of the most popular applications of these materials is in the construction of pavements and embankments on soft soil. The consumption of polymeric geotextiles in India is insignificant compared to the worldwide consumption. The main factor inhibiting the use of geotextiles on a large scale in India is their high cost (Rao and Balan, 1994). In addition to the low cost of natural fibres, the growing concern over the impact of the use and disposal of synthetic materials has recently led to a renowned interest in the possible advantages of natural geotextiles.

Coir geotextiles with Indianised connotation "Coir Bhoovastra", a generic member of the geosynthetic family, is made from coconut fibre extracted from the husks of coconut fruit. Like their polymeric counter parts, coir geotextiles can also be synthesised for specific applications in civil engineering like erosion control, ground improvement, etc. (Rao and Balan, 2000).

The effect of fibre reinforcement on the stress-strain behaviour, strength parameters of compacted mixes has been evaluated through a series of Compaction Test, CBR test. The test results show that the inclusions of fibre reinforcement are very efficient in increasing the failure load.

In the present study, an attempt has therefore been made to carry out CBR tests in Laboratory, keeping soil, synthetic fibre (Recron 3s) and woven geotextile in standard CBR mould with proper compaction and with different configuration of soil and synthetic fibre (Recron 3s), by varying their composition and placing the geotextile sheet at different depths.

CHAPTER 2

SYNTHETIC FIBRE

REINFORCING MATERIAL

General

Basic principles of soil reinforcement already existing in nature and are demonstrated by animals, plants and birds. The modern form of the soil reinforcement was first applied by Vidal (1969). Based on the Vidal"s concept the interaction between soil and the reinforcing horizontal member is solely by friction generated by gravity.

Soil stability is one of the most important topics in geotechnical engineering practices. With frequent failures of soil mass, whether it is on slope or level ground, have proved to be costly in terms of both life and property. Various soil stabilisation techniques including fibre reinforcement have been in use for a while and the results in some of them has been quite satisfactory. Soil reinforcement is defined as a technique to improve the engineering characteristics of soil. The process of soil helps to achieve the required properties in a soil needed for the construction work. A number of materials have been reported to be successfully used as reinforcements such as steels, geofabrics, geogrids, aluminum, glass fibre, wood, rubber and concrete. In developed countries polypropylene based synthetic fibres and grids are now preferred due to their availability with desired properties and durability. The durability of reinforcing materials is shown in. However, they are yet to be used widely in India as they are more costly. The reinforcement may take the form of strips, grids, sheet materials, rope and other combinations. The major requirements of the reinforcing materials are strength, durability, ease of handling, high adhesion or friction with soil and availability at low-cost.

The man made polymers are highly restraint to bacteria, alkalis and acid. Degradation characteristics of polymers are indicated in. Polyamides have a very good mechanical characteristic including excellent resistance to abrasion and absolute imperviousness to rotting. It can withstand high temperature without its performance being affected. However, their performance deteriorates on wetting.

Reainforcing Material	PH	Value	Maximum Chloride content	Maximum Total Sulphate (SO_3)	Maximum resistivity (ohm/cm)
	Min	Min			
Aluminium	6	8	0.05	0.5	3000
Copper	5	9	0.05	0.5	2000
Galvanised Steel	6	9	0.05	0.5	5000
Stainless Steel	5	10	0.05	0.5	3000
Geotextiles	-	-	-	Not affected	-
Geogrid	-	-	-	Not affected	-

Durability of Reinforcing Material

Polyesters have very good resistance to abrasion and its behaviour in water is satisfactory. It has high modulus of elasticity and has only negligible creep. It can also withstand considerable temperature increase.

Resistance to attack by	Types of Synthetics				
	Polyester	**Polyamide**	**Polyethylene**	**Polypropylene**	**PVC**
Fungus	Poor	Good	Excellent	Good	Good
Insects	Fair	Fair	Excellent	Fair	Good
Vermin	Fair	Fair	Excellent	Fair	Good
Mineral	Good	Fair	Excellent	Excellent	Good
Alkalies	Fair	Good	Excellent	Excellent	Good
Dry heat	Good	Fair	Fair	Fair	Good
Moist heat	Fair	Good	Fair	Fair	Fair
Oxidizing agent	Good	Fair	Poor	Good	-
Abrasion	Excellent	Excellent	Good	Good	Excellent
Ultraviolet light	Excellent	Good	Fair	Good	Excellent

Degradation Resistances of Various Synthetic Fibres

Polypropylene is also rot-proof, water and most chemical reagents do not affect its performance. It has only fair resistance to abrasion and is affected by temperature increase. It has only a tendency to creep. However, a majority of geo-fabrics is manufactured from polypropylene.

For use as a reinforcing material, the geo-fabrics should possess a high modulus elasticity, low elongation and satisfactory puncture strength. For use as an asphalted overlay material, adsorption qualities may also be essential.

Resistance to ultraviolet radiations and surface conformity should be considered for all jobs.

Soil has used as a construction material from times immortal. Being poor in mechanical properties, it has been putting, challenge to civil engineering‟s to improve its properties depending upon the requirement which varies from site to site and economic constrains. There are many techniques employed to improve the engineering and mechanical properties of soil can be put into five major categories:

(a) Soil stabilization
(b) Reinforced earth
(c) Soil nailing
(d) Texsol
(e) Fibre reinforced oil or ply soil

Fibre Reinforced Soil (Ply Soil)

Randomly distributed fibres reinforced soil termed as RDFS is among the latest ground improvement techniques in which fibres of desired type and quantity are added in soil, mixed randomly and laid in the position after compaction. Thus, the method of preparation of RDFS is similar to conventional stabilization techniques. RDFS is different from the other soil – reinforcing methods in its orientation. In reinforced earth, the reinforcement in the form of strips, sheets, etc. is laid horizontally at specific intervals, where as in RDFS fibres are mixed randomly in soil thus making a homogenous mass and maintain the isotropy in strength. Modern geotechnical engineering has focused on the use of planar reinforcement (e.g. metal strips, sheet of synthetic fabrics). However reinforcement of soil with discrete fibres is still a relatively new technique in geotechnical project.

Concepts involving the reinforcement of soils using fibres have been used since ancient times. For example, early civilizations added straws and plant roots to soil bricks to improve their properties, although the reinforcing mechanism may have not been fully understood. While building the Great Wall of China, the clay soil was mixed with tamarisk branches. The ancient method of addition of straw of wheat locally called “Turi” to the clay mud plaster is still very popular in villages. Improvement of soil by trees roots is similar to the work fibres. Gray (1947, 1978), Waldron (19770 and Wu et al. (1988) reported that plant roots increase the shear strength of the soil and, consequently the stability of natural slopes. Synthetic fibres have been used since the late 1980s, when the initial studies using polymeric fibres were conducted. Specially, triaxial compression tests, unconfined compression tests, direct shear tests and CBR tests had been conducted to study the effect of fibre reinforcement on strength characteristics and other engineering properties of RDFS. During last twenty –five years, much work has been done on strength deformation behaviour of RDFS and it has been established beyond doubt that addition of fibre in soil improves the overall engineering performance of soil. Among the notable properties that improve are greater extensibility, small loss of post peak strength, isotropy in strength and absence of planes of weakness. RDFS has been used in many civil engineering projects in various countries in the recent past and the further research is in progress for many hidden aspects of it. RDFS is effective in all types of soil (i.e .sand, silt and clay)

Basic Mechanism of RDFS

Randomly oriented discrete inclusions incorporated into soil improve its load – deformation behavior by interacting with the soil particles mechanically through surface friction and also by interlocking. The function of the bond or interlock is transfer the stress from the soil to the discrete inclusions by mobilizing the tensile strength of discrete inclusion. Thus, fiber- reinforcement works as frictional and tension resistance elements.

Applications

When designing civil engineering structures, the function to be performed have to be analyzed first, after those suitable materials and products can be selected. When geosynthetics are provided, the soil structure requires a strong, relatively stiff and preferably water permeable material. 1.4 gives functional applications of geosynthetics.

Application	Primary Function	Products
Sub grade Stabilization	Separation/Reinforcement/Filtrati On	Geotextiles/Geogrid
Railroad Track Bed Stabilization	Drainage /Separation Filtration	Geotextiles/Geogrid
Sedimentation Control Silt	Sediment Retention	Geotextile
Fence	Filtration/separation	
Asphalt overlay	Stress Reliving layer/ Waterproofing	Geogrid/ Geotextiles
Soil reinforcement /Embankments/Steep slope/Vertical walls	Reinforcement	Geotextiles/Geogrid
Erosion control filter	Filtration Separation	Geogrid/ Geotextiles
Geomembrane protection	Protection/cushion	Geomembrane
Subsurface drainage	Filtration/Fluid transmission	Prefabricated drainage composites
Surfacial erosion control	Turf reinforcement	Erosion control mats

Geosynthetics Application Summary Table

MATERIAL USED

Source of Geo-Fibres (Recron-3s)

Geo-fibre used for the test will buy from the market seal packed having size 12mm. The fibre used for reinforced Fly Ash specimens was a polyester fibre (Recron-3s). These fibres are made from polymerization of pure teraphthalic acid and Mono Ethylene Glycol using a catalyst. These fibres were found to be widely used in concrete technology.

S. No.	Properties	Description/ Characteristics
1	Material	Polypropylene
2	Type	Fibrillated
3	Shape	Flat-Narrow
4	Colour	White
5	Specific Gravity	1.334
6	Tensile Strength	$4.55x10^5$ KPa
7	Young"s Modulus	$48.26x10^5$ KPa
8	Elongation at Break	20%
9	Length Evaluated	12 mm
10	Denier(d)	1000
11	Aspect ratio	100
12	Water Absorption	85%
13	Melting Point	>250
14	Alkali Resistance	Good
15	Acidic Resistance	Excellent

Properties of Synthetic Fibre (Recron 3s)

Note: Denier is a unit of measure for linear mass density of fibers. It is defined as the mass in grams per 9000 m.

Role of RECRON-3s

- **Controls Cracking:**

RECRON 3s prevents the shrinkage cracks developed during curing making the structure/plaster/component inherently stronger. Further when the loads imposed on concrete approach that for failure, cracks will propagate, sometimes rapidly. Addition of

RECRON 3s in concrete and plaster prevents/arrests cracking caused by volume change (expansion & contraction).

- **Reduces water permeability:**

A cement structure free from such micro cracks prevents water or moisture from entering and migrating throughout the concrete. This in turn helps prevent the corrosion of steel used for primary reinforcement in the structure. This in turn improves longevity of the structure.

- **Reduces Rebound In Concrete - Brings Direct Saving & Gain:**

RECRON 3s fibres reduce rebound "splattering" of concrete and shotcrete. The raw material wastage reduces & results in direct saving in terms of raw material. More importantly it saves a great deal of labour employed for the job, which could be completed earlier.

- **Increases Flexibility:**

The modulus of elasticity of RECRON 3s is high with respect to the modulus of elasticity of the concrete or mortar binder. The RECRON 3s fibers help increase flexural strength.

- **Safety and easy to use**

RECRON 3s fibres are environmental friendly and non hazardous. They easily disperse and separate in the mix.

Fig. 4.1 View of the Synthetic Fibre Used in the Study

CHAPTER 3

MATERIAL CHARACTERISATION

DETERMINATION OF GEOTECHNICAL PROPERTIES

Determination of Specific Gravity

The specific gravity of soil is determined according to IS: 2720 (Part-III, section-1) 1980.

Determination of Grain Size Distribution

For determination of grain size distribution, the soil was passed through test sieve having an opening size 75µ. Sieve analysis was conducted for coarser particles as per IS: 2720 part (IV), 1975 and hydrometer analysis was conducted for finer particles as per IS: 2720 part (IV).

Determination of Engineering Properties

- **Moisture Content Dry Density Relationship**

The moisture content, dry density relationships were found by using compaction tests as per IS: 2720 (Part 7) 1980. For this test, soil was mixed with required amount of water and the wet sample was compacted in proctor mould either in three or five equal layers using standard proctor rammer of 2.6 kg. The moisture content of the compacted mixture was determined as per IS: 2720 (Part 2) 1973. From the dry density and moisture content relationship, optimum moisture content (OMC) and maximum dry density (MDD) were determined.

- **Determination of California Bearing Ratio**

Bearing ratio is one of the vital parameters, used in the evaluation of soil sub grades for both rigid and flexible pavements design. It is also an integral part of several pavement thickness design methods. To assess the suitability of soil a series of bearing ratio tests have been carried out unreinforced specimens. The bearing ratio tests are conducted in accordance with IS: 2720-16(1961). For this test cylindrical specimens were prepared corresponding to their MDD at OMC in a rigid metallic cylinder mould with an inside diameter of 150 mm and a height of 175 mm. A mechanical loading machine equipped with a movable base that moves at a uniform rate of 1.2 mm/min and a calibrated proving ring is used to record the load. For this, Static compaction is done by keeping the mould assembly in compression machine and compacted the soil by pressing the displacer disc till the level of the disc reaches the top of the mould. Keep the load for some time, and then release. Remove the displacer disc and then put it under testing machine.

EXPERIMENTAL PROGRAMMES

Liquid Limit Determination

Observation					Calculations		
No. of blows	**Can no.**	**Empty can weight (W1) (gm)**	**Can+ wet soil (W2) (gm)**	**Can+ dry soil (W3) (gm)**	**Weight of water (W2-W3) (gm)**	**Weight of dry soil (W3-W1) (gm)**	**Water content [w={(W2-W3)/(W3-W1)}x100] (%)**
9	1	16.11	30.82	27.68	3.14	11.57	27
19	2	14.30	27.32	24.65	2.67	10.35	26
27	3	11.24	22.84	20.53	2.31	9.29	25
37	4	16.26	29.03	26.54	2.49	10.28	24
43	5	14.67	23.28	21.64	1.64	6.97	23

Observation table for liquid limit

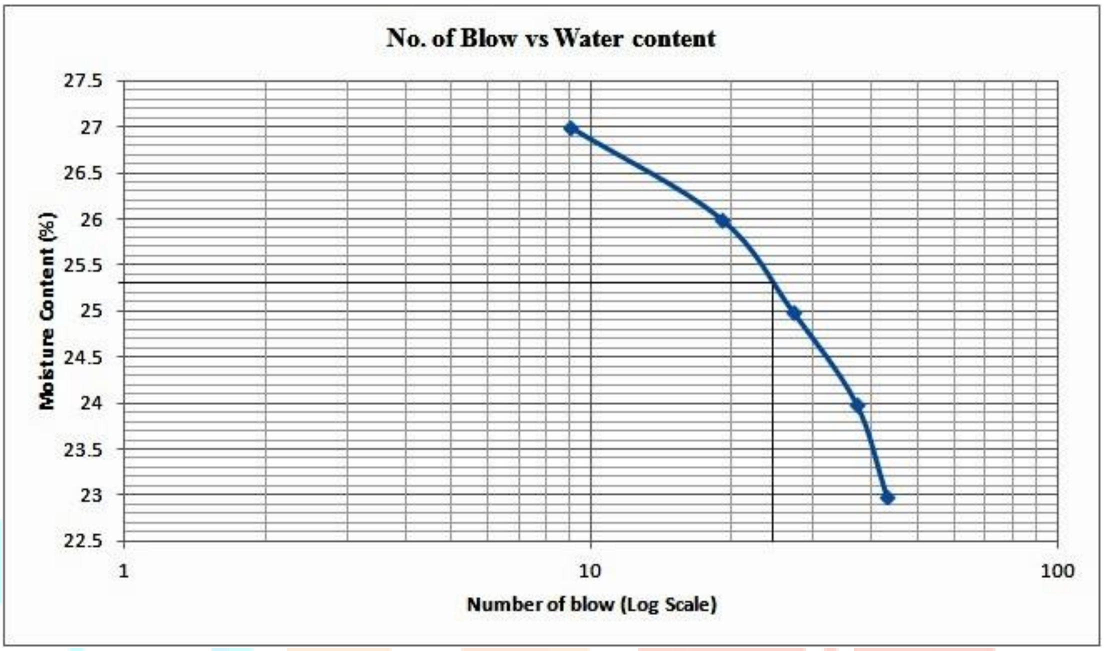

Fig 6.1 - Liquid limit curve

Liquid Limit is the water content at 25 blows. It can be seen from the curve that

Liquid Limit (LL) = **25.3%**

Plastic Limit Determination

Observations				Calculations		
Can no.	**Empty can weight (W1) (gm)**	**Weight of can + wet soil (W2) (gm)**	**Weight of can + dry soil (W3) (gm)**	**Weight of water (W2-W3) (gm)**	**Weight of dry soil (W3-W1) (gm)**	**Water content [w={(W2-W3)/(W3-W1)}x100] (%)**
1	11.24	15.93	15.10	0.83	3.86	21.50
2	14.30	18.28	17.58	0.70	3.28	21.30
3	17.17	21.60	20.83	0.77	3.66	21.10

Observation table for plastic limit

Plastic Limit (PL) = Average w % = (21.50+21.30+21.10)/ **= 21.3 %**

Final Result:

Liquid Limit (LL) = 25.3%

Plastic Limit (PL) = 21.3%

Plasticity Index (PI) = (LL – PL) = (25.3 – 21.3) = 4.0 %

Specific Gravity Determination

Sample No.	Weight of bottle (gm)	Weight of bottle + Distilled Water (gm)	Weight of bottle + half filled material (gm)	Weight of Bottle + half filled material + Distilled Water (gm)	Specific Gravity
1	672	1571	846	1661	2.58
2	672	1571	863	1678	2.69
3	672	1571	846	1672	2.55

Observation table for Specific gravity

Result: Specific gravity of solids at 27 degree Celsius = (2.58+2.69+2.55)/3

= **2.60**

Grain Size Analysis

Total weight of soil = 500 gm

IS Sieve opening, (mm)	Retained Weight (gm)	Cumulative Retained weight (gm)	Cumulative Percentage Retained	Cumulative percentage Finer
4.75	0	0	0	100
2.00	7.50	7.50	1.5	98.5
1.00	5.85	13.35	2.67	97.33
0.600	5.08	18.43	3.69	96.31
0.425	9.11	27.54	5.51	94.49
0.075	60.36	87.9	17.58	82.42
Pan	412.10	500	100	-

Observation table for grain size analysis

HYDROMETER ANALYSIS

Time	Elapsed time (T) (minute)	Tempeter (C)	Hydrometer reading (Ra)	Meniscus Correction (Cm)	R'= (Ra + Cm)	Effective length, L	K	L/T	$(L/T)^{1/2}$
10:50 A.M.	0	20	Above	-	-	-	-	-	-
10:51 A.M.	1	20	40	1	41	9.6	0.01386	9.6000	3.09839
10:52 A.M.	2	20	35	1	36	10.4	0.01386	5.2000	2.28035
10:55 A.M.	5	20	29	1	30	11.4	0.01386	2.2800	1.50997
11:00 A.M.	10	20	25	1	26	12.0	0.01386	1.2000	1.09545
11:05 A.M.	15	20	23	1	24	12.4	0.01386	0.8267	0.90921
11:20 A.M.	30	20	21	1	22	12.7	0.01386	0.4233	0.65064
11:35 A.M.	45	20	20	1	21	12.9	0.01386	0.2867	0.53541
11:50 A.M.	60	20	19	1	20	13.0	0.01386	0.2167	0.46547
12:50 P.M.	120	21	17	1	18	13.3	0.01369	0.1108	0.33292
02:50 P.M.	240	21	14	1	15	13.8	0.01369	0.0575	0.23979
10:50 A.M.	1440	19	11	1	12	14.2	0.01403	0.0099	0.09930

Observation table for Hydrometer analysis

Particle size $D = K(L/t)^{1/2}$ (mm)	Temperature correction (Ct)	Zero correction	Correction factor 'a'	Rc = Ra – zero correction+Ct	Percentage finer N'	F(0.075) (% finer for 75 micron)	Finer or total weight (N)
-	-	-	-	-	-	-	-
0.04294	0	6	1.01	34.0	68.7	82.42	56.62
0.03161	0	6	1.01	29.0	58.6	82.42	48.30
0.02093	0	6	1.01	23.0	46.5	82.42	38.33
0.01518	0	6	1.01	19.0	38.4	82.42	31.65
0.01260	0	6	1.01	17.0	34.3	82.42	28.27
0.00902	0	6	1.01	15.0	30.3	82.42	24.97
0.00742	0	6	1.01	14.0	28.3	82.42	23.33
0.00645	0	6	1.01	13.0	26.3	82.42	21.68
0.00456	0.2	6	1.01	11.2	22.6	82.42	18.63
0.00328	0.2	6	1.01	8.2	16.6	82.42	13.68
0.00139	-0.3	6	1.01	4.7	9.5	82.42	7.86

Observations and calculation

Diameter in mm	% finer
4.7500	100
2.0000	98.50
1.0000	97.33
0.6000	96.31
0.4250	94.49
0.0750	82.42
0.0429	56.62
0.0316	48.30
0.0209	38.33
0.0152	31.65
0.0126	28.27
0.0090	24.97
0.0074	23.33
0.0065	21.68
0.0046	18.63
0.0033	13.68
0.0014	7.86

Observation table for Grain size analysis curve

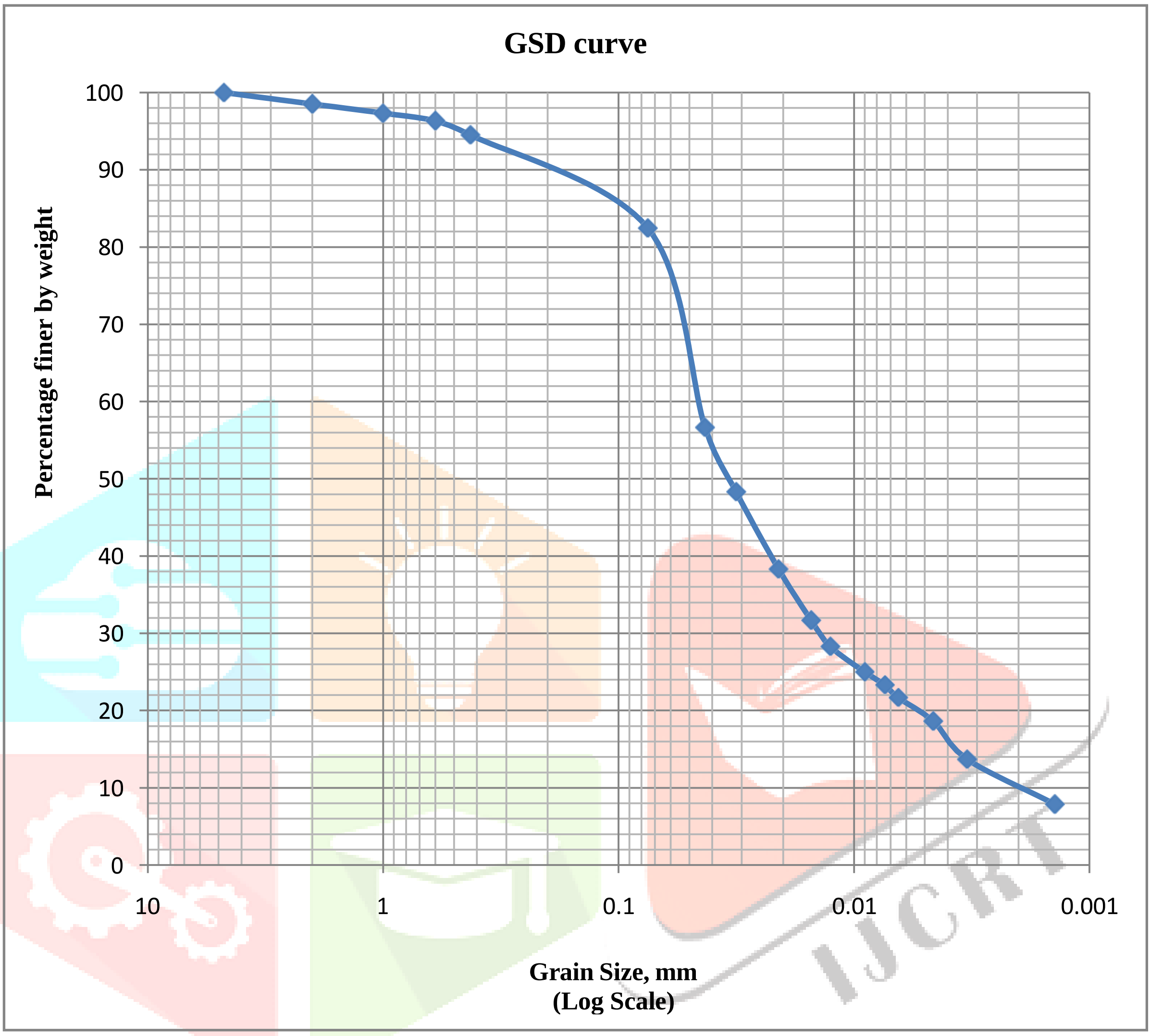

Fig 6.2 - Grain size analysis curve

Optimum Moisture Content

Weight of soil = 2.5 kg.
Mould wt. = 4.660
3 layers and number of blows = 25
Hammer wt. = 2.6 kg
Water mixing = 10 % of the soil sample [{(2.5x10)/100} = 0.25 litre = 250 ml of water

Mould: D=10cm, H= 12.73cm

Volume of mould = 1000 cc

Determination Number	1	2	3	4	5	6
Weight of mould, W_m (gm)	4660	4660	4660	4660	4660	4660
Weight of Mould + Compacted Soil, W (gm)	6360	6460	6590	6680	6620	6620
Moisture Container Number	135	196	152	200	129	118
Weight of moisture container W_1 (gm)	16.11	11.24	11.16	14.02	15.51	16.26
Weight of container + wet soil W_2 (gm)	32.60	29.13	34.88	37.54	39.89	41.02
Weight of container + dry soil W_3 (gm)	31.08	27..34	32.15	34.47	35.99	36.79
Wet Density, $\gamma_m = (W-W_m)/V_m$	1.70	1.80	1.93	2.02	1.96	1.93
Moisture Content, w% = $(W_2-W_3)100/(W_3-W_1)$	10.15	11.11	13.01	15.01	19.04	20.60
Dry Density, $\gamma_d = \gamma_m/(1+w/100)$	1.54	1.62	1.71	1.76	1.65	1.60

observation table for OMCCurve

between Water content and dry density:

Water content (w) in %	Dry density in g/cc
10.15	1.54
11.11	1.62
13.01	1.71
15.01	1.76
19.04	1.65
20.60	1.60

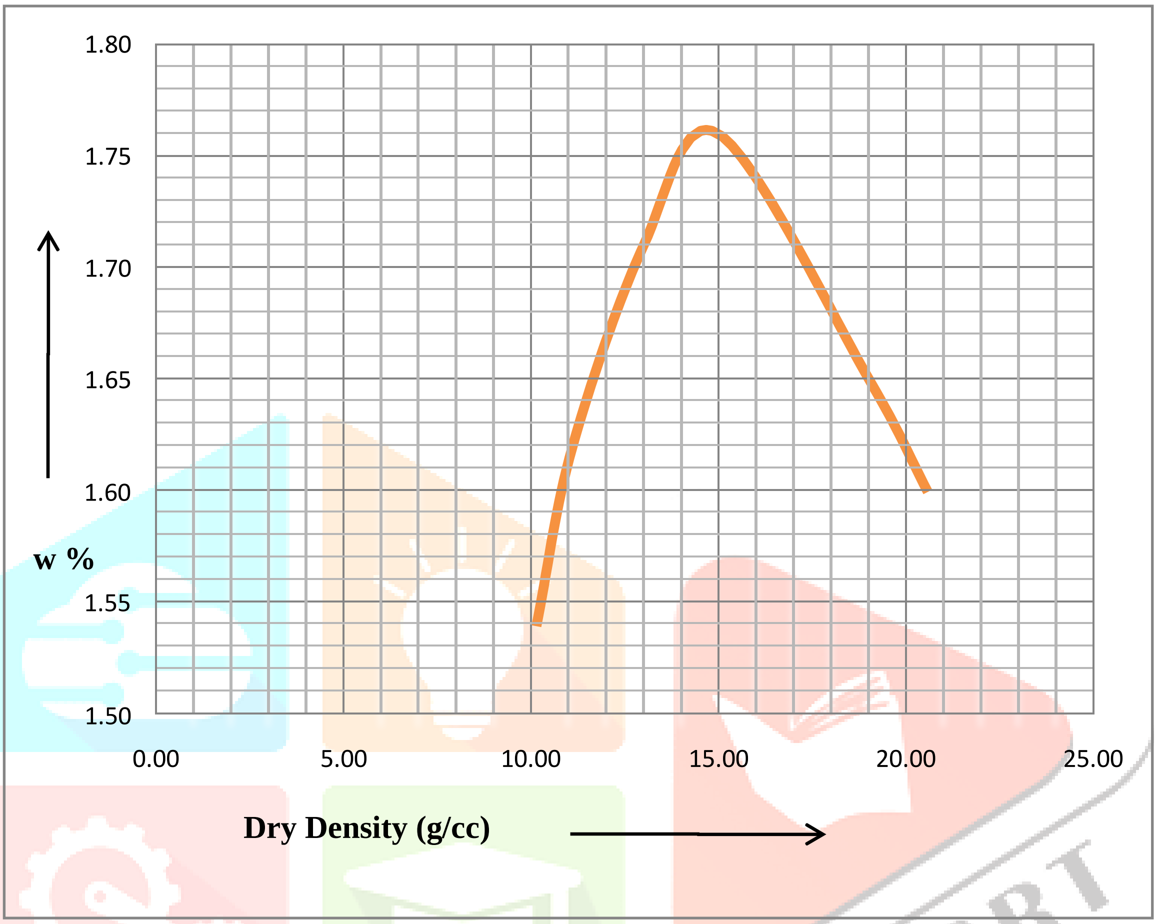

Fig 6.3 - Curve between water content and Dry density

Result: The water content of the sample = **15% (approx)** and Draw a curve between water content and dry density

Physical Properties of Soil

Physical Properties		**Values**
Grain	Gravel size (%)	0
Size distribution	Sand size (%)	17.58
	Silt (%)	71.65
	Clay (%)	10.77
Specific gravity		2.60
Liquid limit (%)		25.3
Plastic limit (%)		21.3
Plasticity Index (%)		4
Maximum dry density (MDD) (gm/cc)		1.76
Optimum moisture content (OMC) (%)		15%

With the help of the plasticity chart, soil classified as following:

- More than half of material is smaller than 75 micron IS sieve size.
- Silts and clays with low compressibility and liquid limit less than 35% with limits plotted below „A"-Line
- **Group Letter Symbol** - ML

CBR DETERMINATION

CBR determination of soil is done in the following investigation.
OMC = 15%
Soil sample = 5.50 kg
Mixing water = 5.50 x 15% = 0.825 litre = 825 ml

3 layers and number of blows = 56

Hammer weight =2.6 kg (light compaction)

Penetration (mm)	Proving Ring (Load) (kg-f)		
	Sample (1)	Sample (2)	Sample (3)
0.5	14	12	17
1.0	22	19	22
1.5	26	24	26
2.0	31	29	31
2.5	40	35	37
3.0	46	41	41
3.5	51	49	46
4.0	58	53	51
4.5	63	61	56
5.0	69	66	64
5.5	73	71	68
6.0	78	78	73
6.5	85	85	80
7.0	90	93	88
7.5	98	100	95
8.0	103	105	100
8.5	110	110	110
9.0	115	117	115
9.5	120	122	122
10.0	125	127	129
10.5	132	134	134
11.0	139	142	142
11.5	147	147	149
12.0	154	152	156

Observations of soil

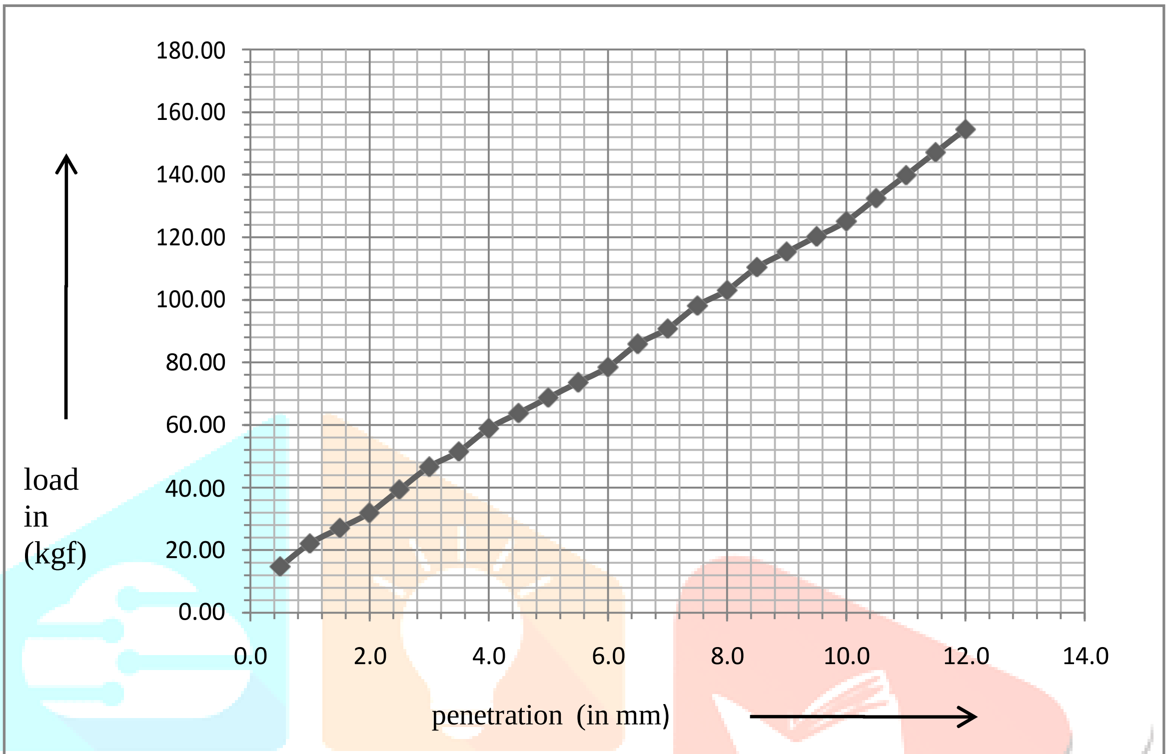

Fig 6.4 (a) Sample 1

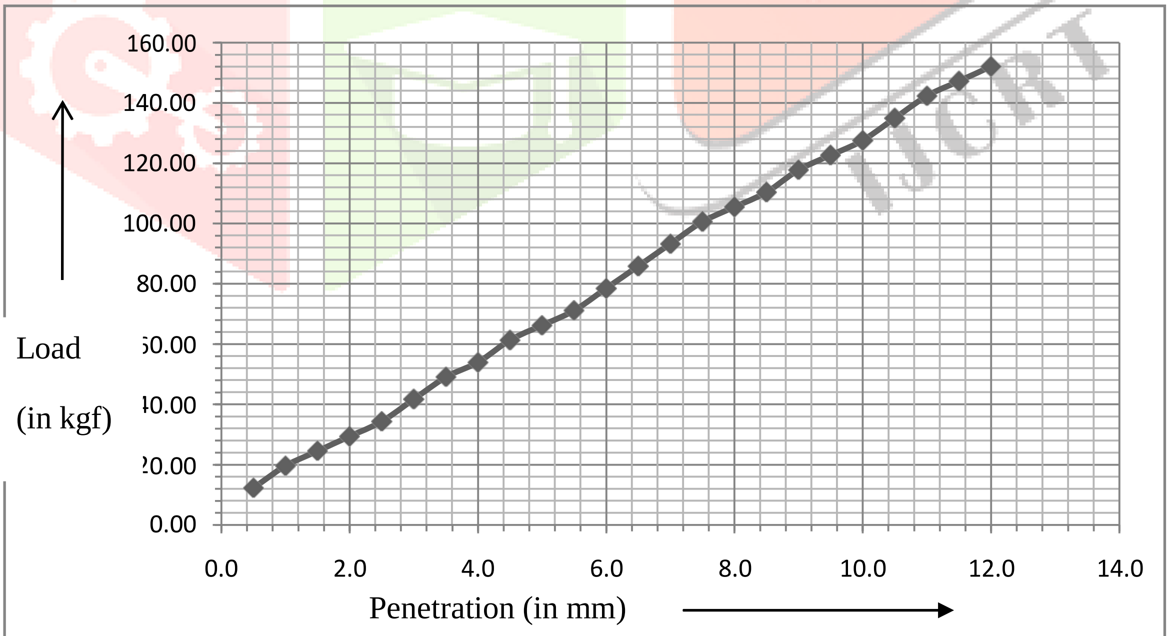

Fig 6.4 (b) Sample 2

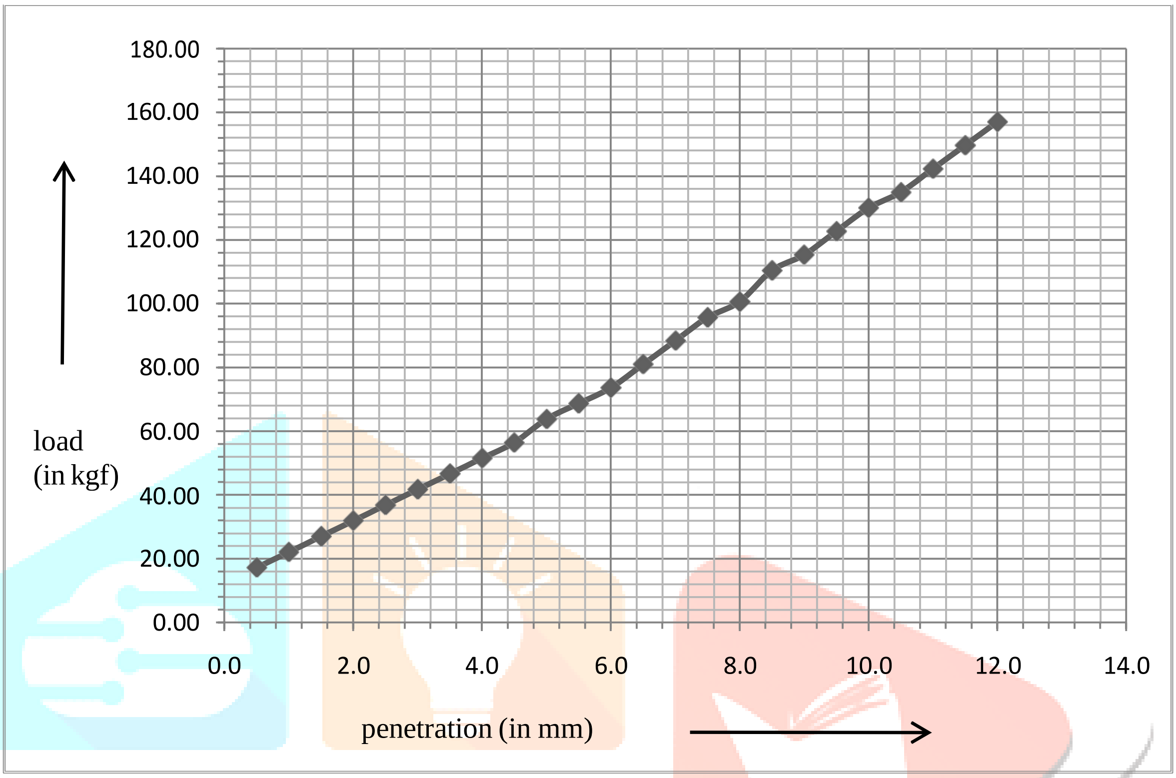

Fig 6.4 (c) Sample 3

CALCULATION

Standard Values of load for different penetration

Sr. No.	Penetration of plunger (mm)	Standard load (Kg-f)
1	2.5	1370
2	5	2055
3	7.5	2630
4	10	3180
5	12.5	3600

CBR

Sample (1)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	40	1370	2.91	3.35
2	5.0	69	2055	3.35	

Sample (2)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	35	1370	2.55	3.21
2	5.0	66	2055	3.21	

Sample (3)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	37	1370	2.70	3.11
2	5.0	64	2055	3.11	

Final CBR is **= (3.35+3.21+3.11)/3**

= 3.22%

CHAPTER 4

STRENGTH BEHAVIOUR OF SOIL WITH SYNTHETIC FIBRE

INTRODUCTION

Polypropylene fiber is the most common synthetic fiber used as a reinforcement material for the soil improvement and concrete. This fiber has properties of hydrophobic, non-corrosive resistance over chemicals, alkalis and chlorides. Reinforcing soil with polypropylene fiber can increase CBR value UCS and shear strength.

In the present study Recron 3S fibre which is a polypropylene fibre is used as a stabilizer to improve the CBR of the soil. Soil stabilization is a useful technique for improving the performance (strength) of subgrade soil.

A series of Light compaction, CBR (unsoaked) were carried out on the soil and mixed with Recron 3S fibre in 0.25%, 0.50%, 0.75 % and 1.0% by weight of dry soil.

SOIL BEHAVIOR WITH RECRON 3S

1. **CBR Determination using 0.25% of polypropylene fiber as reinforcement in soil**

OMC = 15%

Soil sample = 5.50 kg

Mixing water = 5.50 x 15% = 0.825 litre = 825 ml

3 layers and number of blows = 56

Hammer weight =2.6 kg (light compaction)

penetration	Proving Ring		
(mm)	(Load)		
	(kg-f)		
	Sample (1)	Sample (2)	Sample (3)
0.5	38	37	38
1	44	44	45
1.5	49	48	50
2	53	51	54
2.5	58	56	59
3	66	65	66
3.5	73	73	73
4	79	79	80
4.5	85	83	86
5	93	91	94
5.5	96	96	97
6	104	103	105
6.5	110	108	112
7	116	115	116
7.5	121	121	122
8	125	125	126
8.5	129	129	130
9	135	134	136
9.5	141	140	142
10	148	146	148
10.5	154	152	155
11	160	159	160
11.5	166	164	167
12	173	171	174

Observations of soil

CALCULATION

Standard Values of load for different penetration

Sr. No.	Penetration of plunger (mm)	Standard load (Kg-f)
1	2.5	1370
2	5	2055
3	7.5	2630
4	10	3180
5	12.5	3600

CBR

Sample (1)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	58	1370	4.23	4.52
2	5.0	93	2055	4.52	

Sample (2)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	56	1370	4.08	4.42
2	5.0	91	2055	4.42	

Sample (3)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	59	1370	4.30	4.57
2	5.0	94	2055	4.57	

Final CBR is = (4.52 + 4.42 + 4.57)/3 = **4.50%**

2. CBR Determination using 0. 50% of polypropylene fiber as reinforcement in soil

OMC = 15%
Soil sample = 5.50 kg
Mixing water = 5.50 x 15% = 0.825 litre = 825 ml
3 layers and number of blows = 56
Hammer weight =2.6 kg (light compaction)

penetration (mm)	Proving Ring (Load) (kg-f)		
	Sample (1)	Sample (2)	Sample (3)
0.5	51	50	51
1	56	56	57
1.5	60	59	60
2	65	64	66
2.5	71	70	71
3	78	77	78
3.5	85	85	87
4	91	90	93
4.5	97	96	99
5	108	107	110
5.5	115	113	114
6	123	122	123
6.5	129	129	130
7	134	133	135
7.5	140	140	142
8	148	147	148
8.5	153	153	155
9	160	159	162
9.5	166	166	167
10	172	170	172
10.5	177	176	178
11	185	185	186
11.5	190	190	192
12	196	193	197

Observations of soil

CALCULATION

Standard Values of load for different penetration

Sr. No.	Penetration of plunger (mm)	Standard load (Kg-f)
1	2.5	1370
2	5	2055
3	7.5	2630
4	10	3180
5	12.5	3600

CBR

Sample (1)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	71	1370	5.18	5.25
2	5.0	108	2055	5.25	

Sample (2)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	70	1370	5.10	5.20
2	5.0	107	2055	5.20	

Sample (3)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	71	1370	5.18	5.35
2	5.0	110	2055	5.35	

Final CBR is = (5.25 + 5.20 +5.35)/3 = **5.26%**

3. CBR Determination using 0.75% of polypropylene fiber as reinforcement in soil

OMC = 15%
Soil sample = 5.50 kg
Mixing water = 5.50 x 15% = 0.825 litre = 825 ml
3 layers and number of blows = 56
Hammer weight =2.6 kg (light compaction)

penetration	Proving Ring		
	(Load)		
(mm)	(kg-f)		
	Sample (1)	Sample (2)	Sample (3)
0.5	49	48	49
1	55	55	56
1.5	61	60	62
2	69	67	70
2.5	75	73	76
3	83	80	84
3.5	90	87	90
4	97	95	97
4.5	105	103	106
5	114	111	116
5.5	121	119	122
6	128	125	128
6.5	135	133	136
7	141	140	142
7.5	149	148	150
8	155	153	156
8.5	161	160	161
9	168	167	168
9.5	175	173	175
10	182	181	183
10.5	189	189	190
11	196	196	197
11.5	201	201	203
12	208	208	210

Observations of soil

CALCULATION

Standard Values of load for different penetration

Sr. No.	Penetration of plunger (mm)	Standard load (Kg-f)
1	2.5	1370
2	5	2055
3	7.5	2630
4	10	3180
5	12.5	3600

CBR

Sample (1)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	75	1370	5.47	5.54
2	5.0	114	2055	5.54	

Sample (2)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	73	1370	5.32	5.40
2	5.0	111	2055	5.40	

Sample (3)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	76	1370	5.54	5.64
2	5.0	116	2055	5.64	

Final CBR is = (5.54 + 5.40 + 5.64)/3 = **5.52%**

4. CBR Determination using 1.0% of polypropylene fiber as reinforcement in soil

OMC = 15%
Soil sample = 5.50 kg
Mixing water = 5.50 x 15% = 0.825 litre = 825 ml
3 layers and number of blows = 56
Hammer weight =2.6 kg (light compaction)

penetration	Proving Ring		
(mm)	(Load)		
	(kg-f)		
	Sample (1)	Sample (2)	Sample (3)
0.5	54	53	54
1	59	59	61
1.5	65	64	66
2	73	71	74
2.5	81	79	83
3	89	88	90
3.5	97	95	98
4	107	107	108
4.5	115	114	116
5	122	121	125
5.5	130	129	131
6	137	136	138
6.5	144	144	145
7	151	150	152
7.5	159	159	160
8	166	165	167
8.5	173	172	175
9	179	178	180
9.5	187	186	188
10	195	193	196
10.5	201	200	201
11	209	208	210
11.5	216	216	217
12	222	221	224

Observations of soil

CALCULATION

Standard Values of load for different penetration

Sr. No.	Penetration of plunger (mm)	Standard load (Kg-f)
1	2.5	1370
2	5	2055
3	7.5	2630
4	10	3180
5	12.5	3600

CBR

Sample (1)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	81	1370	5.91	5.93
2	5.0	122	2055	5.93	

Sample (2)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	79	1370	5.76	5.88
2	5.0	121	2055	5.88	

Sample (3)

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	83	1370	6.05	6.08
2	5.0	125	2055	6.08	

Final CBR is = (5.93+5.88+6.08)/3 = **5.96%**

Fibre Content (%)	CBR Value	% Increase in CBR Value
0	3.22%	-
0.25	4.50%	39.75%
0.50	5.26%	63%
0.75	5.52%	71.42%
1	5.96%	85.09%

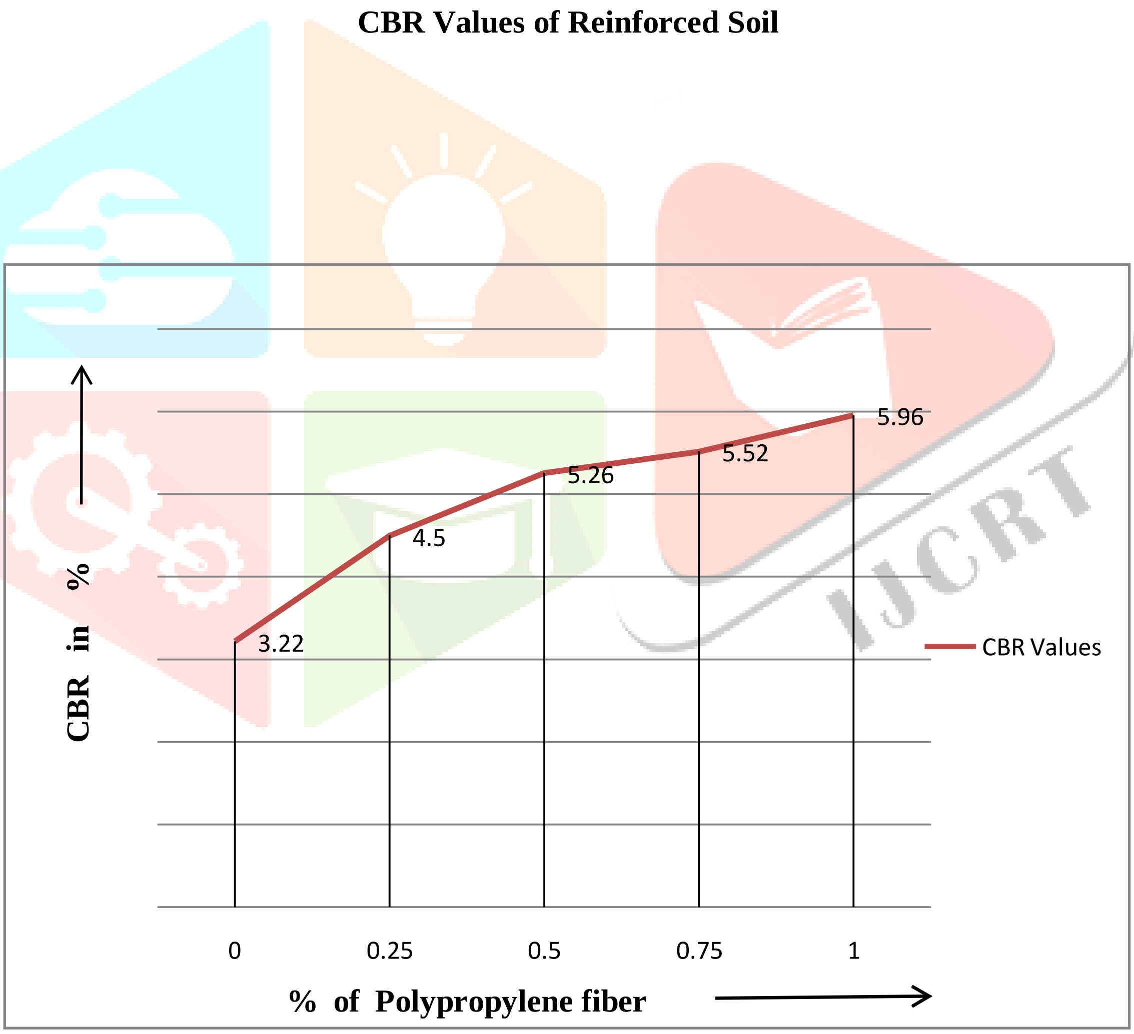

Fig 7.1 variation of CBR% with the variation of synthetic fibre

Amount of Polypropylene fiber (length of 12 mm) mixed with unreinforced soil varies from 0 to 1%. The result of this study shows that significant increase in CBR value with the inclusion of Polypropylene fiber up to **0.50%**, and then the *rate of increase* in CBR value decreases with further inclusion of fibers.

Hence in the further study 0.5% of Polypropylene fiber is taken as optimum fiber content.

CHAPTER 5

STRENGTH BEHAVIOUR OF COIR

GEOTEXTILE REINFORCED SOIL

INTRODUCTION

The behaviour of road surface depends on the strength of the fill material and the subgrade below it. Road construction over soft subgrade soil is a major issue affecting cost and scheduling of highway projects in regions where soft subgrades are common. The strength of the subgrade is most often expressed in terms of California Bearing Ratio (CBR), which is the ratio of test load to standard load at a specified penetration, by a standard plunger.

EXPERIMENTAL PROGFRAMME

The objective of this study was to find out the increase in strength mobilisation in terms of CBR values, by conducting CBR tests on the subgrade soil when reinforced with coir geotextiles placed at different positions. It was also aimed at in assessing the saving in aggregate thickness due to the use of coir geotextiles in unpaved roads.

1. **CBR Determination using 0.5% of polypropylene fiber and Non woven Geotextile at H/2 depth from top surface**

   OMC = 15%

   Soil sample = 5.50 kg

   Mixing water = 5.50 x 15% = 0.825 litre = 825 ml

   3 layers and number of blows = 56

   Hammer weight =2.6 kg (light compaction)

penetration (mm)	Proving Ring (Load) (kg-f) Sample (1)
0.5	56
1	65
1.5	73
2	79
2.5	84
3	90
3.5	97
4	106
4.5	116
5	122
5.5	128
6	136
6.5	142
7	150
7.5	156
8	161
8.5	168
9	175
9.5	183
10	190
10.5	197
11	203
11.5	210
12	218

Observations of soil

CBR

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	84	1370	6.13	**6.13**
2	5.0	122	2055	5.93	

2. **CBR Determination using 0.5% of polypropylene fiber and Non woven Geotextile at H/3 depth from top surface**

OMC = 15%

Soil sample = 5.50 kg

Mixing water = 5.50 x 15% = 0.825 litre = 825 ml

3 layers and number of blows = 56

Hammer weight =2.6 kg (light compaction)

penetration	Proving Ring
(mm)	(Load) (kg-f) Sample (1)
0.5	65
1	71
1.5	79
2	88
2.5	94
3	107
3.5	114
4	121
4.5	129
5	136
5.5	144
6	150
6.5	159
7	165
7.5	172
8	178
8.5	186
9	193
9.5	200
10	208
10.5	216
11	221
11.5	230
12	237

Observations of soil

CBR

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	94	1370	6.86	6.86
2	5.0	136	2055	6.61	

3. **CBR Determination using 0.5% of polypropylene fiber and Non wovenGeotextile at H/4 depth from top surface**

OMC = 15%

Soil sample = 5.50 kg

Mixing water = 5.50 x 15% = 0.825 litre = 825 ml3 layers

and number of blows = 56

Hammer weight =2.6 kg (light compaction)

penetration (mm)	**Proving Ring (Load) (kg-f) Sample (1)**
0.5	73
1	80
1.5	87
2	95
2.5	102
3	111
3.5	119
4	125
4.5	133
5	140
5.5	148
6	153
6.5	160

7	167
7.5	173
8	181
8.5	189
9	196
9.5	201
10	208
10.5	215
11	222
11.5	230
12	237

Observations of soil

CBR

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	102	1370	7.44	7.44
2	5.0	140	2055	6.81	

4. CBR Determination using 0.5% of polypropylene fiber and H2M8 Geotextile at H/2 depth from top surface

OMC = 15%

Soil sample = 5.50 kg

Mixing water = 5.50 x 15% = 0.825 litre = 825 ml

3 layers and number of blows = 56

Hammer weight =2.6 kg (light compaction)

penetration	Proving Ring
(mm)	(Load) (kg-f) Sample (1)
0.5	53
1	59
1.5	65
2	73
2.5	82
3	87
3.5	95
4	103
4.5	111
5	119
5.5	125
6	133
6.5	140
7	148
7.5	153
8	160
8.5	167
9	173
9.5	181
10	189
10.5	196
11	201
11.5	208
12	215

Observations of soil

CBR

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	82	1370	5.98	5.98
2	5.0	122	2055	5.93	

5. CBR Determination using 0.5% of polypropylene fiber and H2M8 Geotextile at H/3 depth from top surface

OMC = 15%
Soil sample = 5.50 kg
Mixing water = 5.50 x 15% = 0.825 litre = 825 ml
3 layers and number of blows = 56
Hammer weight =2.6 kg (light compaction)

penetration	Proving Ring
(mm)	(Load) (kg-f) Sample (1)
0.5	51
1	58
1.5	65
2	72
2.5	83
3	88
3.5	96
4	106
4.5	114
5	121
5.5	129
6	136
6.5	143
7	150
7.5	159
8	165
8.5	172
9	178
9.5	187
10	194
10.5	200
11	209
11.5	215
12	221

Observations of soil

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	83	1370	6.05	6.05
2	5.0	121	2055	5.88	

6. CBR Determination using 0.5% of polypropylene fiber and H2M8 Geotextile at H/4 depth from top surface

OMC = 15%

Soil sample = 5.50 kg

Mixing water = 5.50 x 15% = 0.825 litre = 825 ml

3 layers and number of blows = 56

Hammer weight =2.6 kg (light compaction)

penetration (mm)	Proving Ring (Load) (kg-f) Sample (1)
0.5	65
1	73
1.5	79
2	83
2.5	92
3	97
3.5	105
4	112
4.5	118
5	125
5.5	129
6	136
6.5	143
7	151

7.5	159

IJCRT

8	165
8.5	172
9	179
9.5	187
10	194
10.5	200
11	209
11.5	216
12	223

Observations of soil

CBR

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	92	1370	6.71	6.71
2	5.0	125	2055	6.08	

7. CBR Determination using 0.5% of polypropylene fiber and H2M6 Geotextile at H/2 depth from top surface

OMC = 15%

Soil sample = 5.50 kg

Mixing water = 5.50 x 15% = 0.825 litre = 825 ml

3 layers and number of blows = 56

Hammer weight =2.6 kg (light compaction)

penetration (mm)	**Proving Ring (Load) (kg-f) Sample (1)**
0.5	54
1	59
1.5	66
2	73
2.5	80
3	86
3.5	94
4	97
4.5	105
5	112
5.5	116
6	122
6.5	126
7	130
7.5	136
8	142
8.5	148
9	155
9.5	160
10	167
10.5	174
11	181
11.5	189
12	196

Observations of soil

CBR

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	82	1370	5.83	5.83

2	5.0	112	2055	5.45	

8. CBR Determination using 0.5% of polypropylene fiber and H2M6 Geotextile at H/3 depth from top surface

OMC = 15%
Soil sample = 5.50 kg
Mixing water = 5.50 x 15% = 0.825 litre = 825 ml
3 layers and number of blows = 56
Hammer weight =2.6 kg (light compaction)

penetration	**Proving Ring**
(mm)	**(Load)**
	(kg-f)
	Sample (1)
0.5	53
1	59
1.5	65
2	73
2.5	81
3	89
3.5	97
4	107
4.5	115
5	120
5.5	128
6	135
6.5	143
7	151
7.5	158
8	166
8.5	173
9	179
9.5	186
10	195
10.5	201
11	209
11.5	216
12	221

Observations of soil

CBR

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	81	1370	5.91	5.91
2	5.0	120	2055	5.83	

9. CBR Determination using 0.5% of polypropylene fiber and H2M6 Geotextileat H/4 depth from top surface

OMC = 15%

Soil sample = 5.50 kg

Mixing water = 5.50 x 15% = 0.825 litre = 825 ml3

layers and number of blows = 56

Hammer weight =2.6 kg (light compaction)

penetration (mm)	Proving Ring (Load) (kg-f) Sample (1)
0.5	59
1	63
1.5	70
2	77
2.5	83
3	90
3.5	98
4	108
4.5	116
5	124
5.5	131
6	138
6.5	145

7	152
7.5	160
8	167
8.5	175
9	180
9.5	188
10	196
10.5	201
11	210
11.5	217
12	224

Observations of soil

CBR

Sr. No	Penetration (mm)	Test load (kg-f)	Standard load (kg-f)	CBR (%)	CBR (%)
1	2.5	83	1370	6.05	**6.05**
2	5.0	124	2055	6.03	

CBR values expressed in percentage for different cases are summarised in, in which the initial CBR refers to percentage CBR obtained for soil alone without any coir geotextiles. The experimental results give a clear indication that the presence of coir geotextiles influences the California Bearing Ratio (CBR) of the soil. The improvement in strength of soil due to the placement of coir geotextiles is a function of interaction of coir geotextiles with the soil.

Inital CBR (with Recron 3S *as 0.5%) =* ***5.26%***			
Depth of placement from top	**Type of Coir Geotextile**		
	Non-Woven	**Woven H2M8**	**Woven H2M6**
H/4	7.44	6.71	6.05
H/3	6.86	6.05	5.91
H/2	6.13	5.98	5.83

CBR values for all cases

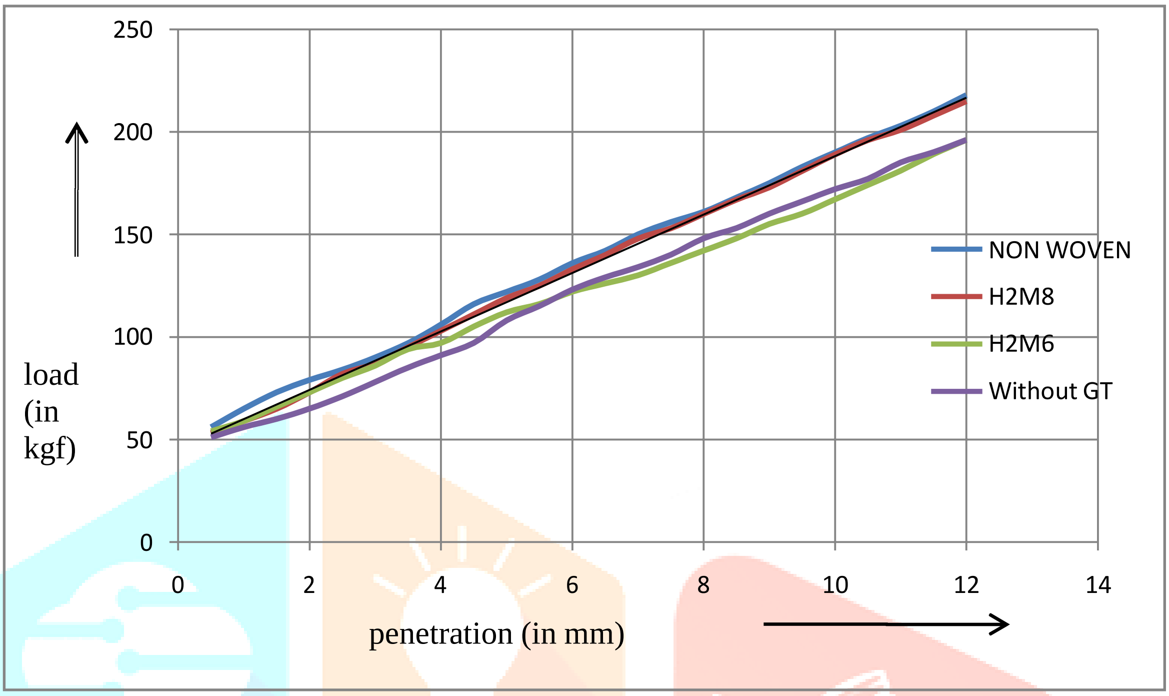

Figure 8.1 Load-penetration curves with synthetic fibre (0.5%) and coir geotextiles placed at H/2 from top

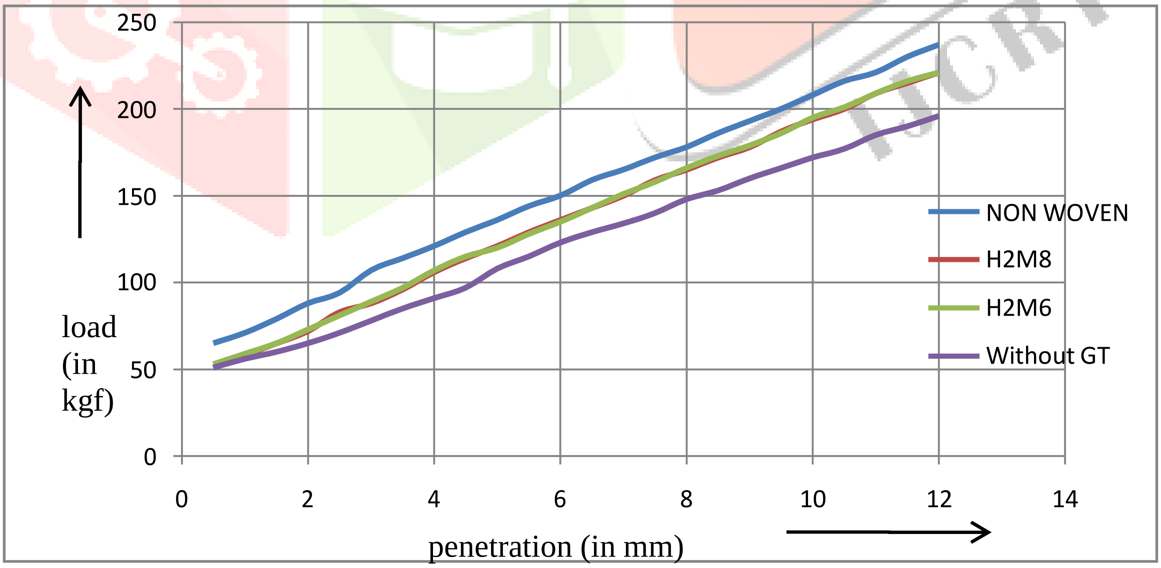

Figure 8.2 Load-penetration curves with synthetic fibre (0.5%) and coir geotextiles placed at H/3 from top

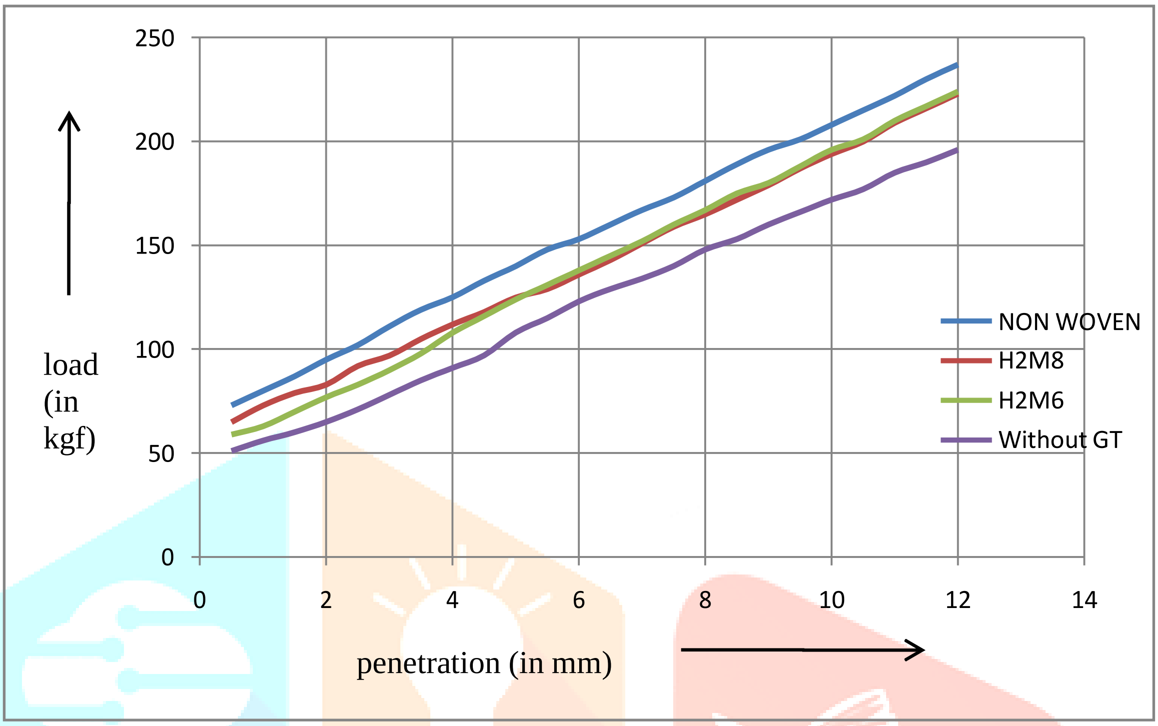

Figure 8 3 Load-penetration curves with synthetic fibre (0.5%) and coir geotextiles placed at H/4 from top

Type of Coir Geotextiles

The type of coir geotextile used has a role in the performance of CBR of coir geotextile reinforced soil. The properties of coir geotextile *i.e.* its mass density, mesh size and modulus may affect the strength of the soil. In all cases it could be seen that the performance of H2M6 in terms of improving the CBR value is only marginal when compared to other types of coir geotextiles. Thus it can be concluded that for the enhancement of CBR, non woven GT or H2M8 will be a better option as the CBR values were more.

Effect of Placement Depth

Fig.8.1, fig 8.2, and fig 8.3 shows the variation of CBR in unsoaked conditions with the three coir geotextiles placed at three positions. The position of geotextile was expressed in terms of depth at H/2, H/3, and H/4, where H is the total depth of the sample in the CBR mould. It can be clearly seen from the graph that due to the placement of coir geotextiles, the CBR value is increased irrespective of type of coir geotextiles and placement depth, but the quantum of increase depends on type of coir geotextile and placement depth. It is observed that, though the CBR values were increased in all cases, the percentage increase was found to be much higher when Non-woven coir geotextile was placed in the upper one-third region.

CHAPTER 6

CONCLUSION & SCOPE FOR FURTHER RESEARCH

GENERAL

This thesis is the outcome of the extensive laboratory research work carried out to explore the possibility of utilising synthetic fibre (i.e. Recron 3s) and coir geotextiles (with lndianised connotation "Coir Bhoovastra"), a natural eco friendly material, for the construction of unpaved roads.

This was accomplished by performing elaborate laboratory investigations in different aspects. The main focus in the present investigation was to conduct systematic research work on the behavior of coir geotextiles with a Polypropylene fibre, so that new methodsof application can be evolved which will pave way for the growth of traditional coir industry.

SOIL CHARACTERISTIC WITH SYNTHETIC FIBRE

1. CBR value of unreinforced soil is observed exceptionally low but on increasing value of fibre content (0.25% to 1.0%) CBR value increased up to 85.09%.
2. The CBR value of specimens is found to increase with the fibre content. However, the rate of increase of strength with fibre content is not uniform, CBR value isfound to remain almost constant with higher value of fibre content.
3. Inclusion of fibre increase frictional force between particles of specimens. It can further be notice that increasing fibre content increases the bonding between particles so CBR value increases up to some extent.
4. This indicates that inclusion of fibre gives ductility to the specimens but increase in ductile nature is not uniform.
5. It can be safely concluded that using polypropylene fibre in construction, it will be easier than other techniques. Polypropylene fibre will be costly initially but in long term it will be economical as it will provide soil reinforcement and improve the design life of subgrade soil.

STRENGTH OF COIR REINFORCED SUBGRADE

The strength of the sub grade was studied in terms of California Bearing Ratio, in unsoaked condition. Three types of coir geotextiles were used in the study in the combination with synthetic fibre with different layout. Following are the conclusions arrived at:

1. Higher CBR was obtained with Non - woven coir geotextiles in unsoakedcondition.
2. Better results were obtained when coir geotextiles were placed nearer to the topsurface.
3. The CBR of the coir geotextile reinforced subgrade depends on the strength of subgrade, properties of coir geotextile and the placement depth of coir geotextile.

SCOPE FOR FURTHER RESEARCH

1. Effect of aspect ratio that is different fibre length on strength parameters and toarrive at an optimum value.
2. Effect of other natural and synthetic fibres on geo-engineering properties.
3. The present work can be extended considering more varieties of coir geotextilesand soils.
4. Field tests can be carried out to get the long-term effects.
5. Studies related to degradation aspects and their effects can be studied.