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A STUDY ON BLACK COTTON SOIL TO ENHANCE CBR VALUE OF SOIL SUB-GRADE USING COCONUT COIR FIBER FOR RURAL ROADS

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ABSTRACT— The (CBR) California bearing ratio Test is a test first developed by the California State Highway Department (U.S.A.) for evaluating and enhance the bearing capacity of sub grade soil for design of flexible pavement.

Soft soils form problematic sub-grade for pavements due to its low bearing capacity and their strength. Pavement loads coming on the soft sub-grade soil may cause pumping actions when it is located in areas with high water table which causes both construction and in-service performance problem. The common solutions on en counting such problems include excavation and replacement of soil. Excavation and replacement of soil becomes very expensive especially when used as soils have to significant distance. Stabilization using various additives and different material can improve the properties of soils. Now-A-days recent trend in stabilization is to be utilized locally available industrial and material wastes to improve the properties of soils.

In this procedure has the dual advantage of increase the strength of soil and a solution for the problematic disposal of such wastes. Coir waste consisting of coir pith and coir fiber is a by product of coir manufacturing industry obtained from coconut husk during extraction of coir fiber. The pollution is caused due to the poly phenol leaching and the resistance to degradation due to the stable lignin structure makes the coir waste a potential threat to the land resources.

The permeability and the CBR constitute two important parameters in the design and assessment of long term performance of the pavement. In this project only strength aspects of pavement sub-grade have considered. It is very natural process.

In laboratory investigations and experiment have been carried out on a number of soil samples procure from different roadwork sites. Starting tests, it provide a good strength.

Keywords— Stabilization, Coir waste, pavement, Coconut coir fibre.

INTRODUCTION

A **sub-grade** is made up of natural soil that has been compacted to withstand the loads above it and many factors are considered. It is the layer requires in many structures such as the pavements and slabs, about it needs to have certain characteristics. It is the functions firstly as structural support but it can be also minimize the intrusion of fines from the sub-grade into the pavement structure and improve drainage.

The Service life of the pavement is dependent on sub-grade conditions among many other factors. Soil forms the receiving platform for the pavement layers and hence should be strong enough to support the weight of overlying pavement layers and also the weight of the wheel loads coming over it. In a developing country like India, where a large number of Population reside, the inadequate availability of land is the major hindrance to carry out construction. This situation forces engineers to carry out construction on weak or soft soils.

Natural soil or Soft soils such as clayey or silty soil does not have sufficient strength to wear heavy loads and hence pavements constructed over those soils are subjected to early degradation. Earlier practice of replacing soft soil or natural soil with good quality soils are now-a-days not feasible due to the high cost involved and construction rate also. The method of treating soft soils at the field itself using additives is called stabilization of soils.

The different types of waste materials were used to improve the properties and strength of weak soil. Fly ash when used in weak soil improves the CBR value of the soil. Industrial waste such as blast furnace slag, rice husk ash, foundry slag, cement kiln dust when used to stabilize clayey sand have shown satisfactory strength and durability characteristics. Recycled or new use of plastic waste from waste bottles is used to improve bearing capacity of soft soil.

Improve the sub base or sub-grade layer with fibers is also common area of research. Inclusion of coir fibers in clayey soil along with fly ash is found to increase the shear strength parameter.

In this experiment the properties of soil are improved by mechanical or chemically properties. Stabilization of soils has been always an interesting topic to researchers. Over the years various materials have been used for stabilization of weak soils such as clays. A new trend is to utilized waste materials for Modify natural or soft soils.
The advantage of using waste materials in construction includes its low cost to improve strength of soil involved and a new solution for the waste disposal.
The present experiment aims to study how coir waste can be effectively utilized in combination with soft soil to improve sub-grade strength. Different properties like grain size distribution, moisture- content -density relations, California bearing ratio and elastic modulus are studied individually and the soil blended with coir fiber waste.

As the sub-grade is intended to variations of 12 moisture due to flood, precipitations or Ppt all other climatic changes, so it is necessary to enable or understand the sub-grade according to the variation of moisture.

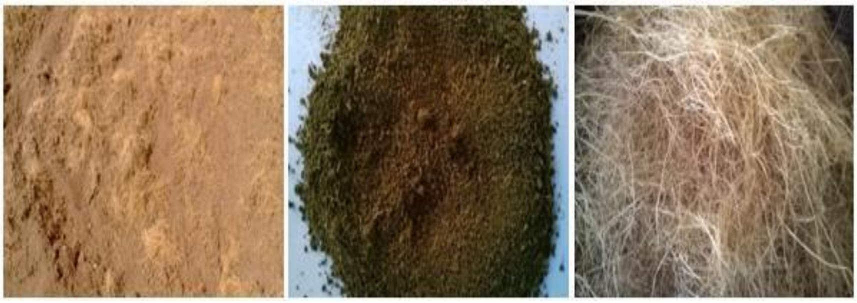

Fig 1 Soil Sample and Coconut Fiber

1.1 Objectives:-

The objective of this study is to analyse the strength of black cotton soil using coconut fibers. Black Cotton Soil is mixed with randomly distributed coir fiber in range of 0.5% to 2.5% with step increase of 0.5%. During which following properties will be observed. The objective of soil stabilized is to increase the strength or stability of the soil and to reduce its sensitivity to moisture changes.

1. Changes in Optimum Moisture Content and Maximum Dry Density of black cotton soil due to addition of coir.

2. Changes in UCS result due to addition of coir fiber and find the optimum fiber content.

3. Changes in free swelling characteristics of black Cotton soil with an addition of coir fiber.

This experiment study on attempts to understand and investigate the variation of CBR with moisture contents resulting due to different days of soaking and to assess the influence of test conditions in determination of CBR value . The various soil samples with different densities and moisture content are to be tabulated in terms of CBR test for determination of their strength at variable water contents by soaking the soil samples in water bath for variable number of days.

1.3 Scope of work:-

- The collection of various samples of black cotton soil from different sites of work and to find its basic physical properties such as plastic limit, liquid limit, and grain size distribution.
- To study the soil under heavy compaction test and determine the optimum moisture content and maximum dry density for the soil sample.
- To conduct the different CBR value of black cotton soil mix with coconut coir fiber.
- To study the submergence of the soil under different days of soaking condition.

2. REVIEW OF LITERATURE:-
3.

The aim of the review is to identify, integrate and synthesis the existing evidence and experimental work on black cotton soil and coconut coir fiber.
The Soil stabilization refers to the procedures employed with a view to altering one or more than one properties of soil so as to improve its engineering performance.

Daniel Yaw Osei conducted experimental studies on coconut fiber shells as aggregate in concrete and found that a potential exists for the use of coconut shells as replacement of conventional aggregate in both conventional reinforced concrete and lightweight reinforced concrete construction. The use of coconut shells as partial replacement for conventional aggregates should be encouraged as an environmental protection and construction cost reduction measure.

All the civil engineering structures whether small or huge, simple or complex rests on the ground surface and ultimately transfers the structure load to soil or rock. Stability of any such structure depends on the properties of the underlying soil. If we can improve the strength of existing soil by means of some ground improvement techniques utilizing the waste material generated locally, then the cost of construction can be reduced drastically. Under the traffic loads, the soil sub-base is subjected to compression in the vertical direction accompanied by tension in the lateral direction (Meshram et al.). Most of the available soil generally shows good compressive strength and sufficient shear strength but are weak in tension. Fiber reinforced soil is effective in all types of soils like sand, silt and clay (Kumar et al).

Earth reinforcement is an ancient technique, demonstrated abundantly in nature by animals, birds and the action of tree roots. These reinforcements interact with the soil through friction and adhesion and resists tensile stress developed within the soil mass thereby restricting shear failure. (Chaple and Dhatrak).

In construction of pavements, either rigid or flexible if the underlying soil (sub-grade) is of good quality then the thickness of pavement becomes less thus reducing the construction cost and saving the conventional natural resources for the next generation. Also the life of pavements depends on the strength and stability of underlying sub-grade soil. One of the reasons for rapid deterioration of a pavement structure is due to poor sub-grade which increases the maintenance cost, leads to traffic interruptions and causes inconvenience to public.

Deformations in sub-grade due to repeated traffic loads can be avoided and strength of sub-grade soil can be improved by reinforcing the soil by means of natural fibers like coconut coir, jute, bamboo, straw etc. and by using synthetic fibers like polypropylene, polyester, polyethylene, glass fiber, shredded rubber tire, geo-synthetic or goe-textile etc. In this experimental study, non-woven randomly distributed coconut coir fibers (CCF) were used to reinforce the soil. CCF is produced in large quantities in South Asian countries like India, Malaysia, Philippines, Indonesia etc. Coconut coir is a natural fiber belonging to the group of hard structural fibers (Maurya et al.). It can be extracted from the husk of coconut which is easily and locally available, cheap, bio and ecofriendly. It is waste by product of the coir manufacturing industry and for every ton of fiber extracted, about two tons of coir waste is produced (Jayasree et al.).

Durability of natural fiber can be improved by chemical treatment and by coating the fiber with Phenol, Bitumen and polymer (Abhijith).

As coconut fiber has high lignin content and low cellulose content, it is resilient, strong and highly durable (Enokela and Alada).

Compared to jute fiber, service life of coir is more up to 10 years because of its high lignin content (Rowell et al.).

According to Goyal et al. , degradation of coir depends on the medium of embedment and the climatic conditions and is found to retain 80% of its tensile strength even after six months.

Coir has low tenacity but the elongation is much higher (Babu and Vasudevan) and it shows better resilient response against synthetic fibers by higher coefficient of friction (Chouhan et al.).

Coir retains much of its tensile strength when wet and shows reduced swelling tendency of the soil (Subaida et al).

Many researchers have worked on CCF reinforced soil. Mali and Singh observed that soft silty or clayey soils can be improved with randomly distributed fibers of natural and synthetic types. When loaded, the fibers mobilize tensile resistance, which in turn imparts greater strength to the soil.

As per the study conducted by Arathy V B, Christina Jery, Jumy Raj and Lakshmi V S , the effect of coconut shell powder on soil samples were studied by conducting tests with various percentage(1%,2%,3%, and 4%) of coconut shell powder and the following conclusions were drawn. Max dry density was obtained when 1% CCS was added to the soil and minimum OMC was obtained for 2%, increase in soil strength could be seen from results of various experiments. It was recommended for short term stabilization of slope. Johnson R, Solomon and Olukorede. aimed at assessing the effects of coconut husk ash on the stabilization of poor lateritic soil deposit found at Out in Itesiwaju Local Government Area in Oyo State, Southwestern Nigeria, using 0, 2, 4, 6, 8, and 10% of coconut ash by mass of soil sample. The following laboratory soil tests were carried out on the stabilized soil samples: particle size distribution analysis, Atterberg limit test, compaction test, and California Bearing Ratio in accordance with British Standard. Chemical composition analysis of the coconut husk ash was done as well. The result indicated that coconut husk ash is suitable for improving the California bearing ratio because this parameter increases with addition of coconut husk ash. Addition of coconut husk ash also increased the plastic limit but reduced the plasticity index. Therefore, this study showed that coconut husk ash can be effectively used to improve lateritic soils with low CBR values.

3. EXPERIMENTAL INVESTIGATIONS:-

1. Investigation-

The experimental investigations have been conducted on the soil (from VIDISHA M.P.) Black Cotton Soil sample. The experiment was conduct to find out different properties of soil such as index properties, grain size distribution etc.

3.The Grain Size Distribution:-

1. **Dry Sieve Analysis**
2. **Hydrometer Analysis**
3. **Liquid Limit Test**
4. **Plastic Limit Test**

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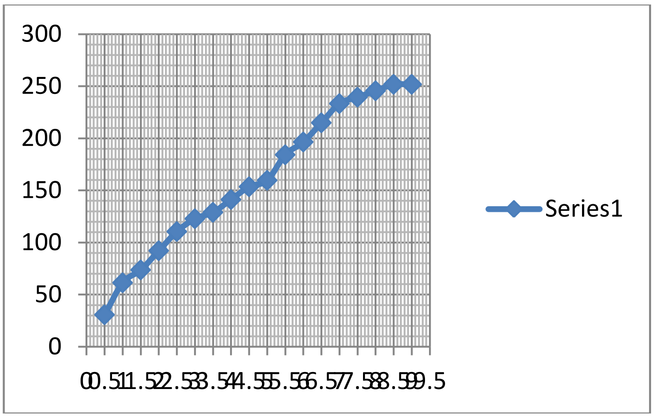
6. Experimental Study on CBR Value of Black Cotton Soil:-

Table 2 Normal CBR Value Of Black Cotton Soil

CBR VALUE OF BLACK COTTON SOIL			
(2) CBR - LOAD - PENETRATION TEST DATA		CORRECTION FACTOR	6.140
		MOULD NO. 1	
S.N.	PENETRATION (in mm)	PROVING RING READING	CORRECTED LOAD (IN KG)
1	0.5	5	30.70
2	1.0	10	61.40
3	1.5	12	73.68
4	2.0	15	92.10
5	2.5	18	110.52
6	3.0	20	122.80
7	3.5	21	128.94
8	4.0	23	141.22
9	4.5	25	153.50
10	5.0	26	159.64
11	5.5	30	184.20
12	6.0	32	196.48
13	6.5	35	214.90
14	7.0	38	233.32
15	7.5	39	239.46
16	8.0	40	245.60
17	8.5	41	251.74
18	9.0	41	251.74
CBR VALUE AT @ 2.5 mm (IN %) =			8.067
CBR VALUE AT @ 5.0 mm (IN %) =			7.768



Graph:-Load Penetration Curve CBR of Black Cotton Soil

4. Experimental Study on CBR Value of Black Cotton Soil Mix with Crushed Coconut :-

The Sub-grade is the lower portion of the road which is constructed in close conformance with the lines, grades and cross-sections indicated on the plans, to receive the base and surface of layers. The performance of the pavement structure depends on the strength and stability of the sub-grade under adverse loading and climatic conditions.

It means that the pressure transmitted on the top of the sub-grade is within the allowable limit. The weak sub-grade whether in cut or fill should be well compacted to utilized it is full of strength and to there by economize the overall thickness of the pavement required.

The sub-grade soil which is weak in condition has to be treated or stabilized to suit the requirements. The Black Cotton soil is one of the fertile soils which is a very good for agriculture. Due to presence of good irrigation systems and the rainfall causes the people to settle around in these areas. However the black cotton soils are preferable for carry out agricultural activities, but they are not preferred for laying the durable roads.

The sub-grade comprising of black cotton soil is highly unpredictable and therefore the behavior of this soil plays a vital role in design, construction and maintenance operations of the pavement. Improper treatment of this soil leads to failures in the pavement in the form of potholes, cracks, undulation, deformation, fissures or more.

Materials And Methodology

The Black Cotton Soil Or Natural Soil:-

The present investigations and experiment have been made on the black cotton soil obtained from VIDISHA (M.P) India. This is a residual soil and is collected from an open excavation, at a depth of 30cm below the natural ground surface. The soil was air dried, pulverized and then passed through IS sieve size of 425 µ before being used for the study. The physical properties of the black cotton soil are presented in Table 3.

Table 3 . Physical Properties Of Black Cotton Soil

Property	Observation
Colour	Black
Liquid limit	60%
Plastic Limit	29%
plasticity index	31%
Shrinkage limit	12.87%
Optimum moisture content	22%
Maximum dry density	1.55Ggm/cc

Coconut

Coconut used in the present experiment and investigation is collected from home and near temples. Coconut coir fiber is collected for the study has shell thickness in the range of 2mm-8mm. They were crushed to the required sizes in the range 3cm to 5cm using hammer sizzler and mechanical crusher. The physical and mechanical properties of coconut is given in Table 4

S. No	Physical and Mechanical Properties	Observations
1	Moisture Content	4.20%
2	Water Absorption	24%
3	Specific Gravity	1.40
4	Impact Value	8.15%
5	Crushing Value	2.58%
6	Abrasion Value	1.63%
7	Bulk Density	55kg/m3
8	Coconut Shell Thickness	2-8mm

Table 4 Physical and Mechanical Properties of Crushed Coconut Strength tests on the normal black cotton soil sample

The basic laboratory tests on the soil were followed by strength tests namely unconfined compression test and California bearing ratio CBR test as per standards. The unconfined compression of strength value of soil sample was found to be 380.28kN/m2.

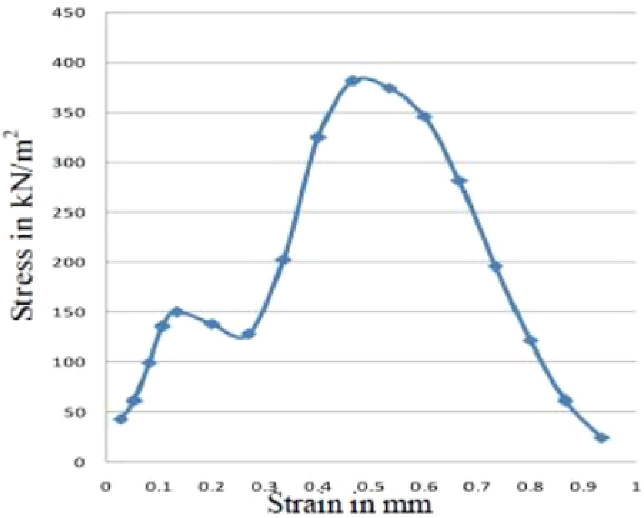


Fig 17 Stress-Strain Curve Of Normal Black Cotton Soil

Stress-strain curve of normal black cotton soil California bearing ratio (CBR) tests were conducted to determine the load penetration curve for the normal black cotton soil sample for trials.
CBR test was conducted on the soil sample under soaked conditions and the results are tabulated in Table 5

Table.5 CBR Values Of Soil Sample For Soaked Condition

Penetration at	CBR Value For Soaked Condition				
	mould-1	mould-2	mould-3	mould-4	mould-5
2.5 mm	9.860	10.756	11.204	11.653	12.101
5.0 mm	8.964	9.561	9.860	10.457	10.457

The quantity of coconut coir fiber in black cotton soil was then varied and different trails were conducted to determine the CBR value of this treated soil for both soaked condition. Coconut coir fiber was added at a depth of 0.2H of the CBR mould where H is the height of the mould.
The Black cotton soil treated with 30gm of coconut. The load-penetration curve for black cotton soil treated with 30 gm .Black cotton soil treated with 60gm of coconut. The load-penetration curve for black cotton soil treated with 30gm.

RESULTS:-
- The maintenance cost of pavement will be decrease about 30%.
- The most of uses of Coconut coir fiber for improve the soil capacity.
- It is Eco-friendly waste material and easily used.
- The optimum moisture content decrease 12.08%.
- The maximum dry density is 1.55%.

A graphical representation of variation in CBR values under different conditions of the study is table.6

Table-6 CBR Values of Soil For Different Amount of Coconut coir fiber CCF

Different Amount Of Crushed	
Coconut	
Cbr Value	Soaked Condition
Normal Black Cotton Soil	8.06%
Black Cotton Soil With 30 Gm Of Ccf	9.86%
Black Cotton Soil With 60 Gm Of Ccf	10.75%
Black Cotton Soil With 90 Gm Of Ccf	11.20%
Black Cotton Soil With 120 Gm Of Ccf	11.65%
Black Cotton Soil With 150 Gm Of Ccf	12.10%

VIII Calculation And Discussion Graph:-

Table. 7 CBR Test Machine Proving Ring Correction Factor

Applied force (kN)	Series 1	Series 2	Series 3	Average	Percentage
A	B	C	D	E	F
0	0	0	0	0	0
5	80	80	80	80	6.250
10	161	162	162	161.67	6.186
15	244	241	242	242.33	6.190

20	325	326	326	325.67	6.141
25	406	407	407	406.67	6.148
30	489	489	490	489.33	6.131
35	572	572	573	572.33	6.115
40	655	655	657	655.67	6.101
45	740	740	741	740.33	6.078
50	824	824	825	824.33	6.066
				% AVERAGE=	6.140

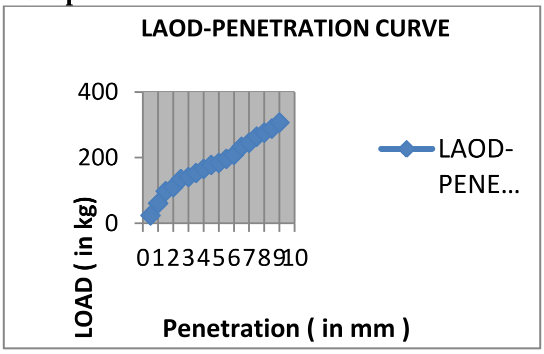
Correction Factor of Proving Ring = 6.140

 # Mould-1 @ 0.5 % :-

Table 8 Load -Penetration Test @ 0.5 %

CBR - LOAD -PENETRATION TEST DATA		CORRECTION FACTOR		6.140
		MOULD NO. 1 @ 0.50 %		
S.N.	PENETRATION (in mm)	PROVING RING READING	CORRECTED LOAD (IN KG)	
1	0.5	4	24.56	
2	1.0	10	61.40	
3	1.5	16	98.24	
4	2.0	18	110.52	
5	2.5	22	135.08	
6	3.0	23	141.22	
7	3.5	25	153.50	
8	4.0	27	165.78	
9	4.5	29	178.06	
10	5.0	30	184.20	
11	5.5	32	196.48	
12	6.0	34	208.76	
13	6.5	38	233.32	
14	7.0	40	245.60	
15	7.5	43	264.02	
16	8.0	45	276.30	
17	8.5	47	288.58	
18	9.0	50	307.00	
CBR VALUE AT @ 2.5 mm (IN %) =			9.860	
CBR VALUE AT @ 5 mm (IN %) =			8.964	

 # Graph 1



Load penetration curve for Mould No. 1 @ 0.5

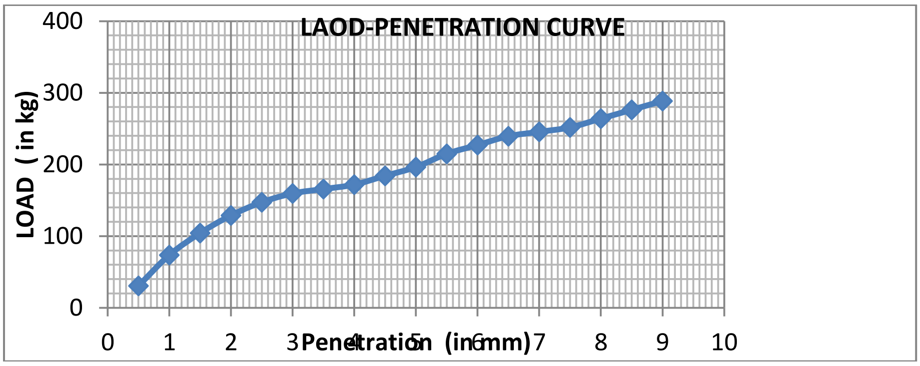
 # Mould-2 @ 1 % :-

Table 9 Load -Penetration Test @ 1.0 %

(2) CBR - LOAD -PENETRATION TEST DATA		CORRECTION FACTOR		6.140
		MOULD NO. 2 @ 1.0 %		
S.N.	PENETRATION (in mm)	PROVING RING READING	CORRECTED LOAD (IN KG)	
1	0.5	5	30.70	
2	1.0	12	73.68	
3	1.5	17	104.38	

4	2.0	21	128.94
5	2.5	24	147.36
6	3.0	26	159.64
7	3.5	27	165.78
8	4.0	28	171.92
9	4.5	30	184.20
10	5.0	32	196.48
11	5.5	35	214.90
12	6.0	37	227.18
13	6.5	39	239.46
14	7.0	40	245.60
15	7.5	41	251.74
16	8.0	43	264.02
17	8.5	45	276.30
18	9.0	47	288.58
CBR VALUE AT @ 2.5 mm (IN %) =		10.756	
CBR VALUE AT @ 5 mm (IN %) =		9.561	

 # Graph:-2



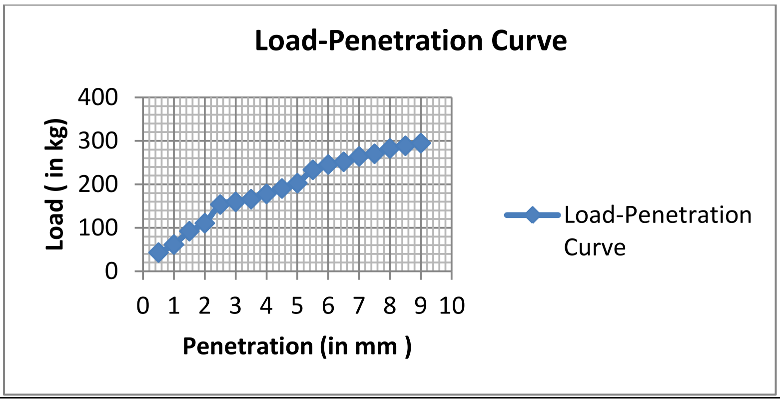
Load penetration curve for Mould-2 @ 1 %

 # Mould-3 @ 1.5 % :- Table 10 Load -Penetration Test @ 1.5 %

(2) CBR - LOAD -PENETRATION TEST DATA			CORRECTION FACTOR	6.140
S.N.	PENETRATION (in mm)	MOULD NO. 3 @ 1.5 %		
		PROVING RING READING	CORRECTED LOAD (IN KG)	
1	0.5	7	42.98	
2	1.0	10	61.40	
3	1.5	15	92.10	
4	2.0	18	110.52	
5	2.5	25	153.50	
6	3.0	26	159.64	
7	3.5	27	165.78	

8	4.0	29	178.06
9	4.5	31	190.34
10	5.0	33	202.62
11	5.5	38	233.32
12	6.0	40	245.60
13	6.5	41	251.74
14	7.0	43	264.02
15	7.5	44	270.16
16	8.0	46	282.44
17	8.5	47	288.58
18	9.0	48	294.72
CBR VALUE AT @ 2.5 mm (IN %) =		11.204	
CBR VALUE AT @ 5 mm (IN %) =		9.860	

#GRAPH:-3



Load penetration curve for Mould-3 @ 1.5 %

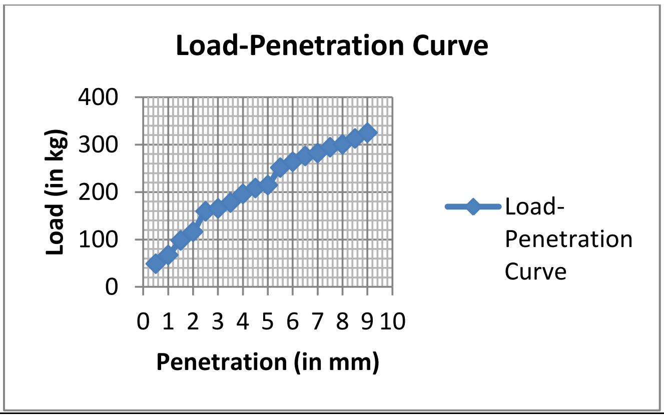
MOULD-4 @ 2.0 % :-

Table 11 Load -Penetration Test @ 2.0 %

(2) CBR - LOAD -PENETRATION TEST DATA		CORRECTION FACTOR		6.140
		MOULD NO. 4 @ 2.0%		
S.N.	PENETRATION (in mm)	PROVING RING READING	CORRECTED LOAD (IN KG)	
1	0.5	8	49.12	
2	1.0	11	67.54	
3	1.5	16	98.24	
4	2.0	19	116.66	
5	2.5	26	159.64	
6	3.0	27	165.78	
7	3.5	29	178.06	
8	4.0	32	196.48	
9	4.5	34	208.76	

10	5.0	35	214.90	
11	5.5	41	251.74	
12	6.0	43	264.02	
13	6.5	45	276.30	
14	7.0	46	282.44	
15	7.5	48	294.72	
16	8.0	49	300.86	
17	8.5	51	313.14	
18	9.0	53	325.42	
CBR VALUE AT @ 2.5 mm (IN %) =		11.653		
CBR VALUE AT @ 5 mm (IN %) =		10.457		

 # GRAPH:-4



Load penetration curve for Mould-4 @ 2.0 %

 # Mould-5 @ 2.5 %:-

Table 12 Load -Penetration Test @ 2.5 %

(2) CBR - LOAD -PENETRATION TEST DATA		**CORRECTION FACTOR**		**6.140**
S.N.	PENETRATION (in mm)	MOULD NO. 5 @ 2.5%		
		PROVING RING READING	CORRECTED LOAD (IN KG)	
1	0.5	9	55.26	
2	1.0	13	79.82	
3	1.5	17	104.38	
4	2.0	23	141.22	
5	2.5	27	165.78	
6	3.0	29	178.06	
7	3.5	30	184.2	
8	4.0	31	190.34	
9	4.5	33	202.62	
10	5.0	35	214.9	
11	5.5	39	239.46	
12	6.0	39	239.46	
13	6.5	40	245.6	
14	7.0	40	245.6	
15	7.5	41	251.74	
16	8.0	41	251.74	
17	8.5	42	257.88	

18	9.0	42	257.88	
CBR VALUE AT @ 2.5 mm (IN %) =			12.101	
CBR VALUE AT @ 5 mm (IN %) =			10.457	

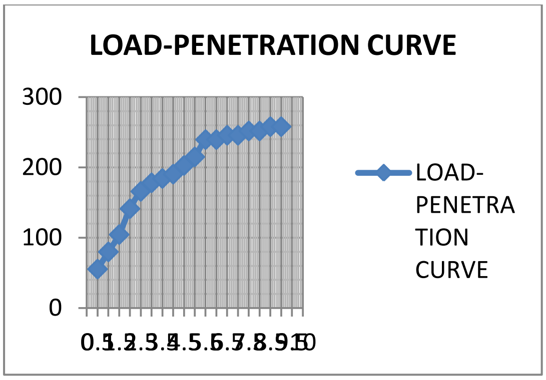
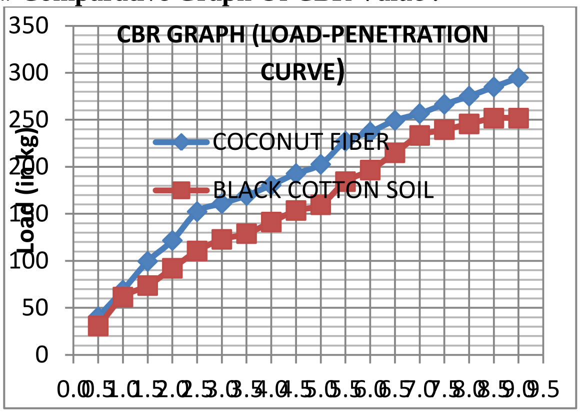


Fig 23 Load penetration curve for Mould-5 @ 2.5 %

 # Comparative Graph Of CBR Value :-



 # Comparative Graph of Mould-1 to Mould-5:-

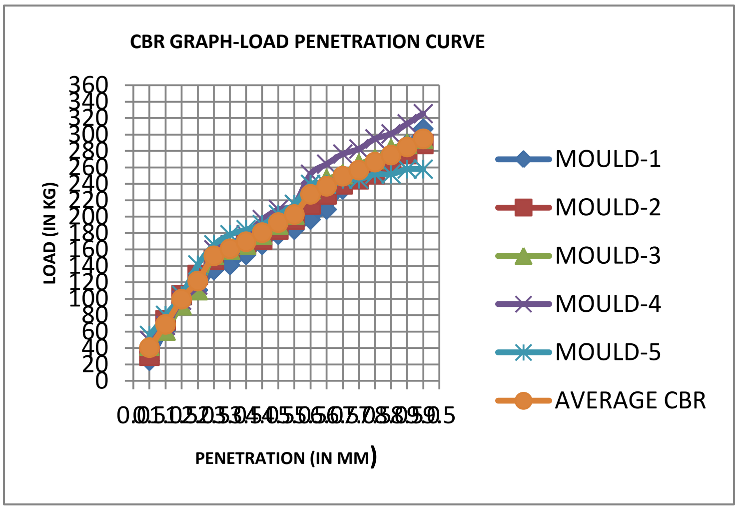


Fig 25 Comparative Graph

DISCUSSIONS CONCLUSIONS AND RECOMMENDATION:-

- The coconut coir fiber is a waste disposal material is used in sub base of flexible pavements.
- The Optimum moisture content OMC of soil-coir mix increases with increasing the percentage of coir fiber.
- Thus Maximum improvement in U.C.S. and C.B.R. values are observed when 2% of coir is mixed with the soil.
- It is concluded that proportion of 2% of soil and coconut fiber are mix well.

Based on the observation of the study it is found that the strength of black cotton soil is improved by the addition of coconut. The experimental results give a clear indication of influence of on CBR value of soil. The normal black cotton soil which is otherwise not suitable for pavement construction is found to have improved CBR value with the addition of coconut. From the laboratory study it is observed that increase in coconut results in increase in CBR value.

This result in increased strength of - soil, reduced base course thickness for same repetitions of traffic load. Use of Coconut is found to be effective and ecofriendly method of stabilizing the weak sub-grade soil. The study can be further enhanced by determining the optimum amount of Coconut for stabilization of weak sub-grade soil.

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