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Design of Subgrade for the Highway Transport by using Fiber Reinforcement

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Abstract: India is a vast country with diversity in the soil sub grade. The behavior of certain soils is excellent to bear the traffic loads under the adverse climate conditions. But as far as sub grade is concerned the most of the soils are weak like black-cotton soil, peats etc. So attempts are being made to search for suitable sub grade material or alternatively to improve/ strengthen the weak existing sub grade by suitable methods. Numerous examples exist where soils at shallow depths have inadequate strength for supporting the proposed structures.

Stabilization has been the age-old method of soil improvement. In stabilization, physical or chemical binding by adding certain stabilizing agents can modify the matrix of the soil. The common methods of stabilization are chemical, thermal, consolidation, compaction and mechanical stabilization. In all these techniques the strengthening of soil is done at micro-scale. The disadvantage of this methods is that there is reduction in permeability and ductility of soil mass.

An attempt has been made to use lime and fiber to improve the strength of base for road construction in varying proportion ,It was established that maximum dry density deceases as the as the optimum moisture content increases. The CBR values increases with 12 percentage of lime and one percent of fiber.

Key Words: Sub grade, stabilization, fiber, ductility, penetration.

Review of Literature

- **(i)** **Mc- Gown, A.et.al (1978) (9)** gave the concept of ply soil (1978) thereafter earth reinforcement with fiber started.
- **(ii)** **Henary Vidal (1969) (22)** worked a lot on reinforced earth.
- **(iii)** **B Satyanarayan (18)** studied the effect of inclusion of glass fibers and asbestos fibers on cement stabilized soil.
- **(iv)** **P.G. Bhattacharya** and **B.B. Pandey (1994) (1)** studied the effect of inclusion of coir fibers in lime stabilized lateritic soil.
- **(v)** **Mc- Gown, A.et.al (1978) (9)** studied the effect of inclusion properties on behavior of sand.
- **(vi)** **Gray, D.H. and Ohashi, H.(1983) (4)** studied the mechanism of fiber reinforcement in soil.
- **(vii)** **Hoare, D.J. (1979) (5)** studied the laboratory performance of granular soil reinforced with randomly distributed discrete fibers.
- **(viii)** **Setty K.R.N.S. (1987) (20)** did some work to determine the effects of inclusion of fibers in black-cotton soil as well as lateritic soil. Several investigators like Hoare Gray, Maher, Setty & Rao concluded that fibre reinforcement is a potential composite material.
- **(ix)** **Gray, D.H. and Maher, M.H. (1989) (3)** reported that strength and stiffness of fiber-reinforced soil depends upon so many parameters. It depends upon the fiber characteristics (weight fraction, aspect ratio, surface, and modulus of elasticity of fiber)
- **(x)** **In gold. T. S. and Thomson. J. C. (1985) (6)** Results of Current Research of Synthetic and Natural Fiber erosion Control System. ITC (1985), “Jute for erosion Control” Jute market promotion Project, International Trade Centre, UNTC/GATT. Geneva, Switzerland
- **(xi)** **Setty & Rao (1987) & Setty & Murthy (1990) (19,20)** carried out triaxial tests, CBR tests and tensile strength test on silty sand and black cotton soil respectively reinforced with randomly distributed polypropylene fibres. The test result indicated that both the soils exhibited significant increase in cohesion intercept and slight decrease in angle of internal friction with an increase in fibre content up to 3% (by weight).
- **(xii)** **Singh, H.P. and Bagra, M.(21)** made the comparative study between the improvement in CBR value of soil using jute and coir fiber as reinforcing materials separately, and suggested the dominance of jute fiber. Based on his study, he concluded that the load carrying capacity of soil increases and amount of immediate settlement decreases when soil is reinforced with jute geotextile sheets.

From the above investigations it is established that no much work has been done on the stabilization of soil sub grade reinforced with lime, fibre and soil. Attempt has therefore been made to study the characteristics of such technology to improve the strength by experimental analysis using lime and fibre with soil at the sub base.

Objective of Studies

The present investigation is aimed to evaluate the performance of lime and plastic fiber reinforced sand by carrying out laboratory studies such as compaction test for Optimum Moisture Content (OMC) determination, CBR(California Bearing Ratio) and plate load test. The various percentages of fibers, which vary from 0.25% to 1.0% and lime percentage, which varies from 3.0% to 12.0%, were taken. A suitable combination of lime and fibre was mixed with soil. The soil, which is used, is locally available silt clay fine sand soil Santor Tehsil Buhana. A maximum percentage of 1.0% by weight of soil was taken in the present investigations of discrete fibers with varying percentage of lime. Beyond 1.0% fiber, the mixing of fiber with the soil becomes very difficult and also gain in strength beyond 1% of fiber is not so significant. Lime is added to see the change of OMC , CBR and plate load test results on fiber-reinforced soil. The main objective of the present study is to evaluate the changes in the strength characteristics of sub grade soil by addition of lime and plastic fiber.

Selection of Tests:

The main objective of the present investigation is to determine the change in the strength and structural properties of poorly graded silt clay fine sand due to addition of lime and fibers so that it can be effectively used as pavement subgrade or base course.

The Compaction test was conducted to determine the OMC and hence the maximum dry density. The degree of compaction, which is required to be achieved, is about 95% The thickness of the pavement layers in the flexible type of pavement depends upon the CBR value. IRC 37-1984 has given certain guidelines regarding CBR tests. This test was conducted for both soaked and unsoaked conditions.

Plate load test was conducted to calculate the k-value of soil sub grade.

Experiments Carried out

Proctor Compaction Test

The apparatus used consists of a cylindrical metal mould of internal diameter 10 Cm and height 12.5cm. It has a detachable base and a detachable collar, which fits on the top. The soil specimen is brought to a certain moisture content and compacted into the mould with a specified number of blows from a standard hammer. The dry density of the soil is calculated and procedure repeated with increasing moisture contents and a curve is plotted, until maximum soil density is obtained The test is used to determine the moisture content at which the soil should be compacted to obtain the maximum dry density(MDD), and the dry density likely to be achieved by compaction in the field. The soil is compacted in three equal layers each layer of the soil is compacted by 25 blows. The weight of the hammer is 2.5 kg. And height of falls is 30 cm.

California Bearing Ratio (CBR) Test

Compaction of soil is a mechanical processes by which the soils particles are constrain to be packed more closely together by reducing the air voids. Soil compaction causes decrease in air voids and consequently increase in dry density. This may result in increase in shearing strength. The possibility of future settlement of compressibility decreases and also the tendency for subsequent changes in moisture content decreases. Degree of compaction is usually measured quantitatively by maximum dry density. (MDD).

The test has been extensively investigated for field correlation of flexible pavement thickness requirement. Briefly, the test consists of causing a cylindrical plunger of 50 mm diameter to penetrate a pavement component material at 1.25 mm/minute. The loads, for 2.5 mm and 5 mm are recorded. This load is expressed as a percentage of standard load value obtained from the average of a large number of tests on different crushed stones .The results are given below.

Plate Load Test:

The plate load test is used to evaluate the supporting power of sub grade, bases and in some cases completes pavements by utilizing relatively large diameter plates. Data obtained from the tests circular plates are used to ensure even bearing surface. The deflection dial gauge is placed near the outer periphery of the largest plate, preferably at one-third position on the circumference of the plate. The test setup consists of plates of diameter 75 cm. A loading device consisting of jack and proving ring arrangement and reaction frame against which the jack can give thrust to the plate.

This plate load test was done in the laboratory. The test site was leveled and the plate was properly seated on the prepared surface. A seating load of 0.07 Kg./cm2 (320 kg for 75-cm diameter plate) was applied and released after a few seconds to give a deflection of 0.25 mm and dial gauge was set to zero. The load is applied in small increment. Each increment should be maintained until the rate of settlement is less than 0.025 mm/min.

Experimental Results and Discussion

In the present investigation, Proctor Compaction test, CBR tests and plate load tests were conducted on the soil subgrade as well as soil reinforced with fiber and lime. For better understanding, results are presented in the graphical form and where applicable these are also presented in tabular form.

Proctor Compaction Test:

This test was carried out to determine the optimum moisture content for soil subgrade and for soil reinforced with different combinations of lime and plastic fiber contents. We see from the fig.6, that as lime and fiber contents are go on increasing, the maximum dry density decreases with the increase in optimum moisture content. This is because density of mixture is defined as the weight divided by volume. The volume of the specimen is fixed. It is only the weight, which is changing. The unit weight of fiber (0.93 gm/cm3) and that of lime (2.13 gm/cm3) is less than that of soil 2.65 gm/cm3. Thus, with the increase in fiber and lime content the weight of the specimen consequently reduces and hence unit weight and therefore dry density decreases. The result obtained from the proctor compaction test are shown in the table 1.

Table 1: Proctor compaction test results

TYPE	OMC (%)	Dry Density (gm/cm3)
SOIL	14.92	1.58
SOIL+3% LIME + 0.25 % FIBRE	17.10	1.60
SOIL+ 6% LIME +0.50 % FIBRE	20.20	1.585
SOIL + 9% LIME + 0.75% FIBRE	24.00	1.58
SOIL +12% LIME + 1.0 % FIBRE	31.03	1.56

From fig. B1 to B6 as lime + fiber % go on increasing ,OMC (Optimum Moisture Content) also increases. The increase is linear up to 9% lime + 0.75% fibers. Beyond this the nature is not well defined.

From table it is seen that the dry density decreases as lime + fiber content increases. Beyond 9% lime + 0.75% fiber content, there is appreciable reduction in the dry density.

California Bearing Ratio Test: (CBR)

The CBR tests were conducted on the un-reinforced soil as well as soil reinforced with fiber and lime. The fiber content was varied from 0.25% to 1% and lime content was varied from 3 to 12%. The fiber used in the investigation was natural plastic fiber having the aspect ratio 75 to 150. This is because we are interested in knowing the effect of reinforcement of fiber and lime on the strength properties of the reinforced soil. The test was conducted for heavy compaction and the moisture content was taken as optimum moisture content to achieve maximum dry density. The tests were done for both soaked and unsoaked condition. The reason for keeping the maximum limit of fiber content to 1% is that beyond this limit the mixing becomes very difficult and prior studies have shown that increase in strength and properties of the soil is very less and some time it decreases also.

The load and corresponding penetration were ended and plotted. The load penetration curves were drawn for un-reinforced soil as well as soil reinforced with lime and fiber. The tests were conducted for both soaked as well as unsoaked condition. The combination of 3% lime + 0.25% fiber, 6% lime + 0.50% fiber, 9% + 0.75% fiber and 12% lime + 1% fiber were used. The result obtained in CBR test for both soaked and unsoaked conditions are presented in tabular form (Table -2).

Table 2: CBR Tests Results

Unsoaked Soil						Soaked Soil				
Penetration (mm)	Silt clay fine sand soil From(borrow pit)	Soil + 3% Lime + 0.25 %	Soil + 6% Lime + 0.50 %	Soil + 9% Lime + 0.75 %	Soil + 12% Lime + 1%	Silt clay fine sand soil From(borrow pit)	Soil + 3% Lime + 0.25 %	Soil + 6% Lime + 0.50 %	Soil + 9% Lime + 0.75 %	Soil + 12% Lime + 1%

		Fiber	**Fiber**	**Fiber**	**Fiber**		**Fiber**	**Fiber**	**Fiber**	**Fiber**
0	0	0	0	0	0	0	0	0	0	0
0.50	19	39	44	48	52	12	29	31	44	49
1.00	49	67	83	88	99	31	50	60	75	74
1.50	70	101	118	126	157	44	83	75	95	106
2.00	88	132	151	159	195	49	101	98	117	147
2.50	114	169	177	200	242	62	115	112	148	184
3.00	133	188	224	222	283	89	132	141	191	228
3.50	142	217	252	282	325	112	164	182	239	282
4.00	171	238	302	335	371	121	188	231	290	358
5.00	212	305	395	450	495	190	262	337	478	465
7.50	318	430	585	725	769	416	519	588	585	798
10.00	225	555	772	978	1021	680	775	822	828	905
12.50	516	685	970	1275	1302	1006	1021	1069	1110	1122

shown in figs.17 & 18. Some of the curves show initial concavity. The reason for this concavity may be due to the fact that either the top of the soil is not horizontal or the bottom of the plunger is not horizontal and as a result the plunger surface does not remain fully in contact with the soil. For such curves corrections have been applied and CBR was calculated on that basis. The initial concavity may also be there if top layer of the specimen is too soft or irregular. The CBR corresponding to 2.5 mm & 5 mm penetration were calculated from the curves for both soaked and unsoaked condition. Fig. 19 shows the comparison of the CBR value at the penetration of 2.5mm and 5.0mm for different lime and fiber content for unsoaked conditions. As the lime + Fiber content go on increasing the CBR value increases for both penetration level Fig.20 shows the comparison of CBR value at the penetration of 2.5 mm and 5.0 mm for different lime and fiber content for soaked conditions. There is increasing trend in CBR value with increase in lime and fiber contents.

From the table -2 we see that CBR value corresponding to 5.0 mm penetration is always greater than the soaked condition for the same percentage of fiber and lime content. We also see from the table 9 that with the increase in fiber and fiber and lime content the CBR value for both soaked and unsoaked condition goes on increasing. The percentage increase in CBR value for both soaked and unsoaked conditions with the increase in lime and fiber content is shown in Table -3.

Table 3: Percentage increase in CBR value for both soaked and un soaked condition

Type	**CBR Value %**		**% Increase in CBR**	
	soaked	**unsoaked**	**soaked**	**uncoaked**
Soil	10.30	8.06	-	-
Soil+3% lime+0.25% fiber	14.10	11.07	36.89	37.34
Soil+6% lime+0.50% fiber	16.3	13.95	58.25	73.07
Soil+9% lime+0.75% fiber	19.2	16.20	86.40	100.99
Soil+12% lime+1.0% fiber	22.4	20.10	117.4	148.13

Thus from the table we observe that percentage increase in CBR values for unsoaked condition are 36.89%, 58.25%, 86.40% and 127.18% respectively with respect to 3% lime + 0.25 fiber, 6% lime + 0.50% fiber, 9% lime + 0.75% fiber, 12% lime +1% fiber respectively.

Similarly the percentage increase in the CBR values for unsoaked condition are 36.04%, 62.20%, 88.37 & 133.72% respectively for 3% lime + 0.25% fiber, 6% lime + 0.50% fiber, 9% lime + 0.75% fiber, 12% lime + 1% fiber respectively.

Thus the percentage increase in the CBR value for unsoaked condition is higher vis-à-vis soaked condition. From Fig. 21,the percentage increase in CBR value for both soaked and unsoaked condition are somewhat same up-to 6% lime + 0.50% fiber content. Beyond 9% lime + 0.75% fiber contents, the increase in CBR value for with soaked and unsoaked conditions becomes more significant. This is because at higher lime and fiber content the volume of lime and fibre increases significantly due to its low specific gravity (0.98). As a result of this, quantity of soil matrix present to hold the fibers and to develop an effective bond between the fiber and soil decreases.

Conclusion, Recommendations And Future Scope

This investigation was carried out to study the strength characteristics of randomly distributed fibre reinforced in lime soil subgrade with respect to their load carrying capacity, modulus of subgrade reaction and California bearing ratio values. The present investigation was carried out in the lab and in semi full-scale field tests. The results show that lime fiber reinforced soil though slightly higher in cost as compared to unreinforced soil subgrade, exhibits superior performance as compared to conventional unreinforced soil subgrades. As a result of experimental investigations tests and semi-full scale pavement testing on lime-fiber reinforced soil subgrade with natural plastic fibers, the following conclusions are drawn:

1. The maximum dry density of unreinforced soil is higher. As the soil is reinforced with fibbers and lime in percentage wise, the maximum dry density decreases and the OMC increases. The increase in OMC is not significant with decreases in maximum dry density.
2. CBR Value increases with increases in 12% lime and 1% fiber in soil. The percentage increase in CBR unsoaked and soaked are 127.18 and 133.72 respectively.
3. Advantages of using Plastic waste: 8% of the bitumen by weight shall be replaced by plastic waste therefore the cost of bitumen saved 8% of the total bitumen cost. Increase fatigue resistance of bituminous mixes. Improve cohesion which assists resistance to weathering and stripping. Resistance to cracking raveling and failure. Test results indicate improvement in the field studies**.**
4. Environmental benefits: Reduce Carbon emission. When plastic are removed, what remain is organic waste which can be converted in to high quality organic manure for use of farmers. Rag pickers are paid for collection of plastic waste. Food borne and water borne disease are reduced due to less accumulation of waste.

Photo 1: CBR Testing Machine

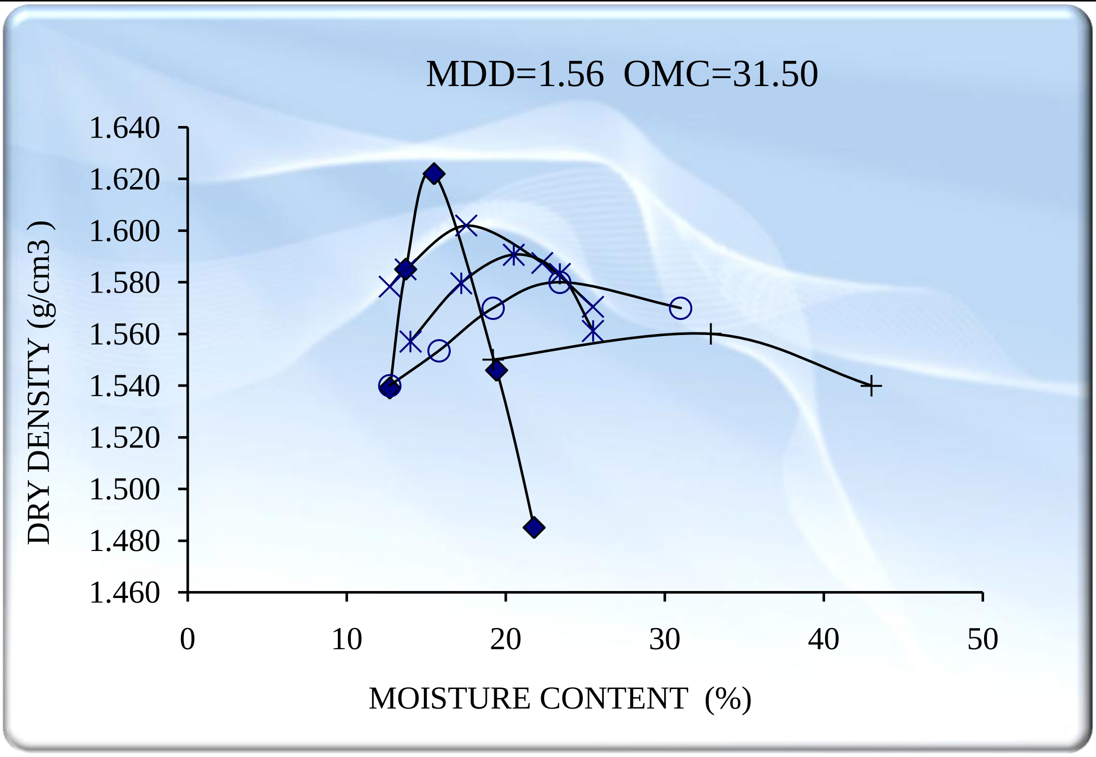

Fig. 1: OMC VS Dry Density Curve Comparison at a glance

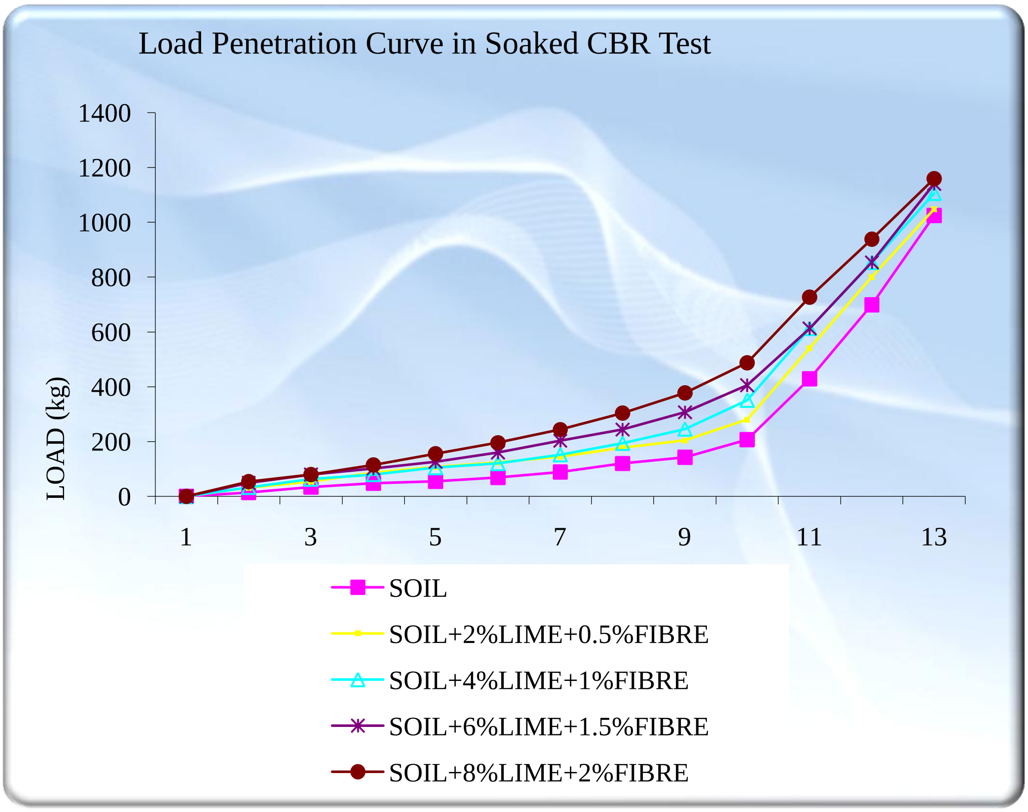

Fig. 2: Load Penetration Curve in Soaked CBR Test
(COMPARISON)

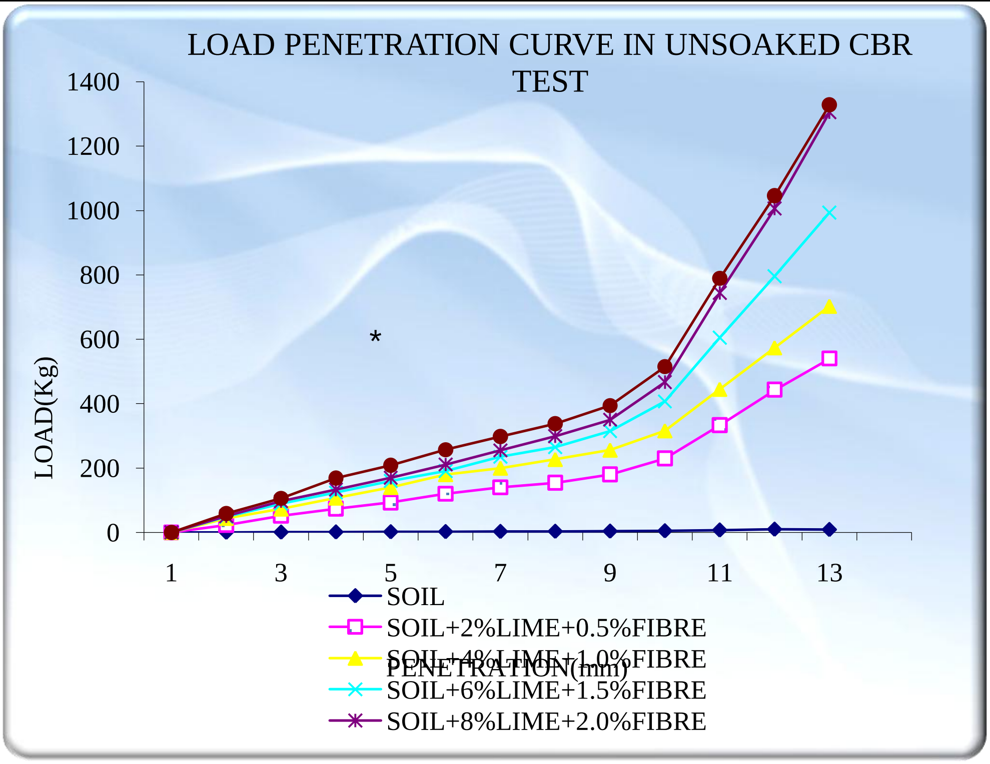

Fig. 3: Load Penetration Curve in Unsoaked CBR Test

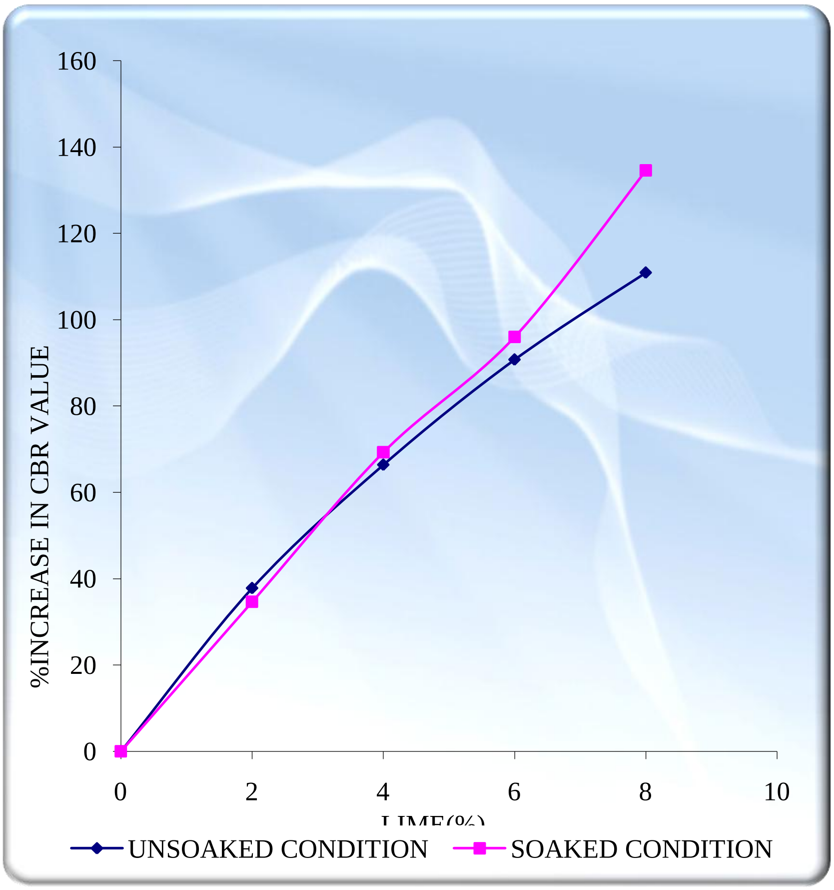

Fig. B-4: Variation of % Increase in CBR Value with Different Soil Reinforcement (Soil+Fibre %)

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