EXPERIMENTAL STUDY ON THE STRENGTH OF SUBGRADE LAYER OF ROAD PAVEMENT BY CBR METHOD

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Abstract - *The success and failure of road pavement is mostly dependent upon the underlying subgrade. Thus it is very important to enhance the strength of the subgrade layer. The value of California Bearing Ratio (CBR) of subgrade is used to design the flexible pavements and runway of airfields. Through CBR value one can understand the strength of the soil. In this paper, attempts have been made to obtain the CBR value of soil when mixed in different proportions of fly ash or/and cement. The fly ash has been collected from the NTPC Kahalgao, Bihar, India and OPC 43 grade cement has been collected from the local market of Begusarai, India. The soil used in this project for testing was picked up from chainage 236+900(LHS) to 237+500(LHS) which is borrowed from chainage 234+500(LHS) of NH-31, Begusarai, Bihar, India. The analysis of CBR value has been done by mixing the soil with fly ash at 5%, 10%, 15% and 20%, and with cement at 2%, 4%, 5%, and 10%. Another analysis was done by mixing both fly ash and cement at 18% and 2% respectively with soil. The objective of this study was to evaluate the effect of fly ash or/and cement on CBR value and hence ultimately on soil strength. Besides, soaked or unsoaked condition of soil also affects the CBR value.*

Key Words: California Bearing Ratio, Flexible pavement, Subgrade, Chainage, admixtures.

1. INTRODUCTION

California bearing ratio is an empirical test and widely used in the design of flexible pavements in India and all over the world. This method was developed during 1928-29 by the California Highway Department. The California bearing ratio test is frequently used in the evaluation of granular materials in base, sub-base and subgrade layers of roads, highways and airfield pavements. The significance of the CBR test emerged from the following two facts, for almost all pavement design charts, unbound materials are characterized in terms of their CBR values when they are compacted in pavement layers. And the CBR value can be correlated with some fundamental properties of soils, such as plasticity index, grain size distribution, Optimum moisture content, Maximum dry density, Bearing Capacity.

On the construction site engineers usually faces several problems related to the bearing capacity and strength of soil. It is very difficult to implement the conventional engineering techniques on these sites to start the projects. Conventional techniques on such sites can affect the project economically and also on the environmental conditions. Thus, in such conditions the soil mixed with various admixtures like cement and some industrial waste products like fly ash, which may be used to improve the strength of the soil. Since fly ash is a waste product it may help the soil to stabilize economically as well as environmentally to a very good extent. There was many researchers done successfully to analyze the strength behavior of soil when added with various admixtures based on their CBR values and some of the researchers are Basha et al. (2004), Brook. (2009), Patel and Patel (2011), Joshi and Choudhary (2014), Ramteke et al. (2014), Zumrawi (2015). The strength behaviour of soil with fly ash and Cement has been studied by some other researchers also and to some extent, similar trend observed by Sahu and Kamble (2017), Raj et al. (2017), Pandey (2017), Jigar and Patel (2013).

2. EXPERIMENTAL PROGRAM

In this paper, various laboratory test has been done on soil and soil mixed with different admixtures to determine the CBR value of the soil.

Grain Size Analysis, specific gravity, free swell index, maximum dry density (MDD), Optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI) has been done in the laboratory to obtain the soil and the mixture characteristics. Soaked and Unsoaked California Bearing Ratio test has been done.

2.1 MATERIALS

Materials used in the laboratory for testing are: Natural soil, cement and fly ash.

1.) Natural soil (Locally available soil):- The soil used in this project was collected from chainage 236+900(LHS) to 237+500(LHS) which is borrowed from chainage 234+500(LHS) of National Highway(NH) -31 in Begusarai, Bihar, India.
2.) Flyash:- The fly ash has been collected from the NTPC KAHALGAO, Bihar, India.

3.) Cement:- OPC 43 grade cement has been collected from the local market of Begusarai. And its chemical composition is mention in table 1.

Table: 1 Chemical Composition of Cement

CHEMICAL REQUIREMENTS	TEST RESULTS	REQUIREMENTS AS PER IS 269:2015
$\frac{CaO-0.7SO_3}{2.8SiO_2+1.2Al_2O_3+0.65Fe_2O_3}$	0.91	0.66 to 1.02
$\%Al_2O_3/\% Fe_2O_3$	1.45	0.66 Min.
Insoulble Residue (% by mass)	0.90	5.0 Max.
Magnesia (% by mass)	3.71	6.0 Max.
Sulphuric Anhydride (% by mass)	2.05	3.5 Max.
Loss on Ignition (% by mass)	1.90	5.0 Max.
Chloride Content (% by mass)	0.02	0.1 Max.

2.2 LABORATORY TESTS AND CALCULATION

Table: 2 Grain Size Analysis

GRAIN SIZE ANALYSIS (AS PER IS: 2720 (P-8))				
IS SIEVE SIZE (mm)	Wt of material retained (gm)	% Wt retained	% Cumulative wt retained	% Passing
20	-	-	-	-
4.75	0.264	0.05	0.05	99.95
2	0.836	0.16	0.21	99.79
0.425	3.036	0.6	0.81	99.19
0.075	92.745	18.55	19.36	80.64
SOIL CLASSIFICATION				
Gravel (Soil particles > 4.75 mm)			0.05%	
Sand (Soil particles <4.75 mm & > 0.075 mm)			19.31%	
Silt & Clay (Soil particles < 0.075 mm)			80.64%	

Table: 3 Atterberg Limits

ATTERBERG LIMITS OF SOIL (AS PER IS: 2720 (P-5))							
Description	LIQUID LIMIT(LL)				PLASTIC LIMIT(PL)		
	1	2	3	4	1	2	3
No. of Blows/ Penetration in mm	16	22	30	34			
Container No.	40	30	35	53	78	87	26
Wt of Container (W1) in gm	14.76	15.14	16.21	16.29	16.08	14.96	13.76
Wet of container + wet material (W2) in gm	22.541	26.316	23.897	26.095	18.655	17.797	16.694
Wt of container + dry material (W3) in gm	20.74	24.042	22.579	24.734	18.244	17.341	16.22
Wt of water (W2-W3) in gm	1.801	2.274	1.318	1.361	0.411	0.456	0.474
Wt of dry material (W3-W1) in gm	5.98	8.902	6.369	8.444	2.164	2.381	2.46
Water Content % = (W2-W3)/(W3-W1)*100	30.117	25.544	20.693	16.118	18.992	19.151	19.268

Table: 4 Result from Chart 1 & 2

LIQUID LIMIT	24
PLASTIC LIMIT	19.137
PLASTICITY INDEX (LL-PL)	4.863

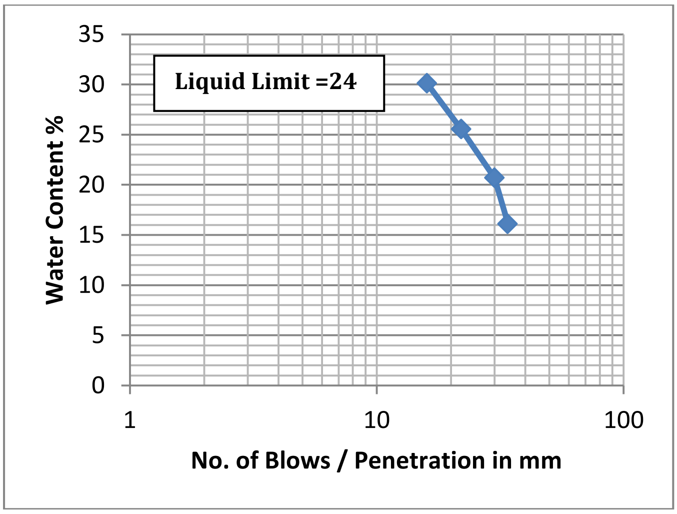

Chart: 1 Flow Curve

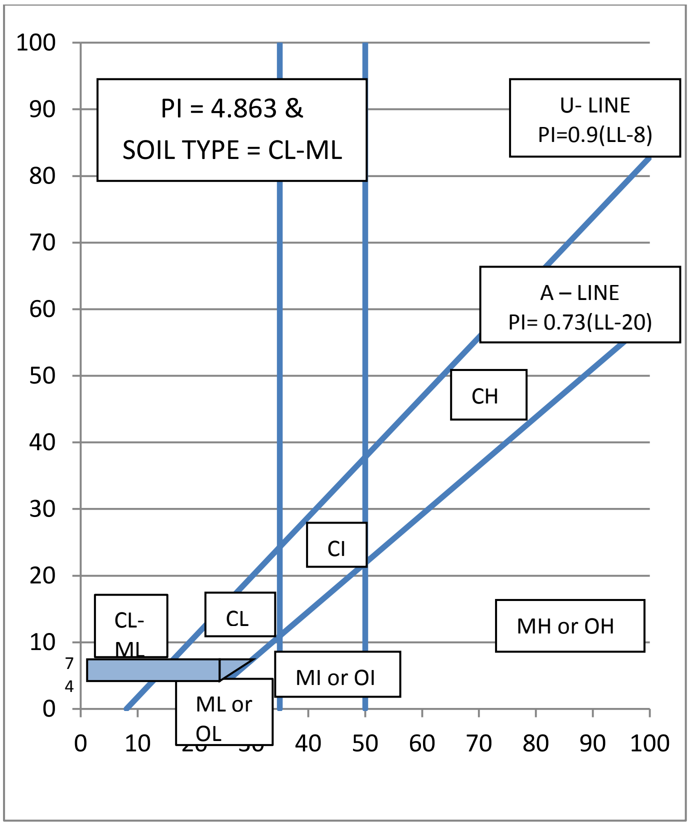

Chart: 2 Plasticity Chart

Table: 5 Specific Gravity of Soil

SPECIFIC GRAVITY OF SOIL (AS PER IS: 2720 (P-3))	
DESCRIPTION	**DETERMINATION No. 1**
Temperature in °C	24
Weight of bottle (W1) in gm	32.32
Weight of bottle + Dry soil (W2) in gm	48.262
Weight of bottle + Soil + Water (W3) in gm	88.92
Weight of bottle + Water (W4) in gm	78.97
CALCULATION :	
SPECIFIC GRAVITY G (at 24°C) = (W2-W1)/((W4-W1)-(W3-W2))	2.661
Corrected G (at 27°C) = G'	
G' = G X Relative density of water at room temperature/Relative density of water at 27 °C	
= 2.661 x 0.99732/0.99654	2.663

Table: 6 Modified Procter Test of Soil

MODIFIED PROCTER TEST (AS PER IS: 2720 (P-8))					
Volume of the mould (V) : 1000 cc			**Weight of the mould in gm m1 : 4352**		
Description	1	2	3	4	5
% water added	12%	14%	16%	18%	20%
Wt of mould + compacted material M2	6221	6380	6397	6465	6414
Wt of compacted material m3=(m2-m1)	1869	1956	2045	2113	2062
Wet density: yb=m3/v	1.869	1.956	2.045	2.113	2.062
Container No.	34 A	27 A	12A	39A	46B
Wt of Container W1	64.721	62.873	68.556	63.663	66.874
Wet of container + wet material W2	139.313	144.142	149.667	129.062	151.934
Wt of container + dry material W3	132.764	135.718	139.062	120.062	138.825
Wt of water (W2-W3)	6.549	8.424	10.605	9	13.109
Wt of dry material (W3-W1)	68.043	72.845	70.506	56.399	71.951
Moisture Content % W=(W2-W3)/(W3-W1)*100	9.62	11.56	15.04	15.96	18.21

Dry density: yd=yb/(1+W/100)	1.71	1.75	1.78	1.822	1.74
	MDD: 1.822gm/cc		**OMC: 15.96%**		

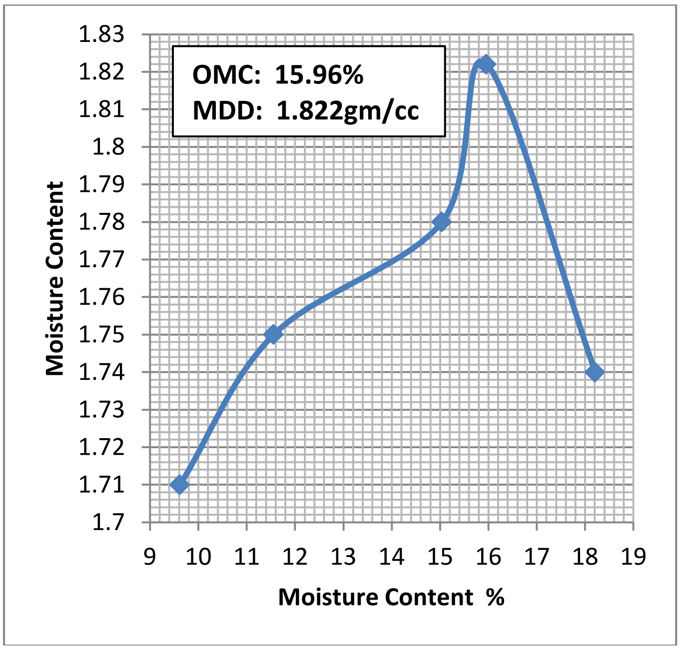

Chart: 3 Proctor compaction test curve

Table: 7 California Bearing Ratio test of Soil

CALIFORNIA BEARING RATIO TEST (AS PER IS: 2720 (P-16)) CBR(%) = (CORRECT UNIT LOAD / STANDARD UNIT LOAD)*100 STANDARD UNIT LOAD: at 2.5 mm- 1370 Kg & at 5.0 mm- 2055 Kg CALIBRATION FACTOR = 3.56		
Penetration(mm)	**Load(Kg)**	
0.5	8	
1	14.5	
1.5	22	
2	28.5	
2.5	34.5	
3	40.5	
4	52	
5	62.5	
7.5	87	
10.5	114.5	
12.5	134	

	at 2.5 mm	**at 5.0 mm**
CBR(%) =	8.964	10.827
FINAL CBR(%) = 10.827		

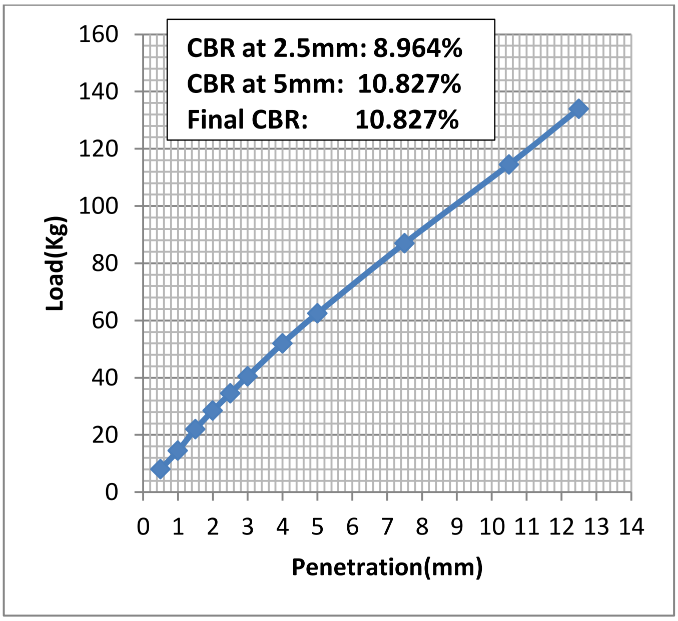

Chart: 4 CBR Test Curve

3. RESULTS AND DISCUSSIONS

3.1 RESULTS

Table: 8 Results of all Modified Procter Test and California Bearing Ratio performed on Soil, Soil+Flyash, Soil+Cement, Soil+Flyash+Cement

SI No.	TYPE OF MATERIALS	MODIFIED PROCTER TEST		CALIFORNIA BEARING RATIO TEST	
		MDD(gm/cc)	OMC(%)	SOAKED CBR(%)	UNSOAKED CBR(%)
1	SOIL	1.822	15.96	10.827	x
2	FLYASH	1.358	21.5	x	21.135
3	SOIL+FLYASH(5%)	1.776	14.2	11.953	15.643
4	SOIL+FLYASH(10%)	1.761	14.651	14.118	18.882
5	SOIL+FLYASH(15%)	1.727	15.1	14.725	21.914
6	SOIL+FLYASH(20%)	1.702	16	3.031	7.449

9	SOIL+CEMENT(2%)	1.768	16.225	31.572	x
10	SOIL+CEMENT(4%)	1.798	15.002	65.137	x
11	SOIL+CEMENT(5%)	1.751	16.2	88.61	x
12	SOIL+CEMENT(10%)	1.767	16.8	104.72	x
13	SOIL+CEMENT(15%)	1.765	16.12	***	x
14	SOIL+FLYASH(18%)+ CEMENT(2%)	1.713	16.5	48.506	x

3.2 DISCUSSIONS

[1] *Effect of Fly Ash on MDD and OMC of the Soil-fly ash mix*

The maximum dry density (MDD) and optimum moisture content (OMC) of the sample soil and the soil mixed with fly ash are summarised in chart 5 & 6 and in table 8, it can be observed that with an increase of fly ash content by 5%, 10%, 15%, 20%, in the soil the dry density of the soil-fly ash mix decreased by 1.776, 1.761, 1.727, 1.702 and optimum moisture content increases by 14.2%, 14.651%, 15.1%, 16% respectively. It may be due to the soil has a large amount of silt and clay and some appreciable amount of sand. Since the fly ash has a large amount of silt size particles (63.04%), it reduces the dry density of the mixture.

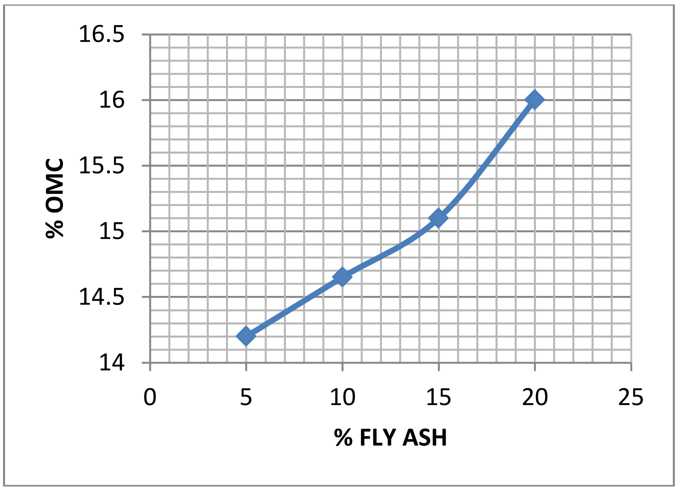

Chart: 5 Effect of Flyash on OMC

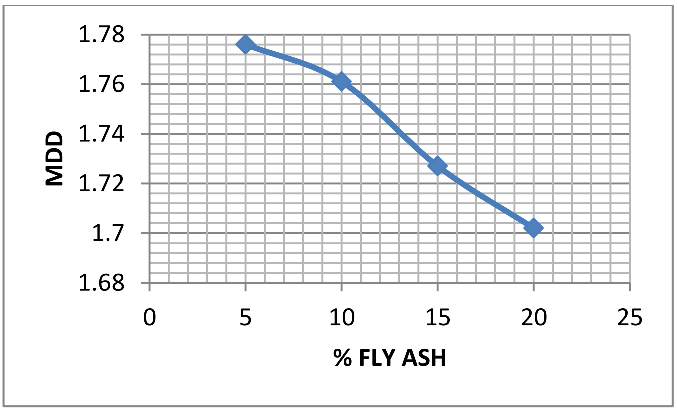

Chart: 6 Effect Flyash on Swell MDD

[2] *Effect of cement on MDD and OMC of the soil-cement mix*

The maximum dry density (MDD) and optimum moisture content (OMC) of the sample soil and the soil mixed with cement are summarized in table 8, it can be observed that with an increase of cement content by 2%, 4%, 5%, 10%, in the soil the dry density of the soil-cement mix observed as 1.768, 1.798, 1.751, 1.767 and optimum moisture content recorded as 16.225%, 15.002%, 16.2%, 16.8%. These results observed may be due to the soil type of CL-ML with an appreciable amount of Sand (19.31%).

[3] *Effect of fly ash and cement on MDD and OMC of the soil-fly ash- cement mix*

The maximum dry density (MDD) and optimum moisture content (OMC) of the sample soil and the soil mixed with fly ash and cement are given in table 8, it can be observed that at 18% fly ash and 2 % cement the dry density of soil-fly ash-cement mix is 1.713 and its OMC is recorded as 16.5%.

[4] *Effect of fly ash on CBR value of Soil-Fly ash mix*

The CBR of sample soil and soil mixed with fly ash has been conducted in the laboratory. The results of CBR value of soil-fly ash mix in soaked and unsoaked condition has been given in a chart 7 and table 8. From the tables and figures, it can be observed that the CBR value of soil-fly ash mix in soaked condition increases up to 14.725 when 15% of fly ash is mixed with the soil. After the further addition of fly ash 20% in the mix a sudden decrease in CBR value recorded as 3.031%. In unsoaked condition, it is observed that on increasing the fly ash content in mix by 5%, 10%, 15% the CBR value of soil-fly ash mix increases by 15.643, 18.882, 21.914. After the further increment of fly ash content by 20%, a sudden decrease is recorded in CBR value as 7.449. The CBR value of the soil-fly ash mix increases with increases of fly ash content upto a certain limit. The reason may due to cation exchange in the soil-fly ash mix during which the sodium ions in the soil are

replaced by the calcium ions in the fly ash thus reduces the settlement and hence increases the CBR value.
As the fly ash content in the soil reaches upto a certain limit at which cation exchange in the soil -fly ash mix stopped then the value of CBR reduces.

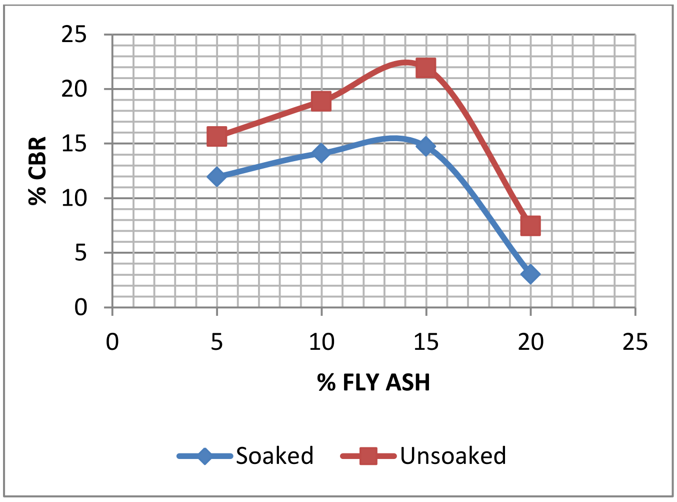

Chart: 7 Effect of Fly ash on CBR

[5] *Effect of cement on CBR value of Soil-Cement mix*

The test results of CBR value of soil-cement mix have been given in table 8. From the above table and fig it can be seen that with increase of soil-cement mix by 2%, 4%, 5%, 10% the CBR value of soil-cement mix increased by 31.572, 65.137, 88.61, 104.72 respectively. CBR value increases with increase in cement content in soil because cement creates strong bonding between soil particles and improves plasticity behaviour. Usually immediately after adding cement to the soil, there is an increase in the soil strength.
The reason for the CBR improvement was because of the cementing pozzolanic reaction between the soil and cement

[6] Effect of cement and fly ash on CBR value of soil-cement-fly ash mix

The test results of CBR value of soil-cement-fly ash mix has been given in table 8. From the above table and fig it can be seen that at 18% fly ash and 2 % cement the CBR value is 48.506. The reason for the CBR improvement was because of the cementing pozzolanic reaction between the soil and cement and due to cation exchange in the soil- fly ash mix during which the sodium ions in the soil are replaced by the calcium ions in the fly ash thus reduces the settlement and hence increases the CBR value.

4. CONCLUSIONS

The major conclusions drawn at the end of this work are as follows:

1. From these experimental results, it has been observed that soil is of type CL-ML with an appreciable amount of sand with a specific gravity of 2.663.
2. Soil and fly ash attains CBR value of 10.827% in soaked and 21.123% in unsoaked condition respectively.
3. Soil-fly ash mix attains maximum CBR value when mixed with 15% fly ash in soil in comparison with soil mix with 5%, 10% and 20% of fly ash, both in soaked as well as unsoaked condition.
4. CBR value of unsoaked soil-fly ash mix is greater than CBR value of soaked soil-fly ash mix.
5. In soil-fly ash mix as the % of fly ash increases, MDD decreases.
6. In soil-fly ash mix as the % of fly ash increases OMC increases.
7. On increasing the % of cement in soil-cement mix CBR value increases.
8. A very small % of cement, even 2% is capable of providing high strength.
9. On addition of 10% cement in soil, CBR value is even greater than 100% i.e 104.72% calculated at 2.5mm penetration as maximum penetration is 4mm having load of 572 kg.
10. On addition of 15% cement in the soil even 2.5mm penetration is not achieved for CBR test, maximum penetration is 2mm having a load of 353 kg.
11. When Soil(80%)+Flyash(18%)+Cement(2%) mix together CBR value of 48.506%, MDD- 1.713 gm/cc and OMC-16.5% is achieved.
12. Further this Research work can be carried with different materials to improve CBR values and also with different Soaking Conditions.

5. NEED AND SCOPE

The California Bearing Ratio Test (IS: 2720 - Part 16) is an empirical test and widely applied in the design of flexible pavement all over the world. CBR test is the ratio of force per unit area required to penetrate a soil mass with a standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of standard materials.

The California bearing ratio test is a penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the standard empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavements.

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