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Experimental Study on the Strength of Subgrade Layer of Road Pavement by CBR Method

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ABSTRACT

The flourshment and deterioration of asphalt pavement is predominantly depending on the fundamental layer of the pavement (i.e., sub grade soil). Therefore, it is important to enhance the strength of the sub grade soil. The California Bearing Proportion (CBR) of the sub grade soil is predominant in utilization to plan the adaptable asphalts and for runway of the landing strips. Through CBR value one can determine the strength of the soil so it is foremost to determine it. As it would help us to attain the required strength that is suitable for sub grade layer. The project envisages and stresses the idea, to acquire the CBR value of the soil when mixed in different proportions of fly ash or/and concrete. The fly ash is collected from nearby industry and OPC 43 grade cement was taken. The investigation of CBR value has been determined by blending the soil with fly ash at 5%, 10%, 15% and 20%, and with cement at 2%, 4%, 5% and 10%. Also, the soil was mixed with both the fly ash and cement at 18% and 2% respectively with the soil. The main aim of this project was to determine the impact of fly ash or/and cement by CBR value and subsequently attaining the soil strength. Furthermore, soaked and un soaked state of the soil also influences the CBR value.

1. INTRODUCTION:

Pavement is a hard surface formed of durable surface material that is laid down on an area meant to conduct automotive or pedestrian traffic. Its principal role is to disperse the applied vehicle loads to the various layers. It should have adequate skid resistance, good riding quality, good light reflecting properties, and little noise pollution. Pavements for roads serve a critical part in the development of any structure. Pavements are divided into two categories: flexible and stiff pavements.

1.1. Layers Of Pavement:

Surface course:

The main layer that bears the direct traffic load and generally contains superior quality materials. It is constructed with graded asphalt for 25-50mm. The main characteristics are friction, smoothness, drainage etc., it prevents the entry of excess water into the underlying base, sub-base and sub grade layers. It should be hard to resist the distortion under traffic and provide a smooth and skid resistance surface.

Base Course:

This is the second layer below the surface binder course and it provides additional load distribution and contributes to the sub-surface drainage. The thickness of the layer is 100-300mm, the materials used in the layer are crushed stone, slag and other untreated or stabilized materials.

Sub-base Course:

This is below the base course layer. The main aim of this layer is to provide structural support, improve drainage, reduce the intrusion of fines from the sub grade in the pavement structure. The sub base course has finer material that can be used as filler between the sub grade and the base course. The thickness is 100-300mm; this layer may or may not be needed as it is not a compulsory layer.

Sub-grade layer:

This is predominant layer in the pavement as it bears the stresses of all the layers from the top. The thickness of this layer is 150-300mm. So, it is essential to ensure that the soil sub grade is not overstressed and it should be properly compacted and should have maximum bearing capacity near to the optimum moisture content.

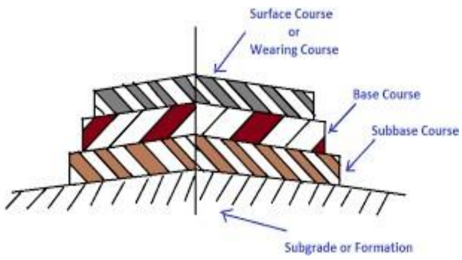

Fig: 1.Layers of Pavement

1.2. DIFFERENT LAYERS OF PAVEMENT:

There are two different types of pavements. They are

Flexible pavement:

The pavements which can change their shape to some extent without rupture are known as flexible pavement. The material used is asphalt, bitumen for the pavement construction. This pavement is cheap and easy in construction, materials can be easily available, and less supervision is required.

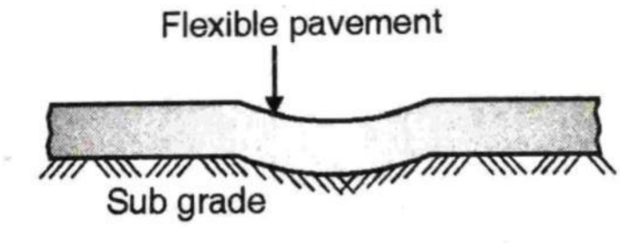

Fig: 2 Flexible pavements

Rigid pavement:

The pavements which cannot change their shape without rupture are known as rigid pavement. The materials used are cement and concrete. They don't have many layers as compared with the flexible pavement. It is directly placed on the compacted sub grade layer. It has longer life span, maintenance costs are low.

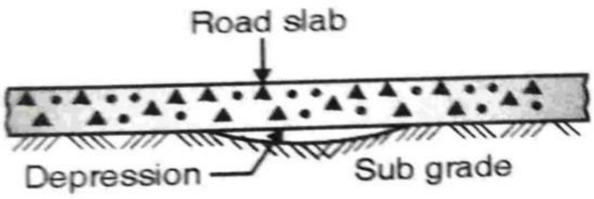

Fig: 3.Rigid pavement

1.3. SUBGRADE LAYER FUNCTION:

Sub grade soil provides base for the whole pavement structure. Weak sub grades of expansive soil have great tendency to swell and shrink when in contact with water. Clay rich in the mineral montmorillonite is thought to have caused this characteristic. Chemical or cementitious additives might be added to these expansive soils to improve their properties. These additions include fly ash, cement, lime, and special chemical stabilizers, and they range from waste sources to manufactured goods. Cement or lime are commonly used to improve weak subgrade soils. In fact, if a weak subgrade exists in the pavement structure, cement stabilization provides an efficient solution to the problem of fatigue failures produced by recurrent high deflection of asphalt surfaces.

1.4 .CBR (CALIFORNIA BEARING RATIO) IMPORTANCE:

The California bearing ratio is an empirical test that is commonly used in India and around the world to construct flexible pavements. The California Highway Department devised this system between 1928 and 1929. The California bearing ratio test is commonly used to assess granular materials in the foundation, sub-base, and subgrade layers of roads, highways, and airport pavements. Engineers on the construction site are frequently confronted with issues relating to the bearing capacity and strength of the soil. On these sites, implementing traditional engineering approaches to begin projects is extremely difficult. On such settings, traditional practices might have an economic and environmental impact on the project. In such circumstances, the soil is combined with various admixtures such as cement and industrial waste products such as fly ash, which can be utilized to improve the soil's strength. Because fly ash is a waste product, it has the potential to assist the soil stabilize both economically and environmentally.

The significance of the CBR test can be seen in the following two facts: unbound materials are basically characterized in terms of their CBR values when compacted in pavement layers in almost all pavement design charts, and the CBR value has been correlated with some fundamental soil properties like plasticity indices, grainsize distribution, bearing capacity, modulus of subgrade reaction, modulus of resilience, shear strength, density, and moisture content. The CBR test remains popular because these correlations are now easily available to professional engineers who have gained extensive expertise with them. The majority of the Indian highway system is made up of flexible pavement, which can be designed in a variety of ways. The California Bearing Ratio (CBR) test is a flexible pavement design empirical method. It's a load test that's applied to the surface and utilized in soil investigations to help with pavement design.

1.5. OBJECTIVE:

The objective of the project is to determine the maximum strength of the soil when mixed with fly ash or/and cement by determining the CBR value. And to also determine at what percentage the soil strength is more and should also the material used should be an economical one and should be helpful for the society.

1.6. FUTURE SCOPE:

If the strength of the soil is increased by adding fly ash or/and cement then these values can used further for the determination of thickness of the pavement and its components in compared to the standards.

2. LITERATURE REVIEW

E.A. Basha, R. Hasim, H.B. Mahmud, A.S. Muntohar. et.al (2004) An experiment was conducted on the residual soil to find out the strength of the soil by using rice husk ash and cement. The soil properties tests like compaction, strength, optimum moisture content, maximum dry density was found out. Normally replacement of natural soils and aggregates is highly desirable and economic also. It was found that addition of 6-8% of cement and 10-15% of rice husk ash is recommended with the optimum moisture content as there was an improve at that percentages.

Anil Pandey, Prof. Ahsan Rabbani et.al (2007) Soil stabilization using cement helps to improve the geotechnical properties of soil. He has determined that when higher quantity of cement was added to the soil the dry density was decreased and moisture content was increased. With the addition of cement to the soil it was found that unconfined compressive strength was increased as well as after the curing period the strength was increased.

Sathawara Jigar K., Prof. A.K. Patel. et. Al (2009) had described that load bearing capacity is important for the soil which is determined by CBR method. If the soil beneath is undisturbed and the compacted to attain strength and stiffness of the subgrade strength is main and the cbr value is attained for the both soaked and un soaked conditions and the values are compared at which value the highest strength is attained.

Dr. Robert M. Brooks et.al (2009) The stabilization of the soil was conducted by fly ash and rice husk ash which were waste materials released from the industries. The expansive clay was mixed with the materials and strength was determined. This mix was used in the footing of the foundation and subgrade as a swell reduction layer. A cost comparison was also made for the preparation of highway with or without admixtures and was found that at 12% of rice husk ash and 25% of fly ash attains maximum strength for the expansive soil.

Er. Devendra Kumar Choudhary, Dr. Y. P Joshi et al. (2014) A detailed study was conducted for determining the strength of sub grade layer for flexible pavement by CBR method. As it is one of the most important engineering properties of the soil for design of sub grade of roads. CBR mainly depends on the factors like maximum dry density, optimum moisture content, LL, PL, PI, type of the soil, permeability of the soil and also if the soil is under soaked or unsoaked conditions. The tests were conducted in the laboratory and by conducting these tests it would consume less time, cost and to get information about the strength of the soil. With the results it was easy to design the required flexible pavement under the guidelines of IRC: SP: 37-2001.

Magdi M. E. Zumrawi et.al (2015) Soil stabilization is widely known as an effective alternative for improving soil properties. As the soil performance is very responsible character for the pavement designing as it will help to improve the strength of the soil. He conducted an experimental study by combining both the fly ash and cement. He kept changing the fly ash percentages but kept the cement content constant. Different tests like Atterberg limits, compaction, CBR, swell index was conducted for both treated and untreated soils. And finally found that at 15% of fly ash and 5% of cement content there was a significant improvement on the properties of the soil.

Salvant Raj, Nikita Gupta, Love Sharma. et.al (2017) Low bearing capacity for the expansive soils is a challenge for engineers to work they are many methods to improve the soil strength by stabilization or using admixtures. In this paper they have also tried to determine the index properties of the soil as well as CBR value. They have mixed soil with various admixtures like cement kiln dust, rice husk ash and cement an found that for the treated soil mixture as the cbr value increases with an increase in the rice husk ash content and cement kiln dust.

3. MATERIALS

Cement:

Cement is a binder, a substance used in construction to bind materials together by setting, hardening, and adhering to them. Inorganic cements, such as lime or calcium-based cements, are commonly used in construction and are classified as hydraulic or non-hydraulic depending on their ability to set in the presence of water. Wet or submerged, non-hydraulic cement does not set; it dries and interacts with carbon dioxide in the air. After setting, it is resistant to chemical attack. A chemical interaction between the dry materials and water causes hydraulic cement to set and become sticky. Mineral hydrates are formed as a result of the reaction, which are not particularly water soluble and so are extremely durable in water and chemically resistant.

For the experimental task, ordinary Portland cement from the local market is used. The Indian code IS 12269-1987 was used to test the cement for various qualities. The grade OPC 43 is used.

Fly Ash:

Fly ash is the finely divided residue that follows from the combustion of pulverized coal and is carried away by exhaust gases from the combustion chamber. Coal-fired power and steam generating plants produce fly ash. Coal is often crushed and pushed into the boiler's combustion chamber with air, where it burns instantly, producing heat and a molten mineral residue. The heat is extracted from the boiler through boiler tubes, which cools the flue gas and causes the molten mineral residue to harden and create ash. The heavier fine ash particles, referred to as fly ash, fall to the bottom of the combustion chamber, while the coarse ash particles, referred to as bottom ash or slag, remain suspended in the flue gas. Particulate emission control equipment, such as electrostatic precipitators or filter fabric baghouses, remove fly ash before the flue gas is exhausted. Fly ash is currently employed in about 20 million metric tons (22 million tons) of technical applications each year. Portland cement concrete (PCC), soil and road foundation stabilization, flowable fills, grouts, structural fill, and asphalt filler are all common highway engineering applications.

4. METHODOLOGY

AIM AND OBJECTIVE OF STUDY

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LITERATURE SURVEY

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SELECTION OF SITE

↓

MATERIALS COLLECTION

↓

TESTS ON THE MATERIALS

↓

ANALYSIS OF THE TESTS CONDUCTED

↓

RESULT ANALYSIS

↓

CONCLUSION

5. EXPERIMENTAL PROCEDURE:

5.1. Grain Size Analysis:

To determine the grain size analysis, the soil is tested:

Soil gradation (sieve analysis) is a method of determining a granular material's particle size distribution (also known as gradation) by passing it through a series of sieves with increasingly lower mesh sizes and weighing the material retained on each sieve as a percentage of the total mass. Dry sieve analysis is used for soil particles larger than 4.75mm, and wet sieve analysis is used for soil particles smaller than 75 micron and larger than 4.75mm. If the soil particles are covered with clay or silt, wet sieve analysis is also required. Particle size distribution (PSD) in a soil mass is a property that gives a main concept about soil bearing capacity, and soil bearing capacity is a vital element in foundation design for any civil engineering construction.

Table no: 1 Grain size analysis

Grain Size Analysis				
IS Sieve Size (mm)	**Weight of material retained (gm)**	**% Weight retained**	**% Cumulative Weight 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 > 4.75mm)			0.05%	
Sand (Soil particles < 4.75mm & >0.075 mm)			19.31%	
Silt & Clay (Soil particles < 0.075mm)			80.64%	

5.2. Consistency Limts And Soil Classification:

The firmness of a fine-grained soil is determined by its consistency, which changes depending on the amount of water in the soil. As the water content in the soil increases, it transitions from solid to semi-solid to plastic to liquid. Consistency limits are the water contents at which the consistency changes from one state to another (or Atterberg limits). The shrinkage limit (WS), plastic limit (WP), and liquid limit (WL) are the three limits shown. Laboratory tests can be used to determine the values of these limitations.·

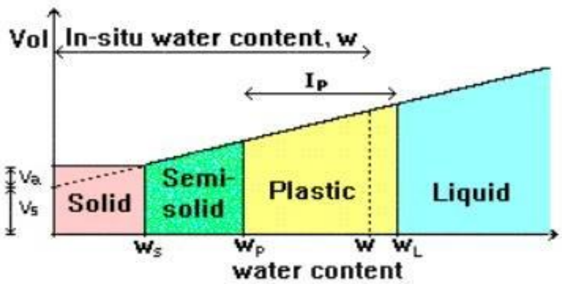


Fig: 4 Atterberg limits

Two of these are utilised in the classification of fine soils:

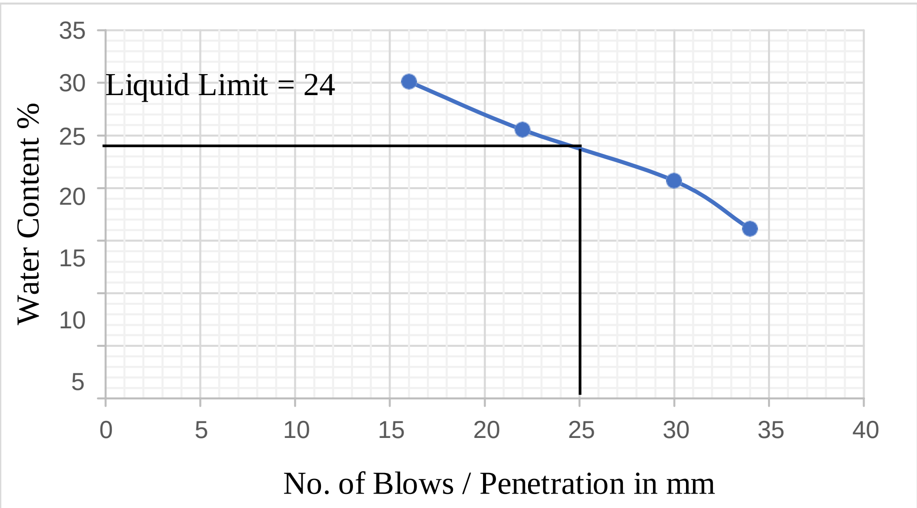
Liquid limit (W_L) - change of consistency from plastic to liquid state

Plastic limit (W_P) - change of consistency from brittle/crumbly to plastic state.

The difference between the liquid limit and the plastic limit is known as the plasticity index (I_P), and it is in this range of water content that the soil has a plastic consistency. The consistency of most soils in the field will be plastic or semi-solid.

Table no 2. Atterberg limits of soil

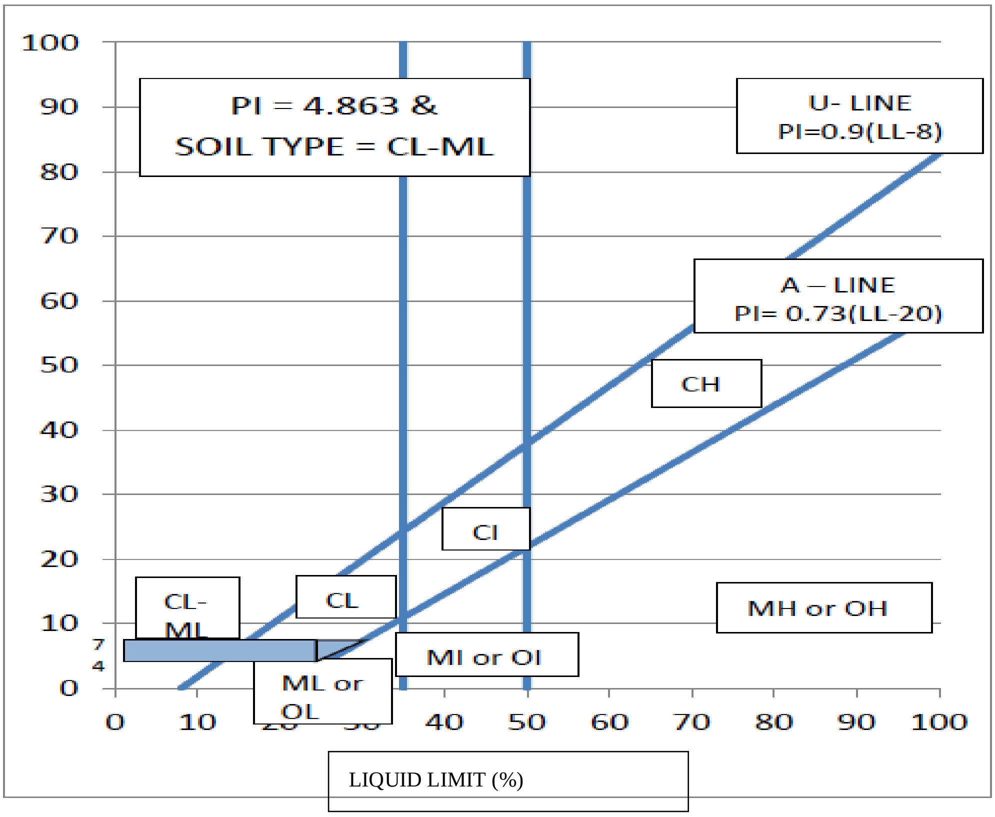
Atterberg Limits of soil							
Description	Liquid Limit (LL)				Plastic Limit (PL)		
	1	2	3	4	1	2	3
No. of Blows/ Penetration in mm	16	22	30	34			
Container No	40	30	35	53	78	87	26
Wt. of container (W_1) in gm	14.76	15.14	16.21	16.29	16.08	14.96	13.76
Wt. of container + Wet Wt. material (W_2) in gm	22.541	26.316	23.897	26.095	18.655	17.797	16.694
Wt. of container + Dry Wt. material (W3) in gm	20.74	24.042	22.579	24.734	18.244	17.341	16.22
Wt. of water(W_2-W_3) in gm	1.801	2.274	1.318	1.361	0.411	0.456	0.474
Wt. of dry material(W3-W_1) in gm	5.98	8.902	6.369	8.444	2.164	2.381	2.46
% Of Water content = $\frac{(W2 - W3)}{(W3 - W1)} * 100$	30.117	25.544	20.693	16.118	18.992	19.151	19.268
					$\frac{18.992 + 19.151 + 19.268}{3}$ = 19.137		



Graph no 1 Determination of Liquid limit (flow curve)

As per Indian Standard Soil Classification System:

Fine-grained soils are those for which more than 50% of the material has particle sizes less than 0.075 mm. Clay particles have a flaky shape to which water adheres, thus imparting the property of plasticity. A plasticity chart, based on the values of liquid limit (W_L) and plasticity index (I_P), is provided in ISSCS to aid classification. The 'A' line in this chart is expressed as $I_P = 0.73 (W_L - 20)$.



Graph no.2 Plasticity Chart

Fine soils are classified as clays (C), silts (M), or organic soils, depending on where they fall on the chart (O). The organic content is calculated by dividing the mass of organic matter in a given mass of soil by the mass of dry soil solids. Plasticity is also divided into three categories, as follows:

Table no 3. Plasticity standard values

Low Plasticity	$W_L < 35\%$
Intermediate Plasticity	$35\% < W_L < 50\%$
High Plasticity	$W_L > 50\%$

The 'A' line and vertical lines at W_L equal to 35% and 50% separate the soils into various classes. For example, the combined symbol CH refers to clay of high plasticity.

Soil classification using group symbols is a s following:

Table no 4. Soil Classification

Group Symbol	Classification
Coarse soils	
GW	Well-graded Gravel
GP	Poorly-graded Gravel
GM	Silty Gravel
GC	Clayey Gravel
SW	Well-graded Sand
SP	Poorly-graded Sand
SM	Silty Sand

SC	Clayey Sand
Fine soils	
ML	Silt of low plasticity
MI	Silt of intermediate plasticity
MH	Silt of high plasticity
CL	Clay of low plasticity
CI	Clay of intermediate plasticity
CH	Clay of high plasticity
OL	Organic soil of low plasticity
OI	Organic soil of intermediate plasticity
OH	Organic soil of high plasticity
Pt	Peat

From flow curve and plasticity chart we determine

Table no 5. Result from plasticity curve and flow curve

Liquid limit	24
Plastic limit	19.137
Plasticity Index (LL-PL)	4.863

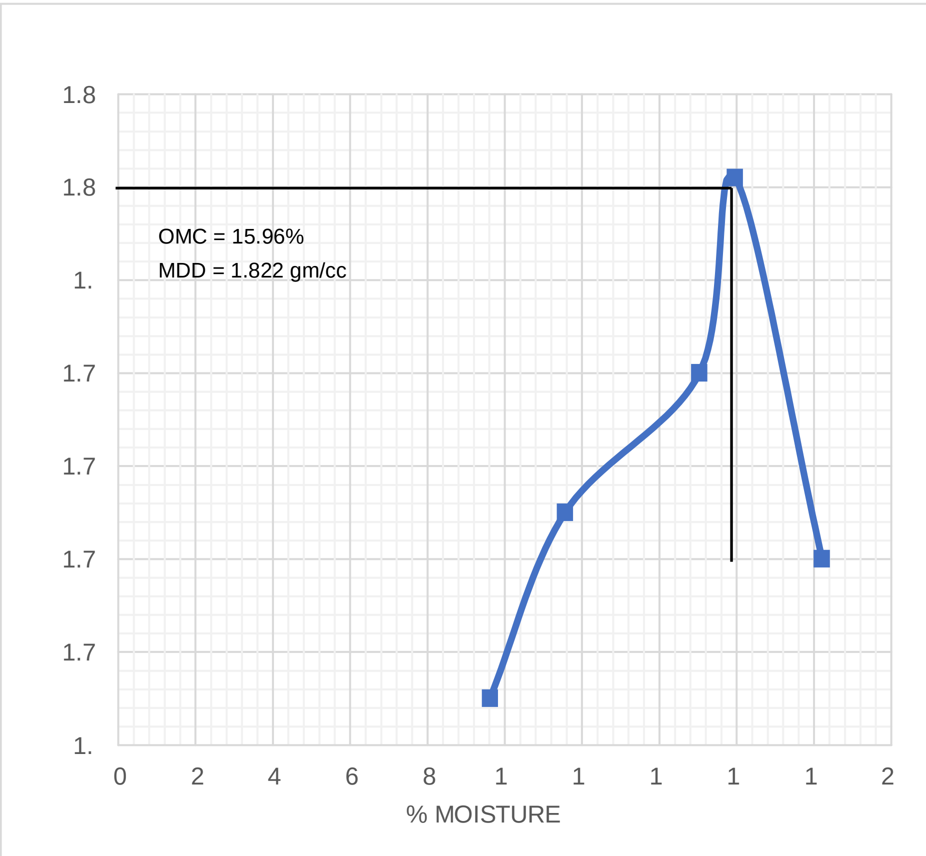
5.3. Modified Proctor Test:

Proctor test is used to find two major properties i.e., optimum moisture content (OMC) and maximum dry density (MDD). It is a field or lab test to perform the compaction of the soil. Proctor test are of two types spt (standard proctor test)- light compaction mpt (modified proctor test)- heavy compaction. By performing this test accurately, we can relate to field and lab data. By finding MDD on field and lab, we are about to know that how much amount of compaction we can achieve on-site/field. And ultimately, MDD helps in various construction techniques such as earthen dam construction, concrete structures, etc. Proctor compaction test is used to determine the optimum moisture content during compaction which gives the greatest soil density. In turn, it increases the soil capacity for bearing load.

Table no 6. Modified proctor test calculations

Modified Proctor Test					
	Volume of the mould (V_m): 1000 cc		Weight of the mould in gm m_1: 4352		
Description	1	2	3	4	5
% Water Added	12%	14%	16%	18%	20%
Wt. of mould + compacted material m_2	6221	6380	6397	6465	6414
Wt. of compacted material $m_3 = m_2 - m_1$	1869	1956	2045	2113	2062
Bulk density $Y_b = \frac{m_2 - m_1}{V_m}$	1.869	1.956	2.045	2.113	2.062
Container No.	34 A	27 A	12 A	39 A	46 B

Wt. of container W_1	64.721	62.873	68.556	63.663	66.874
Wt. of container + wet material W_2	139.313	144.142	149.667	129.092	151.934
Wt. of container + dry material W_3	132.746	135.718	139.062	120.062	138.852
Wt. of water (W_2-W_3)	6.549	8.424	10.605	9	13.109
Wt. of dry material (W_3-W_1)	68.043	72.845	70.506	56.399	71.951
Moisture content = $\frac{(W_2 - W_3)}{(W_3 - W_1)} * 100$	9.62	11.56	15.04	15.96	18.21
Dry density $Y_d = \frac{100\ Y_m}{(100+W)}$	1.71	1.75	1.78	1.822	1.74
	MDD (Maximum Dry Density) = 1.822 gm/cc		OMC (Optimum Moisture Content) = 15.96%		



Graph 3. Proctor compaction test curve

5.4. California Bearing Ratio Test:

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

Table7. CBR values

California Bearing Ratio values	
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

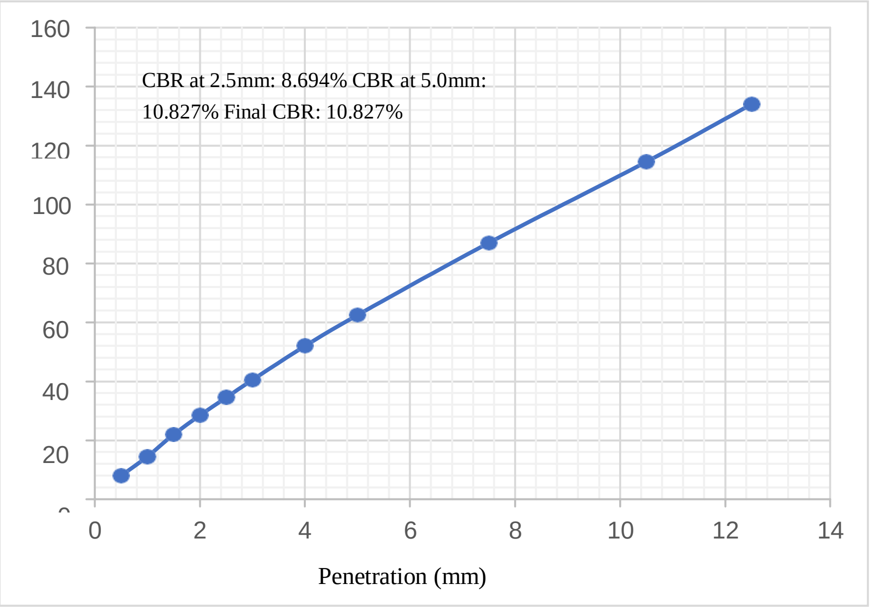
Calculations:

$$= \frac{\text{penetration load}}{\text{standard load}} \times 100$$

Standard unit load: at 2.5mm – 1370Kg

at 5.0mm – 2055 Kg Calibration factor = 3.56

	At 2.5mm	At 5.0mm
CBR (%)	8.964	10.827
Final CBR (%) = 10.827		



Graph 4. CBR (California Bearing Ratio Values)

RESULTS AND DISCUSSIONS

TEST RESULTS ON THE MATERIALS:

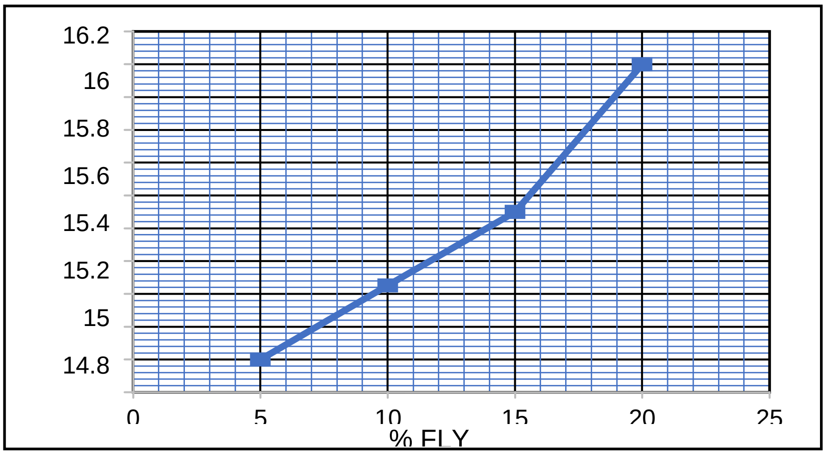
Table 8. Results when soil mixed with fly ash or/and cement

Sl. No.	Type of Materials	Modified Proctor Test		California Bearing Ratio Test	
		Maximum Dry Density (MDD) [g/cc]	Optimum Moisture Content (OMC) [%]	Soaked CBR (%)	Unsoaked CBR (%)
1	Soil	1.822	15.96	10.827	-
2	Fly Ash	1.358	21.5	-	21.135
3	Soil + Fly Ash (5%)	1.776	14.2	11.953	15.643
4	Soil + Fly Ash (10%)	1.761	14.651	14.118	18.882
5	Soil + Fly Ash (15%)	1.727	15.1	14.725	21.914
6	Soil + Fly Ash (20%)	1.702	16	3.031	7.449
7	Soil + Cement (2%)	1.768	16.225	31.572	-
8	Soil + Cement (4%)	1.798	7.215.002	65.137	-
9	Soil + Cement (5%)	1.751	16.2	88.61	-
10	Soil + Cement (10%)	1.767	16.8	104.72	-
11	Soil + Cement (15%)	1.765	16.12	-	-
12	Soil + Fly Ash (18%) + Cement (2%)	1.713	16.5	48.506	-

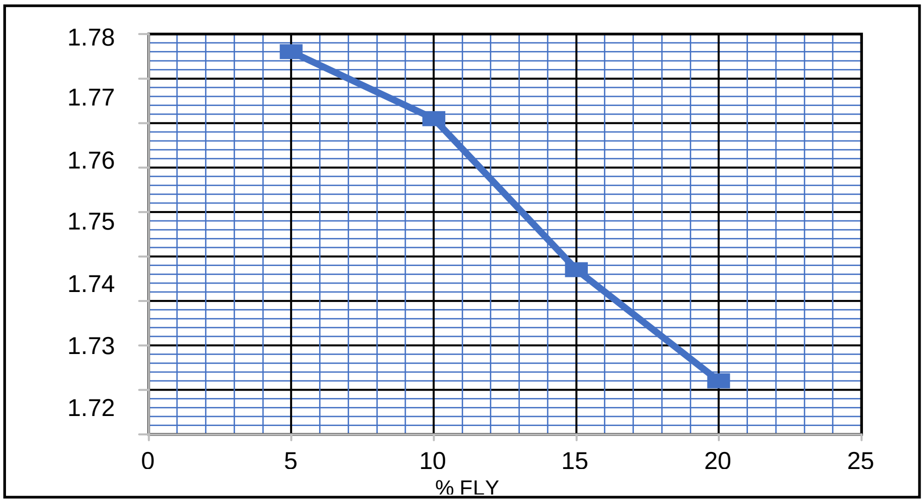
Graphical Representation of Results:

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.



Graph 5. Effect of fly ash on OMC



Graph 6. Effect of fly ash on MDD

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

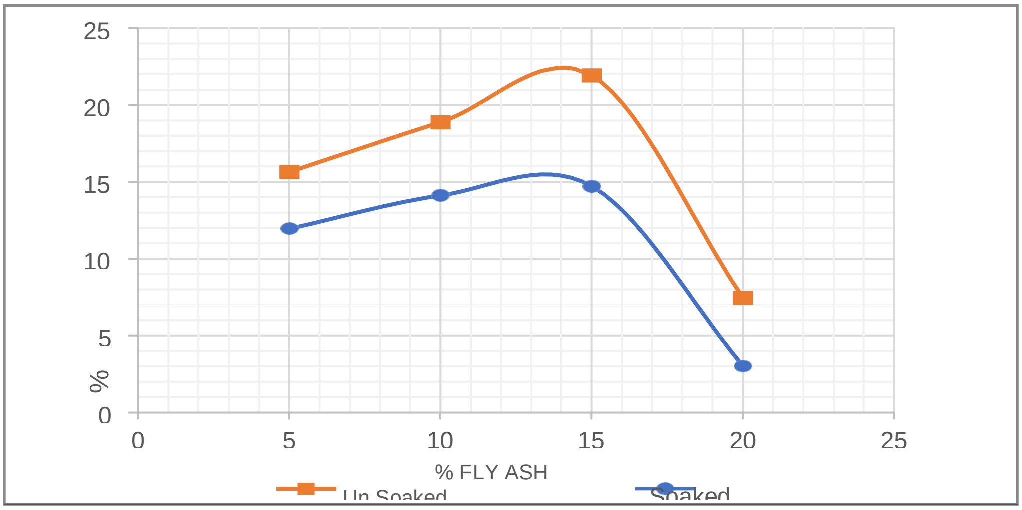
content recorded as 16.225%, 15.002%, 16.2%, 16.8%. These results observed may be due to the soil type of CL- ML with an appreciable amount of Sand (19.31%).

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%.

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 up to 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 up to a certain limit at which cation exchange in the soil -fly ash mix stopped then the value of CBR reduces.



Graph 7 Effect of fly ash on CBR

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 behavior. 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

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 have 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.

CONCLUSION:

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

- From these experimental results, it has been observed that soil is of type clayey silt CL-ML with an appreciable amount of sand with a specific gravity of 2.663.
- Soil and fly ash attain CBR value of 10.827% in soaked and 21.123% in unsoaked condition respectively. And the 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. So, CBR value of unsoaked soil-fly ash mix is greater than CBR value of soaked soil-fly ash mix. In soil-fly ash mix as the % of fly ash increases, MDD decreases. Whereas in OMC of the soil-fly ash mix OMC increases as the % of fly ash increases.
- On increasing the % of cement in soil-cement mix CBR value increases. A very small

  % of cement, even 2% is capable of providing high strength. 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. 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.
- When Soil (80%) +Fly ash (18%) +Cement (2%) mix together CBR value of 48.506%, MDD- 1.713 gm/cc and OMC-16.5% is achieved.

Further this Research work can be carried with different materials to improve CBR values and also with different Soaking Conditions.

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