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Experimental Investigation on Soil and Strengthening using Mineral Admixtures

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Abstract - *Soil stabilization is the process of enhancing the engineering properties of the soil such as shear strength, bearing capacity, shrink- swell property and making the soil more stable. The main objectives of the soil stabilization are to increase the bearing capacity and CBR of the soil. Therefore soil stabilization techniques are necessary to ensure the good stability of soil so that it can successfully transfer the load of the superstructure to the soil especially in case of soil which are highly active, also it saves a lot of time and money when compared to the method of replacing the whole unstable soil. Soil stabilization techniques are necessary to ensure good stability of the soil. This project deals with the complete analysis of the improvement of soil properties and its stabilization with the help of the mineral admixtures. With the same objective the literature review is undertaken on utilization of the mineral admixture for the stabilization of the soils and their performance was discussed.*

***Key Words*: Shear Strength, Bearing Strength, Stabilization, Admixture, CBR**

1. INTRODUCTION

Soil is a naturally available material which is used for civil engineering projects. For any structure, the foundation is very important to support the superstructure and therefore it transfers the loads from the superstructure to the substructure. Improving the engineering properties of the soil which is naturally available at the site is known as Soil Stabilization.

Soils may be separated into three very broad categories: cohesion less, cohesive, and organic soils. Cohesive soils are identified by very small particle size distribution where surface chemical effects are predominant. The cohesive particles do tend to stick together with each other as a result of water- soil particle interaction and attractive forces between the soil particles. Cohesive soils are therefore both sticky and plastic in nature.

Clayey soils cannot be separated by sieve analysis into size categories because no practical sieve can be made with openings so small; instead, particle sizes may be determined by observing settling velocities of the particles in a water mixture.

Construction of highways and buildings over soft soils is one of the most common civil engineering problems in many parts of the world since soft soils generally show low strength and high compressibility. To improve the Bearing capacity and CBR by grouting various mineral admixtures are used.

1.1 Soil Stabilization

Soil Stabilization is the technique of alteration or the enhancement of the engineering properties of the soils. Stabilization of the soil will increase the strength parameters of the soil and also helps in the control of the shrink and swell properties of the soil, thus helps in the improvement of the load bearing capacity of the sub-grade to support pavements and foundation.

1.2 TYPES OF SOIL STABILIZATION TECHNIQUES

- Mechanical Stabilization
- Chemical Stabilization
- Polymer/Alternatives
- Ground Reinforcement
- Soil Stabilization with Additives

1.3 Material Used

- Black Cotton Soil
- Lime
- GGBS
- Silica Fumes
- Metakaolin
- Fly Ash

2. LITERATURE REVIEW

Priyanka Mohile, et.al (2019) in this, the author discussed about the effect of adding silica fume to black cotton soil in order to improve its engineering properties. Silica fume has been added in different percentages 0%, 2.5%, 5%, 10% by weight of soil. The results of test show that the addition of silica fume reduces the liquid limit, plasticity index, specific gravity, optimum moisture content, free swell % and increases plastic limit, unconfined compression strength with increasing California bearing ratio. Keywords: Expansive Soil, Silica Fume, California Bearing Ratio, Atterberg's Limit

N. Prakash. S et al. (2018), in this paper the author describes that, the clay soil is a problematic soil which cannot be directly used for the construction of structures because it has high shrinkage. Various techniques are available to stabilize the soil to make better foundation for structures. Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable. This project deal with stabilization of clay soil by using Metakaolin like with constant proportion of 10%, 20%, 30% and granite powder with proportions of 10%, 20%, 8%. After the conclusion made from the laboratory test liquid limit, Plastic limit, MDD , OMC and CBR test value are to be determined. CBR value increases the bearing capacity of the soil. From these tests it increases the strength and it improves the improves the behavior of the Expansive soil using these admixtures.

Ankit Singh Negi et al. (2013), in this paper the author discussed that, Soil stabilization can be explained as the alteration of the soil properties by chemical or physical means in order to enhance the engineering quality of the soil . The main objectives of the soil stabilization are to increase the bearing capacity of the soil, its resistance to weathering process and soil permeability. The long-term performance of any construction project depends on the soundness of the underlying soils. Unstable soils can create significant problems for pavements or structures, Therefore soil stabilization techniques are necessary to ensure the good stability of soil so that it can successfully sustain the load of the superstructure especially in case of soil which are highly active, also it saves a lot of time and millions of money when compared to the method of cutting out and replacing the unstable soil. This paper deals with the complete analysis of the improvement of soil properties and its stabilization using lime.

Alex Wilkinson et al. (2010), in this paper the author describes that, Lime slurry pressure injection (LSPI) is a stabilization technique used in problematic soils by transportation industries with the aim of improving the geotechnical properties and bringing excessive maintenance costs to an acceptable standard. This paper presents detailed field and laboratory studies of a lime/flyash stabilized site at Breeza, NSW, Australia. The mixing of slurry into the soils with depths was investigated by excavating a trench while the improvement of the geotechnical properties was determined in detailed field and laboratory tests. Visual observations of the surface of an excavated trench showed slurry to be distributed within the shrinkage cracks in the desiccated upper soil horizon whereas slurry was conveyed through planes of hydraulic fracture in the soils at greater depths. Laboratory swell tests on the stabilized soils demonstrated a statistically significant reduction of the intrinsic swell properties in the upper horizon of the highly plastic clayey soils by LSPI. A gain in soil strength was observed in cone penetrometer test soundings conducted in stabilized soils. Scanning electron microscope and x-ray diffraction studies proved the underlying physicochemical and cementitious reaction processes in stabilized soils. Aggregation of the soils was observed with the outward diffusion of calcium cations within proximity of slurry seams and resulted in a subdued shrink/swell propensity.

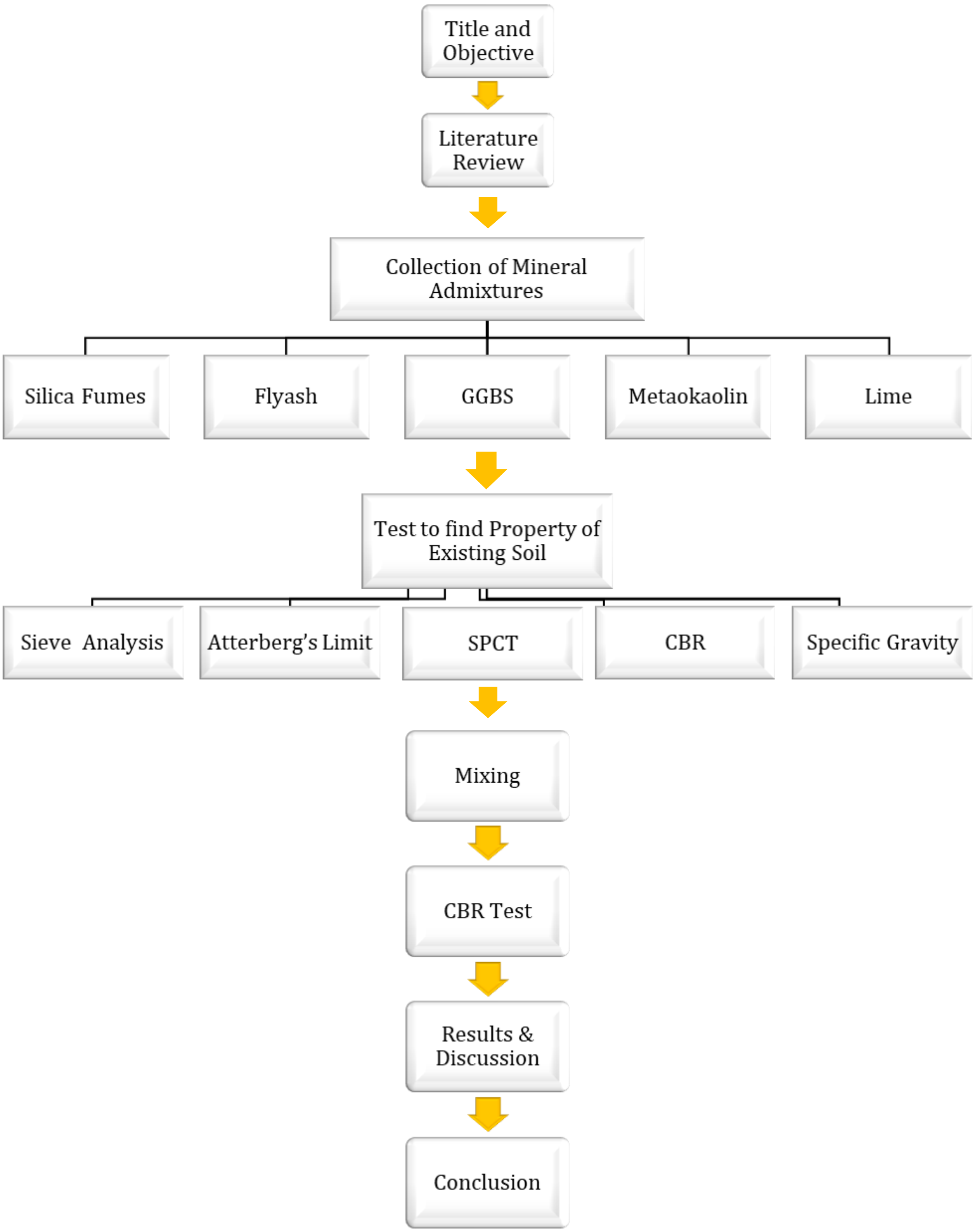
Fig-1: Soil Sample

Fig-2: Lime (left) **& Fly Ash** (right)

Fig-3: GGBS (left) **& Metakaolin** (right)

Fig-4: Silica Fumes

3. METHODOLOGY



4. EXPERIMENTAL INVESTIGATION

The experimental investigation on the existing soil carried out as per Indian standard. The laboratory tests include Specific Gravity, Grain Size Distribution, Atterberg's limit test, Standard Proctor Compaction test, and California Bearing Ratio test. The testing program designed in this project is to improve the CBR value of the subgrade using mineral admixtures like lime, fly ash, GGBS, Metakaolin, Silica Fumes. The preliminary tests were carried out to determine the properties of the soil.

4.1 Specific Gravity

The specific gravity test for the soil sample was carried out as per IS 2720: 1980 (Part 3). In this test, the pycnometer was dried and weighed with its cap as W_1, and 200 gm or 1/3rd of oven dried soil passing through 4.75 mm sieve and weigh as W_2. The enough water was added in pycnometer until it is about two – third full. Weigh the Pycnometer as W_3. Empty the pycnometer and wash it. Then fill it with water up to the mark and weigh as W_4. Repeat the above procedure three times. Specific Gravity of Soil is then, computed by taking averages.

Table -1: Specific Gravity

Trial No.	W_1 (g)	W_2(g)	W_3 (g)	W_4 (g)	G
1.	556	892	1669	1491	2.436
2.	556	906	1681	1491	2.391
3.	556	854	1654	1491	2.384
				Avg.	2.404

4.2 Sieve Analysis Test

The sieve analysis test for the soil sample was carried out as per IS 2720: 1980 (Part 4). In this test for sieve analysis test starts from observation of the weight of each sieve as well as the bottom pan to be used in the analysis. Record the weight of the dry soil sample. Make sure that all the sieves are clean and assemble them in the ascending order of sieve numbers. Place the pan below sieve. Carefully pour the soil sample into the top sieve and place the cap over it. Place the sieve stack in the mechanical shaker and shake for 10 minutes. Remove the stack from the shaker and carefully weigh and record the weight of each sieve with its retained soil. In addition, remember to weigh and record the weight of the bottom pan with its retained fine soil.

Weight of soil Sample taken for Testing = **1000 g**

Table -2: Sieve Analysis

S. No	Aperture Size of Sieve in mm	Weight of Soil Retained (g)	% Weight Retained	Cumulative % Retained	% Passing
1.	4.75	0	0	0	100
2.	2.36	181	18.1	18.1	81.9
3.	1.18	260	26.0	44.1	55.9
4.	0.60	230	23.0	67.1	32.9
5.	0.425	105	10.5	77.6	22.4
6.	0.30	102	10.2	87.8	12.2
7.	0.15	81	8.1	95.9	4.1
8.	0.075	30	3.0	98.9	1.1
9.	Pan	11	1.1	100	0

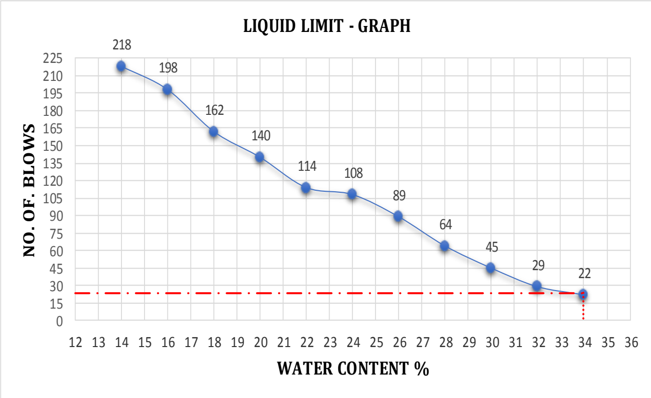
4.3 Liquid Limit Test

The liquid limit test for the soil sample was carried out as per IS 2720: 1980 (Part 5). 120g of the soil was taken and passed through 425-micron sieve is mixed thoroughly with water in the evaporating dish to form a uniform paste. The grooving tool was drawn through the sample along the symmetrical axis of the cup. The handle was rotated at a rate of about 2 rev/sec and numbers of blows were counted till the two parts of the soil sample come into contact at the bottom. The experiment was repeated by along little more water trials are made so that the numbers of blows were more than 25 in two cases and less than 25 in other two cases. The flow curve was plotted with water content as the ordinate and log of the number of blows. The water content corresponding to 25 blows is taken as the liquid limit of the soil.

Table -3: Liquid Limit

Water Content %	Number of Blow
14	218
16	198
18	162
20	140
22	114
24	108
26	89
28	64
30	45
32	29
34	22

Liquid Limit value for Soil Sample from graph **= 22%**



Graph -1: Liquid Limit Graph

4.4 Plastic Limit Test

The plastic limit test for the soil sample was carried out as per IS 2720: 1980 (Part 5).30 gm of soil was taken and passed through 425-micron sieve is mixed thoroughly with water in the evaporating dish to form a uniform plate. A ball was formed by taking a small amount of soil mass. The soil particle was rolled on the glass plate using palm, into thread. Initially it may be possible to roll into thread whose diameter is less than 3mm.

Observation and Calculation

Percentage of moisture content= (W2-W3)/(W3-W1) x100

- Wt. of empty container (W1) = 5g
- Wt. of container + sample before drying (W2)= 15 g
- Wt. of container + sample after drying (W3) = 13 g
- Wt. of water (W2-W3) = 2 g
- Plastic limit of soil = 25%

It is evident that, from the experiment the average results of plastic limit test of soil sample is **25%**

4.5 Shrinkage Limit

The shrinkage limit test for the soil sample was carried out as per IS 2720: 1980 (Part 6).100 gm of soil sample from a thoroughly mixed portion of the material passing through 425 microns IS sieve is taken. About 30 gm of above soil sample is placed in the evaporating dish and thoroughly mixed with distilled water to make a paste. The weight of the clean empty shrinkage dish is determined and recorded. The dish is filled in three layers by placing approximately 1/3rd of the amount of wet soil with the help of spatula. Then it is oven dried at a temperature of 1050 C to 1100 C for 12 to 16 hours. The weight of the dish with dry sample is determined and recorded. Then the weight of oven dry soil pat is calculated (W).

Shrinkage limit = (W2-W3) - γw (V1-V2)/(W3-V1)

W_1 - Empty wt. of shrinkage dish = 33 g
W_2 - Empty wt. of shrinkage dish +wet soil = 63 g
W- Wt of wet soil in shrinkage dish (W2-W1) = 30 g
W_3 - Empty wt. of shrinkage dish +dry soil = 56 g
V_1 - Volume of wet soil = 24.93 cm^3
V_2 - Volume of dry soil = 18.75 cm^3
Shrinkage limit of soil sample = **2.63%**

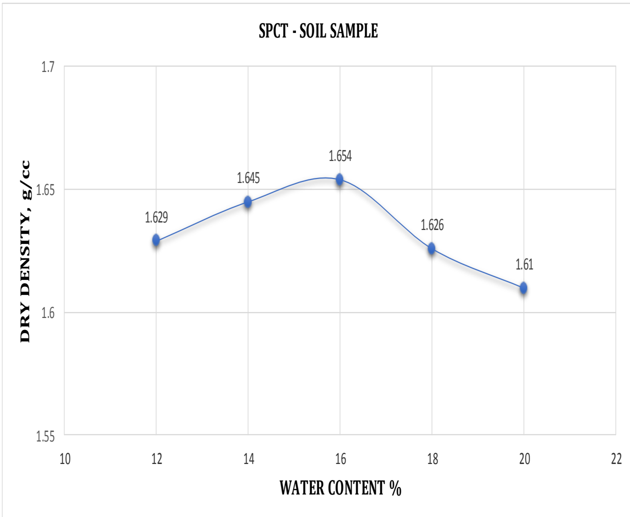
4.6 Standard Proctor Compaction Test

The Standard Proctor Compaction test for the soil sample was carried out as per IS 2720: 1980 (Part 7). 2500 gm of dry soil sample was taken and passed through 4.75 mm sieve. The soil was mixed in water thoroughly. The soil was filled into the mould to about 1/3 rd height of the mould. The soil was compacted used rammer by given 25 blows for each layer. The blows evenly distributed over the entire surface of the soil sample. The mixed soil was transferred to another 1/3 rd height and repeat step 6. The collar was removed and trimmed the top surface. The compacted soil was weighed with mould and base plate. The moisture content was increased 2% and repeated above all steps. A graph was plotted between dry unit weight and moisture content.

Table -4: Standard Proctor Compaction Test

S. No	Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
1	(w)	12 %	14 %	16 %	18 %	20 %
2	(W_2) (g)	6172	6190	6199	6169	6151
3	W = W_2 – W_1(g)	1792	1810	1819	1789	1771
4	(ɤ) = W/V	1.792	1.810	1.819	1.789	1.771
5	(ɤd) = ɤ/(1+w)	1.629	1.645	1.654	1.626	1.610

Graph-2: SPCT – Soil Sample



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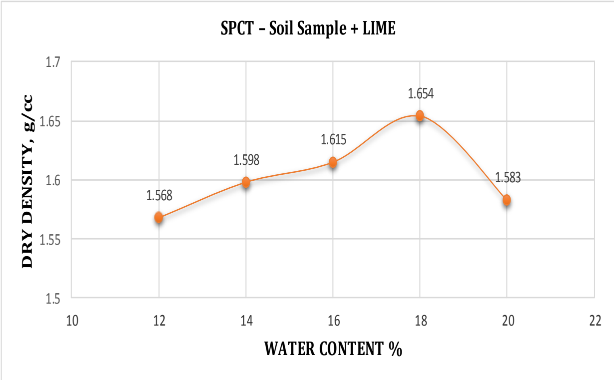
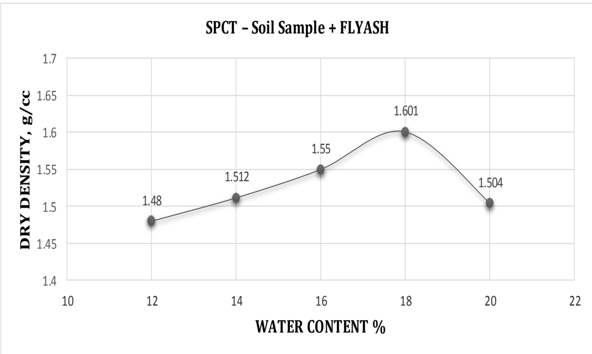
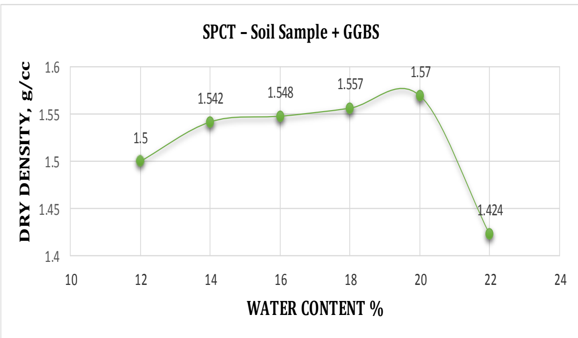


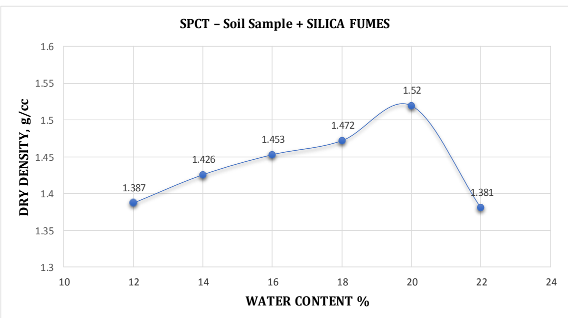
Graph-3: SPCT – Soil Sample + Lime



Graph-4: SPCT – Soil Sample +Fly Ash



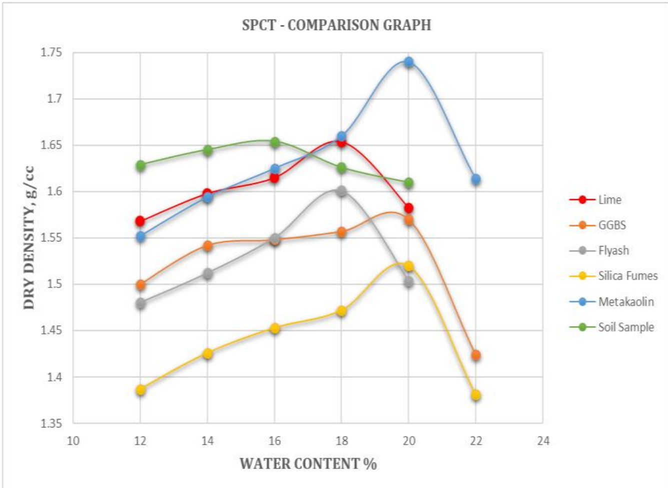
Graph-5: SPCT – Soil Sample + GGBS



Graph-6: SPCT – Soil Sample + Silica Fumes

Table-5: SPCT – Comparison Table

S. No	Description	Optimum Moisture Content (%)	Maximum Dry Density (g/cc)
1.	Soil Sample	16%	1.82 g/cc
2.	SS with 10 % of Lime	18%	1.654 g/cc
3.	SS with 10 % of GGBS	20%	1.570 g/cc
4.	SS with 10 % of Flyash	18%	1.601 g/cc
5.	SS with 10 % of Silica Fumes	20%	1.520 g/cc
6.	SS with 10 % of Metakaolin	20%	1.740 g/cc



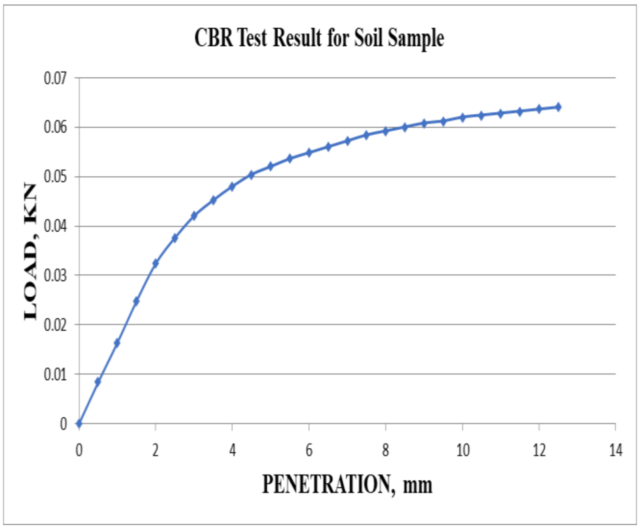
Graph-7: SPCT – Comparison Graph

4.7 CALIFORNIA BEARING RATIO TEST

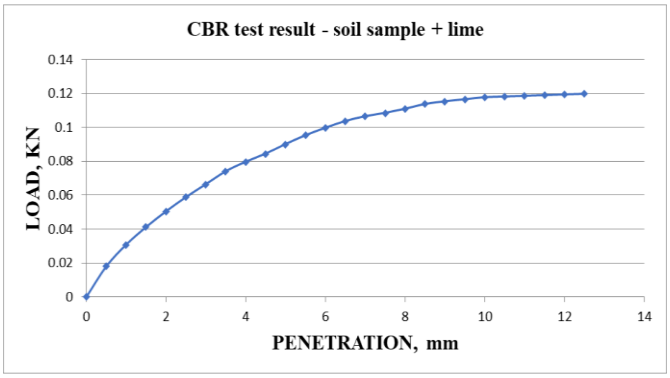
The CBR test for the soil sample was carried out as per IS 2720: 1980 (Part 16). A 5 kg of soil sample passing 1.75mm sieve is taken and mixed with the required amount of water to attain the moisture content at which the soil is to be compacted at the field. The CBR mould is properly fitted with the base plate and the collar and the bottom dead weight placed in the mould. After compaction, the collar is removed, and the top excess soil is trimmed properly to obtain a plain smooth surface. The mould is then inverted and the bottom dead weight is removed. A compacted soil of precisely 125 mm height in the CBR mould. The stress and strain was set gauges to zero. The load was applied at the rate of 1.25 mm/min. The readings of the load at penetration are 0.5, 1.0, 1.5, 2.0, 2.5, 4, 5, 7.5 and 12.5. Raised the plunger and detach the mould from the loading equipment. Collected the sample of about 20 to 50gms of soil from the top 30 mm layer of specimen and determine the water content in accordance with IS: 2720 (Part 4) 1973 to affect the results if they happen to be located directly below the penetration plunger. The specimen was examined carefully after the test is completed for the presence of any oversize soil particles.

Table-6: CBR Test Result for Soil Sample

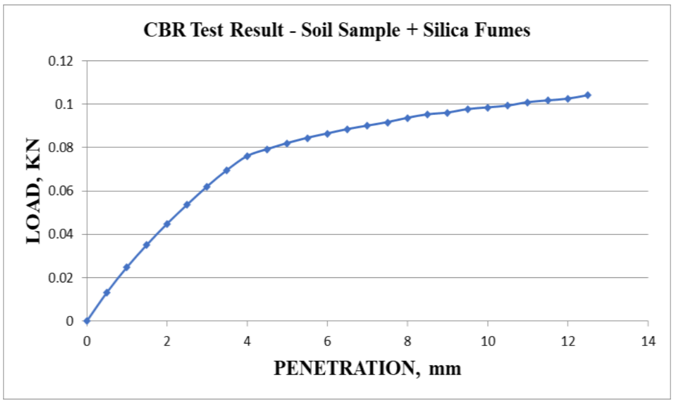
S. No	Dial Gauge Reading	Penetration (mm)	Proving Ring Reading	Load in kN
1	50	0.5	4.2	0.0084
2	100	1.0	8.2	0.0164
3	150	1.5	12.4	0.0248
4	200	2.0	16.2	0.0324
5	250	2.5	18.8	0.0376
6	300	3	21	0.042
7	350	3.5	22.6	0.0452
8	400	4.0	24	0.048
9	450	4.5	25.2	0.0504
10	500	5.0	26	0.052
11	550	5.5	26.8	0.0536
12	600	6	27.4	0.0548
13	650	6.5	28	0.056
14	700	7	28.6	0.0572
15	750	7.5	29.2	0.0584
16	800	8	29.6	0.0592
17	850	8.5	30	0.06
18	900	9	30.4	0.0608
19	950	9.5	30.6	0.0612
20	1000	10	31	0.062
21	1050	10.5	31.2	0.0624
22	1100	11	31.4	0.0628
23	1150	11.5	31.6	0.0632
24	1200	12	31.8	0.0636
25	1250	12.5	32	0.064



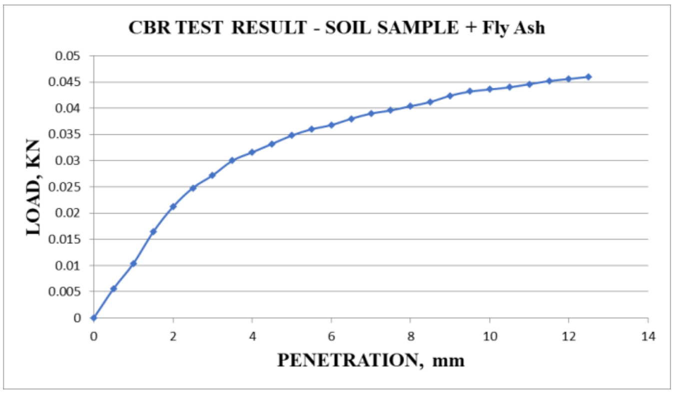
Graph-8: CBR – Soil Sample



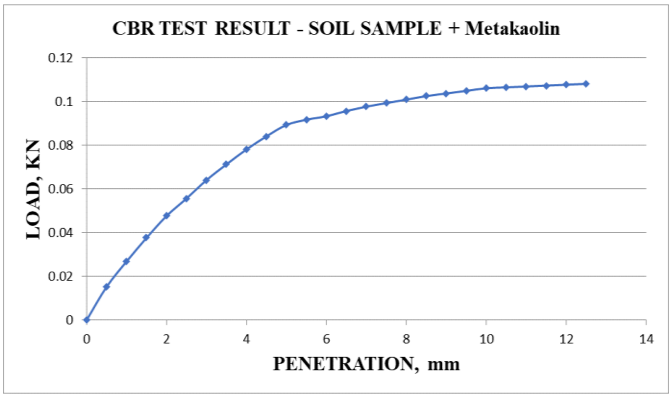
Graph-9: CBR – Soil Sample + Lime



Graph-10: CBR – Soil Sample + Silica Fumes



Graph-11: CBR – Soil Sample + Fly Ash



Graph-12: CBR – Soil Sample + Metakaolin

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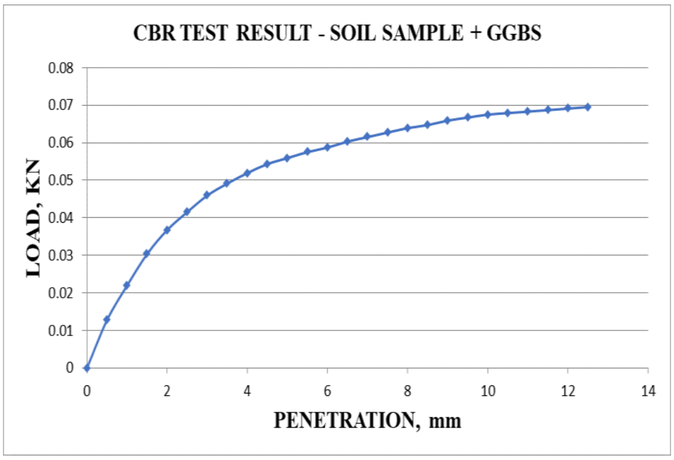
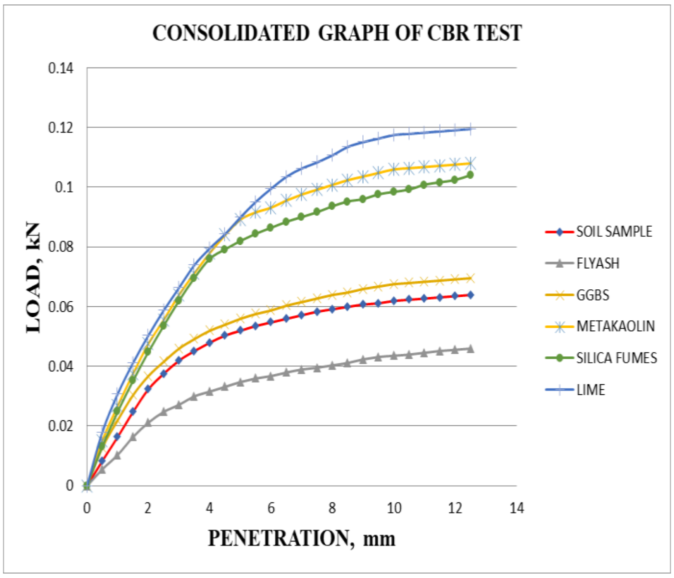


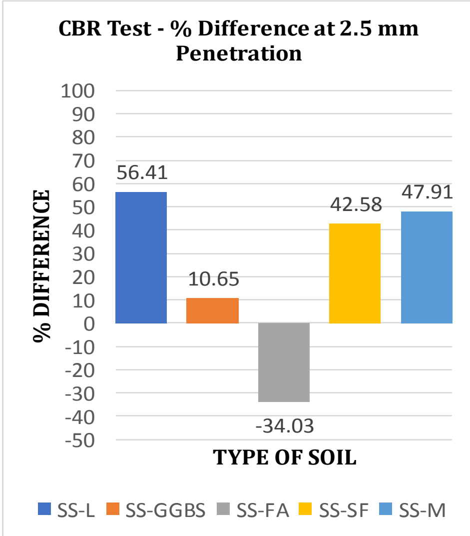
Graph-13: CBR – Soil Sample + GGBS



Graph-14: CBR – Comparison Graph

Table-7: CBR Test - % Difference at 2.5 mm Penetration

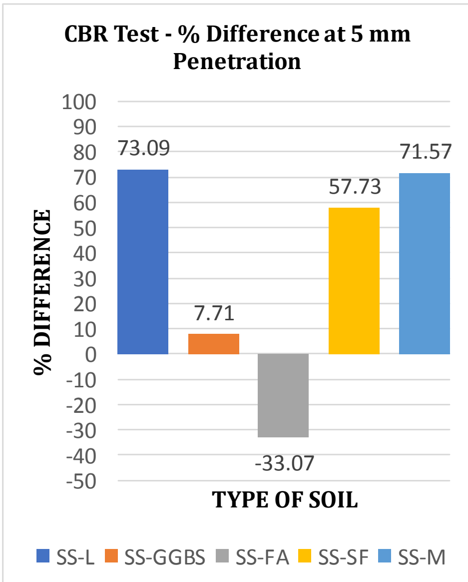
S.No	Type of Soil	CBR Value for 2.5 mm Penetration	% Difference
1.	Soil Sample	2.797	-
2.	SS with 10% of Lime	4.375	**56.41**
3.	SS with 10% of GGBS	3.095	**10.65**
4.	SS with 10% of Flyash	1.845	**34.03**
5.	SS with 10% of Silica Fumes	3.988	**42.58**
6.	SS with 10% of Metakaolin	4.137	**47.91**



Graph-15: % Difference at 2.5 mm Penetration

Table-8: CBR Test - % Difference at 5 mm Penetration

S.No	Type of Soil	CBR Value for 5 mm Penetration	% Difference
1.	Soil Sample	2.579	-
2.	SS with 10% of Lime	4.464	**73.09**
3.	SS with 10% of GGBS	2.778	**7.71**
4.	SS with 10% of Flyash	1.726	**33.07**
5.	SS with 10% of Silica Fumes	4.068	**57.73**
6.	SS with 10% of Metakaolin	4.425	**71.57**



Graph-16: % Difference at 5 mm Penetration

5. CONCLUSIONS

For the various experiments which were carried out on the soil sample and the soil sample with different mineral admixtures the following conclusions were arrived.

1. It has been noted that there is an improvement in the maximum dry density and the optimum moisture content for the soil sample which is treated with lime as an admixture.
2. Lime and Metakaolin shows a high increase in the CBR value when compared to soil with other mineral admixtures.
3. The use of lime as a stabilization agent with the soil sample increases the CBR value for 2.5mm penetration by 55.41 % and for 5 mm penetration 73.09 %.
4. Next to that of lime, metakaolin can also be used which shows nearly 47.91 % of increase in the CBR value for 2.5mm penetration and 71.57% increment in 5 mm penetration.
5. In terms of the cost, there is a reduction of the pavement when lime and metakaolin were added to stabilize the soil.
6. After several results that were concluded from the various experiments it suggests the use of lime as a major soil stabilization agent.
7. Next to which metakaolin can also be used. The addition of lime, Metakaolin, Silica fume and GGBS increases the CBR value than any other ordinary methods.
8. Further studies are also been suggested for the stabilization of the soil by increasing the percentage.

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