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Stabilization of Soil with Calcium Chloride using Gypsum

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Abstract: The engineering strength properties of expensive soils (clayey soil) such as compaction characteristics and bearing capacity can be improved by stabilization process of the soil. These properties can be improved by controlled compaction using the mechanical equipment's or by addition of suitable admixtures like cement, fly ash, lime, gypsum or by reinforcing the soil with shredded tyre, crumb rubber, plastic waste etc.

But gypsum is used now a days to enhance the geotechnical properties. So, in this research paper gypsum and calcium chloride has been used to improve the various strength properties of natural soil. The objective of this research paper is to investigate the strength properties of natural clayey soil reinforced with different percentage of gypsum by the weight of soil and fixed percentage of calcium chloride as a binding material.

A series of Standard Proctor test, Free swell Index and California Bearing Ratio (CBR) tests are conducted on both natural soil and reinforced soil with varying percentages of gypsum (2%, 4%, 6% and 8%) by weight and fixed percentage of calcium chloride (1%).

Keywords: liquid limit, plastic limit, Atterberg limits, Proctor Compaction Test, Free Swell Index, CBR

I. INTRODUCTION

Soil Stabilization is enhancement of soil and their physical properties. Soil stabilization control the shrink-swell properties of a soil and increases the shear strength of a soil, thus improve the load bearing capacity of a sub-grade to support pavements and foundations.

Stabilized soil can be utilized on airports, roads, parking areas, development site and other conditions where subgrade are not suitable for construction. Stabilization can be used to treat a wide range of sub - grade materials, varying from expansive clays to granular materials. This process is found using additives, fly-ash, lime, and portland cement.

II. CLAYEY SOIL

A soil that contains a high percentage of fine particles and colloidal substance and becomes sticky when wet. Clays are plastic due to particle size and geometry as well as water content, and become hard, brittle and non–plastic upon drying or firing. Depending on the soil content in which it is found, clay can appear in various colors from white to dull grey or brown to deep orange-red. Although many naturally occurring deposits include both silts and clay, clays are distinguished from other fine-grained soils by differences in size and mineralogy. ISO 14688 grades clay particles as being smaller than 2 μm and silt particles as being larger.

III. GYPSUM

Gypsum is a soft sulphate mineral consist of calcium sulphate dehydrate, with the chemical formula $CaSO_4 \cdot 2H_2O$. It is extracted by mining and used as a fertilizer and as the main role in many form of plaster, blackboard/sidewalk chalk, and drywall. A massive fine-grained white or lightly tinted variety of gypsum, called alabaster, has been used for carve by many cultures including Ancient Egypt, Mesopotamia, Ancient Rome, the Byzantine Empire, and the Nottingham alabasters of Medieval England. Gypsum also crystallizes as translucent crystals of selenite. It also forms as an evaporate mineral and as a hydration product of anhydrite.

IV. CALCIUM CHLORIDE

Calcium chloride is an inorganic compound, a salt with the chemical formula $CaCl_2$. It is a white colored crystalline solid at room temperature, highly soluble in water.

Calcium chloride is commonly encountered as a hydrated solid with generic formula $CaCl_2.(H_2O)_x$, where x = 0, 1, 2, 4, and 6. These compounds are mainly used for de-icing and dust control. Because the anhydrous salt is hygroscopic, it is used as a desiccant.

V. RESEARCH METHODOLOGY

1) Literature Review.
2) Design of sampling, collection and preparation of soil sample.
3) Tests to be performed on above soil sample.
a) Liquid limit and Plastic limit
b) Maximum dry density and Optimum moisture content.
c) Unconfined compressive strength test
d) California bearing ratio test
4) Interpretation of obtained data and investigation of their co-relation with standard soil.
5) Conclusion and recommendation.

VI. LITERATURE REVIEW

Kasa and Chik (1) The object of this paper is to investigate the effect of adding different chloride compounds including (NaCl, MgCl2, CaCl2) on the engineering properties of silty clay soil. Various amounts of salts (2%, 4%, and 8%) were added to the soil to study the effect of salts on the compaction characteristics, consistency limits and compressive strength.

The soil was tested for its liquid limit, plastic limit, dry unit weight, moisture content and shear strength. The addition of each one of the chloride compounds decreased the liquid limit and plastic limit and plasticity index for the soil. The dry density increased and the optimum moisture content decreased with the increased in salts percentage.

Arash B. (2) The experiment was conducted with different percentages of gypsum 2%, 4%, 6% and 8% is used to stabilize the clayey soil. In this study the gypsum of different percentages (2%, 4%, 6% and 8%) is added to the soil sample and tests are performed after seven days of curing. At 4% of Gypsum the swelling of soil decreases from 47% to 4.16%, optimum moisture content (OMC) and maximum dry density (MDD) is 11.76% and 19.16 KN/m3 and CBR value is increase from 2.73% to 7.57%.

Goyal and Parkash (3) This study are to improve the strength of the expansive soil by making soil- jute and soil-jute-gypsum mixture. Twelve specimens are prepared to investigate the properties of soil out of which four specimens are prepared by adding 0.5%, 1%, 1.5% and 2% of jute with length of approximately 2 cm and the remaining specimens are prepared by adding 5% and 10% gypsum in each of the above sample with approximate length of 2 cm of jute.

With the addition of jute percentage in the soil the maximum dry density increases up to 1% and the optimum moisture content decreases. But with further addition of jute percentage in the soil the maximum dry density starts to decreases with an increase in optimum moisture content. Further with addition of gypsum in soil-jute mixture the maximum dry density increases and the optimum moisture content decreases.

Ahmed (4) The main objective of the paper was to study about stabilization of clayey soil using Pine needles and calcium chloride. Index properties of parent soil, compaction characteristics and CBR of both parent soil and soil treated with pine needles and calcium chloride were found out.

It was found that that with addition of pine needles in the parent soil, the dry density decreases and OMC increases. When pines were added dry density reduces, on increasing the percentage of pines from 0% to 1.8 % dry density decreases from 1.96g/cc to 1.59 g/cc respectively .As far as OMC was concerned, it was increasing with increasing in quantity of pines in soil that is from 13% to 17.56%. The optimum percentage of both pine and calcium chloride at which soil acquires best results was found to be 0.6% and 3 % respectively.

VII. OBSERVATIONS OF NATURAL SOIL

A. *Specific Gravity*

Determination	Sample-1 (gm)	Sample-2 (gm)	Sample-3 (gm)	Average specific Gravity
Empty weight of pycnometer (w_1)	596	596	596	2.671
Weight of pycnometer + oven dried soil (w_2)	767	826	882	
Weight of pycnometer + soil + water (w_3)	1626.5	1666	1697	
Weight of pycnometer + water (w_4)	1520	1520	1520	
Specific gravity (g)	2.651	2.738	2.624	

Table 1: Specific Gravity of Natural Soil

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B. Grain Size Distribution

SIEVE SIZE	Empty wt. of sieve (gm)	Wt. of sieve + retained soil (gm)	Wt. of soil retained (gm)	%Wt. of retained	%Cumulative weight retained	%Finer
4.75 mm	382.5	385.5	3.0	0.6	0.6%	99.4%
2 mm	322.5	335.5	13	2.6	3.2	96.8
1 mm	330.5	337.0	7.5	1.5	4.7	95.3
600 micron	298	306.5	8.5	1.7	6.4	93.6
425 micron	315.5	331.0	16	3.2	9.6	90.4
212 micron	305.5	351.5	46	9.2	18.8	81.2
150 micron	310.5	361.5	51	10	28.8	71.2
75 micron	340.0	371.5	32.5	6.5	35.3	64.7

Table 2: Observation of Sieve Analysis of Natural Soil

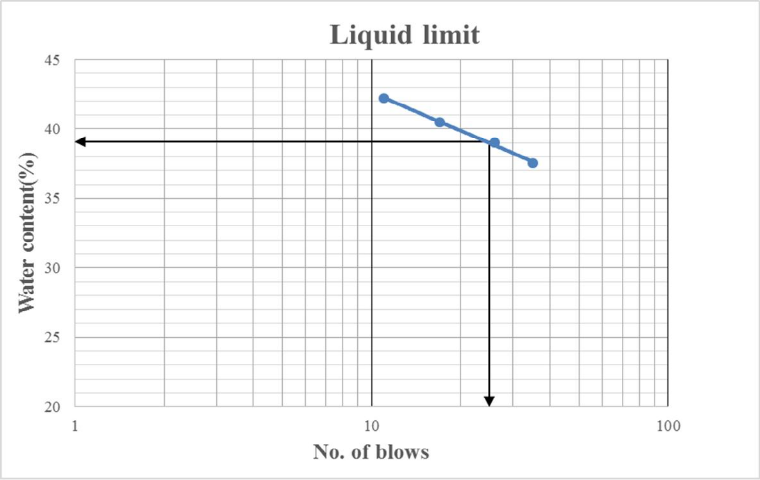
From the wet sieve analysis of soil, it is found that 64.7% soil passed through 75micron sieve and it is known fact from IS code, that if more than 50% soil passes through 75 micron sieve, then the soil is fine grained soil, hence our soil is fine grained soil.

C. Atterberg Limit Test

Liquid Limit

Weight of container (g)	Weight of container + soil (g)	Weight of container + dry soil (g)	Weight of dry soil (g)	Weight of moisture (g)	Moisture content (%)	No. of blows
8.83	11.39	10.63	1.8	0.76	42.22	11
9.26	12.8	11.78	2.52	1.02	40.47	17
9.31	16.08	14.18	4.87	1.90	39.0	26
9.81	17.58	15.46	5.65	2.12	37.52	35

Table 3: Determination of Liquid Limit of Natural Soil



From graph, it is found that water content corresponding to 25 blows is 39.3%.
Hence, Liquid limit = 39.3%.

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Plastic Limit

Weight of container (g)	Weight of container + soil (g)	Weight of container + dry soil (g)	Weight of dry soil (g)	Weight of moisture (g)	Moisture content (%)
7.97	8.90	8.80	0.83	0.10	19.05
8.60	9.27	9.21	0.61	0.06	22.84

Table 4: Determination of Plastic Limit of Soil

Plastic limit=20.95%
Plasticity Index (PI) =Liquid limit-Plastic limit = 39.3-20.95 = 18.35% (Medium plastic)

D. Maximum Dry Density And Optimum Moisture Content

Weight of container (g)	Weight of container + soil (g)	Weight of container + dry soil (g)	Weight of dry soil (g)	Weight of moisture (g)	Moisture content (%)
13.83	32.29	31.21	16.79	1.08	6.4
13.38	33.19	31.54	17.06	1.65	9.6
14.82	34.98	32.81	17.99	2.17	12.1
13.04	28.82	26.83	13.79	1.99	14.4
14.44	34.09	31.36	16.92	2.73	16.13
14.87	30.42	28.07	13.2	2.35	17.8

Table 5: Observation and Calculation of Moisture Content of Natural Soil

Weight of mould (g)	Weight of mould + compacted soil (g)	Weight of soil (g)	Bulk density (g/cc)	Dry density (g/cc)
4468	6081	1613	1.62	1.52
4468	6202	1734	1.74	1.59
4468	6332	1804	1.87	1.67
4468	6443	1975	1.98	1.73
4468	6493	2025	2.03	1.75
4468	6470	2002	2.01	1.71

Table 6: Observation and Calculation of Dry Density of Natural Soil

OMC = 16.13%, MDD = 1.750 g/cc

E. Unconfined Compressive Strength Test Of Natural Soil

This is an special case of the tri axial test in which confining and cell pressure is zero. This test is an untrained test or quick test and is often used to determine the in situ strength of soft, saturated fine grained soil deposits. The test was carried out on clayey soil as per procedure given in IS: 2720 Part 10-199.

S. No	PARAMETERS	SAMPLE 1	SAMPLE 2	SAMPLE 3
1.	Initial length (L)	76mm	76mm	76mm
2.	Final length (L)	70.0mm	68mm	67.5mm
3.	Average diameter (D)	38mm	38mm	38mm
4.	Strain (e = dL/L)	0.0789	0.105	0.118
5.	Area ($A_O = \pi$ X D X D/4)	11.34cm^2	11.34cm^2	11.34cm^2
6.	Corrected area ($A = A_O$/1-e)	12.31cm^2	12.67cm^2	12.85cm^2
7.	Maximum proving ring reading	2.8	3.0	3.2
8.	Load (P)	5x2.8x2.82366 = 39.53 kg	5x3.0x2.82366 = 42.35 kg	5x3.2x2.82366 = 45.17 kg
9.	UCS (P/A)	3.21 kg/cm^2	3.34 kg/cm^2	3.51 kg/cm^2

Table 7: Observation and Calculation for UCS Test of Natural Soil

Taking average value = (3.21+3.34+3.51)/3 = 3.35
Hence the unconfined compressive strength = 3.35 kg/cm^2.

F. California Bearing Ratio (CBR) Test

CBR is a penetration test for evaluation of the mechanical strength of natural ground, subgrades and base courses beneath new carriage way. CBR values are usually calculated for penetration of 2.5 and 5.0 mm. Corresponding to the penetration value at which the CBR values is desired, corrected load value shall be taken from the load penetration curve and the CBR value is calculated.

S.N	Penetration Value		Load		CBR Value (%)
	DGR	Penetration mm	PRR	Load Kg	
1.	0	0	0	0	
2.	50	0.50	5.8	31.9	
3.	100	1.00	6.4	35.2	
4.	150	1.50	7.8	42.9	
5.	200	2.00	8.5	46.75	
6.	250	2.50	9.7	53.35	$\frac{53.35\times100}{1370}$ = 3.89%
7.	300	3.00	10.4	57.2	
8.	400	4.00	12.6	69.3	
9.	500	5.00	13.8	75.9	$\frac{75.9\times100}{2055}$= 3.70%
10.	750	7.50	15.7	86.35	
11.	1000	10.00	16.9	92.95	
12.	1250	12.50	18.5	101.75	

Table 8: Observation and Calculation for CBR of Natural Soil

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G. *Properties Of Natural Soil*

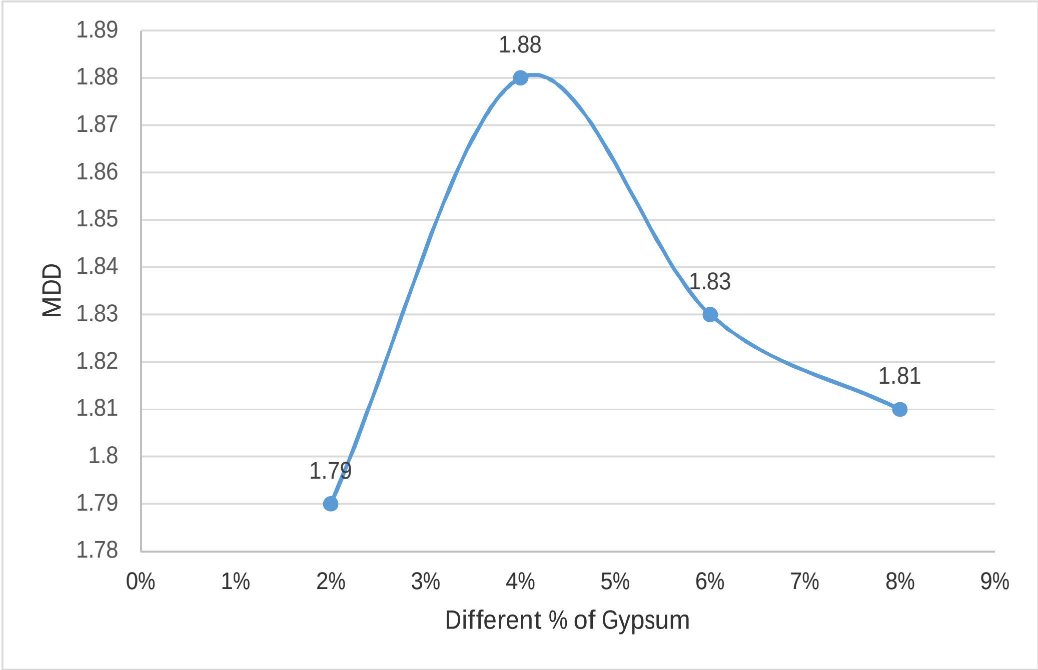
S. No.	Parameters	Values
1.	Specific Gravity	2.671
2.	Liquid limit	39.30%
3.	Plastic limit	20.95%
4.	Shrinkage limit	15.21%
5.	Plasticity index	18.35%
6.	Shrinkage index	5.74%
7.	OMC	16.13%
8.	MDD	1.750 g/cc
9.	UCS	3.35 kg/cm^2
10.	Unsoaked CBR	3.89%
11.	% finer(clay+silt)	63.5 %
12.	Percentage of clay	15.25%

VIII. RESULTS AND DISCUSSION

Test Results Of Soil Sample With Different Percentage Of Gypsum

A. *Compaction Test Of Soil Sample After Mixing With Different Percentage Of Gypsum*

Content	MDD (g/cc)	OMC (%)
Clayey Soil	1.750	16.13
2% Gypsum	1.833	11.17
4% Gypsum	1.88	10.07
6% Gypsum	1.83	11.08
8% Gypsum	1.81	12.23



Variation of MDD in soil sample with Different % of Gypsum

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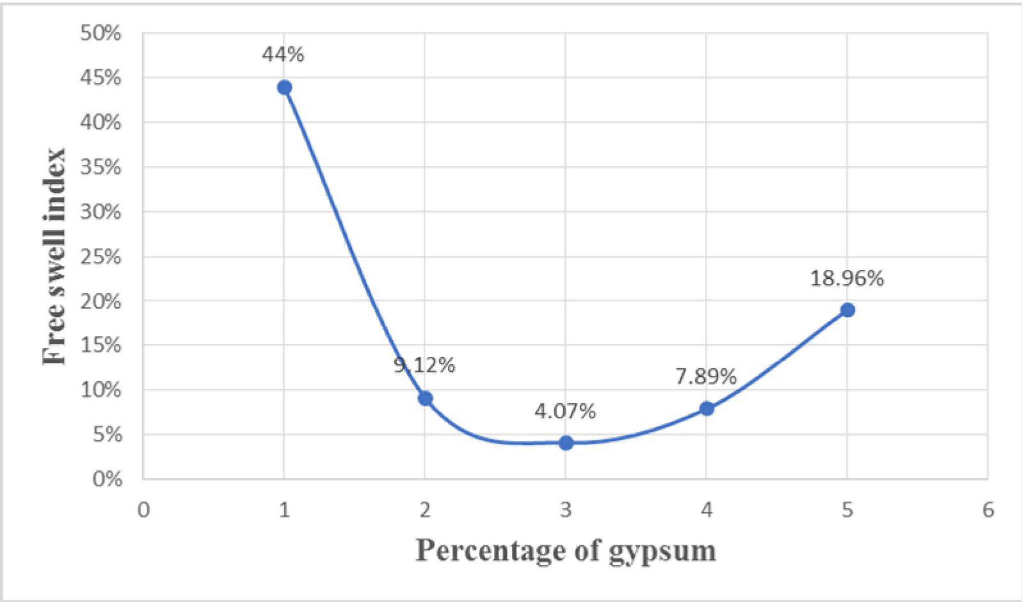
B. Free swell Index of soil Sample with Different Percentage of Gypsum

Percentage of gypsum (%)	Free swell index (%)
0	44
2	9.12
4	4.07
6	7.89
8	18.96

Table 9: Variation of free swell index in soil sample with different % of gypsum

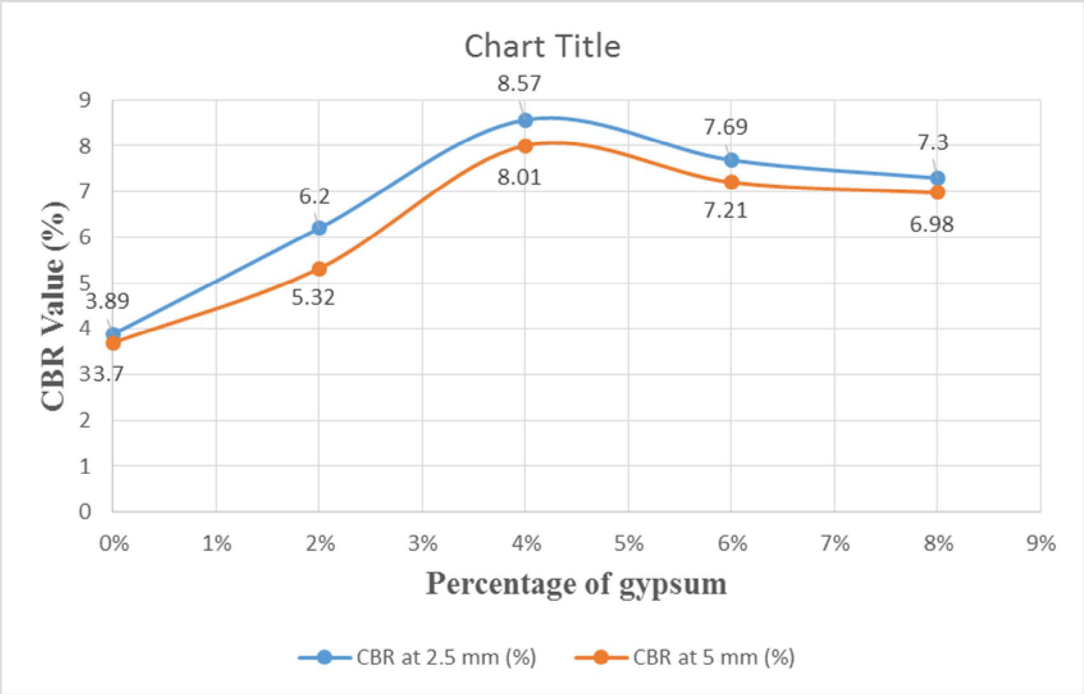


Variation of free swell index in soil sample with different % of gypsum

C. CBR Value of Soil Sample with Different Percentage Of Gypsum

Percentage of gypsum (%)	CBR at 2.5 mm (%)	CBR at 5 mm (%)
0	3.89	3.70
2	6.2	5.32
4	8.57	8.01
6	7.69	7.21
8	7.3	6.98

Table 10. CBR value of Soil Sample after Mixing Different Percentage of Gypsum



Variation of CBR Values in Soil Sample with Different Percentage of Gypsum

D. Compaction Test Of Soil Sample After Mixing With Different Percentage Of Gypsum And Fixed Percentage Of Calcium Chloride

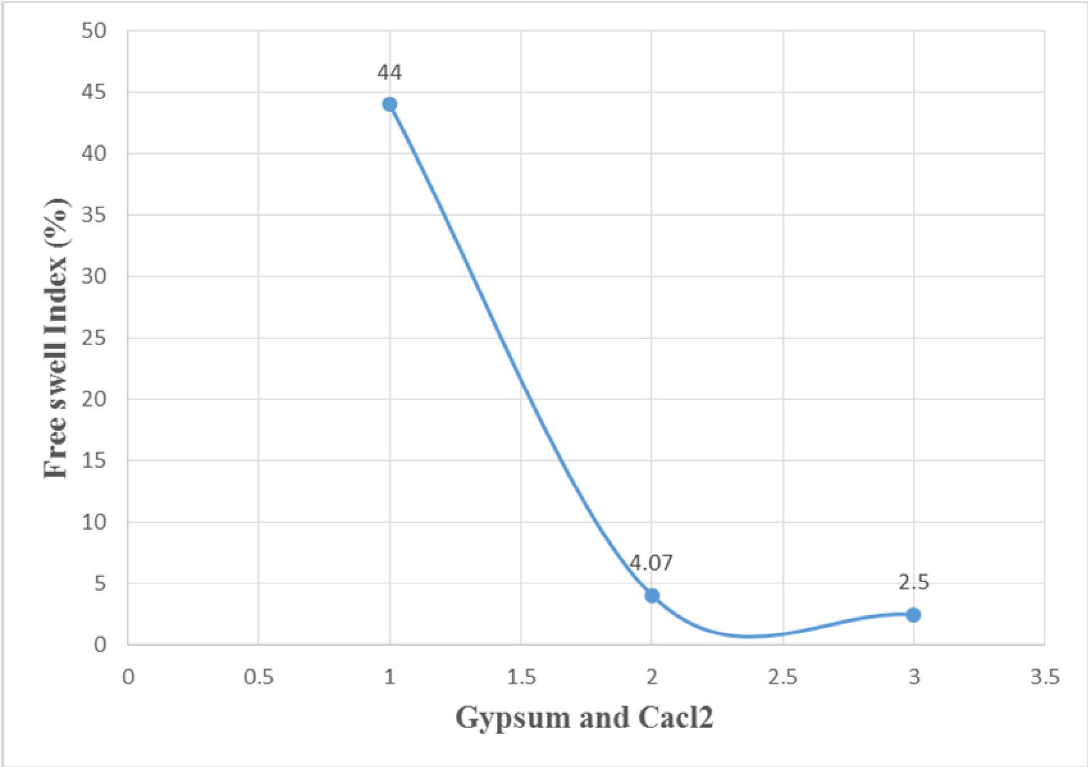
Content	MDD (g/cc)	OMC (%)
0% Gypsum	1.75	16.13
4% Gypsum	1.88	10.07
4% Gypsum + 1% $Cacl_2$	1.92	9.76

Table 11: Compaction Test Result of Soil Sample with Constant Percentage of Cacl2 at Maximum MDD Condition

E. Free Swell Index Of Soil Sample With Different Percentage Of Gypsum And Fixed Percentage Of Calcium Chloride

Content	Free swell Index (%)
0% gypsum	44
4% gypsum	4.07
4% gypsum + 1% $Cacl_2$	2.5

Table 12: Free Swell Index of Soil Sample with 1% Cacl2 after Attaining Maximum MDD with GYPSUM

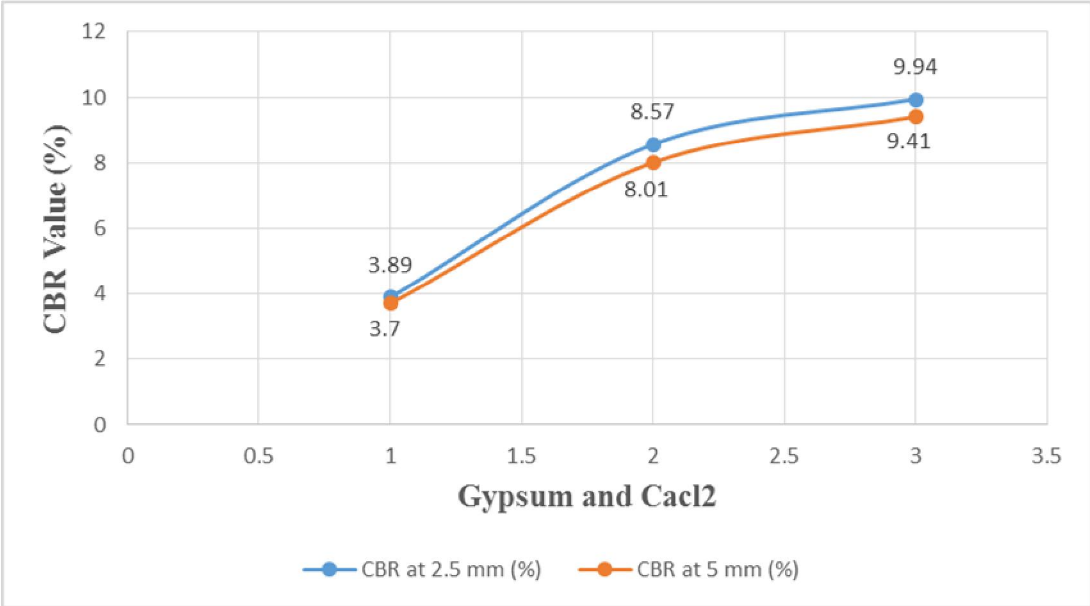


Variation of free swell Index in soil sample with 1% Cacl2 and 4% gypsum

F. Cbr Value Of Soil Sample With Different Percentage Of Gypsum And Constant Percentage Of Calcium Chloride

Content	CBR at 2.5 mm (%)	CBR at 5 mm (%)
0% gypsum	3.89	3.70
4% gypsum	8.57	8.01
4% gypsum + 1% $Cacl_2$	9.94	9.41

Table 13: CBR value of soil sample with 1% cacl2 and 4% of gypsum



Variation of CBR value at 2.5 mm and 5 mm of soil sample with 1% $Cacl_2$ and 4% gypsum

XI. CONCLUSIONS

A. Based on the results from the compaction test, it can be stated that with increase in percentage of gypsum and fixed percentage of $Cacl_2$, the compaction parameters (MDD, OMC) are also increased from

B. Based on free swell index test, it is observed that free swell index value at 0% gypsum in soil is 44%. But when percentage of gypsum increases to 2% it decreases from 44% to 9.12%.

C. Based on CBR test results, it is observed that addition of gypsum and calcium chloride as stabilizing agent for clayey soils produces significant increase in CBR value.

D. From the above discussions, it is concluded that addition of gypsum and $Cacl_2$ to the clayey soil there is considerable effect on the compaction parameters and bearing capacity of the soil.

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