

Stabilization of Clayey Soil using Gypsum and Calcium Chloride

Jayant Singh, U.K. Singh, R.K. Singh

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 examine the strength properties of natural clayey soil reinforced with different percentage of gypsum by the weight of soil and fixed percentage of calcium chloride ($CaCl_2$) as a binding material.

A series of Standard Proctor tests (for calculation of MDD and OMC) and California Bearing Ratio (C.B.R) tests are conducted on both raw clayey soil and reinforced soil with different percentages of gypsum (2%, 4%, 6% and 8%) by weight and with fixed percentage of calcium chloride (0.75%). A comparison between properties of raw clayey soil, raw clayey soil mixed with gypsum and raw clayey soil mixed with gypsum and calcium chloride ($CaCl_2$) are performed. It is found that the properties of clayey soil mixed with gypsum and calcium chloride ($CaCl_2$) are suitably enhanced.

Keywords: Gypsum, Soil stabilization, $CaCl_2$, Standard Proctor Test.

I. INTRODUCTION

Soil stabilization is the term in which engineering properties of soil are revamped with the help of another material. Soil stabilization control the different 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 used on airports, roads, parking areas, development site and other conditions where subgrade material are not qualified 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 like fly-ash, rice husk, lime, portland cement etc.

ADVANTAGES OF STABILIZATION:

- Utilization of local and in situ materials.
- Waste materials can be utilized according to their properties.
- Savings in disposal of unsuitable materials.
- Large savings in aggregate consumption.
- Savings in transportation of material.
- Protection of roads (less truck transport).

Revised Manuscript Received on June 22, 2020.

* Correspondence Author

Jayant Singh *, Research Scholar, Department of Civil, BIT Sindri, Dhanbad, Jharkhand, India. E-mail: jayantsingh1996@gmail.com.

Dr. U.K Singh, Department of Civil, BIT Sindri, Dhanbad, Jharkhand, India. E-mail: uksingh8888@gmail.com.

Dr.R.K Singh, Department of Chemistry, BIT Sindri, Dhanbad, Jharkhand, India. E-mail: ks_chem@rediffmail.com

APPLICATIONS:

- Road constructions.
- Foundations.
- Dams and Reservoir.

II. MATERIALS USED

Clayey Soil-A soil that contains a high percentage of fine particles and colloidal substance and becomes sticky when wet. Clays are plastic because of its particle size and geometry as well as water retention ability, and become hard, brittle and non-plastic upon drying or firing.

Depending on the soil content in which it's found, clay can appear in various colors from white to dull grey or brown to deep orange-red. Although many present 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 $2 \mu m$ and silt particles as being larger.

Clayey soil was collected from Baliapur, Dhanbad, Jharkhand and then sent to soil laboratory of Civil Engineering Department, BIT Sindri. The soil was spread on the floor for natural drying and then were broken into smaller size so that it can be used in experiments.

Gypsum-Gypsum is a soft sulphate mineral which contains 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 huge 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.

Gypsum is brought from Kalpana Trading India Private Limited, Nainpur, Madhya Pradesh.

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

$CaCl_2$ is brought from Kalyani Chemicals, Delhi.

Properties of the raw clayey soil

The clayey soil sample used in this project has been collected from Baliapur, Dhanbad. It was dug from depth of 1.5m to 2 m beneath the ground surface by open excavation. After that it was dried and shattered to perform the experiments.



Stabilization of Clayey Soil using Gypsum and Calcium Chloride

Table I: Properties of the natural clayey soil

Sl. No.	Parameters	Values
1.	Specific gravity	2.475
2.	Liquid Limit(W_L)	35.60%
3.	Plastic Limit(W_P)	20.20%
4.	OMC (Optimum moisture content)	16.13%
5.	MDD (Maximum dry density)	1.750g/cc
6.	U.C.S(Unconfined compressive strength)	3.33%
7.	Soaked C.B.R (California bearing ration)	2.04%
8.	Un-soaked C.B.R(California bearing ratio)	4.17%



Fig.1. Clayey soil



Fig.2. Calcium Chloride



Fig.3. Gypsum

III. EXPERIMENTAL DETAILS

A. Fixing the percentage of Calcium Chloride.

For fixing the $CaCl_2$ percentage in the soil and gypsum mix, add the $CaCl_2$ in raw clayey soil with different percentages that is 0.25%, 0.5%, 0.75%, 1%, 1.25%, 1.5% of the dry weight of soil and find out the OMC-MDD for different percentages. At 0.75% amount of $CaCl_2$ the MDD(maximum dry density) have been found maximum.

Table II: Standard Proctor Test Result for fixing $CaCl_2$ (%)

Sl. No.	Soil (%)	$CaCl_2$ (%)	OMC (%)	MDD (g/cc)
1	100	0	16.13	1.75
2	99.75	0.25	16.76	1.79
3	99.5	0.5	16.95	1.93
4	99.25	0.75	17.19	1.98
5	99	1	17.7	1.9
6	89.75	1.25	18.12	1.84
7	89.5	1.5	18.75	1.78

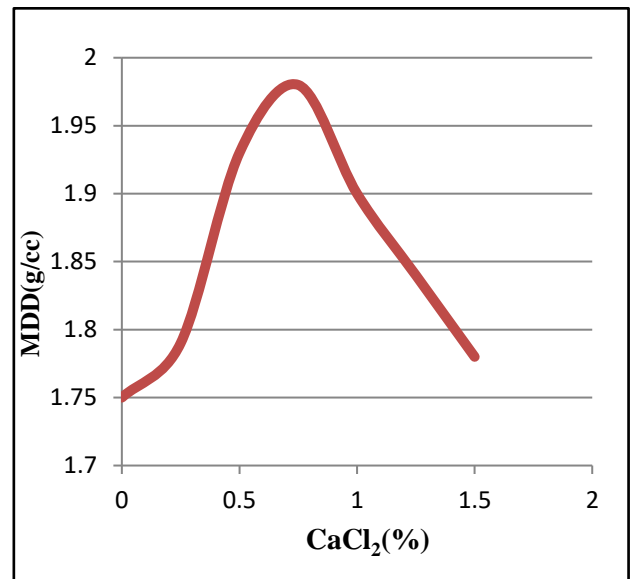


Fig.5. Calcium Chloride(%) and MDD graph

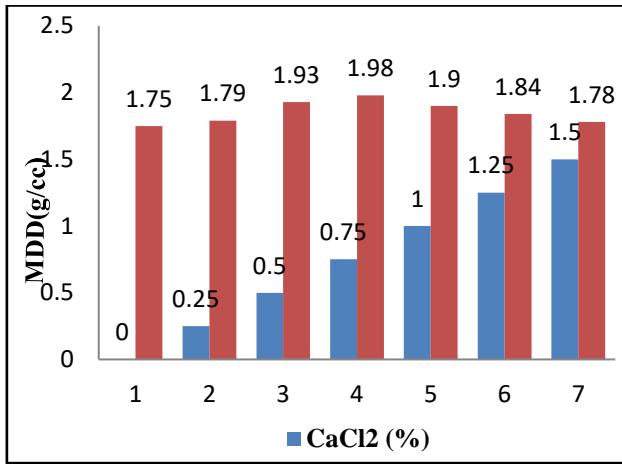


Fig.6. Bar Chart Variation of MDD soil sample with CaCl₂ MDD = 1.98 g/cc at CaCl₂=0.75%.

So, I have fixed the percentage of Calcium Chloride at 0.75% by weight.

B. Standard Proctor compaction test of soil sample after mixing with different percentage of gypsum.

In this segment, results for reinforced soil sample with different percentages of gypsum (2%,4%,6%and8%) are shown in details. A series of standard proctor compaction tests are performed on reinforced soil with vary in percentages of gypsum and the corresponding test results are demonstrated below.

Table III: MDD and OMC of Soil after mixing different percentage of Gypsum.

CONTENT	MDD(g/cc)	OMC(%)
Clayey soil	1.750	16.13
2% Gypsum	1.82	11.84
4% Gypsum	1.92	10.36
6% Gypsum	1.85	11.21
8% Gypsum	1.80	12.84

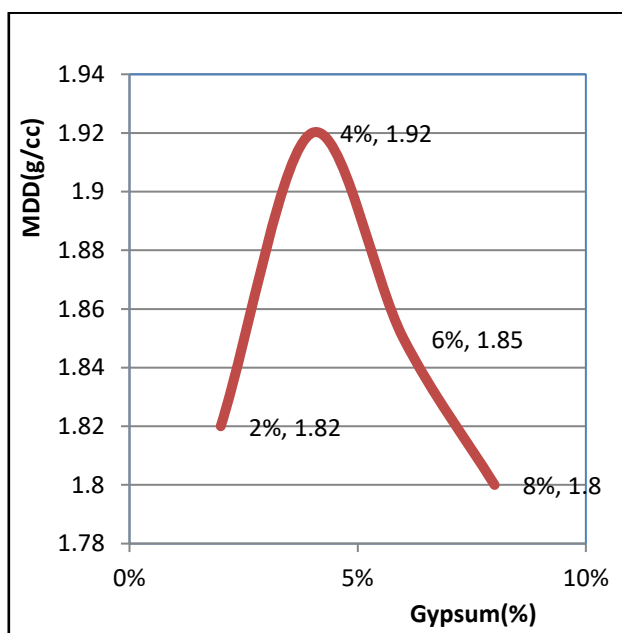


Fig.7. Variation in MDD of soil sample with Different % of Gypsum

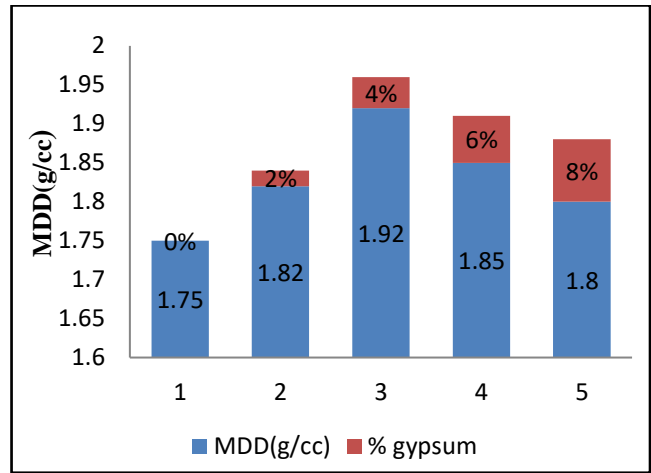


Fig.8. Bar Chart Variation of MDD soil sample with Different % of Gypsum.

It can be inferred that, there is an augmentation in maximum dry density of clayey soil with increment in percentage of gypsum up to a certain percentage (i.e. 4%).

C. C.B.R value of soil sample with different percentage of gypsum.

The following results are obtained from laboratory for C.B.R(California bearing ratio) value of sample soil with varying percentage of gypsum has been demonstrated below

Table IV: C.B.R values at different percentage of Gypsum

Percentage of Gypsum(%)	C.B.R at 2.5mm	C.B.R. at 5mm
0	4.17	3.64
2	6.48	5.26
4	8.85	7.95
6	7.97	7.15
8	7.58	6.92

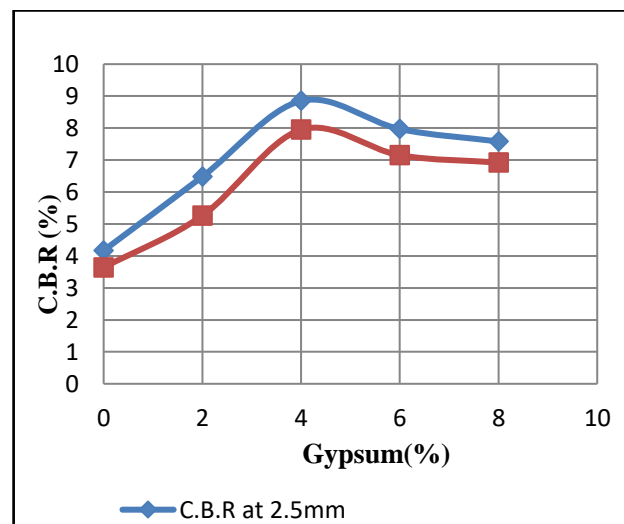


Fig.9. Variation of C.B.R Values in Soil Sample with Different Percentage of Gypsum.

Stabilization of Clayey Soil using Gypsum and Calcium Chloride

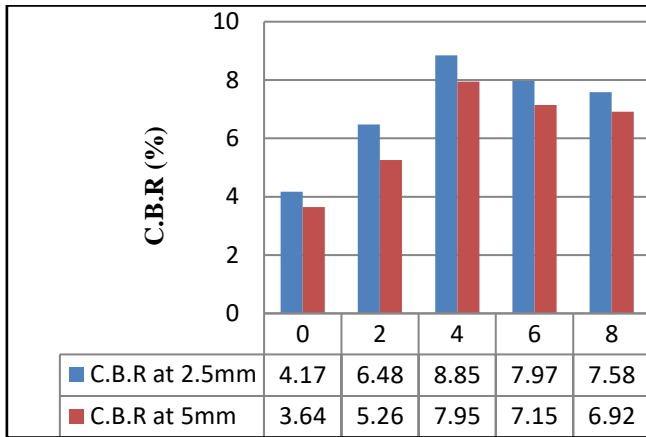


Fig.9. Bar Chart Variation of C.B.R Value in Soil Sample with Gypsum.

Here results can be seen that with addition of gypsum upto 4% in soil sample, C.B.R value increases from 4.17 to 8.85%. After that further addition of gypsum, C.B.R value decreases.

D. Standard Proctor Test results after mixing with different percentage of gypsum and fixed percentage of calcium chloride.

A series of standard proctor compaction tests are performed on reinforced soil with different percentages of gypsum and constant percentage of calcium chloride and the corresponding results are demonstrated below

Table V: MDD and OMC Values at different percentage of gypsum and constant percentage of CaCl₂.

Sl.no.	Percentage Content	MDD (g/cc)	(%) OMC
1	0% Gypsum	1.75	16.13
2	4% Gypsum	1.92	10.36
3	4% Gypsum+ 0.75% CaCl ₂	1.97	10.08

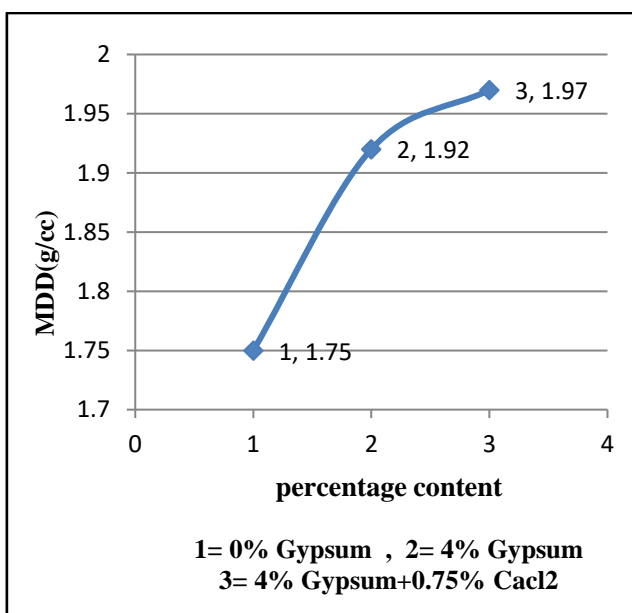


Fig.10. Variation of MDD in Soil Sample after Addition of Gypsum and CaCl₂.

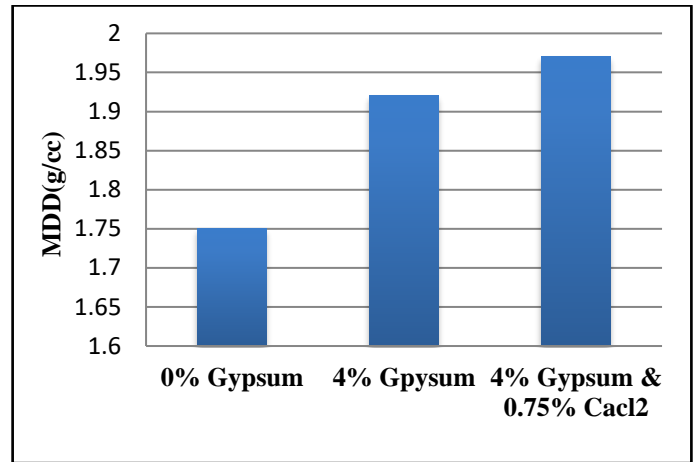


Fig.11. Bar chart variation of MDD in Soil Sample after Addition of Gypsum and 0.75% of CaCl₂.

It can be seen that soil sample attains maximum dry density (1.92) after adding 4% gypsum and further addition of gypsum decreases the MDD. Further when 0.75% CaCl₂ is added to soil sample with 4% gypsum, MDD increases to 1.97.

E. C.B.R value of soil sample with varying percentage of gypsum and constant percentage of CaCl₂(i.e 0.75%).

The following results are obtained from laboratory for C.B.R(california bearing ratio) value of soil sample with different percentage of gypsum and fixed percentage of CaCl₂ (i.e 0.75%) has been demonstrated below

Table VI: C.B.R values at different percentage of gypsum and constant percentage of CaCl₂.

Percentage Content	C.B.R at 2.5 mm (%)	C.B.R at 5 mm (%)
0% gypsum	4.17	3.64
4% gypsum	8.85	7.95
4% gypsum + 0.75% CaCl ₂	10.22	9.35

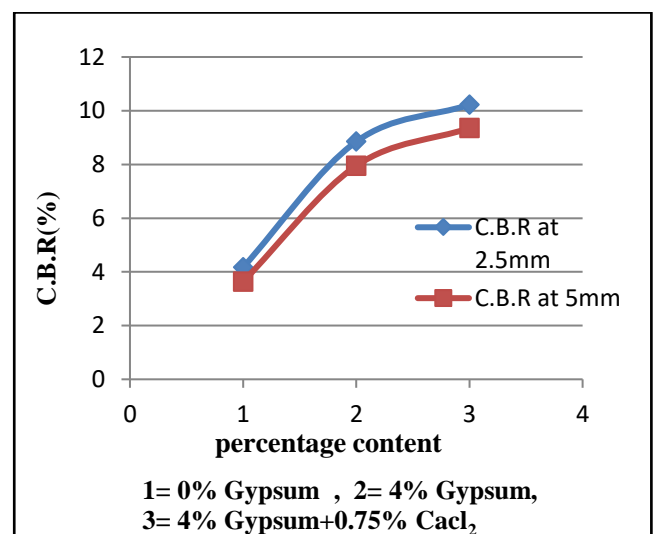


Fig.12. Variation value of C.B.R at 2.5 mm and 5 mm of soil sample with 0.75% CaCl₂ and 4% gypsum.

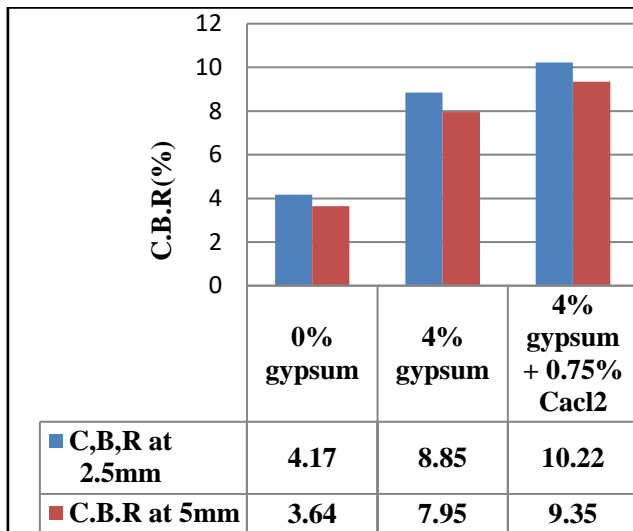


Fig.13. Bar chart variation of C.B.R value in soil sample with 0.75%CaCl₂and 4% gypsum.

It can be seen that C.B.R value at 2.5mm and C.B.R value at 5mm in soil sample are 4.17 and 3.64 respectively increases to 8.85 and 7.95 after mixing with 4% gypsum. Its value further increases to 10.22 and 9.35 respectively when 0.75% CaCl₂ is added with 4% gypsum.

II. CONCLUSION

According to the data and results acquired from the experimental work on soil stability investigation with different percentages of gypsum i.e.(2%, 4%, 6% and 8%) and fixed percentage of calcium chloride i.e. (0.75%), the following inference can be drawn in the aspect of strength properties due to application of gypsum and CaCl₂ as a stabilizing agent for the natural clayey soil.

- From the above data, the MDD(maximum dry densities) are found to be 1.75g/cc for 0%, 1.82g/cc for 2%, 1.92g/cc for 4%, 1.85g/cc for 6% and 1.80g/cc of 8% gypsum. In view of the outcome from the compaction test, it can be inferred that with increase in percentage of gypsum the compaction parameter i.e. MDD(maximum dry density) is increased up to 1.92g/cc at 4% gypsum content and then decreases. Other compaction parameter i.e. OMC(optimum moisture content) is found out to be 10.36% at 4% gypsum content. So, it is concluded that for effective soil stabilization at 4% gypsum gives better result.
- Based on the results from the compaction test, it can be inferred that at 4% gypsum content and 0.75% CaCl₂ content, the compaction parameter i.e. MDD(maximum dry density) is found out to be maximum and is equals to 1.97gm/cc. Other compaction parameter i.e. OMC(optimum moisture content) is found out to be minimum(10.08%) at 4% gypsum content and 0.75% CaCl₂ content.
- On the basis of obtained C.B.R test results, it is inferred that addition of gypsum and calcium chloride as reinforcement in clayey soils produces significant increase in C.B.R value. It is concluded that, with increase in gypsum and for constant percentage of CaCl₂, the C.B.R values are also increased appreciably and is found to be maximum 10.22% for 4% gypsum and 0.75%CaCl₂.
- From the above confabulation, it is inferred that

addition of gypsum and CaCl₂ to the clayey soil there is appreciable impact on the compaction parameters and bearing capacity of the soil. It is also inferred that, expensive methods for stabilization of soils such as with cement, fly ash etc. can be supplanted together with gypsum and CaCl₂ as an alternative method to improve the weak clayey soil properties. Gypsum and CaCl₂ can be used for stabilization of pavement sub-grade, embankment and other fields of civil engineering according to the requirements for clayey soils.

REFERENCE

1. Yasser I.O. and H Alsharie, "Stabilization of clayey soil using cement, gypsum and recycling concrete in Jareh city-Jordan", INTERNATIONAL JOURNAL OF CURRENT RESEARCH, Vol. 10, Issue 10, pp 74135-74137, October2018.
2. Tamadher T, Abood, Anuar Bin Kasa and Zamri Bin Chik, "Stabilization of silty clay soil using chemical compounds" Journal of Engineering Science and Technology,2007, Vol. 2, No. 1 Pages 102-110.
3. Arash B., "The effect of adding iron powder on atterberg limits of clay soils". International Research Journal of Applied and Basic Sciences, Intl. Res. J. Appl. Basic. Sci. Vol. 3, Issue 11, 2012.
4. Ramadas, T.L., Kumar, N.D., and Yesuratnam, G., 2012. A study on strength and swelling characteristics of three expansive soils treated with CaCl₂. International Journal of Advances in Civil Engineering and Architecture. 1(1):77-86.
5. Aly Ahmed and Usama H.Iss, "Stability of soft clay soil with recycled gypsum in a wet environment". Soils and Foundations, 2014, 54(3), Pages 405–416.
6. Dina Kuttah and Kenichi Sato, "Review on the effect of gypsum content on soil behavior". Transportation Geotechnics, September 2015, Volume 4, Pages 28-37.
7. A.Goyal, "Soil stabilization of clayey soil using jute fibre and gypsum" International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 8, pp 15513-15519, August 2016.
8. B.P. Singh Sikarwar," Stabilization of clayey soil by using gypsum" IJSRD – International Journal for Scientific Research & Development, Vol.5, Issue03, pp886- 888, 2017.
9. Peddaiah and K.Suresh, "Experimental study on effect of gypsum and Nacl in improvement of engineering properties of clayey soil" International Journal of Engineering and Technology (IJET), Vol. 9, Issue 4, pp 2771-2778, Aug-Sep2017.
10. IS: 2720-Part 3-1980, Bureau of Indian Standards New Delhi, Feb (1981).Determination of Specific Gravity of Soil Solids.
11. IS: 2720-Part 16-1987, Bureau of Indian Standards New Delhi, May (1988). Laboratory determination of C.B.R Value.
12. IS: 2720-Part 7-1980, Bureau of Indian Standards New Delhi, December (1980). Laboratory method for Standard Proctor Test.
13. IS: 2720-Part 5-1985, Bureau of Indian Standards New Delhi, August (1985). Laboratory method for determination of LL and PL of soil.
14. IS: 2720-Part 10-1991, Bureau of Indian Standards New Delhi, May (1992). Laboratory method for determination of Unconfined Compressive Strength of Soil.

AUTHORS PROFILE



Jayant Singh, M. Tech from BIT Sindri, Dhanbad, Jharkhand, INDIA, PIN-828123.

E-mail: jayantsingh1996@gmail.com. Jayant Singh is currently pursuing M. Tech in Soil and Foundation from Department of Civil from BIT Sindri, Dhanbad, Jharkhand, PIN-828123. He had his B. Tech in Civil engineering from B.C.E, Bhagalpur. He had done training from D.M.R.C, New Delhi. He

had done B.tech project on "Concrete Mix Design Of Grade M35 " in 2017.



Stabilization of Clayey Soil using Gypsum and Calcium Chloride



Dr. U. K. Singh, Department of Civil Engineering, BIT Sindri, Dhanbad, Jharkhand, INDIA, PIN 828123.
E-mail :uksingh8888@gmail.com.

Dr. U.K. Singh is currently working as Professor in the Department of Civil, BIT Sindri (under Ministry of Higher, Technical Education, Skill Development, Government of Jharkhand), Dhanbad, PIN-828123. He has

chaired different posts in departments of government of Jharkhand. He has guided many M. Tech students. He is professional member of ISTE etc. He has been given credit in over 15 publications in National and International Journals.



Dr. R. K. Singh, Department of Chemistry, BIT Sindri, Dhanbad, Jharkhand, INDIA, PIN-828123. E-mail: rks_chem@rediffmail.com.

Dr. R. K. Singh is currently working as Professor and Head of Department of Chemistry, BIT Sindri (under Ministry of Higher, Technical Education, Skill Development, Government of Jharkhand), Dhanbad, PIN-828123. He is former pro-vice chancellor of Kolhan University, Chaibasa,

Jharkhand. He is life member of Indian Science Congress and the Institution of Chemists (India). He has awarded Rastriya Gaurav award. He has keen interest in research and development in interdisciplinary work also. He had supervised Ph.D and M.Tech students. He has examined several Ph.D thesis in different universities of India. He has to his credit, over 100 publication in National and International Journals and proceeding, books chapters and books.