Experimental Evaluation of Expansive Soil Stabilized with Ceramic Dust and Phosphogypsum

Kanik[1], Anoop Sharma[2]

[1]PG student, Dept. of Civil Engineering, Sri Sai College of Engineering& Technology, Badhani, Punjab, India
[2]Assistant Professor, Dept. of Civil Engineering, Sri Sai College Of Engineering& Technology, Badhani, Punjab, India
anoopsharma777r@gmail.com
kanikchoudhary01@gmail.com

---***---

Abstract - In India, expansive soils account for 20% of the country's total land area. These soils inflate (increase in volume) during the winter and shrink (reduce in volume) during the summer. Due to this contradictory behavior, many civil engineering buildings built on expansive soils suffer serious damage, with pavement suffering the most because of their low weight and extensive coverage. Expansive soil stabilization is crucial in order to improve soil strength and lower building costs by making the most use of resources that are already readily available in the area. Through the use of laboratory tests such as Atterberg's limit, Compaction characteristics, Unconfined Compressive Strength and California Bearing Ratio among others, the impacts of Phosphogypsum and Ceramic Dust (CD) on expansive soil were investigated. Phosphogypsum and CD, which ranged in concentration from 10 to 20%with an increment of 5% for Phosphogypsum and 3 to 7 % with an increment of 2% for CD, were added to locally source clayey soil. The analysis of the test findings revealed that the percentages of Phosphogypsum and CD reduced with increasing liquid limit (LL), plasticity index (PI) and optimal moisture content (OMC). With an increase in Phosphogypsum and CD percentage, the plastic limit (PL), maximum dry density (MDD), unconfined compressive strength (UCS), and California bearing ratio (CBR) were all raised. We have deduced from this study that due to the properties of Phosphogypsum, which have a very high lime (CaO) content up to 60% and CD, which have a very high silicon dioxide (SiO2) content, they can be employed as an effective soil treatment for foundations, embankments, and roadways.

***Key Words*: Compaction test, CBR, UCS, Ceramic Dust, Phosphogypsum**

1. INTRODUCTION

In early times before the fly ash in geotechnical engineering, the only way for engineers was to design the foundation matching to the sub soil conditions at a particular site. If the soil was not as per the requirement either the soil upto certain depth had to be replaced or had to change the site. But now days with the help of various Ground Improvement techniques and with the help of latest technology it is possible to modify the weak foundation soil for required parameters such as shear strength and compressibility. Thus these techniques of improving the quality of the foundation soil upto desired parameters are called Ground Improvement Techniques. The main objective of these processes is to increase the density, and shear strength, decrease settlement, permeability and compressibility which make the soil more stable, durable and water resistant. Ground Improvement is the best way where the soil replafly ash is not feasible for the geological or technical reasons, or it is too costly.

Ground Improvement has one or more than one of the following main functions:-

- Increase density
- Increase bearing capacity, shear or frictional strength
- Control deformations
- Provide lateral stability
- Accelerate consolidation

- Fill voids
- Lower liquefaction susceptibility

Depending upon the type of the soil, geological features and availability of the technology and materials required, one of the following Ground Improvement Techniques can be used for the above described purposes :-

1. Compaction
2. Consolidation
3. Grouting and Injection
4. Soil Stabilization

2. Literature Review

Jijo James et al. (2023) The study involved the utilization of an industrial waste product, Phosphogypsum (PG) as an additive to lime for the stabilization of soil. Three lime dosages, viz. initial consumption of lime (ICL), optimum lime content (OLC) and less than ICL (LICL) were adopted for stabilizing the soil. The study investigated the stress-strain characteristics of soil composites stabilized with these three lime contents modified with optimum dosages of PG. Mineralogical studies were performed on the spent samples used for a series of determinations of unconfined compression strength tests with various combinations of lime and optimum PG content. The addition of an optimum dosage of PG resulted in an early strength gain of 8.8%, 14.1% and 13.9% and a delayed strength gain of 9.9%, 19% and 19.7% for 3%, 5.5% and 7% for the lime-stabilized soil, respectively. It was found that the addition of PG to the lime resulted in enhanced stiffness, residual strength and reduced brittleness due to the PG amendment of the stabilization reactions. However, in terms of the overall improvement of soil properties, the most favorable benefit was obtained by optimal PG modification of ICL rather than OLC. Microanalysis of the X-ray diffraction scatter also supported the results revealed through stress-strain characteristics. ICL with its optimal PG dosage showed a better progression of pozzolanic reactions when compared to the other two in terms of reduction of peaks of soil minerals and increase in peaks of CSH.

Wadhonkar et al. (2022) nowadays many experimental studies have been carried on black cotton soil to improve its characteristics. This soil is highly clayey in nature as it has low bearing capacity and high swelling shrinkage characteristics. In most of areas of India there is wide spread black cotton soil which causes the problem to the civil related to structures. This soil mainly shrinks in the absence of moisture and swells in the presence of moisture which may leads to the failure of engineering structures resting on it. On reviewing various past research works, it has been found that the utilization of admixtures such as fly ash, Rice husk ash, GGBS, WMP, WCP etc. may be used to increase the geotechnical properties of black cotton soil. Now a day's rapid industrialization causes problems such as disposal of industrial waste materials, environmental pollution etc. In this review, utilization of industrial material is highlighted. On proper reviewing it has been found that there is a wide scope for utilization of industrial waste and other waste material for the stabilization of expansive soils.

Guoping Qian et al. (2022) Phosphogypsum (PG), as a by-product of the production of phosphoric acid, faces the problems of large annual output and difficult treatment. There is a large demand for fillers in the process of road paving, which may be an effective method for the utilization of PG resources. In this study, three proportions of phosphogypsum–lime–fly ash (PLF) mixture were designed, first, according to orthogonal tests. The comprehensive performance of the PLF mixture was tested by the compression rebound modulus test, unconfined compressive strength test, flexural tensile strength test, dry shrinkage test, and temperature shrinkage test, respectively. The results show that adding crushed stone to the PLF mixture can effectively improve the compression rebound modulus, unconfined compressive strength, and flexural tensile strength. The high content of PG in the mixture can also improve the dry shrinkage and temperature shrinkage properties of the mixture. According to the road layer requirements, the optimum proportion of the PLF mixture is recommended, which may benefit the road construction and PG resources.

J. James et al. (2021) This study investigates the potential of a blended binder formulated from two industrial solid wastes viz. phosphogypsum and fly ash in combination with lime. Three mix proportions of phosphogypsum and fly ash were investigated, and the minimum lime contents required for activation were determined using the Eades and Grim pH test. The lime–fly ash–phosphogypsum blends were then cast into cubes, both in their paste form as well as mortar form, mixed with sand in the ratio of 1:3. They were cured for a period of seven days, and afterwards, their compressive strength was determined. Ordinary Portland cement and lime mortar blocks were also cast as control specimens for comparative evaluation of the strength. The optimal lime–fly ash–phosphogypsum blend was identified and used to construct a masonry prism, and the strengths of the masonry prisms were also evaluated. The optimal lime–fly ash–phosphogypsum blend mortar was also subjected to an X-ray diffraction analysis to determine the reaction products formed during hydration. The study revealed that 5% lime mixed with fly ash:phosphogypsum in the ratio of 3:1 was the optimal proportion which gave the maximum strength to the cubes. The optimal lime–fly ash–phosphogypsum blend mortar developed strength that was higher than conventional Portland cement and lime mortar. The optimal lime–fly ash–phosphogypsum blend mortar masonry prisms developed strength that was comparable to that of Portland cement mortar masonry.

Anusha H M et al (2021) Expansive soils are those soils which pose a very serious problem when they are subjected to moisture variation. Phosphogypsum is one of the in-dustrial waste by-products that can be utilized for the purpose of soil stabiliza-tion. In this study, the strength of lime stabilized soil added with Phosphogyp-sum for immediate,7 and 14 days of curing periods is compared with the strength of Phosphogypsum amended black cotton soil for immediate, 7 and 14 days of curing. From Unconfined compressive strength test, it was found that 6% of Phosphogypsum is the optimum content, that imparts the maximum strength to the soil that when it is used alone. The combination of 3% of lime and 6% of Phosphogypsum gives the maximum strength and the strength ob-tained is relatively higher than the strength of the black cotton soil stabilized with Phosphogypsum alone.

Dhanasekar et al (2021) Expansive soils are problematic soils for Civil Engineers. Black cotton (BC) soils possess low strength and high compressibility, due to these properties black cotton soils are considered to be challenging one for analysis. To achieve desired properties of soil for construction purpose these black cotton soil must be enhanced to meet its requirement. To modify the properties of black cotton soils, many treatment methods are there. In this paper an attempt has been made to improve the properties of black cotton soil by using industrial

waste through stabilization method. By stabilizing the soil properties are enhanced and make it suitable for subgrade construction. In this work, the combined effect of Lime and Phosphogypsum (PG) on compaction characteristics, Atterberg's Limit, Unconfined Compressive Strength (UCS) for original soil, California Bearing Ratio (CBR) and direct shear Test of a black cotton soil with percentage varying of Lime and Phosphogypsum was carried out. The soil samples were tested for tri-axial compression test and CBR tests were carried out after 4 days curing period. From the results, it has been inferred that the black cotton soil treated with Lime and Phosphogypsum in the percentages of (4:4) has better strength characteristics. Hence, it may be concluded that

Lime and Phosphogypsum can be used for stabilization of black cotton soils for pavement subgrade

Sabhnani et al (2021)

This paper discusses the stabilization results of various studies conducted by different researchers, which is useful for determining the potential of industrial wastes for clayey soil stabilization. This review paper discusses the studies about the uses of phosphogypsum and surkhi generated as waste from the industries as a soil stabilizer. Phosphogypsum is generated as byproduct during the production of phosphoric fertilizer and surkhi or brick kiln dust is produced as waste during the manufacturing of fire clay bricks. The soil stabilized using these wastes which is generated from industries have significant effect on the clayey soil. Moreover, this soil stabilization method not only a very eco-friendly and cost effective but also utilizes the wastes generated from industries in a more purposeful manner.

Tebogo Pilgrene Mashifana et al (2018) In order to explore the potential stabilization of vastly abundant expansive soil using larger quantity phosphogypsum waste as a potential modifier, composites with a mixture of lime-fly ash-phosphogypsum-basic oxygen furnace slag were developed. However because of the presence of radionuclide, it was necessary to treat the phosphogypsum waste with mild citric acid. +e effect of the acid treatment on the geotechnical properties and microstructure of expansive soil stabilized with phosphogypsum-lime-fly ash-basic oxygen furnace slag (PG-LFA-BOF) paste was evaluated, in comparison with the untreated phosphogypsum. Expansive soil stabilized with acid treated PG-LFA-BOF paste exhibited better geotechnical properties; in particular, the high strength mobilized was associated primarily with the formation of various calcium magnesium silicide and coating by calcium silicate hydrate and calcium aluminate hydrate. +e soil microstructure was improved due to the formation of hydration products. +e stabilized expansive soil met the specification for road subgrades and subbase. Stabilization of expansive soils with phosphogypsum, fly ash, and basic oxygen fly

ash does not only improve engineering properties of soil but also provides a solution in relation to disposal and environmental pollution challenges.

Hattamleh et al. (2017) This study intended to explore the effectiveness of using fine steel slag aggregate (FSSA) in improving the geotechnical properties of high plastic subgrade soil. First soil and fine steel slag mechanical and engineering properties were evaluating. Then 0%, 5%, 10%, 15%, 20%, and 25% dry weight of soil of fine steel slag (FSSA) were added and mixed into the prepared soil samples. The effectiveness of the FSSA was judged by the improvement in consistency limits, compaction, free swell, unconfined compression strength, and California bearing ratio (CBR). Fromthe test results, it is observed that 20% FSSA additives will reduce plasticity index and free swell by 26.3% and 58.3%, respectively. Furthermore, 20% FSSA additives will increase the unconfined compressive strength, maximum dry density, and CBR value by 100%, 6.9%, and 154%. By conclusion FSSA had a positive effect on the geotechnical properties of the soil and it can be used as admixture in proving geotechnical characteristics of

subgrade soil, not only solving the waste disposal problem.

3. Materials

3.1 SOIL

Source of soil

The soil required for the project is taken from an empty field in nearby areas. The soil is alluvial in nature and contains high amounts of clay.

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	40
2.	Plastic limit (%)	26
3.	Plasticity Index (%)	14
4.	Specific Gravity	2.59
5.	Maximum Dry Density (KN/m³)	16.78
6.	Optimum Moisture Content (%)	14.28
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%) (soaked)	2.7
9.	CBR (%) (Unsoaked)	4.5
10.	UCS (kN/m²)	232

3.2 CERAMIC DUST

In the world a lot of ceramic dust is produced during production, transportation and placing of ceramic tiles. This wastage or scrap material is inorganic material and hazardous. Hence its disposal is a problem which can be removed with the idea of utilizing it is an admixture to stabilize BC soil, so that the mix prove to be very economical and can be used as subgrade in low traffic roads or village roads.

It has been estimated that about 30% of daily production in the ceramic industry goes to be ceramic dust. The disposal of which creates environmental and economical problem. To overcome this situation this industrial waste can be used in different application, one of prime is soil stabilization.

Ceramic dust consist of high SiO2, Al2O3 and Fe2O3 contents reaching up to 96%, but the amount of Fe2O3and Tio2 is 1.22%.

Table 2: Chemical Properties of Ceramic Dust

S.No	CONTENT	CD (%)
1	Silicon dioxide (SiO_2)	68.58
2	Aluminum Oxide (Al_2O_3)	27.45
3	Iron Oxide (Fe_2O_3)	0.47
4	Calcium Oxide (CaO)	0.17
5	Magnesium Oxide (MgO)	0.16
6	Potassium Oxide (K_2O)	1.84
7	Sodium Oxide (Na_2O)	0.32
8	Sulphur Oxide (SO_3)	0.13
9	Titanium oxide (TiO_2)	0.75

3.3 PHOSPHOGYPSUM

The material Phosphogypsum was taken from fertilizer industry Bhilwara Distt. Rajasthan.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 09 | Sept - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Table 3:- chemical composition of Phosphogypsum

S. No	Name of constituent	Percentage
1	SiO_2	43.6
2	$Al_2O_3 + Fe_2O_3$	1.82
3	Calcium Oxide (CaO)	32.0
4	Magnesium oxide (MgO)	0.40
5	SiO_2 ins. In HCl	1.64
6	Na_2O	0.36
7	P_2O_5	1.03
8	Organic matter	0.26

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 4: Results of OMC and MDD for mix proportions of Soil, CD and Phosphogypsum

CS:CD:P	MDD (kN/m^3)	OMC (%)
100:0:0	16.78	14.28
83:02:15	16.20	14.81
81:04:15	15.68	15.37
79:06:15	15.16	15.76

Fig:-1 variations b/w MDD and OMC of Ceramic Dust, Phosphogypsum & soil with different proportions

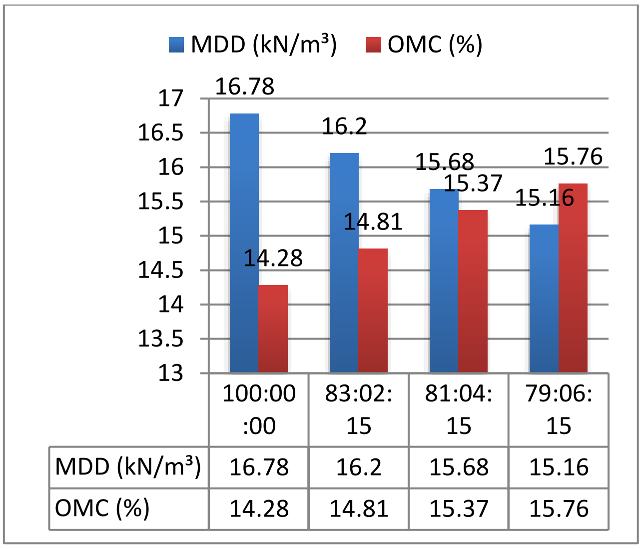


Table 5: Results of UCS of Ceramic Dust and Phosphogypsum Mix with Soil

CS:CD:P	Curing Period (Days)	UCS (kN/m^2)
100:0:0	7	232
83:02:15	7	340
81:04:15	7	397
79:06:15	7	461

Fig:-2 UCS Value of Clayey soil of Ceramic Dust and Phosphogypsum

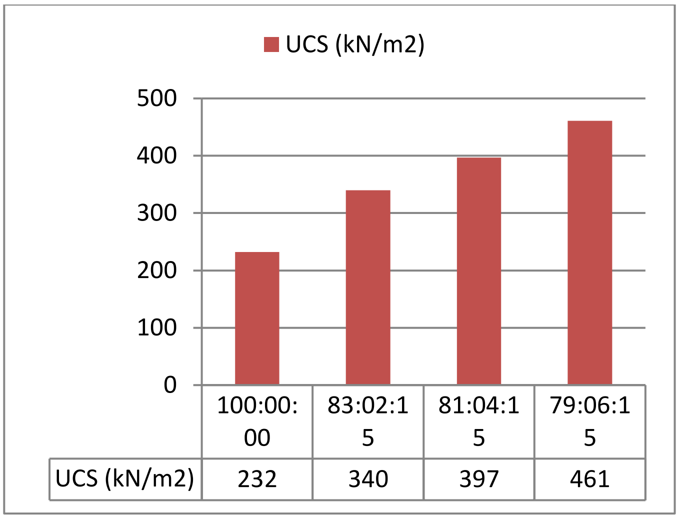
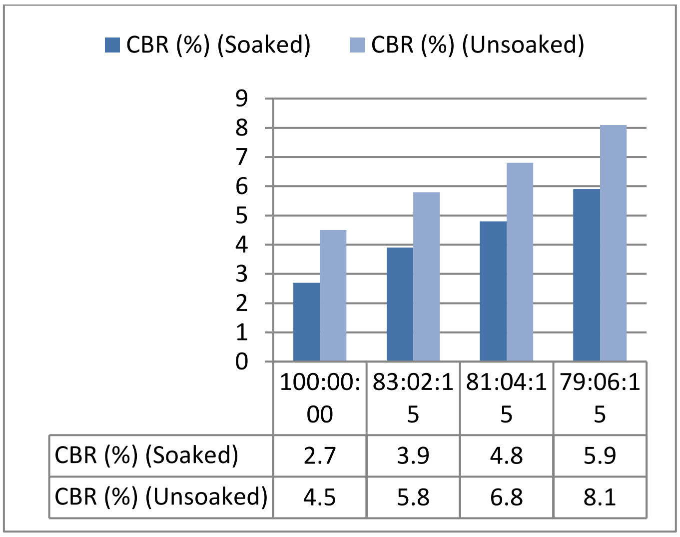


Table 6: Results of CBR of Ceramic Dust and Phosphogypsum Mix with Soil

CS:CD:P	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:0:0	2.7	4.5
83:02:15	3.9	5.8
81:04:15	4.8	6.8
79:06:15	5.9	8.1

Fig:-3 CBR Percentages of Clayey soil, Ceramic Dust and Phosphogypsum



5. DISCUSSIONS

5.1 STANDARD PROCTOR TEST:

- An decrease of OMC from 14.28 to 13.23% and increase of M.D.D. from 16.78 to 18.13 kN/m^3 when the percentages of Ceramic Dust are used as 3%, 5% and 7% respectively.
- There is increase of OMC from 14.28 to15.40% and decrease of MDD from 16.78 to 15.91kN/m^3 when the percentages of Phosphogypum are used as 10%, 15% and 20% respectively.
- There is an also decrease of MDD from 16.78 to 15.16 kN/m^3 and increase of OMC from 14.28 to 15.76% when the percentages of Ceramic Dust vary from 02%, 04% and 06% and Phosphogypum is fixed at 15%. The reason behind of such behavior is Phosphogypsum is lighter in weight and it has high water absorption properties because of presence of calcium oxide and hence OMC increases with increase of Phosphogypsum content.
- The purpose behind increment of OMC of Phosphogypsum is the water retaining limit which is more noteworthy when contrasted with soil particles.

- With Phosphogypum kept constant at 15% MDD decreases with an addition of Ceramic Dust content in soil and Ceramic Dust mix. The reason behind of such behavior is high percentages of reduction in voids affect the density of soil+ Ceramic Dust mixes.

5.2 CBR TEST:

- The CBR value of virgin soil is 2.7 and it increases to 1.74 times with addition of 20% Phosphogypsum when observed in soaked conditions. This enhancement is because of binding action of Phosphogypsum.

- The CBR value of virgin soil is 2.7 and it increase to 2.18 times when Ceramic Dust 06% and Phosphogypsum 15% is added to virgin soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.
- As a result of Phosphogypsum is a light material and with increment the amount of Phosphogypsum lumps are formed. This outcome in arrangement of pockets of low thickness and consequently compaction is impossible accurately bringing about diminishing in CBR value.

5.3 UCS TEST:

- The UCS value of virgin soil is 232kN/m² and it increases to 1.76 times with addition of 20% Phosphogypsum. This improvement is because of increases the cementation property of soil.
- The UCS value of virgin soil also improves considerably with expansion of Ceramic Dust 06% and Phosphogypsum 15%. The value increases from 232kN/m² to 461kN/m² with addition of Ceramic Dust and Phosphogypsum.
- The reason behind of this when Ceramic Dust and Phosphogypsum comes in contact with water, pozzolanic reactions takes place during the curing period. With increases the amount of Phosphogypsum, U.C.S. value starts decreasing because of lumps are formed with extra addition of Phosphogypsum. This outcome in arrangement of pockets of low thickness and consequently compaction is impossible accurately bringing about diminishing in CBR value.

6. CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

1. The different percentages of Ceramic Dust and Phosphogypsum used in this study were 03%, 05% & 07% and 10%, 15% & 20%. Finally, the value of Ceramic Dust varies from 02 to 06% at the interval of 02% with the fixed quantity of Phosphogypsum 15% to clayey soil.
2. The addition of the fixed quantity of Phosphogypsum 15% with changing the content of Ceramic Dust increase the value of optimum moisture content and decreases the value of maximum dry density.
3. The UCS value increases with an increase of Ceramic Dust content along with a fixed quantity of Phosphogypsum. It increased 1.98 times from the untreated soil. Based on the unconfined compression strength test results, the value of UCS increases from 232kN/m² to 461kN/m² with addition of Ceramic Dust and Phosphogypsum.
4. The Maximum value of California Bearing Ratio test was found at Ceramic Dust 06% and Phosphogypsum 15%. The value of CBR increases from 2.7% to 5.9% with addition of Ceramic Dust and Phosphogypsum.
5. From this study it is concluded that Phosphogypsum and Ceramic dust are waste products from industries that can be used as stabilizers to clay soil and this would help to solve the conventional problem of disposal of them.

References

1. Jijo James (2023), "Stress-Strain Characteristics and Mineralogy of an Expansive Soil Stabilized Using Lime and Phosphogypsum". Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).
2. Hareshwar Ashokrao Wadhonkar(2022), "Stabilization of Expansive Soil Using Industrial and Agricultural Wastes". Print ISSN: 2395-1990 | Online ISSN: 2394-4099 IJSRSET.
3. Guoping Qian (2022), "Experimental Study on the Road Performance of High Content of Phosphogypsum in the Lime–Fly Ash Mixture". Front. Mater. 9:935113. doi: 10.3389/fmats.2022.935113 Frontiers in Materials | www.frontiersin.org 1 July 2022 | Volume 9 | Article 935113
4. J. James (2021), "Lime activated flyash-phosphogypsum blend as a low-cost alternative Binder". International Journal of Environmental Science and Technology https://doi.org/10.1007/s13762-021-03618-2
5. Anusha H M (2021), "Analysis of Strength Properties of Lime Stabilized Black Cotton Soil with Phosphogypsum". https://www.researchgate.net/publication/343556029. Researchgate.
6. Dr.K.Dhanasekar (2021), "Stabilization of Black Cotton Soil using Lime and Phosphogypsum". Volume 9. No. 4, April 2021 International Journal of Emerging Trends inEngineeringResearch.https://doi.org/10.30534/ijeter/2021/29942021.https://www.researchgate.net/publication/351067873. Researchgate.
7. Mayur Sabhnani (2021), "Utilization of Phosphogypsum and Surkhi asClayey Soil Stabilizer - A Review". © 2021 JETIR April 2021, Volume 8, Issue 4 www.jetir.org (ISSN-2349-5162). Journal of Emerging Technologies and Innovative Research (JETIR) www.jetir.org
8. Tebogo Pilgrene Mashifana (2018), "Geotechnical Properties and Microstructure of Lime-Fly Ash-Phosphogypsum-Stabilized Soil". Hindawi Advances in Civil Engineering Volume 2018, Article ID 3640868, 9 pages https://doi.org/10.1155/2018/3640868.
9. Shubham More, Apeksha Lokhande, Shaikh Sabir (2018), "Stabilization of Black Cotton Soil by Using Steel Slag". International Journal of Innovative Research in Science, Engineering and Technology. Vol. 7, Issue 5, May 2018.
10. Hussien Aldeeky and Omar Al Hattamleh (2017), "Experimental Study on the Utilization of Fine Steel Slag on Stabilizing High Plastic Subgrade Soil". Hindawi Advances in Civil Engineering Volume 2017, Article ID 9230279.
11. Jijo james et al (2016), "role of phosphogypsum and ceramic dust in Amending the early strength development of a Lime stabilized expansive soil". International Journal of Sustainable Construction Engineering & Technology (ISSN: 2180-3242) Vol 7, No 2, 2016
12. Akshay Kumar Sabat (2016), "Stabilization of expansive soil uing waste ceamic dust". EJGE, Researchgate.
13. Ajay upadhyay (2016), "Review on soil stabilization uing ceramic waste". International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 07 | July 2016.
14. Anil kumar sharma, P.V. Sivallaiah (2016), "Ground granulated blast furnace slag amended

fly ash as an expansive soil stabilizer". Soils and Foundations.

15. Alaa M. Rashad, (2015), "Potential use of Phosphogypsum in alkali-activated fly ash under the effects of elevated temperatures and thermal shock cycles". Journal of Cleaner Production.

16. Divya Krishnan.K , V.Janani , P.T.Ravichandran , R.Annadurai , Manisha Gunturi,(2014). "Soil Stabilisation Using Phosphogypsum and Flyash". International Journal of Engineering Trends and Technology (IJETT).

17. Hanan Tayibi, Mohamed Choura, Fransico J. Alguacil, (2009), "Environmental impact and management of Phosphogypsum". Journal of Environmental Management.

18. Sudong Hua, Kejin Wang, Xiao Yao, Wen Xu, Yuxin He, (2016), "Effects of fibers on mechanical properties and freeze-thaw resistance of Phosphogypsum-slag based cementitious materials". Construction and Building Materials.

19. Yun Huang, ZongShou, (2010), " Lin Investigation on Phosphogypsum–steel slag–granulated blast-furnace slag–limestone cement". Construction and Building Materials

20. Indian Standard Code IS 2720-16, IS 2720-10.

21. Ameta NK, Wayal AS, Hiranandani P. Stabilization of Dune Sand with Ceramic Tile Waste as Admixture. AJER. 2013; 2(9): 133–39p.

22. Singh B, Sharma RK. Evaluation of Geotechnical Properties of Local Clayey Soil Blended with Waste Materials. JJCE. 2014; 8(2): 135–51p.