EXPERIMENTAL STUDY OF CERAMIC DUST STABILIZED CLAYEY SOIL WITH CEMENT KILN DUST

Anuj Sharma[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*

Anujranyal30@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 Cement Kiln Dust (CKD) and Ceramic Dust (CD) on expansive soil were investigated. CKD and CD, which ranged in concentration from 5 to 15%with an increment of 5% for CKD and 2 to 6 % 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 CKD and CD reduced with increasing liquid limit (LL), plasticity index (PI) and optimal moisture content (OMC). With an increase in CKD 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 CKD, 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*: Atterberg limits, CBR, Compaction test, ceramic dust, cement kiln dust*

1. INTRODUCTION

Just like other construction materials soil also has its own chemical and physical characteristics with regard its abilities on dealing with the loadings and other external forces. From all the other civil engineering fields soil engineering and soil mechanics is most complex field when it comes to factor of safety in design of sub-structures e.g. foundations , piles and other soil based constructions like sub-grade for pavements , embankments etc, requires a significantly a higher factor of safety in comparison of other construction materials . That's why the uncertainty in soil analysis and foundations designs is higher.

Therefore the geotechnical properties of the soil are analysed before any major construction work, so as to ensure its stability against the load of the desired structures. The soil normally consists of rock particles, the air and the water are located in the empty spaces (called voids). It is essential to determine the geological properties of the soil that are influenced by the size of the particles, distribution of the grain size, form of the minerals present in the particles and the amount of that minerals. The engineering properties of the soil are generally are considered for carrying out the analysis of the site conditions and design of structures are the bulk unit weight, saturated unit weight, dry unit weight, permeability and porosity. Several laboratory tests are also conducted to check the suitability of the soil, including permeability, relative density, soil compaction characteristics and water content.

Sometimes the existing soil at a particular site may not be suitable for construction of structures due to its low bearing capacity, drainage problem and other problems like high compressibility etc. Clayey soil if found which is ineffective for the construction due to its low bearing capacity against the load due to its swell-shrink characteristics, there is the requirement to improve its characteristics by various ground improvement techniques or by changing the properties of such soils by using some industrial and agricultural wastes such as fly ash, rice husk etc having pozzolanic and fly ashitious properties, resulting in reduction of cost of improvement.

2. LITERATURE REVIEW

Wadhonkar et al. (2022) nowadays many experimental studies have been carried on black cotton soil toimprove its characteristics. This soil is highly clayey in nature as it has lowbearing capacity and high swelling shrinkage characteristics. In most of areas ofIndiathereiswidespreadblackcottonsoilwhichcausesthepro blemtothecivilrelated to structures. This soil mainly shrinks in the absence of moisture andswellsinthepresenceofmoisturewhichmayleadsto thefailureof engineeringstructures resting on it. On reviewing various past research works, it has beenfound 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 blackcotton soil. Now a day's rapid industrialization causes problems such as disposalofindustrialwastematerials,environmentalpollutione tc.Inthisreview,utilizationofindustrialmaterialishighlighted. Onproperreviewingithasbeenfoundthatthereisawidescopefor utilizationofindustrialwasteandotherwastematerialforthesta bilization of expansive soils.

Pawar et al. (2022) Using steel slag for soil stabilization is a modern application of steel slag. In this study the main approach is to investigate the effect of steel slag on the strength characteristics of clayey soil. Steel slag is blended with clayey soil in amounts of 10%, 15%, 20%, 25%, and 30% of dry weight. In our study, the optimum content of steel slag was determined by considering the maximum unconfined compressive strength. A series of further laboratory tests have been performed on this optimum mix to evaluate its suitability as a stabilizer material. The test was also conducted with conventional stabilizing material such as l0% fly ash and 5%cement with clayey soil and the obtained optimum mix was determined. Then the results are compared accordingly. In the above study, it has been observed that the addition of steel slag results in significant improvement in strength parameter as compared to fly ash but less strength in case of cement.

Joshi et al. (2018) The use of steel slag improves the bearing capacity and the strength of black cotton soil and indirectly it saves the construction cost. Different percentage of 5%, 10%, 15% and 20% steel slag have been used to stabilize the black cotton soil and to verify its suitability for using it as a construction material for road. The steel slag collected from Kalika Steel, Jalna and the black cotton soil collected form Himayatbaugh, Aurangabad. The overall program was conducted in 2 phases. In first phase all necessary test such as Atterberg limit, C.B.R and standard proctor compaction test on plain soil were being performed to analyse the maximum dry density (maximum dry density) and optimum moisture content (Optimum Moisture Content). And in 2 phase the black cotton soil was mixed with 5%, 10%, 15%, 20 % of steel slag.

Shalabi et al. (2017) High expansion and reduction in shear strength and foundation bearing capacity will take place due to the increase in water content of these soils. The engineering properties of these kinds of soils can be improved by using additives and chemical stabilizers. In this work, by-product steel slag was used to improve the engineering properties of clay soils. Lab and field experimental programs were developed to investigate the effect of adding different percentages of steel slag on plasticity, swelling, compressibility, shear strength, compaction, and California bearing ratio (CBR) of the treated materials. The results of tests on the clay soil showed that as steel slag content increased, the soil dry density, plasticity, swelling potential, and cohesion intercept decreased and the angle of internal friction increased. For the CBR, the results of the tests showed an increase in the CBR value with the increase in slag content.

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.

Rokade et al. (2017) Addition of nylon fibre along with fly ash to measure the change in the strength parameters of black cotton soil. The CBR of the soil was determined by conducting three series of tests. Tests were carried out on the BC soil mixed with varying percentage of fly ash, from 10% to 40% out of which 20% came out to be cptimum. Then, nylon fibre with aspect ratios (length/ diameter) 20, 40, 60 and 80 and fiber contents were varied from 0.25% to 1.5% with 0.25% interval, out of which 0.75% of fibre content is considered as optimum on the basis of MDD and maximum CBR value.

Anil Kumar Sharma et al., (2016) By mixing of fly ash and Ground Granulate Blast Furnace slag binder was formed. In the beginning the initial strength test was done on different ratios of fly ash and GGBS mixture. It was observed that 70:30 mix of fly ash and GGBS given the higher strength than individual fly ash or GGBS, even in the lack of any chemical activators. The mixing of binder without lime indicated the decrease in both liquid limit and plasticity index. When the binder content increases, the OMC decreases while MDD increases. In order to achieve the strength characteristics of every combination of soil binder samples, the tests were done on different curing periods that is 7,14 and 28 days. From this it can be found that strength increases up to 20% of the binder content and thereafter it decreases.

Mahesh et al. (2016) Soil stabilization is used to reduce the permeability and compressibility of the soil mass in earth structures and to increase its shear strength. Soil stabilization is required to increase the bearing capacity of foundation soils. However, the main use of stabilization is to improve the natural soils for the construction of highways and airfields. CBR value is high at 10% lime + 1.5% fiber when compared to the remaining proportions. CBR value for (soil +10% lime) and (soil + 40% lime) is same. CBR gradually increases with increase in fibers upto 2% (soil + 5% lime).

Wang et al. (2016) The Unconfined Compression Strength of expansive soil is very less without the addition of certain additives which can increase their strength. CKD was chosen to add in various proportions. 2, 4, 6, 8, 10, 12, 14, 16, 18, 20% of CKD was the proposed quantity. The UCS value rises till 10% CKD content after that when CKD quantity is further increased, the value of UCS started to decline gradually. Which concluded that 10% is the optimum value of CKD at the curing period of 28 days?

Tiwari et al. (2016) They studied the stabilization of black cotton soil using fly ash and nylon fibre. In their study, they used different combinations of fly ash as 10%,20%, 30% & 40%. 20% was their optimum value. After which they calculated the optimum value of nylon fibre from various values as0.25%, 0.50%, 0.75%, 1%, 1.5%. From which 0.75% nylon fibre comes to be the optimum. The CBR value of soil+20% fly ash+0.75% fibre was maximum of all other readings. And the MDD was also maximum of this mix proportion.

Alaa M. Rashad et al., (2015) Recycling of waste material is one of the successful solutions of its removal problem. Fly ash (FA) and Phosphogypsum (PG) required large disposal area and generate serious environmental contamination like leaching and dusting. It is important to make use of these wastes as building materials to put away the environmental from degradation. In this paper, the chance of recycling calcined PG (CPG) as a partial substitution of FA in alkali-activated FA (AAFA) paste was considered. FA was partially changed with CPG at point of 0%, 5%, 10% and 15%, by weight. Compressive strength at ages of 3, 7 and 28 days was calculated. The performance of the investigated mixtures after being exposed to 400, 600, 800 and 1000 °C for 2 h was classify by measuring the residual compressive strength.

Babita Singh and Ravi Kumar (2014) had blended the locally available clayey soil with sand, fly ash, tile waste and jute fibers. The mix clay : sand : fly ash : tile waste : jute fiber 63:27:10:9:0.5 was selected as the most appropriate and optimum clay, sand, fly ash, tile waste mix proportion. The maximum dry density of clay-sand-fly ash mix decreases as the content of fly ash is increases while optimum moisture content increases as fly ash content increases. When tile waste was added to the selected appropriate clay-sand-fly ash mix, the maximum dry density increased up to a certain percentage of tile waste and then decreased. On the inclusion of jute fiber in the optimum clay-sand-fly ash-tile waste mix, the maximum dry density increased slightly and then decreased with increasing jute fiber content. Optimum moisture content was not much affected by inclusion of jute fibers. Soaked and unsoaked CBR values improved considerably for the optimum mixes in comparison to that of locally available clayey soil. The value of failure stress obtained for the final composite mix of clay-sand-fly ash-tile waste-jute fiber was not appreciably more than that of the pure clay, but considerable strain absorption capacity can be observed for this final composite mix. The final optimum mix obtained was an improved construction material and when used in the construction of flexible pavement imparts considerable cost saving.

RESEARCH GAP

According to the examination of the literature, ceramic dust and cement kiln dust both have been used individually to modify soil properties, but their combined effective use has not been received attention .So combined effect of both the material have been investigate to know about the change in property of soil.

3. MATERIALS AND METHODOLOGY

3.1 Material used

1. SOIL
2. CERAMIC DUST

3. CEMENT KILN DUST

3.1.1 Soil

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

S.No.	Properties	Result
1.	**Liquid limit (%)**	40
2.	**Plastic limit (%)**	26
3.	**Plasticity Index (%)**	14
4.	**Specific Gravity**	2.62
5.	**Maximum Dry Density (KN/m³)**	15.18
6.	**Optimum Moisture Content (%)**	13.28
7.	**Soil Classification**	CI (Intermediate Compressive Clay)
8.	**CBR (%) (soaked)**	2.8
9.	**CBR (%) (Unsoaked)**	4.6
10.	**UCS (kN/m²)**	168

Table 3.1.1 Properties of soil used in study

3.1.2 Ceramic Dust and Cement Kiln Dust

Chemical Propertiesof CKD and CD

CKDhavedifferentphysicalandchemicalproperties and it depends upon the source, typeof raw materials used, type of plant operation,fuel type used and disposal practices.Table 2 shows the chemical properties of CKDandCD.GenerallyCKDisgrayishincolor.

Table 3.1.2 Chemical composition of cement kiln dust and ceramic dust

CONTENT	CKD(%)	CD(%)
Silicondioxide(SiO_2)	17.62	68.58
AluminumOxide(Al_2O_3)	4.90	27.45
IronOxide(Fe_2O_3)	2.58	0.47
CalciumOxide (CaO)	62.09	0.17
Magnesium Oxide(MgO)	1.93	0.16
PotassiumOxide(K_2O)	3.76	1.84
SodiumOxide(Na_2O)	0.56	0.32
SulphurOxide(SO_3)	5.79	0.13
Titaniumoxide(TiO_2)	-	0.75

Characteristicsof CD

CDconsistsofhighSiO_2,Al_2O_3 andFe_2O_3contentsreachingupto96%,buttheamountofFe_2O_3andTiO_2is1.22%.TheCDcollected from Jammu. Because of high silica content present inCD,the bindingcapacityofsoil is increased.

The objectives of the research work are:

1. To determine Atterberg's limit of the virgin soil and the different proportions of mix.

2. To carry out Standard Proctor test and find out Maximum Dry Density (MDD) & Optimum Moisture Content (OMC) of virgin soil and the different proportions of mix.

3. To find out California bearing ratio values at different proportions of Ceramic Dust and Cement Kiln Dust mix with clayey soil.

4. To find out Unconfined Compresssion strength test values at Different proportions of Ceramic Dust and Cement Kiln Dust mix with clayey soil.

3.2 METHODOLOGY

The present project can serve as an effective method to utilize industrial wastes Ceramic Dust and Cement Kiln Dust in the construction of low cost rural roads and stabilize the subgrade of pavements where the soil is expansive in nature. These various tests needs to be carried out on samples selected for study

1. Liquid Limit test and plastic limit test needed to be performed with the help of Cassegrande's Apparatus first on virgin soil and then the various proportions of the mix. The Plasticity Index of the Optimum Mix should be always less than that of virgin soil.

2. Standard Proctor Test is carried out to calculate Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of virgin soil which is then compared to

MDD of mix proportions. The MDD of the optimum mix should always be higher than pure soil.

CS:CKD	MDD (kN/m³)	OMC (%)
100:00	15.18	13.28
95:05	16.42	12.76
90:10	17.15	12.42
85:15	17.82	11.83

3. California bearing ratio test is conducted to calculate CBR Values at different proportions with material.

4. Unconfined compression strength test is conducted to calculate UCS Values at different proportions with material.

CS:CD:CKD	MDD (kN/m³)	OMC (%)
100:0:0	15.18	13.28
91:04:5	16.92	12.67
88.5:04:7.5	17.76	12.03
86:04:10	18.43	11.47

CS:CD	MDD (kN/m³)	OMC (%)
100:0	15.18	13.28
98:02	16.10	12.86
96:04	16.78	12.32
94:06	16.33	12.76

4. RESULTS

Tests conducted in the laboratory for different objectives are as follows:

.Liquid Limit Test (Casagrande's method)
.Plastic Limite test (Thread method)
.Standard Proctor test (OMC and MDD)
.California Bearing Ratio test
.Unconfined Compression strength test

4.1 STANDARD PROCTOR TEST

4.1.1 Untreated Soil and Ceramic Dust Mix

Table 4.1.1 Results of OMC and MDD for Untreated soil and CD mix

Table no. 4.1.2 Results of OMC and MDD for mix proportions of Soil and CKD

4.1.3 CLAYEY SOIL-CERAMIC DUST AND CKD MIXES

Table 4.1.3 Results of OMC and MDD for mix

4.1.4Proportions of Soil, CD and CKD

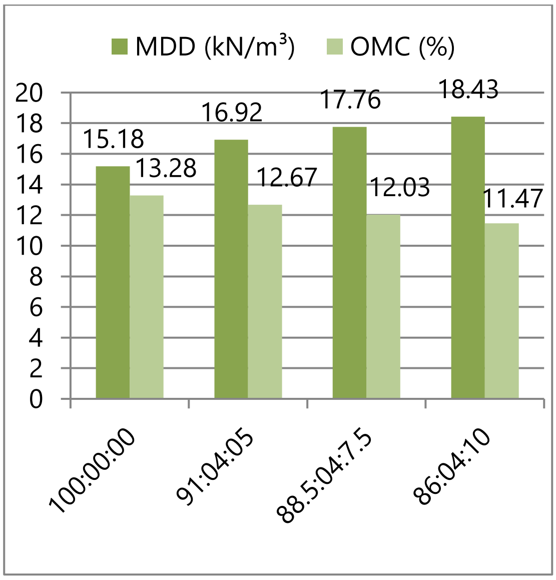


Fig 4.1.4 variations b/w MDD and OMC of Ceramic Dust, CKD & soil with different proportions

4.2 Unconfined Compression Strength Test

Table 4.2.2 Results of UCS Test of untreated soil

Clayey Soil	Curing Period (Days)	UCS (kN/m^2)
100 : 00	7	168

Table 4.2.2 Results of UCS of Ceramic Dust

CS:CD	Curing Period (Days)	UCS (kN/m^2)
100:0	7	168
98:02	7	238
96:04	7	315
94:06	7	249

Fig:-4.2.2 UCS Values of Clayey soil and Ceramic Dust

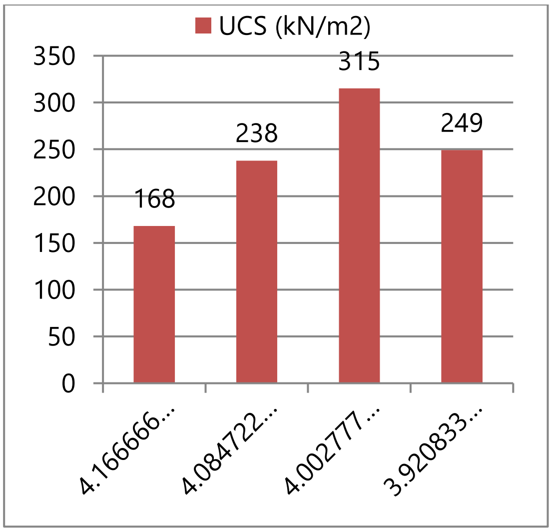


Table 4.2.3: Results of UCS of Cement Kiln Dust

CS:CKD	Curing Period (Days)	UCS (kN/m^2)
100:00	7	168
95:05	7	278
90:10	7	382
85:15	7	471

Fig 4.2.3 UCS Value of Clayey soil And Cement Kiln Dust

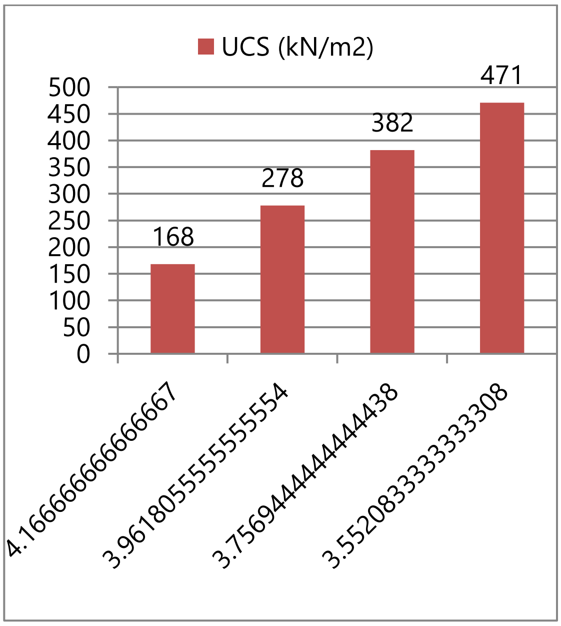


Table 4.2.4 Results of UCS of Ceramic Dust and CKD Mix with Soil

CS:CD:CKD	Curing Period (Days)	UCS (kN/m^2)
100:0:0	7	168
91:04:5	7	321
88.5:04:7.5	7	417
86:04:10	7	511

Fig4.2.4 UCS Value of Clayey soil of Ceramic Dust and CKD

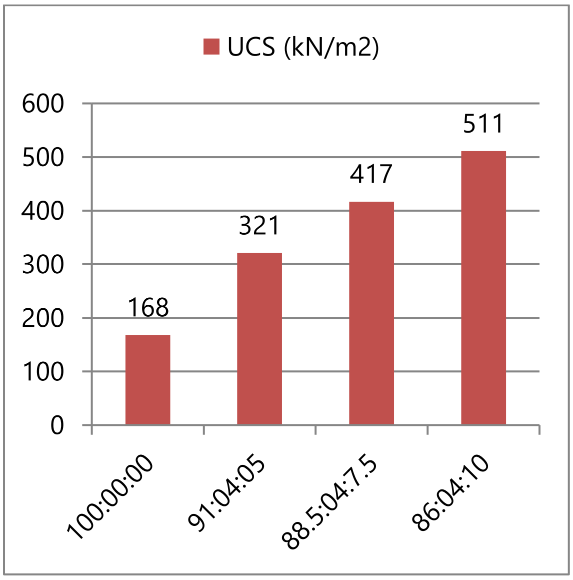
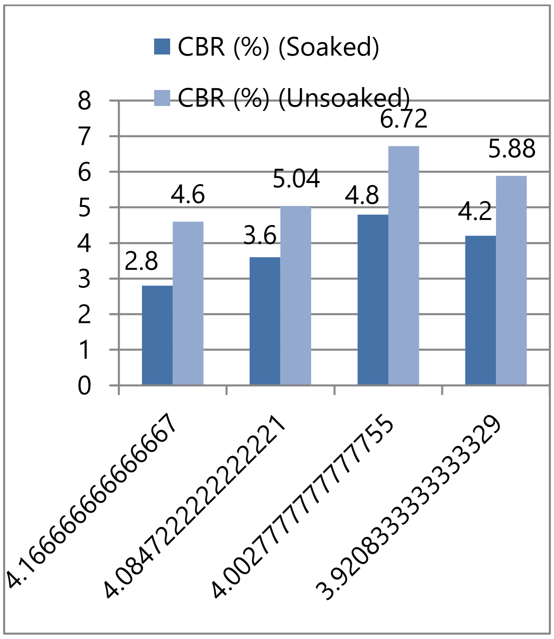


Fig 4.3.2 CBR Percentages of Clayey soil And Ceramic Dust



4.3 California Bearing Ratio Test

Table 4.3.1 Results of CBR value for untreated soil sample.

Clayey soil	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	2.8	4.6

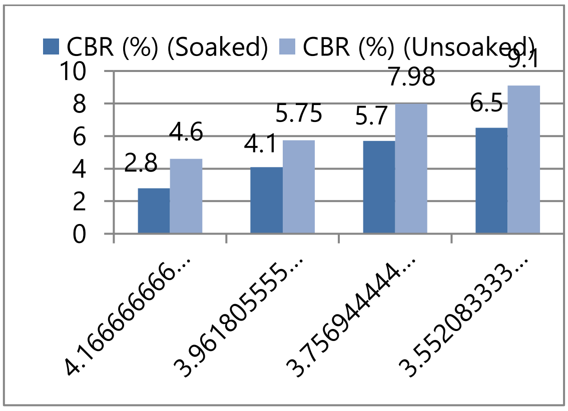
Table 4.3.2 Results of CBR of Ceramic Dust

Mix Proportions (CS:CD)	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:0	2.8	4.6
98:02	3.6	5.04
96:04	4.8	6.72
94:06	4.2	5.88

Table 4.3.3 Results of Soil and Cement Kiln Dust

Mix Proportions (CS:CKD)	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00	2.8	4.6
95:05	4.1	5.75
90:10	5.7	7.98
85:15	6.5	9.1

Fig 4.3.3 CBR Percentages of Clayey soil And Cement Kiln Dust

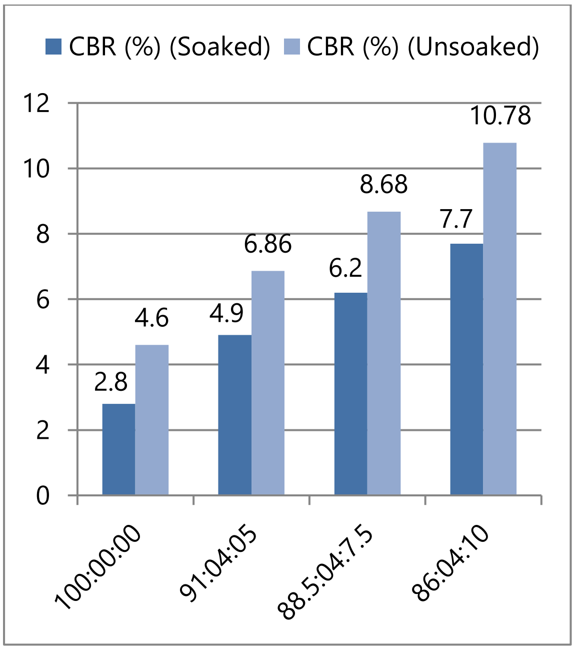


International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 09 | September - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

Table 4.3.4 Results of CBR of Ceramic Dust and CKD Mix with Soil

Mix Proportions (CS:CD:CKD)	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:0:0	2.8	4.6
91:04:5	4.9	6.86
88.5:04:7.5	6.2	8.68
86:04:10	7.7	10.78

Fig4.3.4 CBR Percentages of Clayey soil, Ceramic Dust and CKD



5. DISCUSSIONS

5.1 MODIFIED PROCTOR TEST:

- An decrease of OMC from 13.28 to 12.32% and increase of M.D.D. from 15.18 to 16.78 kN/m^3 when the percentages of Ceramic Dust are used as 2%, 4% and 6% respectively.
- There is an also decrease of OMC from 13.28 to11.83% and increase of MDD from 15.18 to 17.82 kN/m^3 when the percentages of CKD are used as 5%, 10% and 15% respectively.
- There is an also increase of MDD from 15.18 to 18.26 kN/m^3 and decrease of OMC from 12.67 to 11.47% when the percentages of Cement Kiln Dust vary from 5%, 7.5% and 10% and Ceramic Dust is fixed at 4%.
- With Ceramic Dust kept constant at 4% MDD increases with an addition of Cement Kiln 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+ Cement Kiln Dust mixes.

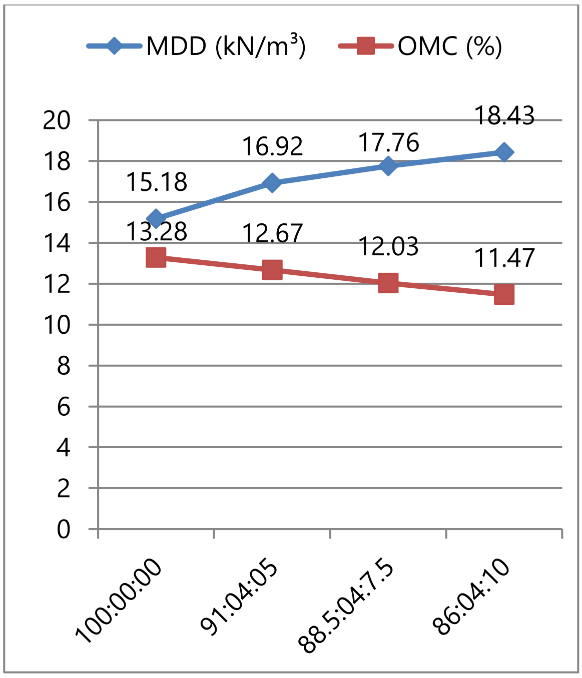


Fig 5.1 Variations b/w MDD and OMC values of Ceramic Dust mix with CKD

5.2 CBR TEST:

- The CBR value of untreated soil is 2.8 and it increases to 2.32 times with addition of 15% Cement Kiln Dust when observed in soaked conditions. This enhancement is because of binding action of Cement Kiln Dust.
- The CBR value of untreated soil is 2.8 and it increase to 2.75 times when Ceramic Dust 4% and Cement Kiln Dust 10% is added to untreated 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.

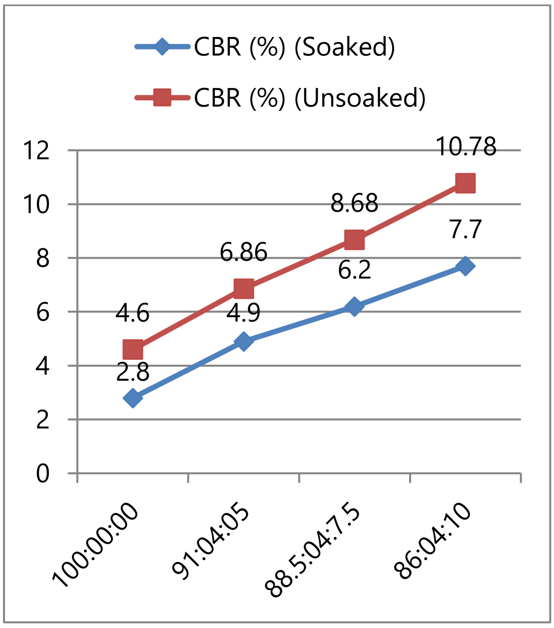


Fig 5.2 Variations b/w CBR Values of Ceramic Dust mix with CKD

5.3 UCS TEST:

- The UCS values of untreated soil also improve considerably with expansion of Ceramic Dust 4% and Cement Kiln Dust 10%. The value increases from 168 kN/m² to 511 kN/m² with addition of Ceramic Dust and Cement Kiln Dust.
- The reason behind of this when Ceramic Dust and Cement Kiln Dust comes in contact withwater, pozzolanic reactions takes place during the curing period.

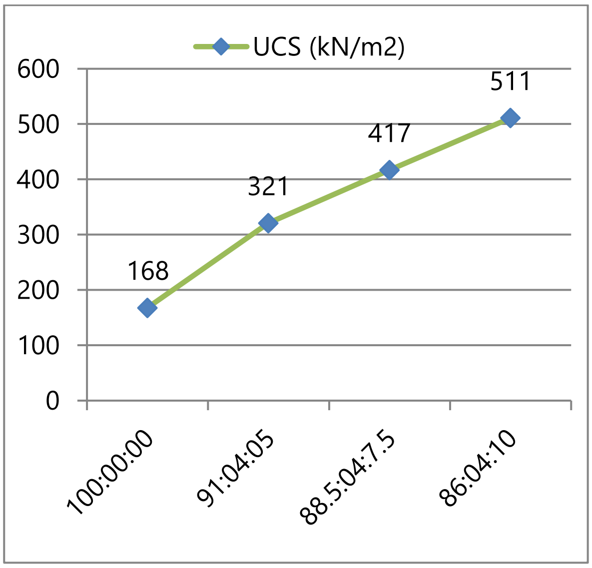


Fig 5.3 Variations b/w UCS Values of Ceramic Dust mix with CKD

CONCLUSIONS

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

1. From this study it is concluded that Cement Kiln Dust 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.
2. The optimum value of Ceramic dust is used for this work was 4% because of the optimum value of C.B.R. is found at 4% of Ceramic dust when added to soil.
3. The C.B.R value increases with increase of Cement Kiln Dust along with fixed quantity of Ceramic dust. It increased 2.75 times from the untreated soil.
4. The optimum value of Cement Kiln Dust and Ceramic dust required for soil stabilization is 10% and 4% by weight of soil respectively.
5. Unconfined compressive strength increases with increase of quantity of Cement Kiln Dust and Ceramic dust with fixed quantity of Ceramic dust. The value of unconfined compressive strength is increased 3.04 times from the untreated soil.

Addition of Cement Kiln Dust and Ceramic dust stabilizer makes the soil mixes durable, low cost and effective for soil improvement. If these two materials are easily available near to the site.

REFERENCES

1. HareshwarAshokrao Wadhonkar(2022), "StabilizationofExpansiveSoilUsingIndustrialandAgricultural Wastes". Print ISSN: 2395-1990 | Online ISSN: 2394-4099 IJSRSET.
2. Kavita Pawar, Ganesh Handibagh, Mayuri Dohitare (2022), "Influence of Steel Slag Addition on Strength Characteristics of Clayey Soil". International Journal for Research in Applied Science & Engineering Technology (IJRASET). ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538. Volume 10 Issue IV Apr 2022.
3. 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.
4. 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.
5. Anil kumar sharma, P.V. Sivallaiah (2016), "Ground granulated blast furnace slag amended fly ash as an expansive soil stabilizer". Soils and Foundations.
6. 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.
7. Bhattacharyya JK, Shekdar AV, Gaikwad SA, (2004), "Recyclability of some major industrial solid wastes", Journal of Indian Association for Environmental Management, 31, pp.71–75
8. Cyr M, Aubert JE, Husson B, Clastres P, (2004), "Recycling Waste in Cement Based Materials: a Studying Methodology" In: RILEM Proceedings of the Conference on the Use of Recycled Materials in Building and Structures, Barcelona, Spain, pp. 306-315
9. 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).
10. Faisal I Shalabi, Ibrahim M Asi (2017). "Effect of by product steel slag on the engineering properties of clayey soil". Journal of King Saud University – Engineering Sciences (2017) 29, 394–399, Elsevier.
11. Hanan Tayibi, Mohamed Choura, Fransico J. Alguacil, (2009), "Environmental impact and management of Phosphogypsum". Journal of Environmental Management.
12. Nurhayat Degirmenci, (2007), " The using of waste Phosphogypsum and natural gypsum in adobe stabilization". Construction and Building Materials
13. 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.
14. Shubham more, Apeksha Lokhande (2018) "Stabiliation of black cotton soil by using steel slag".IJIRSET,Volume 7, Issue 5.
15. Yun Huang, ZongShou, (2010), " Lin Investigation on Phosphogypsum–steel slag–granulated blast-furnace slag–limestone cement". Construction and Building Materials
16. Pallavi, Pradeep Tiwari, Dr P D Poorey(2016) "Stabilization of Black Cotton Soil using Fly Ash and Nylon Fibre". IRJET Volume: 03 Issue: 11 | Nov -2016
17. Indian Standard Code IS 2720-16, IS 2720-10.
18. AparnaJain,RakeshKumar.StudyOfSwelling Behaviour Of Black Cotton SoilImprovedWithSandColumn.IJAET.2014; 7(3):905–910p.
19. GandhiKS.StabilizationofExpansiveSoil of Surat Region using Rice Husk Ash&MarbleDust.IJCET.2013;3(4):1516–21p.
20. Kumar B, Puri N. Stabilization of weakpavementsubgradesusing Cementkilndust.IJCIET. 2013;4(1):26–37p.
21. Roy A. Soil Stabilization using Rice HuskAsh and Cement. IJCER. 2014; 5(1): 49-54p.
22. AmetaNK,WayalAS,HiranandaniP.Stabilization of Dune Sand with CeramicTileWasteasAdmixture.AJER.2013;2(9):133–39p.
23. IsmaielH.CementKilnDustChemicalStabilization of Expansive Soil Exposed atEl-KawtherQuarter,SohagRegion,Egypt.IJG.2013;4: 1416–24p.
24. Keerthi Y, Divya Kanthi P, Tejaswi N,etal.StabilizationofClayeySoilusingCement Kiln Waste. IJASGE. 2013; 7(1):77–82p.
25. RahmanMK,RehmanS,Al-AmoudiOSB. Literature Review on Cement KilnDustUsageinSoilandWasteStabilization and ExperimentalInvestigation.IJRRS. 2011; 7(1):77–87p.
26. SinghB,SharmaRK.EvaluationofGeotechnicalProperti esof LocalClayeySoil Blended with Waste Materials.JJCE.2014; 8(2):135–51p.