Improvement of Strength of soft Clay Soil by Using cement kiln dust, fly ash and Ceramic Dust waste (Times New Roman Bold 12)

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Abstract: Soft clay soils have relatively low strength and high compressibility. For this reason, the construction of the subgrade in soft clay soils has encountered many difficulties. Expensive solutions are utilized in some engineering projects, which usually involve removing and replacing soft soils. Instead, land improvement is currently the best solution to such problems. this paper aim to decrease the use of Portland cement and lime as the most common stabilizers utilized for soft soils, use recycled waste materials and demolition and construction waste as an alternative to stabilize soft clay soils at south of Iraq. was use waste materials such as fly ash (FA), cement kiln dust (CKD) and Marble dust wastes (MDW) to improve soft clay soils in south of Iraq. Some standard laboratory geotechnical tests were conducted to examine some changes in the engineering properties of treated soils with waste cement kiln dust (CKD), fly ash (FA) or ceramic dust waste (CDW) with proportions of (5%,10%,15%) by dry weight of soil. Laboratory tests performed on treated and untreated soil samples included standard compaction tests, Atterberg limits tests, and California Bearing Ratio (CBR) tests. The results showed that FA-soft clay soil samples and CKD-soft clay soil samples showed a decrease in liquid limits (LL%) and plasticity index (P.I%) and the increase in the plastic limits (P.L%) in addition to an increase in the maximum dry density (MMD) and a decrease in the optimum moisture content (OMC%) and an increase in the immersed and non-immersed (CBR) values. While the results of CDW-soft clay soil samples showed a decrease in liquid limits (L.L%), plastic limit (P.L%), the optimum moisture content (OMC%), plasticity index (P.I%) In addition to showed an increase in the maximum dry density (MDD) and an increase in the immersed and non-immersed CBR values. The data that emerged from the testing programs showed that (FA), (CKD) or (CDW) can be utilized to improve soft clay soil, but there is a certain percentage of using them in the improvement, as the best percentage of (FA) was at (10%) by dry weight of soil and the best percentage for (CKD) and (CDW) they were at (15%) by dry weight of soil, but (CKD) stabilizer show much more improvement than (CDW) and (FA), while (CDW) shows greater improvement compared to (FA). In general, these stabilizers can be utilized to improve the geotechnical properties of soil.

Keywords: Cement kiln dust Fly ash4 Ceramic dust waste.

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1. Introduction

Clay soil is a low-strength material that is greatly influenced by water, but it can be relatively solid when dry. When you apply water to clay, it becomes plastic or flows like a liquid (Zukri 2013). Due to the remarkable plasticity of clayey soils, soft clay can experience uncontrollable settling and loss of vital bearing capacity which are increasing moisture retention and induces lower pressure, volume changes, and loss of compressive power. Consequently, certain soils must be modified before they are utilized in construction (Salim, Al-Soudany, and Ahmed 2018). Frequently, project locations are in regions with soft or poor soils. Industrial and economic development have accelerated significantly in recent decades, resulting in an increase in people' quality of life and well-being. However, we should not forget that every manufacturing system generates by-products and waste materials that may have a negative impact on the environment [3]. Environmental concerns and new environmental laws have prompted building experts to enhance the performance of current materials by stabilizing them with additional additions. Waste materials generated by a variety of manufacturing processes may be utilized as additives [4]. Numerous recyclable materials are being utilized in civil engineering applications nowadays. Among the easily accessible waste materials are fly ash, waste ceramic dust, and dust of kiln cement. The cement industry for the one plant in Iraq produces about 2.4 tons per year and thus the production of fly ash and waste of cement kiln increases day after day (Nahla Naji Hilal 2010). Likewise, ceramic waste increases either from factories Ceramics or construction and demolition waste. In this paper, it was revealed that the cement kiln dust, ceramic waste, and fly ash can be utilized to improve the properties of clay soil.

Several researchers have utilized cement kiln dust to improve clay soil. The effect of adding different percentages of cement kiln dust on some properties of soft clay soil was studied. It was found through the test results that the plasticity index, liquid limit and soil activity decreased significantly with the increase in the percentage of cement kiln dust addition, while the plastic limit increased. The maximum dry density decreases and the optimum moisture content increases with the addition of cement kiln dust. It was also found that the observed improvement in the performance of the soil as a sub-layer of the highway with an increase in the percentage of (CKD) resulted from a decrease in the value of the plasticily index (Okafor and Egbe 2013).The suitability of (CKD) to stabilize clay soils was investigated. (CKD) was mixed in various quantities (7.5, 10, 12.5 and 15) percent with clay soils. For each category, various geotechnical tests were carried out. (CBR) test results showed mechanical progression of soil mixed with 10% (CKD) after a seven-day treatment cycle. Other measurements, showed that the geotechnical properties of stable soil improved as the amount of (CKD) by dry weight of clay soil increased (Bilal and Talib 2016).The results of an operational study of soil improved with a certain percentage of (CKD) indicate an increase in the (CKD) content increases the optimum moisture content (OMC) with a decrease in plasticity. 24% of (CKD) content was observed to further improve California bearing ratio (CBR)and unconfined compression strength (UCS) (Belal et al. 2019).The soil treated with (CKD) showed a decrease in plasticity in addition to settlement. On the other hand, an increase in soil cohesion, (CBR) and soil strength was observed. Therefore, clay soil treated with (CKD) shows a significant improvement in the engineering properties of the clay (Sharoubim, Elgendy, and Elsherify 2014). The chemical, mechanical and physical properties of samples composed of marble dust waste and soil were studied. The test results showed that the addition of marble dust increased the shear strength parameters and decreased the swelling potential of the clay samples examined. It was also found that because of the high calcium content, the waste marble played a significant role in the hydration process (Al-Bared et al. 2019). The treatment of soft clay soil with ceramic waste dust (CWD) demonstrated that the swelling potential and shrinkage limitations were increased with the addition of ceramics waste dust (CWD) in concentrations ranging from 10% to 20%, 30% to 60% by dry weight of the soil. This advancement demonstrates that the (CWD) may be utilized as a stabilizing material to mitigate the volume variations experienced by subgrade soils when utilized as foundation materials in a hydraulically constrained environment [10]. According to certain investigations, the increase in unconfined compressive strength of specimens treated with RCT is directly related to the rise in RCT content [11]. The effect of adding fly ash on the strength of cohesive soil was investigated. Due to the pozzolanic and cementitious characteristics of fly ash, its bearing capacity is increased when added to soil [12].It was found that when treating clay soil with the use of fly ash, there is a decrease in the liquid limit, the maximum dry density, and differential free swelling. Thus, the use of fly ash can act as a soil improver, but in certain proportions (Hymavathi, Navya, and Kumar 2018).fly ash (FA) class (C) and Lime kiln dust (LKD) efficacy were examined in stabilizing clay soils. Through the test results, discovered been the addition of (FA) Class C would increase the dry unit weight of the treated soil with (FA), increase the unconfined compressive power, and enhance the elasticity module, make the stability with (FA) Class C and (LKD) cost-effective for road base construction (Atherton 2015) .

2. Material Properties

2.1 Soft Clay Soil

The clayey soil samples utilized in this study were obtained from Al-Daghara village in the city of Diwaniyah, using the method of disturbed sampling. The soft clay soil was obtained by digging a depth (0.5 to 1) meter below ground level. The physical and chemical properties of clay soil are showed in table (1) Before adding the stabilizer. The geotechnical properties of clay soil showed that it is a soft clay soil because it has a liquid limit (L. L) and a plasticity index (P. I) of its value (48.4%) and (24.4%) respectively, and therefore it was classified as CL according to the American specifications ASTM 2487. The sample was dried in the oven at a temperature of 110 C within 24 hours and then grinded to be ready for use in the test.

Table. 1. Physical and Chemical Properties of Natural Soil Utilized.

Index property	Index Valve
liquid limit (L.L) %	48.5
plastic limit (P.L) %	24
plasticity index (P.I) %	24.5
specific gravity (G.S)	2.7
classification (USCS)	CL
calcium oxide (CaO) (%)	15.95
SO_3 content (%)	0.58

PH value (%)	8.4

2.2 Cement Kiln Dust (CKD)

Cement kiln dust utilized in this study was obtained from lavarge cement plant in Karbala. The oxides and acidic compositions present in (CKD) were evaluated by X-ray deflection test as showed in Table (2), where it was found that it has a CaO (65.89%) composition, which is the structure responsible for the exchange of ions between soil and (CKD). Cement kiln dust samples were obtained from the cement manufacturing plant in Karbala and kept in sealed bags.

Index property	Index value	Index property	Index value
SiO_2	8.276	SrO	0.029
Al_2O_3	6.211	V2O5	0.045
Fe_2O_3	6.458	ZrO2	0.011
CaO	65.69	CuO	0.015
K_2O	12.03	ZnO	0.005
TiO_2	0.242	NiO	0.039
SO_3	0.692	Y2O3	0.004
MnO	0.209	Ag2O	0.019

Table. 2. The Chemical Properties of Cement Kiln Dust (CKD).

2.3 Fly Ash

Fly ash utilized in this study was obtained from additive engineering materials sales offices in Baghdad. The oxides and acidic compositions present in (FA) were evaluated by X-ray deflection test as showed in table (3). where it was found that it has a SiO2 composition of about (41.267%), and thus this percentage leads to an increase in the strength of the treated soil.

Table. 3. The Chemical Properties of Fly Ash (FA).

Index property	Index value
SiO_2	41.267
Al_2O_3	53.368
Fe_2O_3	5.321
SO_3	0.044

2.4 Ceramic Dust Waste (CDW)

Ceramic dust waste utilized in this study was obtained from waste of the construction in Baghdad. It was crushed by using a special grinder and making its pellets pass through sieve No.40 to be ready for use. The ratios of oxides and acidic structures present in (CDW) were measured by X-ray deflection test as shown in the table (4). Where it was found that (CKD) possesses a SiO2 composition of about (45.43%) , CaO (3%) , and moderate percentages of alkalis such as K2O about (12.7%), and therefore these percentages lead to an increase in the acquired strength and a decrease in the percentages of water content of the treated soil.

3. The Purpose of This Research

- To investigate the geotechnical characteristics of soft clay soils utilizing cement kiln dust leftovers, fly ash, and ceramic dust wastes.

Index property	Index value	Index property	Index value
SiO_2	45.442	V2O5	0.032
Al_2O_3	31.218	SrO	0.025
K_2O	12.747	SnO2	0.022
Fe_2O_3	6.185	As2O3	0.015
CaO	3.391	Cr2O3	0.01
TiO_2	0.5267	Ag2O	0.009
MnO	0.128	CuO	0.009
ZnO	0.103	Rb2O	0.007
ZrO_2	0.091	Pbo	0.004
SO_3	0.045	Y2O3	0.004

Table. 4. The Chemical Properties of Ceramic Dust Waste (CDW).

- Determine the appropriate additive for treated soil.
- Study the properties of treated soils by studying the Atterberg limits test and the California bearing ratio test for non-immersed and immersed soil samples

4. Sample preparation and Laboratory tests

The sample preparation for the test set carried out in this study was planned according to the specifications listed in Table (5). The sample was dried in an oven at 110°C for 24 hours and then ground and sieved to be ready for use in testing. After that, the soil was mixed with various stabilizers and in specific proportions, then water was added according to the required quantity, and then it was mixed to obtain the appropriate model. A set of geotechnical tests were conducted to examine the natural soil and the treated soil. In the Atterberg boundary test, the soil was sieved through sieve No.40 to be utilized and then the boundary was determined after placing the samples for 24 hours in the drying oven. Through the standard proctor compaction test the relationship between moisture and dry density was drawn until reaching the maximum dry density (MDD) and the optimum moisture content (OMC) for normal and treated soils. California bearing ratio test (CBR) was carried out for non-immersed samples and samples immersed for 4 days.

Table. 5. Specifications Approved for The Tests.

Test	Test Standard
Atterberg limits	ASTM D4318
Specific gravity (G.S)	ASTM D854
Proctor compaction (MDD and OMC)	ASTM D698
California bearing ratio (CBR)	ASTM D1883

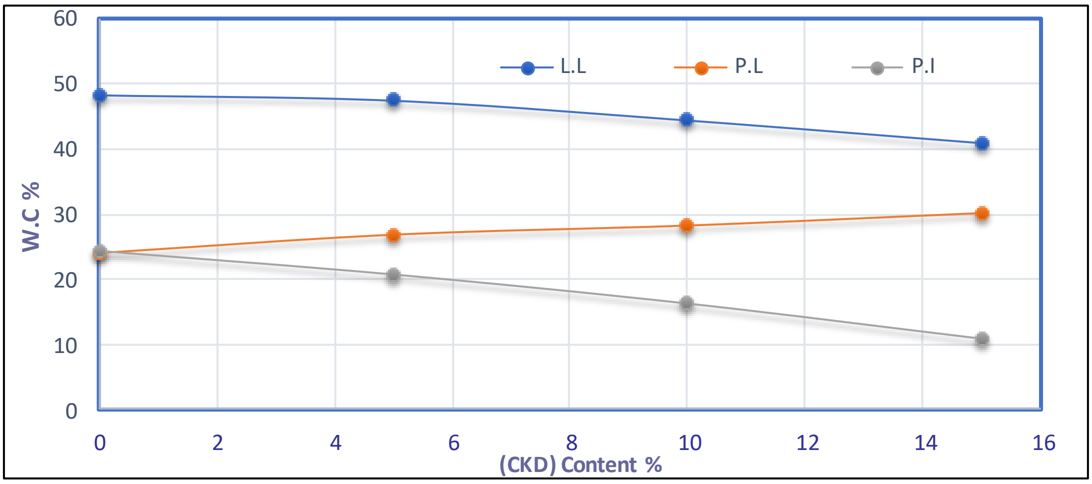
5. Results and Discussions

5.1. Effect on Atterberg Limits

This test was performed for natural soils and treated soils according to the standard specifications ASTM D4318 with different proportions of fly ash (FA) or ceramic dust waste (CDW) or cement kiln dust (CKD), to assess the values of liquidity limit (L.L) plastic limit (P.L), plasticity index (P.I) and to determine the appropriate additive and appropriate addition ratio. Soft clay soil was mixed with (5%, 10%, 15% by dry soil weight) fly ash (FA) or ceramic dust waste (CDW), or cement kiln dust (CKD).

5.1.1. Cement Kiln Dust (CKD)

The results of the Atterberg limits for soils and soils treated with cement kiln dust (CKD) are shown in Figure (1) and table (6). With increasing (CKD) content to clay soils. Both the liquid limit (L.L) and the plasticity index (P.I) decreased and the plastic limit (P.L) increased compared to the natural soil. This decrease and increase occurred due to the cation exchange reaction, which leads to an increase in the attract ability and thus the sintering of the molecules (El-aziz and Abo-hashema 2018) (Muthumari, Ali, and Raja 2020).



Adding (CKD)%	Liquid limit (L.L), %	Plastic limit (P.L), %	Plasticity index (P.I), %
0	48.4	24	24.4
5	47.55	26.8	20.75
10	44.45	28.2	16.25
15	40.9	30.1	10.8

Figure 1: The Effect of adding (CKD) on atterberg limits of soft clay soil.

Table. 6. The effect of adding (CKD) on L.L, P.L and P.I of soft clayey soil.

5.1.2. Fly Ash (FA)

The results of the Atterberg limits for soils and soils treated with fly ash (FA) are shown in Figure (2) and table (7). With increasing (FA) content to clay soils. Both the liquid limit (L.L) and the plasticity index (P.I) decreased and the plastic limit (P.L) increased compared to the natural soil. Addition of fly ash (FA) to soft clay soils may increase the plastic limit (P.L) of treated soils due to the possibility of incorporating fine particles of fly ash (FA) into the vacuums of the sintered soil and thus the percentage of water in the pores decreases and the plastic limit (P.L) decreases (Islam et al. 2018).

%Add FA	Liquid limit (L.L), %	Plastic limit (P.L), %	Plasticity index (P.I), %
0	48.4	24	24.4
5	46.3	25.1	21.2
10	42.99	26.3	16.69

15	39.2	27.21	11.99

Table. 7. The Effect of Adding (FA) on L.L, P.L and P.I of Soft Clayey Soil.

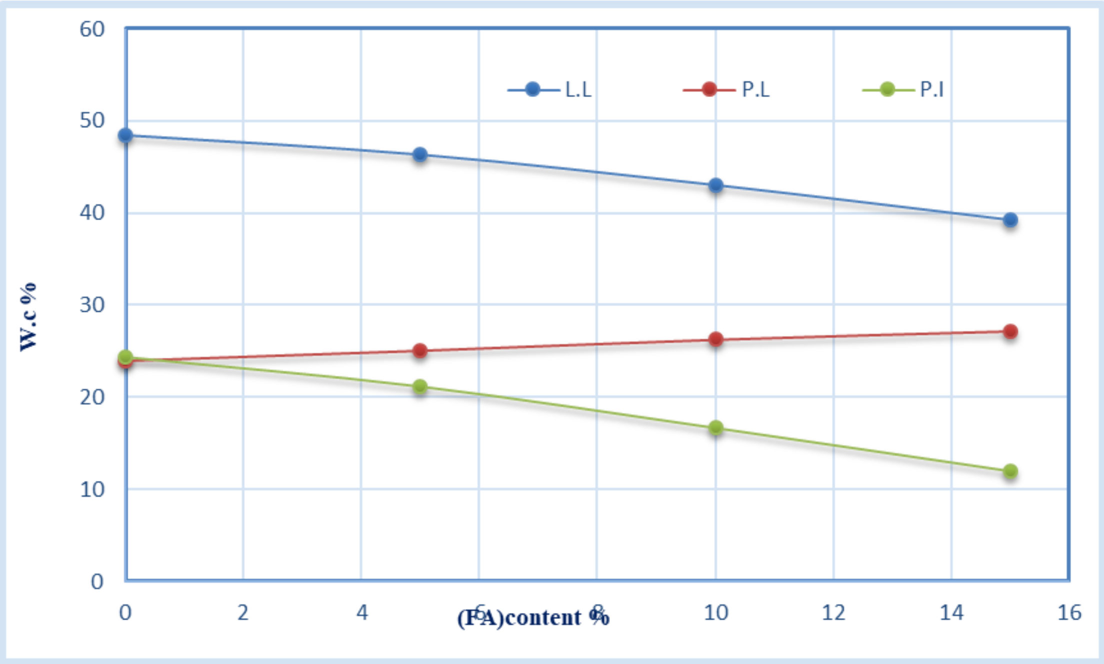


Figure. 2. The Effect of Adding (FA) on Atterberg Limits of Soft Clayey Soil.

5.1.3. Ceramic Dust Waste (CDW)

The results of the Atterberg limits for soils and soils treated with ceramic dust waste (CDW) are shown in Figure (3) and table (8). The

Table. 8. The Effect of Adding (CDW) on L.L, P.L and P.I of Soft Clayey Soil.

ADD of CDW %	Liquid limit (L.L), %	Plastic limit (P.L), %	Plasticity index (P.I), %
0	48.4	24	24.4
5	46.2	23.11	23.09
10	42.6	21.55	21.05
15	38.11	20.09	18.02

liquid limit (L.L), the plastic limit (P.L) and the plasticity index (P.I) decreased with The increase in the content of ceramic dust waste (CDW) is due to the decrease of the Atterberg limits due to the pozzolanic reaction and the flocculation process that takes place between soft clay soil and water and ceramic dust waste (CDW) (Abduljabbar and Dalya 2021) (Sabat 2012).

5.2. Effect on the standard proctor Compaction Test

Compaction tests were conducted on natural soil samples and soil treated with various amounts of fly ash (FA), cement kiln dust (CKD), and ceramic dust waste (CDW) at concentrations of 5%, 10%, and 15% of the dry soil weight, respectively. For this kind of soil treatment, mixing the soil with the proper composition is a difficult procedure that is also critical for achieving the greatest performance at the lowest cost [12].

5.2.1. Cement Kiln Dust (CKD)

The maximum dry density ratios (MDD) and optimal moisture contents (OMC) of natural and treated soil by cement kiln dust (CKD) are shown in figures (4), (5), and table (9). The optimum moisture content (OMC) dropped when the cement kiln dust (CKD) was added to the soft clay soil, but the maximum dry density (MDD) rose. The optimal moisture content (OMC) dropped as the surface area of the compound particles grew, whereas the maximum dry density (MDD) rose as the texture of the treated soil transitioned from plastic to non-plastic [16].

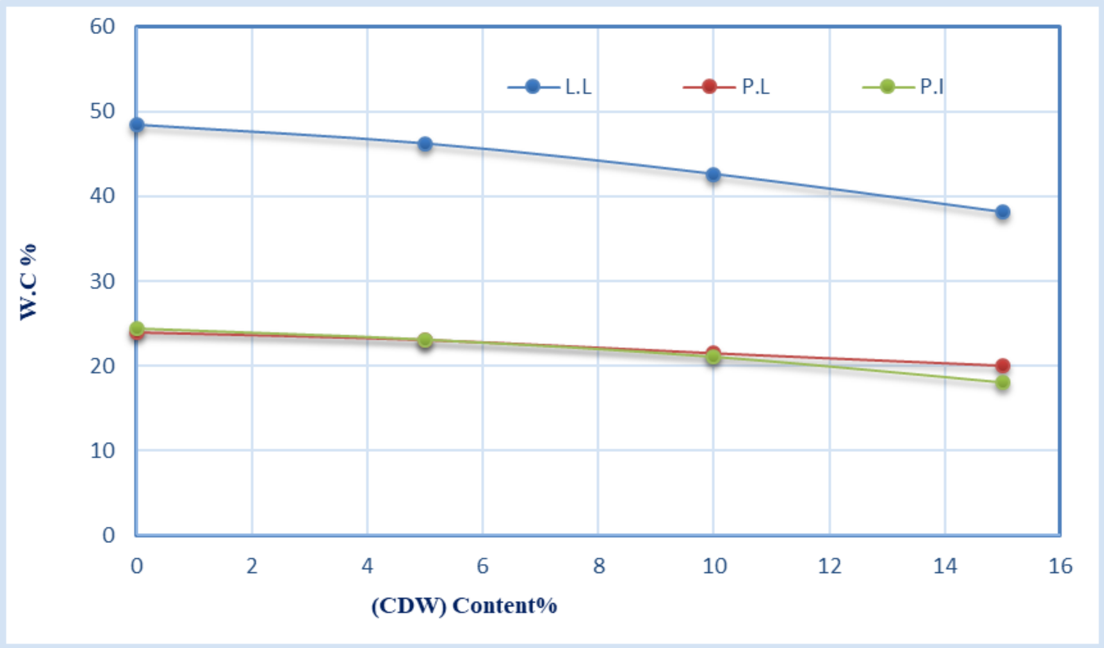


Figure. 3. The Effect of Adding (CDW) on Atterberg Limits of Soft Clayey Soil.

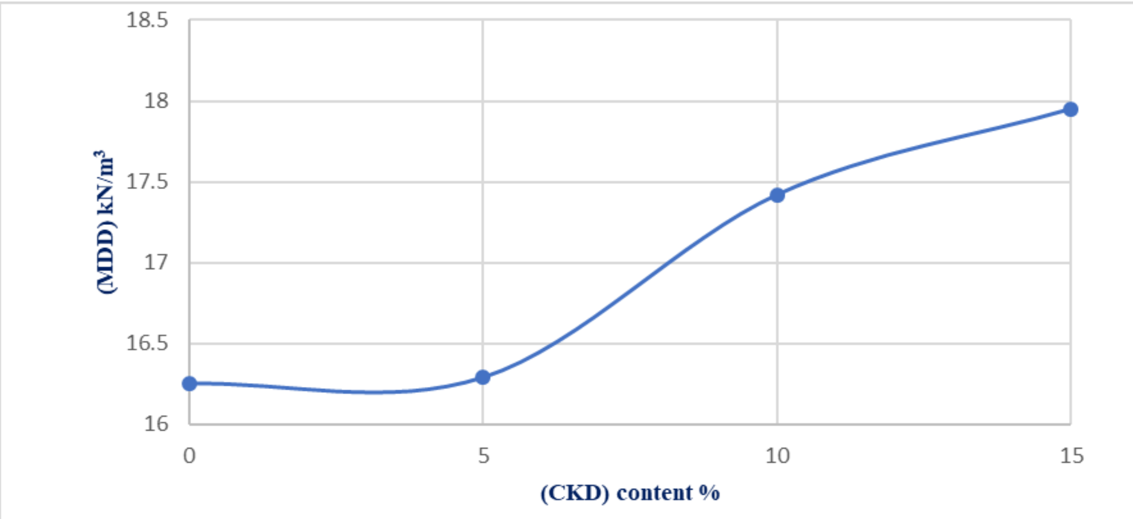


Figure. 4. The Effect of Adding Different Percentages of (CKD) on The Maximum Dry Density.

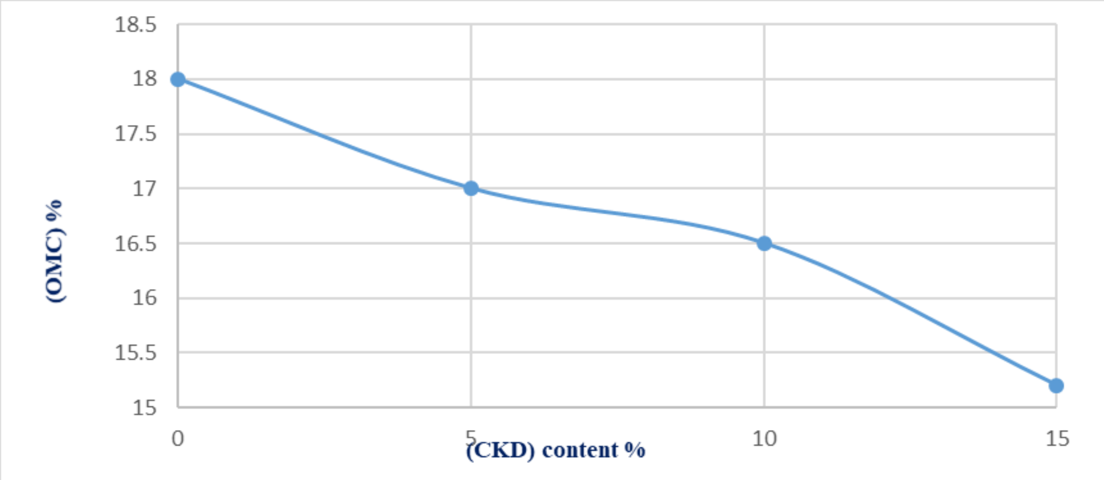


Figure. 5. The Effect of Adding (CKD) on The Optimum Moisture Content.

Table. 9. The Effect of Adding Different Percentages of (CKD) on The Maximum Dry Density and The Optimum Moisture Content.

CKD%	MDD (KN/m3)	OMC (%)
0	16.25	18
5	16.29	17
10	17.42	16.5
15	17.95	15

5.2.2. Fly Ash (FA)

Figure (6) and table (10) illustrate the difference in the maximum dry density (MDD) ratios of natural and treated soils. Maximum dry density (MDD) values rise as fly ash (FA) content increases in this kind of soil, but drop after fly ash content reaches 15%.The figure (7) and table (10) illustrate the difference in the proportions of optimal moisture content (OMC) for natural and treated soils. The proportions of the optimal moisture content (OMC) drop as the fly ash concentration increases (FA).The reason for the increase in the maximum dry density (MDD) and the decrease in the optimum moisture content (OMC) of the treated soil is due to the effectiveness of this type of fly ash (FA) related to the amount of it containing SiO_2 and CaO (Bhutia5 2016) (Edil, Acosta, and Benson 2006).

Table. 10. The Effect of Adding Different Percentages of (FA) on The Maximum Dry Density and The Optimum Moisture Content

FA %	MDD (kN/m3)	OMC%
0	16.25	18
5	16.4	17
10	16.6	16.6
15	16.5	16

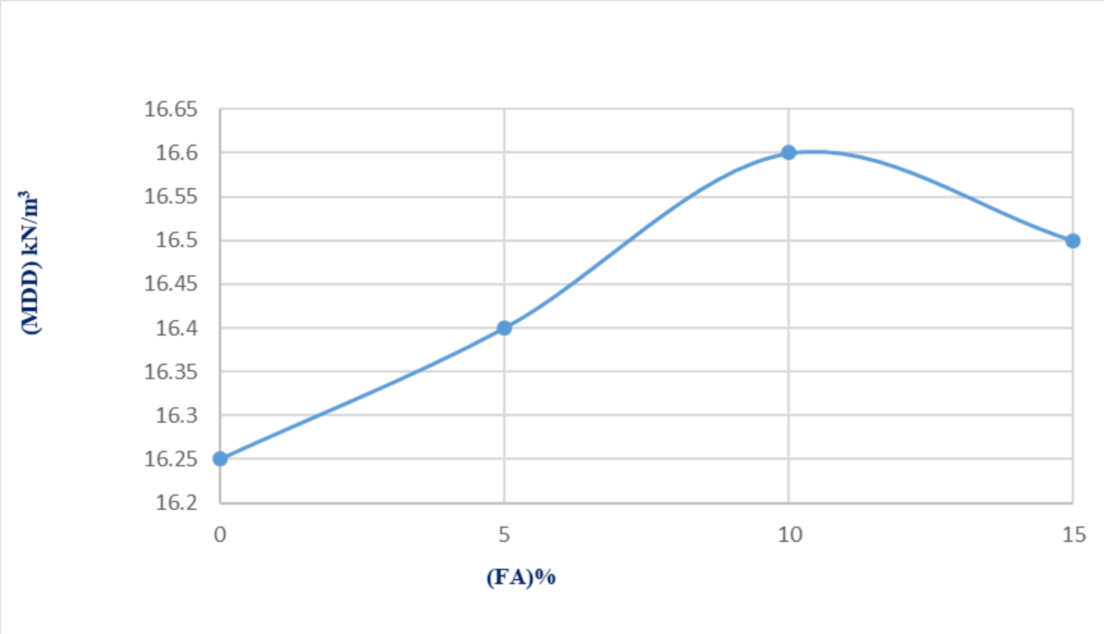


Figure. 6. The Effect of Adding Different Percentages of (FA) on The Maximum Dry Density.

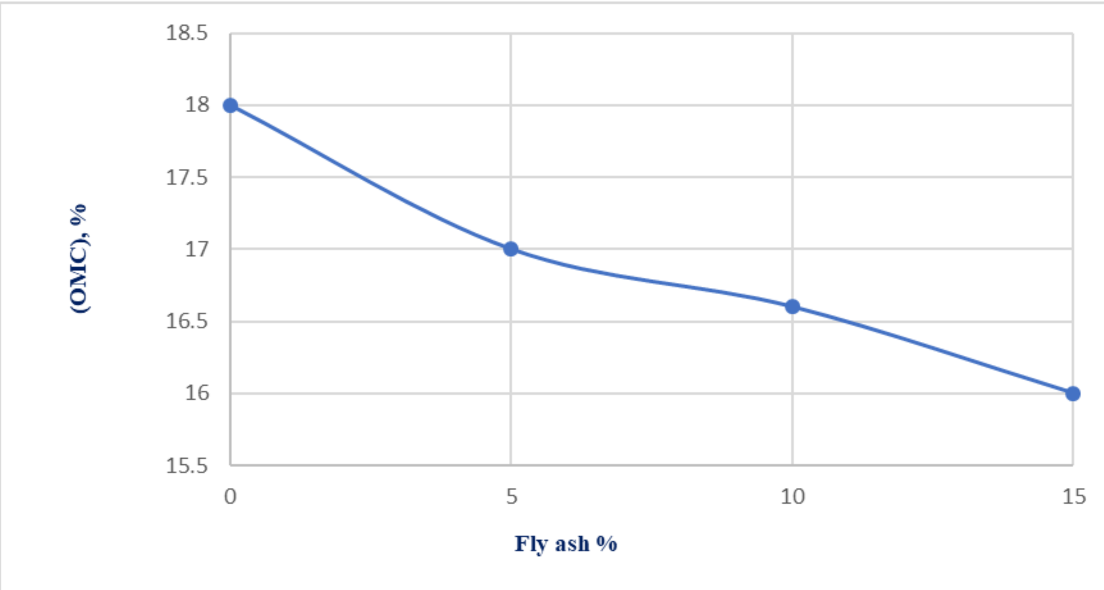


Figure. 7. Effect of Adding (FA) on The Optimum Moisture Content.

5.2.3. Ceramic Dust Waste (CDW)

Figure (8) and table (11) illustrate the difference in the maximum dry density ratios of natural and treated soils . The values of the maximum dry density in this kind of soil rise as the amount of ceramic dust waste increases (CDW). The figure (9) and table (11) illustrate the difference in the proportions of optimal moisture content (OMC) for natural and treated soils. The proportions of the optimal moisture content (OMC) decrease as the ceramic dust waste (CDW) content increases. The reason for the increase in maximum dry density (MDD) and decrease in optimum moisture content (OMC) is that the ceramic dust particles have been replaced by soft clay soil particles, reducing the attractiveness of the water particles and resulting in a decrease in the optimum moisture content (OMC) [16] [21].

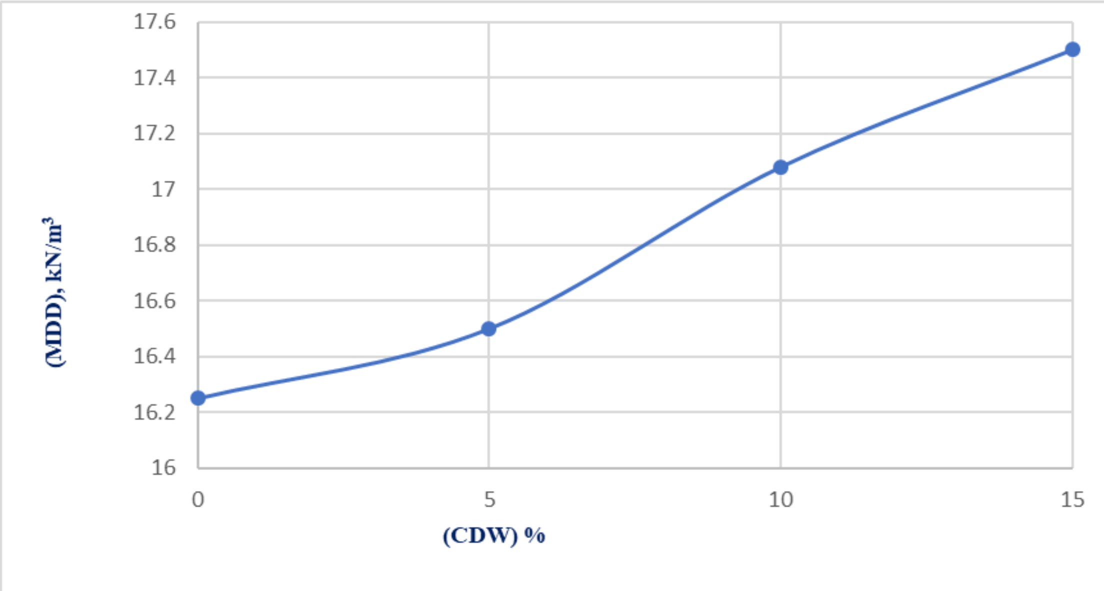


Figure. 8. The Effect of Adding Different Percentages of (CDW) on The Maximum Dry Density

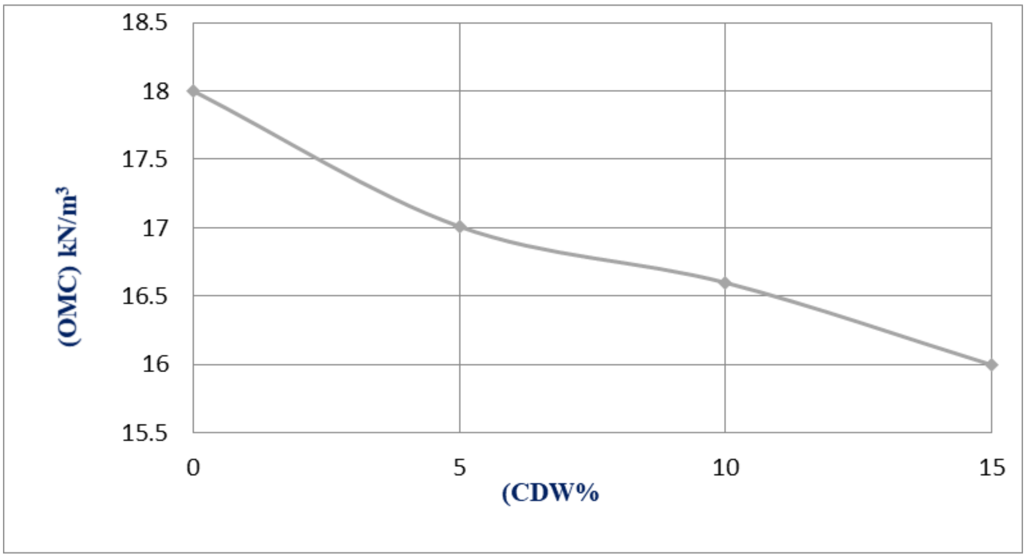


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Figure.9: Effect of Adding (CDW) on The Optimum Moisture Content

Table. 11. The Effect of Adding Different Percentages of (CDW) on The Maximum Dry Density and The Optimum Moisture Content.

(CDW), %	(MDD), kN/m3	(OMC), %
0	**16.26**	**17.1**
5	**16.5**	**17.01**
10	**17.08**	**16.6**
15	**17.5**	**16.0**

5.3. Effect on the California Bearing Ratio (CBR) Test

The California bearing ratio (CBR) test is a marker of soil resilience and strength. It is possible to use soft clay soil under road sidewalks, and because of the ability of this weak layer, it leads to an increase in the thickness of the pavement and thus leads to an increase in the construction cost (Salim et al. 2018). (CBR) tests was carried out on natural soil samples and treated soil with different proportions of fly ash (FA), cement kiln dust (CKD) and ceramic dust waste (CDW) separately with proportions (5%, 10%, 15%) of the dry soil weight.

5.3.1. Cement Kiln Dust (CKD)

The relationship between (CKD) content and (CBR) ratios for natural soil samples and non-immersed treated soil samples are shown in figure (10). Through the test results, there is an increase in the (CBR) values with the increase of the (CKD) content ratios. It increased from (14.2%) to (31.9%) when the (CKD) content from 0 to (15%), respectively as in table (12). The increase in (CBR) may be caused d by cement compounds that are gradually formed in treated soils through the interaction that takes place between (CKD) and CaOH in the soil (Okafor and Egbe 2013) (Mosa, Taher, and Al-Jaberi 2017). Immersed (CBR) behavior was similar to non-immersed (CBR), but there were fewer values for drenched immersed (CBR) as in figure (10) and table (12) where the value of immersed (CBR) increased from (3.8%) to (24.7%).

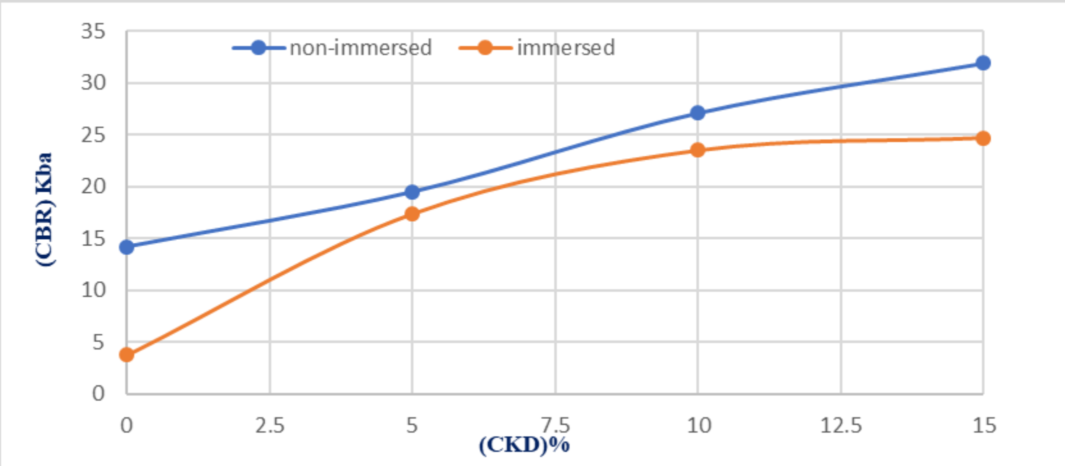

Figure. 10. The Effect of Addition of Different Percentages of (CKD) on (CBR).

Table. 12. The Effect of Addition of (CKD) on (CBR) value.

(CKD)%	CBR% (non-immersed)	CBR% (immersed)
0	14.2	3.8
5	19.5	17.4
10	27.1	23.5
15	31.9	24.7

5.3.2. Fly Ash (FA)

The relationship between fly ash (FA) content and the non-immersed (CBR) test values of normal soil samples and soil mixed with fly ash (FA) are shown in figure (11). Through the test results, there is an increase in non-immersed (CBR) values with the increase in the percentages of (FA) content. It increased from (14.2%) to (17.2%) when the (FA) content from (0) to (15%), respectively as in table (13). Perhaps the reason for the increase in non-immersed (CBR) is the effectiveness of this type of fly ash (FA) associated with the amount of CaO and SiO2 it contains.The behavior of immersed (CBR) was different from that of non-immersed (CBR) because there were lower values for the increase of immersed (CBR), where the value of immersed (CBR) increased from 3.8% to 4.16%, respectively as in table (13) and figure (11). The small increase in immersed (CBR) values is due to the natural soil containing a large percentage of water content and to the fact that this type of fly ash (FA) contains a small percentage of CaO (Trivedi, Nair, and Iyyunni 2013).

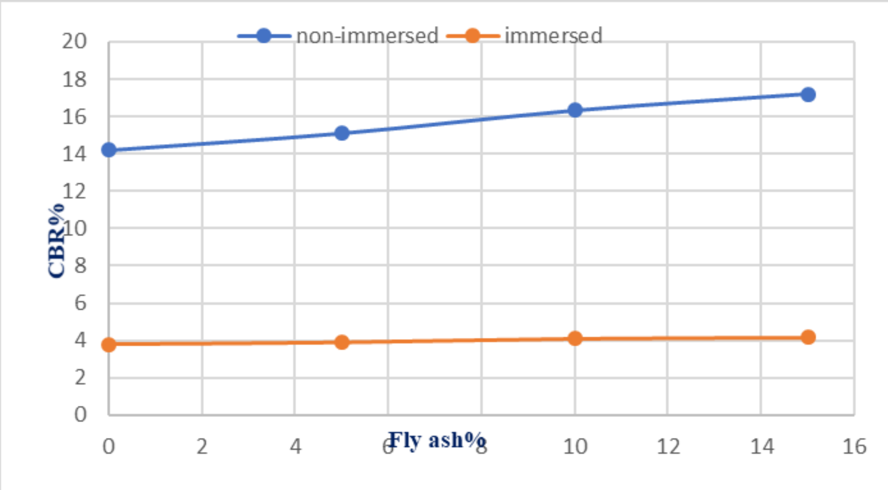

Figure. 11. The Effect of Addition of (FA) on (CBR) value.

Table. 13. The Effect of Addition of (FA) on (CBR).

Fly ash %	CBR% (non-immersed)	CBR% (immersed)
0	14.2	3.8
5	15.1	3.9
10	16.32	4.1
15	17.2	4.16

5.3.3. Ceramic dust waste (CDW)

The relationship between (CDW) content and non-immersed (CBR) test values for natural soil samples and soil mixed with specific percentages of (CDW) are shown in figure (12). Through the test results, there is an increase in non-immersed (CBR) values with an increase in (CDW) content percentages. It increased from (14.2%) to (20.1%) when (CDW) content ranged from 0 to (15%), respectively as in table (14). The increase in non-immersed (CBR) values for soils mixed with (CDW) may be due to the release of a sufficient amount of calcium needed to form calcium silicate compounds CS in addition to calcium aluminate CA compounds, which are one of the main compounds for strengthening. The behavior of (CBR) values for the immersed samples differs from that of the (CBR) values for the non-immersed samples. Despite the increase in immersed (CBR) values from (3.8%) to (5.6%), respectively as in table (14) and figure (12). This increase was small compared to the non-immersed samples. This increase can be explained by the fact that the coarse particles and the amount of lime present in the (CDW), which in turn acts as a cementitious substance. Alumina and amorphous silica present in natural soils, a pozzolanic reaction occurs between them and lime in (CDW), and this interaction is responsible for increasing immersed (CBR) values. For these reasons, there is a bond between clay soil particles and (CDW) but this correlation was relatively weak due to the high-water content of the natural soil, in addition to the percentage of water associated with immersed (CBR) test (Akhtar Hossain 2019) (Engineering 2020).

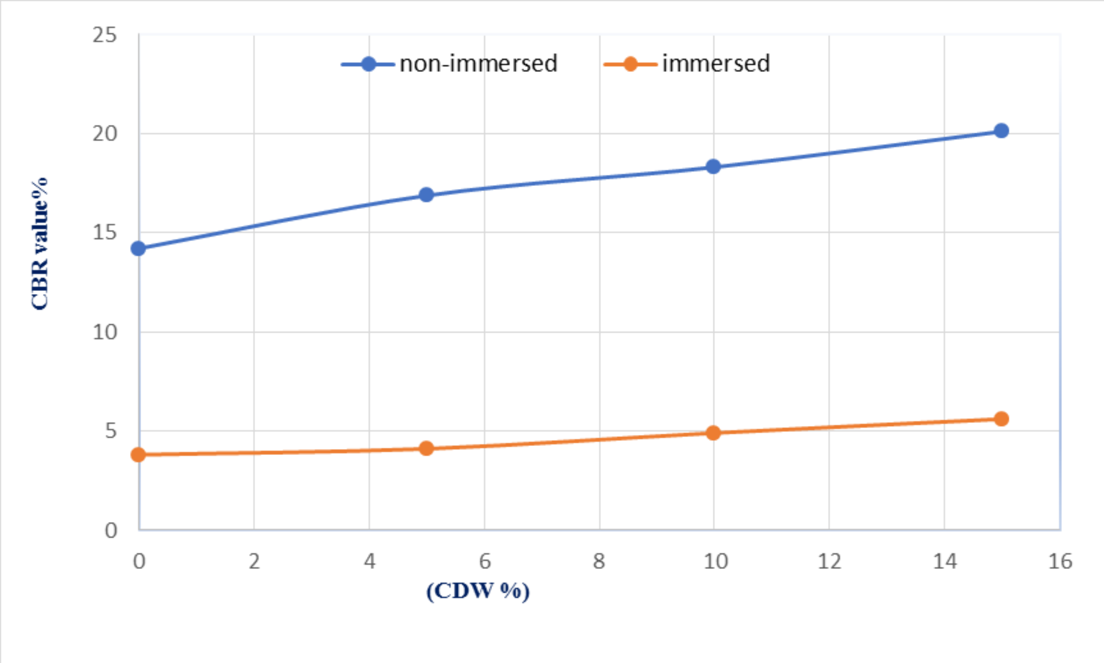

Figure. 12. Effect of Adding (CDW) on (CBR).

6. Conclusion

During the testing process, we found that the tests of Atterberg limits, proctor compaction and California bearing ratio (CBR) are very important for examining the properties of the soil to be built on. Some of the conclusions reached from this study are as follows:

1. Values of L.L and PI decreased with increasing the percentage of (CKD)

added, while the P.L increased with the same proportions increase of added (CKD).

2. As can be seen from the compaction curves, (MDD) increases as the percentage of cement kiln dust (CKD) applied increases. While (OMC) reduces as the percentage of cement kiln dust incorporated increases (CKD).

3. In the case of non-immersed and immersed samples, it can be observed that the value CBR increases when the percentage of cement kiln dust (CKD) increases.

4. When various percentages of fly ash (FA) are added, the liquid limits (L.L) and plasticity index (P.I) values decline and the plastic limit (P.L) rises. As (5%) fly ash (FA) is added, the highest decrease in liquid limit is approximately (39.2%) and in plasticity index (P.I) is approximately (11.99%).

Ceramic	**CBR% (non-immersed)**	**CBR% (immersed)**
0	14.2	3.8
5	16.87	4.1
10	18.3	4.9
15	20.1	5.6

Table. 14. Effect of Adding (CDW) on (CBR).

5. Under the compaction test. It is possible to detect a rise in the maximum dry density (MDD) when the volume of fly ash (FA) is increased to (10%) and then (MDD) decreased.

6. In (CBR) test, In the case of non-immersed samples, it can be noticed that the value of (CBR) increases when fly ash (FA) is added., as the value (CBR) for natural soil is about (14.2%), while the (CBR) value (15.1, 16.32 and 17.2)% when adding (5, 10 and15) % fly ash (FA). And in the case of immersed samples, it can be seen that

the value of (CBR) value slightly increases when the percentage of (FA) increased. The CBR value of stabilized soil equal to (3.9, 4.1 and 4.16)% when adding fly ash by (5, 10 and 15)% respectively.

7. A decline in the liquid limit (L.L), plastic limit (P.L), and plasticity index (P.I) values when adding ceramics dust waste (CDW) , and the maximum amount of decrease was (38 ,20.11 and 18)% respectively when the ceramic added about (15%.)

8. From compaction test, the maximum dry density (MDD) increased when ceramic dust waste (CDW) increased and the optimum moisture content (OMC) decrease with increase the percentage of ceramic dust waste (CDW).

9. In (CBR) test, In the case of non-immersed samples, it can be noticed that the value of (CBR) increases when ceramic dust waste (CDW) is added, as the value (CBR) for natural soil is about (14.2%), while the (CBR) values (16.8, 18.3 and 20.1)% for treated soils when the percentage of ceramic dust waste (CDW) (5, 10 and 15)% respectively.

In the case-immersed samples, it can be observed that the value (CBR) increases when the percentage of ceramic dust waste (CDW) increases. The (CBR) value of stabilized soil with (5, 10 and 15)% ceramic dust waste (CDW) equal to (4.1, 4.9 and 5.6)%.

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