Effect of cement dust on consolidation properties of expansive soil

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Abstract. The utilization of by-product wastes as stabilizer materials to problematic soils has become widely common. Such a situation considers as a solution to the negative effects of these materials on the environment, on one hand, and as an economic solution by recycling the wastes in soils' improvement techniques, on the other. The purpose of the present study is to explore the consolidation properties of Iraqi expansive soil with the addition of one selected by-product wastes materials from the local industry process. The cement dust has been selected as a stabilizer to explored expansive soil. The cement dust has been selected as a stabilizer to explored expansive soil. The cement dust is a waste of cement industry and its deposit is rarely recycled in the local Iraqi industry, and there are significant amounts of cement dust available as waste materials. Herein, the specimens were prepared by mixing the expansive soil with different content of cement dust (from 0% to 30%). An experimental series of consolidation tests were carried out to explore the effects of cement dust on consolidation properties experienced by expansive soil. Test results indicate that cement dust has considerably affected the consolidation properties of expansive soil. In particular, the swelling index (cs) was reduced for one-third of the value of cs of virgin soil.

1. Introduction
One of the widely encountered difficult soils in geotechnical engineering is expansive soil. The properties of expansive soil are undesirable especially under wetting and drying processes, it shrinks, cracks, curls, and expands [1-3]. Expansive soils are distributed in different regions all over the world. In Iraq, this soil can be encountered in large area in the north, south, and middle of Iraq such as Baghdad, Salah Al-Deen, Al-Najaf, Al-Anbar, Babylon [4-8].

In general, different methods are applied to stabilize difficult soils, some techniques used compaction methods, reinforcements, and prewetting. While other techniques used different additives like cement, lime, sand and adding river mixture soil, chemical additives, fly ash, quarry waste, silica fume, cement kiln dust, tire rubber, and rice husk [9-12]. Many of these methods are used to improve the geotechnical properties of expansive soils.

The cement dust is a waste of cement industry which deposit is rarely recycled in the local Iraqi industry. There are significant amounts of cement dust available as waste materials. Cement dust are used in different civil engineering fields. It is used in concrete technology as a partial replacement to ordinary cement. It is used in engineering materials production like building units, and in geotechnical engineering [13-14].
Hussein et al. [15] reviewed some of the researches deal with cement dust application in geotechnical engineering. They were found that the cement dust is used in stabilizing soils like montmorillonite clays [16], expansive clay [17], and black cotton clay [18]. They also mentioned that soil properties like plasticity index, maximum density, optimum water content, pH value, shear strength, and California bearing ratio are affected by the addition of cement dust. The note of these authors is the optimum content of cement dust is 16% [18]. According to Hussein et al. [15] the shear strength of clay mixed with cement dust mixtures is increased with the increasing of dust content up to specified value. These authors concluded cement dust is effective in improving the strength of the soil.

Al-Naje et al. [14] mentioned that waste materials like cement dust provide engineering and economic benefits through improving the geotechnical properties of soils. The soils that reviewed by these authors are sabkha soil [19], black clay subgrade [20], expansive soil [21], demolition aggregate [22], roads subbase material [23] (23 Mahdi et al. 2018), expansive soil [24-25], natural soils [26]. Mostly, these researches are focused on strength characteristics, microstructure, and swelling control of soils. According to these authors, the effect of waste materials on compaction characteristics, California bearing ratio, and unconfined compressive strength have been presented and discussed. The cement dust used widely in soil stabilization to improve soils like clay (with different plasticity), silt, and sand (with different fine contents). According to the literature review carried by Al-Baidhani and Al-Taie [27], the plasticity of montmorillonite clay and its bearing ratio, and compaction properties have been improved by cement dust as a stabilizer.

As can be seen, the previous studies focused on properties like Atterberg limits, compaction properties, chemical values, and bearing and strength of the soil stabilized with cement dust. Attention to consolidation properties of the soils is, almost, limited. Situations like these necessitate an engineering study like the present one.

The aim of this paper was to explore the use of cement dust as a stabilizer in Iraqi expansive soil. For this purpose, an experimental series of consolidation tests were carried out to explore the effects of local cement dust on consolidation properties experienced by the soil. The soil sample was obtained from one location at the Baghdad government. The specimens were prepared by mixing the expansive soil with (10%, 20%, and 30% of cement dust. The physical soil properties were obtained by conducting Atterberg tests, sieve analysis, and compaction tests. The soil-cement dust specimens were prepared at 95% relative compaction and subjected to standard oedometer test as per ASTM standards [28].

2. Materials Used

Many regions in Iraq are known as areas of the important cement production centers. Every year, millions of tons of cement dust are produced as a byproduct waste material to the processing of cement production. The cement dust is rarely recycled in the local Iraqi industry, and there are significant amounts of cement dust available as waste materials which cause a serious problem to the environment. In this paper, the cement dust collected from a local cement factory located about 160km to the south of Baghdad. The chemical components of the collected dust were determined in this paper, it showed high content of CaO and SiO$_2$ (about 60%).

One of the local cohesive soils was selected from the south of Baghdad. The main properties of the selected soil were determined to show the properties shown in Table 1 and Figure 1. According to the physical properties, the selected soil was classified as CH as per ASTM standards. On the other hand, according to the method of Daksanamurthy and Raman [29], the swelling potential of soil used can be classified as a "high" as shown in Figure 1.

| Gs  | LL, % | PL, % | PI, % | USCS |
|-----|-------|-------|-------|------|
| 2.67| 60    | 32    | 28    | CH   |

Table 1. Basic and compaction properties of the soil
3. Experimental Investigation and Test results

The testing program started with carrying out the compaction test (ASTM D698). The CH specimen was compacted with the standard Proctor test procedure. The compaction properties of the soil were determined, the maximum dry density of the soil is 1530 kg/m³, and the optimum content of water is 22%. The soil specimen and cement dust were mixed in different proportions (soil: cement dust, 90%:10%, 80%:20%, and 70%:30%). The dry mixture was mixed firstly then water (22%) was added to produce the wet mixture. Then, the mixture compacted to achieve 95% relative compaction. To achieve the purpose of this paper, a series of consolidation test were carried out on the soil-cement dust specimens using standard oedometer test as per ASTM standards, Figure 2. The specimens were subjected to incrementally applied controlled-stress loading. The six loads used were applied at 25 kPa increments (i.e. 25, 50, 100, 200, 400, and 800) kPa and two unloaded increments, (800, 200 and 50) kPa. These stress increments are maintained until excess pore water are dissipated.

4. Test Results and Discussion

From the results, the void ratio variation with the variation of the load was plotted in a semi-logarithmic scale as shown in Figure 3. These plots used to determine the consolidation soil parameters (i.e. compression index (cc), and swelling index (cs)). Also, the results of consolidation tests were used to calculate the values of the coefficient of consolidation, cv. The values of cv were calculated for incrementally applied loads and plotted below the void ratio-log applied load curves for untreated soil and for soil mixed with cement dust as shown in Figure 3. An examination of this figure shows that the general behavior of the soil under confined consolidation is almost not affected by the addition of cement dust. The trend of cv variation with applied loads for different content of cement dust is the same up to 20% cement dust, for further dust content this trend is totally changed.
However, at the specified applied load, the values of the coefficient of consolidation were decreased with cement dust of 10% then they increased for further dust content, Figure 4.

![Figure 3](image-url) Result of consolidation tests.
Figure 4. cv variation with cement dust under different applied loads

Figure 5 shows the effect of cement dust on the consolidation parameters of the tested soil. The effect of cement dust on the soil's behavior is reflected by its effect on consolidation parameters values, actually, the lesser $cc$ values, the less soil settlement and verse-versa. As shown in the mentioned figure the addition of cement dust has a great effect on soil compressibility. At low content of cement dust (10%) a slight increase or adverse effect has seemed for compression index value. With a further increase in cement dust, the compression index was reduced noticeably. Re-examination of Figure 5 shows that the values of the swelling index have shown a uniform decrease in their values with the addition of dust content. This may be due to the ability of cement dust to increase the amount of soil-joining”. This joining effect the swelling index values, at which the swelling ability of the expansive soil' is reduced by the mixing of cement dust with it, in other words, the soil undergoes fewer volume changes under unloading condition. Finally, the result indicates that the best improvement in $cc$ and $cs$ can be obtained by mixing 20% of cement dust or more with expansive soil. At this content of dust, the reduction in compression and swelling indexes of soil was 39% and 69% respectively.

Figure 5. Consolidation parameters variation with cement dust
5. Conclusions

Cement dust improves the geotechnical properties of soils, including Atterberg limits, compaction properties, chemical values, and bearing and strength. This situation was shown in the previous researches. In this paper, the consolidation properties and behavior of expansive soil mixed with different contents of local cement dust were investigated experimentally.

It was found that the general behavior (i.e. the shape of stress-strain curves) of the soil under confined consolidation is almost not affected by the addition of cement dust. The trend of cv variation with applied loads for different content of cement dust is the same up to 20% cement dust, for further dust content this trend is totally changed. At low content of cement dust (10%) the values of the coefficient of consolidation were decreased. The addition of cement dust has a great effect on soil compressibility. At low content of cement dust (10%) a slight increase or adverse effect has seemed for compression index value. With a further increase in cement dust, the compression index was reduced noticeably. The addition of cement dust has an ability to increase the amount of "soil-joining" and effect the swelling index values, in other words, the soil undergoes fewer volume changes under unloading condition. Finally, the best improvement in cc and cs was obtained by mixing 20% of cement dust or more with expansive soil. At this content of dust, the reduction in compression and swelling indexes of soil was 39% and 69% respectively.

References

[1] Al-Jeznawi DA, Sanchez M, Al-Taie AJ and Zielinsk M 2019 Experimental studies on curling development of artificial soils Journal of Rock Mechanics and Geotechnical Engineering 11 6 1264-1273.

[2] Al-Baidhani A F and Al-Taie A J 2020 Recycled crushed ceramic rubble for improving highly expansive soil Transp. Infrastruct. Geotech. 7 426–444. https://doi.org/10.1007/s40515-020-00120-z.

[3] Al-Jeznawi DA, Sanchez M and Al-Taie AJ 2020 Effect of wetting-drying cycles on desiccation crack pattern and soil behavior J Key Engineering Materials 857 188-194.

[4] Sabba MH 1987 Evaluation of soil expansive properties in mid part of Iraq M.Sc. Thesis, University of Technology, Iraq.

[5] Al-Samara'ee EA 1996 Swelling characteristics of Baghdad soil with some proposed remedies M.Sc. Thesis, Building and Construction Engineering Department, University of Technology, Iraq.

[6] Al-Busoda BS 2009 Evaluation and correlations associated with liquid limit and plasticity index of Baghdad cohesive soil The 6th Engineering Conference College of Engineering-University of Baghdad

[7] Al-Taie AJ 2015 Profiles and geotechnical properties for some Basra soils Al-Khawarizmi Engineering Journal 11 2 74-85.

[8] Al-Taie AJ 2016 Practical aid to identify and evaluate plasticity, swelling and collapsibility of the soil encountered in Badrah, Shatra and Nassiryia cities Journal of Engineering and Sustainable Development 20 1 38-47.

[9] Okagbue CO and Onyeobi TUS 1999 Potential of marble dust to stabilize red tropical soils for road construction J. Eng. Geol. 53 3-4 371–380.

[10] Al-Taie AJ and Al-Shakarchi YJ 2017 Shear strength, collapsibility and compressibility characteristics of compacted Baiji dune soils Journal of Engineering Science and Technology 12 3 767-779.

[11] Al-Taie A, Albusoda B, Alabdullah S and Dabdab A 2019 An experimental study on leaching in gypseous soil subjected to triaxial loading Geotech Geol Eng 37 6 5199–5210. https://doi.org/10.1007/s10706-019-00974-2.

[12] Al-Taie A, Al-Obaidi A and Alzuhaieri M 2020 Utilization of depolymerized recycled polyethylene terephthalate in improving poorly graded soil Transp. Infrastruct. Geotech. 7 206–223. https://doi.org/10.1007/s40515-019-00099-2.
[13] Hussein AF 2020 Using stabilized problematic soil to produce building units M.Sc. thesis, Civil Engineering Dept., University of Baghdad, Iraq.
[14] Al-Naje F Q, Abed A H and Al-Taie A J 2020 A review of sustainable materials to improve geotechnical properties of soils Al-Nahrain Journal for Engineering Sciences NJES 23 3 289-305.
[15] Hussein AF, Ali AS and Al-Taie AJ 2019 A review on stabilization of expansive soil using different methods Journal of Geotechnical Engineering 6 3 32–40.
[16] Peethamparan S and Olek J 2008 Study of the Effectiveness of cement kiln dusts in stabilizing na-montmorillonite clay Journal of Materials in Civil Engineering 20 2 137-146.
[17] Ismaiel AH 2013 Cement kiln dust chemical stabilization of expansive soil exposed at El-Kawther Quarter, Sohag Region, Egypt International Journal of Geosciences 4 10 1416-1424.
[18] Amadi AA and Lubem S 2014 Assessing Stabilization effectiveness of combined cement kiln dust and quarry fines on pavement subgrades dominated by black cotton soil Geotechnical and Geological Engineering 32 5 1231–1238.
[19] Al-Homidy A, Dahim M and Aed El Aal, A 2017 Improvement of geotechnical properties of sabkha soil utilizing cement kiln dust Journal of Rock Mechanics and Geotechnical Engineering 9 4 749-760.
[20] Jimoh I, Amadi and Ogunbod E 2018 Strength characteristics of modified black clay subgrade stabilized with cement kiln dust Innov. Infrastruct. Solut. 3 55. https://doi.org/10.1007/s41062-018-0154-3.
[21] Cui S, Wang J, Wang XD, Du Y and Wang X P 2018 Mechanical behavior and micro-structure of cement kiln dust-stabilized expansive soil Arabian Journal of Geosciences 11 17 1-8. 10.1007/s12517-018-3864-0.
[22] Mohammadinia A, Arulrajah A, Amico A and Horpibulsuk S 2018 Alkali-activation of fly ash and cement kiln dust mixtures for stabilization of demolition aggregate Construction and building materials 186 71-78.
[23] Mahdi Z, Hasan M and Jasim H 2018 Assessment of using cement kiln dust stabilized roads subbase material International Journal of Engineering & Technology 7 4.20 162-65.
[24] Naseem A, Mumtaz W, Jalal F and Bucker H 2019 Stabilization of expansive soil using tire rubber powder and cement kiln dust Soil Mechanics and Foundation Engineering 56 1 54-58.
[25] Almurshedi A 2019 Swelling control of expansive soils using cement dust IOP Conf. Series: Materials Science and Engineering 584 012021.
[26] Rimal S, Poudel R and Gautam D 2019 Experimental study on properties of natural soils treated with cement kiln dust Case Studies in Construction Materials 10 1-7.
[27] Al-Baidhani A and Al-Taie A 2019 Stabilization of expansive soils using stone waste materials: a review IJO-International Journal of Mechanical and Civil Engineering 2 7 1-7.
[28] ASTM 2003 International, formerly known as American Society for Testing and Materials Book of Standards 04.08.
[29] Daksamamurty V and Raman V 1973 A simple method of identifying an expansive soil Soils and Foundation 13 1 97-104.