Evaluation of Dolime Fine Performance in Mitigating the Effects of an Expansive Soil

Ahmed Hisham, Shehab Wissa(✉), and Ayman Hasan

Soil Mechanics and Foundations Department, Public Works Department,
Cairo University, Giza, Egypt
tiba.ce@gmail.com, shehabagaiby@cu.edu.eg,
aymanhl188@gmail.com

Abstract. Expansive soils are classified as problematic soils that expand when in contact with water and shrink after drying out. The soils reactivity with water is due to the presence of clay minerals that react with water such as montmorillonite. Given the geotechnical problems associated with the expansion and shrinkage behavior of expansive soils, it is necessary to treat such soils before constructing on it. Mixing the soils with additives is considered one of the main treatment methods that has been used to reduce the expansion capabilities of these soils rendering them safe to construct on and remain stable. Dolime fine; that is obtained from crushing dolomite stone; has a great potential to be used as an additive to treat expansive soils, the reason for that comes from it being composed of a percent of calcium oxide (CaO) which is known for being a binding agent that can stabilize expansive soils. In the presented experimental study, dolime chips were brought from Erbil city (northern Iraq), while bentonite was brought from Samawa city (southern Iraq), as for natural soil it was brought from the marshes of Basra city (southern Iraq) for investigation. To assess the effectiveness of dolime fine in stabilizing expansive soils, a series of laboratory tests were conducted on an artificial expansive soil; that is composed of 75% bentonite and 25% natural clay; that was mixed with dolime fine passing through sieve No. 40. The series of experimental tests conducted on the dolime fine-expansive soil mixture include unconfined compressive strength tests (UCS); compaction tests; swelling tests; and California bearing ratio tests (CBR). Through the results of these tests, a conclusion can be reached to how much of an effect does the mixing of the dolime fine with an expansive soil have on the expansion ability of the soil under study.

1 Introduction

Expansive soil is a type of clayey soil having montmorillonite minerals which expand significantly when in direct contact with water and shrink when the water dries out. Typically, the shear strength of such soils is very low which can alternate the swell-shrink behavior of the soil which subsequently may damage lightly loaded structures that are constructed on top of it. Expansive soils are treated as problematic soil for construction (Nilson and Miller 1992; Gourley et al. 1993; Rao et al. 2008; Sabat and Pati 2014). Therefore, it is necessary to improve the geotechnical properties (mainly shear strength and deformability) of swelling soils to mitigate potential damages to structures.

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Traditionally, complete or partial replacement of expansive soils with non-expansive engineered fill is used to lower the adverse effects of soil volume changes for structures, roads, and utilities. Alternatively, other methods may be used to reduce soil swelling potential including chemical treatments with additives such as cement or lime or fly ash (Jan et al. 2015). Stabilization is one of the techniques that is widely used to improve the geotechnical properties of expansive soils. The treated expansive soil cab be non-contaminated as summarized in numerous studies in the geotechnical literature carried out by Cocka 2001, Kalkan and Akbulut 2004, Sabat and Das 2009, Ogbonnaya and Illoabachie 2011, Sabat and Nanda 2011, Moses and Saminu 2012, Sabat 2012, Mir and Sridharan 2013, Sabat 2013, Sabat and Pradhan 2014, Ashango and Patra 2014, Sabat and Nayak 2015, Kulkarni et al. 2016, and Sabat and Mohanta 2016. Or stabilization can be utilized with contaminated soils as studied by Sabat and Mohanta (2017); who proposed using dolime fines to improve the strength properties and swelling behavior of expansive soil that is artificially contaminated with diesel. So dolime fines can be utilized to stabilize contaminated and non-contaminated expansive soil.

Dolomite chips are required for different industrial processes, the chips are obtained by crushing dolomite stones where during crushing a solid waste is produced called *dolime fines* (Sabat and Mohanta 2015). Dolime fines have a high percentage of calcium oxide (CaO). The utilization of dolime fines has been recommended by (IRC: 88-1984) as a binding agent that can replace pure lime (Shahu et al. 2013). Sabat and Mohanta (2015) used dolime fines and other mixtures to study the strength and durability characteristics of stabilized red mud cushioned expansive soil whereas Shreyas (2017) used dolime fines to stabilize black cotton soil that is known as expansive soil. The effects of mixing dolime fines with an expansive soil were studied by Golakiya and Savani (2015) and Sabat and Mohanta (2017), where it was observed that mixing soils with dolime fines yields to a decrease in maximum dry density (MDD) and swelling pressure, and on the contrary to an increase in optimum moisture content (OMC), unconfined compressive strength (UCS) and California bearing ratio (CBR).

2 Methodology

Bentonite material; brought from Samawa city (southern Iraq); was mixed with natural clay soil from the marshes of Basra city (southern Iraq) in order to make an expansive soil mix, the mass of the resulting expansive soil comprises 75% bentonite and 25% natural clay, by weight of the soil. Dolomite stones; brought from Erbil city (northern Iraq); were crushed to dolime fines and then passed from sieve No. 40 (0.425 mm). Dolime fines were added to the soil mixture at 0, 4, 8 and 12% by weight of the soil and mixed properly.

Standard Proctor compaction tests were conducted on the expansive soil mix to obtain optimum moisture content and maximum dry density. Samples were prepared for measuring the unconfined compressive strength, California bearing ratio and one-dimensional consolidation behavior of the soil mixture at OMC and MDD. The tests were conducted following ASTM procedures.

3 Analysis of Test Results

3.1 Standard Compaction Test

Standard compaction test was conducted on both natural soil and soil-dolime fine mixtures with different percentages (4%, 8%, and 12% dolime fine as a percentage of the soil weight). The test results are presented in Fig. 1 showing the relationship between the dry density of soil/soil mixtures and water content. The results indicated that the maximum dry density decreases with the increase in the dolime fine content.

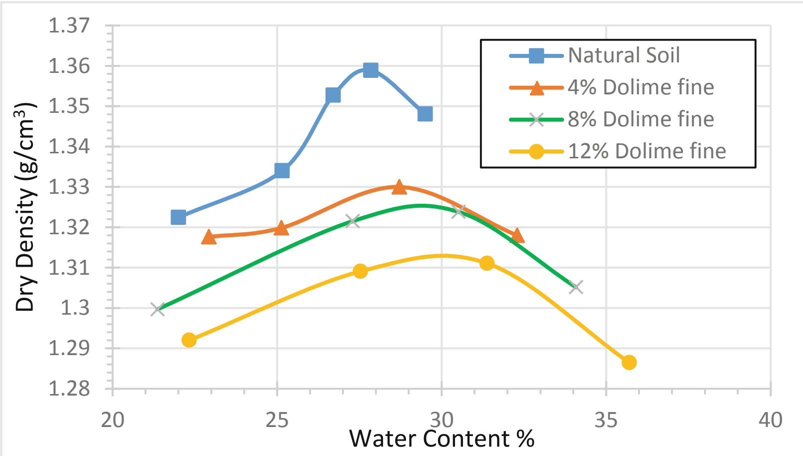

Fig. 1. Dry density versus water content for standard Proctor test

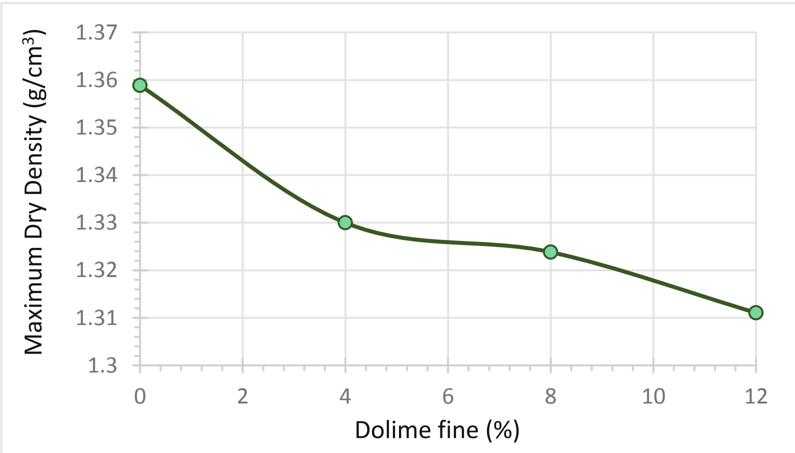

Fig. 2. Maximum dry density versus dolime fine (%)

Figure 2 shows the relationship between the maximum dry density and the dolime fines, where the maximum dry density value decreases from 1.36 g/cm^3 to 1.31 g/cm^3

with the increase of dolime fines from 4 to 12%. Furthermore, the increase in the dolime fine content leads to a corresponding increase in the values of the moisture content. The optimum moisture content increases from 27.8% to 31.4% with the increase in the added dolime fines from 0% to 12% as shown in Fig. 3.

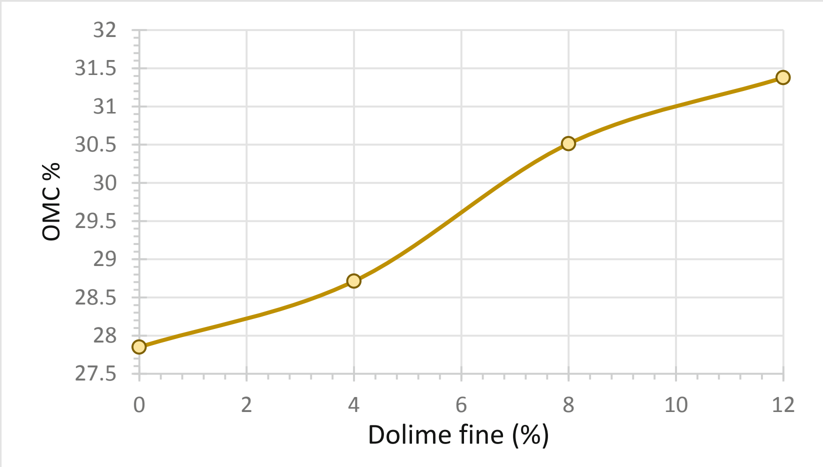

Fig. 3. Optimum moisture content versus dolime fine content

3.2 California Bearing Ratio Test (CBR)

The CBR tests were conducted on samples from natural soil condition and from the soil mixed with 4%, 8%, and 12% dolime fine by the weight. For the soil specimens mixed with dolime fine, the soil mixture resistance to penetration increases with the increase in the dolime fine content as shown in Fig. 4. CBR value for the current study gradually

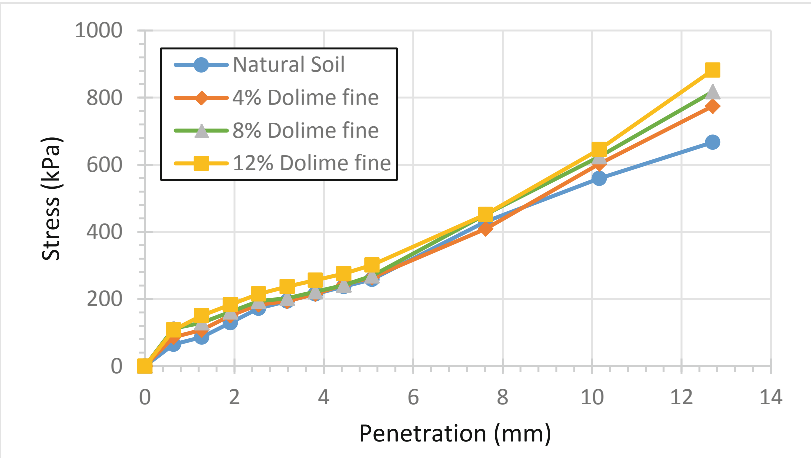

Fig. 4. Stress versus Penetration for CBR test

increases when the dolime fine is added to the swelling soil, it increases by 6.25%, 12.5%, and 25% for 4%, 8%, and 12% dolime fine, respectively; as illustrated in Fig. 5.

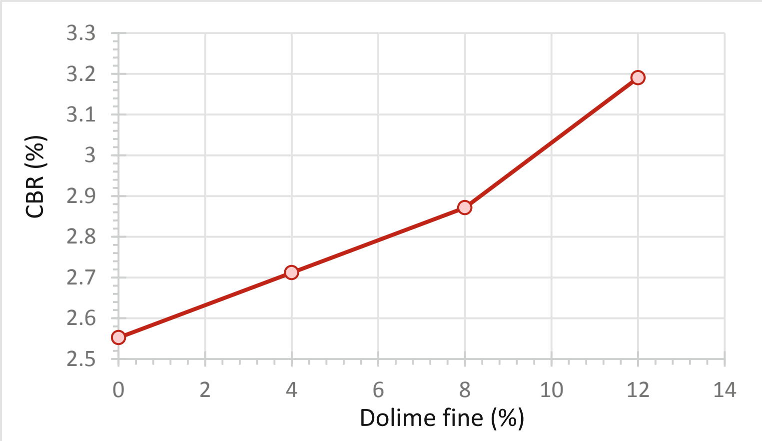

Fig. 5. CBR values versus dolime fine content for CBR test

3.3 Unconfined Compressive Strength (UCS)

Specimens of swelling clay were mixed with 0%, 4%, 8%, and 12% dolime fine by weight. All samples were mixed at its OMC and MDD. Figure 6 presents the stress-strain-strength response for all the tested soil mixtures. Figure 7 shows the increase of the UCS values with the percentage of the mixed dolime fines for the soil under study. Unconfined compressive strength increased by 60%, 90%, and 105% for dolime fine contents 4%, 8%, and 12% of soil weight, respectively.

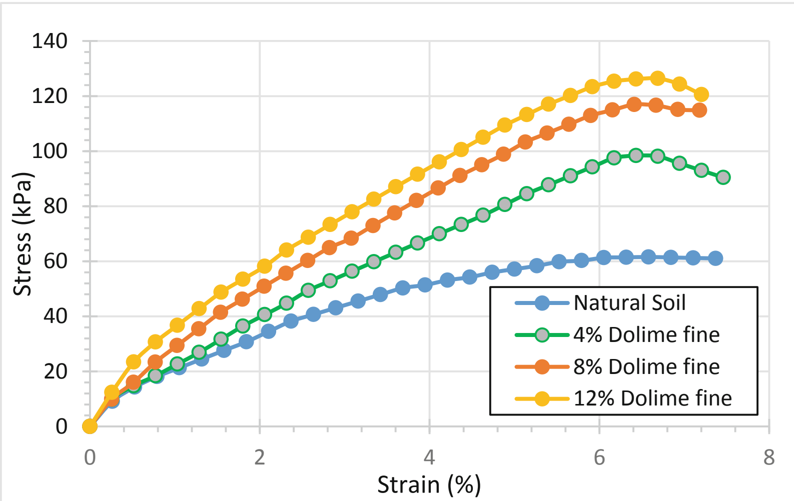

Fig. 6. Stress versus strain for swelling clay mixed with dolime fine.

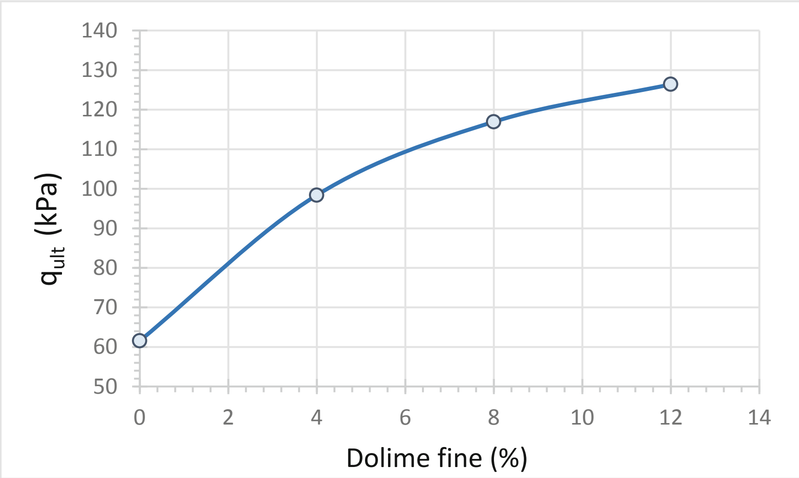

Fig. 7. UCS values versus dolime fine content for the swelling clay

3.4 One-Dimensional Swelling Test

For evaluating the swelling behavior of the expansive soil, one-dimensional swell tests were performed according to ASTM D4546-14 on both treated and untreated samples. From the results of one-dimensional consolidation (swelling pressure tests on confined samples using an oedometer cell), the swelling curves have been plotted as percent swell strain versus swelling pressure, as shown in Fig. 8. Figure 9 illustrates the swelling pressure results for soil mixed with 0%, 4%, 8%, and 12% dolime fine by weight. The increase in dolime fine content results in a decrease in both swelling pressure and corresponding strain. Figure 10 presents the variation of average swelling strain with dolime fine contents, it can be concluded that the swelling strain decreases with the increase in the dolime fines.

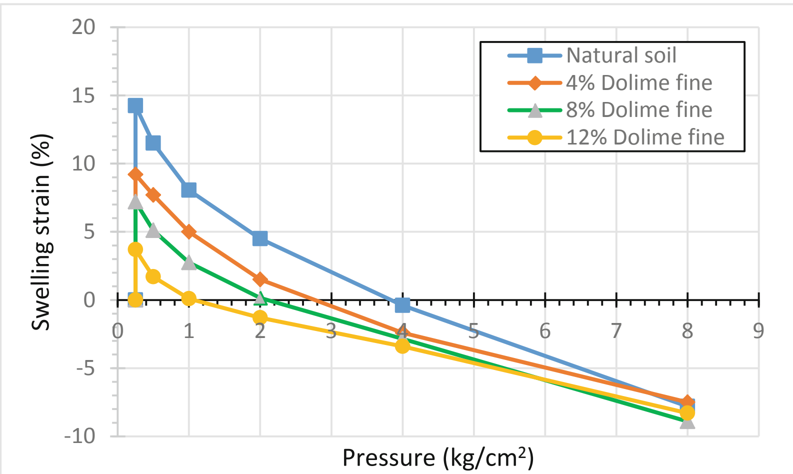

Fig. 8. Swelling strain versus pressure for swelling clay mixed with different dolime fine content

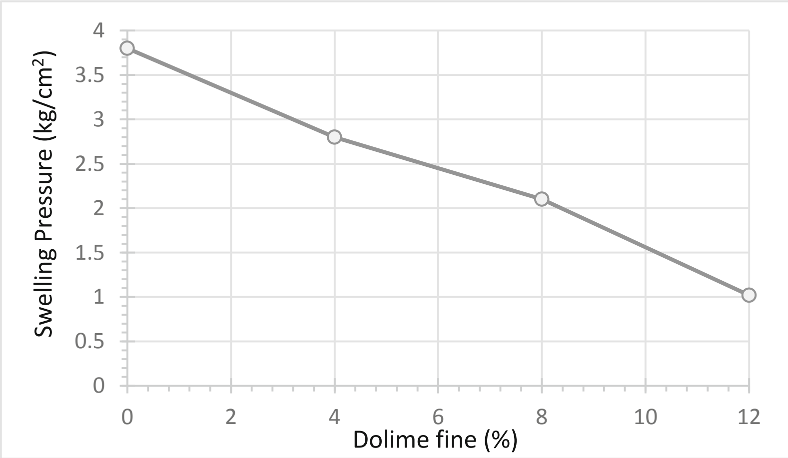

Fig. 9. Swelling pressure values versus dolime fine content for the swelling clay

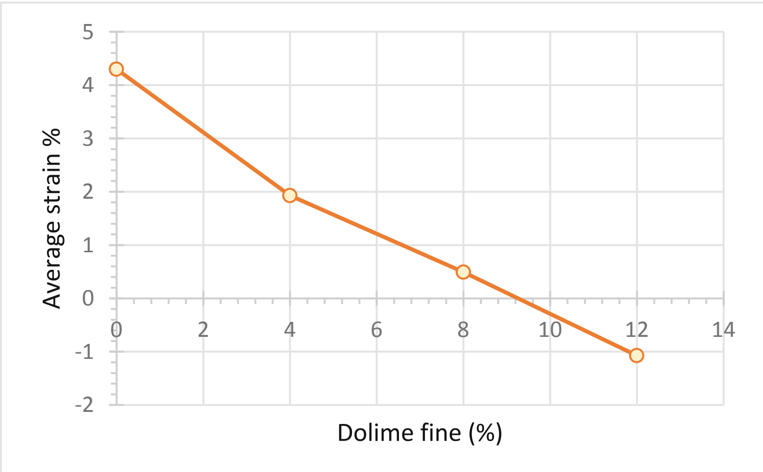

Fig. 10. Average strain versus dolime fine content

4 Conclusion

An experimental study is conducted to investigate the improvement in swelling characteristics of expansive soil due to mixing with dolime fines. A comprehensive laboratory testing program is under taken where dolime fines are added to natural clay from Samawa city (southern Iraq) with different percentages: 4, 8, and 12 by weight, to study the effect of dolime fines on the measurements of maximum dry density; optimum moisture content; unconfined compressive strength; California bearing ratio; and the swelling pressure of the expansive soil. The results were as following:

1. The maximum dry density of swelling soil–dolime fine mixture is reduced by 2%, 2.5%, and 3.5% for dolime fine contains 4%, 8%, and 12% by the weight of soil, respectively. This can be attributed to the relative light weight of the dolime fine weight compared to the weight of soil, and the large area occupied by it. Therefore, increasing dolime fine content leads to a reduction in the density of the mixture.
2. Optimum moisture content is increased by 3%, 9.5%, and 12.7% for dolime fine contains 4%, 8%, and 12% by the weight of soil, respectively. This may be due to the lack of interaction between the granules of dolime fines and water compared to attributed soil.
3. CBR values have gradually increased when dolime fines are added to swelling soil. CBR value is improved by 6.25%, 12.5%, and 25% for dolime fine contents of 4%, 8%, and 12% by the weight of soil, respectively. These increments can be attributed to the interaction between water (used to submerge samples for 4 days) and calcium oxide [CaO] presents in dolime fine. This interaction results calcium hydroxide [$Ca(OH)_2$] that is considered as solid cohesive material.
4. The values of UCS of the swelling soil – dolime fine mixture are improved by 60%, 90%, and 105% for dolime fine contents 4%, 8%, and 12% by the weight of soil, respectively. The UCS value for the current study has gradually increased when the dolime fine is added to swelling soil.
5. Addition of dolime fine to expansive clay specimens caused a considerable reduction in the swell strain and swelling pressure.
   As for the consolidation test results, mixing dolime fine with expansive soil causes a large reduction in the swelling pressure by 26%, 45%, and 73% when the swelling soil contains dolime fine 4%, 8%, and 12% by the weight of soil, respectively.
6. The swelling strain for the swelling soil – dolime fine mixture is reduced by 55%, 88%, and 125% for dolime fine contents of 4%, 8%, and 12% by the weight of soil, respectively. The decrease of swelling strain and swelling pressure occurs due to similar reason as discussed in CBR test results above.
7. The optimal ratio for the current study of the mixture of dolime fine that required for achieving a decrease in swelling properties occurs when swelling soil contains 12% of dolime fine by the weight of soil.
8. CBR, UCS, Swelling Strain and Pressure, MDD, and OMC values for swelling soil mixed with dolime fine can be summarized in Table 1.

Table 1. Summary of laboratory test results

Dolime Fine Content %	Standard Proctor Test		Improving CBR %	Improving UCS %	Decreasing Swelling Pressure %	Decreasing Swelling Strain %
	Decreasing MDD %	Increasing OMC %				
0	0	0	0	0	0	0
4	2	4	6.25	60	26	55
8	2.5	8	12.5	90	45	88
12	3.5	12	25	105	73	125

Where MDD: Maximum Dry Density; OMC: Optimum Moisture Content; CBR: California Bearing Ratio; and UCS: Unconfined Compressive Strength

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