Effect of Sand on Consistency Limits of Swelling Soils

Yahya K. Atemimi1,2, Lamya N. Snodi2, Abduljabbar A. H. Idan3
1Department of Civil Engineering, University of Babylon, Hilla, Iraq.
2Department of Civil Engineering, Tikrite university, Tikrite, Iraq.
3Ministry of Construction and Housing, Iraq.
*yehyeaaltemimi@yahoo.com
*Corresponding author

Abstract. Expansive soils are widely spread around the world. These soils are problematic soil due to low bearing capacity, high compressibility, low permeability, high expansion, with volume change problems. The engineer finally changes the site, which has expansive soil to avoid the difficult problems and save time and money for the project. Today, with the few chances to obtain good soil type, the clients reused the bad sites that leave at the past time; therefore, they must treat this soil to carry the construction loads. This study mixed the commercial sand with grain size between 1-0.6 mm in diameter with the swelling soil with 66% free swelling index (FSI). Three sand percentages were used 10%, 15%, and 20% mixed with the swelling soil by weight. Free swelling index, liquid limits, and plastic limits were tested depend on ASTM specifications. The results show a reduction in LL and PL for all mixtures. The reduction in consistency limits refers to reducing swelling behavior and increasing soil strength due to a decrease in plasticity and compressibility.

Keywords: Swelling soil, Liquid limit, Plastic limit, Free Swelling Index, Expansive soil, Consistency limits

1. Introduction
Problems associated with the potential volume change of soils occur all around the world, mainly in the arid and semi-arid climatic regions, as is the case in our country. These problems are mostly confined to region where the variation in moisture content results in the potential expansiveness of the soil. In Iraq, the expansive soils separate in the different areas in thickness layers in alluvial plain and near of the revers as shown in Figure 1[1]. The changes in the world with growing populations with limited areas to use, push the clients to reuse the expansive soil with spending more money to improve it. Many methods are used to improve this soil type, such as replace the expansive soils with non-expansive or mixed with other materials such as lime, ashes, chemicals …etc. [1]. All the treatment methods are expensive with different degrees of improvement. Actually, Bentonite/Sand mixture is one of the available answers for geotechnical engineering problems such as heaves, cracks, and other damages caused by swelling and shrinkage, and Bentonite/Sand mixture may be used to: 1) Reduce the settlement time of structures. 2) Increase the permeability of soils [2].

The bentonite sand mixture is widely used in different engineering applications such as linear, barriers, and core of earth dams [3]. The grain size and type of sand are significant parameters effect on the degree of expansion [4]. Consistency limit one of the important parameters to evaluate the strength of soils, and many researchers depend on it [5]. This paper is a part of the study on expansive soil to evaluate the engineering properties and trial to improve it using the sand-clay mixture.
2. Materials

Soil used in this study is silty clay soil (MH) as classified according to USCS. The soil used was brought from Al-Mosul university at 1m depth with 98% passing from sieve No. 200 and 58.6% with grain size less than 5µ, the basic properties of soil was listed in table 1. The sand used was brought from the market of the golden sand company with grain size range between 1 to 0.6 mm.

3. Experimental work

Many tests were done in this study to complete the experimental program, such as free swelling index, liquid and plastic limits, direct shear test to obtain the shear parameters (C and φ), sieve analysis, and hydrometer test to classify the clay soil.

3.1 Free swell index (FSI)

Free swell or differential free swell, also termed as a free swell index, increases the volume of soil without any external constraint when subjected to submergence in water. This test was conducted on the original soil only to evaluate the free swell for soil used. The formula used is presented by IS 1498 [7].

\[
FSI = \frac{V_d - V_k}{V_k} \times 100
\]

Where \(V_d\) = volume of soil specimen read from the graduated cylinder containing distilled water, \(V_k\) = volume of soil specimen read from the graduated cylinder containing kerosene.
3.2 Direct Shear Test
Depend on the ASTM specification D 3080-72, [9] applied on the original soil to obtain the shear strength parameters (cohesion C and internal friction angle $\phi$). The results used to define the soil used only.

3.3 Consistency Limits
According to ASTM D 4318-00, method A [9] was used to obtain the liquid limits and plastic limits for all samples used. Four samples were tested, original soil, 10%, 15%, and 20% sand/soil mixture.

3.4 Compaction
Standard compaction test applied on the original soil and soil sand mixture (10, 15, and 20% sand/soil mixture) to evaluate the effect of sand percentages on the density of soil. This test applied according to ASTM D 698 – 12 clauses 2.

4. Results and Discussion
Figure 1 can notice the soil location has swelling pressure is 450 kPa this pressure is very high as presented in. If the swelling pressure of the soil is as low as 1000 psf (4 kPa.) only the soil to a depth of 2 ft (60 cm) would be prevented from swelling. This depth is much smaller than that of the active zone for most sites, and this footing would be ineffective in preventing heave [10]. The results obtained from the direct shear test show the soil is very soft as classified by [11]. The free swelling index result is 66%; this value has classified the soil as a medium swelling [8]. On the other hand, the plasticity of fine soil has an important effect on such engineering properties as shear strength, bearing capacity, compressibility, and water suction [12]. Figure 2 shows the results of consistency limit decreases with the sand percentage increase. The liquid limit was decreased about 230% from 81 to 35. Also, the plastic limits decrease about 63% from 42 to 27%. The reduction in liquid limits and plastic limits is an indicator of the strength of soil due to decreased soil softening and increased bearing capacity.

Also, the reduction in liquid and plastic limit refers to decreasing the specific surface and reducing cation exchange capacity (CEC) of the soil product after mixed with sand [10]. On the other side, the compressibility will be decreased due to decreased consistency limits, as presented by many researchers [7]. Figure 3 is a plasticity chart was suggested by Casagrande that shows the effect of sand additive on the gradation of soil was changed from very high plasticity (LL = 81) to low plasticity (LL = 35) [11]. Also, the classification of the modified soil with 20% sand changed from MH to ML soil; this is new grading due to agglomeration of clay around the sand particles. The results obtained due to Liquid limits and plastic limit beneficial criteria used to evaluate the expansive soil as cited by [8].

The relation between sand percent and density is presented in figure 4. The increase in sand percent leads to an increase in the dry density of the mixture. About 21% increment of density from 13.8 kN/m$^3$ at original soil to 16.7 kN/m$^3$ at 20% sand additive. The increase of density attributed to the sand density and the agglomeration of clay, same results presented by [1]. On the other hand, the relation between liquid limit and density is a linear behavior due to increase density with decrease liquid limit at increase sand content in the same trend as shown in figure 5, these results refer to the density of sand cause increase total density, and the porosity increase caused decrease of water content lead to decrease the liquid limit. It can be seen that the addition of sand increases the maximum dry density for all soils, which affects the reduction in the specific surface. Higher value of $\gamma_{a\, max}$ was found at 20% sand. It can be seen that a soil product becomes coarser. The same behavior was reported by many researchers as [13-15].
Figure 2. Relationship between Atterberg’s limits and sand percentage.

Figure 3. Effect of sand on the gradation of soils result.

Figure 4. Effect of sand on maximum dry density.
5. Conclusions
This study focuses on the benefit of sand used as a modified material to reduce the swelling characteristics, especially the liquid and plastic limits. The results show many points that can be concluding it as below.

- According to the plasticity chart, the sand percent increase caused a decrease in liquid and plastic limits and changed the classified soil from MH to ML soil.
- The maximum dry density increases with the sand percentage increase; this result refers to increased soil strength.
- The soil mixture results can be used as a barrier and landfill area.
- The coarse sand used caused low reduction compare with fine sand grain at the same percentage of additives.

References
[1] Thakur, Y. and Yadav, R.K., 2018. Effect of bentonite clay on compaction, CBR and shear behavior of Narmada sand. International Research Journal of Engineering and Technology (IRJET), 5(3), pp.2087-2090.
[2] Vadlamudi, S. and Mishra, A.K., 2018. Consolidation characteristics of sand–bentonite mixtures and the influence of sand particle size. Journal of Hazardous, Toxic, and Radioactive Waste, 22(4), p.06018001.
[3] Thakur, Y. and Yadav, R. K., 2018. Geotechnical characteristic of compacted sand bentonite mixture. International Journal for Research in Applied Science & Engineering Technology, 6 (III), pp. 2102-2108.
[4] Atemimi, Y.K., 2020. Effect of the Grain Size of Sand on Expansive Soil. In Key Engineering Materials (Vol. 857, pp. 367-373). Trans Tech Publications Ltd.
[5] Prakash, K. and Sridharan, A., 2014. Discussion of “Atterberg Limits and Remolded Shear Strength—Water Content Relationships”. Geotechnical Testing Journal, 37(4), pp.726-728.
[6] Witwit, A. M., 2001. Expansive soil in Iraq-locations, properties and treatment methods. M.Sc. Thesis, Civil Engineering Department, University of Technology, Iraq.
[7] Sridharan, A. and Prakash, K., 1998. Characteristic water contents of a fine-grained soil—water system. Geotechnique, 48(3), pp.337-346.
[8] Sridharan, A. and Prakash, K., 2000. Classification procedures for expansive soils. Proceedings of the Institution of Civil Engineers-Geotechnical Engineering, 143(4), pp.235-240.
[9] ASTM, Annual Book for Laboratory Testing, 2005. Vol.4, Part 8.

Figure 5. Relation between maximum dry density and liquid limit.
[10] Nelson, J. and Miller, D.J., 1997. Expansive soils: problems and practice in foundation and pavement engineering. John Wiley & Sons.

[11] Das, B.M. and Sivakugan, N., 2016. *Fundamentals of geotechnical engineering*. Cengage Learning.

[12] Whitlow, R., 1990. *Basic soil mechanics*. 3rd ed.

[13] Sherif, M.A., Ishibashi, I. and Medhin, B.W., 1982. Swell of Wyoming montmorillonite and sand mixtures. Journal of the Geotechnical Engineering Division, 108(1), pp.33-45.

[14] Yahya K. Atemimi, Improvement Properties of Expansive Soils Using Sand, unpublished M.Sc. Thesis, civil engineering department, University of Al-Mustansirya-Baghdad -Iraq (2001)

[15] Sivapullaiah, P.V., Sridharan, A. and Stalin, V.K., 1996. Swelling behaviour of soil bentonite mixtures. Canadian Geotechnical Journal, 33(5), pp.808-814.