Treatment of a clay soil contaminated with glycerol by using magnesia

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Received: 9 March 2021 Accepted: 5 May 2021

(Paper pages 62-78)

Extended Abstract

Introduction

Treatment of a soil is a process in which the behaviors of soil are improved to make it a suitable material for engineering applications. There are several methods that can be used for the treatment of soils. They are divided into mechanical and chemical methods. The chemical method involves the addition of additives (agents) such as lime, cement or fly ash to the natural soil and new cementitious material is made and caused to enhance the physical and mechanical behaviors of the soil. Lime and cement are two popular agents that are used for the treatment of clay soil. Recently researchers have attempted to consider another agent replacement for cement and lime for the treatment of soil. They have introduced MgO (Magnesia) as an agent for the treatment of soils. Unluer and Al-Tabbaa (2013) stated that it has many advantages over cement. It can be used as an agent alone or as an additive with cement or lime for the treatment of soil. Review of the literature shows that there has been a lot of studies on the treatment of soils contaminated with hydrocarbons using common agents such as cement, lime and fly ash. However, to date, very limited attention has been given to the treatment of soil contaminated with organic matters using MgO. In this study, the effect of different percentages of MgO on the treatment of a clay soil contaminated with different amounts of glycerol solution is studied at different times. The results are compared with the results for stabilized uncontaminated samples at the same conditions as the contaminated soil samples.

Material and methods

The effect of MgO on the treatment of a natural and contaminated soil was studied through performing a set of experimental program. The natural soil that was chosen in this work was a clay soil with high plasticity (CH). Contaminated soil was prepared by adding 4, 8 and 12% solution of glycerol with the concentration of 50%. The treatment of natural and contaminated soil was done by adding 5, 8 and 12% MgO to them. The experimental tests involved Atterberg limits, compaction and unconfined compressive strength that were conducted on the samples of soils in natural or contaminated and treated soil in both conditions of soil. The soil samples for strength tests were made by static compaction method in a special mould by using a loading machine. The water content and dry unit weight of prepared samples were the same as their corresponding compaction curves. The tests were performed according to the ASTM standard. In addition, SEM tests were also conducted on the samples of natural, contaminated soil and treated soil. The aim of conducting the SEM test was to get more information about the microstructure of soil under different conditions.

Results and discussion

The results of Atterberg limits showed that the values of LL (Liquid Limit), PL (Plastic limit) and PI (Plastic Index) for natural soil are 73.0, 26.0 and 47.0% respectively but adding the solution of glycerol to the soil, these values are reduced. For example, for the mixture of soil with 12.0% glycerol, the values of LL, PL and PI are changed to 53.0, 21.0 and 32.0% respectively. The change in the values of them is due to the value of the dielectric constant of liquid between particles. The values of the dielectric constant are 80 and 42.5 for water and the solution of glycerol, respectively. The thickness of DDL is dependent on the value of the dielectric constant so, the reduction of the dielectric constant results in the shrinking of the DDL and increase of the attractive forces. This causes the formation of the flocculated structure in the soil. In the flocculated structure, the particles are pasted to each other and form coarser particles leading to reduction in the specific surface compared with the natural soil. In this condition, the capacity to adsorb water is reduced and hence reduction is observed in the values of Atterberg limits. The results showed that by adding MgO to the soil increases the values of Atterberg limits in comparison with the natural soil. The specific surface of MgO is about 250-300 m^2/g which is more than that of the natural soil. Hence, it has a higher potential than the natural soil to adsorb water. This characteristic of MgO is resulted in increasing in the values of Atterberg limits of soil when it is mixed with MgO.

By increasing the percentage of MgO in the soil the potential for water adsorption increases, resulting in increasing the values of the Atterberg limits. It is resulted that by adding MgO to the mixture of soil with glycerol, the Atterberg limits are reduced in comparison with the mixture of soil with only MgO. It is also seen that for a soil contaminated with a given amount of glycerol, by increasing the percentage of MgO the Atterberg limits are increased. The results of the compaction tests show that the maximum dry unit weight and optimum water content for the natural soil are 14.1 kN/m^3 and 23.0% respectively. Adding glycerol to the soil increases the maximum dry unit weight and decreases the optimum water content. The trend of these variations is a function of the used percentage of glycerol. As explained above, this is due to the formation of the flocculated structure in soil by addition of the glycerol solution. The results of compaction tests for the soil mixed with MgO show that the maximum dry unit weight is decreased and optimum water content is increased by increasing the percentage of MgO. These changes in the values of compaction parameters are due to the high water adsorption capacity of MgO because of its high specific surface. A similar trend is resulted from experimental tests for the mixture of MgO with contaminated soil.

The results of strength tests indicate that the final strength of natural soil is 488 kPa at the strain of 2.97%. The final strengths for 4%, 8% and 12% solutions of glycerol are 234, 163 and 117 kPa at the strain of about 5.27%. Therefore, contamination of soil with glycerol causes a reduction in the final strength and an increase in the strain at failure. It can be concluded that the reduction of strength is a function of the percentage of glycerol. As mentioned above, adding the solution of glycerol to soil results in the formation of the flocculated structure in the soil. It is expected that the flocculated structure would increase the strength of the contaminated soil but the opposite of this trend was observed. It is can be said that in addition to the dielectric constant of pore fluid, the viscosity of a fluid is also an important factor in the behavior of contaminated soil. The viscosity of water is less than the solution of glycerol, therefore, when the load is applied on a sample of contaminated soil, the glycerol facilitates the displacement of soil particles which results in a reduction of the strength in comparison with the natural soil. The results show that the final strength of natural soil is 488 kPa and for mixtures of soil with 5, 8 and 12% MgO at curing time of 7 days it is changed to 940, 1085 and 1226 kPa respectively. It is resulted that at a constant curing time the final strength is increased with increasing the percentage of MgO. Similar results were obtained for samples with curing times of 14 and 28 days. Therefore, the obtained strength is the function of percentage of MgO and curing time.

It can be said when MgO is added to the soil, its hydration starts by adsorbing the water between particles. During the hydration, MgO is changed to $Mg(OH)_2$, which is termed brucite. Brucite reacts with CO_2 and water and produces materials such as nesquehonite ($MgCO_3$, $3H_2O$), hydromagnesite ($4MgCO_3$, $Mg(OH)_2$, $4H_2O$) and dypingite ($4MgCO_3$, $Mg(OH)_2$, $5H_2O$). The carbonation process and production of the materials continue with time by adsorbing the water and CO_2 and they cause increasing in the strength of the soil sample. The results also show that the strength of the soil contaminated with different percentage of the glycerol solution is increased by adding MgO. The increase in the strength of a soil contaminated with a specific percentage of the solution of glycerol is dependent on the percentage of used MgO and the curing time. The mechanism of improvement in strength is similar to the natural soil stabilized with MgO.

Conclusion

The following conclusions can be drawn from the results of this work:

- Reduction in the strength of contaminated soil is happened and the magnitude of the reduction is depended on the percentage of the glycerol solution.
- MgO can increase the strength of natural and contaminated soil and the amount of increase in strength is dependent on the percentage of used MgO and curing time.
- The trend of variations of strength of contaminated soil stabilized with MgO is similar to MgO-stabilized natural soil. However, for the same percentage of MgO and curing time.

References

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Keywords: Treatment, Clay soil, Glycerol, Magnesia, Strength

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