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Araştırma

THE USE OF CUTTING-STONE-SLURRY-WASTE IN ENGINEERING PRACTICE

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Abstract: The paper studies the use of cutting stones-water-slurry-waste in engineering applications. Three types of selected clayey soils with different plasticity index and clay fraction were used. The initial physical properties of the clayey soils such as Atterberg's limits, maximum dry density, optimum water content, specific gravity, and clay fraction were evaluated in accordance with American Standard for Testing and Materials (ASTM) standard specification. Cohesion, angle of internal friction and unconfined compressive strength were evaluated from samples remolded at 95% relative compaction and optimum water content. Two sets of soil samples were prepared for testing purpose in this investigation. The first set is prepared with fresh water at different initial water content and dry densities and without any admixture. The second set is identical to the first set but the water content is replaced with the same percentage of stones slurry waste (SSW). The two sets of samples were tested for the unconfined compressive strength at two different percentages of water content (first set) and cutting stones slurry (second set) and at three different initial dry densities. Additionally, the effect of mixing the soils with cutting stone slurry waste on the plastic index, dry densities and optimum water contents were studied. Results indicated that mixing the clay soil with cutting stone slurry waste increased the max dry density, and decreased the optimum water content percent and the plasticity index. Also, both unconfined compressive strength and the modulus of elasticity of the soil was improved significantly due to the addition of stone slurry waste to the tested soil.
Keywords: Maximum dry density, Plasticity index, Shear strength, Clay, Slurry waste

1. INTRODUCTION

In many countries of the world, the building stones which is obtained from rocks have became a major industry in the construction field. These building stones are extracted from the different types of rocks. The most common building stone is the limestone which is obtained from sedimentary rocks. Other types of rocks also used intensively in the construction industry such as granite and marble which are obtained from igneous rocks and metamorphic rocks respectively.

In order to shape the stones according to the standards and specifications, it has to go through a special treatment and process. This process requires a huge amount of water to cool a special sew to facilitate and accelerate the separation of stone blocks from parent rock (i.e. cutting process). This procedure consumes a huge amount of water and produce high percentage of fines during the cutting process from the original rock. Those fines are mainly limestone, marble and granite. At the end of the day, a huge amount of stone-slurry-waste is produced in the cutting stones factories with no specific regulations in dealing with this type of waste. The municipality prevents the cutting stones factories to connect their sewage system with the public system resulting in a daily dumped of the waste in open urban areas or in agricultural lands causing serious environmental problems.

Many materials have been used to strengthen and stabilize the soft and weak soils. These materials like cement, lime mud, oil-shale, fly ash, fibers, and other industrial solid waste materials has been investigated experimentally (Yetimoglu and Salbas 2003, Bahar et al. 2004, Bujang et al. 2005, Eroglu et al. 2006, Turner 1994, Reyes and Pando 2007, and Attom and Al-Sharif 1998). The result of these studies showed that the soil could gain more strength when mixed with the above materials.

Because of the cheap and the availability of the cutting stone-slurry-waste which is mostly contain a limestone fines, this material could be used as a new stabilizing material. The use of cutting stone slurry waste in soil stabilization could lead to a low-cost construction for the local construction projects and provide an environmental friendly means of disposal of this material.

Previous studied showed that the effect of lime on unstable sub-grade reduced the maximum dry density and plasticity index Hieckel (1997). Lime was also found to increase optimum moisture content, compressive strength and immediate bearing value of sub-grade soils. Eroglu et al. (2006) studied the using of lime mud as soil stabilization agent for forest road. The results indicated that there is a decrease in liquid and plastic limits of the soil with increasing lime mud percentage in the soil.

Many waste materials have been studied and recommended to be used in soil stabilization such as blast furnace slag, fly ash, rich husk ash, and cement kiln dust. Mixing any of these solid wastes with soft and/or weak soils with the predetermined percentages has significantly improved the soil physical engineering properties and reduces or eliminated the problems associated with it.

This paper presents the results of a mixing three types of clayey soils with cutting stones slurry wastes. The clayey soils were mixed with cutting stone slurry wastes at different percentages with different initial physical properties. Compaction, Atterberg's limits and unconfined compression tests were conducted on these samples. The following sections present the experimental program and results and the conclusion of these tests.

2. MATERIAL AND METHODS

The experimental program was conducted on three types of soils selected from different construction sites. The selection was based on the plastic index and clayey content. To avoid the effect of organic matter, the soils were obtained from a depth of 1 meter below the ground surface. American Standard for testing and Materials (ASTM) laboratory tests were carried out such as compaction, Atterberg's limits, and particle size distribution to determine the initial physical properties of the soils. Table 1 presents the engineering properties of the three types of clayey soil used in this research.

Chemical and mineralogical properties of cutting stone slurry waste have been investigated by Colombo et al. (2005). The chemical analysis indicated that the Silica, Alumina, and Calcium oxide are the predominant components of the cutting stone slurry wastes. (Al-Julani 2007) indicated that the cutting stone-slurry waste material has been classified as silty-sand (SM) with 63% natural moisture content, according to Unified classification System (Al-Julani 2007). More details about chemical and mineralogical properties of cutting stone slurry waste used in this study can be found in Al-Julani (2007).

2.1. Preparation of Specimens and Testing Procedures

Three laboratory tests consisting of Atterberg's limits, standard proctor compaction, and unconfined compressive strength tests were conducted on the three selected soils (soil_1, soil_2 and soil_3). The Atterberg's limits (liquid limit and plastic limit) were found by natural water and by using cutting stone slurry waste. Also, the standard proctor density test was conducted to find the maximum dry density and the optimum water content by using the same procedures. After the determination of maximum dry density and optimum water content for both treated and untreated soils six specimen from each types of soil were prepared in the unconfined compression standard mold. For each type of soil two identical samples (treated and untreated) were prepared at three initial different conditions. The identical samples were prepared at the optimum, at the dry side and at the wet side of the optimum. Table 2 presents the testing program conducted in this research. The table indicated that identical samples of un-stabilized and stabilized soil specimens have been prepared and tested for unconfined compressive strength. The prepared samples were then sealed with plastic cover to prevent any moisture loss. Unconfined compression test (ASTM D-2166) was conducted on the two set of samples.

3. RESULTS AND DISCUSSION

3.1. Compaction Test

The standard proctor density test was conducted to study the effect of the cutting stone slurry waste on the maximum dry density and optimum moisture content of the soil. Figure 1 shows the results of cutting stone slurry waste on the compaction curve. It is clear that, the addition of cutting stone slurry waste resulted in increasing the maximum dry density and reduced the optimum water content for all the three soil types. The increase in the maximum dry density can be attributed to fine content in the slurry which fills the voids in the soil resulting in increasing the maximum dry densities. In the meantime most of these fines silica (about 52%) which has high specific gravity. This high specific gravity of the fine tends to increase the maximum dry density of the treated soils.

Table 1. Laboratory tests on soil engineering properties and classification

Soil ID	Atterberg limits (%)			Grain fractions (%)			Compaction		Activity	Classification (USCS)
	LL	PL	PI	Sand	Silt	Clay	$\gamma_{d\ (max.)}$	O.W.C		
Soil-1	81	29	52	5	33	62	13.1	39	0.83	CH
Soil-2	70	45	35	18	37	45	14.4	29	0.55	MH
Soil-3	38	16	22	20	43	37	15.2	22	0.59	CL

Note: $\gamma_{d\ (max.)}$ is in kN/m^3

Table 2. Test samples configuration scheme for both stabilized and unstabilized soil

Soil ID	**Soil-1**			**Soil-2**				**Soil-3**			
Sample group	**S11**	**S12**	**S13**	**S21**	**S22**	**S23**	**S24**	**S31**	**S32**	**S33**	**S34**
γ_d **(kN/m^3)**	**13.5**	**13.5**	$\gamma_{d(max)}$	**12**	**13**	**14**	$\gamma_{d(max)}$	**12**	**13**	**14**	$\gamma_{d(max)}$
w_c **(%)**	**23**	**33**	**O.W.C**	**20**	**20**	**20**	**O.W.C**	**20**	**20**	**20**	**O.W.C**
SSW_c **(%)**	**23**	**33**	**O.W.C**	**20**	**20**	**20**	**O.W.C**	**20**	**20**	**20**	**O.W.C**

Note: $\gamma_{d\ (max.)}$ is in kN/m^3, w_c= water content percent, and SSW_c = stone-slurry-waste content percent

The maximum dry density increased from 15.2 to 15.6 kN/m^3, from 14.4 to 15.2 kN/m^3, and from 13.1 to 13.64 kN/m^3 for soil-1, soil-2 and soil-3 respectively. Also Figure 1 indicted that the optimum moisture content decreased as the soil treated with cutting stone slurry waste. The optimum moisture content percent decreased from 39.1 to 36, from 29 to 23, and from 22 to 20 for soil-1, soil-2 and soil-3 respectively. Figure 2 shows the increase of the maximum dry density and the reduction in optimum water content for the three types of clayey soils due to the addition of the cutting stone slurry.

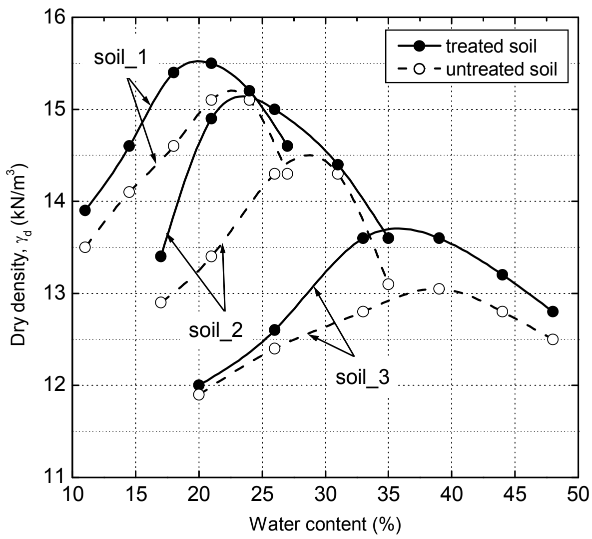

Figure 1. Water content-dry density relationship for the three soil types, both treated and untreated

3.2. Atterberg's Limits

The consistency limits- liquid limit and plastic limit - were determined for three types of soils using natural water and cutting stone slurry waste. The test was conducted in accordance of American Standard for Testing and Materials (ASTM – D-4318). Figure 3 depicts the effect of cutting stone slurry waste on the liquid limit and plastic limit for the three soils. It is obvious that the addition of cutting stone will reduce the liquid limit and the plastic index. This reduction is clearer in soil-1 which has high liquid limit and classified as CH soil. The reduction decreases with increasing the liquid limit of the soil. The percentages in liquid limit reduction are 56% for soil-1 and 30% for soil-3. This reduction in liquid limit is attributed to the addition of the fine in cutting stone slurry waste which has no plasticity resulting in reducing the liquid limit. Also form the same figure the plasticity index decrease for the three types of soil. The reduction in plasticity index gives a good indication to use the cutting stone slurry waste as a stabilizing agent. The lower plasticity index implies that some other physical properties of the soil such as swelling, compressibility, shrinking will be improved.

3.3. Unconfined Compression Test

Identical treated and untreated specimens were prepared and tested for the unconfined compressive strength. Figure 4, 5, and 6 show the effect of cutting stone slurry waste for soil-1, soil-2 and soil-3 respectively. In these three figures, the stress-strain relationship were recorded and plotted for all the tested samples. On each figure there are six curves for treated and untreated specimens; two at the optimum water content, two at the dry side and two at the wet side of the optimum. It is clear from these figures that the use of cutting stone slurry waste increased the unconfined compressive strength for all three soils at any density. The effect of cutting stone is clearer for the specimens prepared at optimum water content and especially for soil with high plasticity (i.e. soil-1).

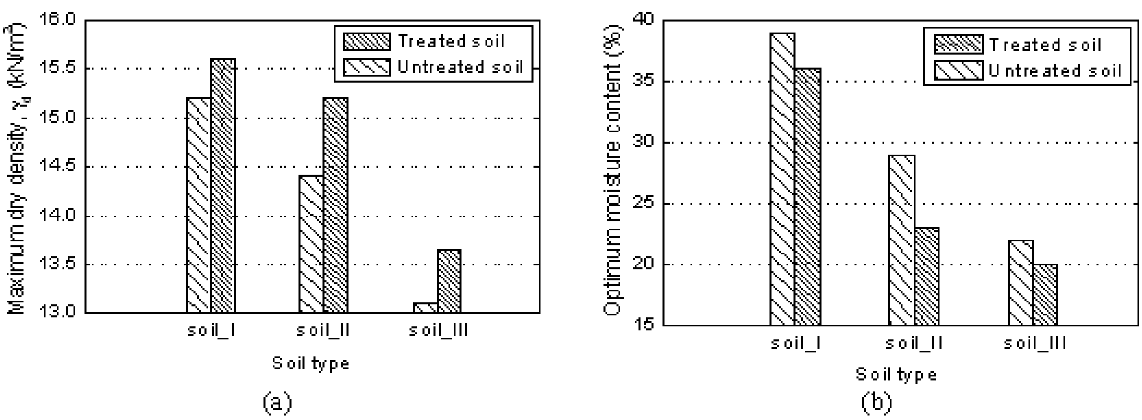

Figure 2. The effect of cutting stone slurry waste on: a) maximum dry density and b) optimum water content

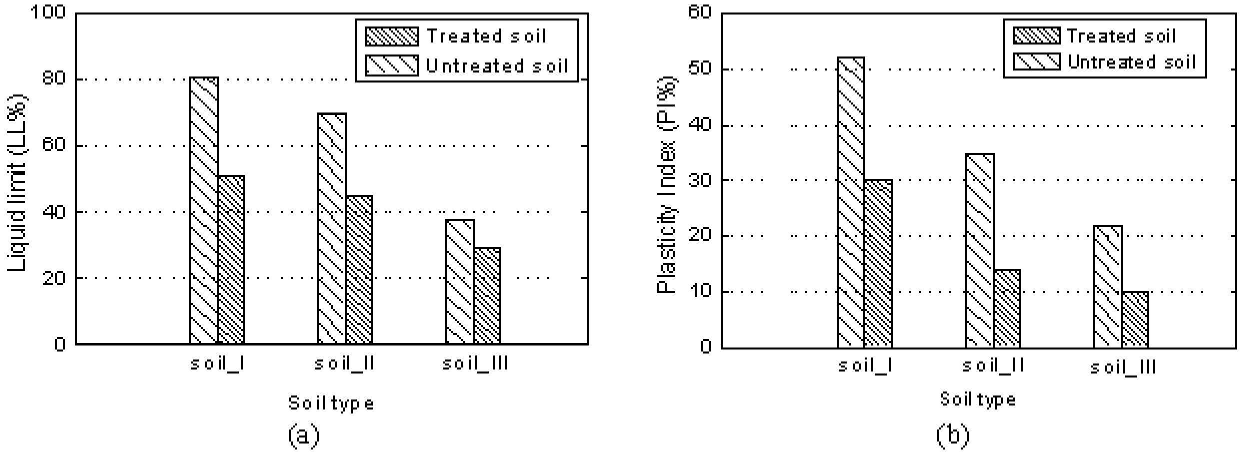

Figure 3. Effect of cutting stone slurry waste on: a) liquid limit and b) plasticity index of clayey soils

The increase in unconfined compressive strength for soil-1 is about 10% due to the addition of the cutting stone slurry waste. Also it is clear from these figures that the unconfined compressive strength for the treated soils is higher in the dry side of the optimum compared to the wet side of the optimum at the same initial dry density. Another important behavior that noticed from these figures is that the strength at the wet side of the treated soils becomes less than the untreated soil at high strain and/or after the peak. This behavior can be explained due to the high water content in the wet side which might develop a repulsive force between the fines resulting in lower strength

4. CONCLUSION

This paper studied the effect of using cutting stone slurry waste on the compaction, Atterberg's limits and the unconfined compressive strength. From the test results on three types of soil mixed with the slurry waste at different initial conditions; the following conclusions may be drawn out:

1. The addition of cutting stone slurry waste increased the maximum dry density and reduces the optimum water content for the soils used in this research.
2. Both the liquid limit and the plastic limit affected by the addition of cutting stone slurry waste. Both limits were decreased with higher reduction noticed in the soil has high liquid limit.
3. The reduction n liquid limits and plasticity index could result in decreasing the swelling pressure and compressibility of the clayey soils.
4. The unconfined compressive strength of the soil increased due to the addition of cutting stone slurry waste. The highest strength was obtained when soils mixed at the maximum dry density and optimum water content.
5. Specimen that has water content at the dry side of the optimum showed higher strength than specimen has water content at the wet side of the optimum at the same initial dry density.

The final conclusion of this research implies that the use of cutting stone slurry waste can be mixed and used with clayey soils. This recommendation reduces the negative environmental effect of this waste and finds a new engineering solution to get rid of this material.

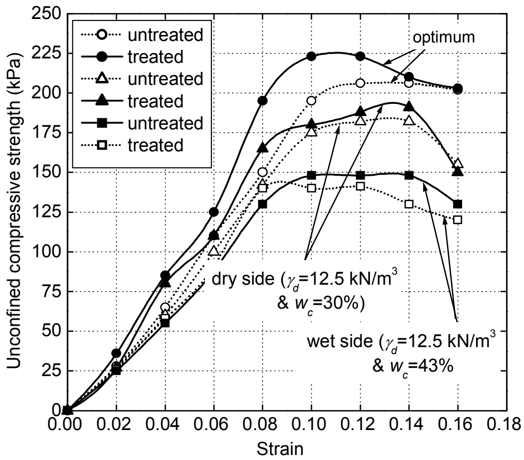

Figure 4. Effect of cutting stone slurry waste on the unconfined compressive strength for soil-1 at the optimum, dry, and wet sides of the optimum

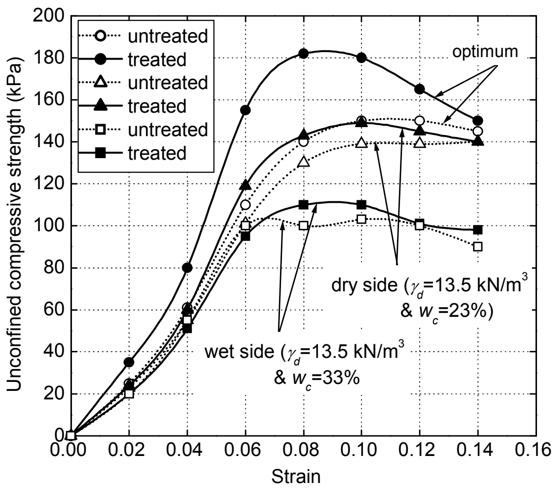

Figure 5. Effect of cutting stone slurry waste on the unconfined compressive strength for soil-2 at the optimum, dry, and wet sides of the optimum

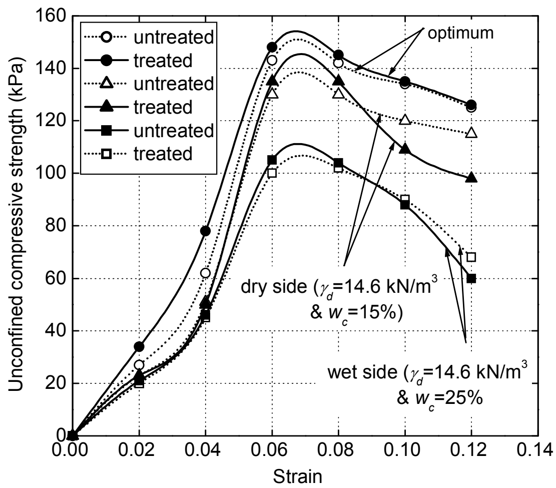

Figure 6. Effect of cutting stone slurry waste on the unconfined compressive strength for soil-3 at the optimum, dry and wet side of the optimum

5. REFERENCES

ASTM, 2000. Standards test method for unconfined compressive strength of cohesive soil. ASTM D 2166-98. West Conshohocken, Pennsylvania: Annual Book of ASTM Standards.

ASTM, 2002. Standards test method for liquid limit, plastic limit and plasticity index of soil. ASTM D 4318-98. West Conshohocken, Pennsylvania: Annual Book of ASTM Standards.

Attom, M.F., Al-Sharif, M.M., 1998. Soil stabilization with burned olive waste. Applied Clay Science, 13: 219-230.

Bahar, R., Benazzoug, M., Kenai, S., 2004. Performance of compacted cement-stabilized soil. Cement Concrete Composite, 26: 811-820.

Bunjan, B.K.H., Shukri, M., Thamer, A.M., 2005. Effect of chemical admixtures on the engineering properties of tropical Peat soil. American Journal of Applied Science, 2(7): 1113-1120.

Colombo, A., Tunesi, A., Barberini, V., Galimberti, L., Cavallo, A., 2005. Chemical and mineralogical characterization of cutting process sludge process. *Exploration of sludge from stone working*, Synthesis of the research, from *www.aigt.ch*.

Edil, T.B., Benson, C.H., Bin-Shafique, M.S., Kim, W., Tanyu, B.F., Senol, A. 2002. Field evaluation of construction alternatives for roadway over soft subgrade. TRB, Washington, DC; National Research Council, p. 36-48.

Eroglu, H., Hulusi, H.A., Ucuncu, O., Imamoglu, S., 2006. Soil stabilization of forest roads sub-base using lime mud waste from the chemical recovery process in alkaline mill. Journal of Applied Sience, 6(5): 1199-1203.

Hiechel, H., 1997. Alternative materials for the modification and stabilization of unstable soils. Laboratory Testing Report, Illinois Department of Transportation, Bureau of Materials and Physical Research Springfield, Illinois, USA.

Miller, G.A., Azad, S., 2000. Influence of soil type on stabilization with cement kiln dust. Construction and Building Materials, 14: 89-97.

Reyes, A., Pando, M., 2007. Evaluation of CFBC fly ash for improvement of soft clays. World of Coal Ash (WOCA) 7-10, 2007, Covington, Kentucky, USA.

Turner, J.P., 1994. Soil stabilization using oil-shale solid waste. Journal of Geotechnical Engineering, 120(4): 646-660.

Winterkorn, H.F., Fang, H.Y., 1975. Foundation engineering handbook. Van Nostrand Reinhold, p. 176.

Yetimogu, T., Salbas, O., 2003. Geotextiles and Geomembranes, 21: 103-110, Elsevier, Netherlands.