SCEgeo CONFERENCE

28th Conference - SURVEYING, CIVIL ENGINEERING, GEOINFORMATION IN SUSTAINABLE DEVELOPMENT
June 2-10, 2020 - Bydgoszcz, Poland

# Some Properties of Clayey Soils Improved with Drinking Water Treatment Sludge

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## INTRODUCTION

One of the main problems in civil engineering concerns the improvement of weak soils that do not meet the mechanical performance required to meet the demands of the construction sector. Generally, geotechnical engineers mix some additional materials into weak soils to give desired properties [1-3]. In some applications, these additional materials can be waste materials. Recently used waste materials in soil improvement are cement [4 ], lime [5], fly ash (FA) [6-7-8], ground granulated blast furnace slag (GGBS) [9], rice husk ash (RHA) [10-11], recycled concrete aggregates (RCA) [12-13], geopolymer based on recycled glass powder (RGP) [14-15], randomly distributed glass fibers (GRC) and recycled glass fibers (RGF) [16-17], kenaf fiber (KFRS) [18] have been used as additives or substituting materials. Drinking water treatment sludge (DWTS), a by-product of the drinking water treatment plant, has become an important issue worldwide within the scope of disposal management. Useful reuse of this waste as a potential alternative material in the construction industry can provide safe disposal [19, 20, 21]. DWTS is used extensively as filler components in construction-based industries. Rodríguez, Martínez-Ramírez, Blanco-Varela, Guillem, Puig, Larrotcha and Flores [22] used in cement clinker production, Hu, Hu and Fu [23] studied on light aggregate production with DWTS, Frías, De La Villa, De Soto, García and Baloa [24] studied on mortar containing DWTS, Tantawy [25] used DWTS in concrete, Benlalla, Elmoussaouiti, Dahhou and Assafi [26] bricks with DWTS. However, due to their increasing amount, these applications are not sufficient to completely consume the produced DWTS. In this respect, this research focused on evaluating the DWTS for clayey soil improvement.

## MATERIALS and METHODS

In the experiments, clayey soil passed from 0.074 mm sieve was used. The liquid and plastic limit values of the soil were obtained as 42% and 24%, respectively. Soil type was classified as clay with intermediate plasticity, according to ASTM D2487 [27]. The DWTS used in this research was taken from Drinking Water Treatment Plant located in Adana City. The water content of DWTS samples used in this study is 85.4 wt%. The amount of volatile matter in the DWTS was found to be low (3.01%). This low volatile matter content can be attributed to the inorganic in nature of DWTS. Also, loss on ignition and ash content were found as 8.78% and 88.79%, respectively. In the experimental process, a consolidation test was applied according to ASTM D2435/D2435M [28] and ASTM D4546 [29] in order to determine of swelling pressure and consolidation parameters.

The first loading for vertical pressure was applied as 0.25 kg/cm2 and consolidation settlements of each sample in the time intervals 0.25, 0.5, 1, 2, 4, 8, 15, 30, 60, 120, 240, and 1440 minutes were recorded. After first loading, 50, 100, 200, 400, and 800 kPa loads were applied on the samples to observe the effect of each loading stage on the consolidations settlements of samples. Each loading level was used to samples for 24 hours. Then an unloading process was performed by decreasing the load to 200 kPa. After this unloading, a vertical pressure of 5 kPa was applied again to observe in increasing data to complete the testing process. Finally, the moisture of samples was measured after the oven-drying process. Swelling pressures, Consolidation coefficients (Cv) and coefficients of volume compressibility (mv) have been determined.

## RESULTS and DISCUSSION

The test apparatus and results of swelling pressure and consolidation parameters were given in Fig. 1. As seen in Fig.1, the swelling pressure was found as 31.3 kPa for 100% clayey soil. The swelling pressures of the clayey soil decreased from 31.3 kPa to 28 kPa by DWTS substitution in the ratios of 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18%, 20% and 22%. According to these results, it was seen that an increase in the ratio of DWTS substitution caused 1.12 times to decrease in swelling pressures. Similar to the swelling pressure, coefficients of volume compressibility (mv) decreased by DWTS substitution (1.59 times decrease). Also, DWTS substitution increased the consolidation coefficients as 1.6 times.

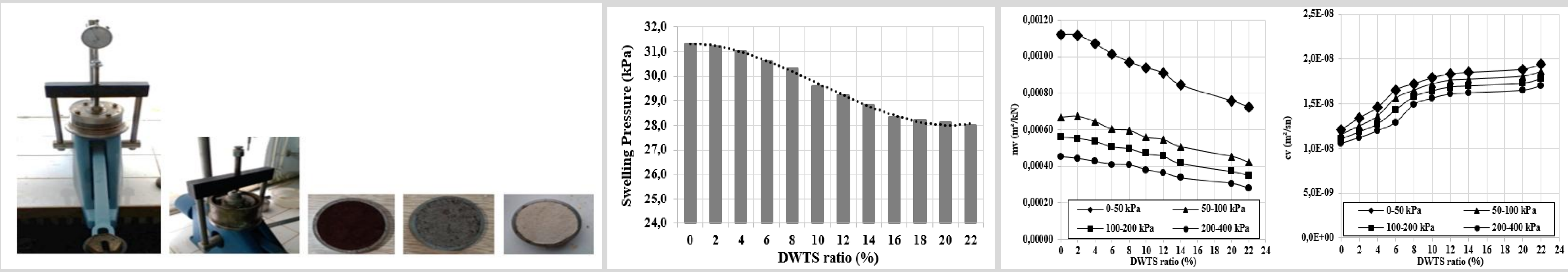


**Figure 1. The Test Apparatus and the Graphs of Swelling Pressure and Consolidation parameters for different DWTS Ratio**

## CONCLUSIONS

I. When DWTS was substituted in the ratio of 22 %, the value of swelling pressure and the coefficient of volume compressibility were decreased as 1.12 times 1.59, respectively. Moreover, the value of the consolidation coefficient increased 1.60 times in the same substitution ratio of DWTS.

II. The increase in the consolidation coefficient indicates that the use of DWTS may be useful to decrease the total consolidation time of soil.

III. The decrease in coefficients of volume compressibility indicates that a remarkable reduction in total consolidation can be achieved by using DWTS.

IV. As a result, it can be interpreted from all findings of this experimental research that DWTS usage in clayey soil may be very useful to decrease deformations of any superstructure constructed on clayey soil.

**This article/material has been supported by the Polish National Agency for Academic Exchange under Grant No. PPI/APM/2019/1/00003**

**Summary:** This paper presents the results of an experimental investigation carried out to study the usability of drinking water treatment sludge (DWTS) for soil improvement. For this purpose, the DWTS was substituted to the mixtures as 2%, 4%, 6%, 8%, 10%, 12%, 14%, 20% and 22% by weight of clayey soil. Consolidation tests were performed on these samples in accordance with standards and swelling pressure, coefficients of consolidation, and coefficients of volume compressibility were determined. Results showed that the increase in the ratio of DWTS substitution caused 1.60 times increase in the coefficient of consolidation and 1.59 times a decrease in the coefficient of volume compressibility. Swelling pressures decreased by 1.12 times with DWTS substitution.

**Keywords:** Soil improvement, Drinking water treatment sludge, Swelling pressure, Consolidation parameters.

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