Settlements of lime treated sand bentonite mixtures

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ABSTRACT: Waste management is one of serious issues due to the excessive increase in population, industrial grow and therefore increase in waste products. Disposing of waste in a landfill is the most applicable and preferred method in developed countries, and it is important to design the landfill area in the manner that soil, air and underground water are not affected by contamination. This study considers the usage of industrial waste materials in the base of disposal areas in order to reduce the amount of waste products and improve the barrier material properties. The improvement of bentonite-sand mixtures as barrier material in waste disposal areas has been experimentally studied by lime treatment. Consolidation tests are done in order to investigate settlement properties and hydraulic conductivity of the mixtures. Mixtures mentioned consist of 100 % bentonite (B), 60 %bentonite – 40 % sand (BS40) , 50 % bentonite – 50 % sand (BS50), 40% bentonite – 60 % sand (BS60) in order to determine proper bentonite amount in barrier material, generally proposed to be between 20 – 50 %. Although no significant difference in settlement and compressive strength occurs by changing bentonite amount, BS50 has been chosen to be treated with lime based on the experimental results. Consolidation tests were done to the mixtures which consist of sand, 50 % bentonite and 2 % or 4 % lime. Results showed that settlement and hydraulic conductivity of the samples have decreased with lime treatment but situation is reversed with increased lime amount.

1 INTRODUCTION

Ascending life standards worldwide bring out the consequences to deal with as the effect of human on nature grows with all technological and industrial improvements. As amount of products used increase and the term of usage decrease, consumption rate cannot get as fast as production, resulting in excess amounts of waste products and consequently waste management becomes one of the most serious issues. Disposing of waste in a landfill is the most applicable and preferred method in developed countries since the method does not bring out new waste products and is a permanent solution. However when application is not right, there is a big chance of serious danger for the environment to occur, thus it is important to design the landfill area in the manner that soil, air and underground water are not affected by contamination. It is essential to control the interaction between environment and waste material; especially to prevent underground water from contamination should be considered before designing the landfill. Therefore, an impermeable layer at the base of disposal area is constructed with various materials. Properties of the material to be used as barrier in waste disposal areas are and determined by regulations. Generally proposed hydraulic conductivity value is not bigger than $1x10^{-8}$ m/s, which may differ for various types of waste products and territories. Clay is preferred frequently due to low permeability characteristics and is generally applied with other natural or produced materials. Bentonite-sand mixtures were widely used in the last few years, with alternatives such as geosynthetic clay liners or geomembranes. In this study, the material to be treated is chosen to be natural or naturally produced without bringing out any new waste products, and is determined considering previous studies. Al-Rawi and Awad (1981) stated that lime-treatment of sandy silt samples result in increasing hydraulic conductivity in contrary with lime treated sand which showed significant decrease in hydraulic conductivity when compacted above optimum water contents. Similar results about compaction were gathered by Haug and Wong (1992) where compaction of lime treated bentonite-sand mixtures at optimum water content resulted in hydraulic conductivity to increase. When specimens compacted 1-2 % above optimum water contents, hydraulic conductivity of them decreases. The aim of this study is to investigate the improvement of bentonite-sand mixtures through laboratory tests to be used as barrier material in waste disposal areas considering the usage of industrial waste materials in order to reduce the amount of waste products and increase the barrier material properties.

2 EXPERIMENTAL WORK

In this study, consolidation tests are carried out in order to investigate settlement and permeability of prepared samples, to analyse their applicability as barrier materials. Bentonite clay classified as CH with liquid limit of 116 and a dry unit weight of 14.6 kN/m^3 is used in the mixtures with sand and lime. Swelling of the bentonite is investigated and it showed very low, insignificant amount of swelling therefore amount of bentonite in the mixtures is determined to be higher than general. The sand used is sieved from standard #40 sieve to eliminate finer grains and to acquire more uniform mixtures. Specific gravities of sand including mixtures showed that sand addition increased unit weight of the mixtures. Standard Proctor tests are done in order to obtain maximum dry unit weights and optimum water contents and to prepare consolidation test samples. Standard Proctor results of the mixtures prepared are given in Figure 1. In the figure, B50L2 means that the mixture consists of 50% bentonite, 48% sand and 2% of lime. B50L4 mixture consists of 50% bentonite, 46% sand and 4% lime. Apart from 100 % bentonite, no distinct changes occur in maximum dry unit weights and optimum water contents with any sand or lime treatment.

Mixtures are prepared progressively to determine suitable percentages of bentonite and lime. First series of the mixtures consist of 100 % bentonite (B), 60 % bentonite – 40 % sand (BS40) , 50 % bentonite – 50 % sand (BS50), 40 % bentonite – 60 % sand (BS60) in order to determine proper bentonite amount in barrier material, generally proposed to be between 20 – 50 % in previous studies. After standard Proctor test results, specimens for odometer tests are prepared considering previous studies, compacted with water content of about 2 % above the optimum. Consolidation test results are given in Figure 2. Although no significant difference in settlement and compressive strength occurs by changing bentonite amount, BS50 has been chosen to be treated with lime based on more stable attitude and low permeability value. Various studies exist about lime treatment of soils, offering a small range of lime percentage for different aims and applications. Lime amount in soils is proposed above 2 % by Galvao et al.(2006) since less than 2 % causes hydraulic conductivity to increase depending on aggregation of lime while further addition causes decreasing in hydraulic conductivity. Kumar et al. (2007) similarly stated that appropriate lime percentage is determined between 2 to 8 percent, as Khattab et al. (2007) gathered the most positively effective results at 4 % lime additive. Abdelmadjid and Muzahim (2008) state that optimum addition of lime is 6 %. Since similar studies applied on clay type materials investigating similar properties generally recommend most effective lime percentage range between 2 to 8, the mixtures with constant 50 % bentonite and 2 % and 4 % lime and sand are prepared to be used in standard proctor and odometer tests. Results are compared with BS50 in order to investigate the lime effect.

3 EXPERIMENTAL RESULTS AND DISCUSSIONS

As expected, standard proctor tests showed that the sand amount increase in bentonite-sand mixtures causes a rise in dry unit weight of the composed material, while increasing lime amount decreased unit weight of the mixtures. Standard proctor test results showed that bentonite-sand ratio is not significantly effective on compressibility of the mixtures between 40 to 60 percent. As seen in Figure 1, optimum water contents of BS50, B50L2 and B50L4 are 20, 22 and 25, respectively.

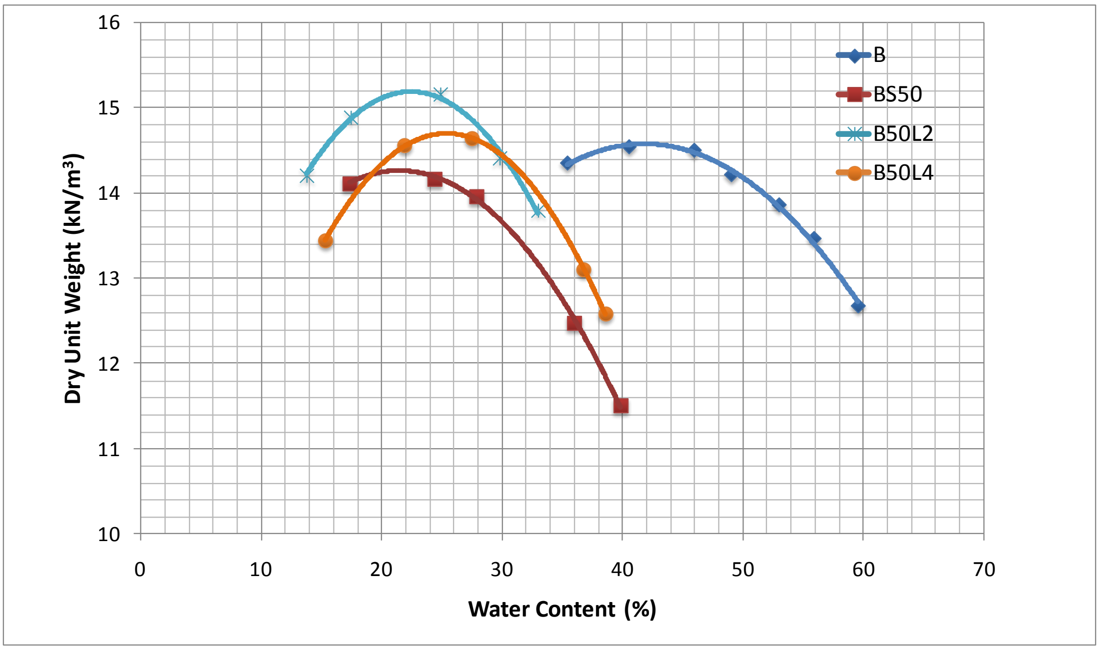

Figure 1. Standard proctor test results of the mixtures.

Using odometer test results, settlement characteristics and hydraulic conductivities of the mixtures are calculated. Using consolidation test results, hydraulic conductivity (k) values are calculated using coefficient of consolidation. Consolidation curves of bentonite-sand mixtures are given in Figure 2. Hydraulic conductivity values of B is 6.41×10^{-9} m/s and without significant correlation with loading stage. BS50 has nearly the same hydraulic conductivity as B which is 6.98×10^{-9} m/s.

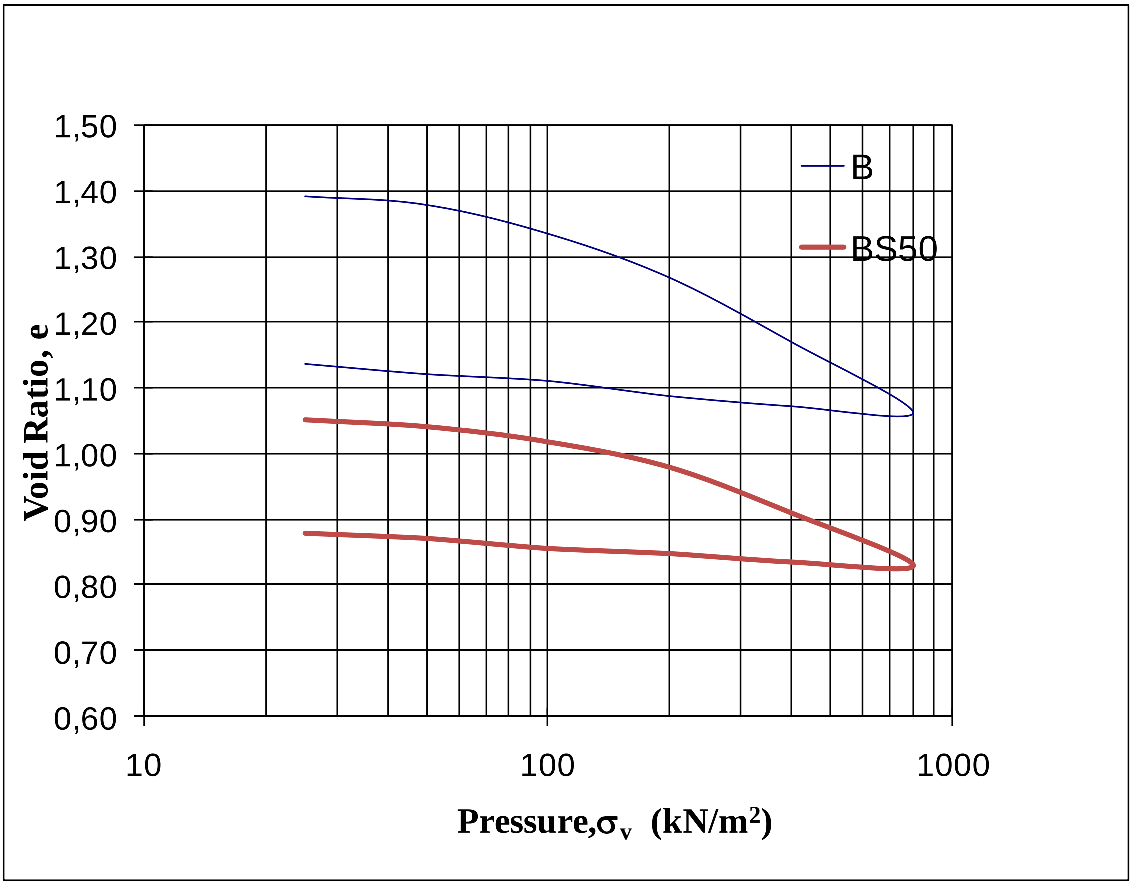

Figure 2 Consolidation results of bentonite and a bentonite-sand mixture.

Results of each bentonite-sand mixture can be defined as similar since there is no significant change in hydraulic conductivities with changing bentonite amount between the ranges of 40 to 60 percent, also can be stated that increasing bentonite amount decreases hydraulic conductivity, as expected. Results are similar to those from Chapius (1990) who noted that ascending bentonite amount brings out decreasing hydraulic conductivity value. Total settlements of B and BS50 for 800 kPa loading stage are 2.36 mm and 2.33 mm respectively from the consolidation tests done on 20 mm high samples. Depending on the results, BS50 is chosen to be treated with lime based on low hydraulic conductivity properties, low settlement capacity and relatively consistent attitude without unexpected rises or falls.

However, effect of lime treatment is obvious from standard proctor tests in both optimum water content and maximum dry unit weight values when compared with BS50 as shown in Figure 1. Adding 2 % lime in bentonite-sand mixtures increase maximum dry unit weight and increase optimum water content but increasing lime amount to 4 % seemed to decrease maximum dry unit weight and increase optimum water content.

Consolidation tests results for bentonite-sand-lime mixtures are given in Figure 3. Hydraulic conductivities of 2 % and 4 % lime treated mixtures are calculated using the same method and compared between them and with BS50. For B50L2, hydraulic conductivity value is calculated as 3.01×10^{-9} m/s, which is lower than BS50 with 6.98×10^{-9} m/s value. B50L4 consolidation test results are not very different from B50L2 with a hydraulic conductivity value of 2.28×10^{-9} m/s. Settlements of the 20 mm thick samples are 1.10 mm, 0.73 mm for B50L2 and B50L4 respectively. Compared to BS50, the effect of lime treatment decreases settlement that the samples undergoes and the hydraulic conductivity decreases.

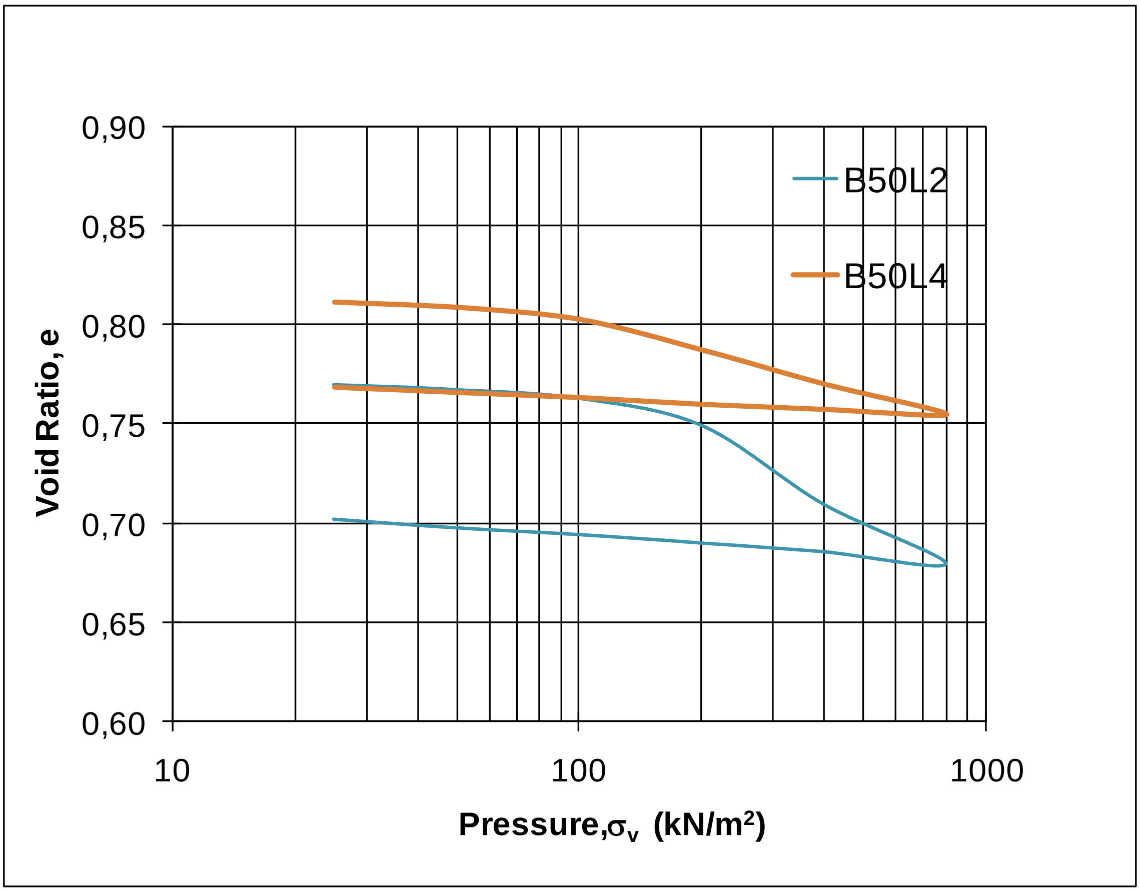

Figure 3. Consolidation results of bentonite-sand-lime mixtures.

4 CONCLUSIONS

Lime stabilised bentonite-sand mixtures resulted in lower hydraulic conductivity values and lower volumetric change with respect to bentonite-sand mixtures. Compared to previous studies, calculated hydraulic conductivity values for sand-bentonite mixtures are not as low, as Tashiro (1998) achieved hydraulic conductivity results between $8.2x10^{-13}$ m/s to $4.2x10^{-12}$ m/s for 30 % bentonite including sand-bentonite mixtures. Komine (2004) acquired values between $6.87x10^{-12}$ to $1.21x10^{-12}$ for 30 % to 50 % bentonite including sand-bentonite mixtures and Kaya et al. (2006) gathered $4.81x10^{-11}$ m/s hydraulic conductivity value for sand-bentonite mixtures with 30 % bentonite, which is probably due to type and index properties of bentonite used. However, effect of lime in decreasing hydraulic conductivity is obvious when compacted 2 % above optimum water content, giving the lowest value at 4 % lime content. Unlike previous studies mostly stating lime treatment increase hydraulic conductivity at lower percentages but decrease it when added above a certain amount, 2 % lime content lowered hydraulic conductivity value from $6.98x10^{-9}$ m/s to $3.01x10^{-9}$ m/s, when adding more lime similarly caused hydraulic conductivity to continue to decrease. Settlement properties also gave improved results when lime treated, decreasing amount of volumetric change. Generally, lime treated sand-bentonite mixtures gave hydraulic conductivity results within determined limits and is considered appropriate to be used as barrier materials in waste disposal areas. Previous studies of Khattab et al. (2006) stated that industrial waste lime generally improves engineering properties of soils and is applicable for roads and earth fills. Therefore, use of lime in waste disposal areas as barrier material would not just improve properties of barrier material but also reduce the amount of waste products, reducing waste product amount when lime is considered as industrial waste product.

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