Effect of wetting- drying cycles on CBR values of silty subgrade soil of Karaj railway

Effet des cycles d'humidification et séchage sur les valeurs CBR des sols de limoneux de fondation de la voie ferrée Karaj

Moayed R.Z., Lahiji B.P.
Imam Khomeini International University, Qazvin
Daghigh Y.
Azad University of Karaj, Karaj

ABSTRACT: In this research we have investigated the effect of lime-microsilica additive as a modern additive stabilizer on a silty soil and have evaluated the wetting- drying cycles on it. Thus, for this purpose and also to observe their usage on a practical project, we have taken some samples from bed soil of a region of Karaj railway in Iran, to improve its strength and use it as a railway subgrade. Lime and microsilica in different percentage of dry soil weight were mixed with the soil at the soil optimum moisture. Then after 28 days curing time, to create saturated condition, they were put in water for 96 hours under a surcharge load of 10 pound (4.5 kilogram). Then California Bearing Ratio (CBR) tests were conducted in order to find the best additive that have the maximum effect on soil strength. In the next step, to observe the effect of wetting- drying cycles on the stabilized soil, several specimens which shows the desired CBR value (from an economic and resistance viewpoint) were rebuilt and were exposed to wetting- drying cycles. Results showed that the CBR values were greatly increased as the soil was stabilized with lime- microsilica additive. In addition, an increase on the CBR values of the stabilized soil by wetting- drying cycles was observed. Results showed that lime- microsilica additive can successfully be considered as a suitable option to stabilize silty soils.

RÉSUMÉ : Dans cette recherche, nous avons étudié l'effet d'un additif de chaux et microsilice en tant que stabilisateur moderne sur un sol limoneux et avons évalué l'effet des cycles de humidification-séchage. Ainsi, dans ce but, et afin d'observer aussi leur utilisation sur un projet concret, nous avons pris des échantillons de sol de la région du chemin de fer de Karaj en Iran, pour en améliorer la résistance et pouvoir l'utiliser comme une plate-forme ferroviaire. La chaux avec microsilice a été mélangée avec le sol à sa teneur en eau sol optimale à différentes teneurs en pourcentage du poids du sols sec. Puis, après 28 jours de temps de prise, les échantillons ont été mis dans de l'eau pendant 96 heures sous une surcharge supplémentaire de 10 livres (4,5 kg), afin de créer des conditions saturées. Des tests CBR tests ont été ensuite effectués afin de trouver le meilleur additif vis-à-vis de la résistance du sol. Dans l'étape suivante, afin d'observer l'effet des cycles d'humidification séchage sur le sol stabilisé, plusieurs spécimens ayant la valeur souhaitée de CBR (d'un point de vue économique et mécanique) ont été reconstitués et exposés à des cycles d'humification et séchage. Les résultats ont montré que les valeurs de CBR ont été considérablement augmentées pour les sols stabilisés avec l'additif de chaux et microsilice. En outre, une augmentation des valeurs de CBR du sol stabilisé par les cycles d'humidification séchage a été observée. Ces résultats ont donc montré que l'additif de chaux et microsilice peut avec succès être considéré comme une option appropriée pour stabiliser les sols limoneux.

KEYWORDS: Stabilization, Lime, Microsilica, CBR, Wetting - Drying Cycles.

1 INTRODUCTION

Increasing the bearing capacity of weak soils is always one of the most important issues in civil engineering projects especially in road construction. Silts are one of the problematic soils which are needed to be replaced with suitable material or improved by various improvement methods like compaction and stabilization. Silt is a kind of sedimentary geomaterial consisting primarily of very fine particles, including fine sand particles, silt particles, and some clay particles which are often less than 10% by weight. Silt is a type of transitional soil between sand and clay. A soil is defined as silt if its plasticity index is no greater than 10 and the amount of particles greater than 0.075 mm is no greater than 50% of the total.

Silty soils aren't considered as suitable materials in civil engineering projects due to their low cohesion and friction angel. Using the soils as a road or railway subgrade is generally not possible without stabilization as their characteristics fall below the minimum required. Consequently, stabilization is needed for this kind of soil. Application of stabilizing agents on soils has a long history. Cement was first used as stabilizing agent at the beginning of the twentieth century to mix with soils and form road materials in the United States. Since then, many other kinds of materials, such as lime (Bell 1996) and special additives such as Pozzolanic materials like Fly Ash (Dermatas and Meng 2003), Microsilica (Abd El Aziz 2003), and Rice Husk Ash (Choobbasti et al 2010), which are as waste material, may be used for soil improvement. Most of the existing stabilizers like lime and cement are not much useful for silts, so the stabilized silts with such kind of stabilizing agents usually cannot satisfy the requirements of road construction. The encountered problems mainly are lower early strength, greater shrinkage, easy cracking, and bad water stability (Bell 1996), (Sheng and Ma 2001).

Indeed, a successful stabilization method depends on many factors such as:

(1) Soil type and properties; (2) stabilizing agent; (3) Stabilizer content; (4) Potential use of the stabilized soil; (5) Field mixing method; and (6) Economical considerations (Mohamedzein et al, 2003).

Therefore, new methods are still being researched to increase the strength properties of silty soils. In this study we evaluate the feasibility of using stabilized silt with microsilica and lime for Karaj railway subgrade in Iran.

Microsilica (or silica fume) is one of the by- product materials which is obtained from silicon material or silicon alloy metal factories. It was discharged into the atmosphere by the factories smoke before the mid-1970s. Nowadays each year nearly 100,000 tons of microsilica is produced on purpose word wide (Karimi et al, 2011). Iran also has a large amount of microsilica production. Although the microsilica is a waste material of industrial applications, it has become the most valuable by-product among the pozzolanic materials due to its very active, high pozzolanic property and very fine particles. These particles are approximately 100 times smaller than the average cement particle (Karimi et al, 2011).

In previous studies, there have been many researchers investigating the effects of microsilica on the strength and swelling characteristics of clayey soils were investigated. It was seen that microsilica improved the properties of clayey soils (Kalkan, 2009, Kalkan, 2011, Abd El-Aziz et al, 2004, McKennon et al, 1994). Likewise, recently, the effects of microsilica and lime have been investigated on CBR values of sand (Karimi et al, 2011), (Kalkan, 2009, Yarbasi et al, 2007). So their effects on cohesionless soils especially silts aren't investigated enough yet. Therefore our aim in this study is to evaluate the feasibility of using stabilized silt with microsilica and lime for a railway subgrade and then evaluate the effect of wetting - drying cycles on the soil resistant.

2 MATERIALS

2.1 *Soil*

The silt used in this research was obtained from an area in Karaj railway project in Iran. Atterberg limits tests were carried out according to ASTM D 4318. The soil Plasticity Index (PI) was obtained 2. The soil was classified as a low plasticity soil according to the unified soil classification system ASTM D 422 - 87. The soil name is ML according to USCS (silty soil with low plasticity). The soil classification is shown in Figure 1.

2.2 *Lime*

Quick lime which was used in this experiment was obtained from the industrial group Qom-Iran limestone and its chemical composition is shown in Table 1.

2.3 *Microsilica*

Microsilica has been obtained from Ferroalloy Industrial Co (I.F.I) in Azna. The composition of microsilica mineral is shown in Table 2.

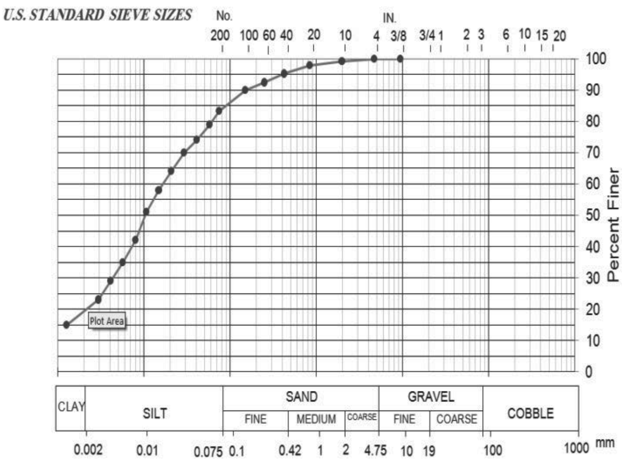

Figure 1. Grain size distribution curve of the silty soil

Table 1. Chemical properties of lime

Chimical names	Percentage
K_2O	4
SO_3	0.8
MgO	2.65
CaO	51.64
Fe_2O_3	0.13
$Al2O_3$	0.24
SiO_2	1.36

3 EXPERIMENTAL PROGRAM

3.1 *Tests procedure*

To evaluate the effects of lime- microsilica on CBR values of stabilized silty soils, first the optimum moisture of soil was calculated from compaction test. Then the soil was mixed with various contents of lime and microsilica at the soil optimum moisture. Then the oven- dried soil was sieved from sieve #4 and lime and microsilica were added into them in 1, 3 and 5% for lime and 2, 5, 8 and 12 percent of dried soil weight for microsilica. Required amount of water was added to the mixture to obtain soil optimum moisture, beyond. Time and attention were paid to provide homogenous soil additive mixture samples. The CBR tests were carried out on samples which were cured for 28 days after 96 hours immersing according to ASTM D 1883 - 99. And at the end, several wetting- drying cycles were conducted to the optimum mixture of samples which was economic and had proper CBR values to evaluate the effect of the cycles on them.

Table 2. Chemical properties of microsilica

Chimical names	Percentage
MgO	0.5~2
CaO	0.5~1.5
Fe_2O_3	0.3~1.3
Al_2O_3	0.6~1.2
SiO_2	90~95
C	0.2~0.4
Na_2O_3	0.3~0.5
SiO_2	0.04~0.08
MO	0.02~0.07
P_2O_5	0.04
Moisture	0.01~0.4
PH	6.6~8.8

3.2 *Compaction tests*

To determine the soil optimum water content and the soil maximum dry unit weight, the modified compaction tests were carried out according to ASTM D 1557 – 91. For this purpose, the oven- dried soil passing sieve #4 was compacted in five layers by 56 blows with 4.5 Kg hammer from 45 cm height in 6- inch mold according to procedure C from respective standard test method.

3.3 *California bearing ratio (CBR) Tests*

The California Bearing Ratio (CBR) test is one of the most widespread tests to determine strength and bearing capacity of base, sub- base and subgrades for use in road, railway and airfields pavements. To demonstrate the influence of lime-microsilica additive on the bearing ratio of the silty soil, a series of bearing ratio tests were carried out on stabilized and unstabilized specimens. The tests were conducted according to ASTM D 1883 – 99. The soil with different mixtures of lime and microsilica were compacted in 6" modified proctor mold in five layers by 56 blows in per layer at the soil optimum moisture obtained from compaction tests. For curing the samples, they were placed in constant moisture and temperature for 28 days. To conduct the tests in soaked condition, they were immersed in water for 96 hours under the 4.5 Kg (10 pound) overload according to standard test method. The CBR tests were carried out after 20 minutes to drain the samples. Meanwhile swelling potential changes were measured during the soaking time.

3.4 *Wetting - drying tests*

After performing the CBR tests, one mixture was chosen as a desired sample from an economic and resistance viewpoint. To evaluate the effect of wetting-drying cycles on strength of selected sample, CBR tests were taken. The desired sample was rebuilt three more times in the same previous condition on 6-inch CBR molds. The samples were subjected to wetting-drying cycles after 28-day curing time and required 96 hours for soaking. The samples were placed in room to air-dry after soaking for 24 hours. Then they were again submerged in water for next 24 hours and thus to expose to one wetting-drying cycle. This process was repeated 3 and 5 times for samples; Then CBR tests were carried out on them.

4 RESULTS AND DISCUSSION

4.1 *Compaction tests*

Compaction tests were carried out on the silty soil. The soil optimum moisture and the soil maximum unit weight were found to be 14.2% and 17.2 KN/m3 respectively. Compaction tests results are drawn in Figure 2.

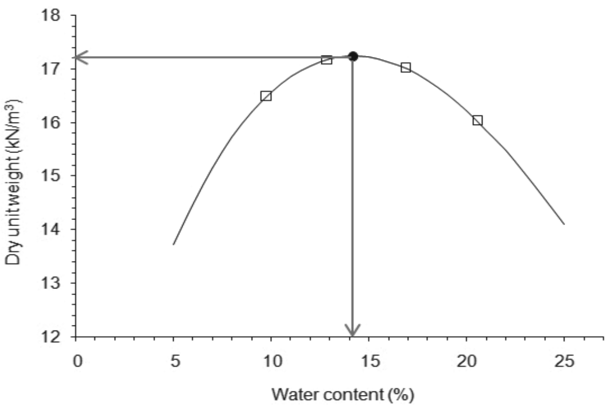

Figure 2. Compaction test curve

4.2 *Effect of additives on the CBR*

To compare the soil resistant with different amount of additive, a series of samples were prepared in modified proctor mold. The CBR tests were conducted in both stabilized and unstabilized silty soils at the soil optimum moisture with different amount of lime and microsilica. The CBR value of the unstabilized soil was 4.8%. The effect of various amount of additive on CBR values of samples are shown in Figure 3.

From Figure 3, it can be observed that in low amount of lime (1 percent of dry soil) increase in microsilica amount up to 8% causes increase in CBR values and then decrease but for 3% and 5% lime increase in microsilica amount causes increase in CBR values. The maximum CBR value of the samples was occurred in 5% lime and 12% microsilica. CBR value in this composition was increased from 4.8% for unstablized soil to 470.8% for the stabilized soil. So it is seen that up to 466% increase in CBR value of stabilized soil in compare of unstabilized silty soil.

In addition, it is observed that the dry unit weights were increased by adding the lime-microsilica additive to samples and samples moistures were decreased by adding the lime-microsilica additive to them in overall.

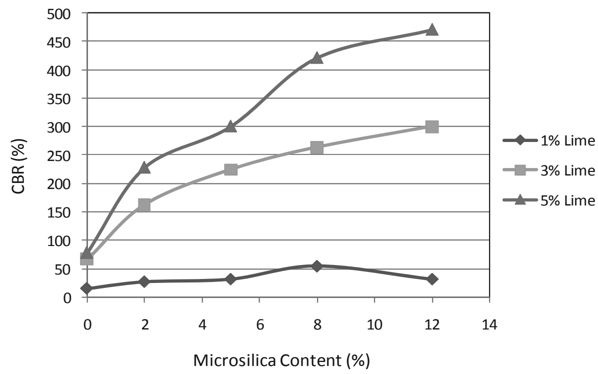

Figure 3. The effect of various amount of lime- microsilica additive on CBR values of stabilized soil

4.3 *Effect of additives on samples swelling*

The samples swelling were measured during the 96-hour of CBR samples soaking. There were seen swelling potential rate were decreased reverse of strength. Unstabilized soil swelling was 0.55mm and stabilized swelling samples were decreased up to 0 mm.

4.4 *Effect of wetting - drying cycles on samples CBR values*

The sample stabilized with 3% lime and 2% microsilica was chosen as the most desirable sample in terms of economy and resistance and alternate wetting-drying cycles were conducted on it. The result of wetting-drying cycles on CBR values of the sample are given in Figure 4. It is observed that the CBR value was increased after first wetting- drying cycle. Thereafter the sample CBR starts to decrease gradually. The reason for increasing CBR at first is assessed by decreasing in permeation due to lime- silica fume stabilizer that 96 hours submerging was not enough for required moisture for the reaction between lime, silica fume and soil that noticed in introduction section. It is noteable that the CBR rate after fifth cycle is still more than initial CBR rate. Therefore wetting- drying cycle not only had no negative effect on specimen strengths but also help to gain the soil strength stabilized with lime- silica fume additive.

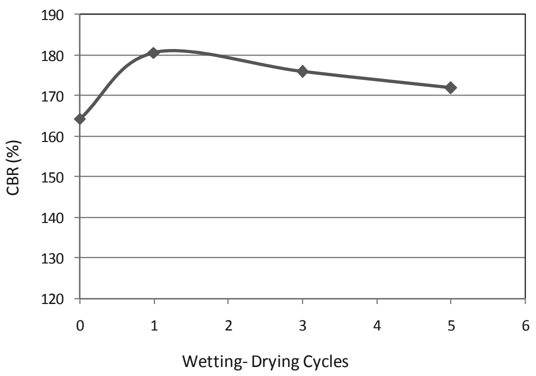

Figure 4. The effect of wetting-drying cycles on CBR values of the 28-day sample stabilized with 3% lime and 2% microsilica

5 CONCLUSIONS

The influences of lime- microsilica additive on silts and also wetting-drying cycles on them and its utilization in Karaj railway subgrade were investigated in this study and following conclusions were drawn:

Lime- microsilica additive played an important role in the development of the CBR values of the soil. The CBR values increased in response to adding the stabilizer. The CBR value of the unstabilized soil was increased from 4.8% to 470.8% by adding 5% lime and 12% microsilica.

Results show lime-microsilica additive increase the samples dry unit weight and sample's moistures are decreased after soaking by adding lime-microsilica additive.

It is an important result that samples swellings had a large reduction by increase of the lime- microsilica additive content.

It is an important result that wetting- drying cycles not only had no negative effect on CBR values of the sample but also help to gain the strength of the silt which is stabilized with lime-silica fume additive due to increasing required moisture for lime, silica fume and soil reaction.

In conclusion, because of considerable strength of stabilized silty soil with lime- microsilica additive in comparison of unstabilized soil, application of lime- microsilica additive is recommended for subgrade and even base of civil projects.

6 REFERENCES

Bell, F.G. 1996. "Lime stabilization of clay minerals and soils", Engineering Geology 42, pp. 223–237.

Dermatas, D., Meng, X.G. 2003. "Utilization of fly ash for stabilization/ solidification of heavy metal contaminated soils", Engineering Geology, pp. 377–394.

Abd El Aziz, 2003. "The Effect of Silica Fume Substitution on the Characteristics of Ordinery Portland cements Pastes and Mortars", Civil Engineering Magazine, Vol. 24 No. 2, p. 715-725.

Choobbasti, A.J., Ghodrat, H., Vahdatirad, M.J., Firouzian, S., Barari, A., Torabi, M., Bagherian A., 2010 "Influence of using rice husk ash in soil stabilization method with lime", Earth Sci. China, pp. 471–480

Bell, F.G., 1995. "Cement stabilization and clay soils, with examples", Environmental and Engineering Geoscience, pp.139–151.

Sheng, A.Q., Ma, M., 2001. "Experimental study on stabilization of subbase of bearing sand silt with low liquid limit", East China Highway 5, pp.42–46.

Mohamedzein, Y.E., Al-Rawas, A.A. and Al-Aghbari, M.Y. 2003. "Assessment of sand– clay mixtures for use in landfill liners", Proceedings of the International Conference on Geo- environmental Engineering, Singapore, pp. 211–218.

Karimi, M., Ghorbani, A., Daghigh, Y., Kia Alhosseini, S., Rabbani, P., 2011. "Stabilization of silty sand soils with lime and microsilica admixture in presence of sulfates" Pan- Am CGS Geotechnical conference.

Kalkan E, 2009. "Influence of silica fume on the desiccation cracks of compacted clayey soils", Applied Clay Science, pp. 296–302.

Kalkan, E., 2011. "Impact of wetting–drying cycles on swelling behavior of clayey soils modified by silica fume", Applied Clay Science, pp. 345–352.

Abd El-Aziz, M.A., Abo-Hashema, M.A., El-Shourbagy, M., 2004. "The Effect of Lime-Silica Fume Stabilizer on Engineering Properties of Clayey Subgrade", Engineering Conference, Faculty of Engineering, Mansoura University, Paper No. 96.

McKennon, J.T., Hains, N.L., Hoffman, D.C., 1994. "Method for stabilizing clay bearing soils by addition of silica and lime", Patent Cooperation Treaty (PCT), International Application Published Under the Patent Cooperation Treaty (PCT), Patent Classification: C09K 17/00, Publication Number: WO 94/06884.