Surface soil enhancement for MSW lining by silica fume

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Abstract. The improvement of engineering properties for surface soils is of significance through the resources shortage. Therefore, the present study focused on determined the silica fume influence as industrial waste products on engineering characteristics of surface available soil as a soft soil with poor engineering properties to enhance the hydraulic properties to be used for landfill lining layer and prevent migration leachate for surrounding environment. Silica fume was added to the soil to enhance the permeability with 5%, 10% weight ratio. Then, Atterberg limits and permeability tests were conducted. The results indicated that silica fume increase the flow and plasticity characteristics of the stabilized soils. Addition of 5% and 10% silica fume to surface soil reduce the permeability up to 46% and 57% respectively. It was concluded that silica fume filled pore space between soil particles and a dense matrix were formed. This textural event caused an improvement in permeability characteristics which represent the major concern in design MSW lining layer.

Key Word: Surface Soil, Permeability, Silica Fume, Landfill Liner.

1. Introduction

The stability of the landfill and its adoption for future use as construction projects depends on the stability of the underlay layer, as the liner is considered a supporting and insulating layer at the same time [1], so increasing attention to immunization and ensuring the efficiency of this layer is one of the basics of the optimal landfill design. Landfill design requirements have become one of the biggest challenges due to the enormous multiplication of waste quantities that are disposed as a result of community activities [2].

The lining layer is considered the natural insulator and first shield to confront environmental pollution resulting from sanitary landfill waste leachate, as it is protective containment for the environment surrounding the landfill [3].

Clay soil is the most available option used as lining for landfills for decades due to its availability in most countries, but many solid waste landfills use locally available soil as a lining for a landfill due to its low cost. The surface excavated soil may not meet specific environmental requirements and must be improved to accomplish the desired purpose [4]. For example, in united state, the hydraulic conductivity of soil used should not be greater than 1.0*10⁻³ m/s in the USA [5].

Unfortunately, surface soils with its naturally formed components do not meet the recommended standards for landfill lining layer, because it contains a high ratio of sand, which makes it a highly...
permeable soil. In this case, additives such as synthetic and natural materials are allowed to improve the basic properties of the available surface soil [6]. Leakage problem resulting from high infiltration rate of lining liner considered one of the most important considerations that must be determined and controlled in advance. Additives are one of the easiest and most economical ways to control infiltration rate and reduce the seepages through controlled soil permeability incorporating with enhance soil stability characteristics. Cement, lime, and fly ash are additives that have been used effectively to stabilize soils [7, 8, 9, 10, 11]. However, surface soil permeability has rarely been studied directly as it long time test. Therefore, the present study aims to improve surface soil permeability by silica fume to be used as landfill liner layer.

2. Material and Methods

2.1 Soil

The surface soil used collected from the north of Al-Diwaniyah city. The soil was brought in plastic bags. The clay soil was prepared in laboratory and dried well in the oven at 105°C for 24 hours then grinded well and sieved in No.4 U.S sieve.

2.2 Silica fume

Silica fume used was obtained commercially, silica fume is highly active pozzolanic material, a by-product of the manufacture of silicon or the mineral ferrosilicon. It is obtained from the flue gas of an electric arc furnace. Silica fume consists primarily of very fine smooth spherical glassy particles with high surface area. The surface area measured by the nitrogen absorption method is about 20,000 m²/kg [12]. The chemical composition of silica fume used in this investigation presented in Table 1.

3. Soil preparation

To conclude the silica fume influence on permeability of surface soil, three percentages of silica fumes were used (0%, 5%, 10%) of soil weight. A team laboratory study was conducted on the soil samples prepared to calculate the physical properties of the soil samples such atterberg limits, optimum water content and maximum dry unit weight. All experiments were conducted according to ASTM D 4318; and D 698 respectively. permeability tests were prepared according to ASTM D 5084.

| Table 1. Chemical composition of silica fume( from the manufacturer company). |
|-----------------------------|------------------|
| Composition | %               |
| SiO₂         | 45-75 %         |
| ZrO₂         | 6-10 %          |
| Fe₂O₃        | < 0.4 %         |
| Al₂O₃        | <0.5 %          |
| Na₂O₃        | <0.05 %         |
| K₂O          | <0.02 %         |

4. Results and Discussion
4.1 The effect of silica fume on the liquid limit and plastic limit

Results of plastic and liquid limits tests on surface soil treated with silica fume are shown in Figure 1. It is observed that as the percentage of silica fume increases, there is a marked increment in liquid limit and plastic limit of soil tested. From this, it can be deduced that the plastic characteristics and flow characteristics of the soil samples are gradually increase with increase in the percentage of silica fume. This increment plasticity of soil is significantly required to resistance of soils to deformation and rupture and avoid the failure pattern in the lining layer of landfill. As we all know, high plasticity soil will absorb water many times its weight [13-14].

![Figure 1](image_url)

**Figure 1.** The effect of Silica Fume on (A) liquid limit and (B) plastic limit

4.2 The effect of silica fume on the permeability

The Falling head permeability tests were carried out on all samples with different percent of additives at optimum moisture content and at 95% of maximum dry unit weight for untreated soil sample. The results of experiments conducted on the soil-silica fume mixture are presented in Figures 2. Compared with the original surface soil sample, the permeability of the surface soil with 5% silica fume mixture decreased from 1.226*10^3 cm/sec to 6.8*10^4 cm/sec with 46% reduction ratio, while the reduce in permeability value for surface soil sample with 10% silica fume mixture was from 1.226*10^3 to 5.4*10^4 cm/sec with 57% reduction ratio compared with natural surface soil. This significant reduction in permeability values for soil-silica fume mixture can be attributed to the formation of flocculation products in bonding between the surface soil particles in addition to pozzolanic reactions in addition to denser matrix that filled the voids that resulted from addition of silica fume.
5. Conclusion

- Silica fume causes significant increment in the plastic limits and liquid limits in all surface soil samples. The increase in the plasticity limit leads to resistance to the effects of distortion in the layers of the liner, as well as increase the containment of moisture, which provides the possibility of retaining the permeable leachate from the liner to protect the surrounding environment from the risks of leakage of pollutants.
- A significant improvement were obtained in the permeability with reduction ratio 46% and 57% for 5% and 10% silica fume addition respectively.
- study has shown that silica fume is of great significance for changing the performance of surface soil linings used in landfills. In the design of the lining system, the content of silica fume in the lining must be considered because it will have a positive effect on permeability.

References

[1] Salemi N, Abtahi S M , Rowshanzamir M and Hejazi S M 2018 Geosynthetic clay liners: effect of structural properties and additives on hydraulic performance and durability. Environmental earth sciences. 5 1-13.

[2] Karakus M, Liu Y, Zhang G, and Tang H 2016 A new shear strength model incorporating influence of infill materials for rock joints. Geomechanics and Geophysics forGeo-Energy and Geo-Resources. 3 183-193

[3] Firoozfar A, and Khosroshiri N 2017 Kerman clay improvement by lime and bentonite to be used as materials of landfill liner Geotechnical and Geological Engineering. 2 559-571.

[4] Sharma L K, Sirdesai N N, Sharma K M and Singh T N 2018 Experimental study to examine the independent roles of lime and cement on the stabilization of a mountain soil: A comparative study. Applied Clay Science. 152 183-195.

[5] US EPA 1993 MSW landfill criteria technical manual subpart D. Environmental Protection Agency, Cincinnati

[6] Mudimby A, Chandrasekhar M and Viswanadh G K 2012 Diffusion characteristics of geosynthetic clay liners amended with partial replacement of bentonite by fly ash Textile Light Ind Sci Technol. 2 20-23

[7] Locat J, Bérubé M A, and Choquette M 1990. Laboratory investigations on the lime stabilization of sensitive clays: shear strength development. Canadian Geotechnical Journal. 3 294-304

[8] Bell F G 1996 Lime stabilization of clay minerals and soils Engineering geology. 4 223-237
[9] Kumar B R, and Sharma R S 2004 Effect of fly ash on engineering properties of expansive soils. Journal of Geotechnical and Geoenvironmental Engineering. 7 764-767
[10] AL-Soudany K Y 2018 Improvement of expansive soil by using silica fume Kufa Journal of Engineering. 1 222-239
[11] Xu K, Yang B, Wang J and Wu M 2020. Improvement of mechanical properties of clay in landfill lines with biochar additive Arabian Journal of Geosciences. 13 1-12.
[12] ACI Committee 226, 1987 Silica Fume in Concrete: Preliminary Report. ACI Materials Journal March-April. 66-158.
[13] Kalkan E and Akbulut S 2004 The positive effects of silica fume on the permeability, swelling pressure and compressive strength of natural clay liners. Engineering geology. 2 145-156.
[14] Yasir, A.R., and Naji Abudi, Z. 2017. Characteristics And Compositions Of Solid Waste In Nassiriya CITY. Al-Qadisiyah Journal for Engineering Sciences, 2(2), 136-148.