Improving Geotechnical Properties of Closed Landfills for Redevelopment Using Fly ash and Quicklime

By

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledge within the text.

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Abstract

Many closed municipal solid waste (MSW) landfills are located near urban areas, even though originally established away from residential or commercial communities. Construction on top of closed landfills is generally a challenging task due to complex behaviour of creep, settlement and weak shear strength of waste materials. There is a high prospective to reuse these sites for redevelopment in spite of potential risk for human health and environment. The deep dynamic compaction technique is a common ground improvement technique due to its relatively economical and easy application for landfill sites. With deep dynamic compaction, large voids reduce and afterward other techniques such as cement, fly ash or lime grouting can further reduce the remaining smaller voids. Numerous studies have been conducted to treat and stabilise different types of problematic soils using fly ash with combination of lime. However, there is no comprehensive research on improvement of physical properties of MSW landfills using chemical admixtures such as fly ash and lime.

This study presents the experimental and numerical results of employing fly ash (class F) and quicklime (calcium oxide) in stabilisation of municipal solid wastes. The waste materials, used in this study, were collected from a closed landfill in the south-west of Sydney. The samples were prepared by integrating MSW, with a mixture of fly ash-quicklime with a ratio of 3:1 in percentages of 5, 10, 15 and 20 of fly ash by dry weight of the MSW. An array of experimental tests has been conducted on treated and untreated MSW samples including sieve analysis, Atterberg limits, compaction, permeability, large direct shear, unconfined compressive strength and consolidated-drained triaxial tests. Results of this investigation are evidence for a significant improvement in geotechnical properties of MSW materials, mixed with fly ash and quicklime. It has been found that the chemical stabilisation effectively increases the maximum dry density, the compressive strength, the shear strength parameters, the stiffness and the brittleness index, while decreases the compressibility, the permeability coefficient and the optimum moisture content of the MSW.
It has been quantified that by increasing fly ash-quicklime admixtures from 0 to 26.7% (0 to 20% fly ash) the internal friction angle increased from 29° to 39° and the cohesion intercept increased from 11 kPa to 30 kPa. Under an effective confining pressure of 300 kPa, the peak strength, the brittleness index and the Young’s modulus at failure increased from 600 kPa to 1150 kPa, 0.13 to 0.35 and 5.5 MPa to 28 MPa, respectively, by addition of 26.7% fly ash-quicklime admixture. The coefficient of permeability for untreated specimen was $6.2 \times 10^{-8}$ m/s and it was reduced to $3.2 \times 10^{-8}$ m/s for specimens mixed with 26% fly ash-quicklime (under average confining pressure of 250 kPa). The compression and the secondary compression indices decreased from 0.33 to 0.23 and 0.052 to 0.033, respectively. Moreover, increasing the curing time enhanced the unconfined compressive strength, the friction angle, the cohesion and the preconsolidation pressure of the treated specimens, whereas no change in the permeability coefficient, the primary compression index and the secondary compression index were observed. The findings of this study may facilitate the calculations of the bearing capacity and settlement as well as the slope stability analysis of chemically treated closed landfill sites.

A finite element program, PLAXIS version 9, has been used to evaluate the settlement of the untreated and chemically treated landfill layers for 10 and 20 years after applying surcharge loads such as the traffic load. The effects of depth of stabilisation and the fly ash-quicklime content on vertical and horizontal displacements of the model have been investigated. Treated and untreated MSW parameters, used for the model, have been obtained from the results of the extensive laboratory program performed in this study. The numerical results indicated that treatment of MSW with fly ash-quicklime reduced the vertical displacement of the model under traffic load at the midpoint below the embankment. This reduction is more pronounced with higher fly ash-quicklime contents and deeper improvement of layers. For depths of 3m, 6m, 9m, 12m and 24m of the landfill improved with 26.7% fly ash-quicklime, the vertical settlements at the centreline of the embankment, 10 years after applying traffic load, were reduced by 20%, 32%, 40%, 46% and 58%, respectively. Horizontal displacements of the landfill model also significantly reduced in sections below the toe of the embankment, under traffic load. The reduction in horizontal displacements is more pronounced with improvement into deeper layers.
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Dedication

I would like to dedicate this Doctoral dissertation to my family, particularly my wife Fouzieh Lotfi for her love, understanding and the sacrifice she has had to support my study, my father Dr Bahram Fatahi and my mother Monir Kheirandish for instilling in me the wisdom needed to complete this PhD project.
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