Enhancing the Engineering Properties of Expansive Soil Using Bagasse Ash, Bagasse Fibre and Hydrated Lime

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in 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 acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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DEDICATION

I would like to deeply dedicate this thesis to my family, especially my respective parents, Chien Minh Dang and Oanh Thi Truong, for their sacrifices, endless love, inspiration and hard working, my brother Cong Chi Dang and my sister Hanh Nhu Thi Dang for imparting to me the wisdom, the strength and the determination necessary to fully finish my PhD research study.

ABSTRACT

Expansive soils exhibit massive volume change against fluctuations of moisture content. Shrinkage and expansion of soil can commonly take place near the ground surface, where it is directly subjected to seasonal and environmental variations. Construction of civil engineering structures on expansive soils is highly risky, as this type of soil is susceptible to seasonal drying and wetting cycles, causing significant deformations. Frequent soil movements can generate cracks and damage residential buildings, roads, and other civil structures directly placed on this type of problematic soil. Many efforts have been applied in practice to overcome the adverse effects of expansive soil including replacement of existing expansive soil with non-expansive soil, maintaining a constant moisture content, and ground improvement techniques such as the application of granular pile-anchors, sand cushion technique, and belled piers, and soil stabilisation with chemical agents (e.g. lime or cement) and so on. On top of that, lime stabilisation is the most commonly used method for controlling the shrink-swell behaviour of expansive soil due to seasonal variations. Lime reacts with expansive clay in the presence of water and changes the physicochemical properties of expansive soil, which in turn alters the engineering properties of treated soil. Moreover, soil stabilisation and reinforcement using lime combined with agricultural and industrial waste by-products (e.g. fly ash, rice husk ash, recycled fibres) can extend the effectiveness of lime stabilised expansive soil.

This study presents an experimental investigation on the improvement of the geotechnical properties of expansive soil stabilised with bagasse fibre, bagasse ash combined without or with lime stabilisation. The agricultural waste by-products of bagasse ash and fibre, remained after crushing of sugar-cane for juice extraction, and the expansive soils, used in this investigation, were collected from Queensland, Australia. The stabilised soil specimens were prepared by changing the contents of bagasse ash from 0% to 25%, bagasse fibre from 0% to 2%, hydrated lime from 0% to 6.25%, and combined bagasse ash-hydrated lime from 0% to 25% by the dry mass of expansive soil. Several series of laboratory experiments have been performed on untreated and treated expansive soil samples with different additive contents and various curing times of 3, 7, 28, and 56 days. Another extensive microstructural analysis using scanning electron microscopy

(SEM), pH measurements, and Fourier transform infrared (FTIR) techniques has been carried out to evaluate the microstructure development of untreated and treated expansive soils. The outcomes of these experimental investigations showed that when the addition of bagasse ash into the expansive soils increased from 0% to 25%, the linear shrinkage reduced by 47%, the free swell potential decreased from approximately 10% to less than 0.5%, the swelling pressure reduction was from 80 kPa to 35 kPa (about 60%), the compressive strength at failure and the corresponding strain increased significantly by 48% and 40%. Meanwhile, the combination of bagasse ash and lime to stabilise soils when combined additive content increased up to 25% caused a significant increase in the compressive strength of 815% and the secant modulus of elasticity from 7.2 MPa to 107.2 MPa; reduced the linear shrinkage of 84% and the free swell potential down to less 0.5%; significantly decreased the swelling pressure from 80 kPa to around 10 kPa (88% reduction) and the compression indices from 0.484 to 0.083, just to name a few. It was noted that the improved geotechnical characteristics were more pronounced for lime treated soils with the combination of bagasse ash or fibre. The utilisation of bagasse ash or fibre for expansive soil stabilisation without or with lime combination not only effectively improved the geotechnical properties of expansive soil as curing time and additive content increased, but also assisted in minimising the adverse effects of agricultural waste by-products on the environment.

Numerical investigations based on the finite element method (FEM) incorporated in PLAXIS were carried out to evaluate a possible practical application of recycled fibre-lime reinforced soil as a replacement of geosynthetic reinforced traditional angular load transfer platform layer combined with columns or piles supported embankments founded on soft soils. An equivalent two-dimensional FEM model with proper modified parameters of structure and soil models has been adopted to investigate the performance of floating columns supported embankment reinforced without or with an FRLTP (fibre reinforced load transfer platform). Firstly, a series of numerical analysis was performed on the full geometry of columns supported embankment reinforced without or with an FRLTP of 0.5 m to examine the effectiveness of the FRLTP inclusion into the columns supported embankment system. The numerical results revealed that the embankment with FRLTP could effectively reduce the total and differential settlements, and the lateral displacement of the embankment by 20%, 74% and 46%, respectively, when compared with the embankment without FRLTP. Subsequently, several series of extensive parametric studies on the influence of FRLTP properties, and the improvement depth ratios of soft soils, have been carried out to assess the behaviour of the columns supported embankment with FRLTP. The findings of the extensive parametric study indicated that the platform thickness has a significant influence on the embankment behaviour, especially in improving the total and differential settlements, the rigidity and stability of the embankment, and the more load transfer from the embankment to DCM columns. Meanwhile, Young's modulus of the FRLTP shows considerable effects on the differential settlement, the stress concentration ratio, but has a negligible effect on the lateral deformation of the investigated embankment. The improvement depth ratio reveals substantial impacts on the final settlement and the lateral deformation, but shows insignificant influence on the stress concentration ratio and the differential settlement during the embankment construction and post-construction time. The FRLTP shear strength parameters show significant influences on the stress concentration ratio and the differential settlement of the embankment. However, the enhancement in the embankment performance was more noticeable for the cohesion than the internal friction angle of the FRLTP.

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LIST OF PUBLICATIONS

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1. Dang, L.C., Dang, C., Fatahi, B. & Khabbaz, H. 2016, 'Numerical Assessment of Fibre Inclusion in a Load Transfer Platform for Pile-Supported Embankments over Soft Soil', *Geo-China 2016*, eds D. Chen, J. Lee & W.J. Steyn, vol. GSP 266, ASCE, pp. 148-55.

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