A RATIONAL APPROACH OF THE DESIGN FOR HIGHWAY FORMATIONS

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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

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ABSTRACT

A RATIONAL APPROACH OF THE DESIGN FOR HIGHWAY FORMATION

Highways are important components for bolstering the economic development and industrial growth of every country, and hence, should be well designed. The formations should be stable enough to facilitate increased efficiency while ensuring longer life coupled with low maintenance costs, thus, safely allowing the running of heavier and faster vehicles. Two approaches in improving highway formations have been investigated in this thesis. In the first approach, studies on improving the subgrade strength by adding natural agricultural wastes as additives was carried out. In the second approach, a more realistic methodology for the design of highway formations was investigated. Accordingly, the improvement of soil subgrade by adding different percentages of Oil Palm Shell aggregate (OPS agg), Oil Palm Shell granule (OPS granule), Oil Palm Shell ash (OPS ash), and lime was studied. The California Bearing Ratio (CBR) test was used to investigate this improvement and to determine soil suitability for highway formations. It is suggested that optimal improvement in the CBR values can be attained by adding 10% OPS agg, 5% OPS granule, 30% OPS ash and 3% lime for subgrade soil in unsoaked condition, and 30% OPS aggregate, 10% OPS ash, 10% lime in soaked condition. The empirical CBR test is traditionally used for the design of highway formations. However, pavements and runways are also designed using the elastic foundation approach, i.e., the modulus of subgrade reaction, k_s, and Modulus of Elasticity, E. Both k_s and E are determined by plate load tests and widely used by Geotechnical engineers for the design of substructures. In this thesis, to take advantage of several available advanced methods using the elasticity approach, the CBR test is correlated with E and k_s using the Finite Element Method. Thus, the choices available for the design of highway formations can be widened and methods used in highway engineering and geotechnical engineering could be integrated. In this context, with vehicles actually transmitting cyclic stresses onto the highway formations, it is crucial to determine the threshold stress of the soil. This approach is developed by conducting cyclic triaxial tests on soils. The design of highways using threshold stress approach proposed to take into account a more realistic assessment of the soil behaviour that is subjected to repeated loadings due to running vehicles compared to the CBR test-based design. Cyclic triaxial test is used to determine the subgrade properties needed, including the threshold stress. Accordingly, Unconfined Cyclic Triaxial tests, Unconsolidated Undrained Cyclic Triaxial tests and Consolidated Undrained Cyclic Triaxial tests are conducted on the soil. Stresses caused by wheel loads of vehicles are computed using Boussinesq's solutions for simplicity. The formations thickness is then obtained in such a manner that the induced stresses on top of the subgrade are less than the threshold stress as determined in the above-mentioned laboratory tests. Design charts are developed for designing highway formations using threshold stress of the soil. Typical designs are compared to the CBR values-based design.

ABSTRAK

Jalan raya adalah komponen penting untuk meningkatkan pembangunan ekonomi dan pertumbuhan industri setiap negara dan oleh itu harus dirancang dengan baik. Kestabilan bentukan adalah penting untuk memudahkan peningkatan kecekapan dan memastikan jangka hayat yang lebih lama menggunakan kos penyelenggaraan yang rendah, justeru memungkinkan perjalanan kenderaan lebih berat dan lebih cepat dengan cara selamat. Dua pendekatan peningkatan bentukan jalan raya telah diteliti dalam tesis ini. Pada pendekatan pertama, mengukuhkan kekuatan tanah subgred dengan menambah sampah alam sisa pertanian sebagai penstabil tanah telah dijalankan. Pada pendekatan kedua, metodologi yang lebih realistik untuk mereka bentuk bentukan jalan raya telah diteliti. Dengan demikian, pengukuhan tanah subgred dengan penambahan agregat Kelapa Sawit (OPS Agg), granul Kelapa Sawit (OPS granule), abu Kelapa Sawit (OPS ash), dan kapur dengan peratusan berbeza telah dikaji. Ujian nisbah galas California (CBR) digunakan untuk menyiasat pembaikan ini dan menentukan kesesuaian tanah untuk bentukan jalan raya. Disarankan bahawa peningkatan optimum nilai CBR dapat dicapai dengan penambahan 10% agregat OPS, 5% granul OPS, 30% abu OPS dan 3% kapur dalam keadaan tanah subgred tak terendam, 30% agregat OPS, 10% abu OPS, atau 10% kapur dalam keadaan tanah berendam. Ujian empirik CBR secara tradisional digunakan untuk mereka bentuk bentukan jalan raya. Namun, lebuh raya dan landasan pacu juga direka dengan menggunakan pendekatan asas elastik dengan modulus reaksi tanah subgred, k_s, dan modulus keanjalan, E. k_s dan E ditentukan oleh ujian beban plat dan digunakan oleh para jurutera Geoteknik secara meluas untuk mereka bentuk substruktur. Dalam tesis ini, untuk mendapat manfaat daripada beberapa kaedah canggih yang sedia ada menerusi pendekatan keanjalan, maka ujian CBR dikorelasikan dengan E dan k_s menggunakan Kaedah Unsur Terhingga. Dengan demikian, pilihan untuk mereka bentuk bentukan jalan raya dapat diperluaskan dan kaedah yang digunakan dalam kejuruteraan Geoteknik jalan raya dapat diintegrasikan. Dalam konteks ini, telah dicatatkan bahawa kenderaan benar-benar mengalirkan tegasan berkitar ke atas bentukan jalan raya, maka adalah penting pendekatan titik terdaya tekanan dibangunkan menggunakan ujian tiga paksi berkitar ke atas tanah. Titik terdaya tekanan boleh ditakrifkan sebagai tahap tekanan di atas mana beban berkitar menyebabkan cangaan kumulatif yang berlebihan dan kegagalan akhirnya. Reka bentuk jalan raya menggunakan pendekatan titik terdaya tekanan yang dicadangkan dalam tesis ini digunakan untuk penilaian yang lebih realistik dari perilaku tanah mengalami beban berulang kerana pergerakkan kenderaan dibandingkan dengan reka bentuk berdasarkan ujian CBR. Ujian tiga paksi berkitar digunakan untuk menentukan sifat-sifat tanah subgred yang diperlukan termasuk titik terdaya tekanan. Dengan demikian, ujian tiga paksi berkitar tak terkurung, Ujian tiga paksi berkitar tak terkukuh tak bersalir dan Ujian tiga paksi terkukuh tak bersalir telah dilakukan ke atas tanah. Tegasan akibat beban roda kenderaan dikira menggunakan penyelesaian Boussinesq untuk kesederhanaan. Kemudian, ketebalan bentukan boleh diperolehi sedemikian rupa apabila tekanan aruhan di atas tanah subgred adalah kurang dari titik terdaya tekanan yang ditentukan dalam ujian makmal yang disebut di atas. Carta reka bentuk dibangunkan untuk merancang pembentukan jalan raya menggunakan pendekatan titik terdaya tekanan tanah. Reka bentuk jenisan dibandingkan dengan reka bentuk nilai CBR.

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