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Cement-stabilized Modified High Fines Melaka Series for Roadbases

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ABSTRAK

Jalan raya merupakan elemen prasarana yang penting untuk pembangunan sesebuah negara. Kekurangan bahan binaan yang sesuai akan menaikkan kos pembinaan. Banyak bahan-bahan subpiawai tidak akan terpakai (dan merugikan) jika piawaian untuk keadaan paling teruk digunakan. Kertas kerja ini membentangkan kerja-kerja yang dilakukan keatas bahan subpiawai untuk memungkinkan ianya digunakan sebagai tapak jalan. Bahan ini telah diubahsuai untuk meningkatkan ciri kekuatannya. Oleh kerana isipadu trafik jalan ladang dan kawasan kampong agak ringan, maka wajarlah jika nilai tara kekuatan yang lebih rendah (1.7MN/m^2) digunakan.

Tanah yang mengandungi zarah halus yang tinggi tidak sesuai digunakan untuk penstabilan dengan kaedah campuran simen. Dengan itu tanah siri Melaka telah diubahsuai peratus zarah halusnya dengan campuran pasir sungai. Kemudian simen digaulkan dengan campuran tadi dan dipadatkan secara hentaman. Beberapa nisbah campuran tanah-pasir-simen digunakan dalam penyelidikan ini. Perubahan kekuatan yang agak ketara telah diperolehi, iaitu dari 0.2 MN/m^2 hingga 3 MN/m^2 untuk campuran tanah-pasir berkadar 1:1 dan simen sebanyak 12%. Ini merupakan peningkatan sebanyak 14 kali ganda, dan seterusnya mengatasi tara kekuatan tapak 2.8 MN/m^2, yang digunakan sekarang. Unit kos untuk mengeluarkan bahan terubahsuai ini adalah setanding dengan penggunaan batu hancur sebagai tapak. Kekuatan 1.7 MN/m^2 boleh diperolehi dengan hanya menggunakan 8% simen dan campuran tanah-pasir berkadar 2:1. Penjimatan kos sebanyak 35% boleh diperolehi sekiranya tanah Siri Melaka terubahsuai, dengan kekuatan 1.7 MN/m^2, digunakan berbanding dengan batu hancur.

ABSTRACT

Roads are a crucial infrastructural element in the progress of a nation. Unavailability of suitable base materials causes total building cost to escalate. Strict adherence to standards to satisfy maximum working conditions would disregard the abundant supply of substandard materials. This paper discusses the potential exploitation of such substandard materials through modification of the strength characteristics. Rural and farm roads in developing countries are generally lightly trafficked, thus justifying a lower strength criterion (1.7 MN/m^2) than normally adopted.

Soils with high fines content are unsuitable for cement stabilization. The selected Melaka series was modified by the addition of river sand. Cement was subsequently added to the mixture and stabilized mechanically. Various soil-sand-cement proportions were studied in terms of strength characteristics. A significant increase in strength, from 0.2 MN/m^2 to nearly 3 MN/m^2, was noted with soil-sand ratio of 1:1 with 12% cement content. This represents about a 14-fold strength increase satisfying the current compressive strength of 2.8 MN/m^2 for roadbases. The unit cost of producing the mixture was equivalent to supplying crusher run in a typical road project. The 1.7 MN/m^2 criterion was met with a minimum cement content of 8% and a soil-sand ratio of 2:1. With 1.7 MN/m^2 strength criterion, nearly 35% savings could be made by using the modified Melaka series soil instead of crusher run.

Keywords: soil-cement, cement stabilization, soil stabilization

INTRODUCTION

Rural areas tend to be given a low priority in most development programmes since these areas are normally regarded as non-strategic for the progress of most nations. Agriculture, located in the rural areas, is thus affected and especially so when the focus is concentrated on industrialization. It is strategically important to preserve the agricultural sector and enhance its capability in order to be a self-sustaining nation. Greater efforts to improve the infrastructural setup are required to achieve this goal.

Good infrastructural development is a prerequisite to higher efficiency and productivity. This calls for a network of passable all-season roads. The standard, however, could be lowered so as not to compromise productivity. A study conducted in Kenya showed that productivity in a tea- growing area increased sharply with the provision of substandard materials for roadbases, saving between 20 to 60% of the total cost of the roads (Grace and Hight 1982). Similar successful applications of substandard materials were reported in Nigeria. The roadbases were constructed to meet the medium traffic intensity of 10000 standard axles (Aggarwal and Jafri 1987).

Several stabilizing agents such as cement (Lilley 1973; Lay 1981; Williams 1986), lime (Mitchell 1981) and sulphonated oil (Escobar 1986) have been applied with considerable success. They improved the strength and reduced the permeability of the stabilized materials. The application of cement in roadbases dates back to the 1920s. Cement for soil stabilization has ever since been an alternative method to increase the strength capacity of substandard materials.

There have been several applications of cement stabilization in Malaysia. In Sabah, soil-cement was used as a roadbase in place of mine gravel in the North and Labuk Roads (Shaik pers. comm). The use of crushed aggregate was minimized with the use of soil-cement in a road project in Sandakan and Labuan (Lo pers. comm). A 5-km trial using cement to stabilize soil for a plantation road was conducted in the Pendang area, Kedah (Teoh pers. comm). A prototype soil-cement road was also constructed to study the effect of weathering (Megat Johari and Azlan 1988). However, the technique has not received much interest due to the cost factor (Ting 1971), which has yet to be proven. The potential use of cement-stabilized soil for roadbases is high in Malaysia since cement is a controlled item, thus stabilizing the construction cost. Minimizing cement content should make it a more viable stabilizing agent economically.

Soils with high fines content, generally having substantial amounts of particle sizes less than 63μm, are normally unsuitable for cement stabilization. High cement content would be required due to the high specific surface area of such soils. Megat Johari and Azlan (1988) reported the relatively low unconfined compressive strength (UCS) below 1.7 MN/m^2 with 75% fines and 11% cement, as recommended for lightly trafficked roads in the United Kingdom (Andrews 1955). The UCS criterion was satisfied with 30% fines content. Modification of the soil gradation by increasing the content of coarse grains is a desirable option, if cement is to be used as a stabilizing agent in initially high fines soils, based on the UCS criterion.

The UCS criterion of 1.7 MN/m^2, which was known to satisfy the American wet and dry test for durability (ASTM 1982), has now been replaced with 2.8 MN/m^2 (Williams 1986). This criterion takes into consideration the increasing traffic. Jabatan Kerja Raya(JKR) specified 30 kg/cm^2 (2.9 MN/m^2) as the minimum criterion for cement stabilized roadbase (JKR 1985). However, the basis for adopting the 1.7 MN/m^2 was not clear. Earlier literature showed that it satisfied the American wet and dry durability test and the full-scale trials under the traffic conditions then. Rural areas of developing countries which have yet to reach such a level of development may make do with strengths below the UCS criterion. Secondary roads in Nigeria, with substandard laterite for roadbases, have proven to be equally successful even though the specifications required were 25% higher in terms of CBR (Aggarwal and Jafri 1987).

A laboratory study was conducted to evaluate the strength characteristics of stabilized soil for roadbases, through a reduction of its fines content. This was achieved with the addition of river sand. The stabilizing agent used in the study was Portland cement. Lateritic soil of Melaka series with a high content of fines was selected for the study. This paper presents the findings of the above-mentioned study.

MATERIALS AND METHODS

Soil samples (Melaka series) were taken from 0.5 m depth, after removing the topsoil. The samples were air dried and pulverized carefully, without altering the actual grading, to a maximum conglomerated size of 5 mm. River sand was utilized in the study as the added granular soil. Ordinary Portland cement was used as the stabilizing agent.

The physical properties, including wet and dry sieve analysis, of the Melaka series were obtained in accordance with BS 1377(BSI 1975a). Grading curves for the composite material, i.e. modified with addition of river sand at varying percentage (at 10% increment based upon the dry weight of the series) were also obtained. Cement proportions used in the study varied between 2 and 12% of the dry weight of the composite material.

Strength characteristics were selected for the study since other properties are closely associated with it, namely permeability and durability. High geological strength materials are generally less permeable and have greater durability, a common phenomenon in concrete. The same parallel can be attributed to the materials used in the study, which were sand, modified soil (or fine aggregates) and cement. A set of 5 specimens was prepared for each UCS test, totalling 660 specimens. Both the dry and wet UCS tests were performed in accordance with BS 1924. Standard Proctor compaction tests, to obtain the optimum moisture content, were also carried out in accordance with BS 1924(BSI 1975b).

RESULTS AND DISCUSSION

Fig. 1 shows the particle size distribution curves for both Melaka series and river sand, utilized in the study. The fines percentage was 75%, similar to that reported by Megat Johari and Azlan (1988). The fines content of the series was higher (62%) in a later study by Megat Johari *et al.* (1990). The former was taken from the same horizon and topography whereas the latter was from a different site but of similar topography. Loh (1986) reported that on Melaka series, the presence of 30% fines was indicated in samples taken on sloping ground. Soils of the same series, from a similar horizon and topography, behaved alike when stabilized under the same conditions, as reflected in the discussion on UCS in the latter part of this section.

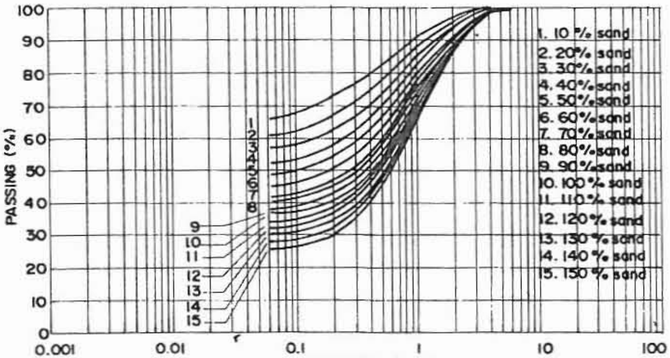

Fig. 1. Particle size distribution of Melaka series and river sand

The dry sieving was done on the Melaka series in order to indicate the final size of the conglomerated soil particles. It followed a distribution similar to that of the river sand. The distribution indicates that homogeneous conglomerated soil particles were obtained. Cementation effect is normally influenced by the conglomeration size. The efficiency of cement penetration on the conglomeration reduces with the conglomeration size. Dry sieving facilitates quality control at site through the conglomerated particle size distribution achievable.

Table 1 shows the physical properties of the series. The soil is classified as silty clay under the Unified Soil Classification System (BSI 1975a). Cement stabilization is unsuitable for this type of clayey soil according to Das (1984) and Cleghorn (1979), because of its high liquid limit and plasticity index. The percentage of fines generally acceptable for cement stabilization ranges between 30 and 60%, although Das (1984) suggested less than 40% fines. This limit, however, depends on the quantity of stabilizing agent applied, which will be discussed in the later part. Reduction of the fines content is justified in order to use cement as a stabilizing agent. High fines soils are better stabilized with lime or pozzolanic materials (Williams 1986).

TABLE 1
Properties of Melaka series utilized in the study

Liquid Limit (%)	62
Plastic Limit (%)	29
Plasticity Index (%)	33
Specific Gravity	2.69
% Passing No. 200 sieve (%)	75

Fig. 2 shows the modified particle size distribution curves for soil-sand, from 10% to 150% sand addition by weight, at 10% increment. The percentage of fines decreased to as low as 25% with sand occupying two-thirds of the total soil-sand composition. The 60% fines was achieved with 20% sand content.

Fig. 3 and *4* show the trends of dry density and optimum moisture content at increasing sand proportion. The dry density improved gradually with increased sand percentage, similar to the trend of UCS, as can be seen later (*Fig. 5* and *6*). Variation in cement content did not have any significant effect on density. The cement portion acted as a binder that enhanced the strength development, as will be discussed later. The OMC stabilized at 14%, thus giving a water-cement ratio of 1:1 which is still higher than that required for hydration.

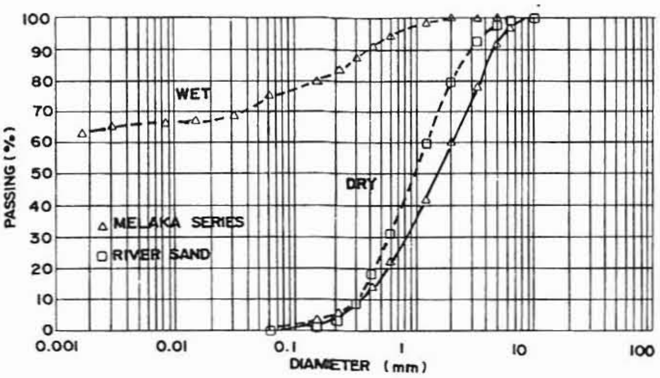

Fig. 2. Sand modified particle size distribution of Melaka series

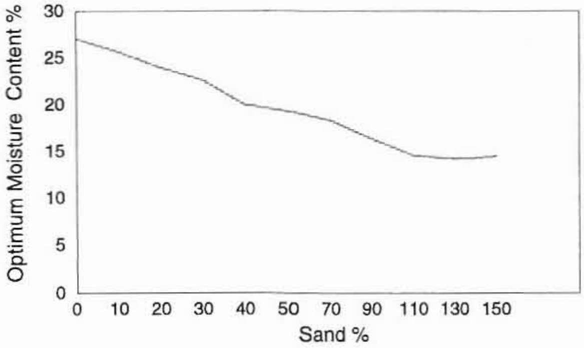

Fig. 3. Effect of sand content on optimum dry density

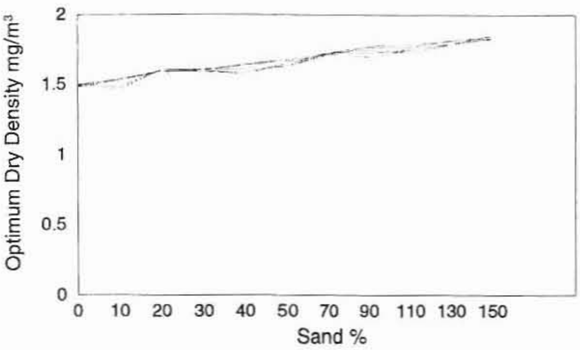

Fig. 4. Effect of sand content on optimum moisture content

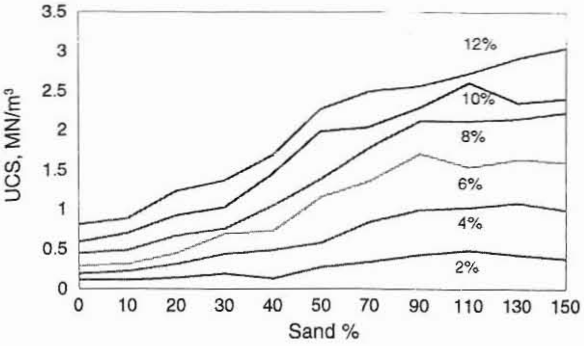

Fig. 5. Dry UCS values

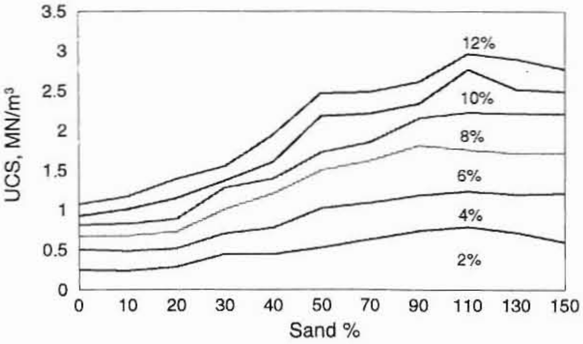

Fig. 6. Wet UCS values

Fig. 5 shows the average dry UCS of various proportions of soil-sand mixtures of varying cement content. None of the dry strength achieved the minimum UCS requirement for roadbases for heavy traffic conditions of 2.8 MN/m^2 (Williams 1986). The 110% sand added samples with 12% cement just managed the 2.8 MN/m^2 criterion; further increase in sand quantity reflected a downward trend in the dry UCS.

Fig. 6 shows the wet UCS values which, as expected, exhibited lower values than dry UCS. The strength differences between the dry and wet strengths indicated a narrowing down trend (or closing up the gap). With cement content reaching 6% and at high sand proportions, the wet strengths were greater than the dry strengths. *Fig. 7* gives an example of the comparison between the two strengths, for 12% cement content. This phenomenon is possibly attributed to the curing effect of cement. Low cement content makes cement function as a modifier, i.e. changing the plasticity of the soil concerned. However, at higher cement content, cement acts as a stabilizer cementing the soil particles. Thus strength increase is expected with time, and greater strength is expected if properly cured, as with soaked samples for wet UCS test.

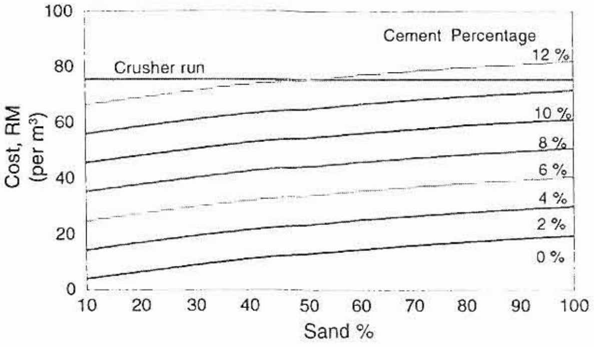

Fig. 7. 12% dry wet UCS values

The 1.7 MN/m^2 criterion was achieved with a minimum cement content of 8% and soil-sand ratio of 2:1 at 48% fines content. Further reduction in cement content to 6% required a lower fines quantity, i.e. of about 35%, indicated by a decrease in the soil-sand ratio. This confirms the view expressed earlier that the fines limit set for stabilization depends on the amount of stabilizing agent applied.

Further increase in sand composition showed a gradual increase in strength. Samples with sand composition greater than 100% of the soil weight (ratio 1:1) showed a downward trend in UCS, which is expected of sandy soils as they are generally poor in cohesion and static compaction.

The 2% cement content, which was hardly adequate for stabilization, gave an average UCS of nearly 0.3 MN/m^2 (without sand addition) similar to that obtained on samples of the same series, with 75% fines (Megat Johari and Azlan 1988). Similar UCS values, when using 11% cement (Megat Johari and Azlan 1988), were obtained when stabilized with 12% cement. This confirms, as mentioned earlier, that soils from the same horizon and topography behave alike when stabilized.

COSTING

Table 2 indicates the cost of several materials pertinent to the study. The cost of river sand is approximately 8% of the cost of cement. *Fig. 8* shows the materials costing at various sand and cement increments.

Increase in cement content allows a reduction in sand requirement, for example, a sample with 35% sand content and 12% cement produced an equivalent UCS to that of 45% sand content and 10% cement. The economics of achieving a particular UCS depends on the proportions of

TABLE 2
Materials costing (1994)

Materials	Cost (RM)	Cost/kg (RM)
River sand (12 tonnes)	180.00	0.015
Mining sand (12 tonnes)	160.00	0.013
Crusher run (12 tonnes)	350.00	0.021
Cement (bag of 50kg)	10.00	0.200

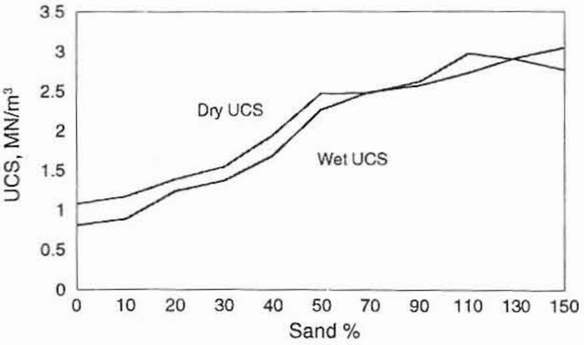

Fig. 8. Materials cost per unit volume

sand and cement, whereby increasing the sand content and reducing the cement content is more favourable, as reflected in *Fig. 8.*

The improvement in strength attained with an additional 2% cement content, per unit volume, would increase the total cost by a further 9%. Modification of fines content with sand addition can therefore reduce the overall cost of stabilization. Even unsuitable material, as shown in the study, can be modified to achieve the acceptable strength requirement for roadbases.

Traditionally, crusher run has been used for roadbases. The cost per unit volume of crusher run compared to modified soil (50% sand) with 8% cement content is about 40% higher. The weight ratio of crusher run to modified soil in this case stands at 2:3, which would incur a considerable transportation cost for the long haul.

Samples at soil-sand ratio of approximately 1:1 with 12% cement content, managed to achieve the targeted UCS of 2.8 MN/m^2. This is equivalent to less than 40% fine content. The cost per unit volume was almost equal for both materials, i.e. soil-sand (ratio of 1:1) and crusher run. Transport cost is high and increases yearly, rendering crusher run uneconomical, especially when long haul is required. As cement is a controlled item in Malaysia, cement-stabilized modified soil would fare better as an alternative material than crusher run.

CONCLUSIONS

Cement stabilization of high fines Melaka series can achieve the current compressive strength criterion of 2.8 MN/m^2 through modifying its fines content with river sand. The cost per unit volume of achieving this strength is equivalent to supplying crusher run for roadbases. Nearly 35% saving on material cost is possible when lower strength criterion (1.7 MN/m^2) is considered. This is justified by the medium traffic intensity in developing countries.

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