DURABILITY AND STRENGTH CHARACTERISTICS OF CEMENT STABILIZED MODIFIED MELAKA SERIES

MEGAT J.M. M. NOOR*

SUMMARY: A study to compare the relationship between strength and durability of cement stabilized Melaka Series (modified with river sand) was carried out. Reduction in fines percentage and increase in cement content improved the strength characteristics. Cement content had a greater influence on durability compared to percentage of fines. The percentage of weight loss obtained was well within the durability limit even though the unconfined compressive strength was 1.6 MN/m^2 (below the recommended strength for roadbases of lightlytraficked roads, 1.7MN/m^2). Thus durability will simultaneously be satisfied if the strength criterion is met, within the fines percentage of 37 and 56 were studied.

Key Words: Durability of cement, Strength of cement.

INTRODUCTION

Cement stabilization of soil began with a trial on Salisbury Plain in 1917. The technique has since gained acceptance as an alternative for improving substandard materials, especially for roadbases. In Malaysia the practice of using cement stabilized soil is still uncommon, attributed to its high cost compared with the production cost of bituminous mix and concrete (17). Most of the applications were in the east Malaysia, as with the Sabah's North and Labuk Roads, where soil-cement mixture has been used as roadbase in place of mine gravel (16). Similarly a reduction in the utilization of crushed aggregate was achieved with the use of cement modified soil in the Sandakan and Labuan road projects (11). Soil-cement has also been used for road shoulder in Pahang (9).

Cement stabilized soil must not be confused with lean concrete, where cement is mixed with granular aggregates at a relatively high aggregate-cement content. Soil-cement in fact lies between unbound material and conventional concrete. Thus, there is either soil mechanics or concrete technology approach to soil-cement study. The cement element would act as a binding agent within the soil matrix. Mechanical compaction, at the optimum moisture content, is required to enhance stabilization. The moisture content to achieve the maximum dry density is generally higher than the amount required for cement hydration.

Numerous work have been published on cement stabilized soil, among which by Bofinger, Dunlop et. al., George, Lilley and William, Ola, and William (3, 7, 8, 10, 15, 18). Most of these deal with shrinkage and cracking, application in roads and strength characteristics. Different testing procedures have been applied in various studies, which made comparison difficult. However, compressive strength and durability were the two major approaches made, with the Americans mori inclined towards durability technique. Other techniques employed were California bearing ratio, tensile and flexural tests.

The earlier British unconfined compressive strength criterion of 1.7 MN/m^2 was said to satisfy the American durability tests, namely, freezing and thawing, and wetting and drying (18). The strength criterion was set for lightly trafficked roads. The current British requirement stipulated 2.8 MN/m^2 to cater for the increasing traffic

* From Department of Civil and Environmental Engineering, University Pertanian, Malaysia.

volume. Malaysia adopted a similar limit of 30 kg/cm2 (2.9 MN/m^2) for soil-cement mixture (1). Although, an increase in strength would lead to an improved durability, the relationship may not be direct.

The technique of measuring durability, as in the American wetting and drying test, requires brushing off the specimen's side with a wire brush. It can be inferred here that the test is also a measure of abrasion resistance by the brushing effect. Cementing effect is thus expected to be more influential than the physical compaction when dealing with abrasion. This paper sets to identify the more influential criterion when dealing with abrasion. This paper sets to identify the more influential criterion, comparing between the unconfined compressive strength (5) and durability via the wetting and drying test (2) of a particular stabilized soil.

Granular soils with less than 40% fines content are normally suitable for cement stabilization (6). Soils with higher fines percentages, for example about 60%, were reported as suitable for cement stabilization (14,16). This has led to the modification of the fines content of the Melaka Series used in the study, since having greater than 60% fines.

MATERIALS AND METHODS

The Melaka Series that contained high fines content, was sampled to a 0.5 m depth. Sampling was done after removing the top soil. The soil samples were air dried and pulverized to a maximum conglomerated size of 5 mm. River sand was used to reduce the fines content of the soil. Ordinary Portland Cement was selected as the stabilizing agent since the fines content was within the acceptable limit for its usage.

The physical properties and sieve analysis of the Melaka Series were obtained in accordance with BS 1377 (4). Grading curves for the composite material, i.e. modified with addition of river sand at 30, 40, 60 and 90% (based upon the dry weight of the Series) were also obtained. The cement proportions used in the study varied between 2 and 12% of the dry weight of the composite materials.

A set of five cylindrical specimens were prepared and tested for their dry unconfined compressive strength, in accordance with BS 1924 (5). The wetting and drying test was performed according to ASTM D599 (2). Specimens were prepared at varying cement contents, with cement composition expressed as a percentage of soil-sand mixture. These mix proportions were 100-90-6, 100-60-8, 100-40-10 and 100-30-12. A set of five specimens were prepared for each mixture. The various cement proportions were selected on the basis of satisfying a similar strength criterion of nearly 1.6 MN/m^2. Specimens for both test (strength and durability) were compacted at the optimum moisture content, obtained from the Proctor compaction test.

RESULTS AND DISCUSSION

Table 1 shows the physical properties of the Melaka Series. The soil was classified as silty clay under the unified Soil Classification System. Extremely high liquid limit and plasticity index rendered the Series unsuitable for direct cement stabilization. Lime or pozzolanic stabilization would be more appropriate for this type of soil (18).

Figure 1: Particle size distributions.

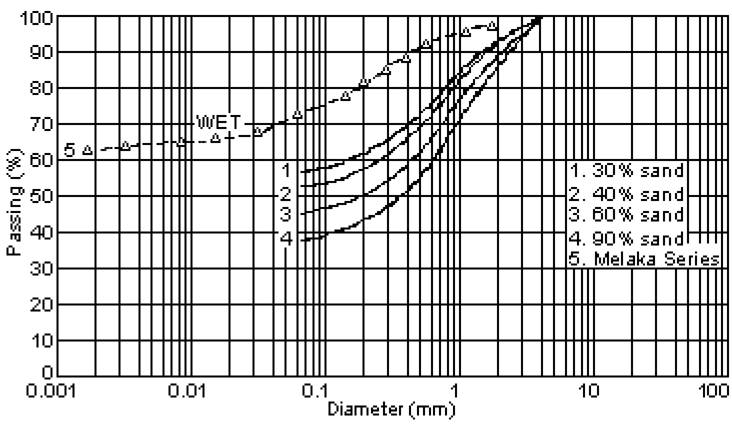


Table 1: Properties of Melaka Series

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

The particle size distribution curve for the Melaka Series is shown in Figure 1. The percentage of fines for the Melaka Series was 75%, expected of a highly weathered lateritic soil, obtained from a flat topographical site. Melaka Series is a residual sedimentary rock soil rich in iron, which gives its lateritic nature. Weathered soil of the same Series obtained from a sloping ground indicated a lower fines percentage, as reported by Loh (12).

Soils with fines proportion varied between 30 and 60% are generally acceptable for cement stabilization, although Das (6) suggested less than 40% fines. The modified distribution curves for the various soil-sand compositions, shown in Figure 1, indicated containing 37, 45, 51 and 56% fines. These were within the acceptable limit for cement stabilization. The reduction in fines content of the Melaka Series thus justified the use of cement as a stabilizing agent.

Figure 2 shows the average dry unconfined compressive strength of the various soil-sand mixtures, at varying cement contents. As expected, an increase in cement content resulted in an increase in strength. Greater binding capacity was enabled due to greater quantity of cement present, while the compactive efforts remained the same. Reduced fines content was also noted to improve strength characteristics. Nevertheless, all the strength values were below 2.8 MN/m2, the minimum strength requirement for roadbase for a heavy traffic condition (18).

The 1.7 MN/m^2 strength criterion was achieved with a soil-sand content, the lower was the cement requirement to satisfy the strength criterion. The fines content thus determined the amount of cement required to satisfy the strength requirement.

The selected mix proportions (100-90-60-8, 100-40-10 and 100-30-12), shown in Figure 3, indicated a similar strength value of nearly 1.6 MN/m^2 achieved. The relationship in Figure 3 was obtained from an extensive study on the effect of bodifying fines and cement contents on strength characteristics, conducted at the University Pertanian Malaysia. The results shown followed a second order polynomial. The wetting and drying test performed on the selected mixtures, however, had different performance characteristics, although having a similar strength value.

Figure 4 shows the the results of wetting and drying test on the selected mixtures. The maximum percentage weight loss was less than 5% for all the four mixtures. The least weight loss was obtained with the highest cement content of 12%, i.e. only 1.5% loss. The 8 and 10% cement contents exhibited almost a similar trend, with the 10% edged the 8% slightly. The

Figure 2: Unconfined compressive strength of sand modified Melaka Series at varying cement content.

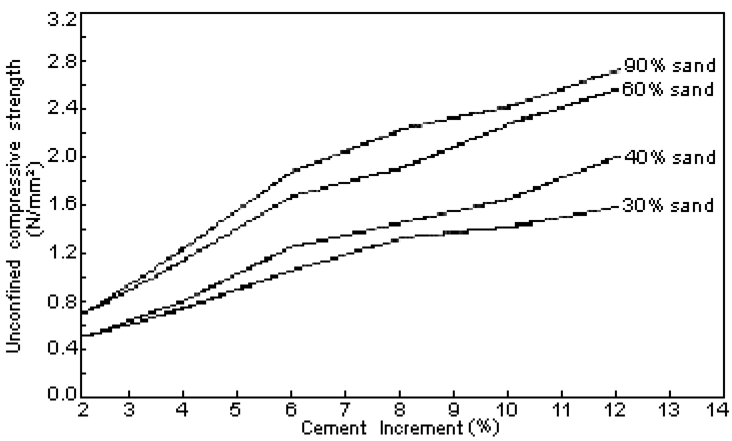
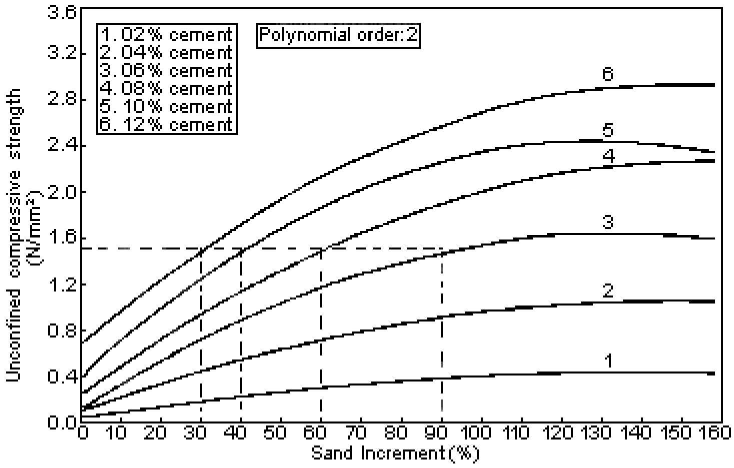


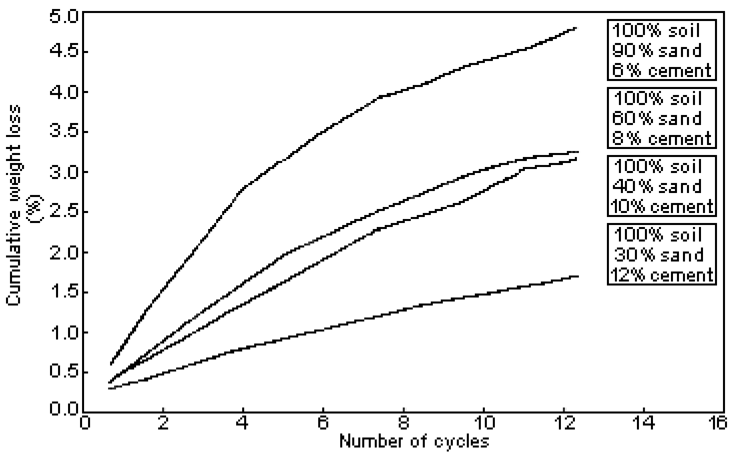
Figure 3: Unconfined compressive strength of Melaka Series modified at various sand-cement proportions.



Canadian Portland Cement Association recommended a maximum allowable loss of 7% for clayey soils and 10% for silty soils. All the four mixtures satisfied the Association's durability requirement even though the strength criterion was not satisfied. Cement content rather than fines content was thus the governing factor in improving durability since strength wise the mixtures were equivalent. The fines content only influenced the mechanical compaction whereas the cement element acted as a chemical binder, which resisted abrasion. Increased cement quantity thus provided a greater binding capacity, and consequently enabled better abrasion resistance, a measure of durability.

In order for soil-cement to be an effective material for roadbase, satisfying the durability condition is essential. This is more often important in the tropical region where a wet and dry climatic condition prevails. From the study conducted, the mixtures selected had strength lower than the requirement for lightly trafficked roads. Nevertheless, the durability condition was satisfied. Cement content rather than fines content was thus the governing factor in improving durability since strength wise the mixtures were equivalent. The fines content only influenced the mechanical compaction whereas the cement element acted as a chemical binder, which resisted abrasion. Increased cement

Figure 4: Wetting and drying test on several mixtures.



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CONCLUSIONS

Modified Melaka Series (greater than 40% sand content) satisfied the strength criterion of 1.7MN/m^2 without difficulty. The durability condition based upon the twelve cycles of wetting and drying was simultaneously satisfied. Lower strength (i.e.1.6 MN/m^2) samples exhibited a percentage weight loss of about 5% well below the requirement even for clayey soil. Durability of cement stabilized modified Melaka Series is thus not the limiting factor in determining the suitability of the mixture for roadbases. Strength criterion alone is adequate in determining the potential of a soil-cement mixture for roadbase. Durability is highly affected by the cement content rather than the fines content, within the fines percentage of 37 and 56%.

REFERENCES

1. Arahan Teknik (Jalan) : Manual on pavement design. Public Works Department, Malaysia, 5:85, 1985.

2. ASTM D599 : Wetting and drying test of compacted soil-cement mixtures. American Standard Testing Materials, 1982.

3. Bofinger HE : Soil-cement : Recent research by the overseas unit of TRRL. Proceedings of 9th Conference Australian Road Research Board, University of Queensland, Brisbane, 1979.

4. BS 1377 : Methods of tests for stabilized soils. British Standard Institution, 1975.

5. BS 1924 : Methods of tests for stabilized soils. British Standard Institution, 1975.

6. Das BM : Principles of foundation engineering. Brooks Cole Engineering Division, Monterery, California, 1984.

7. Dunlop RJ, Moss PJ and Dodd TAH : Prediction of cracking in soil-cement. Proceedings 2nd Australian-New Zealand Conference of Geomechanics, 1975.

8. George KP : Theory of brittle fracture applied to soil-cement. ASCE Journal of Soil Mechanics Foundation Division, (6) SM3, 1970.

9. Lee SH : Perconal communication. Pahang Public Works Department, Malaysia, 1988.

10. Lilley AA and William RIT : Cement-stabilized materials in Great Britain. Highway Research Recommendation, No 442, 1973.

11. Lo PK : Sabah Public Work Department, Malaysia. Personal communication, 1989.

12. Loh SH : Preliminary studies of soil-cement as a road building material. B E Project. University Pertanian Malaysia, 1986.

13. Noor Megat JML, Azlan AA and Radin Umar RS : Effects of cement rice husk ash mixtures on compaction strength and durability of Melaka Series lateritic soil. Journal of Institution of Engineers Malaysia, 1990.

14. Noor Megat JML, Azlan AA and Shukri M : Cement stabilized modified high fines Melaka Series for roadbases. Submitted for publication in Pertanika Journal of Science and Technology.

15. Ola SA : Need for estimated cement requirements for stabilizing lateritic soils. ASCE Transport Engineering Journal, (100) TE2, 1974.

16. Shaik AW : Geotechnical and Environmental Associates Sdn Bhd, Malaysia. Personal communication, 1988.

17. Ting WH : Zaidun-Leeng Sdn Bhd, Malaysia. Personal communication, 1988.

18. William RIT : Cement-treated pavement. Elsevier Applied Science Publisher, London, 1986.

Correspondence:
Megat Johari Megat Lohd Noor
Department of Civil and
Environmental Engineering
University Pertanian Malaysia,
43400 UPM Malaysia,
MALAYSIA.