Progress in the Design and Construction of Soil-Cement Roads

Progrès réalisés dans la conception et la réalisation des routes en sol ciment

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Summary

The author reviews the experience gained and progress made in the construction and subsequent behaviour of soil-cement roads in Mozambique, and refers to various unsolved problems.

The classical method of determining cement content is criticised, and new methods which take into account soil surface area, grain-size distribution and Californian Bearing Ratio are discussed and analysed. Excellent results have been obtained by site control of single-pass machines with high output, deviation from a specified thickness being within the required tolerance.

Sommaire

Cette communication expose les résultats de l'expérience acquise en Mozambique en ce qui concerne la conception, la construction et la prévision du comportement des couches de base en sol ciment. On fait la critique des méthodes classiques pour la détermination du pourcentage de ciment et on examine de nouvelles méthodes basées sur la surface spécifique des sols, leur constante granulométrique *a* et leur CBR.

En ce qui concerne la construction, on a constaté que l'on pouvait obtenir une faible dispersion de l'épaisseur spécifiée pour la chaussée, même en utilisant des machines de grande production pour stabilisation en une seule passe.

L'excellent comportement de ces chaussées sous le trafic semble indiquer l'excessive sévérité des spécifications actuelles pour la détermination du dosage en ciment.

Introduction

The execution of a large road construction programme in Mozambique, covering about 8 000 km of roads, stimulated a remarkable development of the techniques of soil stabilization, with special emphasis on the construction of soil-cement base courses. The experience gained over more than 10 years make it already possible to reach certain firm conclusions in the field of design, construction, control and observation of the finished works.

Methods of design

The determination of the cement content necessary for soil stabilization is being carried out in Mozambique according to the standard ASTM methods, with the exclusion of the freeze-thaw test, due to the prevailing climatic conditions. This policy was decided a long time ago, after having abandoned a method of determining cement content by an unconfined compressive strength test after curing the sample for 7 days, for 18 kg/cm^2 (250 lb./sq. inch.). In practice, it was found that a great number of local soils, which entirely satisfied the ASTM standard, did not attain the specified compressive strength after 7 days. However, its subsequent behaviour in the pavement was perfect. Figs. 1 and 2 enable these points to be appreciated.

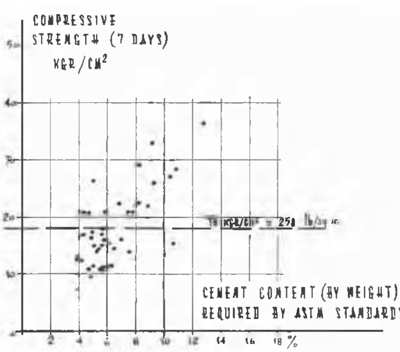

Fig. 1 Compressive strength after 7 days curing for cement content determined by the ASTM tests.

Résistance à la compression après 7 jours avec le pourcentage de ciment déterminé par les essais ASTM.

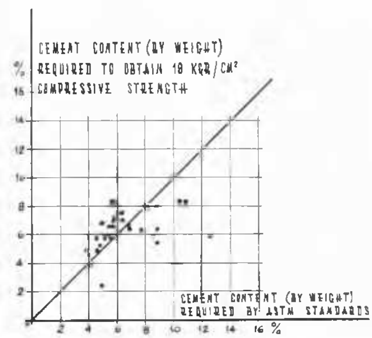

Fig. 2 Relationship between the cement content determined by the ASTM tests and by the compressive strength of 18 kg per sq. cm after 7 days curing.

Relation entre le pourcentage de ciment déterminé par les essais ASTM et par la condition de résistance à la compression minimum de 18 kg/cm^2 après 7 jours.

Inconveniences of the ASTM methods

Although the ASTM specifications have given complete satisfaction in the behaviour of soil-cement base courses, two handicaps must be considered. The first results from the time necessary for the completion of tests and the soil quantity necessary for them (about 6 weeks and 45 kgs of soil). The second refers to the fact that, for a great number of soils tested, the ASTM method leads to cement contents exceeding those strictly necessary to ensure a good performance.

The first fact has been recognised by various workers. It is to be noted the efforts of LEADABRAND and NORLING (1953) (1956), LEADABRAND, NORLING and HURLESS (1957), DIAMOND and KINTER (1958) and the Road Research Laboratory researchers, namely MACLEAN (1956).

The use of the Leadabrand and Norling short-cut techniques was not satisfactory for Mozambique soils and had to be abandoned. Now, the work of Diamond and Kinter and those of the Road Research Laboratory opened up new possibilities.

Surface area method and the grain-size distribution curve of soils

In their paper, Diamond and Kinter use the value of the soil surface area, measured by the glycerol retention method, to predict the cement content necessary for stabilization of soils, based on the permissible losses in the freeze-thaw ASTM test. The conclusions reached are most valuable, although they apply only to a few soils.

Yet it seems possible to substitute a determination of surface area for a more simple and rapid determination of grain-size distribution of soils, using the *a* - constant, introduced by the author (DOS SANTOS, 1953, 1955, 1955). In fact, this constant, which is proportional to the area limited by the grain-size distribution curve, the axis $y = 0$ and the No. 200 and 7 BSS sieves ordinates (sand fraction), is related to the soil surface area. Using the soils mentioned by Diamond and Kinter, drawing the respective grain-size distribution curves and deducting the values of the *a*-constant, it is possible to verify this correlation (Fig. 3).

It is therefore not surprising that there is a defined correlation for the same soils, between the grain-size distribution *a*-constant and the required cement content according to the ASTM freeze-thaw test. This is shown in Fig. 4.

In the present paper, the cement content refers to the weight of the dry soil and not to its volume, for the reasons stated by Diamond and Kinter.

In Fig. 5, instead of the cement content being deducted from the permissible losses in the freeze-thaw test, which

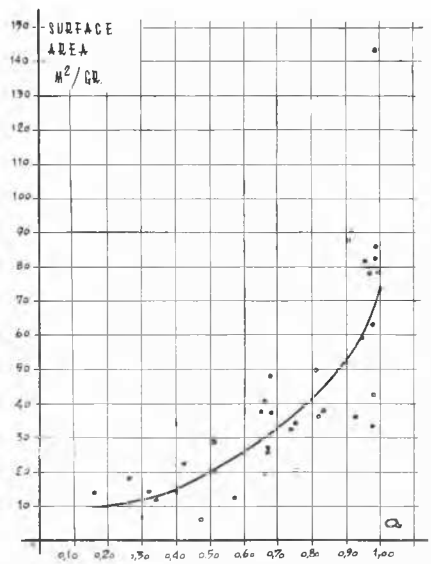

Fig. 3 Correlation between the *a* - constant and the soil surface area.

Corrélation entre la constante *a* et la surface spécifique des sols.

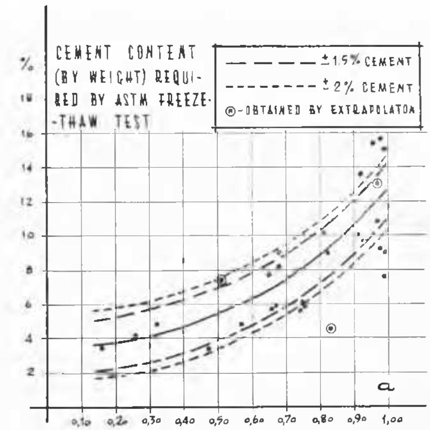

Fig. 4 Correlation between the *a* - constant and the cement content for the maximum permissible losses in the freeze-thaw ASTM test (American soils).

Corrélation entre la constante *a* et le pourcentage de de ciment correspondant aux pertes tolérées dans l'essai ASTM « freeze-thaw » (sols Américains).

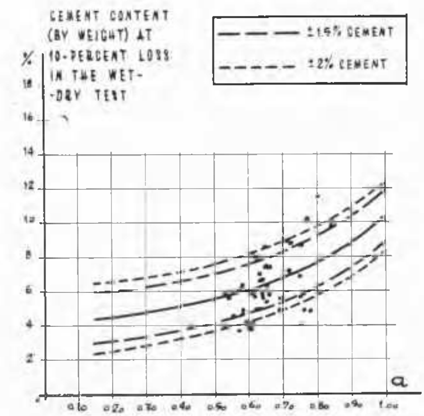

Fig. 5 Correlation between the *a*-constant and the cement content corresponding to 10 per cent loss in the freeze-thaw ASTM test (American soils).

Corrélation entre la constante *a* et le pourcentage de ciment correspondant à 10 pour cent de pertes dans l'essai ASTM « freeze-thaw » (sols Américains).

vary according to the type of soil, a cement content corresponding to a uniform loss of 10 per cent is employed. In both cases, it was verified that correlation becomes worse for soils with high clay content ($a = 0{\cdot}95$ to $1{\cdot}00$), which are those of least interest for cement stabilization.

Working in the same way with 47 soils of Mozambique, from those more frequently used in cement stabilization (groups A-1-b, A-2-4, A-2-6, A-2-7, A-3 and A-7-6), taking the cement content corresponding to a 10 per cent uniform loss, in the wet-dry test, the results obtained are shown in Fig. 6, in which the reference curves are the same as those on Fig. 5. Only 9 soils showed deviation higher than ± 2 per cent of cement.

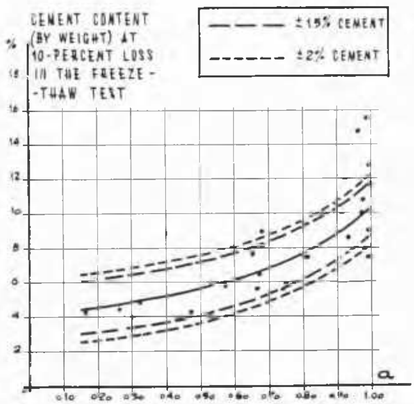

Fig. 6 Correlation between the *a*-constant and the cement content corresponding to a 10 per cent loss in the wet-dry ASTM test (Mozambique soils).

Corrélation entre la constante *a* et le pourcentage de ciment correspondant à 10 pour cent de pertes dans l'essai ASTM « wet-dry » (sols du Mozambique).

The CBR test for the determination of the cement content

The above mentioned work of the Road Research Laboratory namely that of MACLEAN (1956), has permitted the CBR test to be used for the determination of cement content in soil cement base courses. A CBR value equal to 120 per cent was suggested as giving satisfaction, according to British conditions. Since then the problem has been closely studied in Mozambique with results of considerable interest.

Fig. 7 shows an excellent correlation, for a group of sandy soils in Mozambique — A-2-4 and A-3 — between the cement content by weight corresponding to the maximum permissible losses in the wet-dry ASTM test and the corresponding CBR values. Fig. 8 shows an identical correlation, however less well defined, giving the cement content necessary to obtain a compressive strength of 18 kg/cm^2 (250 lb./sq. inch.), after curing for 7 days.

In practice, the CBR = 120 per cent value is not satisfactory for a large number of soils, or for a minimum compressive strength of 18 kg/cm^2 after 7 days' curing, according to British Standard Specification requirements.

The author believes that the CBR method is not as suitable as the ASTM method or the compressive test method. Therefore the adoption of a fixed CBR value for all soils will lead to cement contents which can either be much lower or much greater than those necessary to ensure durability or compressive strength, which are generally specified.

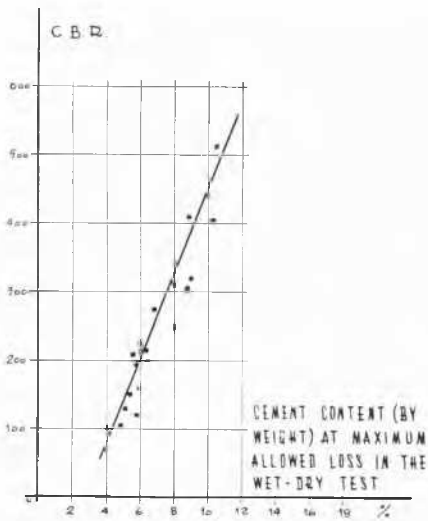

Fig. 7 Required CBR for the allowed losses in the wet-dry ASTM test (Mozambique soils).

CBR correspondant aux pertes tolérées dans l'essai ASTM « wet-dry » (sols du Mozambique).

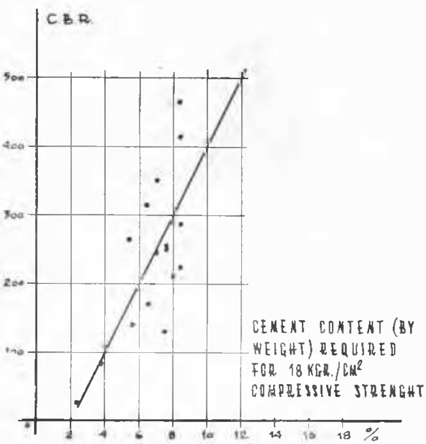

Fig. 8 Required CBR to ensure 18 kg per sq. cm (250 lb/sq. inch) of compressive strength after 7 days curing.

CBR correspondant à 18 kg/cm^2 de résistance à la compression après 7 jours.

For the group of soils investigated, a 200 per cent CBR leads to losses between 4 per cent and 55 per cent in the wet-dry test (for the majority of these soils the losses are between 4 per cent and 23 per cent). If we assume a 150 per cent CBR, the dispersion of losses varies between 5 per cent and 85 per cent with the great majority between 5 per cent and 42 per cent.

Without new progress in research work, it does not seem prudent to design the soil-cement content to a CBR value of less than 200 per cent. It is possible that, in the future, instead of a fixed value, it will be more suitable to adopt a CBR value which varies according to the type of soil.

Construction control

At present soil-cement stabilization in Mozambique is almost entirely carried out with single-pass machines of high output. It is therefore necessary to rely on a careful system of construction control, whether in the verification of the soils employed and previously studied, or in the quality of the base course.

As for the latter, immediate control covers relative compaction, moisture content, compressive strength, CBR and final thickness.

The control of the base course thickness is fundamental : variation may cause either the reduction of the pavement load capacity as regards the load transmission to the subgrade, or weakening of the base course by reduction of cement-content.

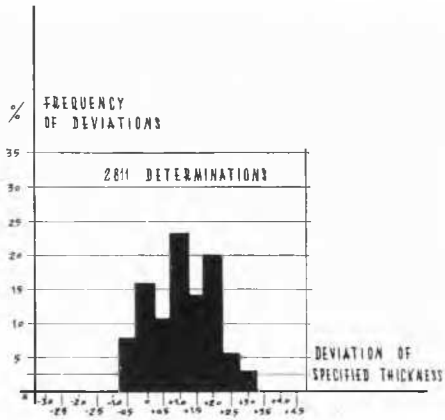

Fig. 9 Frequency of deviations in relations to the specified thickness in a soil-cement base course.

Fréquence des différences constatées sur l'épaisseur calculée d'une couche de base en sol-ciment.

In Mozambique, for machines of high output (1 km/day of stabilization with 6·00 m width) a tolerance of $\pm$ 1·5 cm is specified, which has been achieved by simple processes. Fig. 9 represents, as a frequency diagram of 2 811 determinations in a base course of 15 cm in which the specified tolerance was from 14 to 17 cm.

Behaviour of the base courses

In many hundred of kilometers of soil-cement base courses, some with more than 10 years of traffic intensity greater than expected, no failure was reported. This may suggest that the ASTM standards, in accordance with which they were designed, are too severe for local conditions.

Acknowledgements

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