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THE BEHAVIOUR OF TWO TRIAL EMBANKMENTS AT PERLIS, MALAYSIA WITH DIFFERENT RATES OF CONSTRUCTION

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ABSTRACT

Two trial embankments namely the North and South trial embankments were constructed in the state of Perlis, Peninsular Malaysia. The embankments have a finished height of 4m and dimensions of 60m in width and 90m in length and were constructed side by side. The trial embankments were staged constructed with a counterberm at 2m and side slopes of 2:3. The South trial embankment was rapidly constructed in 36 days while the North embankment was slowly constructed in about one year. Detailed site investigation works included borehole logging, field and laboratory testing. These were carried out to obtain the subsoil profile and geotechnical parameters of the subsoils at the trial site. Geotechnical instrumentation installed to monitor the behaviour of the embankments including settlement plates, heave markers, pneumatic piezometers and inclinometers.

This paper briefly describes the location of the trial site, the detailed layout and the construction details of the embankments. Geotechnical parameters for the fill and the subsoil profile obtained from the detailed site investigation works are briefly described. The behaviours of the two embankments identified from various geotechnical instrumentation are described.

KEYWORDS

trial embankments, staged construction, goetechnical properties, geotechnical instrumentation, behaviour.

1.0. INTRODUCTION

In 1991, due to rapid infrastructure developments occurring in Malaysia, the Public Works Department of Malaysia decided to embark on a joint research program with the University of Strathclyde, United Kingdom to study the geotechnical characteristics and behaviour under sustained loading of the coastal soft soil deposits of Peninsular Malaysia. As a part of this study, two trial embankments were constructed at a trial site situated at Kuala Perlis, Perlis, the northernmost state of Peninsular Malaysia, Fig. 1.

The trial embankments were constructed at different rate of construction and their behaviour were observed through detailed geotechnical instrumentation installed in both embankments. Detail site investigation works which included field and laboratory tests were also carried out prior to the construction of the trial embankments to obtained geotechnical properties of the trial site.

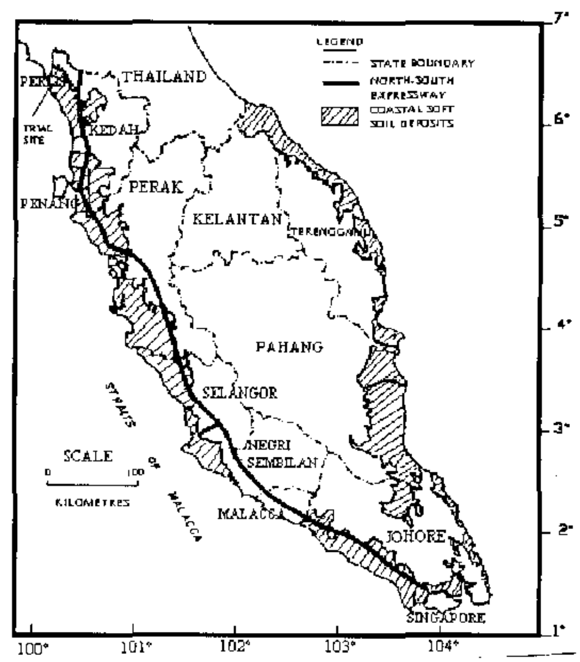


Fig. 1: Location of Trial Site

2.0. THE DETAILED LAYOUT OF THE TRIAL EMBANKMENTS

Both trial embankments were 60m in width and 90m in length with a finished height of 4m, constructed with a berm at 2m. The embankments had side slopes of gradient 2:3. The details of the layout of the embankments are shown in Fig.2.

The embankments were constructed with different rates of construction. The first, called the South embankment was rapidly constructed, being completed in 36days while the second, called the North embankment was constructed at a slower rate of construction, being completed in one year. Prior to the construction of the embankments, a geotextile separation layer was laid between the weak soil and the fill material to facilitate placing of the fill. A drainage blanket of about 350mm was first laid on the geotextile to allow drainage during consolidation of the trial embankments.

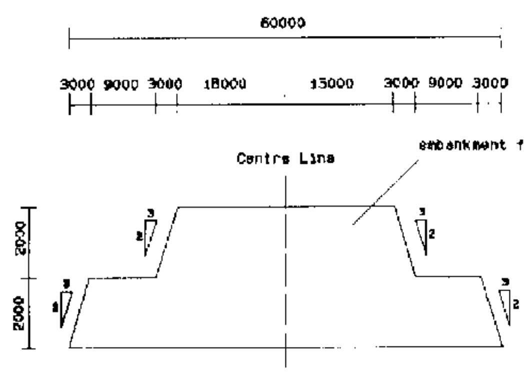


Fig. 2 : Cross Section of Each Trial Embankment

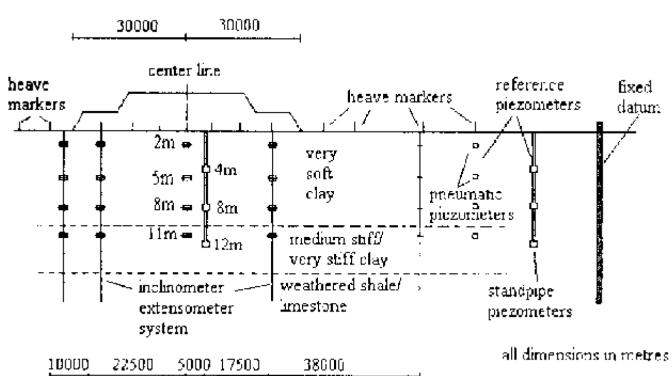


Fig. 3 : Instrumentation for Each Trial Embankment

3.0. INSTRUMENTATION LAYOUT

The embankments were fully instrumented in order to monitor their behaviour with time. The instruments installed included settlement plates, pnuematic and standpipe piezometers, extensometers, inclinometers and heave markers. The settlement plates were installed at the bottom of the embankment at a spacing of about 5m. Pneumatic piezometers were installed at depths of 2m, 5m, 8m and 11m while standpipe piezometers at depths of 4m, 8m and 12m. Inclinometers were installed at a distance of 22.5m from the centre of the embankments and at the edge of the embankments. The inclinometers were installed down to solid bedrock. Extensometers were installed at depths similar to that of the pneumatic piezometers depth. The extensometer were installed either alone or together with an inclinometer. The geotechnical instruments were installed along the East-West direction which is the shorter distance across the embankments (60m). The details of the intrumentation layout are as shown in Fig.3.

4.0. GEOTECHNICAL PROPERTIES OF THE SUB-SOIL

Site investigation works carried out at the trial site included borehole logging, field and laboratory testing. Eleven boreholes were carried out at each trial embankment. Piezocone and field vane testing were carried out at five locations. Results from boreholes and piezocone testing showed that the subsoil consists of very soft silty clay up to 13m depth followed by a much stiffer clay layer. Field vane tests of the geonor vane type showed that average shear strength values varies from about 12kPa to 32kPa. The strength of the layers were confirmed by the piezocone tests which also indicated that the soft soil were made up of silty clays. The sensitivity of the soft soil deposits ranged from 2 to 7 with an average of about 3.

Laboratory tests were carried out on seventy seven undisturbed samples obtained from eleven boreholes from each trial embankment. The types of tests carried out included classification, compressibility, shear strength and chemical tests as well as mineralogy together with macro and microfabric studies.

Classification tests included moisture content, Atterberg limits, particle size distribution, specific gravity and bulk density. Classification tests showed that the subsoil had a moisture content ranging from 20% to 160%, liquid limit from 40% to 125%, plastic limit from 10% to 40%, liquidity index of 0.1 to 2.1, specific gravity of 2.5 to 2.8, bulk density of 13 to 16kN/m^3. The particle size distribution was 50% to 60% clay, 20% to 40% silt and 0 to 25% sand and gravel.

Compressibility tests were carried out using both Standard Oedometer and Rowe Cells. These showed that the preconsolidation pressure ranged from 20kPa to 100kPa with an overconsolidation ratio (OCR) of 1 to 6.5. The soils were thus shown to be slightly overconsolidated. The compression index values ranged from 0.6 to 2.2 indicating presence of very soft layer at the top overlying slightly stiffer soil. Initial void ratio ranged from 2 to 3.8, coefficient of consolidation ranged from to 0.1 to 25m^2/yr. Coefficient of volume compressibility ranged from 0.5 to 1.2 m^2/MN indicating very high compressibility according to classification given in Head

(1980). Secondary coefficient of consolidation values ranged from 0.06 to 0.35 which can be classified as having low to very low compressibility according to Mesri (1973). Laboratory permeability values ranged from 1.5×10^{-11} to 4×10^{-4} m/s.

Laboratory shear strength tests showed that the undisturbed samples have an average undisturbed shear strength obtained from laboratory vane tests from 8kPa to 60kPa. The sensitivity of the soft soil deposits ranged from 2.5 to 13. Effective shear strength parameters obtained from direct shear box and triaxial tests were 8 to 12kN/m^2 for effective cohesion and 15^o to 17^o for the effective angle of friction.

Chemical tests showed that the pH of the undisturbed samples range from 5 to 9 with sulphate contents from 0.1 to 1.7 and chloride contents from 0.007 to 0.026. Carbonate tests on a few samples indicated that the carbonate content ranged from 13.5 to 22%. This was due to presence of broken shell fragments. Organic content was found to range from 2% to 15 % indicating that the soft soil is not highly organic but having certain amount of organic matter. Data from mineralogy tests showed that the sub-soils consists of 35 to 65% kaolinite, 20 to 50% illite and 5 to 45% montmorillonite. Detailed results of field and laboratory tests are described by Hussein (1995) and Hussein et al (1996).

5.0. THE BEHAVIOUR OF THE TRIAL EMBANKMENTS

The behaviour of the two trial embankments can be divided into the following :

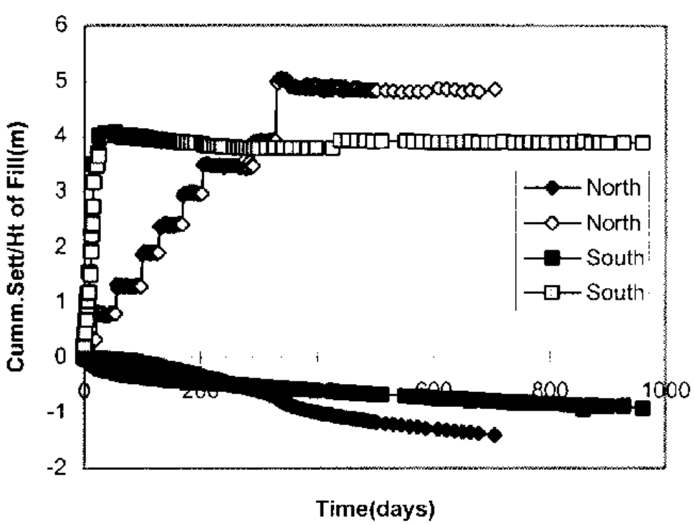


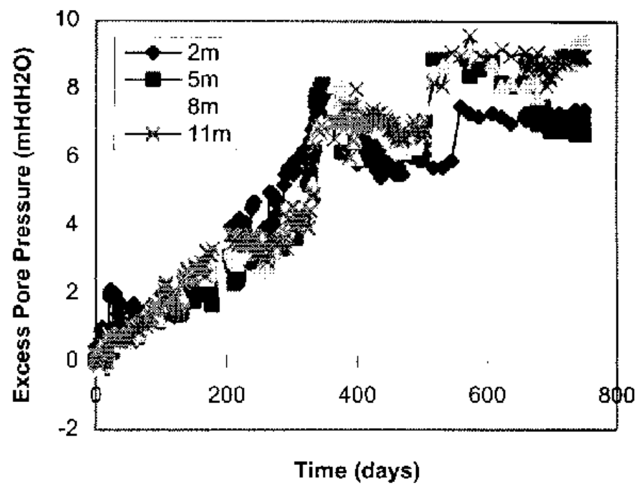
Fig.4 : Cumulative Settlement/Height of Fill with Time at the Centre of Embankment.

5.1. Cumulative Settlement at Centre of Embankment

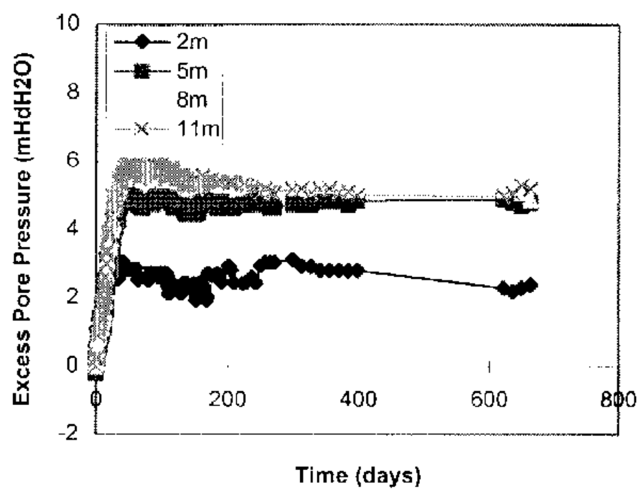
From Fig.4, it can be observed for the slow constructed embankment (the North embankment), the amount of fill is greater than the rapidly constructed embankment (the South embankment) for the same nominal height of embankment. This is due to the fill having settled into the ground during construction. As a result the cumulative settlement at the centre is much higher for the embankments compared. From this point of view, rapid construction is better than slow construction although the rate of construction and the stability of the embankment during construction need to be taken into consideration.

5.2. Excess Pressure Distribution at Centre of Embankment

From Fig. 5a and b, it can be observed that the excess pore pressure developed at the centre of the embankment for the slowly constructed embankment (North embankment), there seems to be some dissipation after end of construction (1 year) before increasing slightly and remaining constant up to 800 days after construction while for the rapid constructed embankment (South embankment), the excess pore pressures increases during construction and then dissipates slowly before remaining constant.



a) North Embankment (slow construction)

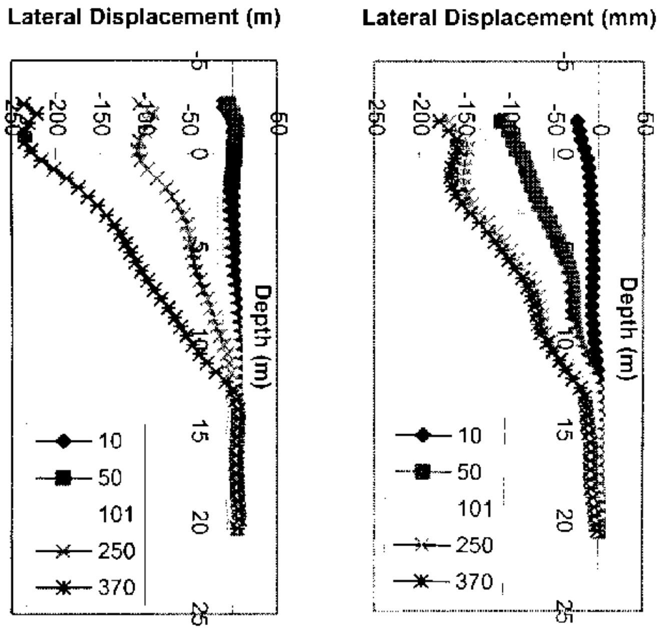


b) South Embankment (rapid construction)

Fig. 5 : Excess Pore Pressure with Time at Centre of Embankment

5.3. Lateral Displacement

Figs. 6a and b shows that the lateral displacement for the rapidly constructed embankment is slightly less than those of the slowly constructed embankment. This is due to the higher height of fill for the slowly constructed embankment which resulted in slightly more lateral displacement.



a) North Embankment (slow construction)   b) South Embankment (rapid construction)

Fig. 6 : Lateral Displacement with Time

5.4. Total Volume Displaced

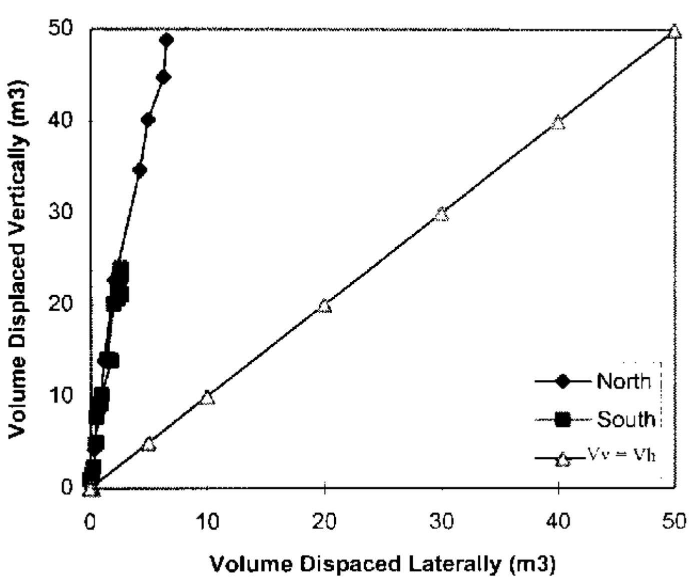


Fig. 7 : Total Volume Displaced Vertically to Total Volume Displaced Horizontally

Fig.7 shows the relationship of total volume displaced vertically with total volume displaced laterally as suggested by Johnston (1973). It can be observed that the volume displaced for both embankments are almost equal although the method of construction are different. The total volume displaced horizontally is about 7 to 14% of the total vertical volume displaced for the North embankment and 3 to 13% for the South embankment.

Detailed behaviour of the rapidly constructed trial embanknent is also described by Hussein and McGown (1996).

6.0. CONCLUSIONS

1. The amount of settlement, pore pressure distribution and lateral displacement seems to be higher for the slowly constructed embankment compared to the rapidly constructed embankment for the same nominal height of embankment.

2. Excess pore pressure distribution for both embankments shows an increase during construction. This then dissipates slightly before increasing or becoming constant.

3. There seems to be little difference in the total volume displaced vertically/volume displaced laterally for both embankments although the construction methods used are different.

7.0. REFERENCES

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