TEST EMBANKMENTS IN A HIGHWAY DEVELOPMENT PROJECT, VIETNAM

by

W. S. Tsai, T. C. Su and C. H. Wang

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W. S. TSAI **Moh and Associates Inc., Taiwan, R.O.C.**
T. C. SU **Moh and Associates Inc., Taiwan, R.O.C.**
C. H. WANG **Moh and Associates Inc., Taiwan, R.O.C.**

SYNOPSIS: Four full-scale test embankments with and without prefabricated vertical drains were carried out to examine in-situ soil properties and to arrive at an economical road embankment design scheme for the Saigon South Parkway. The Saigon South Parkway was near Ho Chi Min City and was constructed over subsoil mainly consisting of very soft organic clay. In addition to the test embankment, back analyses were also performed to predict their settlements. This paper describes the full-scale test program as well as presents the results from the full-scale test embankments and the back analyses.

INTRODUCTION

The Saigon South Parkway is a 17.8 km long and 10 lanes new highway, which will provide a new transportation corridor connecting Tan Thuan Export Processing Zone and ports along Saigon River to National Highway 1 with sound travel quality and without interrupting Ho Chi Minh City's urban transportation. This roadway will also stimulate the development of Saigon South, a new town development on the south fringe of Ho Chi Minh City (Fig. 1). The Saigon South Parkway is currently under construction and runs over subsoil mainly consisting of very soft organic clay. To examine in-situ soil properties and thus to arrive at an economical road embankment design scheme for the Saigon South Parkway, four full-scale test embankments with and without prefabricated vertical drains were conducted. In addition to the field tests, back analyses were performed using the results of the full-scale test embankments to predict their settlements. The back analysis results show that the settlements of the embankments can be well predicted. This paper describes the full-scale test program as well as presents the results from the full-scale test embankments and from the back analyses.

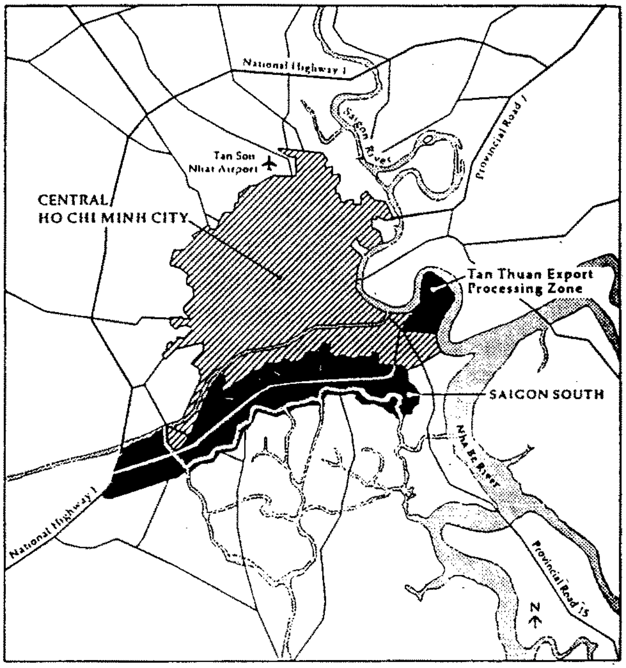


Fig. 1 Location of Saigon South Parkway.

SUBSOIL CONDITION

The subsoils under the 17.8 km long and 10 lanes Saigon South Parkway mainly consists of three layers: (from top) (i) a 11 to 14 m thick very soft to soft marine silty clay layer; (ii) a 5 to 7 m thick stiff to hard silty clay layer; (iii) an about 3.5 m thick medium loose silty fine sand with little clay layer. The clayey soils in this area were locally named Hai-Chi Clay. Some decayed plants, roots and sand seams were observed within the soft marine silty clay layer. The upper layers to a depth of about 13 m had natural moisture contents greater than their liquid limits. Fig. 2 shows a typical soil profile together with distributions of natural moisture contents, Atterberg limits and unit weights at the test embankment site. The groundwater level observed was about 0.5 m above the ground surface, and the groundwater pressure appeared to be hydrostatic.

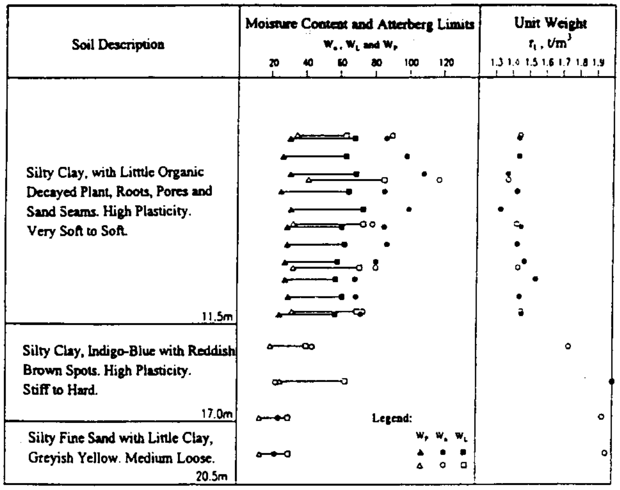


Fig. 2 Typical Soil Profile.

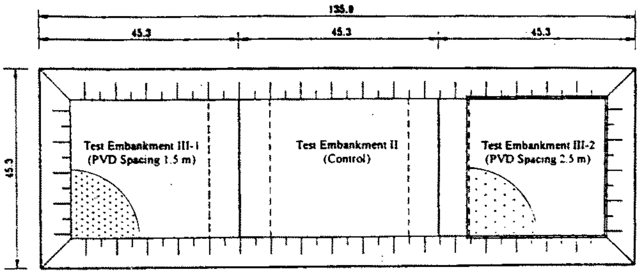
TEST EMBANKMENTS

There were four test embankments (Test Embankments I, II, III-1 and III-2) in the field test program, and all the test embankments had the same base of 45.5 by 45.5 m and the same side slope of 1:3 (V:H). Among the four test embankments, Test Embankment I was intended to be constructed to failure in order to determine the critical height and failure mode. However, no failure took place after a final embankment height of 5.0 m was reached.

On the other hand, Test Embankments II, III-1 and III-2 were constructed to study the settlement behaviors of the subsoils with and without soil improvement. Test Embankments III-1 and III-2 were constructed with ground improvement by using prefabricated vertical drains (PVDs) in triangular spacings of 1.5 and 2.5 m, respectively, whereas Test Embankment II acted as a control unit(i.e. no PVDs were used in this embankment). All prefabricated vertical drains were 14 m long. Fig. 3 shows the layout of PVDs. The backfill material used for the test embankments were sandy material obtained from Dong Nai River, which is located to the north of Ho Chi Min City, and each lift of thickness less than 250 mm was compacted to a degree of 90% of AASHTO T180. Test embankments II, III-1 and III-2 were constructed in six stages for a period of 35 days.

INSTRUMENTATION AND RESULTS

Throughout the whole testing program, instrumentation including inclinometer, Sondex settlement system, standpipe piezometer, settlement gauge, surface settlement marker and datum bench mark, were installed to monitor the subsoil behaviors throughout the testing program. The instrumentation layout of Test Embankment I and that of Test Embankments II, III-1 and III-2 are illustrated in Figs. 4 and 5, respectively. Due to space restraint, among the results from the instruments, only some selected monitoring results will be presented and discussed in the paper.



Note:
1. PVD in Triangular Grid Patern
2. Unit:m

Fig. 3 Layout of Prefabricated Vertical Drains at Test Embankments III-1 and III-2.

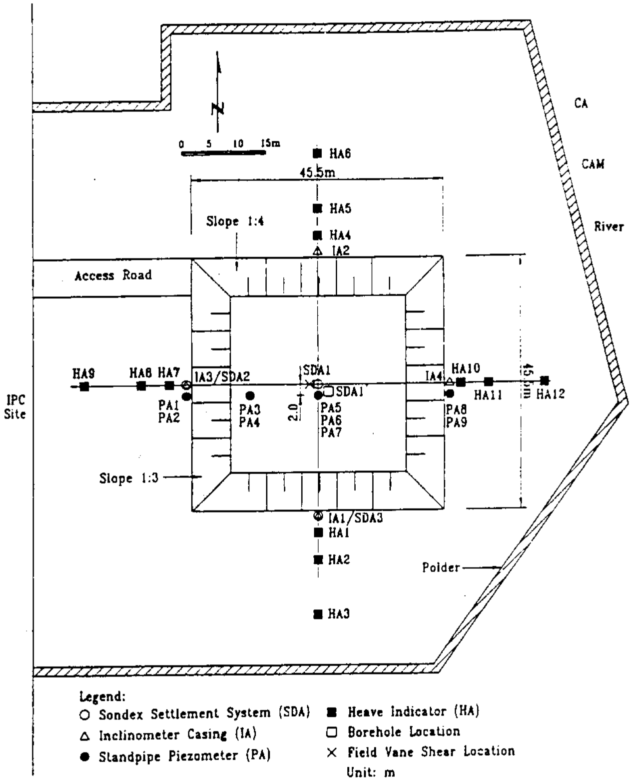


Fig. 4 Layout of Instrumentation at Test Embankment I.

Monitoring Results of Settlement Gauges

Settlement gauges were installed at Test Embankments II, III-1 and III-2. About eight to nine sets of settlement gauges are installed in each test embankment, and a total of 25 sets of them were installed. Fig. 5 shows the layout of the settlement gauge installed.

Fig. 6 shows the monitoring results of the settlement gauges. As shown in Fig. 6, the settlements from the settlement gauges at the centers of Test Embankments II, III-1 and III-2 were about 80 to 90 cm about 100 days after the completion of the test embankment construction. These settlement curves show great resemblance. It indicates that all the settlement rates at these three test embankments are high, and Test Embankments III-1 and III-2, respectively with 1.5 m and 2.5 m PVD spacings, had slightly faster settlements than the Test Embankment II, which did not have PVDs. Thus, the effect of PVDs for ground improvement at the project site is not remarkable. The settlement tough of the test embankments is shown in Fig. 7.

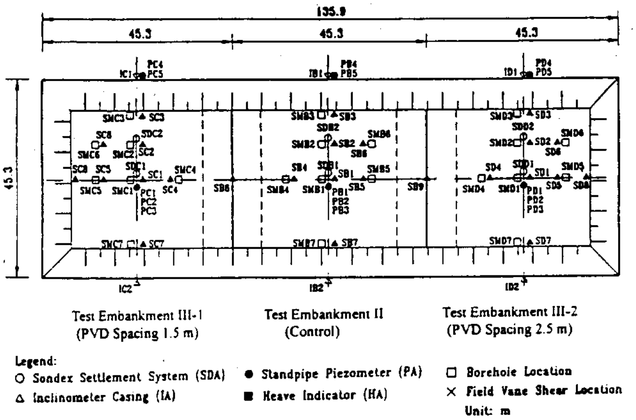


Fig. 5 Layout of Instrumentation at Test Embankments II, III-1 and III-2.

Monitoring Results of Sondex Settlement System

Nine Sondex settlement systems were installed at the test embankments. Each Sondex settlement system was 20 m deep and was equipped with 10 magnetic rings. Each of the magnetic ring was spaced at about two meters, and the first magnetic ring was located about one meter under the ground surface. The compressions of the soil layers could be determined by measuring the changes of the locations of the magnetic rings of the Sondex settlement system.

Among the nine Sondex settlement systems, three were installed at Test Embankment I. On the other hand, each of Test Embankments II, III-1 and III-2 was installed with two Sondex settlement systems. The layouts of the installation are shown in Figs. 4 and 5. Fig. 8 shows the results of the Sondex settlement system measurements for Test Embankment I, and those for Test Embankments II, III-1 and III-2 are illustrated in Fig. 9.

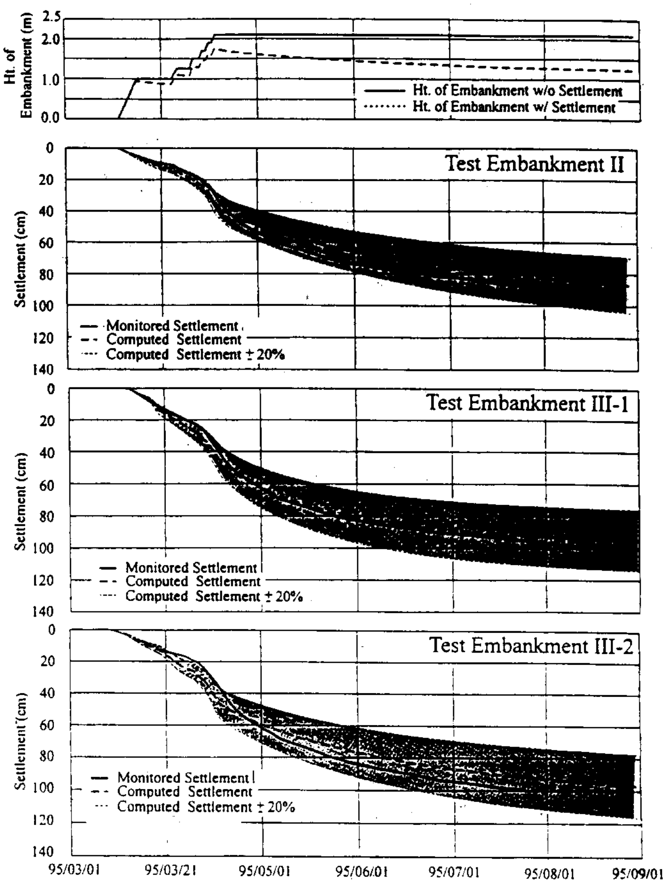


Fig. 6 Settlement Time Histories at Test Embankments II, III-1 and III-2 and Back Analysis Results.

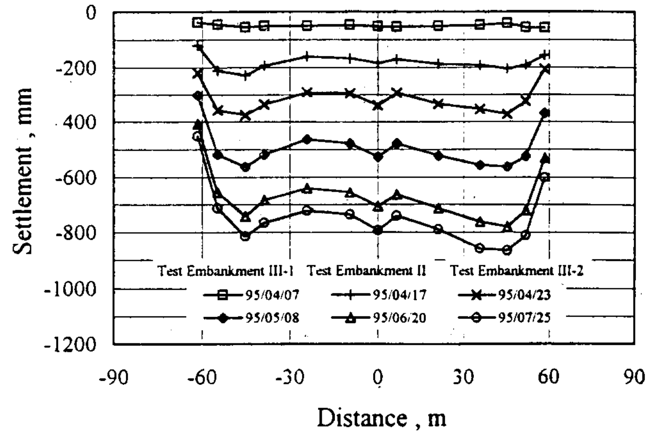


Fig. 7 Settlement Trough at Test Embankments III-1, II and III-2.

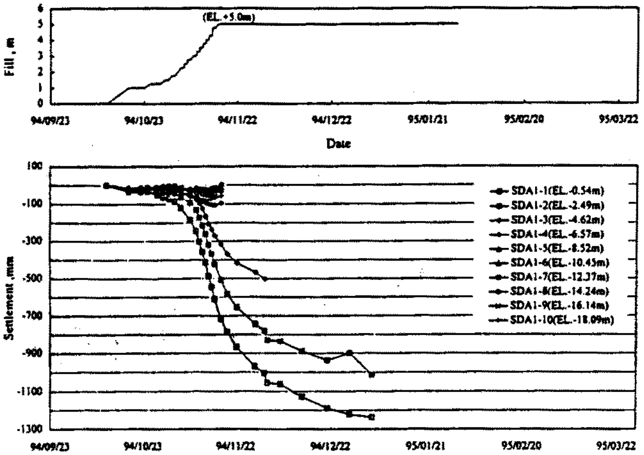


Fig. 8 Settlement Time Histories from Sondex Settlement System at Test Embankment I.

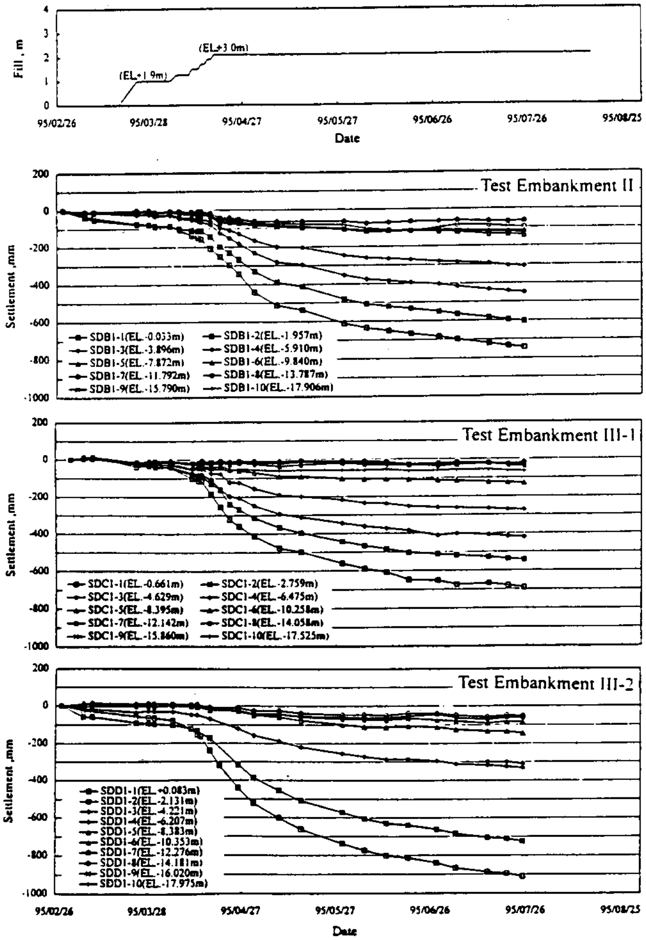


Fig. 9 Settlement Time Histories from Sondex Settlement System at Test Embankments II, III-1 and III-2.

Because the PVC pipe of the settlement system SDA1 installed in Test Embankment I was clogged, only the settlements of the two uppermost layer could be measured. The results (Fig. 8) from SDA1 shows that the largest settlement of the two magnetic rings was 124 cm. According to the measurements at systems SDA2 and SDA3, the largest settlements at Test Embankment I occurred at the toe of the embankment and was about 8 cm.

The monitoring results of the Sondex settlement systems at Test Embankments II, III-1 and III-2 (Fig. 9) show about 10 to 20 cm (i.e. 15% to 25%) of the total settlements are due to the compressions of the soil layers below the depth of 11.5 m. Hence, the compressions of soil layers within 11.5 m of the ground surface were 70% to 85% of the total settlement. Also the settlements of the magnetic rings (spaced at 2 m) above 11.5 m deep were almost the same, and their settlement curves tended to be parallel to each other. It means that the rate of settlement within this depth were identical. The results also illustrated that the settlement was almost proportional to the thickness of the soil layer. Some settlements occurred before the construction of test embankments were observed according to the monitoring data of Sondex settlement systems. The settlements might be due to the movement of construction machinery for the temporary access road.

Monitoring Results of Inclinometers

Four inclinometers, IA1 to IA4, were installed at Test Embankment I, and three pairs of inclinometers, IB1 and IB2, IC1 and IC2, and ID1 and ID2, were installed at Test Embankments II, III-1 and IIII-2, respectively. The inclinometers were installed at both sides of the embankment with a distance of 1 m away from the toe as shown in Figs. 4 and 5. These inclinometers were to monitor the lateral movement of the subsoil. The measured movement was in a direction perpendicular to the longitudinal axis of the embankment. Fig. 10 shows lateral movement of subsoil from inclinometer IA2.

The monitoring results of the inclinometers at Test Embankment I, which was intended to be constructed to failure, show that the lateral movement of the subsoil at various depths were less than 10 mm. Because of the compression of the clay layers at shallow depths and the effect of the construction machinery during backfilling, the lateral movement near the ground surface was larger than the others. As the embankment was constructed 5.0 m high, the greatest lateral displacement occurring at the toe of the embankment increased to about 30 mm. The embankment still remained stable and has no sign of failure.

For the other test embankments such as Test Embankment II, the greatest lateral displacement of soil at the toe was less than 10 mm during the first stage of backfilling (about 1.0 m thick). Throughout the whole construction process, the greatest lateral displacement, which occurred at a depth of 5

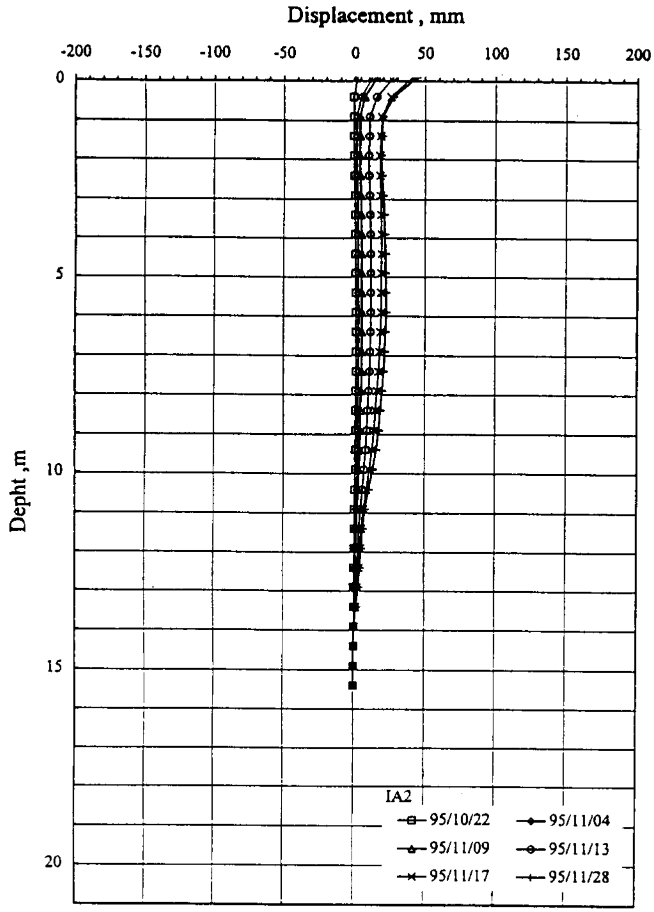


Fig. 10 Lateral Soil Movement from Inclinometer IA2 at Test Embankment I.

m under the toe, merely reached about 20 mm. It also indicates that the side slopes of the embankment also appeared to be stable.

IN SITU DISSIPATION TESTS

Three in situ dissipation tests were performed in three selected piezometers: one at Test Embankment I, the other two at Test Embankment II. In each test, the water table in the piezometer was measured and then water was poured into the piezometer pipe and rose the water table to the top of the pipe. Then, the water table in the piezometer gradually fell down and was recorded at certain time intervals. The results showed that the water tables of at the three piezometers returned to the original water table level within one hour. According to the timeplot and based on the recommended formula recommended by NAVFAC DM 7.1 (1982), the coefficient of permeability was estimated, and the coefficients of permeability of soil layers were 6×10^{-5} to 1×10^{-4} cm/sec. The high permeability is close to the permeability of sandy soils. It is probably due to that sand seams and organics were present in the clay layer, and the drainage path of the clay layer is thus remarkably shortened.

BACK ANALYSIS

In addition to the full scale test embankments, back analyses were also performed. Since the soil parameters such as overconsolidation ratio (OCR), compression index (C_c), recompression index (C_r), coefficient of consolidation in vertical direction (c_v), coefficient of consolidation in horizontal direction (c_h) and drainage path (H_{dr}) are considered most critical to affect the settlements, they were evaluated. After a significant number of trials, among these parameters, short drainage paths (H_{dr}) were found necessary to yield the settlement time histories, which can well simulate the field measurements as shown on Fig. 6. Fig. 6 shows that the deviation of calculated settlements from the measured settlements within the range of ±20% of the measured settlements for Test Embankments II, III-1 and III-2. Hence, the drainage paths of the soft clay layers should be very short and ranges from 1.0 to 1.3 m. These short drainage paths could be due to the presence of thin sand seams and organics as observed in the site investigation.

EVALUATION OF PVDS FOR THE RPOJECT SITE

The settlement monitoring data including the settlement gauges and the Sondex settlement systems showed that the test embankment without PVDs settled as fast as those with PVDs. In the back analyses, short drainage path was calculated to agree with field settlement measurements. The short drainage path could be due to the existence of thin sand seams and organics, which were observed in the continuous soil samples. Moreover, fast dissipation was observed in field permeability tests carried out in the standpipe piezometers. Due to the short drainage paths, it was concluded that the effect of PVDs for ground improvement of the Saigon South Parkway was not significant. Due to the findings from the full scale field test, the Saigon South Parkway is currently constructed without PVDs.

CONCLUSIONS

The settlement behaviors at the test embankments with or without PVDs are identical. Hence, the effect of PVDs to accelerate the preloading process is not significant in this case, It might be due to the presence of thin sand seams and organic materials within the compressible layer. The monitoring results of the Sondex settlement systems show that 70% to 85% of the total settlement were caused by the compressions of soil layers within 11.5 m of the ground surface. After a significant number of trials in the back analyses, the settlement time histories can be so well simulated that the deviation of calculated settlements from the measured settlements within the range of ±20% of the measure settlements. The results of back analyses also show that the drainage path of the soft clay layers are very short and ranges from 1.0 to 1.3 m. It can also be explained by the presence of thin sand seams and organics.

REFERENCE

NAVFAC DM-7.1 (1982) Design Manual 7.1, U. S. Dept. of Navy, Alexandria, VA.

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