2/A/20

# Variation of stresses and deformations in a weak soil

## Variation des contraintes et des déformations dans un sol mou

G. PETRASOVITS, Professor, Technical University Budapest, Hungary
J. FARKAS, Associate Professor, Technical University Budapest, Hungary
GY. HORVÁTH, Research Engineer, Technical University Budapest, Hungary
M. MINKOV, Professor, Bulgarian Academy of Sciences, Sofia, Bulgaria
P. KARATCHOROV, Research Engineer, Bulgarian Academy of Sciences, Sofia, Bulgaria
P. DONTCHEV, Research Engineer, Bulgarian Academy of Sciences, Sofia, Bulgaria

SYNOPSIS The paper presents results of instrumented in-situ tests of the behaviour of a weak sandy-clay soil under load. Sand layers of different thicknesses were placed above the weak soil to improve existing subsoil conditions. The effect of the sand overfill on the behaviour of the weak subsoil was tested by using a load plate having the same size with the planned foundation bodies. During the in-situ tests total and neutral stresses were measured with load cells and pore water pressure meters, respectively. For the measurement of settlements and soil layer displacements at different depth under the rigid load plate electro-inductive measuring instrument was applied.

## INTRODUCTION

We are more and more constrained to built permanent engineering structures on weak soils. The aim of the investigations was to make the loose fill able to bear loads by covering it a sand layer. The determination of the optimum thicknes of the applied sand layer made necessary to measure both the stresses and the displacements at different depths in the soil, including pore water presures generated by the applied test loads. This latter gave useful data for forecasting development of settlements in time. The paper presents part-results of in-situ tests that were carried out within the frame of one of the joint research programs between the Hungarian and Bulgarian Academies of Sciences. In East Bulgaria in the Varna bay several thousand hectares were filled up in 1972 by hydromechanic method. The average thicknes of the fill is 6 m. Below the fill sedimentary deposits can be found. The fill material is a slightly organically polluted sandy-clay soil which is in a very loose condition. The fill was necessitated by a future increase of the harbour cargo area. Low load store houses, light-weight structure buildings are planned to built here needing a load bearing capacity of 80 kPa at least instead of the existing 25-30 kPa load bearing capacity. The existing load bearing capacity of the fill was determined by detailed laboratory and in-situ tests but a large scale model test at the site seemed to be necessary, too. In these tests a load plate of 2 to 2 metres in size was applied. This size equals to the size of the planned foundation bodies of the buildings mentioned above.

## DETERMINATION OF THE SOIL PHYSICAL CHARACTERISTICS

Throughout laboratory and in-situ tests were carried out to determine the physical characteristics of the hydromechanic fill. Disregard listing of different methods only a typical sond diagram is plotted in Fig.1 including the physical characteristics. The fill consists of organically polluted, saturated soil. The water table is at 0.6 m below the ground level.

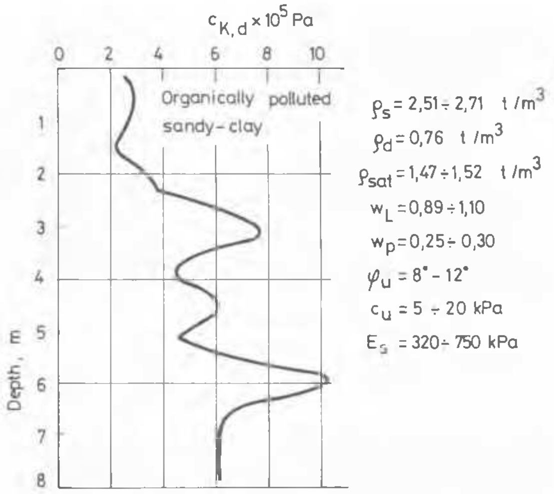

Fig.1 Result of sonding with soil physical characteristics

To determine antecedents of the fill and it's behaviour under load, modified triaxial tests were carried out on big size samples /length: 20 cm, diameter: 10 cm/.
Line a in Fig.2 represents the result of an undrained test with pore water presure measurement. The test started from a $K_o$ stress

condition. Line b in the same Figure is the line of the load increase by $K_o$ and the failure in an open system test. The load increase velocity was v=0.1 mm/min in both tests.

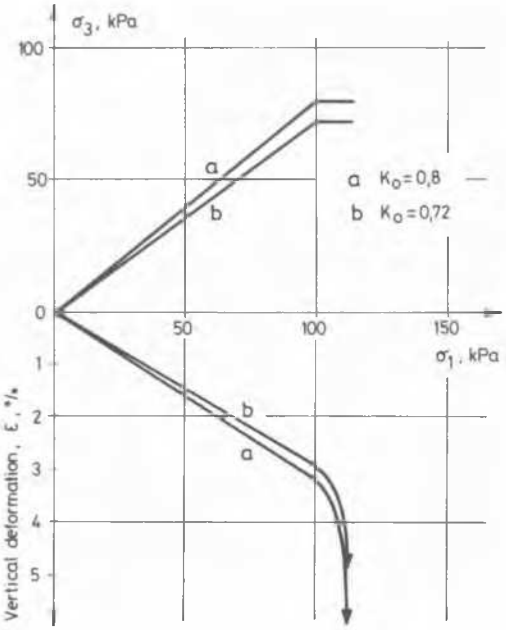

Fig.2 Behaviour of the sandy-clay fill in $K_o$ condition.
a: undrained system
b: drained system experiment

The earth pressure coefficient at rest is very high: $K_o$=0.72-0.8, characteristic of plastic soils. The straightness of the $K_o$ line, that is plotted against the principal stresses, implies normally consolidated antecedents.

## DESCRIPTION OF THE LARGE SCALE IN-SITU MODEL TESTS

To increase the load bearing capacity of the loose hydromechanic fill, layers of nearby deposited sand were intended to place above it. In the first step stresses and settlements were measured in the case of 0.6 m sand overfill.
The in-situ tests were accomplished in September 1983. The applied load plate was a 2 to 2 metres size very rigid ribbed steel plate. To measure stresses under the plate, 7.5 cm diameter load cells were applied. The layout of the plate and the different stress and settlement measuring instruments can be seen in Fig.3. The arrangement of the cells made possible to measure the effect of uneven surface bearing of the plate and the load eccentricity, too.
Beneath the centre of the plate 10 cm diameter load cells were placed at different depths: at 4.0 m and 2.0 m under the ground level and between the sand and sandy-clay fill at 0.6 m.

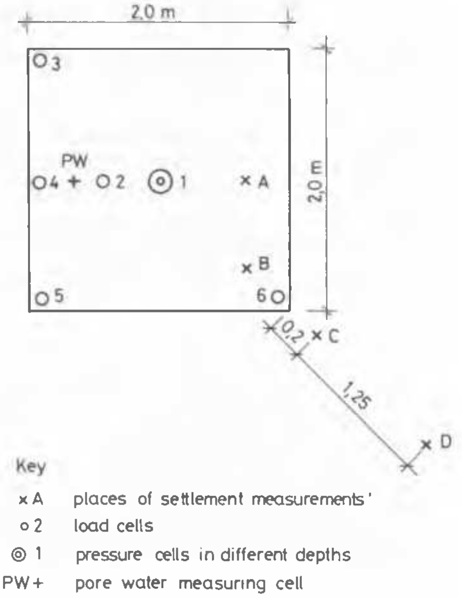

Fig.3 Layout of the rigid loading plate and the measuring places

The neutral pressure generated by the load was measured at 1.9 m under the plate by means of vibrating chord pore water pressure meter. Land surveying method was applied to measure the settlement of the plate and the deformations of the surface around the plate.
The variation of the settlement with depth was detected at 4 places up to 4 metres depth by means of electro inductive device that could find the situation of previously placed small steel plates. The spacing of the plates in depth was about 0.30 m.
On the basis of the results of laboratory tests the load up to failure was intended to increase in 5-6 steps with the help of bunches of steel plates. The failure was reached finally in the 6th step. The stresses and partly the settlements were registrated by electric instruments according to the consolidation. The next load step was decided on the basis of the measured settlement and neutral stress data.

## THE RESULTS OF THE EXPERIMENT

The electrically measured data were processed by means of computer. From the numerous data only some typical will be demonstrated in the following. In Fig.4 stresses in the soil can be seen vs. the depth under the centre of the loading plate at three chosen load steps. The continous line represents the measured stresses while the dotted one is plotted by means of data calculated with the help of soil physical parameters measured in laboratory.
It can be concluded that the stresses decrease much more steeply in the uppermost 60 cm thick sand fill than those in the saturated sandy clay fill. At 4.0 m depth /2B/ 30 percent of the total load can be detected.

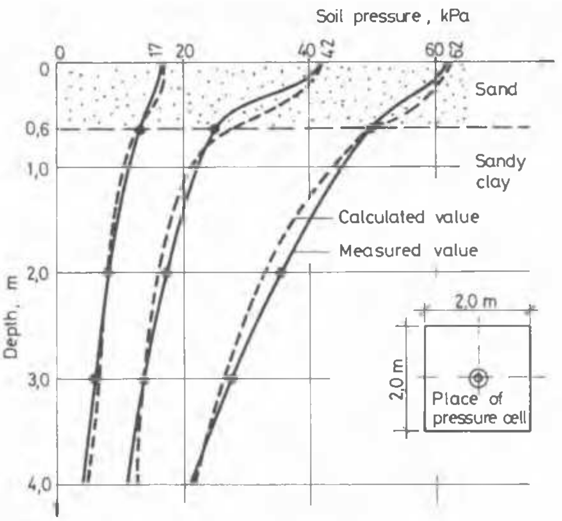

Fig. 4 Stresses in the soil at different depths below the surface

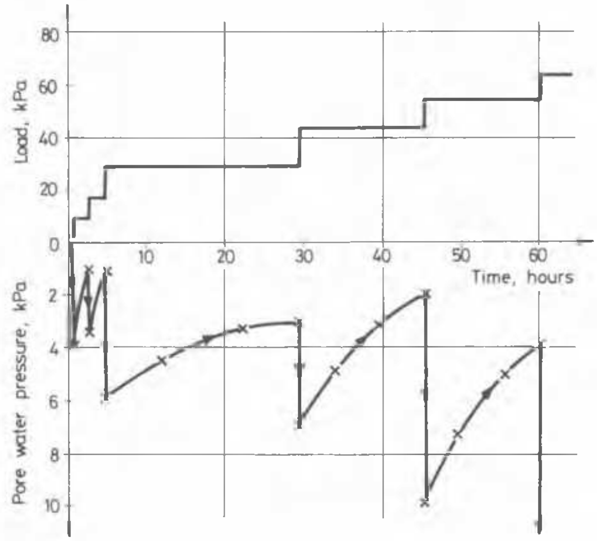

Fig.5 Relationship between load increase and pore water pressure in time

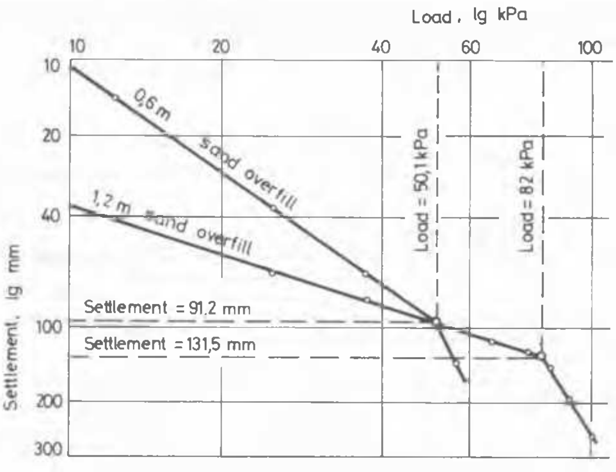

Fig.6 Lood-settlement diagram in log-log coordinate system

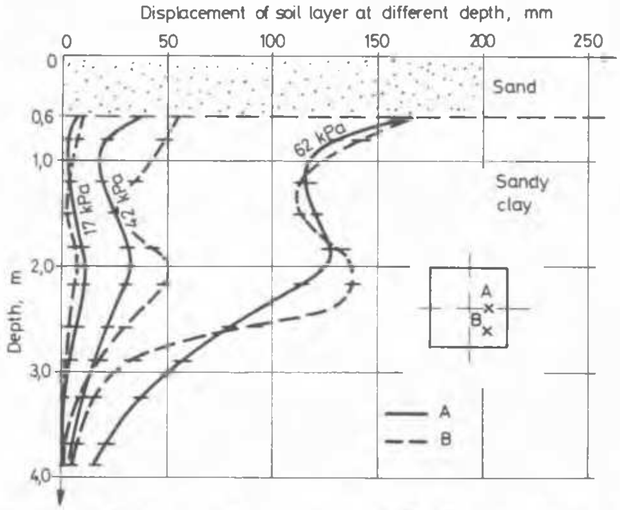

Fig.7 Soil displacements at different depths

Beside of the load increase in time, the variation of neutral stresses at 1.9 m depth can be seen in Fig. 5.
The load was increased after the major part of the consolidation and settlement took place.
The pore water pressure increases almost in the same time with the load and gradually decreases when the consolidation starts and keeps to the initial state. When the load-settlement relations caused by different loads are represented in linear coordinate system, they give a gradually increasing curvature line. If the results are plotted in log-log coordinate system, the beginning of the plastic state of the soil can be determined by the position of intersection of straight lines. According to these results, the load bearing capacity of the loose fill in the case of 0.6 m sand layer is 50.1 kPa to which an average of 91.2 mm vertical settlement belongs /Fig.6/.
Layer displacements vs. depth are shown on Fig.6. The curves imply the existance of a softer, more compressible layer at about 2 metres depth.
The displacements and the stresses alike were measured up to 4 m depth since settlements were negligible below this depth, as it became proved according to Fig.7.
The variation of the displacements is shown on Fig.8. In this figure displacements caused by the load q=62 kPa are plotted against the depth in a section that was made through the diagonal line of the load plate. At settlement measuring place D, that situated 1.45 m from the point of

the plate, no perceptible settlements came into being either on the surface or in the soil.

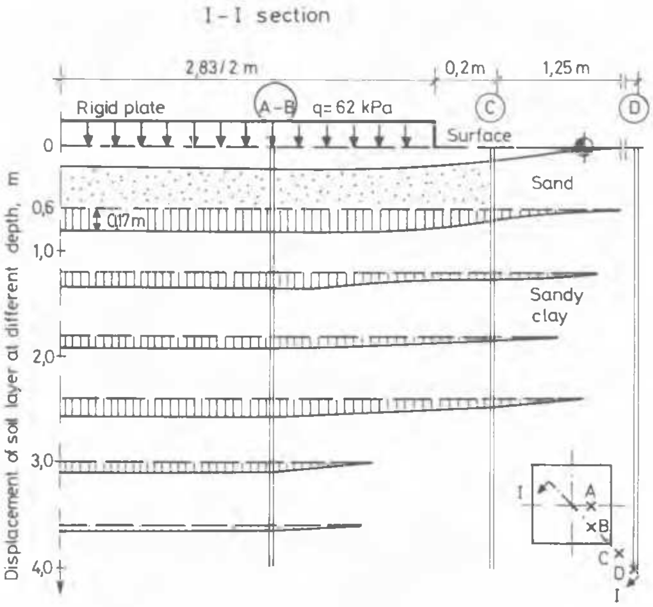

Fig.8 Soil desplacements at different depths

The limit of detectable settlements was about 50 cm from the edge of the loading plate.

## CONCLUSION

The load bearing capacity, the neutral and effective stresses, the settlements and their variation with depth were measured by in-situ large scale model test in the case of 0.60 m sand overfill above a weak, organic fill.
The in-situ tests above were repeated for 1.20 m sand overfill, too. The results can be seen on Fig.6.
On the basis of data gained from in-situ, laboratory and large scale model tests the necessary thicknes of the sand layer above the loose fill to the required 80 kPa load bearing capacity was determined. The required 80 kPa load bearing capacity can be achieved with about 1.20-1.50 m sand overfill.