INVESTIGATION OF LANDSLIDES ON A NATURAL SLOPE AND RECOMMENDED MEASURES

ETUDES DE LA STABILITE D'UN TALUS NATUREL ET LES MESURES RECOMMANDEES

A. HAMDI PEYNIRCIOGLU, Ord Prof. Dr.-Ing.
Technical University of Istanbul, Turkey

SYNOPSIS This paper presents an investigation carried out on an old slide area and the recommended measures to stop the soil movements.

Because of the very erratic nature of the ground theorical investigations based on boring logs and laboratory test results have been found to be not a reliable nature for an efficacious engineering project. Accordingly a long term observation period to determine the actual cause and geometry of the movements and the real position of the sliding surfaces and, for the design of an efficient project a series of lateral load tests on large diameter piles have been considered as an essential prerequisit.

EXPLANATION OF THE SUBJECT AND DESCRIPTION OF THE SLIDE AREA

After a comparatively long period of rest, in 1963, a series of slides began to displace the railway track several meters and destroyed the asphalt road as shown in Figs. 1 and 2.

Each time following a soil movement the railway engineers shifted the track back to its original position to keep the trafic moving. In the same time, to investigate the soil movements they established a series of referens points alongside the track. According to the measurements of the railway engineers the total movement of the track in four years amounted 4,68 meters, and that of a reference line at a distance 25 metres from the track amounted 22,75 meters.

A comparison of the airphoto shown in Fig.1 with a previous air photo taken some ten years ago showed that the movement of the river bank is of the order of 20 meters.

Similarly, a comparison of the original position of the road with that shown in Figs. 1, 2 and 3 gives approximately the same amount of soil movement at the skirts of the slide area.

In 1963 the author has been called for the first time to investigate the area and to recomment some measures to stop the soil movements which was begining to endanger also the newly constructed dwelling houses neighboring the boundaries of the slide area.

Fig.1 Airphoto showing the slide area in 1967

A series of borings and laboratory tests revealed that further investigations and a long term observations to determine the nature of the movements were necessary before to recommend a final an effective measure to meet the local conditions.

Based on the first investigations made in 1963 a detailed and systematic program has been prepared and during the years 1966 and 1967 put into effect.

Borings carried out in 1963 showed that the geology of the area is very complex. To clear the feature of the sand and marly and clayey layers 35 borings, 16 large diameter borings and 9 tests pits 2,5 X 2,5 m^2 in

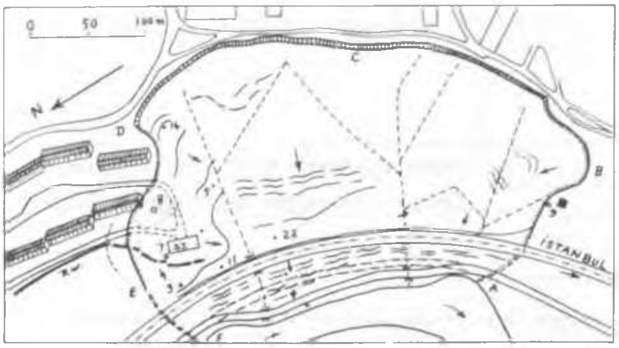


Fig. 2 Plan of the slide area showing the displaced road, septic tank (S.T.), Retaining wall (R.W.), and the tension cracks and wrinkles on the roots and bulged tongues of the slides. Railway track has always been shifted back to its original position following a slide.

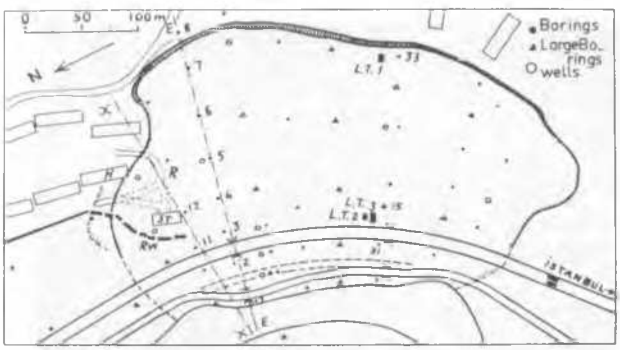


Fig. 3 Plan showing the places of borings and test pits which were converted into observation borings and wells. (L.T.) denotes the locations of the lateral load tests on piles.

plan and 10 meters deep have been carried out to explore the soil conditions and to obtain undisturbed samples.

Afterwards these borings have been converted into observation wells with large diameter concrete pipes.

The localities of these observation borings and wells are marked on the Fig.3.

Fig. 4 Head of one of the large diameter observation borings.

Fig. 5 Precipice formed at the head of the slide area near the boring No.33.

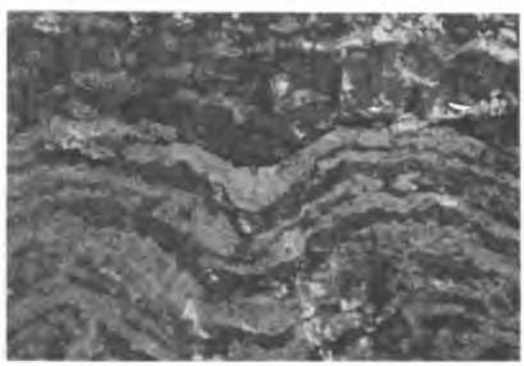


Fig. 6 A close up photograph of the Fig.5.

To establish an observation boring a plastic tube has been lowered into the drill hole and, after inserting the boring rods into the tubes, they hanged freely and the space between the walls of the hole and the tube is filled with the lean concrete.

A similar technique has been used to establish the observation borings and wells with concrete pipes of 20 and 60 centimeters inside diameter respectively.

In this manner we had 60 observation borings and wells to follow the soil movements.

The borings and wells with concrete pipes serve in the same time to observe the groundwater conditions.

Fig. 4 shows the head of one of the large diameter observation borings.

Fig.5 and 6 show undulated clay and calcareous materials underlain the layered and jointed coarse limeston in the vicinity of the boring No.33, Fig.3.

Fig. 7 shows geological sections along the axes E-E and X-X, and the sketch of the destroyed plastic tube of the boring No.11.

Section E-E prepared in 1963 shows the estimated slide surfaces. Section X-X is of a comparatively recent slide. This slide destroyed and moved the road and the low retaining wall and the septic tank shown on Figs.1, 2, 3, 8, 9.

According to the observations made in June 1966 soil movements are still continuing as the Fig. 10 shows. This phograph belongs to the eketch of the sheared away observation borings No.11.

The groundwater conditions is of very irregular nature. Some sand layers were found to have no groundwater whereas in tests pits we encountered water seeping from sand seams and between the fissures of the soft/very hard marley clays.

It is understood that one of the many reasons of the slides is this water of bleeding and sweating nature.

Because of the several old slides in different directions the complex nature of the strata became to be much more erratic and the regime of the underground water flow has been frequently changed and in some places clogged.

As a result of this complicated movements, especially after rainy seasons and snow melting periods the increase of pore pressures may have started the soil, which was on the vertex of its instability, to move.

The unconfined compressive strength determined in the laboratory varied between q_u 0,25 to more than 4,0 kg/cm^2 even some times in the same sampling tube.Repeated

Fig.8 Depression of the ground in front of the house (H) at the edge of the sliding mass along the X-X axis.

Fig.9 Destroyed road (R) on the sliding mass. See Figs. 1 and 3.

Fig.10 Photograph of the displaced plastic tube and destroyed concrete filling of the observation boring No.11.

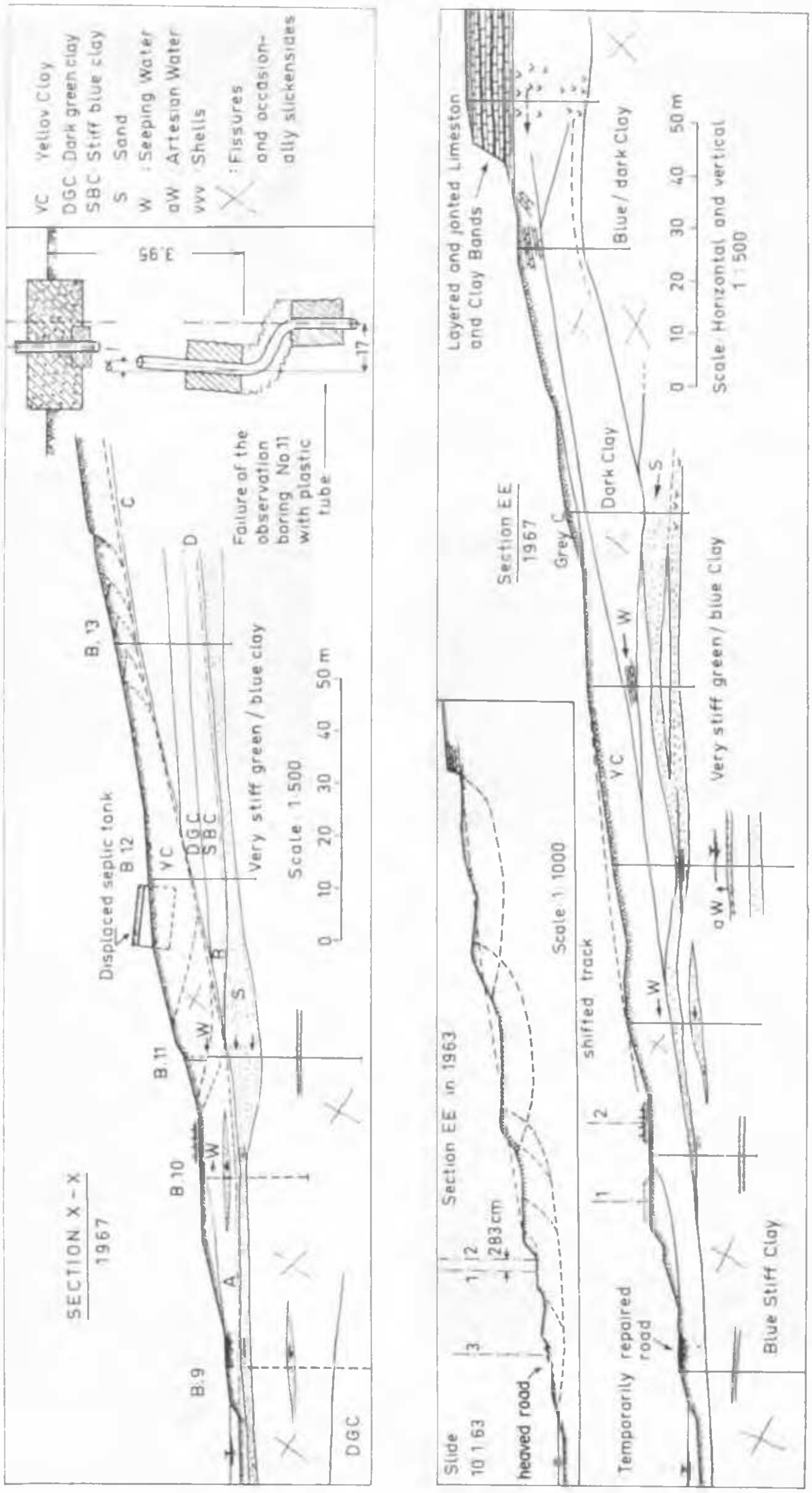


Fig. 7 Geological sections along the axes E-E and X-X. See Fig.3. On the right side of the section X-X the sketch from the photograph shown in Fig.10 is given.

direck shear tests gave after 10 times of repeatings $\phi = 3^o - 14^o$ and $c = 0{,}28 - 0{,}20$ kg/cm^2 respectively.

In order to determine the average value of the shearing strength on an actual slide surface use is made from a recent soil movement shown in section X-X, Fig.7, and found to be of the order of $s = 0{,}185$ kg/cm^2.

NATURE OF THE SOIL MOVEMENTS

On the basis of observations and measurements it has been decided that the slides are occuring on composit sliding surfaces not deeper than about 7 to 10 meters. On slide generating the next one the problem is a successive slides as shown in Fig.7(slide of 10.1.63).

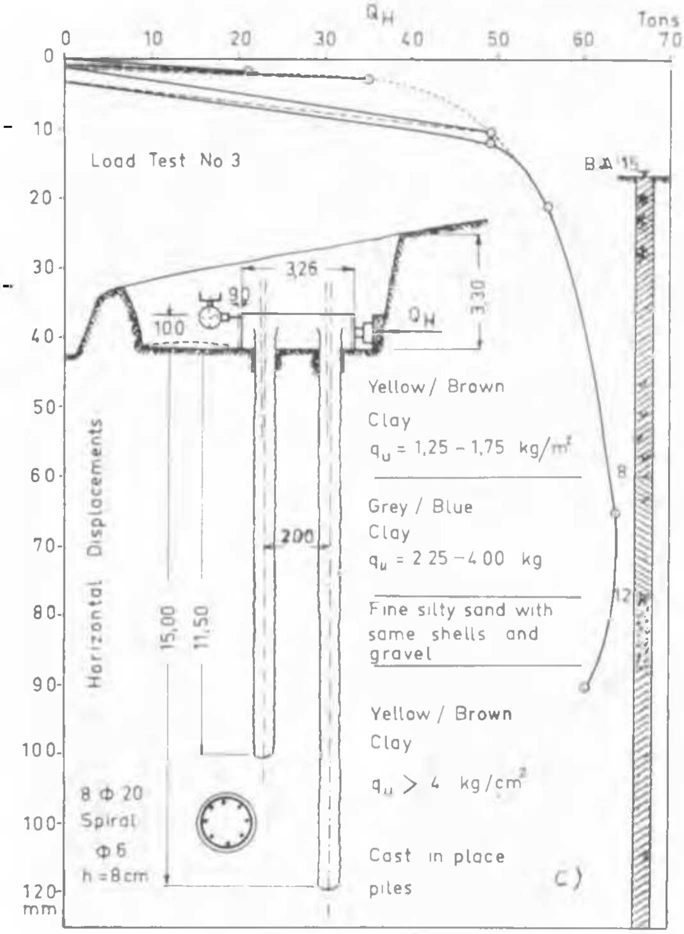
To estimate the necessary horizontal reaction to obtain a safety factor of the order of 1,35 a moving soil mass of 50 meters length and 7 meters depth, and $s = 0{,}2$ kg/cm^2, $\gamma = 2$ t/m^3 have been assumed.

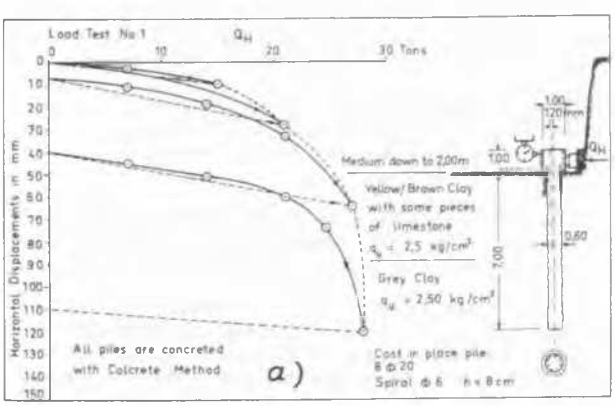
MEASURES RECOMMENDED

Having obtained the necessary reaction to create a safety factor of the order of 1,35 use is made of the results of the lateral load tests carried on 65 cm diameter cast in place piles.

Test arrangements and the results are given in Fig.11 - a,b,c.

Considering that an efficacious drainage of the area being practically impossible a three steps project has been throught as a most efficient measure to be taken to stop the soil movements.





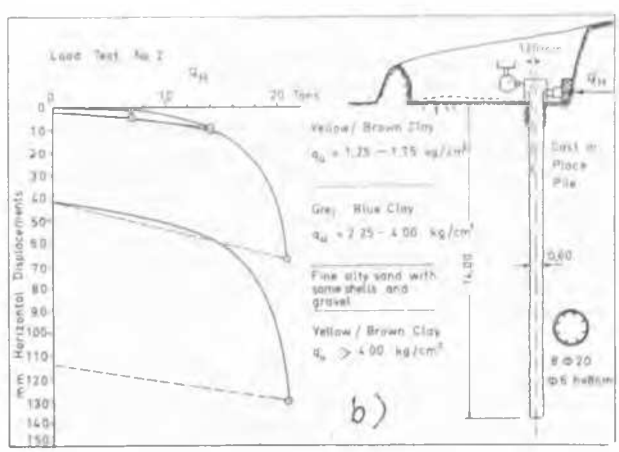


Fig.11 - a, b, c . Lateral load tests on the cast in place piles. Dimentions and test arrangements are to be seen on the diagrams.

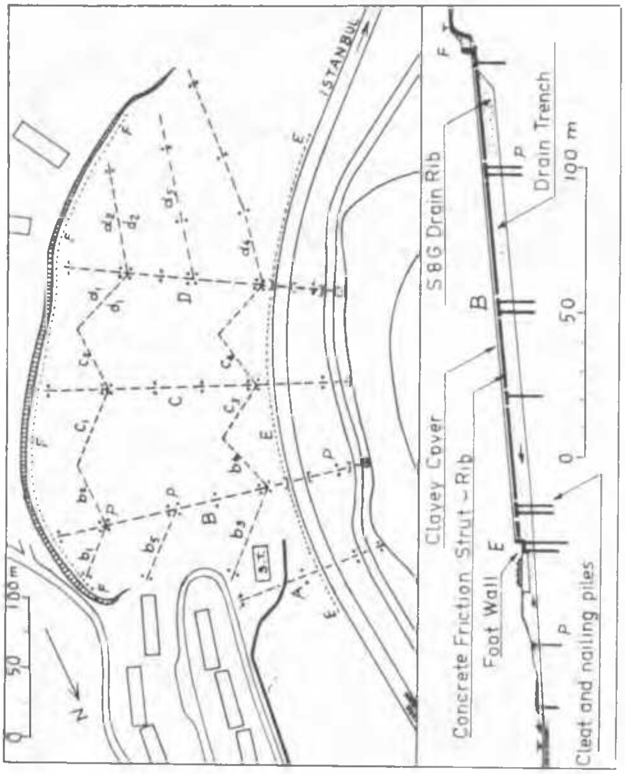


Fig.12 Sketch of the recommended measures to stop the soil movements.

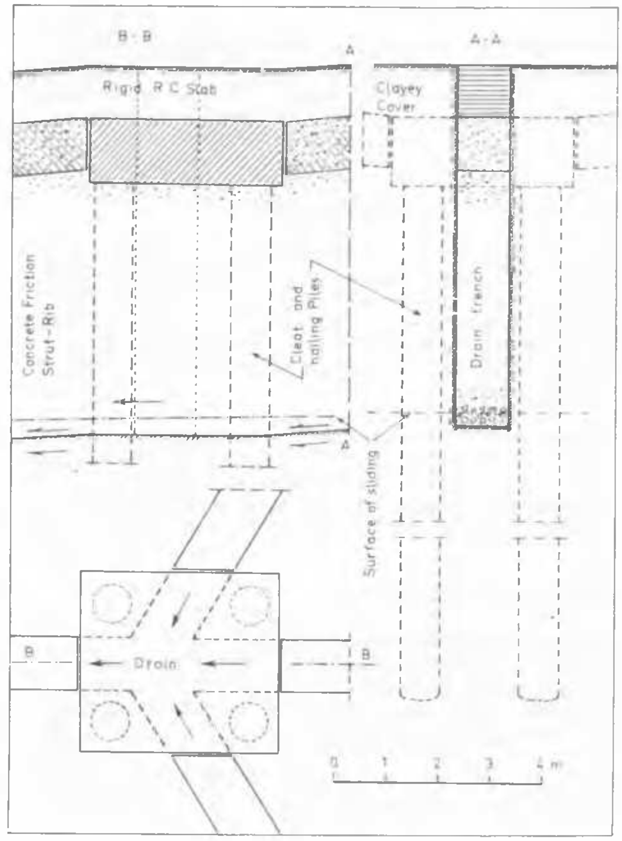


Fig.13 Detail of the drain trenchs and the cap of the cleat and nailing piles.

First step : a retaining wall on piles alongside the track (EE) and hard core drainage trenchs A, B, D as shown in Fig.12.

Second step : is to establish the hard core drainage trench C.

Third step is the retaining wall alongside the toe of the precipice (FF).

As the soil in deeper strata is very stif/hard fissured marls and marly clays bored cast in place piles are recommended. Lateral load tests have been carried out on three pile caps as shown in Fig.11. Piles are cast with the colcrete method and with dimentions and reinforcement as shown in the figures.The places of the test piles are marked on the Fig.3 as (L.T.1 - L.T.3).

From the results of the test loadings the lateral resistance of piles with different diameters can be calculated more accurately on the basis of some assumptions regarding the lateral pressure distributions.

To that effect see for instances :

Bengt B.Broms, (Lateral resistance of piles in cohesionless soils),(Lateral resistance of piles in cohesive soils),Journal of the S.M. and F.E., ASCE, Division SM2,SM3,1964.

J.Folque and G.de Castro, (Horizontal loading tests of very long piles), Proceedings of S.M. and F.E., Vol.II, Paris 1961.

K.Kubo, (Experimental study of the behaviour of laterally loaded piles), Proceeding of S.M. and F.E., Vol.II, Montreal 1965.

In the recommended project piles under the retaining wall alongside the railway track are of 1,0 meter diameter.

The drainage trenchs have a width of 1,0 meter, and a depth of 7,0 meters.Theyare filled with the course granular material of about the same type as the sand layers of the area.

As hard cores long blocks of concrete laid on compacted granular meterial and of a section 1,0 X 1,0 m^2 serve to resist the forces parallel to the ground surface. These long concrete blocks constitutes a kind of floating hard cores and transfer the forces by friction to the caps of cleat and nailing piles.

The main features considered in this project are :

1) Not to render more obstacles to the movement of the groundwater, and to facilitate it wherever it is possible;
2) to prevent any probable pore presure increase;
3) to stop soil movements while the drainage is getting more effective;
4) to avoid the destructions of the drainage trenchs by unexpected soil movements.

The dimentions and the general arrangement of the project will be adapted to the new conditions encountered during the application period, or additional knowledge obtained from the observations which still continuing.

ACKNOWLEDGMENT

This work was financed by the Ministry of Buildings and Dwelling, the borings and test loadings have been executed comformable to the proposed program by the Firm Verdi Ltd, and the laboratory tests have been carried out in the soil mechanics laboratory of the Technical University of Istanbul.

The author wishes to thank the engineers of the Ministry and the Railway engineers, engineers of the firm, and his colleagues in the laboratory for their consent, willingness and assistance.