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SKIN FRICTION ON THE PILE

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In foundation works for a wharf at the Hanko Harbour the firm bottom was at such a depth (over 40 m) and covered by such a quantity of poorly graded fine sand that it proved uneconomic to drive piles down to firm bottom. A test loading was carried out on the site with a Benoto pile, dia 70 cm and length 17,0 m. Pressure cells were fixed to the pile at various depths for measuring vertical pressure. Similar cells were fixed to a pile below the wharf. The diametre of the wharf pile was 90 cm and it was driven down to a depth of —16.00 like the test pile. Skin friction and point resistance were separated and the distribution of skin friction over the length of the pile was examined.

Skin friction proved distinctly larger than point resistance. The share of skin friction of the total load-carrying capacity in the test pile was 85 . . . 90 per cent and in the wharf pile around 60 per cent.

The point resistance in the test pile grew almost linearly as a function of penetration up to approximately 200 Mp/m^2. In the wharf pile the maximum of point resistance has been nearly 60 Mp/m^2. In the wharf pile the point stress required for the penetration of the test pile has been approximately 90 cm/70 cm (relation of pile diametres) smaller. This has also been found in foundations on footings.

There seems to be no direct correlation between skin friction and penetration. Skin friction has a reducing effect on loading transmitted to the pile point and consequently, on penetration. Regardless the density of soil at the point level, penetration will not be very large when skin friction is large, owing to the small point resistance.

Test results indicate that the growth of skin friction in the second power of depth, assumed in the classic earth pressure theory is incorrect. The result was almost contradictory to the theory. In the upper part of the pile skin friction was very large reaching its peak, about 30 Mp/m^2, at a penetration of a little more than 80 mm. Evidently, skin friction would have increased even more if the test could have been continued. Skin friction diminished downwards being about 4 Mp/m^2 in the middle of the test pile and staying always below 1 Mp/m^2 in the lower part of the pile. The development in the wharf pile was similar. It was furthermore noticed that along with variations in loading, skin friction is transferred from the lower to the upper pile sections. Finally, the skin friction of the lower part becomes negative implying that the additional load coming from up remains in soil layers surrounding the lower part of the pile and making the settlement of soil layers larger than that of the pile.

To sum up, the following factors affecting the large skin friction in the upper parts and small friction in the lower parts may be mentioned:

- consolidation of soil on the ground level. For practical purposes a reinforced concrete slab was cast around the pile on the ground surface, from which the test loading anchors were prestressed. As a consequence the soil consolidated with resulting growth in shear stress.
- effect of excavating for the pile. In excavating the tube into the ground the load of surrounding soil obviously exceeded the load-carrying capacity of the soil at the bottom of the tube. In that case soil around the tube started to heave up and soil surrounding the lower part of the pile started to soften and its ability to receive skin frictions decreased. Owing to the load of overlying layers, lower layers may settle even more than the pile.
- effect of repeated loading. During variations in loading the skin friction of the upper parts of the pile decreases and increases in proportion to the change of loading of the upper part. The growth of point

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resistance due to increased loading is not reduced as easily. When loading is increased again, point resistance may still grow and skin friction in the lower part diminishes. The additional pressure staying at the pile point combined with the loading from up towards the soil layer around the lower part may finally change the skin friction of the lower part negative.

- effect of point resistance. The load transferring from the point to the ground results in shear stresses directed along sliding planes towards the skin increasing the skin friction. On the other hand the distribution of skin friction changes, too. In the upper part skin friction increases whereas in the lower part sliding planes may bend downwards reducing skin friction. It was not possible in these tests to measure the effect of point resistance separately on the volume and distribution of skin friction. However, assuming that the effect of point resistance on the skin friction of the upper part was the same as at the end of the test, it may be estimated that about 50 per cent of the large skin friction of the upper part was caused by point resistance.

TORSION OF A BAR WITH TRAPEZOIDAL CROSS SECTION

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In this paper, a study is made of Saint Venant's torsion of a bar with trapezoidal cross section. Mathematically the solution of the problem means the integration of the well-known Poisson's differential equation $\nabla^2 u = -1$ under the homogeneous boundary condition $u(S) = 0$.

Here, the solution is obtained by the application of the Trefftz' variational method which is discussed in details in the reference [1]. The stress function u is approximated with a complete set of harmonic functions φ_i (24). The solution of the system of linear Equations (19) gives the values of the free parameter a_i of the approximation. The numerical treatment is carried out by the use of the digital computer Elliot 503. The program calculates the integrals of Equations (19), solves the parameters a_i, and evatuates the values of the torsion modulus I_t and the section modulus W_t.

The numerical values of I_t and W_t for different trapezoids are given in the table 1. The most results are calculated by the application of nine functions φ_i (24). The results marked with*) are calculated without the three functions φ_i (24) marked with*) because the use of nine functions φ_i caused numerical inexactness. The comparence of the results with the known values of the triangular and rectangular cross sections indicate the errors of 2—4,5 % in the values of W_t. The values obtained for I_t were very accurate except the case of the rectangle $h/a = 0,4$ where the error was about 10 %.