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In Danish fjords soft layers of mud (Cardium) of up to 30 meters magnitude often occur. Below this may even be found additional soft strata, for example melt water clay. The depth of water is seldom more than 15 m, but may rise to as much as 25 m. The distance from water level to the firm strata suitable for bridge foundations has in accomplished bridge piers in such soil reached 45 m.

The above mentioned Cardium layers possess some cohesion and can during excavation for some time stand at quite steep slopes. Downwards in the Cardium may often be encountered increasing contents of fine sand or at intervals thin layers of pure fine sand. As for this reason the friction of the soil increases downwards the bearing capacity also increases. For vertical loads this bearing capacity is however altogether insufficient, but horizontally the soil will always possess enough cohesion and friction to prevent a pile from bending out of its axis. This circumstance is of importance in the foundation method now to be described (Ref. to Fig. 1, showing the arrangement of a bridge pier):

At the pier site the upper soft layers of Cardium are removed in a few meters depth and replaced by a sand fill (a sand cushion). A group of piles - wooden or reinforced concrete piles according to the circumstances - is then driven.

The length of the piles is so chosen that the top of the piles will stop at about 1-2 m above the sand cushion.

Two methods of different principles are used for the pile driving (Ref. to Fig. 2 and 3). In both arrangements the piles are driven from pile drivers mounted on anchored barges. The heavy adjustable leads guiding pile and hammer are extended down to the sand cushion. In Fig. 2 underwaters-hammers are used, Terry-Hammers or similar make. In Fig. 3 a pile extension is inserted between pile and hammer, so that underwater hammering is avoided.

The drop hammer in this arrangement frequently weighs 6000 kg and is lifted by steam with a drop of up to 50 cm.

The piles are generally all battered, except 4 or 6 vertical piles, which for use in placing the caisson are cut off somewhat higher than the battered piles with tops in exactly same level.

On top of the now completed pile foundation is built a solid pier body constructed by means of a reinforced concrete caisson with 2 to 3 m high working chamber with sufficient base area to encircle the top of the pile group.

The caisson is lowered by water ballasting until resting on the above mentioned vertical piles, on which it can be adjusted for correct position.

After a suitable amount of concreting and water ballasting in the caisson cells above the working chamber, this latter can be emptied of water by the use of compressed air and in the dry filled with concrete establishing an integral connection between piles and pier body. Finally additional sand fill covered with stone is placed around the base of the pier.

The considerable dead weight of the pier body together with the superimposed vertical loads cause high compressive stresses in the piles, so that very considerable horizontal forces are required to introduce more than negligible tension stresses in any of the piles. Variations in the height and general dimensions of the pier body are means of controlling this stress condition.

In the analysis of the pier only the piles are assumed bearing, while the supporting capacity of the soil is neglected entirely.

For resistance to horizontal forces the supporting capacity of the sand-cushion and the stone deposits is likewise neglected and only the piles are considered.

It is endeavoured to obtain a good connection between the caisson and the concrete in the working chamber and between the concrete and the piles. To this effect the reinforcing in concrete piles is laid bare over a certain length, while wooden piles are shaped with dove tailed ends.

A proper grouping of the piles is very important as having a great influence on the number of piles. In Fig. 4 is shown a design where great pressures from ice and currents are taken in account in the pile arrangement, even when this pressure acts at an angle to the longitudinal axis of the pier so as to twist the pier about its vertical axis.

The proposal for constructing bridge piers along these lines was submitted by the author in 1920. In the following years 6 bridges were completed with 25 bridge piers of this type, while in the very near future 12 more piers for 2 bridges will be completed.

At one of the first adoptions of this foundation type (on the Highway Bridge across the Limfjord at Aalborg, completed in 1933, contractors Kampmann, Kierulff and Saxild, Ltd. Copenhagen), the proposed method as now described was met with some scepticism, for one thing because beforehand it was doubted that the proposed heavy piles could retain the requisite bearing capacity without the occurrence of problematical settlements, perhaps extending over long periods. To examine this further a number of circular reinforced concrete piles were driven and submitted to test loadings. The piles were test loaded with 200 t as shown in Fig. 5.

Each pile, of 55 cm diameter, is placed in the centre of a quadrangle, in the four corners of which heavy wooden piles of built-up section are driven. A heavy steel frame is supported on these corner piles and anchored down by reinforced concrete "jackets" around the head of the piles. This frame supports a cross girder of double I-beam section. At the centre of the frame - between the cross girder and the top of the test pile - a hydraulic jack is inserted, pressing with the necessary force downwards on the test pile. The upward reaction is transferred by the frame to tension in the corner piles.

The result of the test loadings was that the piles withstood 200 t of load without any settlements in a test period extended over several weeks. It was therefore concluded that heavy piles driven under similar conditions could safely carry the considered loads without settlements.

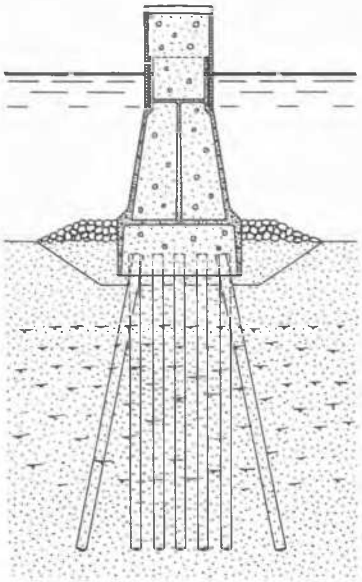


FIG. 1

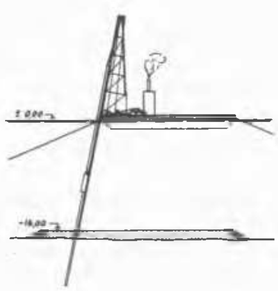


FIG. 2

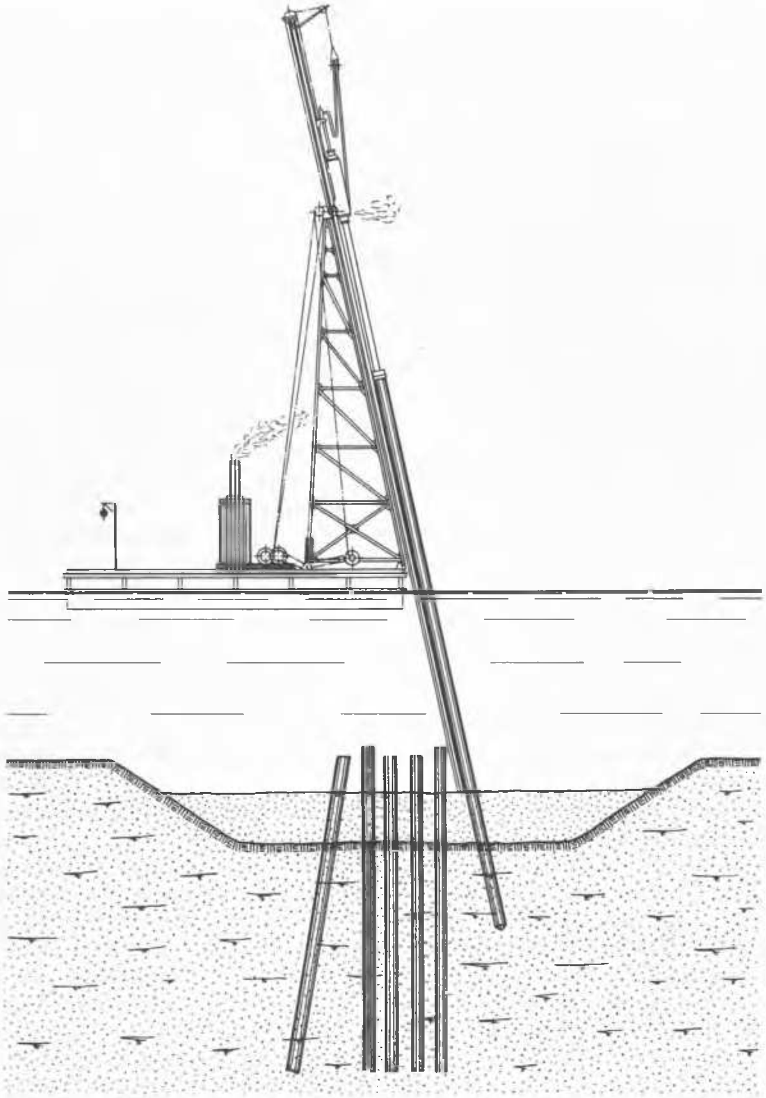


FIG. 3

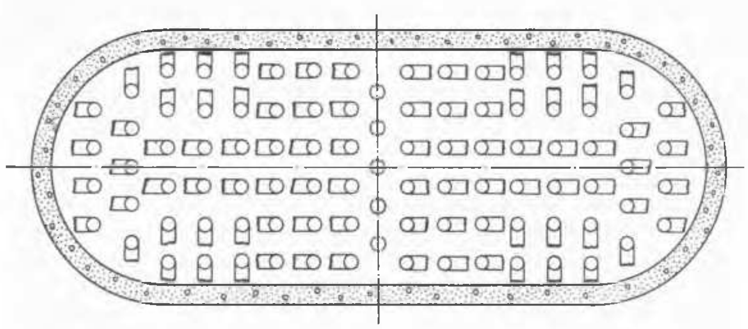
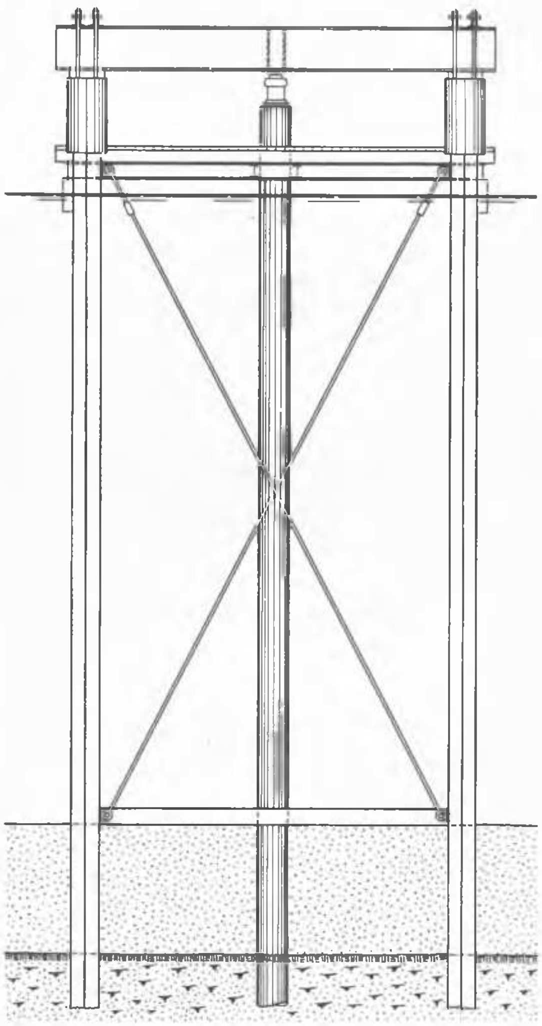


FIG. 4



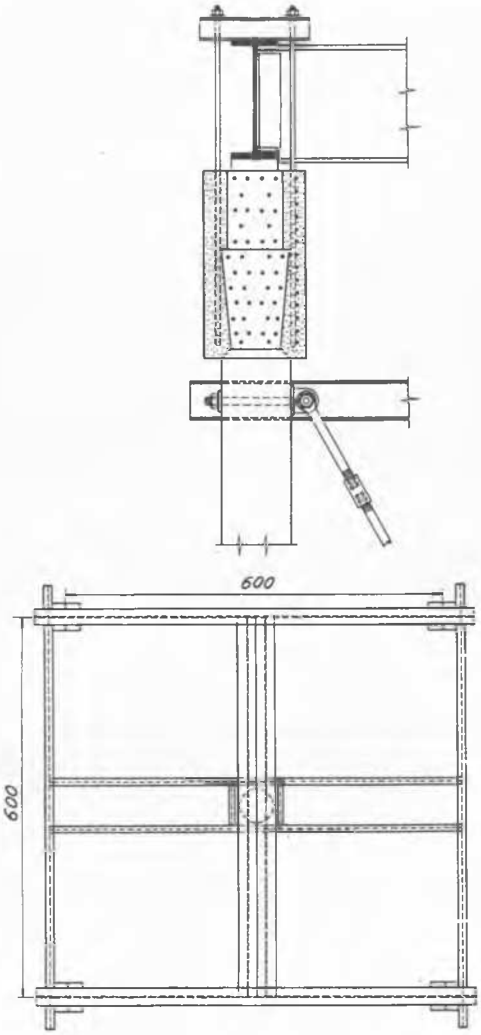


FIG. 5

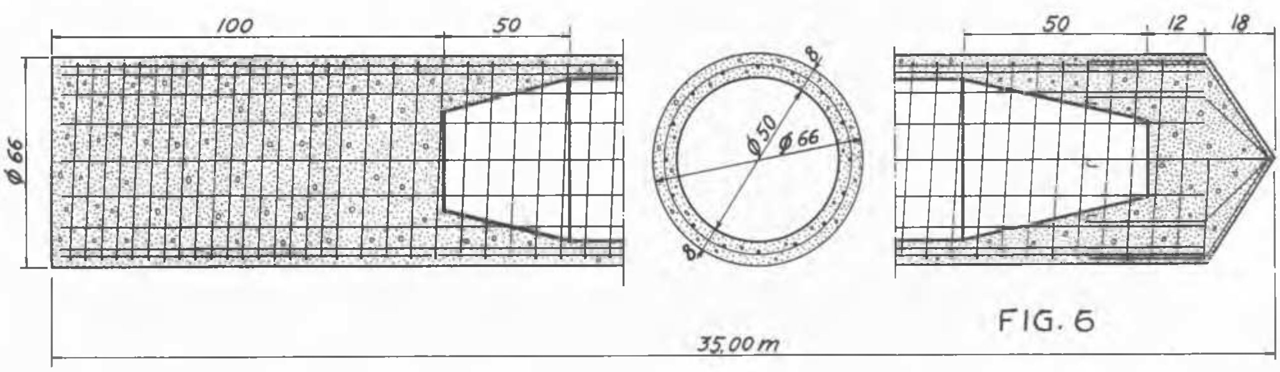


FIG. 6

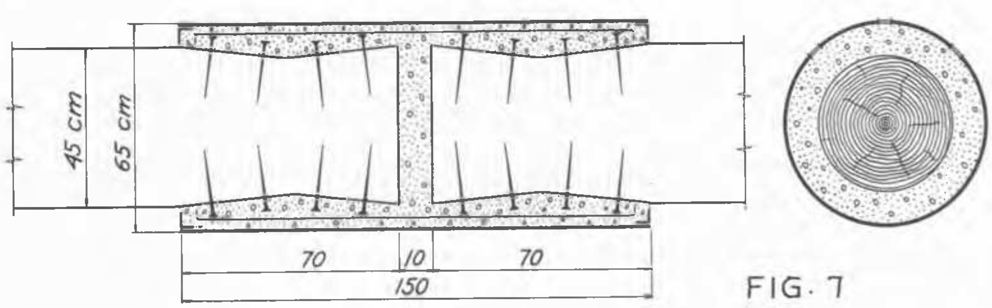


FIG. 7

The piles for the bridge piers were then dimensioned as shown in Fig. 6, and it was found that for a weight of pile up to 15 t a hammer of 6 t weight with a drop of 50 cm must be assumed.

During the construction of bridge piers as described, it becomes natural to carry out a test loading on the vertical piles supporting the caisson. By loading the caisson with water ballast the piles can be stressed to about 50% higher loads than those assumed in the computations. This test loading is ordinarily extended over a couple of weeks.

The material for the piles is generally timber rounds of Danish spruce. In large numbers they can be obtained only in lengths up to 25 m.

In one of the bridges, where piles longer than 25 m were required, piles up to 36 m, length, were successfully used being made up of two timber rounds connected into one length. This connection was carried out as shown in Fig. 7. The two pieces of pile are laid out perfectly on line with 10 cm clear at the butt joint. A suitable number of spikes are driven into the ends of the piles, and a reinforcement of steel rounds is fastened to these. The entire joint is enclosed in a steel sheet casing (of length about $4\frac{1}{2}$ pile-diameters and 15-20 cm larger in diameter than the pile), and the space between casing and pile ends is filled with cement mortar. Computations as well as tests indicate that this joint in no way represents a weak point in the pile.

Hollow reinforced concrete piles are used when still longer piles are needed, or when the number of piles should preferably be reduced. The piles are emptied for water from the working chamber and filled with concrete.

Often, when using a 3 m high working chamber, it may be sufficient to pour only a 1 meter seal of concrete in the compressed air. When this seal has hardened, the work can be continued in the dry without compressed air, which facilitates the emptying of the hollow piles and the filling in of concrete. Fig. 8 pictures this condition in one of the working chambers of the above mentioned bridge at Aalborg.

Fig. 8

No. N-5 THE FLOATING FOUNDATION OF THE NEW BUILDING FOR THE NATIONAL LOTTERY OF MEXICO: AN ACTUAL SIZE STUDY OF THE DEFORMATIONS OF A FLOCCULENT-STRUCTURED DEEP SOIL

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I.- General Description of the Soil and Subsoil of Mexico City. The valley of Mexico, where the old lake was, is filled with a light flocculent structure of eolic origin, down to a depth of hundreds of meters.

This mass is interrupted at different depths with layers of denser and stronger material of volcanic or alluvial origin. The thickness of these deposits ranges from a few centimeters to a few meters.

The whole subsoil of the City is covered with alluvial deposits or has been artificially gained to the lake and covered with detritus. The thickness of this artificial "crust" varies from nearly a meter up to three or four meters, and even more in some places.