PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

EXAMPLES OF SOME SPECIAL POINTS, WHICH WE CONSIDER IMPORTANT IN NORWAY FOR DESIGN AND CONSTRUCTION OF CONCRETE QUAYS UNDER ARCTIC CONDITIONS

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As we know from the map, Norway has a very long coast-line, and more than 1/3 of this is north of th Arctic Circle.

Most of the larger quays in Norway are concrete quays, the slab resting on either piles or pillars.

Even on the few quays where steel-sheet-pile-walls are used, the front wall above sea-level usually is of concrete.

A few quays have concrete caissons as foundation, but this is usually much too expensive, compared with piles of pillar foundation. It is very important that the design as well as the construction carefully considers the tough arctic conditions which will occur in winter.

Concreting under water is in Norway almost always carried out with tremie pipes.

The report from dr. O.E. Gjørv shows the result of an investigation made of concrete in quays made in Norway the last 50-60 years. One of the conclusions Mr. Gjørv has drawn from his studies is that where tremie pipe-concrete was made and placed with the necessary know-how, it is even today in a remarkably good condition.

Under arctic conditions, the concrete may be attacked from thawing as well as freezing and also mechanical hits from floating ice-floes.

Today's concrete in quays is very carefully mixed and proportioned, and air entraining nearly always used for the superstructure.

For concreting under water by tremie pipes, one has to be very careful, and rather not use air-entraining means. Many of these means will, especially if the sand is rich of fines, make the concrete sticky as glue, and impossible to get through the pipes in a proper way.

The whole technique with the tremie-pipe concreting is rather complicated, and a rather skilled gang is needed.

Unfortunately, the time today only permits me to deal with the problems related to the arctic conditions.

By concreting in a temperature lower than - 5° C, the concrete aggregates, and water should be heated, and the fresh concrete covered with some sort of insulation.

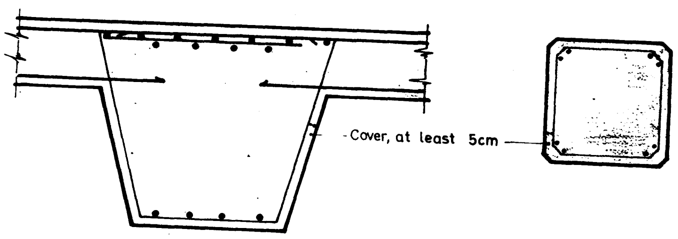
This is especially important with thin walls and slabs, where it even can pay to cover the concrete with a house or tent, heated with hot air.

In the area between daily high and low tide, it should never be permitted to concrete in extreme frost, due to the difficulties in providing a proper insulation.

The most exposed parts of a quay are always the parts on the border between sea and air. That means that in the area between high and low tide water level, all pillars, piles or walls should have some sort of protection against ice-attack and frost.
The difference between high tide and low tide in Norway alters from approx. 0,5 meters in the south, and up to 3,5 meters in the north.

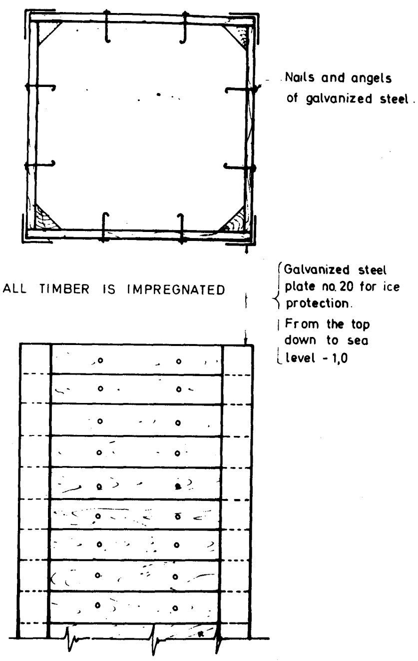
The pictures will illustrate some typical points of the above mentioned:

Fig. 1



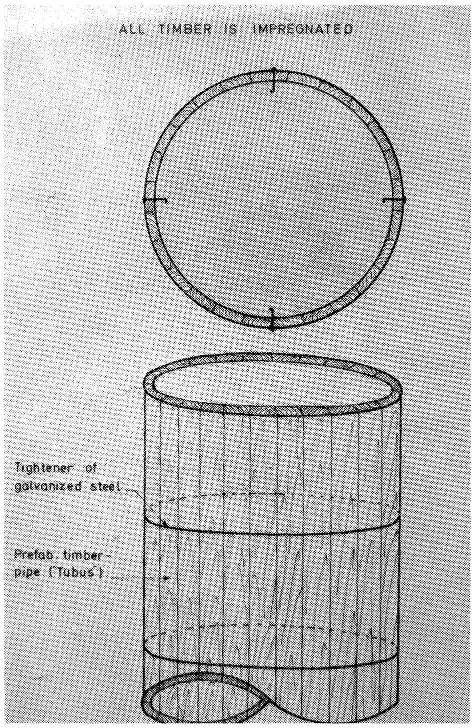
Beams and pillars - no sharp corners, and smooth surfaces due to dressed formwork

Fig. 2



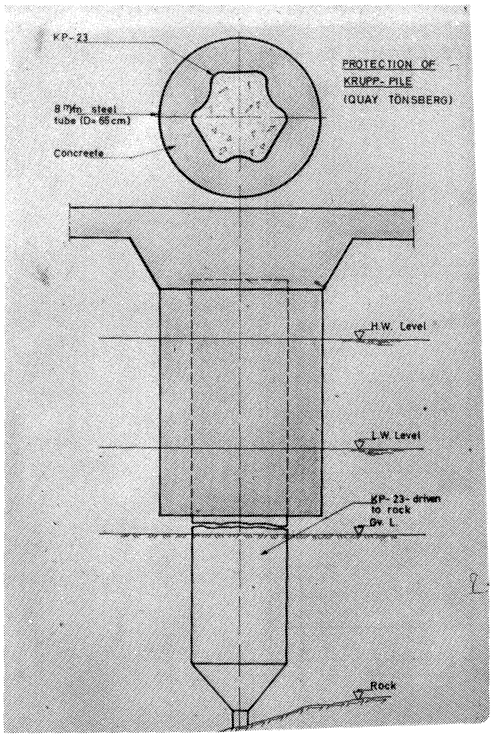
Impregnated ice skin - square pillar

Fig. 3



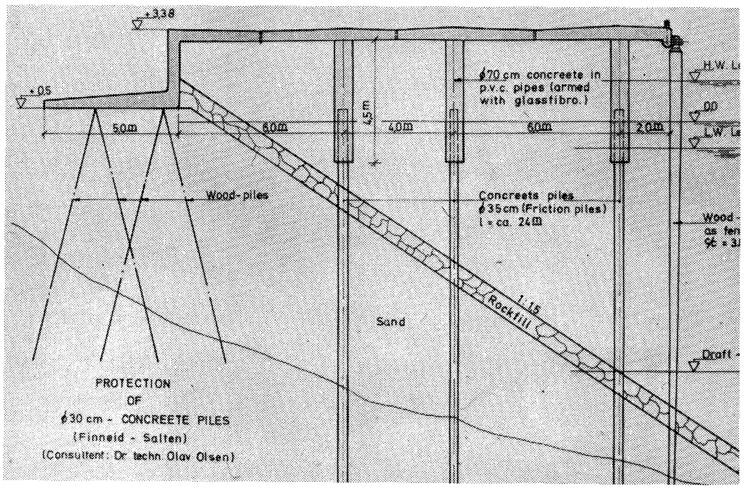
Impregnated
ice-skin -
circular pillar

Fig. 4



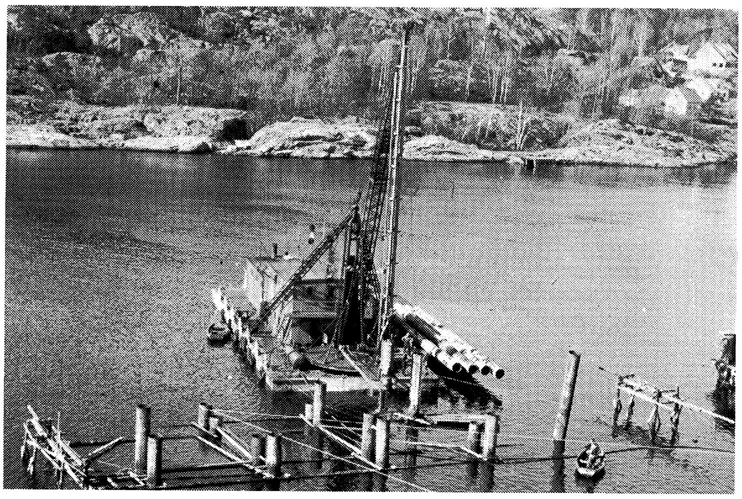
Protection of
Krupp-pile
(Tønsberg)

Fig. 5



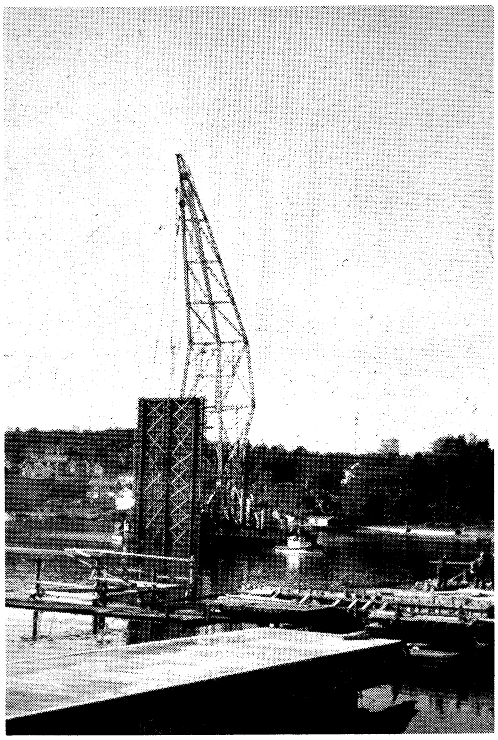
Protection of concrete pile (Finneid)

Fig. 6



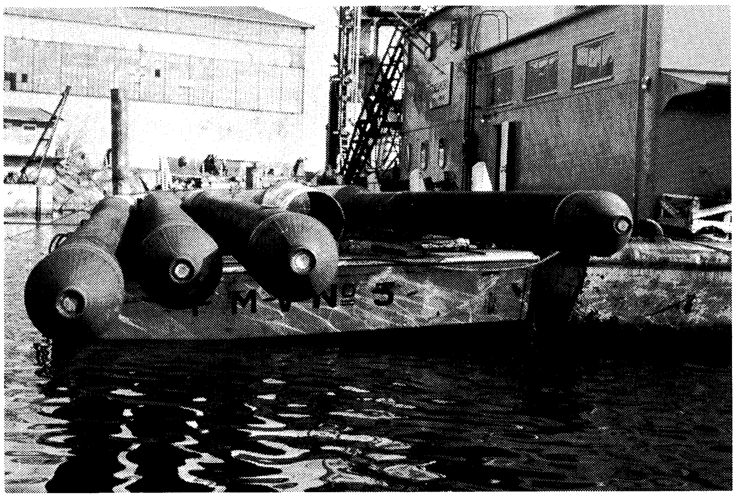
Steel pipe-piles - reinforced and concreted as pillar
(Framnes, Sandefjord) and the 7 m/m steel pipe can be regarded as "ice-skin"

Fig. 7



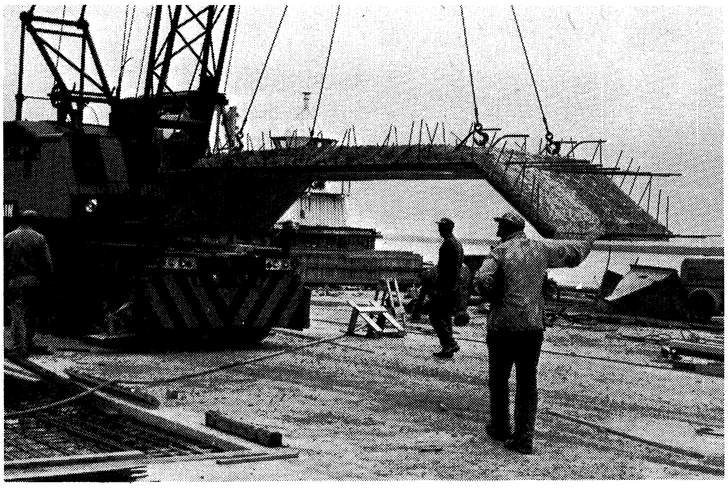
Ready made form-work for concrete shear-wall. (Framnes)
The wall takes the horisontal forces from the superstructure
(2-tremie pipes) used for concreting

Fig. 8



Steel pipe-piles at Framnes, Sandefjord. (Diametre decreases from 70 cm to 50 cm). The points are hollow, and filled with concrete. This gives us the possibility to drill through the point and place a bolt in the rock if it is any danger of sliding. The edge of the point is made extremely hard by welding with special hard-electrodes.

Fig. 9

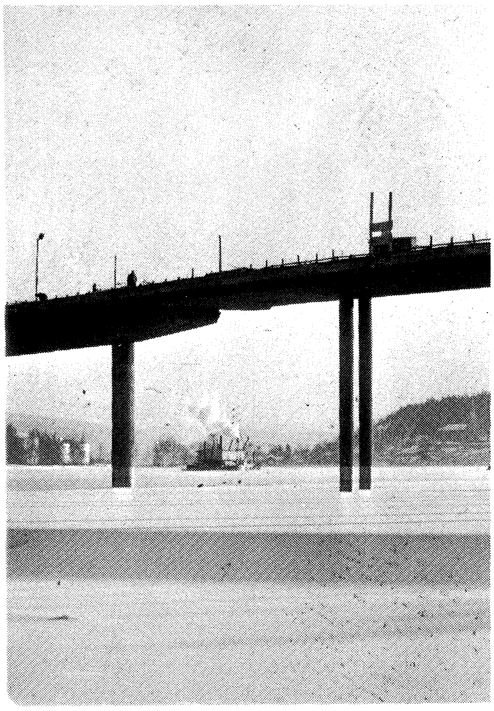


Pre-fab quay slabs - Moss
The formwork of plywood gave a very smooth surface, and the strong concrete used gave good resistance against tear and wear

Fig. 10

Pre-fab quay slabs - Placed

Fig. 11

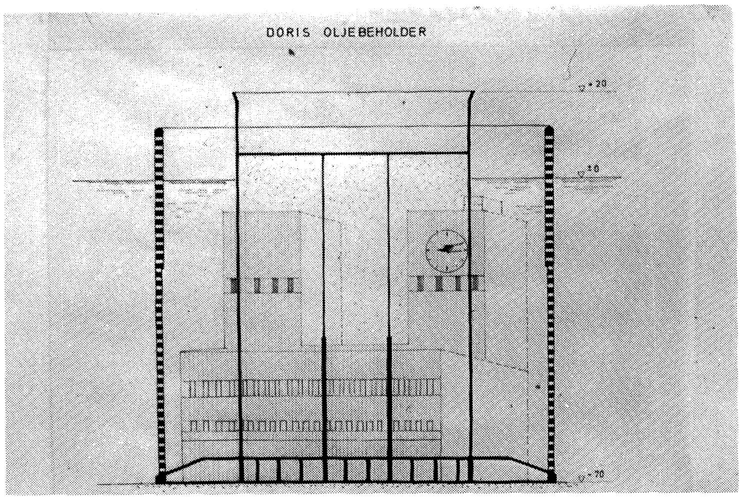


"Ice-skin" of stainless steel (Drammen bridge)

Snow and ice cause every winter a lot of trouble on our quays, blocking railway-switches, cranes, hatches a.s.o. It is common practice to use salt to remove ice, but even the best concrete may then crackulate, and be destroyed in the long run. As we have heard, Calcium Chloride instead of salt is used for ice-melting in Drammen harbour, but also this will make som damage to the concrete. The best way to prevent destruction of the concrete by these melting means, would be to protect the most critical parts with asphalt or epoxy.

The wind, waves and currents in the North Sea have special interest in these days, due to the succesful oil-drilling there.
It might be of some interest to end this article with a few slides of an oil storage caisson which is going to be placed at the bottom of the Ekofisk field in August next year. The design is made by the French consultant engineers, DORIS, and the construction contract taken over by our company F. SELMER A/S in joint-venture with Høyer-Ellefsen A/S.

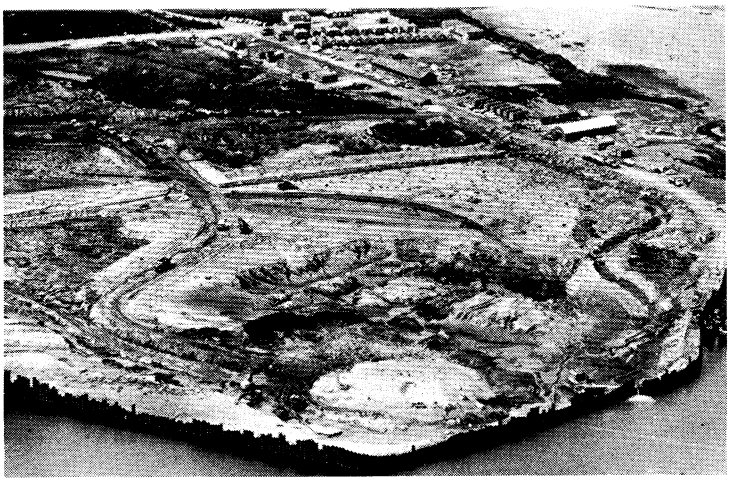
Fig. 12



The caisson has a height of approx. 90 meters, and a distance between the breakwater walls of 92 meters. The oil-storage tanks are cells in the core of the caisson, and can store one million barrels of oil. The breakwater walls are penetrated with about 10.000 holes of a diameter from 0,80 to 1,30 meters and these serve as energy killers for the waves.

According to model tests this design may also prevent the bottomcurrent to underwash the fine sand at the sea-bed, and effectively enough break the up to 18 meters high waves at the sea level, 70 meters above the bottom.

Fig. 13



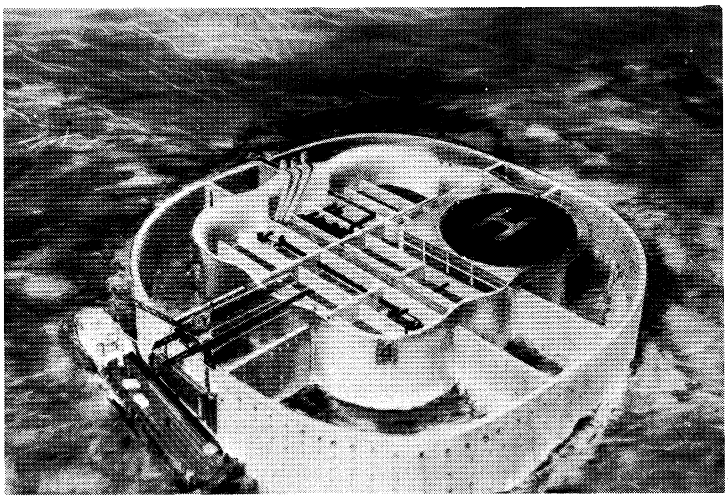
Here is a slide of the natural "dry-dock" where we will build the bottom section. We have cut off the bay "Jåttåvågen" near Stavanger with a sheet-pile-wall, and pumped out the water.

The bottom is excavated in the dry to a depth of approx. 7,5 meters below sea level outside.

When the bottom section is concreted ready to approx. 10 meters height, it will have a draft of approx. 6 meters, when the water again is let into the bay. After removal of the steel-sheet-wall, the bottom section will be towed outside the bay, where the depth is more than 70 meters.

By using slipform system, the walls will be extended up to the correct height (90 meter), as the caisson gradually sinks down to a draft of approx. 60 meters.

Fig. 14



The finished caisson will be towed out and sunk down at Ekofisk in August next summer, as shown on this drawing.