PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

DESIGN AND CONSTRUCTION IN NORWEGIAN PORT ENGINEERING

P.S. Hafskjold, Chief Design Engineer
Ingeniør F. SELMER A/S, Civil Engineers and Contractors
Oslo, Norway

INTRODUCTION

During the last 60 years an almost specific Norwegian method has been developed in constructing quays.

Although it has proved to be very economical to pour slender structural elements of reinforced concrete under water, quays supported by pillars cast in this way have not been accepted outside Norway. In this country, however, they are dominating.

It should, however, also be made clear that the success of the method depends upon knowledge and skill through all phases, and from the conception of design to pouring the concrete into the under-water forms no weak link can be tolerated.

Otherwise, the method is independent of heavy and expensive equipment, and it can be adapted under the most different conditions.

Along the Norwegian coast with its scattered population, conditions do differ: Tidewater ranging from almost nothing, (a quarter of a metre) - to 3 metres, soil conditions ranging from the hardest rock to the softest clay; - and ice-problems, especially in the south-east.

The great amount of quays required to serve the small communities along the coast, calls for an extreme economy in construction of harbours. As the optimum solution will be greatly influenced by the available resources in equipment and personnel, the constructors of quays in many cases also do the design work.

STRENGTHENING OF AN ORE LOADING PIER

Because of the ever larger ships berthing at the ore loading pier at Narvik, the owners considered a protection of it by means of a dolphin to be placed some 50 metres from the pier head and asked Ingeniør F. SELMER A/S for a cost estimate.

Two major problems were present: A very soft subsoil, and an extremely high frequency of berthing ships, - at both sides of the pier.

The narrow working place is shown on the picture of the finished job, Fig. 1.

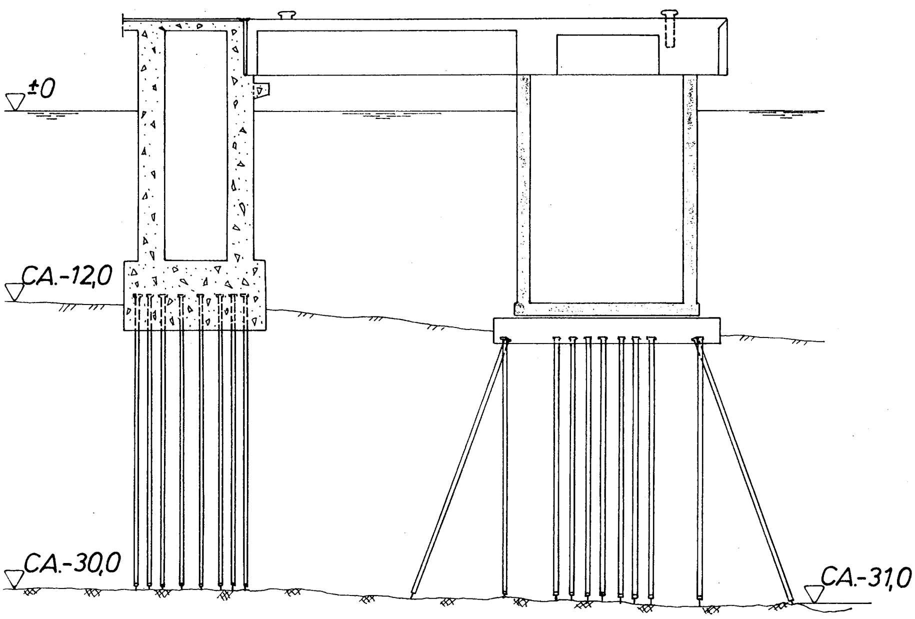
The first project was based upon dredging away some of the clay, and placing a circular caisson on a sand bed. Then large box piles were to be driven to bedrock through holes in the bottom of the caisson, and connected to it by means of under water poured concrete.

Fig. 1

However, the pier would still be exposed to a strike from the bow of a ship, and the analysis of the stability of the pier, made by professor dr. techn. Anton Brandtzæg, showed that the pier head needed lateral support.

Therefore, the dolphin was moved close to it, and the quay deck extended in full width to the dolphin to carry over lateral loads from the pier, Fig. 2.

A joint, from the berthing side of the large ships, across the greater part of the deck slab would prevent transferring excessive loads from the dolphin to the pier.



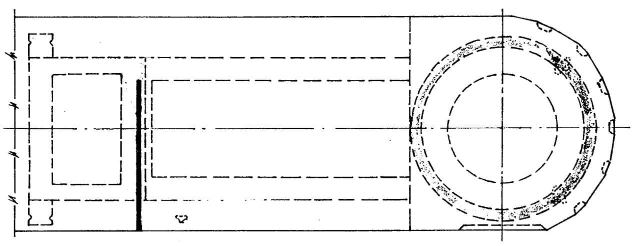


Fig. 2

To cut construction time the final design was modified in order to complete the foundation and the caisson simultaneously.

A floating rig, equipped with a single acting steam hammer, driven by compressed air, was placed within the limits of the two quay lines of the pier.

Steel profile piles with Oslo-points were driven at a batter 3:1 to bedrock. One pile failed and was pulled up again. It is shown on Fig. 3, together with the follower used for the piling.

Auxiliary vertical steel piles were also driven, box piles, supporting the scaffolding between the pier and the dolphin, and profile piles as guides for the plank shuttering for the 1,4 m thick foundation slab as well as supports for the platform from which the reinforcing steel mat was lowered and finally the slab, 14 m x 14 m, was poured under water by means of 10 pipes.

The lower part of the caisson was built on a slipway, Fig. 5, launched and finished afloat in the usual way by gradually sinking it as the walls were completed to their full height. After it had been floated into position, Fig. 6, and sunk on the ready-made foundation, the joint between the caisson and the foundation slab was grouted and the caisson filled with sand.

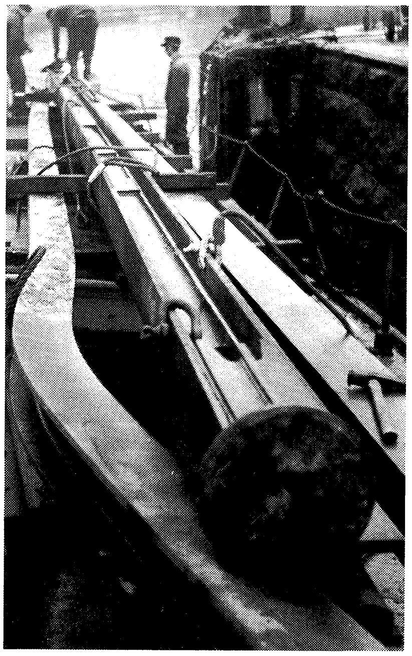


Fig. 3

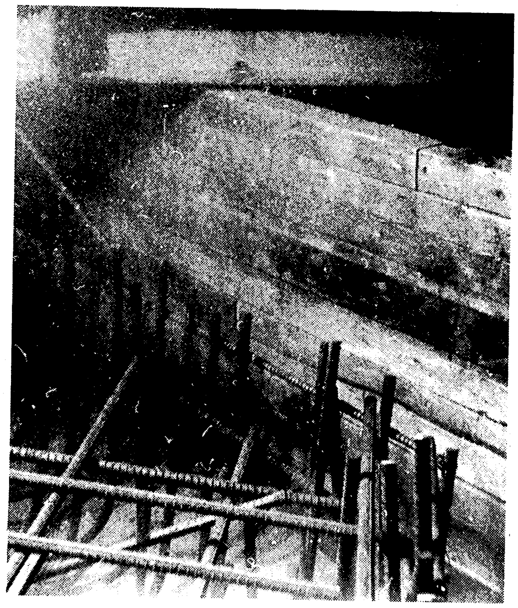


Fig. 4

Reinforcement and plank shuttering (under water)

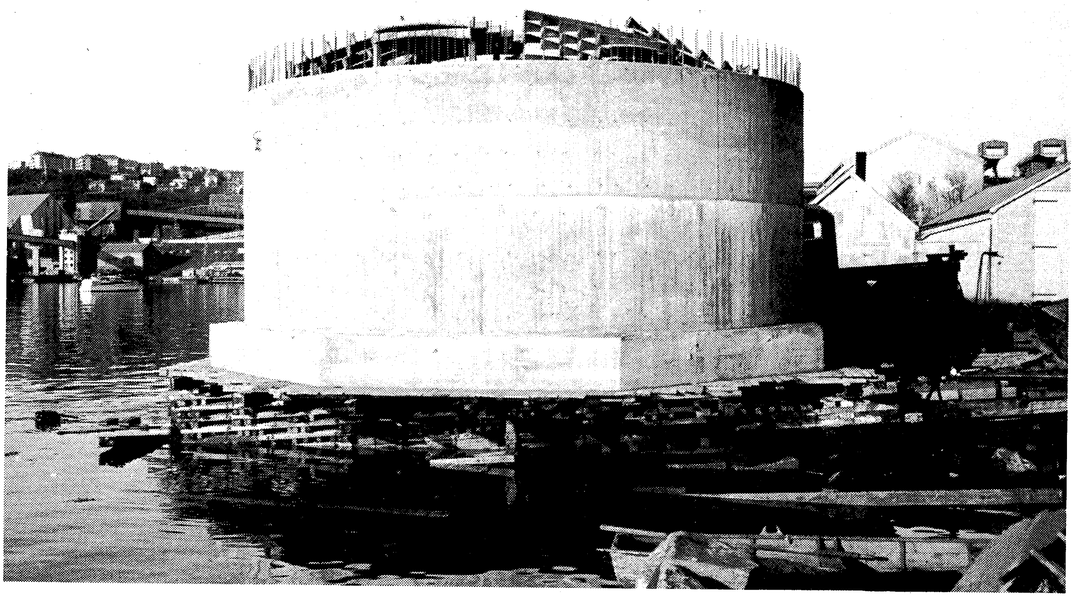


Fig. 5

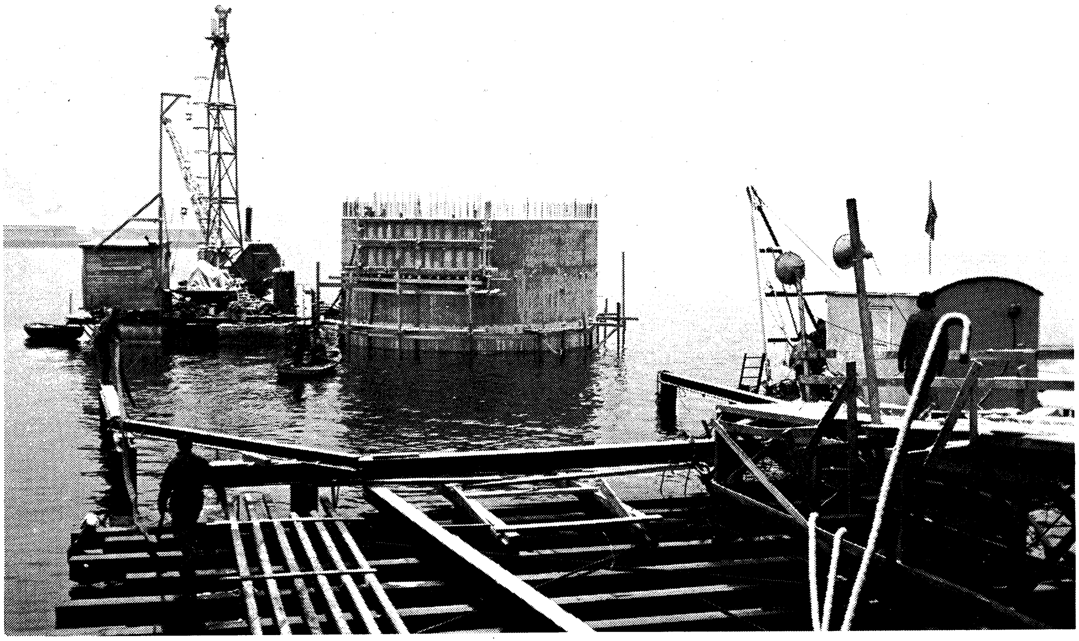


Fig. 6

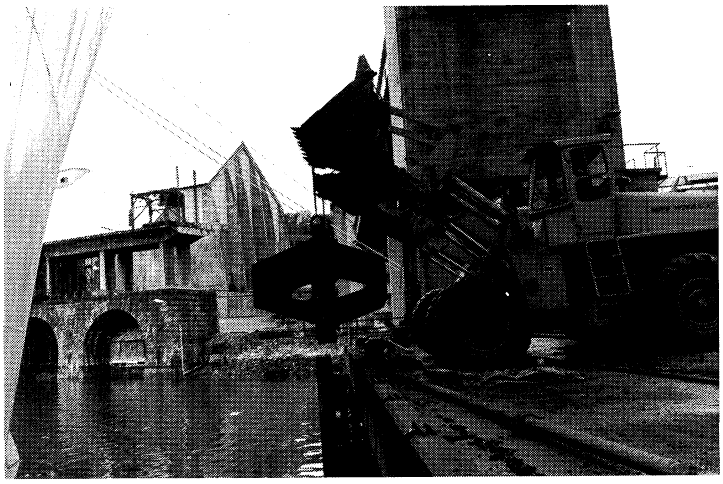


Fig. 7

The double Seibu fender units were lowered into place by two shovels.

To avoid damage to the expensive fenders in case of overloading, the shackles are the weak links in the suspension system.

ORDINARY NORWEGIAN QUAY TYPES

On Fig. 7 an end of the old ore wharf appears. It is a block wall of natural stone, which was the method previously used for quays which were subject to heavy loads or to ice.

The stone walls were carried down to bedrock, or they rested on wooden piling.

The majority of old quays, however, were made of timber and may be looked upon as a combination of a quay structure and a fender, as the whole structure yields to a certain extent during the berthing of a ship.

Wooden wharves are still being built, now of impregnated timber.

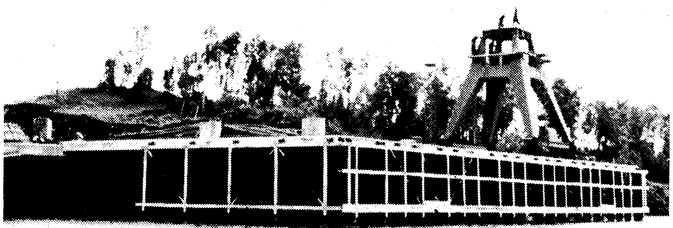


Fig. 8

A modification appeared when scrap rails became available from the railway from Sweden to Narvik, and used rails were tried as replacement for timber piles. These wharves have proved to be surprisingly successful, probably due to the high quality of steel used in rails.

A reminiscence of it is also seen as a wooden structure along the front of modern wharves in reinforced concrete, serving as protection between the ship and the quay side, Fig. 8 and 9. An outer layer of untreated planks 2" - 3" thick, is easily replaceable, and for further protection used tires are added.

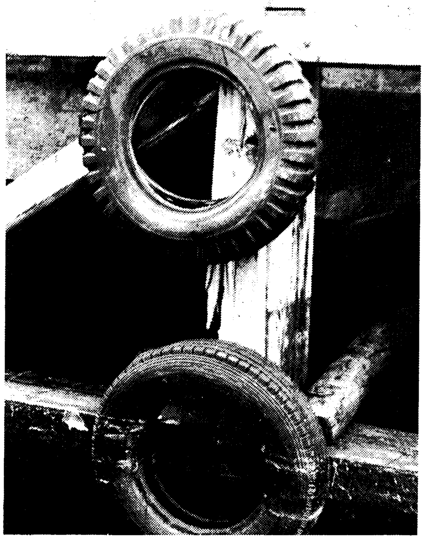
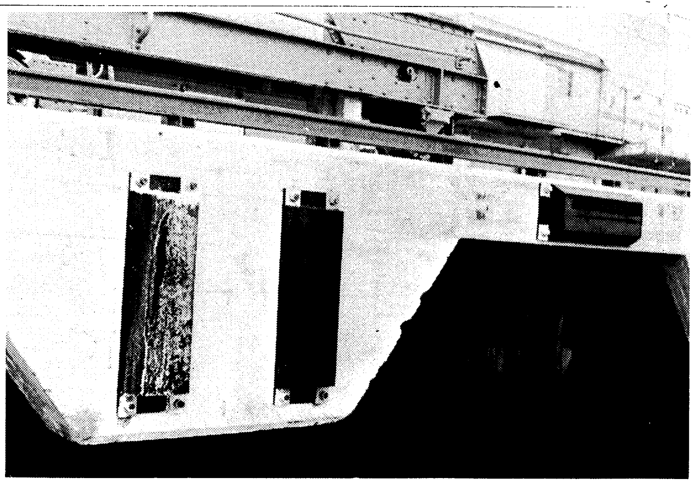


Fig. 9

However, due to expensive maintenance, new quays have concrete fronts protected by rubber blocks, Fig. 10, or used tires.

Fig. 10



In 1957 a heavy industrial wharf, Fig. 11, was built on a slightly compressible soil. The design aims at smoothening the influence of settlements and arranging structural elements to serve the construction process, as f.i. the horizontal reinforced concrete slab which provides the anchorage. During the construction period it served as an excellent road for a crane as well as for general transportation.

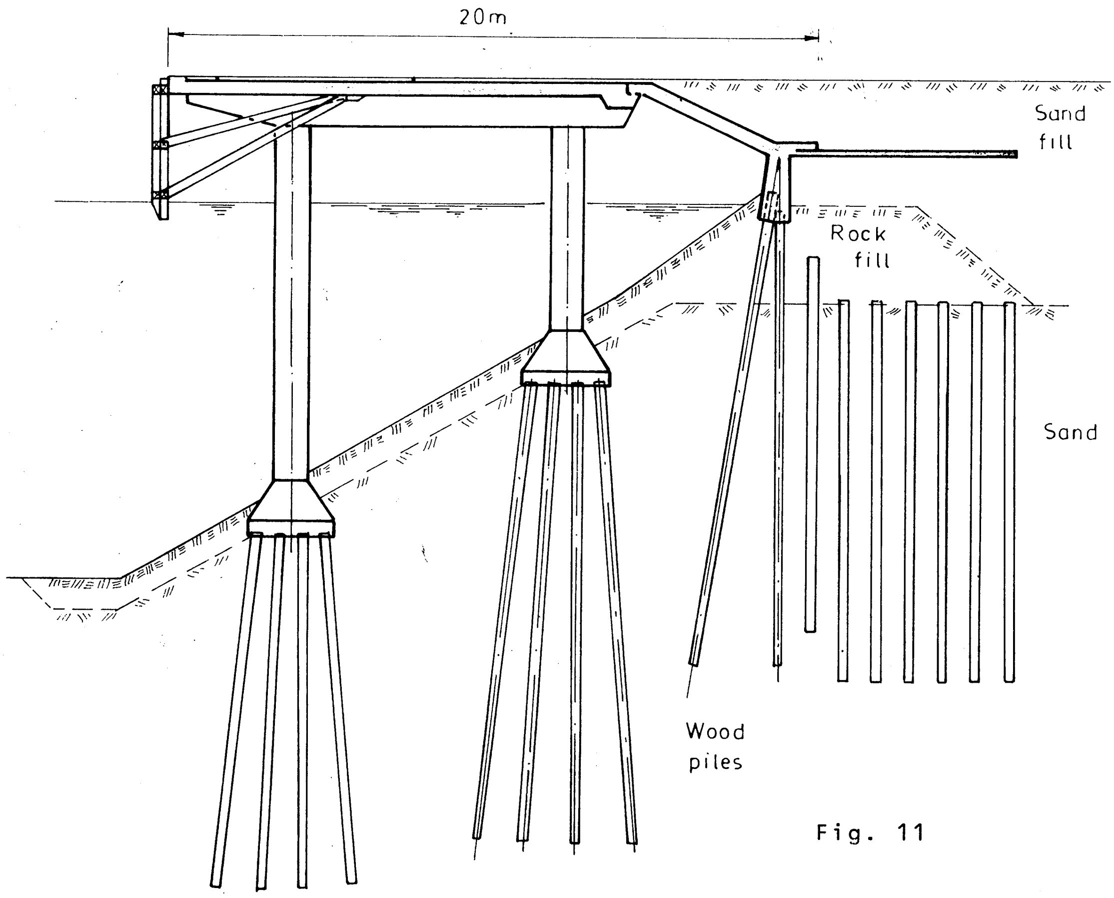


Fig. 11

In this case the pillars and the pile caps were tremie-poured in one operation, and a prefabricated form as shown in Fig. 12, was used.

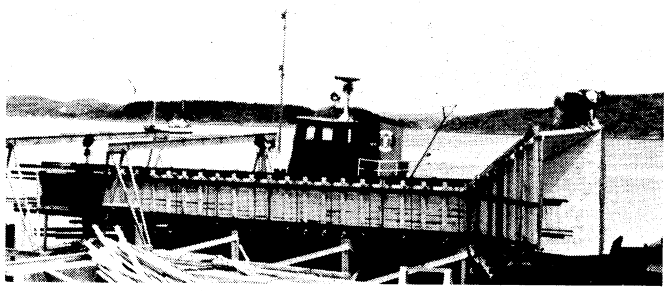


Fig. 12

A corresponding case in 1961 is shown in Fig. 13, but here the pile cap was concreted in a separate operation, thus establishing a sort of an artificial rock surface on which the prefabricated pillar form was placed, and then concreted separately.

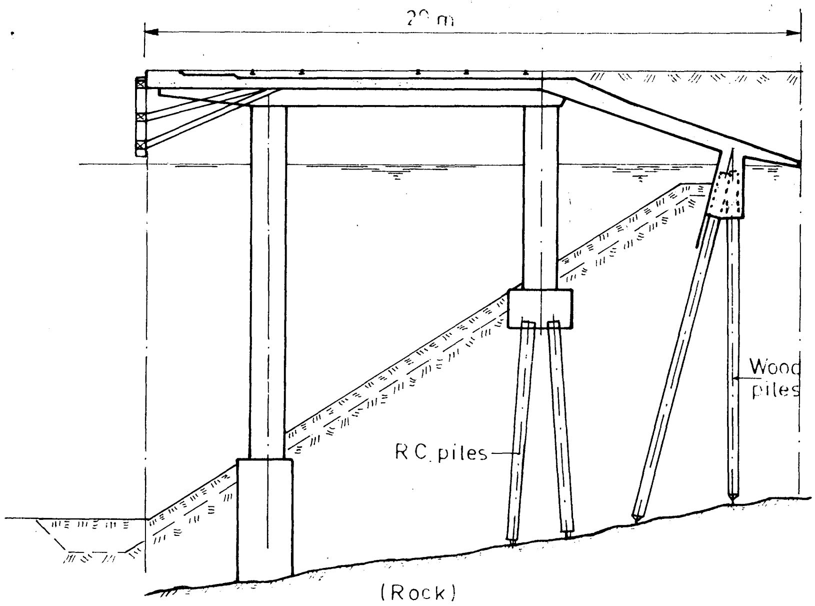


Fig. 13

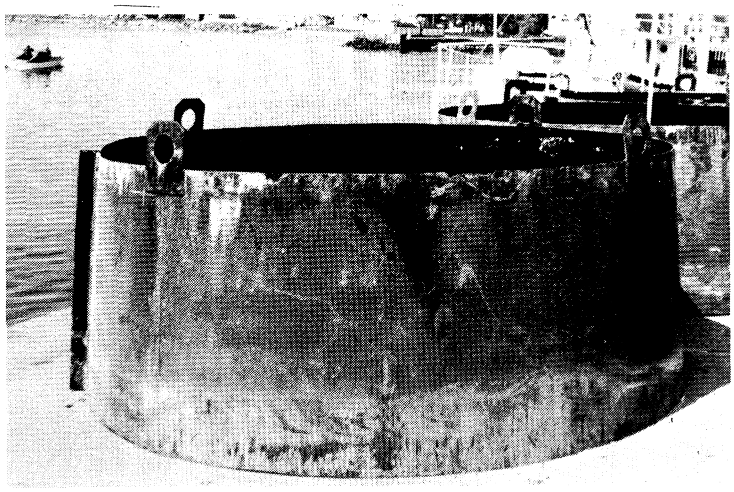


Fig. 14

Steel form, used for pile caps under water.

During its geological history Norway has repeatedly been covered by immense ice layers. These glaciers have swept away loose material and polished the hard bedrock, both above and below present sea level. Young and very soft sediments are often overlying the hard and hilly rock, and make foundation work difficult. This was the case when the jetty, in Fig. 15, was built in 1967.

Reinforced concrete pillars were completely prefabricated on shore, erected and embedded in concrete foundations. Other places piling was necessary, and steel tube piles were driven and afterwards concreted. Section A-A, Fig. 15.

Lateral support was provided by a shear wall to bedrock, 9,5 m wide, 21 m high, thickness: 0,9 m. The shuttering, with all reinforcement steel, lifted into place, Fig. 16, and tremie poured by using 2 pipes.

The bottom was prepared carefully, and the exact profile of the rock was taken at every 0,25 m and transferred to the sides of the form, Fig. 17.

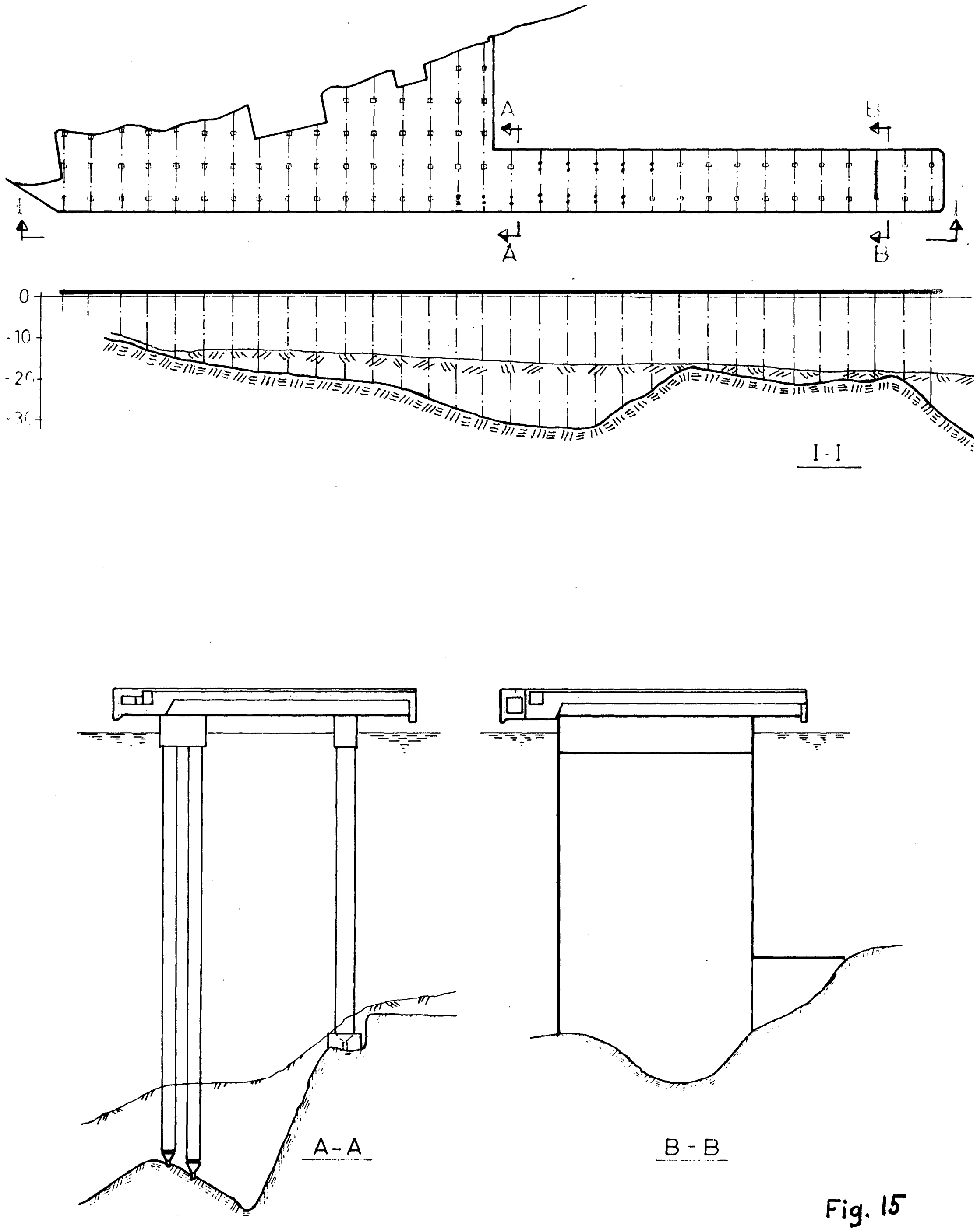


Fig. 15

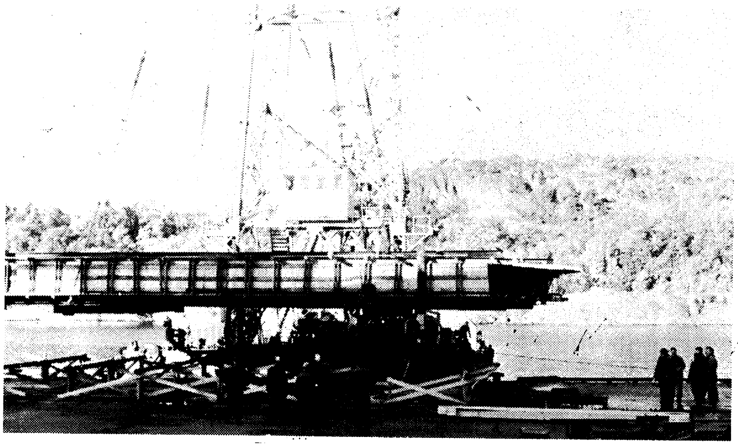


Fig. 16

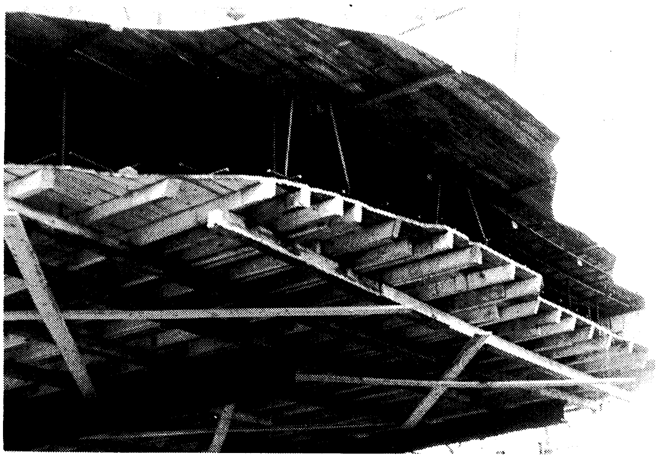


Fig. 17

A very soft beach was to be developed into a shallow small-craft harbour, and a sheet pile wall of creosote-impregnated wood, more than 400 m long, had to be driven, Fig. 18.

A major problem under such conditions is to keep the sheet piles in proper position. This problem was solved by using reinforced concrete slabs with great stiffness in the horizontal direction as anchorage, - Fig. 19.

After the contract was awarded late in the year 1962, winter conditions soon occured, and a calculated risk was taken by pouring the concrete slabs on a sand layer laid out on the ice. The sheet pile wall was placed half a metre from a construction joint and when the ice had melted, and the slabs settled, the two parts were interlocked by casting the last concrete strip. The slabs served as excellent roads and working areas, Fig. 20.

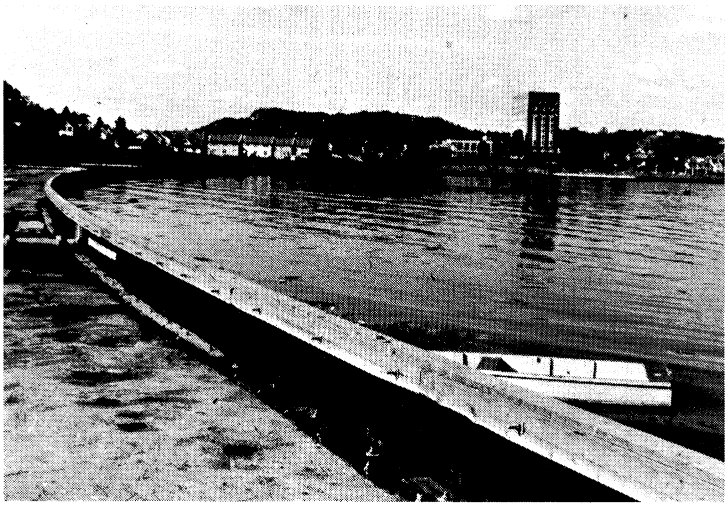


Fig. 18

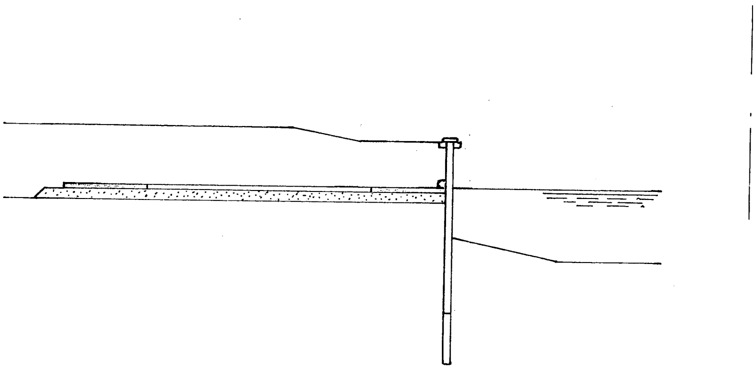
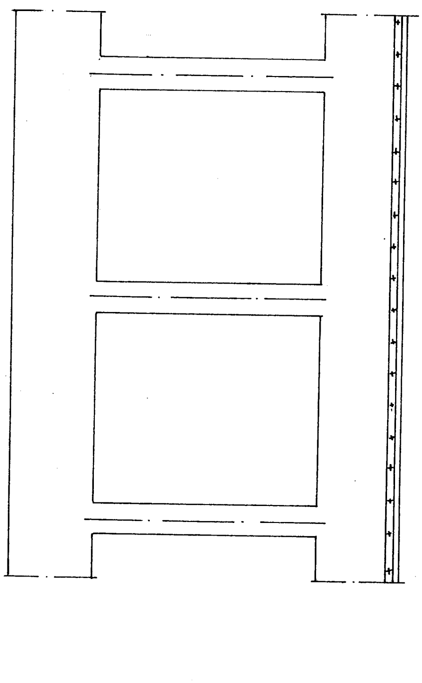


Fig. 19



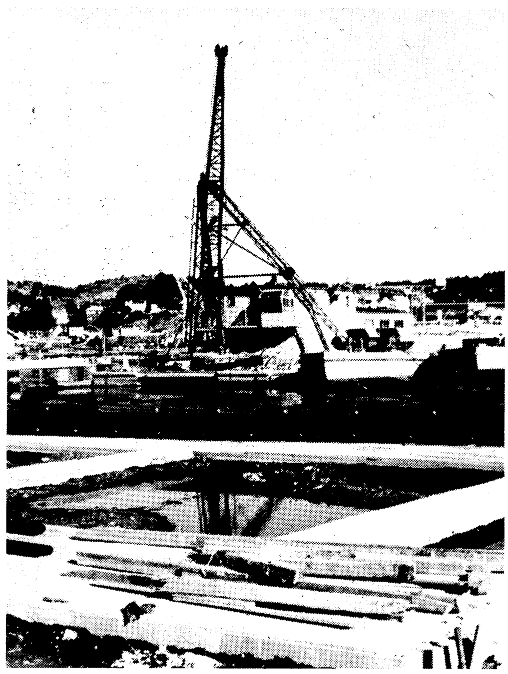


Fig. 20

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As a last example some illustrations from the design and construction of a roll on - roll off quay at Drammen.

From 11th Nov. 1963 to 22nd Febr. 1964. 112 metres of quay wall, water depth 6 metres was constructed.

Plan shown in Fig. 22, cross-section in Fig. 24. Steel sheet piling in front and wooden piles 3 metres behind, carrying a narrow reinforced concrete slab, which was built under a movable canvas tent, seen on Fig. 21 (and Fig. 23 during the curing of the concrete front wall.).

Fig. 21

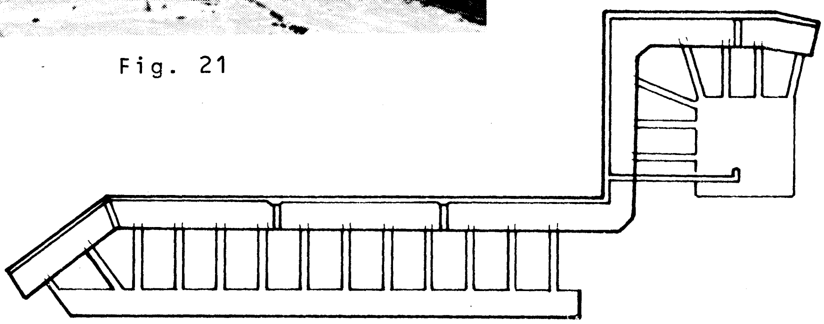

Fig.22

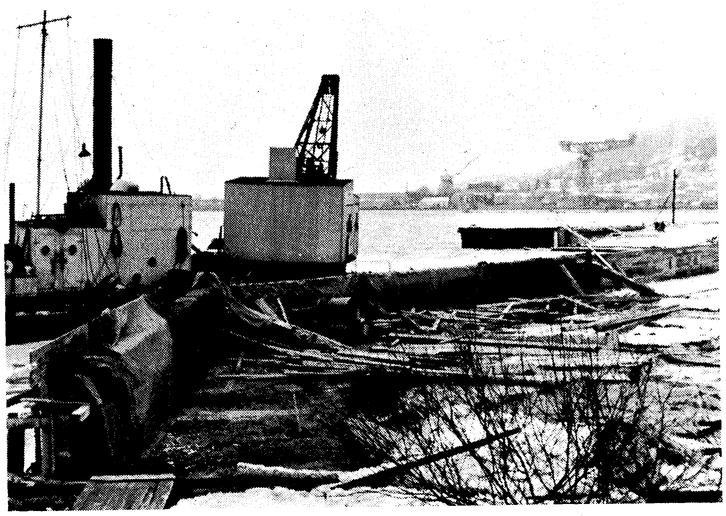

Fig. 23

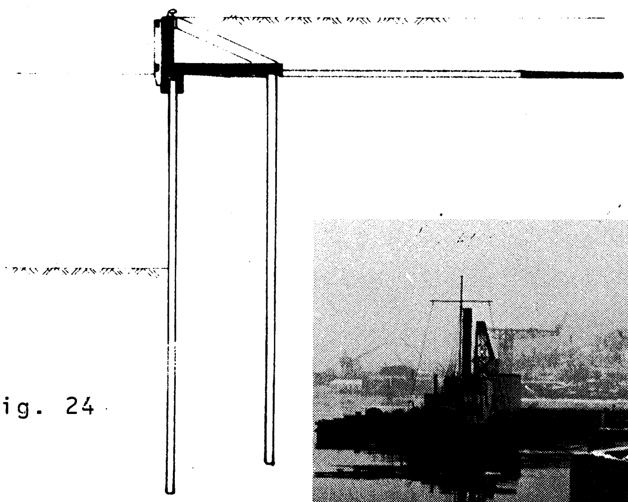

Fig. 24

Fig. 25

CONCLUSION

During more than half a century, high quality concrete has proved its durability in harbour structures in Norwegian waters, and it should be very suitable also in the off shore structures to come in the same waters.