PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

SOME SOLUTIONS OF THE LATERAL BOTTOM SUPPORT FOR ARCTIC WHARF STRUCTURES.

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INTRODUCTION

A characteristic feature of bed conditions over large parts of the arctic region is that the bottom is bare rock or is covered by only a relatively thin layer of sediments. For this reason one of the most difficult - and often one of the most expensive and economically most unpredictable - problems facing the designer of arctic wharves is that of providing lateral support for wharf structures at the bottom.

During the last ten years, in which a considerable number of wharves have been designed and constructed in Greenland, an almost equally large number of different solutions to this problem have been tried with varying degrees of success. The paper presents some of these solutions with comments as to the experiences gained during construction.

In Greenland the problem is aggravated by the fact that on many sites the possibility of drifting ice in the form of icebergs or large floes makes it necessary to use backfilled structures requiring strong lateral support at the bottom.

BOTTOM FILL

The simplest solution to the problem is of course to provide the lacking sediment cover over the rock by filling a layer of sand or shingle on the bottom of sufficient thickness for the provision of the required lateral support for a driven sheet pile wall. This is also the easiest to estimate and the least prone to unforeseen complications. Unfortunately it is not always applicable, either because of insufficient water depth or because of too strongly sloping bed. In border cases where the slope is just sufficiently small special precautions may have to be taken in connection with the execution of a sand fill.

The bottom fill solution was used in Sukkertoppen i 197o (FIG.1), and was indeed found not to give rise to unforeseen difficulties.

LOWER ANCHORS

In cases where a bottom fill is not feasible the most common solution in Greenland has been that of providing a set of lower anchors near the bed connected to anchor plates in the backfill. This requires the connection of anchors to the wall to be designed as a hinge, and the general solution involves provision of an anchor for each double iron of the sheet pile wall and for each two piles in the case of wooden pile walls, thus avoiding the mounting of a longitudinal horizontal beam on the wall near the bottom.

FIG. 2 shows a typical structure using rock fill and a wall of spaced greenheart piles.

In one case a backfilled structure on a strongly sloping rock face has been "suspended" in upper and lower anchors connected to the same mountings bolted above low water into very sound rock. This solution was quite successful and gave little unforeseen trouble (FIG. 3).

FIG. 4 shows this type of solution used on a structure consisting of a steel sheet pile wall backfilled with sand (Sukkertoppen).

In all these cases the work has been executed in the way that the hinge has been mounted before the piles are placed. Later the diver has placed the anchors.

With this type of structure there has in one case been some trouble which in a sense was trivial, but also a classical example of the kind of trouble that has often been encountered in Greenland and is often very expensive.

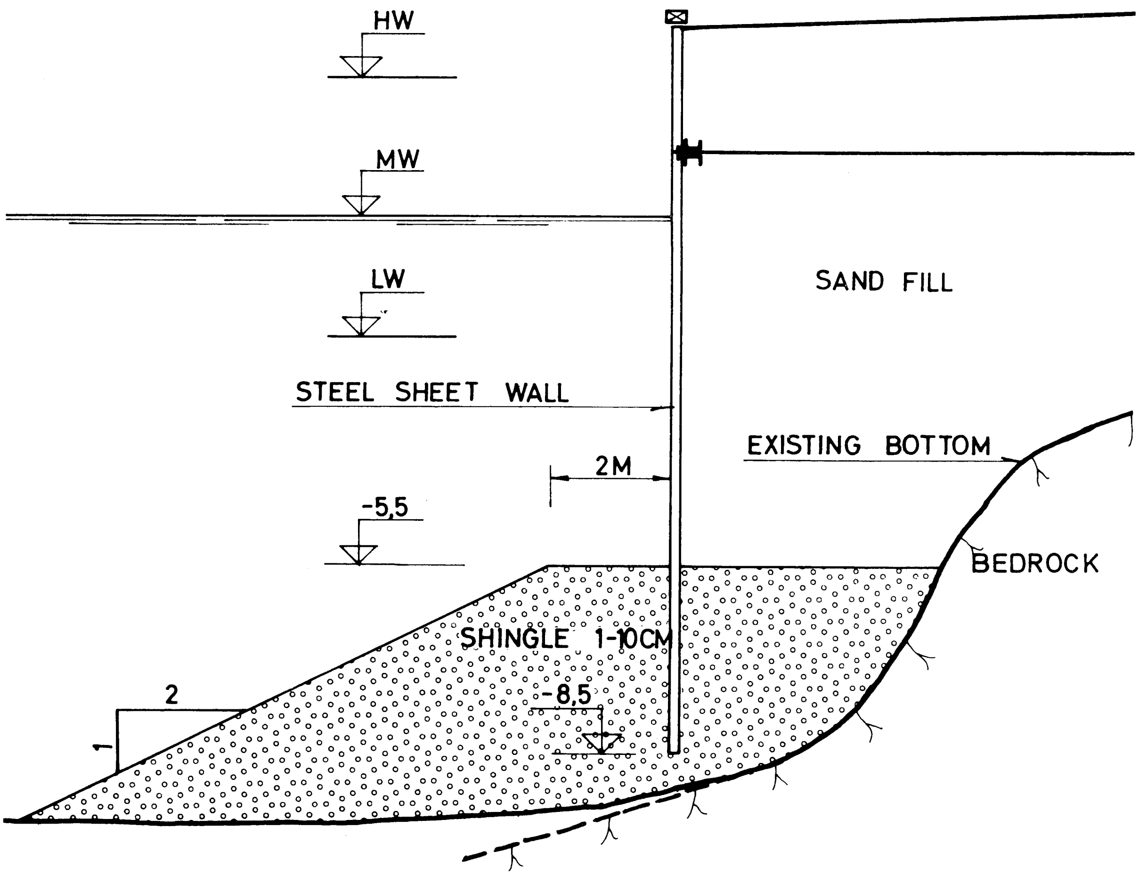
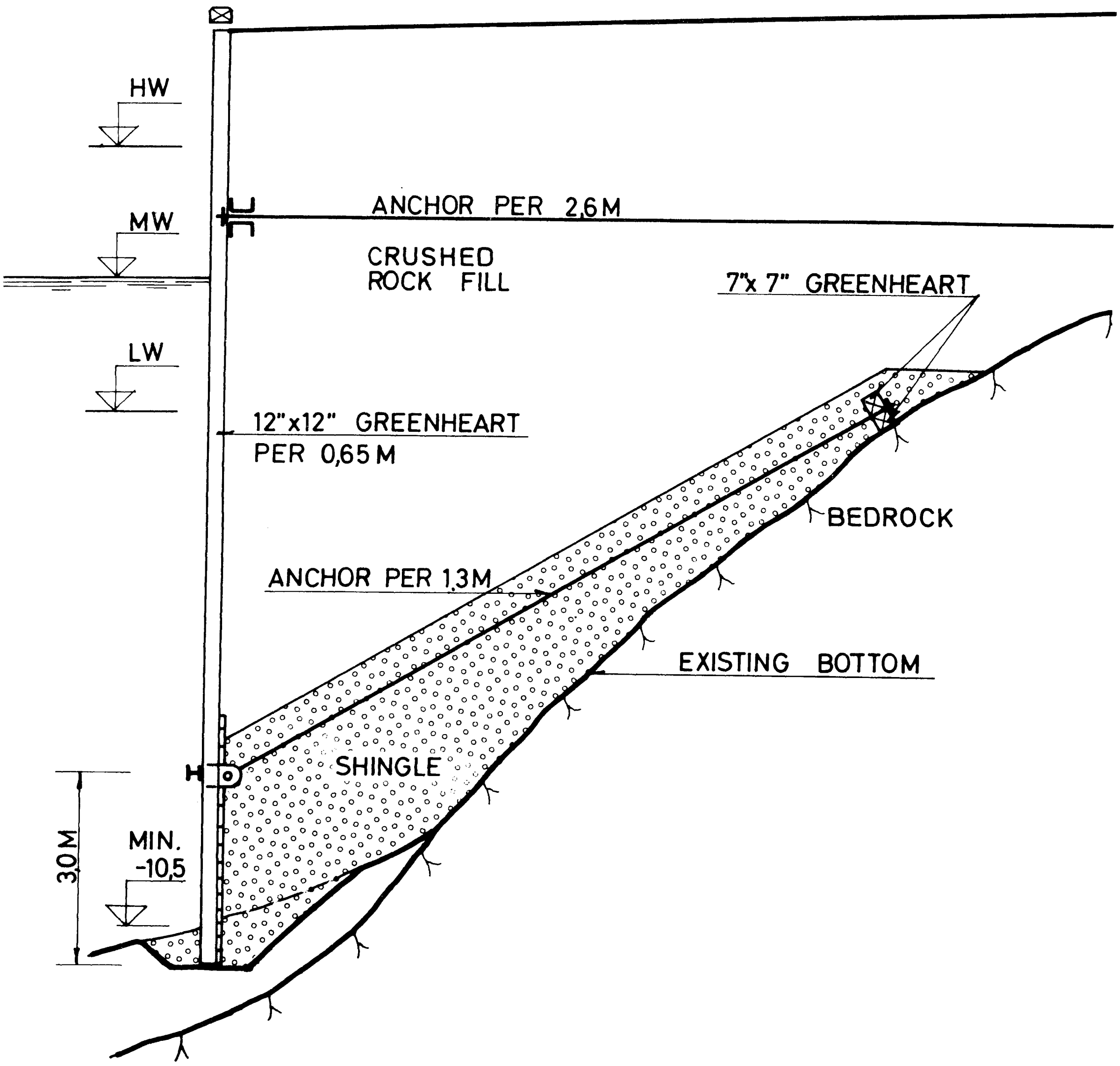

HW
MW
LW
STEEL SHEET WALL
2M
-5,5
SAND FILL
EXISTING BOTTOM
BEDROCK
SHINGLE 1-10CM
-8,5
2
1

FIG. 1

CROSS SECTION



PLAN

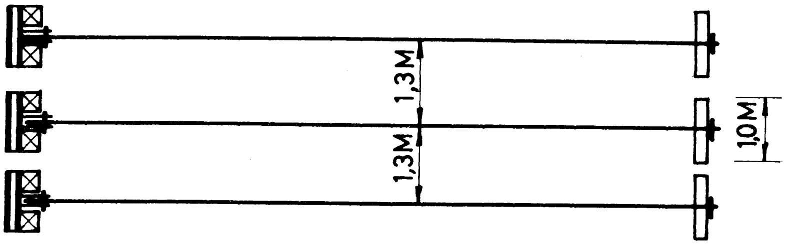


FIG. 2

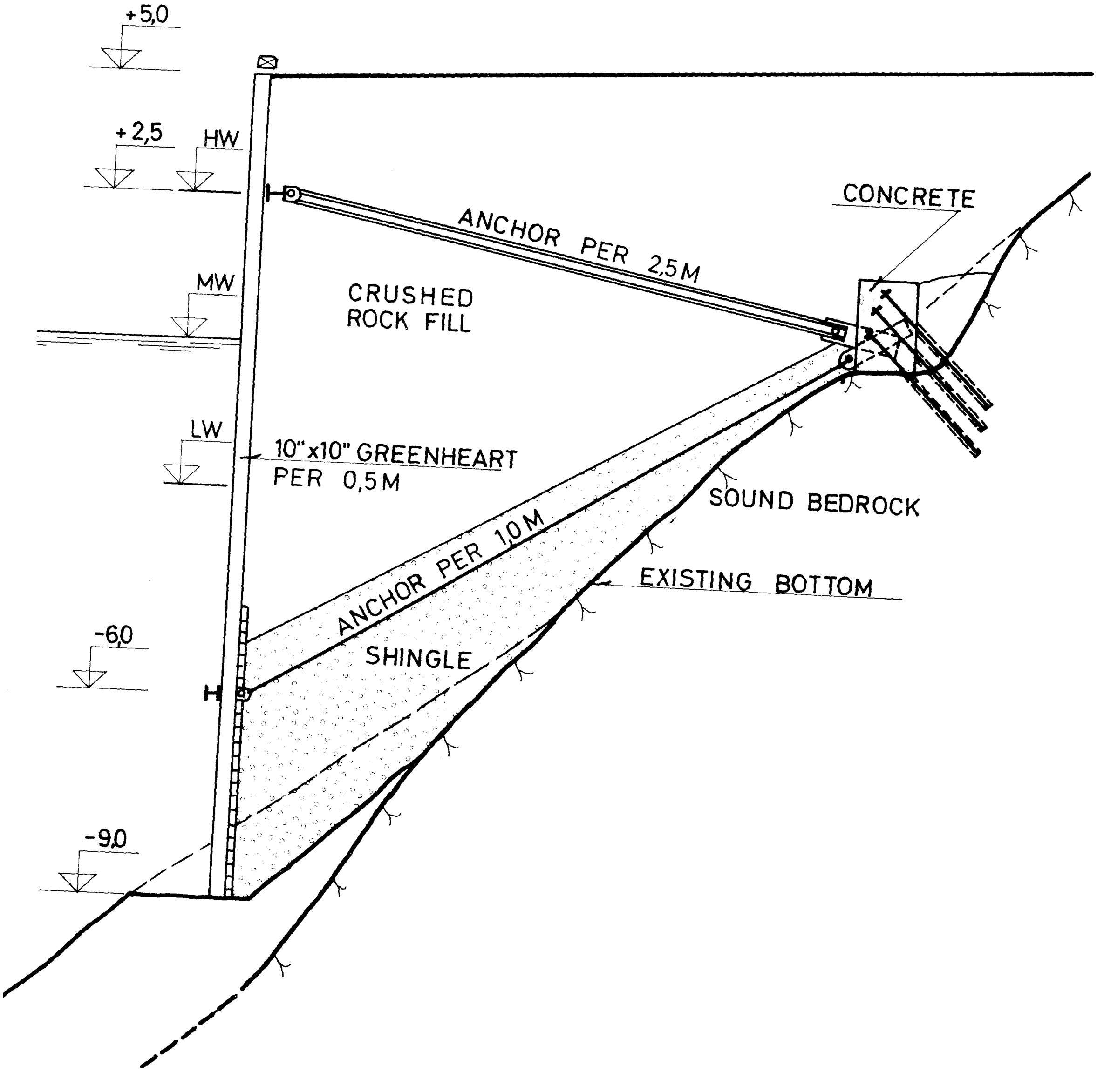
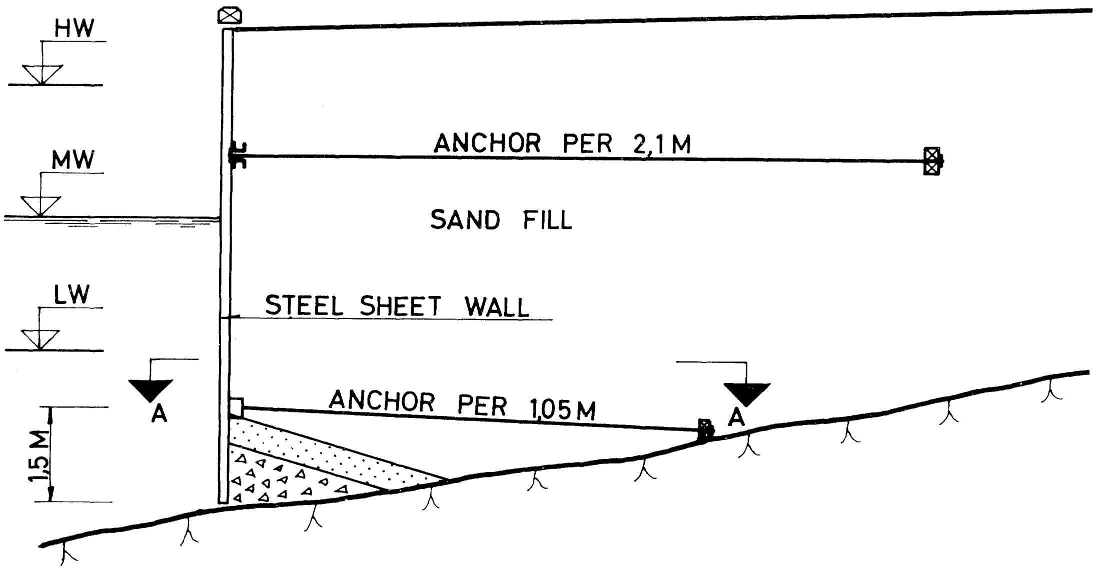

+5,0
+2,5
HW
MW
LW
-6,0
-9,0
ANCHOR PER 2,5M
CRUSHED
ROCK FILL
CONCRETE
10"x10" GREENHEART
PER 0,5M
ANCHOR PER 1,0M
SOUND BEDROCK
EXISTING BOTTOM
SHINGLE

FIG. 3

CROSS SECTION



PLAN
SECTION A-A

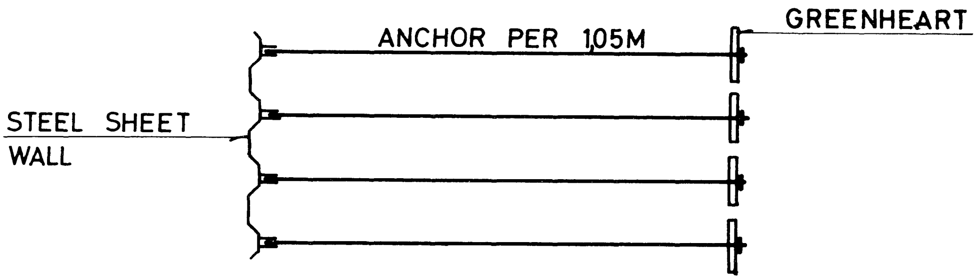


FIG. 4

In that particular case the site investigations had indicated the existence of a thin (abt. o,5 m) sediment layer on top of the bedrock. The contractor designed his scaffolding on the assumption that this layer would be sufficient to provide lateral support at the bottom during contruction until the lower anchors could begin to take effect. However, when contruction was under way this sediment layer was found to be non-existent in certain places, and therefore costly alternative measures for providing lower lateral support during contruction had to be improvised. Through this and many other similar experiences it has been found repeatedly that at sites with bedrock at or near the surface of the bed it is simply not possible within reasonable costs to make enough and sufficiently accurate site investigations to preclude unforeseeable trouble, if the structure to be erected is in some way dependent on details in bed conditions.

The solution with anchors at two levels gives in general small values of the bending moments in the wall. The solution with spaced greenheart piles gives futhermore small forces from waves during execution and long durability of the construction.

DRILLED OR BLASTED HOLES OR TRENCHES.

In cases where the sediment cover is non-existent or very thin various procedures for drilling holes for each individual pile of a wooden wall of spaced piles or blasting a trench in the bedrock have been tried (FIG. 5). In general the experiences have been unencouraging, and the costs of such work have often sky-rocketed.

This solution requires sound bedrock at the surface of the bed as well as high professional standard of the contractor.

OPEN STRUCTURES

In a number of cases the conditions have been so that it has been found acceptable to use an open structure with its smaller lateral strength, whereby the problem is of course greatly reduced.

This of course requires the site to be well protected from severe ice conditions.

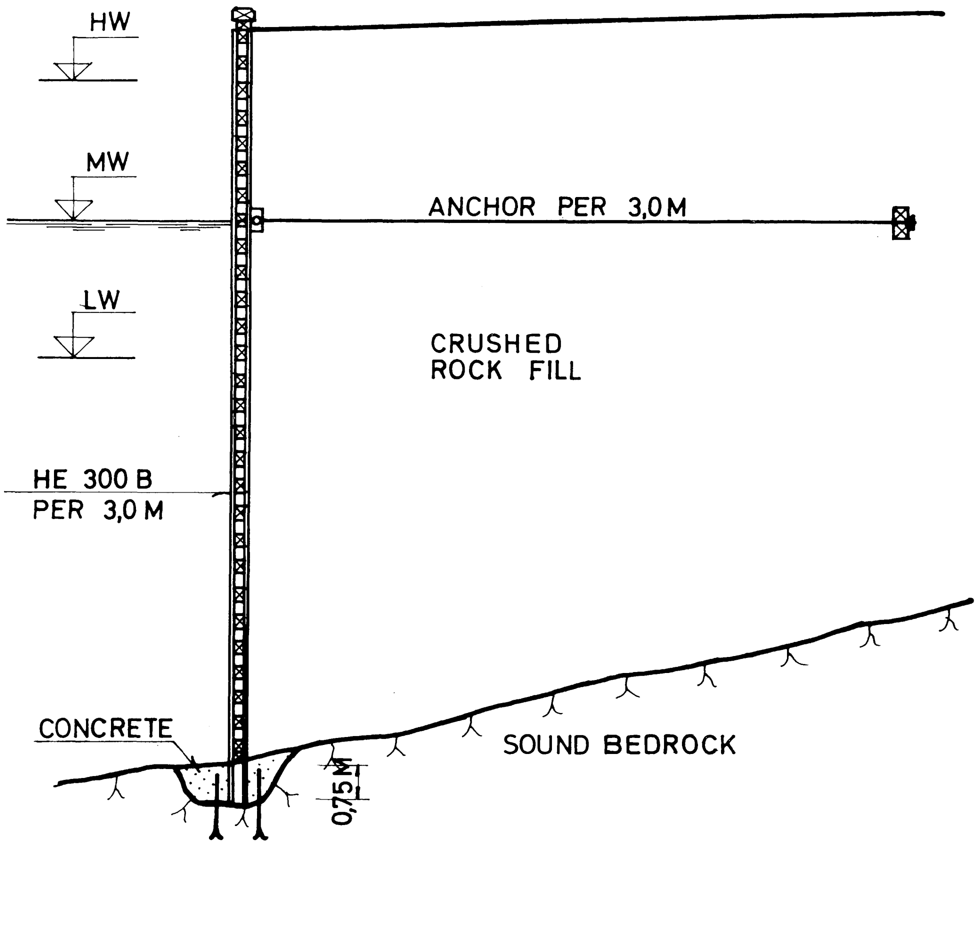

HW
MW
ANCHOR PER 3,0 M
LW
CRUSHED
ROCK FILL
HE 300 B
PER 3,0 M
CONCRETE
SOUND BEDROCK
0,75 M

FIG. 5

FIG. 6 shows a structure made in Godthåb, which was succesfully executed in 1968-7o. In this case the open structure was chosen on account of expected difficult driving conditions in stony bottom and to avoid settlement in soft layers consolidating from the weight of the fill that would otherwise be required.

FIG. 7 shows a light structure also constructed in Godthåb. This structure is suspended in a strongly sloping rockface with bolts and fastenings placed above low water.

In this case a certain risk of damage was acknowledged and accepted. In fact the construction, which was executed in 1964, has suffered no damage at all in spite of the fact that the harbour has been completely filled with drift ice several times since construction.

COMBINED STRUCTURES

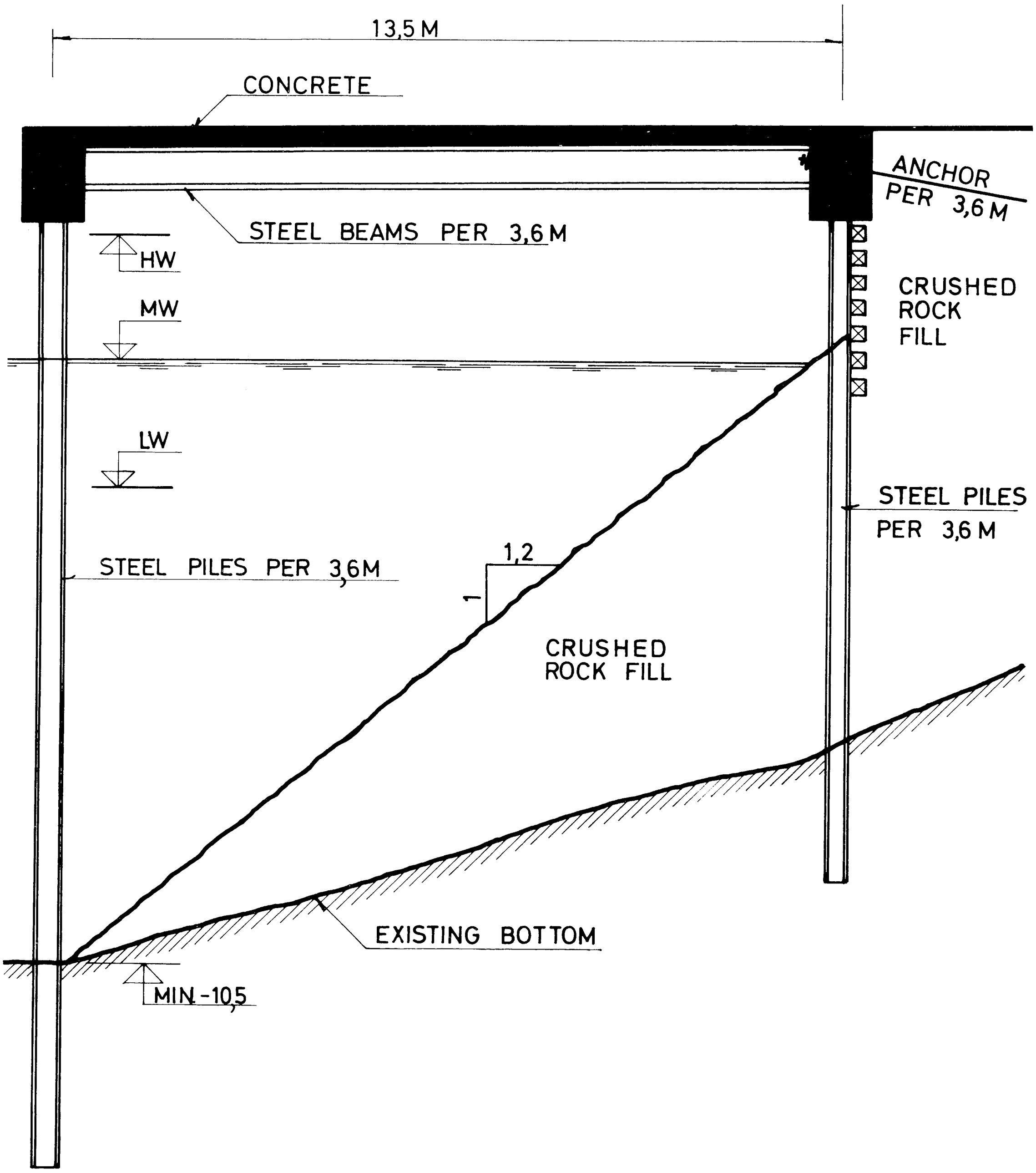
Finally, there is a large number of possible combinations of strong-points and bridge structures, including structures utilizing vertical piles for intermediate vertical support.

FIG. 8 shows an example of this type. The concrete slab distributes horisontal forces from ice or ship loads to the strong-points and to the abutment in the causeway.

In this case the strong-points are constructed from rock fill and greenheart piles held together at two levels by steel frames. This type of structure can be very economical, but can of course only be used at sites with comparatively mild ice conditions.

CONCLUSION

On basis of experiences gained from execution of a considerable number of wharf structures in Greenland it appears that a primary consideration of the designing engineer should be to try to reduce underwater work as much as possible, and to make the structure as independent of the bottom conditions as possible.



13,5 M
CONCRETE
ANCHOR
PER 3,6 M
STEEL BEAMS PER 3,6 M
HW
MW
LW
CRUSHED
ROCK
FILL
STEEL PILES
PER 3,6 M
STEEL PILES PER 3,6M
1,2
1
CRUSHED
ROCK FILL
EXISTING BOTTOM
MIN.-10,5

FIG. 6

1271

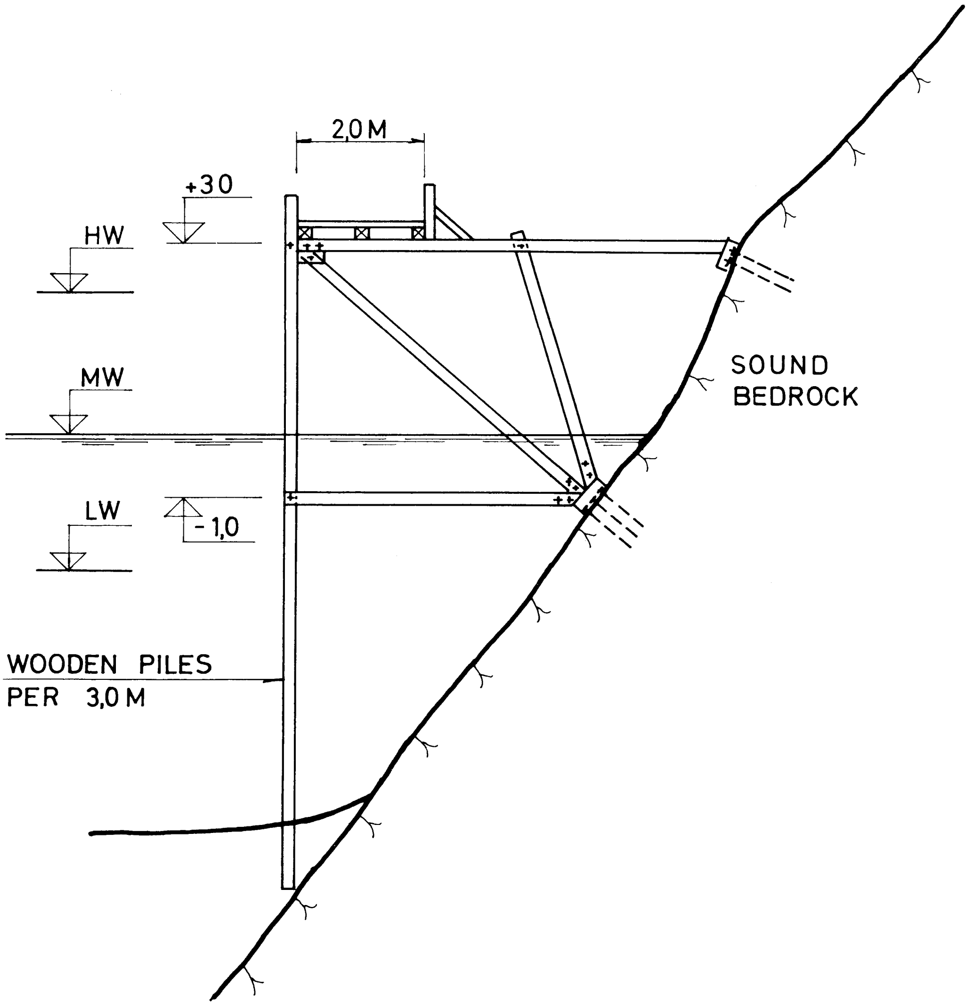


FIG. 7

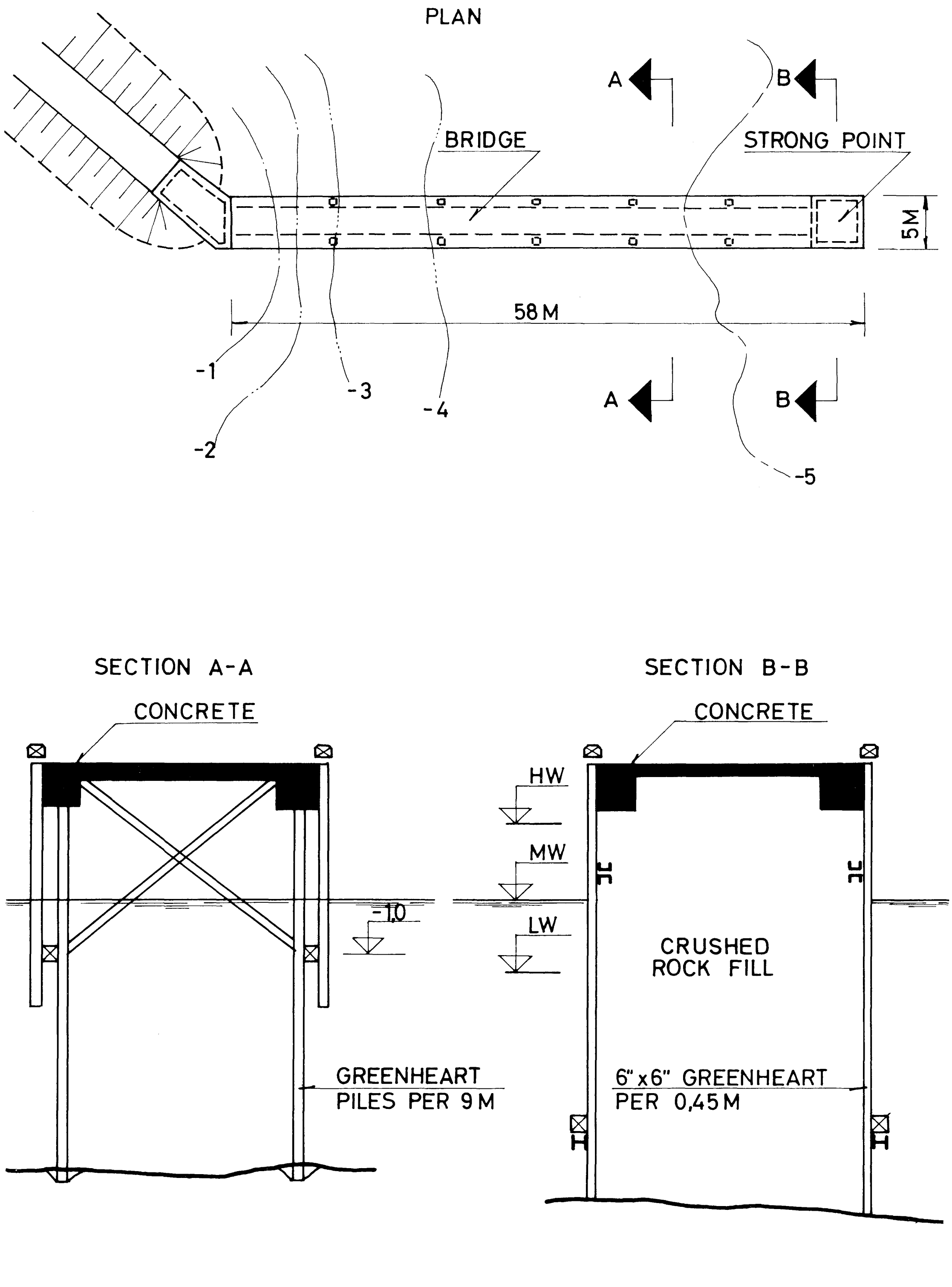

PLAN
A
B
BRIDGE
STRONG POINT
5M
58M
-1
-2
-3
-4
-5
A
B
SECTION A-A
CONCRETE
-1,0
GREENHEART
PILES PER 9M
SECTION B-B
CONCRETE
HW
MW
LW
CRUSHED
ROCK FILL
6"x6" GREENHEART
PER 0,45M

FIG. 8