PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

DESIGNS FOR THE CONSTRUCTION OF HARBOURS IN HOLSTEINSBORG AND JULIANEHÅB, GREENLAND.

C. P. Olsen
Chief Engineer, M.D.A.C.E.
Dansk Geoteknik A/S
Consulting Engineers
Vestergade 17
1456 Copenhagen K
Denmark

This paper about Harbour Constructions in Greenland, in the towns Holsteinsborg and Julianehåb, deals with the work of Danish Geotecnic Ltd. during a period of nearly 1o years. In this span of years, our firm has been Consulting Engineers for the Danish Ministry of Greenland. The Greenland Technical Organisation, G.T.O., has in this period been working with a program of developing modern harbours along the western coast of Greenland.

For the general Cargo there have been built facilities for Atlantic ships up to 7.ooo - 8.ooo DWT and with 1o m of water depth at MLW. The Unit Load system has been preferred.

For the Fishery there have been built special facilities with separate functions for Unloading of fish and for Supply and Outfit. Further there have been built Sheltered Basins for the ships in bad weather, or when the ships are not in use. Ships of 5oo GRT as well as of less tonnage have been chosen for the fishery.

For the shipyards there have been built a number of slipways up to 25o t docking weight and also a number of special shipyard quays provided with cranes for lifting ships up to 5o t weight out of the water, and placing them on the quay.

In this harbour developing program we have been working especially in Holsteinsborg, starting with Soil Investigations all over the harbour area, and later when the poor geotechnical conditions were stated, we have had a very interesting work as no traditional constructions have been possible in the area, either due to rocky bottom with no or little soil deposits, or due to very loose and soft deposits covering the bedrock.

Because of this and of the special arctic conditions, new principles have been developed, as mentioned in the abstracts.

There you will find a detailed discription, and I am now going to give you a brief oral explanation of the various constructions. At the same time Mr. Skærbo from G.T.O. has asked me to show you some slides of the location in Holsteinsborg.

Later during the panel discussion there will be time to reply to questions from the audience.

Slide 1. This is a Site of HBG. Harbour.

In the Centre you will see the old Inner Harbour with buildings for the Fishing Industry.

A new Breakwater has been built as far outwards as possible, due to sloping bottom.

A 5 m deep Inside Wharf has been placed all over the lenght of the Breakwater. In future the wharf will have 6 m of water depth at MWL, and will serve for fishing vessels up to 125 GRT.

A 8 m deep Outside Wharf will serve Coasters or Schooners with General Cargo for distribution along the coast.

A lo m deep Atlantic Quay will serve 8.ooo DWT ships crossing the Atlantic Ocean.

A new Warehouse has been placed just inside the Quay. The new Areas have partly been reclaimed by sand fill, and partly by blasting down the bedrock.

A 5 m deep Quay for Supply and Outfit has been built as western bulkhead for the new reclamations.

The new areas are strictly separated in use by a fence between the General Cargo purpose of Atlantic and Schooner Quays, and the Supply and Outfit purpose of the fishery harbour.

A new 6 m deep Shipyard Quay is under construction and the existing slipway is going to be reconstructed for vessels of 25o t docking weight.

A new 8 m deep Industrial Pier is under construction as a compensation for the old wharf for combined use of Schooners and Fishing Vessels. The new pier will serve for unloading of fish from 5oo GRT Trawlers, as well as for smaller fishing vessels.

In the new harbour plan an attempt is made to have all the various functions seperated from each other in special areas, as well for the Fishery as for the General Cargo.

Slide no. 2. This is a Photo of the new Sheltered harbour basin during construction period. You are looking north across the old inner harbour to the new reclaimed Areas and the Breakwater.

Slide no. 3. This Photo of the new Breakwater, with Mole head, Schooner Quay, Atlantic Quay and Warehouse is taken this year in month of April, and you will notice, that there is still ice in the fond of the bay, whereas the harbour area is free of ice.

Slide no. 4. (Fig. 1 in the abstracts). This shows the cross section of the Atlantic Quay for General Cargo.

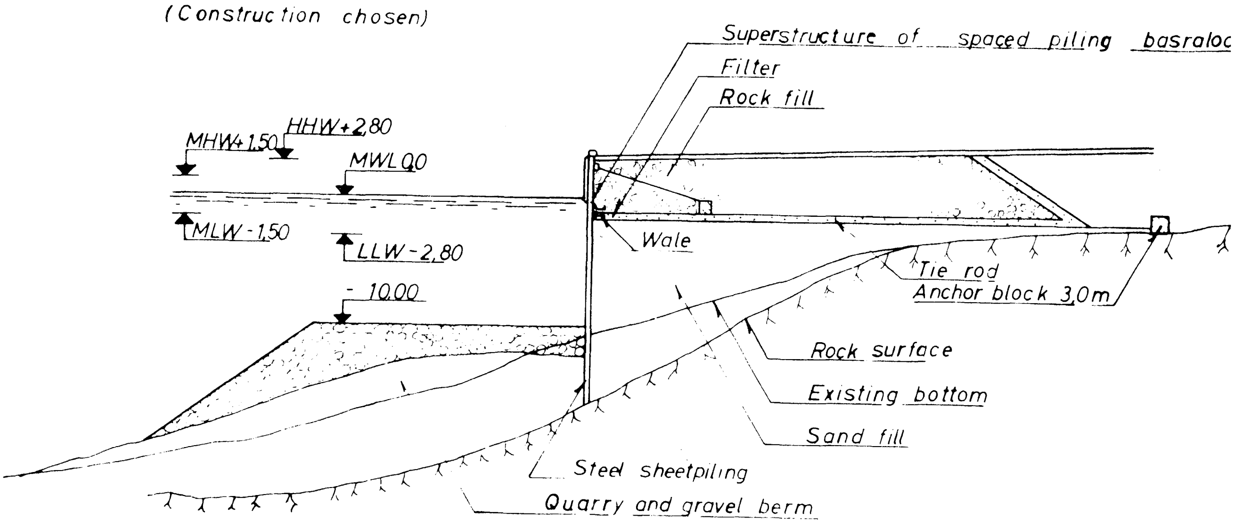
You will notice the water depth of 1o m at MWL and a tidal Range of 5 - 6 m.

The cross section of an anchored steel sheetpiling is quite normal, and therefore, only the untraditional features of the structure will be commented here.

1. A very big gravel and quarry berm has been placed upon the loose postglacial sediments.

The extension of the berm has been determined by the stability analysis, as being necessary because of a very soft silty layer, just over the sloping bedrock. This layer was very thin, but had to be consolidated to greater strength during the construction period.

Fig. 1 Atlantic Quay, General Cargo
Anchored bulkhead 1:500
(Construction chosen)



Price relative, 100%

The stability of the berm is sufficient with sandfill, but for safety a coarse material has been used, as some trouble arose, when the contractor was pumping sand without taking care of dispersing the flow.

Later on, neither the vast blastings of rock, nor dumping of the underwater rock dam, nor vibrations of sheet pile ramming, have been able to provoke any underwater failures in the slope.

2. The top layer of the berm had to be quarry, 1. In order to secure a high passive earth pressure, 2. In order to secure a yield hinge near the surface, thus reducing the span of the sheet piles.

3. The sheet piling had to be rammed to the bedrock, not because of the wall itself, but due to the necessity of forcing downwards the rupture line of stability.

4. The big extension of quarry fill over MWL had to be performed, in order to reduce excessive water pressure all over the volume of driving dead-load according to the stability analysis.

5. Most noticeable is the choise of a superstructure on a substructure.

Choosing a superstructure of wood on a steel sheet piling offers great advantages without being more expensive, than a steel sheet piling to the top.

In addition I want to state the following 6 advantages.

Point A) Dangerous provisional conditions during high tide and stormy weather are avoided completely, as the superstructure of wood is not mounted until a later stage, when a sand fill has been supplied. During a storm in the provisory state the dynamic wave pressures on a sheet piling of full height can not be absorbed within the limits of reasonable economy, and the substructure will just be flooded, wich will do no harm.

Point B) By using wood, corrosion of steel or concrete has been avoided in the whole tidal range, where water and air alternate, and corrosion is at a maximum. Corrosion of steel in Greenland seems to be as big as in Denmark, about to o.3o mm/year.

Point C) The piles of the superstructure are of the tropical hard wood basralocus, which is resistant to rot and marine borers. Gribble attacks have been recorded in normal softwood in Greenland. Durability of basralocus is considered unlimited.

Point D) The mounting of the wooden superstructure means inserting a hinge in the wall at the anchor level, so that a dominating negative bending moment has been avoided at the top of the steel sheet piling.

where corrosion is at a maximum.

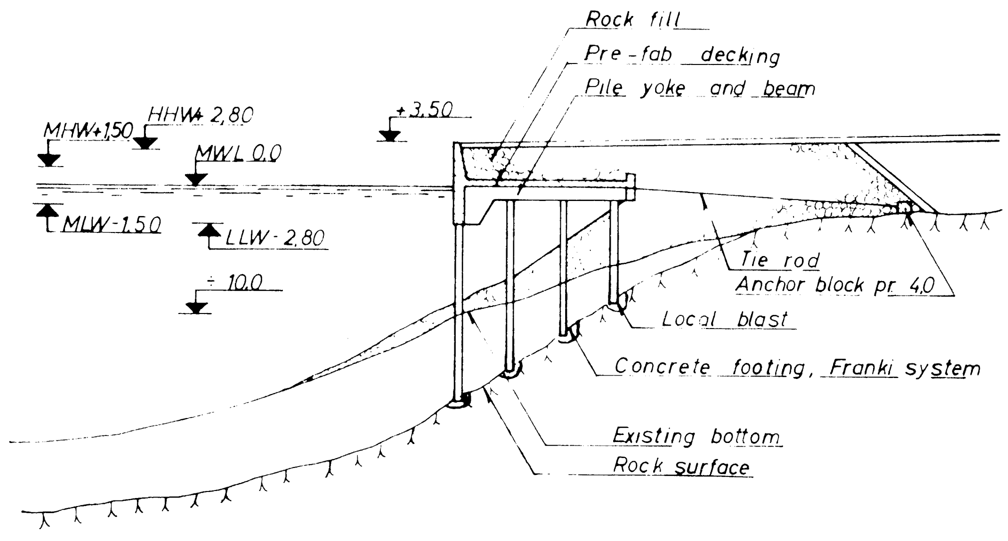
Moreover the steel sheet piling is safeguarded against corrosion on the top 2 m by sandblasting to metallic cleannes and by application of 4ooμ coal tar epoxy.

Point E) Spaced piling with rock fill ensure the most secure and quickest possible draining of differential water pressure caused by the variation of tide, both concerning the sheet pile dimensions and the total stability.

Point F) In case of collisions the wooden structure is less dangerous for the ship's hull, and repairs are easier to make than in the case of a steel sheet piling.

Slide no. 5. (Fig. 2 in the abstracts). This shows an alternative construction to Fig. 1. Atlantic Quay General Cargo. lo m depth.

Fig. 2 Atlantic Quay, General Cargo
Open Quay, Alternative



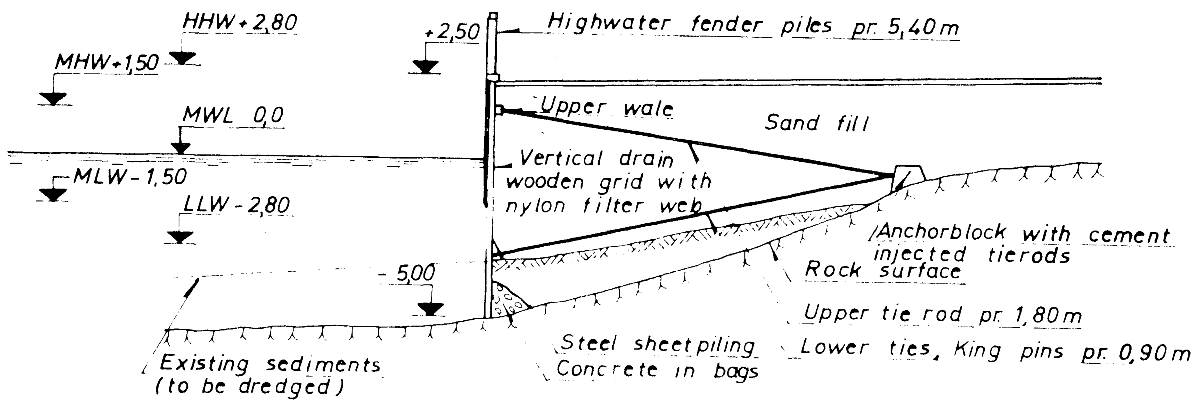
Price relative, 100 %

This open construction was estimated to the same cost, as the anchored bulkhead, and allthough the open quay in this case was not chosen, it shall be mentioned because of its principles.

Here the structure is an open quay on a pile foundation with a front wall in the whole tidal range to prevent ice floes from breaking the piles. Thus all single piles are protected against horizontal forces in the <u>free length</u>. The relieving platform is made, partly prefabricated, as a lowlevel deck, so that the preload of the fill compensates possible coincident lifting forces from buoyancy, ice, upward wave pressure at high tide, or excentric ship's impacts. Depending on time, further details will be given later.

<u>Slide no. 6. (Fig. 3 in the abstracts).</u> <u>Quay for Supply and Outfit.</u> 5 m depth. The construction consists of a substructur of square sheet pile-cells, and on top of this a wooden superstructure of tropical hardwood.

Fig. 3 Quay, Supply and Outfit
Double anchored sheet piling



Price relative, 112 %

Provisional vertical piles are rammed in the berm for the mounting of prefabricated wales. The wales form closed frames supported for horizontal forces on the cell latest fulfilled. For this reason all risk during provisory work is limited to the deposited gravel berm, and does not include risk of overturning a long stretch of sheet piling, as does a sheet piling of full heigth.

To reduce the height of the quay for dayly use the walls cap level is fixed at + 2,5o. The quay is therefore provided with high water fender piles every 3.6o m.

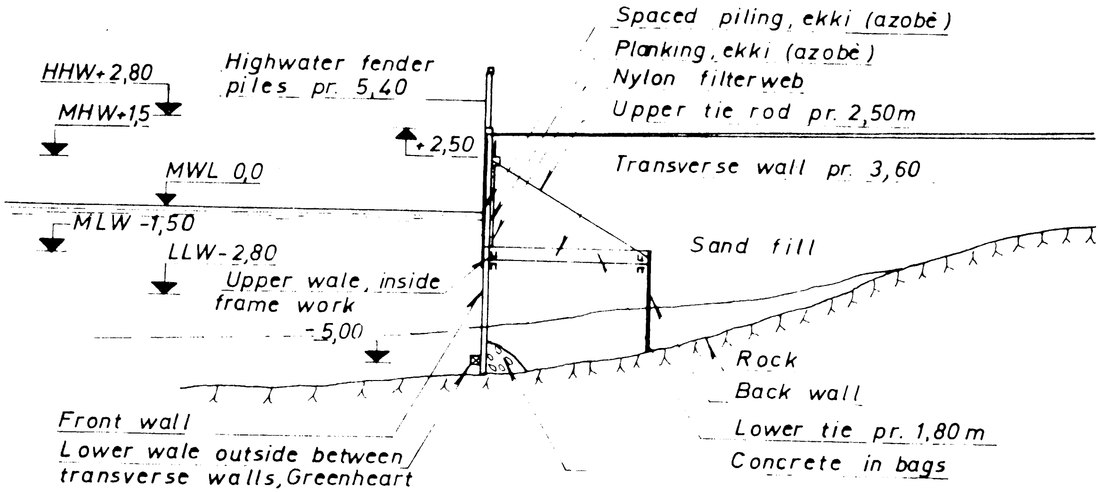
The sheet piling cells here are square angled instead of circular, for which reason tensile stresses in a circular ring cannot be utilized. Instead, the sheet piling must as usual carry the earth pressures with vertical bending moments between an upper wale and a lower wale. The latter is of the tropical hard wood, greenheart, and is placed on the outer side of the sheet piling by a diver before the superstructure is mounted. The submerged wale is placed at shifting levels from cell to cell and anchored to the transverse-walls. The assembling is carried out as a field connection made by a diver, as all details of the work have been made before the sheet piling is rammed.

As mentioned, the construction consists of sheet pile cells, with wooden superstructure. The principle of cells seem to be the easyiest solution of the problem of provisory bracing, and at the same time being solution to the problem of lower anchorage under the water. The construction can even be performed without further trouble, if Rocksurface has the same level as basin bottom, and deposits are lacking.

The only reservation is, that it must be possible to make a temporary gravel berm for ramming the sheet piles. Afterwards the sheet piling is fulfilled, the outside berm can be completely removed, and it is possible by simple means to secure the bottom tightnes for the inside fill. This can be done, because the transverse walls and lower outside wale form a lower bracing in the provisory state. This bracing is lacking for the double anchored wall solution, being shown at next slide.

<u>Slide no. 7. (Fig. 4 in the abstracts).</u> This double anchor sheet piling was not chosen, as tenders from the contractors showed it to be some 12 % more costly, than the sheet pile cell construction. If there will be time later I will tell more about the double anchored sheet piling.

Fig. 4 Quay, Supply and Outfit
Sheet pile cells 1:200, Alternative
(Construction chosen)



Price relative, 100%

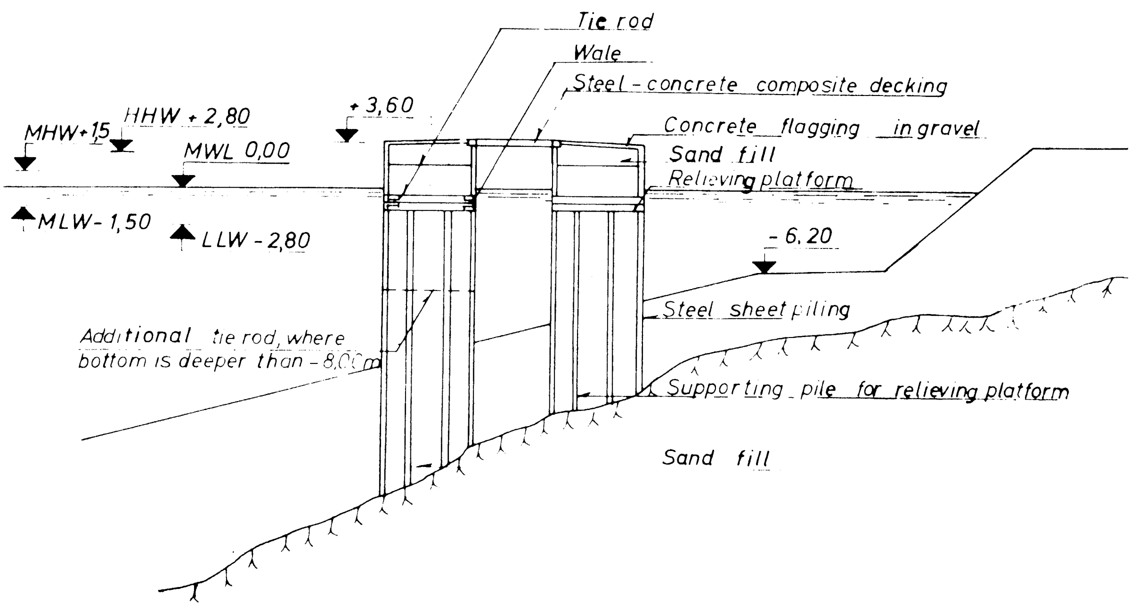
Slide no. 8. (Fig. 6 in the abstracts). Industrial Pier, Lay Out.

Soil conditions show that existing deposits have a thickness of 8 to 1o m, and they consist of postglacial marine sand and gravel layers with underlying mud and silt layers of varying thickness. The rock surface slopes about 3o° outwards.

The structure, which are built out from the coast at 5 m - 13 m depth consist of sand filled single sheet piling cells. They are mutually connected with a bridge deck of steel and reinforced concrete, according to the composite girder principle.

It has been impossible to build a normal bulkhead, because of too big dead loads in stability analysis.

Fig 5 Industral Pier, Unloading of fish
Single cells of sheet piles and steel-concrete composite decking 1:500



Slide no. 9. (Fig. 5 in the abstracts). Industrial Pier, cross section. 8 m depth.

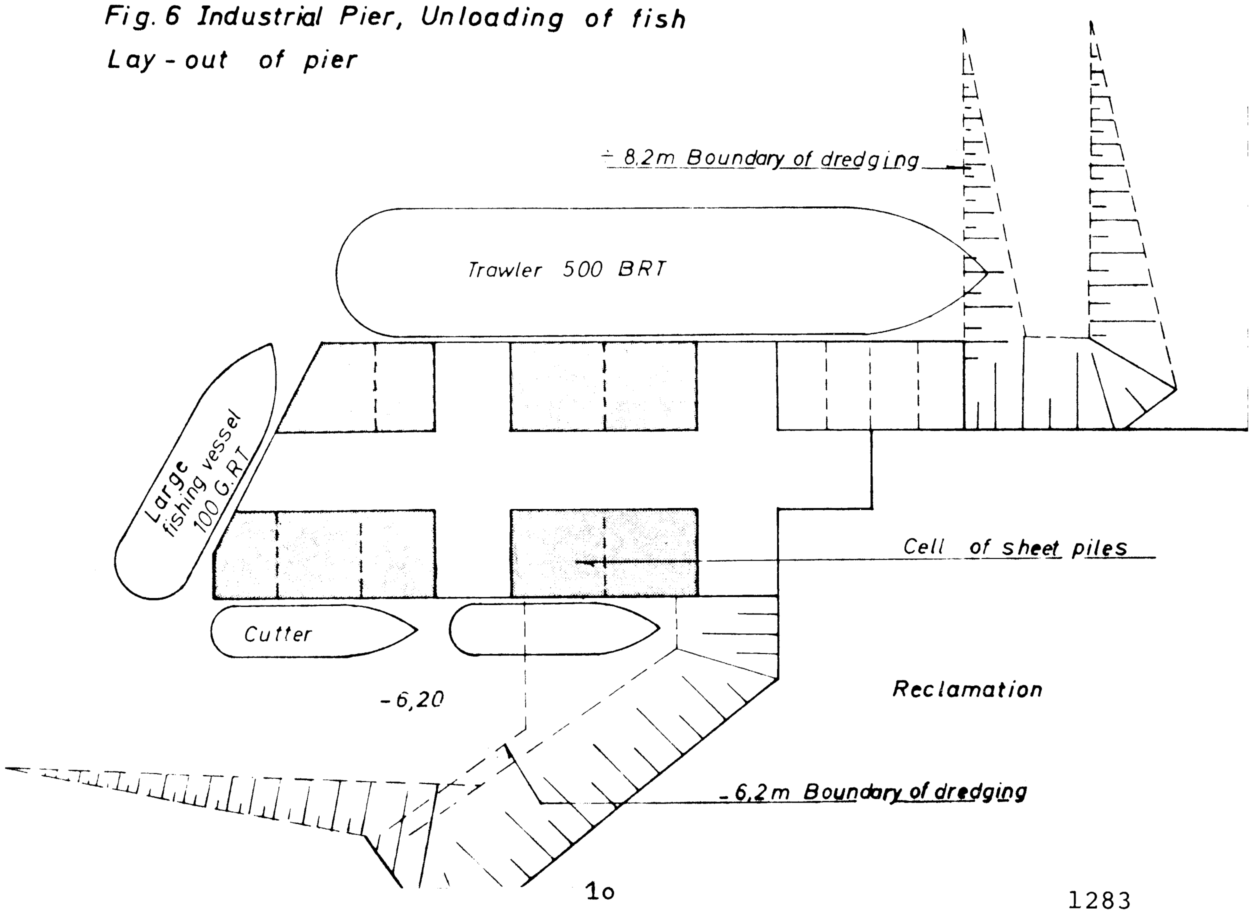
By construction of single sheet piling cells without backfill driving dead loads are removed, and the result is, that the greater part of the surface load and the weight of the fill is transmitted trough the wall to solid rock, while the horizontal earth pressures on the wall are small and become inner forces in the cells.

Due to ice lift and ice pressure, slender piles have not been used. The single cells will act as a kind of heavy pillers. The heavy dead load will stabilize overturning from horizontal forces, and secure the construction from lifting forces.

Basralocus pile fenders have been placed between cells in order to prevent large ice floes from drifting under the bridge deck and damaging it according to high water updrift and waveaction.

This was a little about the constructions in Holsteinsborg, and some further photographs from the 4 years constructionsperiod will be shown.

Fig. 6 Industrial Pier, Unloading of fish
Lay - out of pier



Slide	no.	lo	1968.	5 m Quay, sheet pile cells, back wall being rammed.
-	-	11	1968.	5 m Quay, sheet pile cells, cells ready for sandfilling.
-	-	12	1968.	5 m Quay, sheet pile cells, Mounting of wooden-superstructure.
-	-	13	1968.	5 m Quay, sheet pile cells, Anchors of wall and bollards.
-	-	14	1969.	5 m Quay, sheet pile cells, Superstructure, highwater fenderpiles.
-	-	15	1969.	lo m Atlantic Quay. Wooden Superstructure being mounted.
-	-	16	1969.	lo m Atlantic Quay. Anchor blocks of concrete.
-	-	17	197o.	Winter time in inner harbour of HBG,
-	-	18	197o.	Winter time outside harbour of HBG.
-	-	19	197o.	5 m Quay. Superstructure of spaced piling being erected.
-	-	2o	197o.	Wharf at breakwater. Prefabricated wooden superstructure, mounting.
-	-	21	1971.	Corner between Breakwater and 5 m Quay, Superstructure.
-	-	22	1971.	Finished Breakwater, Mole head, Schooner Wharf, Atlantic Quay, Warehouse.
-	-	23	1971.	Outside Breakwater, Wave screen and sheetpile threshold.
-	-	24	1971.	Outside Breakwater, Schooner Quay.
-	-	25	1971.	Automobile Tyre Fenders of Schooner Quay, Cord. cap.
-	-	26	1971.	Spaced Piling of Mole head, Quarry Fill.
-	-	27	1971.	Inside Quay of Breakwater highwater fenderpiles.
-	-	28	1971.	Industrial Pier. Cells being rammed.
-	-29-3o		1971.	Slipways in Frederikshåb and Julianehåb.