XBLOC INNOVATIONS AT SWINOUJSCIE BREAKWATER

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For the new breakwater in Swinoujscie, Poland, Xbloc has been used as breakwater armour layer. The local conditions in this region with low temperatures in the winter season and poor under water visibility required some innovative solutions to design and build this impressive marine structure. The project was the first Xbloc application where sea ice is expected. An assessment was therefore made of the expected ice loads and possible damage mechanisms due to these ice loads. It was concluded that the chance of damage to the armour layer as a whole was minimal, but an increased concrete strength was applied to deal with the ice forces on individual units. The concrete mix and the production process were adjusted as a result of the low winter temperatures. Furthermore the echoscope® realtime sonar was used to guide the underwater placement in poor visibility conditions. In this paper design and construction aspects are presented of the Swinoujscie breakwater.

Keywords: rubble mound breakwater; Xbloc; ice loads; underwater placement; echoscope®

INTRODUCTION

The port of Swinoujscie is located on the Polish Baltic Sea coast, close to the border with Germany. On the east side of the existing breakwater an LNG import terminal is developed for which a new 3 kilometer long breakwater was built, creating the new Swinoujscie External Port.

The breakwater was built by a joint venture of Hochtief, Boskalis, Per Aarsleff and Doraco. The consultants involved in the project were Grontmij, Projmors and Delta Marine Consultants [DMC].

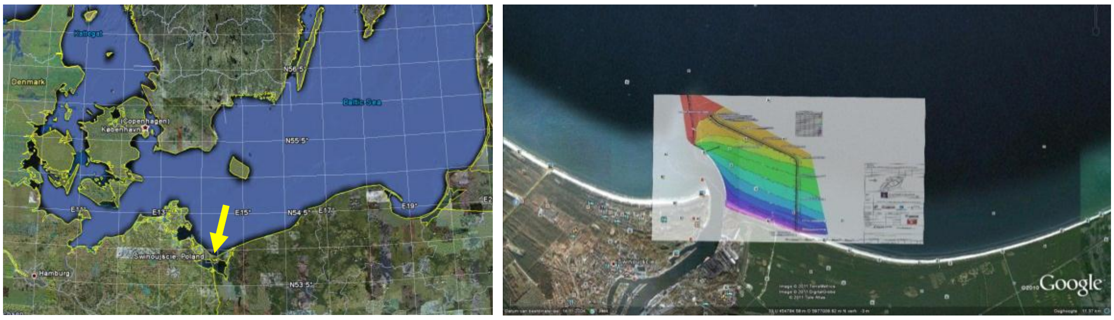

Figure 1. Project location and layout of new Swinoujscie breakwater.

DESIGN

Although breakwaters in Poland are traditionally armoured with tetrapodes, Xbloc armour units were applied for this project in order to reduce the required concrete quantity. The block sizes used were 1m^3, 2.5m^3 and 5m^3 as can be seen in Figure 2. The stability of the 1m^3 and 2.5m^3 blocks was confirmed by 2D physical model tests in DMC's wave flume. For the 5m^3 blocks, no physical model tests were carried out, given the conservative block size that was chosen and the tight project schedule.

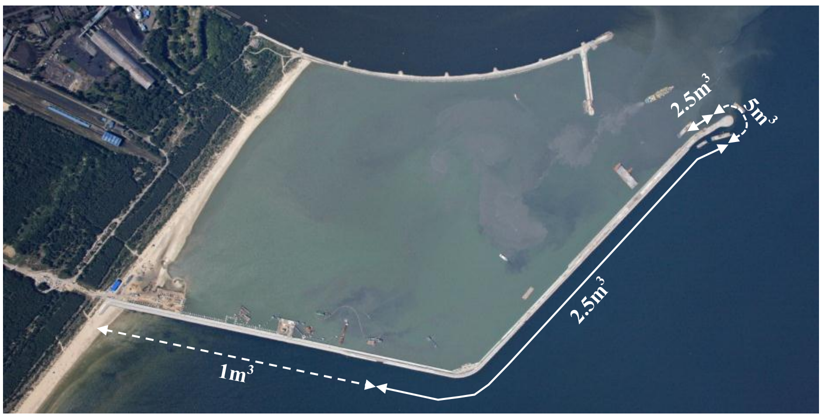

Figure 2. Overview of Xbloc sizes along breakwater alignment

[1] Delta Marine Consultants; The Netherlands; www.dmc.nl or www.xbloc.com

Hydraulic Design

The main cross section (Figure 3) consists of a quay wall at the port side of the breakwater and a rubble mound breakwater slope on the sea side. The design wave height for the structure is Hs=4m, and initially a 1.5m3 Xbloc armour was chosen for the main section of the breakwater. However during the physical model tests at high water levels (KR + 2.2m) the armour layer stability did not meet the design requirements as a result of the low relative freeboard in combination with the large impermeable crown wall. As a result of these tests, an Xbloc size of 2.5m^3 was chosen. The under layer consists of 300-1000kg rock and a secondary under layer of 0.5-25kg rock is applied to separate the 300-1000kg under layer from the fine core material. At the breakwater toe, a rock apron is partly buried into a dredged trench in order to accommodate possible seabed erosion. A geotextile is applied underneath the breakwater toe in combination with a layer of 0.5-25kg rock.

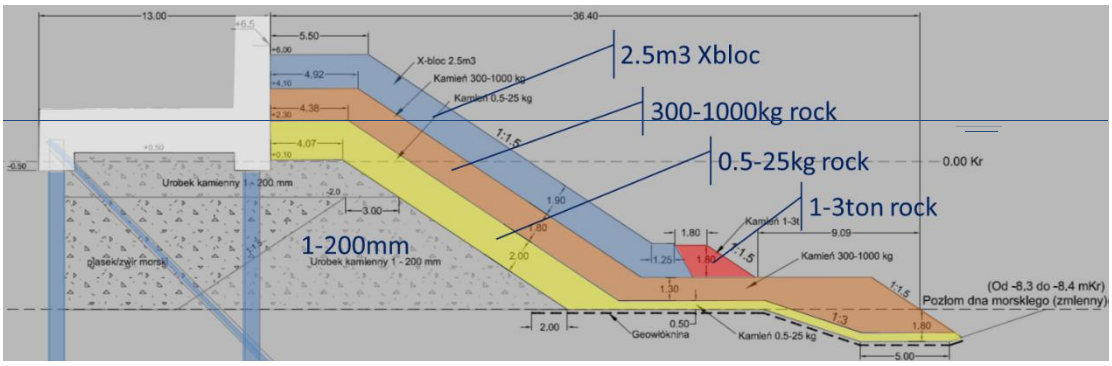

Figure 3. Main breakwater cross section

Ice Loads on Armour Layer

Due to the low winter temperatures in the Swinoujscie area, sea ice can occur at project location (Figure 4). An assessment was made in consultancy with Witteveen+Bos of possible damage mechanisms as a result of sea ice (see Figure 5). The damage mechanisms that were assessed are:

1. Global failure: the ice moves the whole breakwater from its position.
2. Edge failure: the ice moves a part of the armour layer.
3. Local failure: units which are frozen into the ice sheet are removed from the armour layer due to movement of the ice sheet.

Figure 4. Impression of winter conditions during the construction period of the breakwater

It was concluded that the chance of these types of damage occurring at the Swinoujscie breakwater is very low given the limited thickness and crushing strength of the ice in this area of the Baltic Sea and due to the fact that there is no significant tidal water level variation.

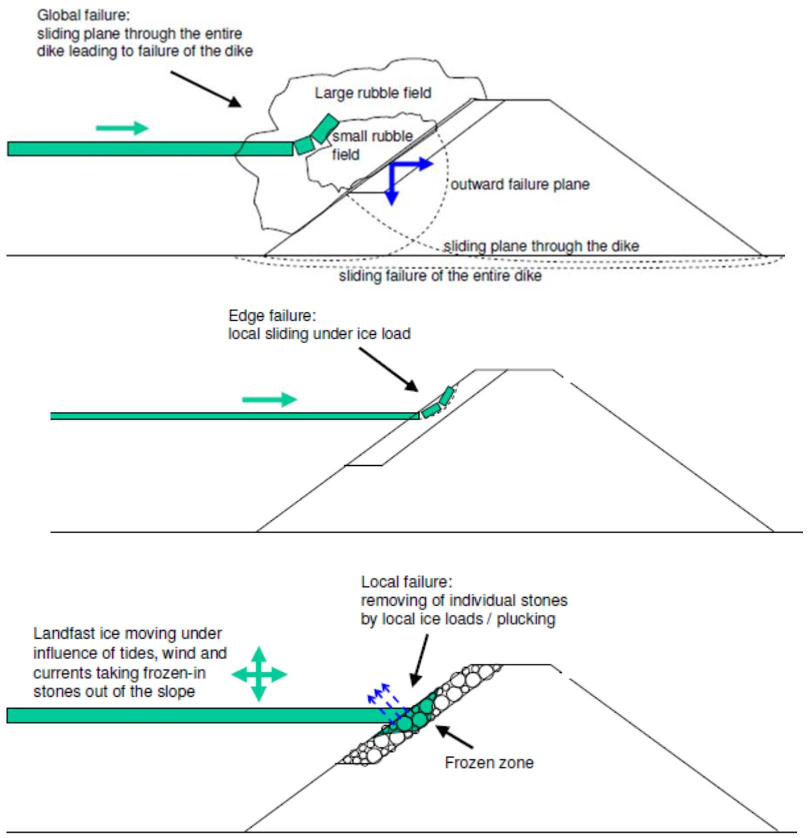

Figure 5. Damage mechanisms due to ice load: A) Global failure (top); B) Edge failure (middle); C) Local failure (bottom)

Apart from the analysis described above, FEM calculations were performed in order to determine the concrete tensile strength required to withstand the force of the ice sheet pushing with its maximum crushing strength on one leg of an Xbloc which is conservatively assumed to be fixated fully by interlocking with the surrounding blocks. On the basis of these calculations, the concrete tensile strength was increased from 2.5MPa to 3.8MPa.

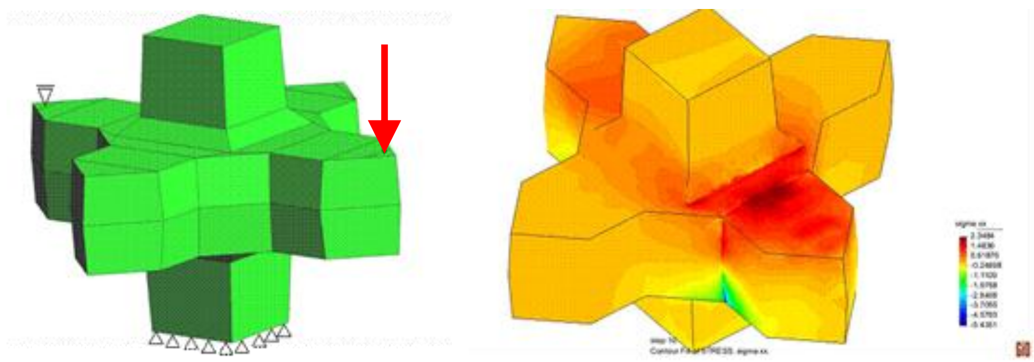

Figure 6. FEM Calculations to determine required concrete strength to withstand ice force on a unit

CONSTRUCTION

Two construction aspects where the Swinoujscie project differs from previous Xbloc breakwater projects are 1) the block production in cold winter conditions and 2) the underwater unit placement with very poor visibility aided by the Echoscope®.

Xbloc Production in Winter Conditions

Given the tight schedule of the project, Xbloc production continued during the winter months when the temperatures dropped below 0°C. The concrete mix design was adjusted by pre-heating the mixing water and the aggregates. The moulds were insulated with polystyrene (Figure 7) and the blocks were de-moulded after 2 or sometimes 3 days instead of after 1 day in order to obtain sufficient concrete strength and an acceptable temperature gradient between the fresh concrete surface and the ambient temperature.

Figure 7. Xbloc moulds with polystyrene insulation for winter production

Xbloc Placement with Echoscope®

The seawater visibility around the project site is very low and as a consequence it is difficult for divers to see the blocks during placement of the armour layer and to give instructions to the crane operator. In order to enhance the placement quality and speed, the Xbloc placement was guided with the Echoscope®.

The echoscope is a high definition sonar device which, in combination with fast processing software, provides the crane operator a real time image of the block which is being placed, the surrounding blocks and the under layer. The sonar is attached to the boom via a frame (Figure 8) and transmits images to the operator as soon as the sonar is submerged.

Figure 8. Excavator with Echoscope frame attached to the boom (left); example of Echoscope image (right)

The experiences with the echoscope during the Swinoujscie project were very positive. The sonar enabled the crane operators to manoeuvre the Xblocs in a good interlocking position and to see the chain during the releasing of the block. This was especially useful during the placement of the units in the first 2 rows as it reduced the number of blocks that rolled away due to the chain getting stuck during the releasing of the block. The placement rates that were achieved in the Swinoujscie project were in the order of 2-8 blocks per hour for the blocks in the 1st and 2nd row and in the order of 12-16 blocks per hour for the blocks in the remaining rows.

The echoscope basically functions as a camera in water where a normal video camera would not work due to the poor visibility. An important advantage of an acoustic system like the echoscope, compared to systems which are based on recording the blocks motions and rotations with an attached sensor, is that the acoustic system gives a real image of the blocks around the unit which is being placed. Systems which are based on the motion and rotation recording provide an image that is based on a model which contains information about the position and orientation of the other blocks at the moment that the sensor was disconnected, but block movements after the removal of the sensor are not included in this model. Therefore there can be a significant difference between the image and the real situation.

Xbloc Survey with Echoscope®

As a result of the poor visibility below the water surface, it was difficult to carry out a dive survey to inspect completed breakwater sections. With limited visibility, a diver can only see a part of an armour unit from a very close distance and as a consequence it is difficult to get an understanding of the orientation of an armour unit in relation to the surrounding blocks and to inspect the interlocking between the units. Therefore the surveys of the placed Xblocs were done with the echoscope. For these surveys, the echoscope was attached to a survey boat which sailed slowly along the breakwater. As the boat was equipped with DGPS, it was possible to store the echoscope measurements in a 3D model.

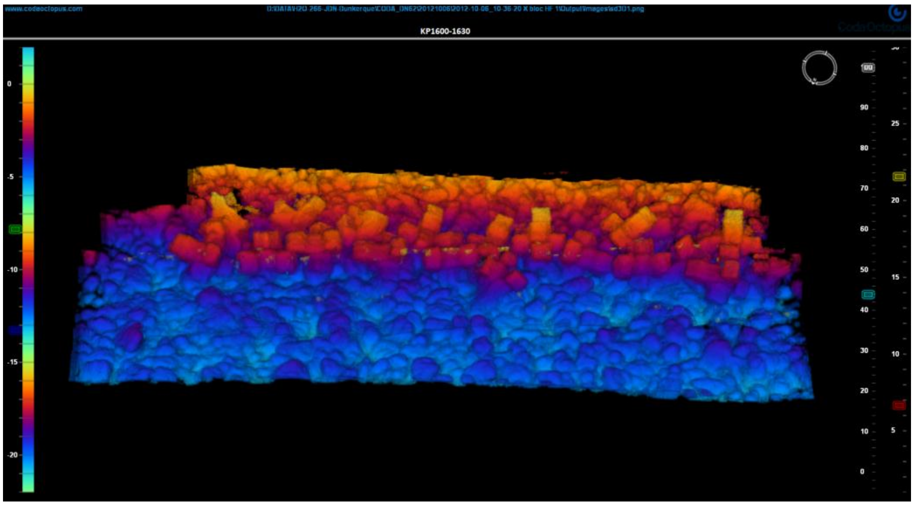

Figure 9. Example of echoscope survey after placement of the 2nd row of blocks.

It was found that the echoscope survey gives clear images to check the placement of the blocks after the placement of the 2nd row of units (Figure 9). the units are clearly distinguishable and it is possible to identify block that rolled into a cavity in the under layer rock bed. With regard to the survey after placement of the blocks up to the water line, it was found that close to the water line, the echoscope images show disturbance of reflections by the water surface. It was also found that the survey images were quite difficult to read (Figure 10). Due to the large number of blocks shown on an image it was difficult to identify the individual blocks in such detail that the interlocking between all the blocks could be checked. The survey results were therefore used to identify large voids in the armour layer and locations where a block protrudes out of the armour layer. Divers then inspected these areas in the armour layer to see if a rectification was required or if the interlocking between the blocks was sufficient.

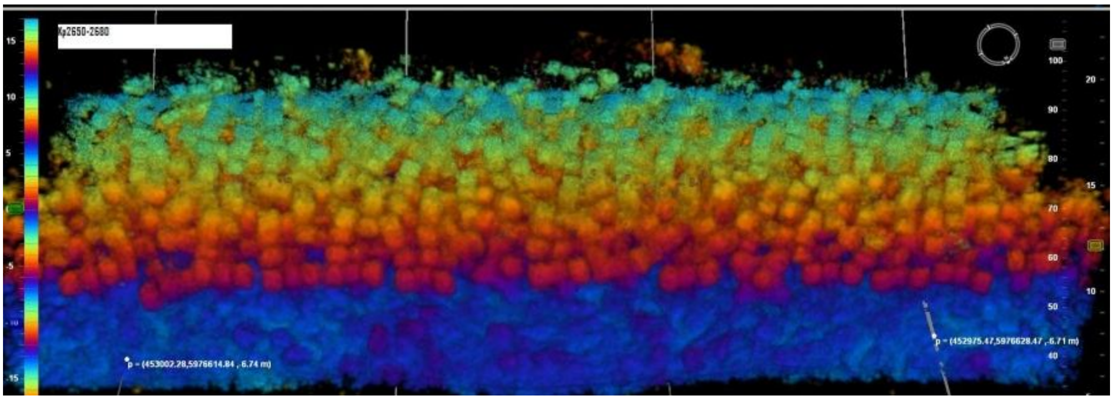

Figure 10. Example of echoscope survey after placement up to the water line.

Despite the fact that an echoscope survey does not allow for an inspection that is as detailed as a diver inspection in good visibility conditions, DMC considers the survey method to be one of the best possible options in poor visibility conditions such as in Swinoujscie.

CONCLUSION

For the design of the Swinoujscie breakwater, a significant design optimisation was made by applying single layer Xblocs which resulted in a significant reduction of the number of armour units and the time required for casting and placing the blocks.

After an assessment of the expected ice conditions and the possible breakwater damage due to ice loads, it was concluded that Xbloc is a technically good armouring solution for the Swinoujscie project location.

Because of the cold winter conditions during the block production, Xblocs were produced with an adjusted mix design, insulated moulds and an increased curing time.

Because of the bad under water visibility during the placement of the blocks, the Xblocs were placed with an excavator equipped with the echoscope to improve the quality and speed of unit placement.

The echoscope was also used for the surveying of completed breakwater sections.

The Swinoujscie breakwater was constructed by the JV in a very tight project schedule and completed successfully in December 2012.

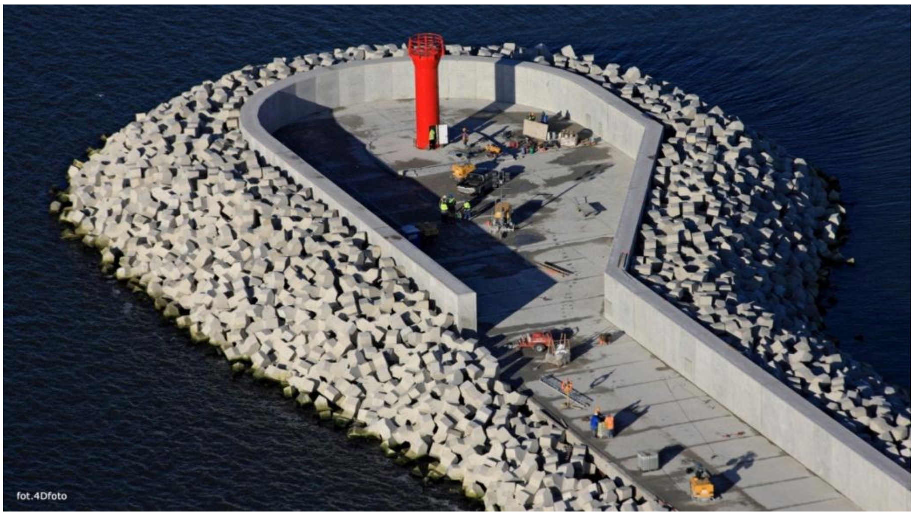

Figure 10. Breakwater successfully completed

ACKNOWLEDGMENTS

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