RECONSTRUCTION OF THE PORT ORIEL BREAKWATER FIRST XBLOC APPLICATION IN EUROPE

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From 2001 to 2003 Delta Marine Consultants developed a new breakwater armour unit, named Xbloc®. Extensive testing and studies were carried out, and the new armour unit has proved to be reliable and easy to use. Port Oriel, an existing fishing port on the East coast of Ireland has been rehabilitated in order to upgrade the port. For the protection of the breakwater Xbloc armour units were used, which is the first Xbloc application in Europe. The design was prepared by RPS Kirk McClure Morton in Belfast and the construction of the project was awarded to Lagan Construction. This paper describes the project, the design and the construction works of the Port Oriel reconstruction. The works started in May 2005, and the breakwater was completed in December 2006.

INTRODUCTION

Port Oriel, County of Louth, is the existing fishing harbour of Clogherhead which is located on the East coast of Ireland approximately 50 km north of Dublin (see Figure 1). The port was constructed in 1885 and consists of a small inland harbour basin and a pier. Due to the bad condition of the port and the limited mooring capacity for fishing boats, the council of Louth decided to upgrade the port.

Figure 1: Location of Port Oriel

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The aim of the project was to extend and widen the existing pier and construct 188 meters of quay wall on the inner side to provide safe mooring for the fishing vessels (see Figure 2). The exposed side of the pier was to be protected by a breakwater consisting of an armour layer of concrete armour units. Louth county council appointed RPS Kirk McClure Morton as consultant for the job, and after the tender stage Charles Brand Ltd (currently known as Lagan Construction Ltd) was awarded the construction of the project in August 2004.

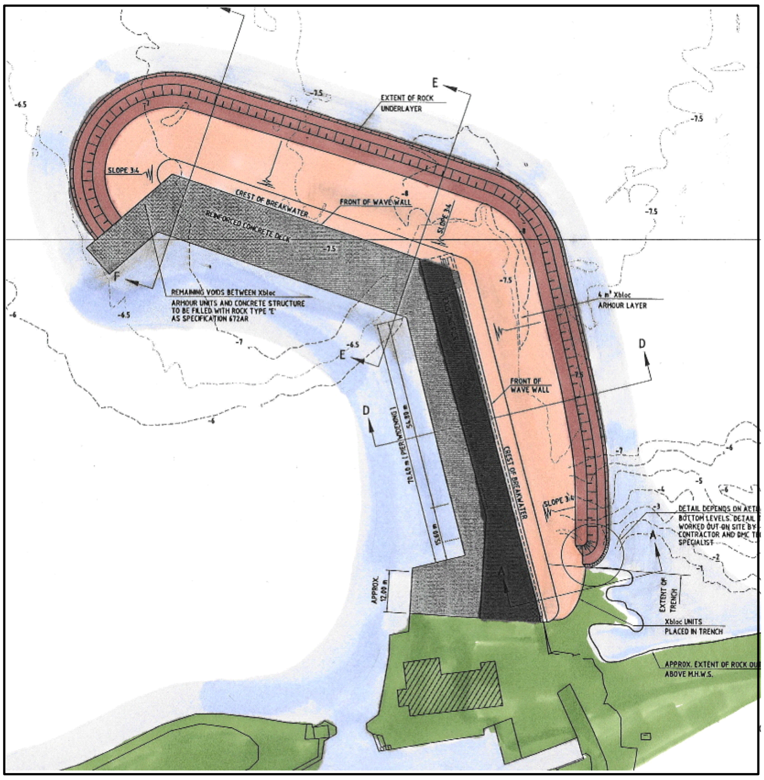

Figure 2: Overview of the Port Oriel breakwater

The original design of the armour layer consisted of 3.9 m3 Core-loc® armour units. After being awarded the construction works, the project manager for the job was looking for a more economic and easier to place armour unit and contacted Delta Marine Consultants [DMC] with the request to prepare an alternative Xbloc design for the armour layer of the Port Oriel Breakwater. Due to the Xbloc design a significant cost saving could be obtained and due to the more symmetrical shape of the Xbloc, easier placement was possible.

In consultation with Kirk McClure Morton, DMC prepared an alternative design for the armour layer consisting of 4.0 m3 Xbloc units. Casting of the Xblocs started in July 2005, and the breakwater was completed in December 2006. Port Oriel is the first application of the Xbloc armour unit in Europe. During the project DMC provided technical assistance to the contractor while casting and placing of the Xbloc armour units.

XBLOC ARMOUR UNIT

Based on several decades of breakwater experience, DMC decided in 2001 to develop a new breakwater armour unit, which would build on the strengths of existing armour units, but exclude their weaknesses (Reedijk et al. 2003). For more than two years extensive studies and model tests were carried out, including shape development, 2D and 3D physical model tests, finite element stress calculations, prototype drop tests, production and handling studies, and placement studies.

The new armour unit, named the Xbloc® is a simple, reliable and robust breakwater armour unit, which is easy to cast and easy to place. The 2D and 3D model tests were carried out at a wide range of water depths, wave heights and wave periods, which proved the great hydraulic stability of the Xbloc. For preliminary design purposes a KD (Hudson Stability Coefficient) of 16 can be used for the trunk, and a KD of 13 for the head (Bakker et al 2005). Figure 3 shows the dimensions of the Xbloc.

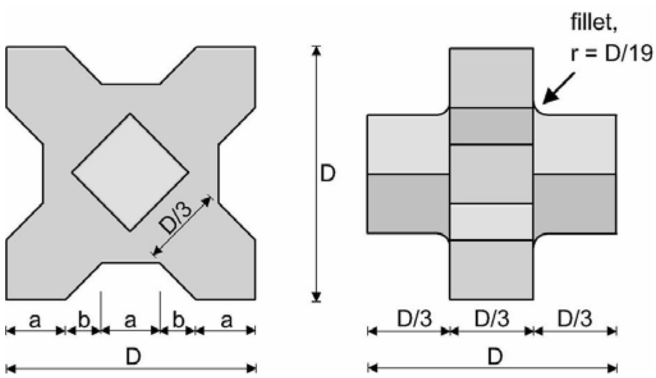

Figure 3: Dimensions of the Xbloc

DESIGN

The nearshore design wave climate was established by Kirk McClure Morton in 2004, using numerical model analysis which included shoaling, wave breaking and refraction. The resulting 1:50 years nearshore design wave height was Hs = 5.7 m, with corresponding peak periods up to 10.7 seconds. The governing wave direction was found to be 90 degrees North. Based on the design wave height of 5.7 m an Xbloc size of 4.0 m3 was determined for the trunk of the breakwater. Generally, with a 4.0 m3 Xbloc on the trunk, a corresponding Xbloc size of 5.0 m3 would be applicable for the head. However, since the design wave height approaches the head almost parallel to the trunk, it was determined that a 4.0 m3 Xbloc could be applied on the head as well.

The 4.0 m3 Xblocs are placed on a slope of 3V : 4H. Underneath the Xblocs a filter layer of 600 – 1300 kg rock is placed; the filter layer itself lies on a core of quarry run. Figure 4 shows a typical cross-section of the design. The armour layer is supported by a toe of 1 to 3 ton rock. The breakwater is built up against the existing and to be constructed wave wall. The length of the total breakwater is approximately 210 m.

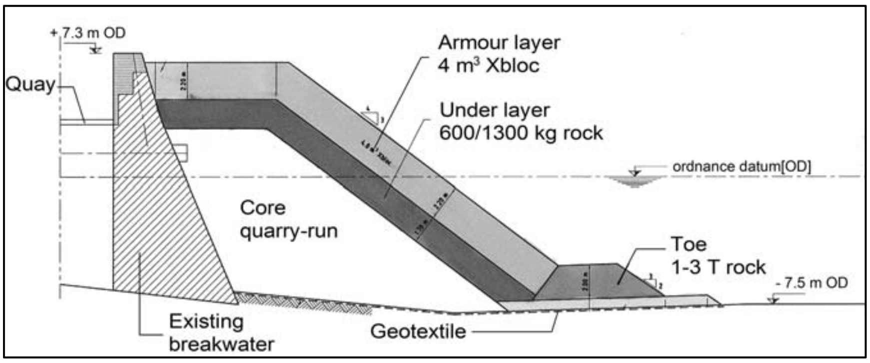

Figure 4: Typical cross-section Port Oriel Breakwater

TECHNICAL ASSISTANCE FROM DMC

During the project technical assistance was provided by DMC. At the start of the project 4.0 m3 Xbloc mould drawings were supplied by DMC to the contractor, who had sixteen Xbloc moulds fabricated by Javlin Formwork Ltd. Next detailed Xbloc specifications were provided to the contractor, which included amongst others advice on the concrete mix.

When the first Xblocs were being cast, a DMC specialist visited the site to assist and advise the contractor to optimize the casting process. Based on the bathymetry and the detailed design drawings, DMC prepared Xbloc placement drawings. The placement drawings provide the coordinates of each Xbloc and give the contractor a good indication of the total Xblocs to be used. Before the actual start of placement, trial placement was performed on the head of the breakwater, with assistance of a DMC specialist. During the remainder of the placement of the Xblocs, DMC visited the site three times more to advise on the placement and the packing density of the Xbloc armour layer.

FABRICATION OF THE XBLOCS

Concrete

The concrete mix was determined based on the Xbloc specifications. The following durability aspects were covered:

- Resistance to seawater (sulphate resistant and erosion)
- Resistance to alkali aggregate reaction

The cement quality had to be either Ordinary Portland cement with a C3A content ≤ 8% or Portland-fly ash cement with a C3A content ≤ 8% or Sulfate-resisting Portland cement. Furthermore, the minimum concrete density was set at 2375 kg/m3 and the nominal 28 days compressive strength at 30 MPA.

Moulds

Sixteen steel moulds were fabricated and placed at the casting yard on site. The Xbloc moulds were of the vertical type (see Figure 5). This type of moulds consists of two steel forms that slide over steel rails when being opened or closed. The concrete is poured in through the two large fill openings on the top of the two legs of the X. Vibrating is done through these fill openings and through hatches on the noses. The moulds were placed on a concrete floor. However, due to the rail system, the moulds could have been placed directly on the soil as well.

Figure 5: Xbloc moulds, 4 m3 size.

Casting

The sixteen moulds were placed in two rows of eight, with an elevated road in between. As a result the concrete, which was supplied by concrete mixer trucks, could be poured directly from the truck into the fill openings, which proved to be very efficient (see Figure 6). Before the striking of the mould the concrete had to reach a compressive strength of 7 MPA. With the used concrete mix, an average outside temperature of 15 degrees Celsius and a wet climate, this resulted in a one-day-casting cycle: from each mould one Xbloc unit per day was fabricated. After striking of the mould, the Xblocs were sprayed with curing compound.

Figure 6: casting and curing of Xbloc armour units

STORAGE AND HANDLING

The Port Oriel harbour is surrounded with small hills, and together with a limited storage capacity on the quays of the harbour, it was required to store the Xbloc units on various locations in and around the harbour. To limit the total storage the Xblocs were stored two high (see Figure 7).

Figure 7: Storage of Xbloc armour units

Due to the spread out storage areas it wasn't feasible to handle and store the Xblocs with a tower crane and consequently the Xblocs were transported from the casting yard to the storage areas with a 10 ton wheel loader. The contractor manufactured a special device on the fork, which enabled them to handle and place the Xblocs quite easily (see Figure 8).

Figure 8: Handling of Xbloc armour units

PLACEMENT OF THE XBLOCS

The structure of the Xbloc armour can be described as a semi brick bond pattern (Muttray et al. 2005). A row of Xbloc units is placed at a horizontal distance of 1.3 * D (where D is the height of the unit). The next row is placed on top of this row, and each unit is lowered in between two lower units. The unit itself does not require any individual orientation and can be placed randomly. Figure 9 shows placement tests which give a good indication of the Xbloc placement concept.

Figure 9: Xbloc placement pattern (placement of scale units)

At Port Oriel two placement processes could be distinguished: underwater and above water placement of the Xblocs. The underwater placement was carried out with a crawler crane (see Figure 10a). The position of the Xbloc units was checked after placement using experienced divers; during placement operations they were kept at a safe distance. The average under water placement rate was 4 to 6 units per hour. Above water placement was carried out with an excavator (see Figure 10b). Due to the easy placement of the Xblocs, high placement rates were achieved: approximately 10 to 15 units per hour were placed above water.

Figure 10: Xbloc placement a) by crawler crane and b) by excavator

In total approximately 1450 Xbloc units were placed on the Port Oriel breakwater. The average packing density at the breakwater trunk was 99% of the prescribed packing density, which is within the allowed tolerances according to the Xbloc specifications.

Figure 11: Impression of breakwater slope covered with Xblocs

ACKNOWLEDGMENTS

At the end of the Port Oriel project, DMC looks back on a successful first Xbloc application in Europe. DMC would like to thank Lagan Construction and RPS Kirk McClure Morton for the efficient cooperation during the execution of the project.

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