

Frequently Asked Questions about the Xbloc® unit [FAQ]

GENERAL

What is the Xbloc® ?

The Xbloc® is a pre-cast concrete structural element used in the construction of certain types of marine structures. It is an innovative interlocking unit, made from non-reinforced concrete, designed to protect rubble mound breakwaters and shores over the long term and in extreme conditions. The unit is placed in a single layer as the outer layer [i.e. armour] of the structure.

What is a rubble mound breakwater?

A breakwater is a structure made of natural stone or concrete elements which gives shelter to a shoreline, harbour, anchorage, or basin from the direct impact of incoming waves. A rubble mound breakwater normally consists of a core of small size rock covered with large [heavy] rocks or concrete elements. This outer layer is called the armour layer. An under-layer of rock is provided between the core and the armour layer.

How does an armour layer of Xbloc® units protect the breakwater?

The Xbloc® armour derives its hydraulic stability from its own weight and by interlocking with surrounding units. Due to the highly porous armour layer constructed with Xbloc® units the energy of the incoming waves will be absorbed. The Xbloc® armour layer is therefore able to protect the rock in the under layer from erosion due to waves.

What determines the choice between rock and concrete as armour layer?

For design wave heights below 3 m [significant wave height], rock is often economically viable for use as armour layer. For design wave heights above 4 m extremely large rock sizes are required which are difficult to obtain, handle and place. Limited availability of such material leads to greater expense. In areas where good quality rock is difficult to obtain concrete armour may also be preferred for smaller wave heights.

How big is an Xbloc® unit?

The size of an Xbloc® unit depends on the design wave height expected at the breakwater location. The Xbloc® unit has been developed for use in sizes varying from 0.75 m³ up to 20 m³. Using the design table, provided in the Xbloc® folder or at the internet site, the appropriate unit size can be determined for concept designs. See also the guidelines for Xbloc concept designs.

What does interlocking mean?

Interlocking is the mechanism by which armour units can hook into each other due to the shape of the unit. This increases the resistance against wave attack. The advantage of units shaped to allow a high degree of interlock over other shapes where less interlock is possible, is that smaller and lighter elements can be placed. This reduces the cost of a structure as lighter equipment is required for handling and placement and less concrete is required for the armour layer.

On what type of construction are the Xbloc® units applicable?

The Xbloc® units are applicable for all marine structures in which a stable armour layer is required. Examples are breakwaters, groins, shore protection and harbour entrances. The Xbloc® units can be applied for new construction works as well as for rehabilitation of existing structures.

Why are Xbloc® units placed as a single layer?

The armour layer of a breakwater is relatively expensive as it either consists of large size rocks or concrete units. It is therefore economical to reduce the thickness of the armour layer by the application of a single armour layer. In the past concrete armour units were placed in double layers as this was the common practice with rock armour layers. More recent concrete armour units are designed to be placed in a single layer. It was found that a single layer of Xbloc® armour units will result in a highly stable structure. Besides a major saving in the total concrete volume the construction time is also significantly reduced when compared to construction with a double layer of concrete armour units.

Double layer concrete armour units are more susceptible to rocking as the second layer does interlock effectively.

Can the Xbloc® system be used by all contractors?

The Xbloc® system has been developed for application by all qualified marine contractors. Normal pre-qualification of contractors is all that is necessary.

What are the advantages of the Xbloc® compared with other units?

The most obvious advantage of the Xbloc® unit is the cost benefit of the unit. Compared to other single layer units, cost savings in the range of 15 % may be anticipated due to the low concrete usage of the Xbloc® unit. Compared to double layer elements the cost savings are much larger. Additional savings are achieved as less units are placed. Furthermore the unit is easier to place than other single layer interlocking units and this results in decreased construction time. Another major advantage over other units is the large hydraulic stability [high interlocking] combined with a highly robust shape.

Does the Xbloc® unit have disadvantages?

Compared to other armour units, the Xbloc® has no disadvantages. The Xbloc® is designed as a balance between good hydraulic stability and still remains a strong and robust unit. If for instance the interlocking were to be increased by making the unit more slender the risk of unit breakage would increase. With all interlocking units concrete quality needs to be well assured as tensile stresses do occur.

Xbloc® is most effective on relatively steep slopes as gravity enhances interlocking. Therefore Xbloc® is less effective on flat slopes and berms.

How can we get an Xbloc® design?

Delta Marine Consultants may be directly contacted with a request to make a concept design, without any obligations. A further option is to carry out your own concept design, using the Xbloc® design tables. This design can subsequently be checked by DMC, again

without any obligation on your part. DMC has extensive expertise in the field of breakwaters and shore protection, and would be pleased to assist at the detailed design phase of the project. At this stage confirmative model tests should be included for which model Xbloc[®] armour units can be hired from DMC. For application of the Xbloc[®] the detailed design should be checked by DMC.

ECONOMICS & FINANCE

What are the cost savings using Xbloc® units?

Compared to other single layer units cost savings can readily amount to approximately 15 % due to the lower quantity of concrete demanded by Xbloc® armour units. Compared to double layer units the cost savings are much larger. Additional savings are achieved as fewer units are required. As unit orientation is not prescribed the unit is easier to place than other single layer interlocking units and this results in decreased construction time.

What are the costs of the armour layer in relation to the overall costs of the structure?

In general the cost of a breakwater depends on its size. The costs of the armour layer can amount to 30 % of the cost of the complete structure, depending on the water depth. Furthermore a breakwater built in an area with a rough wave climate and a high extreme design wave requires a heavier armour layer than a more sheltered location. As larger armour units have a larger concrete volume this has an influence on the costs of the armour layer and the complete structure.

What is the lifetime of a structure with Xbloc® units?

The lifetime of a structure containing Xbloc® units is determined by the relationship between the design conditions and the chosen unit size. In many cases armour units are designed to withstand extreme storm conditions that will occur only once in 100 years time span. A unit size is chosen such that the Xbloc® structure will withstand these conditions without any damage. Concrete durability is the other factor affecting the lifetime and this is a function of the concrete mix design and workmanship.

Does a structure with Xbloc® armour units require maintenance?

A structure containing Xbloc® armour units is designed to incur no damage during the most extreme event expected during its life-time. Therefore no maintenance of an Xbloc® breakwater should be required provided that the design has been based on correct input data and it is constructed according to the Xbloc® specifications.

What is the amount of the royalty fee that will be charged?

Please contact Delta Marine Consultants who will be pleased to provide a quotation of royalty fees for your specific project.

What does Delta Marine Consultants offer for this royalty fee?

The fee provides for the assistance of DMC during the most important phases of the project. This includes a check of the Xbloc® design if made by others, together with assistance during physical model testing. Furthermore on-site assistance during unit casting and placement will be provided along with technical specifications, formwork drawings and a placement plan.

DMC has already invested heavily in the research and development of the Xbloc® armour unit. Additional research is ongoing and will continue in future to expand the range of applications of Xbloc® armour units.

Why should we pay royalties for the use of a patented unit if there are also armour units available for which the patent has expired?

The cost saving associated with use of the patented Xbloc[®] may be expected to exceed by far the royalties paid for the use of the Xbloc[®] system. Thus, even if a non-patented armour unit is chosen, the application of the Xbloc[®] unit should still be economically viable. In addition the use of all armour units may necessitate assistance from specialists during the design, model testing, production and placement stages. This assistance is included in the Xbloc[®] royalty fee. Considering patent free units it should be noted that copyright and trademark laws are applicable.

HYDRAULIC STABILITY

What is 'hydraulic stability' of a breakwater?

Hydraulic stability is the resistance of the breakwater in general and of the armour layer in particular against the forces generated by incoming waves.

How has the hydraulic stability of the Xbloc been determined?

The hydraulic stability of the Xbloc® has been determined by means of small scale hydraulic model tests. Model tests have been carried out at laboratories all over the world.

How does the hydraulic stability of the Xbloc® compare to other units?

From the first 2D tests at Delft Hydraulics it was found that the hydraulic stability is at least comparable with the hydraulic stability of other single layer armour units. The Hudson equation [$K_d = 16$] or the Van der Meer's equation [stability number = 2.8] can be used for preliminary design, based on a slope angle of 3:4. In further 2D model testing even better stability results were obtained, as a result of an improved unit placement method. This results in additional safety of the design.

What is the safety factor of the Xbloc® unit?

The design values stated above are based on a safety factor of 1.25. This means that a design wave could be exceeded by 25% before the first unit extractions would occur. The safety on unit weight is therefore $1.95 [(1.25)^3]$.

How are such parameters accounted for in the stability assessment?

During hydraulic model tests, the effects of different wave steepness were analysed. Moreover the crest height was varied and deepwater and shallow water waves were analysed. The tests indicate that the governing factor for the stability of the Xbloc® is the wave height and not the wave steepness or the wave period.

On what slope angles can the Xbloc® be laid?

The Xbloc® has been tested on slope angles of 3 [V]: 4 [H] and 1 [V]: 1.5 [H], as such slopes are commonly used for single layer armour units. Also tests have been carried out for a slope of 1 [V] : 2 [H], as such a slope may be required in severe seismic areas for geotechnical reasons. Xbloc® has been applied on slopes of 3:4 and 1:2. Note that for slopes flatter than 3:4 no reduction in weight is advised. For Xbloc® application at different slope angles the stability should be investigated in the model tests and larger unit sizes may be required. See also the Guidelines for Xbloc Concept Designs.

What is the influence of wave period on the stability?

Tests have been performed with various wave heights and various wave periods. The wave steepness was varied between 2% and 6%. For all values of wave steepness the hydraulic stability is excellent.

What is the influence of breaking and non-breaking waves on stability?

Tests have been performed with both breaking and non-breaking wave conditions. No significant influence of either breaking or non-breaking waves on the hydraulic stability was observed.

What is the influence of a steep foreshore on the stability?

Based on experience with other armour units it is known that the effect of a steep foreshore may be expected to reduce the stability of the armour layer. Therefore where the foreshore is steeper than 1:30 the armour mass in conceptual design should be increased. See also the Guidelines for Xbloc Concept Designs.

Are larger units required for the roundhead of a breakwater?

In common with other single layer armour units the roundhead may normally be expected to be constructed of armour units with a mass that is about 25% heavier than the units at the trunk. The slope angle of the roundhead may be kept equal to the slope angle of the trunk.

Are model tests always required?

In general model tests are an essential part of the design scope of breakwaters. This is considered to be best practice.

Where can we get model units for model testing?

Xbloc[®] armour units of various sizes can be hired through Delta Marine Consultants. DMC will also provide instructions on placement of the units.

How does self-repairing work?

A self-healing process can take place when an Xbloc[®] unit is taken out of the slope by wave action during an extreme overload situation [$> 125\%$ of design wave conditions]. The result would be that under wave attack one or two Xbloc[®] above the hole so caused would settle slightly towards the hole and would automatically interlock with its neighbouring units. This would partly re-establish the stability of the armour layer. Due to such rearrangement of the armour units the slope would be able to withstand such conditions and probably even more extreme wave conditions before failure of the armour layer would occur.

When do the armour units start to 'rock'?

Some rocking of model armour units may be observed during physical model testing. When model tests are repeated rocking generally decreases as interlocking increases due to better packing. In extreme wave conditions still some rocking may be observed.

What is the effect of a rocking unit on a slope?

Severe rocking of armour units will cause high forces in the armour units. Under wave conditions that may typically be expected during the lifetime of the structure limited rocking of some units may be expected. Furthermore, from extensive calculations and prototype drop tests it was found in contrast with some other armour units, that the

Xbloc[®] unit can deal with forces related to limited rocking. Therefore rocking of a few units is not regarded to be a serious threat for a structure built using Xbloc[®] armour.

How much overtopping occurs over an Xbloc[®] armoured breakwater compared to other units?

Results of the CLASH tests indicated that the overtopping of a Xbloc[®] armour layer is approximately the same as it would be with other single layer armour units.

What is the influence of oblique wave attack on the stability of the armour units?

In the 3D tests it was found that the stability of the armour layer increases for oblique wave attack. The number of oblique tests undertaken to date is insufficient to enable determination of a reduction coefficient for design purposes.

What is the size of the under layer between the units and the core?

The size of the under layer depends on the size of the units. In the design table the required under layer in a standard rock grading is displayed for each Xbloc[®] unit size.

What kind of supporting toe does an armour layer of Xbloc[®] units require?

A stable toe solution is made with the Xbase[®] toe unit with a rock berm. Read more about Xbase[®] at this site.

STRUCTURAL INTEGRITY

What is meant by structural integrity?

Structural integrity is the robustness or strength of a single unit: the resistance of an armour unit against forces due to handling, placement and movement under extreme wave attack [rocking].

How has the structural integrity of the Xbloc been determined?

The structural integrity of the Xbloc[®] has been determined by Finite Element [FE] calculations. With the aid of FE calculations using standard load cases the tensile stresses in the Xbloc[®] unit and other single layer armour units were determined. Furthermore prototype drop tests have been performed to check the validity of the calculations.

How does the strength of the Xbloc[®] unit compare to other units?

From both Finite Element calculations as well as prototype drop tests it can be concluded that the maximum tensile stresses in the Xbloc[®] unit are certainly no greater than the tensile stresses in other single layer units. Due to its shape the Xbloc[®] is a robust unit. This requires the use of standard non-reinforced concrete with a minimum concrete tensile strength of only 2.5 N/mm². Other modern single layer armour units require concrete with a higher minimum tensile strength.

Why is this strength so important for a unit?

During handling and placement the unit must be strong enough to cope with the stresses imposed. Once placed on the breakwater an armour unit is subject to wave forces which can be extremely high during storms. Extreme wave action can cause small movements [i.e. rocking] of units. In the past this caused failure of other proprietary armour units and subsequent failure of the whole breakwater. An armour unit should therefore be strong enough to resist all loads that may be expected during the lifetime of the structure.

What are the weak spots of the unit considering breakage of the unit?

Following from the finite element calculations for certain standard loads it was found that the highest tensile stresses in the concrete occur at the transition between the X-shaped base and the nose. In order to decrease the tensile forces a chamfer or fillet has been introduced between the base and the nose. The prototype drop tests were however performed with units where no chamfer or fillet had been incorporated and even without the improvement the strength of the unit was excellent.

What kind of damage does occur during droptests?

In the tests it was found that the sharp edges of the concrete will crush, leading to a negligible decrease of the unit mass. At large fall heights on to a rigid concrete base a nose or a leg broke off, depending on the particular orientation of the drop. Stresses inflicting this kind of damage are not expected to occur during the life-time of an Xbloc[®].

Is salty water a threat to the Xbloc® concrete?

Saltwater penetration is a threat to reinforced concrete, as the steel will corrode easier in a saline environment. The Xbloc® is made of non-reinforced concrete, which performs very well in a marine environment provided that other properties (minimum cement content; water/cement ratio) comply with normal code requirements. There are various examples where non-reinforced concrete has been made using seawater that are known to be very durable.

Does the Xbloc® consist of reinforced concrete?

The Xbloc® consists of non-reinforced concrete, similar to other single layer armour units.

What grade of concrete should used?

As the Xbloc® has a robust shape, a standard C25/30 (Eurocode) concrete quality with a minimum tensile strength of 2.5 MPa (tensile splitting strength) at 28 days can be used.

Can heavy aggregates be used in the concrete?

Use of heavy aggregates will increase the specific weight of the concrete which means that smaller units can be used. However this is only economical if the aggregates are readily available as hydraulic stability of the element is not related to unit weight only.

What is the risk of cracking due to heat development during hydration?

Calculations have been made with a Finite Element Model which simulates concrete curing. These calculations have been calibrated using measurements taken during curing of a 3 m³ unit. The calculations show that hydration cracking does not occur. Calculations have been carried out for units up to 20 m³. For very large units in adverse environmental conditions Delta Marine Consultants can perform numerical analysis to check whether special measures are required to prevent hydration cracking.

Is it possible to use concrete with a lower quality, since the Xbloc® is a structurally strong unit?

The use of a lower concrete quality is not recommended as the tensile strength is reduced. Neither is a higher quality concrete recommended, since this material may also display more brittle behaviour.

PRODUCTION AND PLACEMENT

Which parties have been involved in the development of the shape of the mould?

The mould has been developed utilising expertise of concrete specialists as well as mould specialists. Based on their advice different types of Xbloc[®] moulds have been developed. The choice of a particular mould option can be made by the contractor depending on his preferences. The four Xbloc[®] prototypes, each 4 m³ in size, were cast using a horizontal mould. With this type of mould, the upper nose of the Xbloc[®] is cast on top of the X approximately one hour after the rest is cast. The prototype drop tests indicated that this had no affect whatsoever on the strength of that particular nose. In a later stage in the Xbloc[®] development vertical formwork was constructed and used for Xbloc[®] unit production.

How can we get the Xbloc[®] mould for our preferred sizes?

Depending on the required Xbloc[®] unit size, ready-for-use Xbloc[®] moulds may be available for the contractor. Please contact Delta Marine Consultants to check mould availability. If no existing moulds are available, steel moulds can be ordered through DMC. Alternatively it would be possible to have the moulds manufactured locally using the mould drawings provided by DMC.

How do you compact the concrete?

The concrete may be compacted using vibration poker as used in standard concrete works. The nose of the Xbloc[®] can readily be compacted by providing an opening in the nose of the mould.

What is the production rate of the Xbloc[®]?

Under normal circumstances it should be possible to attain a 1-day production cycle. In cold weather conditions additional measures may have to be taken to achieve this production rate. Under good climatic conditions even 2 Xbloc[®] units can be made per mould per day.

After how many days can the block be transported?

The unit can be lifted as soon as a compressive strength of 15 MPa is reached. This value may be typically reached after 3 days depending on the conditions. In some projects it has been possible to move the Xbloc[®] units with a shovel equipped with a modified fork after 1 day. Feel free to contact us to provide you with indications for your specific project.

What other specifications are applicable?

The complete specifications and recommendations are included in a document that can be obtained by Delta Marine Consultants.

What are the requirements regarding placement?

The recommended placement density depends on the size of the unit and may be found in the design table. The required placement density must lie between 98 % and 105 % of

the recommended packing density. Furthermore each Xbloc® must be secured by two other units and must be in contact with the under layer.

Are the Xbloc® units easy to place compared to other units?

Yes, this is one main advantage of the Xbloc® unit compared to other single layer units. Due to its shape the unit can readily find a stable position on the slope. In contrast to other single layer armour units no orientation of the unit is specified. This further increases the placement speed.

If Xbloc® are so easy to place, why does Delta Marine Consultants have to provide assistance?

DMC experience with Xbloc® placement is invaluable and is essential to ensure swift unit placement together with good packing density. Assistance from Delta Marine Consultants during unit placement is included in the royalty fee.

Is the assistance of divers required for placement under water?

Due to its shape the Xbloc® units are easier to place than other single layer units. This decreases the need for assistance from divers. Underwater survey equipment such as Echoscope and cameras have successfully been used.

How fast can Xbloc® be placed?

From experience with unit placement in the Xbloc® projects that have been completed and that are under construction, and in scale models (including slope construction for the model tests) it was found that the Xbloc® armour units are more straightforward and faster to place than other single layer armour units. This is due to the symmetry and the number of interlocking faces of the Xbloc® unit: the unit can easily find an interlocking position. However, the exact placement rate is depending on the project specific conditions. Placement rates of up to 40 Xblocs per hour have been achieved with an excavator placing 2 m³ Xblocs above water. Typically Xbloc® placement rates ly between 8 and 25 blocks per hour, depending on the location, above/below water and use of excavator or wire crane. Please contact us for more information.

What equipment is required for unit placement?

The units may be placed using a crane equipped with a sling, a hook or a clamp. The optimal position of the units during placement is with a leg of the unit pointing downwards, ensuring easy placement. A clamp may also be used in combination with notches in one of the legs of the unit.

How do you deal with loose Xbloc®?

Loose blocks should simply be replaced to enhance interlocking capacity.

What is meant by random unit placement? Does it mean that the units are thrown onto a slope?

Random placement means that the orientation of the units may vary. This does not mean that the units are thrown upon the slope. The units are placed individually, one by one upon a slope, just as with heavy rock and other armour units.

Do the sharp edges of the unit, suffer damage during handling and placement?

Some minor damage may occur, but this does not affect the strength or stability of the unit.

How do you realise the required packing density in practice?

When the advised horizontal distance between the units is achieved, this will result in a placement density within the required range of the specified placement density. A properly placed bottom row of units will specially contribute to achieve this density. Furthermore, in each project the placement should normally start with a trial placement of the units during which the crane driver and other supervisors will be guided by an experienced Delta Marine Consultants specialist.