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THE APPLICATION OF FLEXIBLE AND POROUS CONCRETE STRUCTURES IN TRAINING WORKS AND SCOUR PROTECTION

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1 INTRODUCTION

Concrete armour units such as Xbloc have been applied as armour layer for breakwaters and bank protections for years. These smartly shaped blocks were invented to offer efficient protection at more exposed locations by applying blocks that work together with neighbouring units to withstand high wave loads (Interlocking). Also material use was lowered since steeper slopes could be realized compared to conventional rock structures.

Xstream and Xstone can be applied in a large range of applications that are traditionally built with loose rock, pitched rock or smooth block revetments such as:

- Bed protection (e.g. offshore wind foundations)
- River training works
- Detached breakwaters
- Quay wall protection in harbours
- Revetment structures

This abstract elaborates on why flexible and porous structures made of these small-scale [0.2 – 0.6m] concrete armour units are an interesting, low CO_2 and eco-friendly alternative for bed protections and river training works.

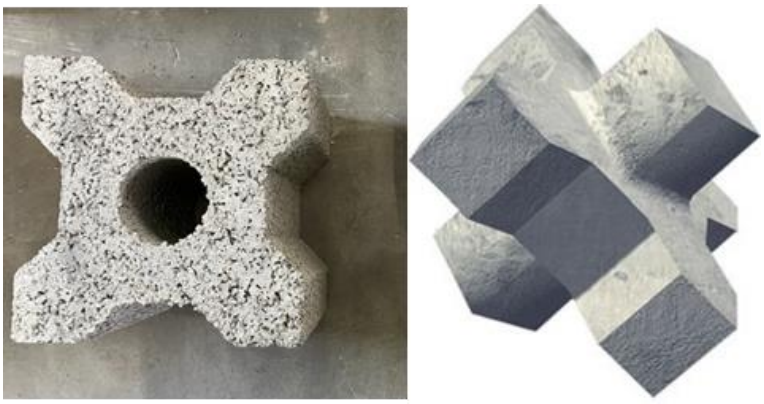

Figure 1. Xstone (left) and Xstream (right)

2 MATERIAL CONSUMPTION

Concrete armour units can be shaped in such a way that material use is minimized. Material consumption can be minimized by maximizing the porosity of the structure without loss of its hydraulic protecting function. Both Xstone and Xstream have a porosity of around 60%, whereas the porosity of loose rock is between 30 and 40%. At equal volume, Xstone and Xstream structures have half the mass compared to loose rock. Material use is also minimized by the capability of Xstone and Xstream to be constructed with a side slope of 1:1 whereas conventional rock-based structures (e.g. groynes) typically have a 1:3 slope. The combination of the high porosity and steep slopes significantly reduces the (carbon) footprint of these

structures.

In a pilot project flexible groynes made of Xstream were placed in 2019 in the river IJssel, in cooperation between Rijkswaterstaat (Ministry of public works), Bam-DMC, Deltares, Meteoor Beton and Van den Herik. The groynes were made using only Xstream blocks that are placed in bulk, directly on the river bed. The combination of the steep structure slopes and the high porosity significantly reduced the volume of material needed (-50%) as compared to a traditional groyne, resulting in reduced costs, lower CO_2 emission and shorter construction time compared to traditional solutions. The CO_2 reduction is significant (>50%) compared to traditional structures due to direct material savings, short transport distances and significant decrease in the total mass of the structure. Similar conditions are tested for Xstone, where similar performance is possible in terms of slope, porosity and applicability in hydraulic conditions (Figure 3).

Figure 2. Xstream blocks applied in flexible groynes

Figure 3. Xstone structure

3 FLEXIBILITY

Due to the fact that these structures with concrete armour units are made of only one material, they can be easily adjusted or placed elsewhere if needed due to changing climate conditions. The blocks are produced and placed in bulk and can be easily removed and reused which makes it a circular solution. No geotextiles or granular filter layers are needed. In addition, deformation by nature is no problem; the flexible nature of the structure allows deformation, climate adaptation and easy repair.

4 FLOW PATTERN GROYNE

In the pilot project in the river IJssel the flow patterns and riverbed adjustments are monitored after the construction of the flexible Xstream groyne, for a period of 4 years and surveying is still ongoing (Buschman 2019). From this study it can be concluded that the high porosity and permeability of the groyne allows water and sediment to pass through without the groyne losing its function. The flow velocity trough the groyne was measured to be 5-10% of the river flow velocity. No deep local scour hole is observed near the head of the groyne. The absence of deep local scour holes and less sedimentation in the navigation channel is explained by the high porosity of the groyne, that prevents strong concentration of currents around the tip of the structures. Although the groynes are built directly on the river bed without a filter layer (or geotextile), No significant settlement of the structure is observed.

5 ECOLOGICAL VALUE

The high porosity of concrete armour units compared to rock creates opportunities for marine life. In the pilot study in the river IJssel much more life and biodiversity was observed at the flexible groyne compared to the traditional groynes nearby. The water turbidity was much lower, which could be explained by the higher porosity that allows water to flow through (Figure 5). The large open spaces of varying size and shape attract marine life that find shelter or breeding grounds between the units. Other species benefit from the hard-substrate that the surface of the units provide and attach to the units themselves (Figure 2). The concrete blocks can be produced in different configurations in terms of mix design, which can be optimized for much higher bio-receptiveness compared to natural stone. A porous surface also provides opportunities to make the blocks more attractive for substrate.

Figure 4 – Xblocs in the North Sea with marine growth

Figure 5 – Marine life on Xstream in river

6 LOGISTICS

Xstone is produced in a dry-cast production plant which allows for very high production volumes. The blocks are easily stacked and can be handled with several types of equipment, therefore allowing for high efficiency in terms of logistics and easy placement. Xstream can be easily loaded and placed in bulk with a large range of equipment.

7 CONCLUSION

Small sized concrete armour units like Xstream and Xstone provide circular opportunities with increased biodiversity for bed protections and river training works. Material quantities can be minimized due to the interlocking capacity of the blocks and the large pore volumes between blocks. Porous structures also lead to improved biodiversity and less scour around structures due to less abrupt changes in the flow pattern. The combination of these measures results in a large MKI (Environmental Cost Indicator) and CO_2 reduction compared to conventional rock structures.

Figure 6 – Xstream groyne (left) and neighbouring traditional groyne (right)

REFERENCES

Buschman et al. (2019, 2024): Pilot flexibele kribben in de IJssel, Deltares report.