DEVELOPMENT OF INTEGRATED TIDAL POOLS FOR AN XBOCPLUS ARMOUR LAYER

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INTRODUCTION

Marine structures, revetments or breakwaters are often made out of rock and/or concrete. Smooth and slippery concrete surfaces don't suit well to all plants and animals to settle. In recent projects concrete tidal pools were placed in or near coastal structures to create microclimates that stimulate flora and fauna by its dynamic qualities which increase the local ecological value. XblocPlus, a single layer concrete armour unit placed in a uniform pattern, creates opportunities to integrate tidal pools in revetments. By combining the water-retaining function and ecological enhancement in the structure, a positive effect on biodiversity can be achieved with limited effort. In this study, research has been done into the effect of different climates on tidal pools and which block adjustments will have the most positive ecological impact per climate type. The hydraulic performance of 5 different XblocPlus units with a tidal pool (XP-Tide) is investigated.

TIDAL POOL DESIGN

Three climate types have been examined; tropical, moderate and dry climate. Examining the different climates was done by studying a variety of studies where similar research was done (Waltham (2018), Underwood (1996), Bergen (2001), Browne (2014), Burt (2019)). The results for the three different climates are summarized in table 1.

Type of climate	Size of the tidal pool	Shape and orientation	Place in tidal zone
Tropical	400x350x 200mm	Oblique shape	In the middle of the tidal zone
Moderate	Bigger is better	More complexity is better	In the middle of the tidal zone
Dry	Bigger is better	Place where shadow can emerge	Low in the tidal zone

Table 1 - Requirements tidal pools per climate type

Based on the requirements per climate, 5 different XP-Tide units are designed varying in ecological impact and effect on hydraulic performance (Figure 1):

- Type 1 has inclined walls to create as much shadow as possible for tropical and dry climates. This type has the largest tidal pool of all types.
- Type 2 has the smallest tidal pool due to the hole in the block still being present. The type has the smallest ecological impact and also the smallest negative impact on hydraulic performance due to the presence of the hole. This type is designed for moderate climates.
- Type 3 has a large complex shaped tidal pool for moderate climates.
- Type 4 has a small complex tidal pool for moderate climates and uplift reduction holes in the wings to minimize the stability impact of the tidal pool.
- Type 5 has a small complex tidal pool for moderate climates and an opening in the nose of the unit to minimize sedimentation.

Type 1 and type 3 are expected to have the largest positive ecological impact.

Figure 1 - Example of tidal pool XblocPlus units

PHYSICAL MODEL TEST

Physical model tests were done in DMC's wave flume. The hydraulic stability of the XP-Tide alternatives was tested on a 3H:4H slope. In total 10 XP-Tide units (2 units per type) were present in the model. One unit of each type was placed at the water line because the upward load (uplift) is expected to be largest at this location. The second model unit of each type was placed 2 rows below the water line near the point of maximum run-down where units are most likely extracted. Also a 0-measurement with solely XblocPlus units was performed for comparison. The breakwater is constructed as shown in figure 2.

During the test series the wave height was increased in steps of 10% up to 160% of the design wave (H_{m0}). Both waves with a wave steepness ($s_{0,p}$) of 2% and 4% were tested, because they can both cause a different failure mode to occur. The duration of the runs was specified such that each run contains approximately 1,000 waves, this is the number of waves required to get a good representation of the JONSWAP spectrum. The generation of the waves is based on a standard JONSWAP spectrum with peak enhancement factor γ=3.3. Since the force required to pull out a block is smaller for blocks higher on the slope due to reduction of the stabilizing effect of the blocks on top (Vos(2017)), two different water levels were tested to assess the effect of the relative freeboard on the hydraulic performance of the XP-Tide units. The two water levels are expressed in terms of relative freeboard:

- Normal water level - R_c/H_{m0} =1.5: Tidal pool units are located in the 9th and 11th row from the top.
- Extreme water level-R_c/H_{m0} =0.5: Tidal pool units are located in the 3rd and 5th row from the top.

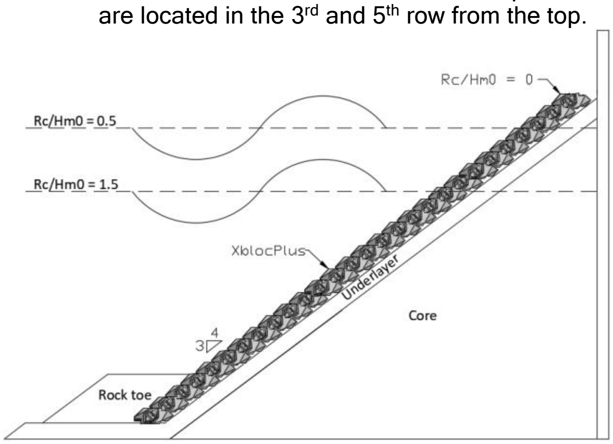

Figure 2 - Cross-section of test set up.

HYDRAULIC STABILITY

The design stability number (N_s) of XblocPlus is 2.5. It is expected that XblocPlus and XP-Tide can handle a minimum load of 125%. This results in a target stability number of 3.13.

During testing, three types of failure were looked at; displacement, rocking and uplift. During the tests, no displacement, uplift or rocking occurred during either the 0-measurement or the XP-Tide test. Based on the actual wave height and wave period at normal water level (R_c/H_{m0} = 1.5), the actual stability number and the actual wave steepness of each successfully completed run is plotted in Figure 3. XP-Tide achieves a stability of 4.14 without the blocks failing in waves with a wave steepness ($s_{0,p}$) of 2% (166% of design stability N_s). For waves with a wave steepness ($s_{0,p}$) of 4%, the XP-Tide blocks achieve a stability number of 3.92, which is 157% of the design stability N_s. Also with the extreme water level (R_c/H_{m0} = 0.5) no failure occurred in both the 0-measurement and the tests with XP-Tide. Rocking, uplift and displacement were not visible. Figure 4 shows the actual wave steepness ($s_{0,p}$) and the actual stability number plotted against each other. For waves with a wave steepness ($s_{0,p}$) of 2%, the XP-Tide blocks achieve a stability number of 3.96 and for waves with a wave steepness of 4%, the blocks achieve a stability number of 3.86 (Resp. 144% and 154% of design stability N_s).

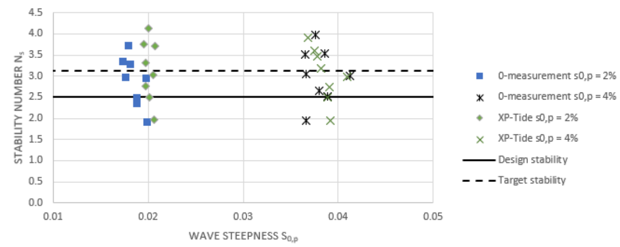

Figure 3 - Stability number plotted against wave steepness at the normative water levels (R_c/H_{m0} = 1.5).

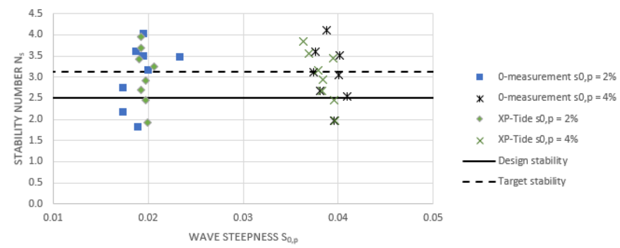

Figure 4 - Stability number plotted against wave steepness at the extreme water level (R_c/H_{m0} = 0.5).

CONCLUSION

During the test none of the five XP-Tide alternatives failed. The results of the research can be summarized as:

- Alternatives 1 and 3 have the most positive ecological impact.
- All alternatives remain stable during testing, a fraction of the XblocPlus units can be replaced by XP-Tide units without affecting the overall revetment stability. Alternatives 1 and 3 are preferred because they have the largest ecological impact.
- Adjustments as with alternative 5 turned out not to be feasible because making them turned out to be too difficult.

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