Review of proposed section on Accropode and Xbloc stability for CRESS update

DMC, 24-1-2006 (Marcus Muttray)

Critical stability coefficients for Accropodes ($H_s/\Delta D_n$ = 3.7 for start of damage and $H_s/\Delta D_n$ = 4.1 for failure) were determined by van der Meer (1988). Sogreah determined significantly lower average values ($H_s/\Delta D_n$ = 3.2 for start of damage and $H_s/\Delta D_n$ = 3.7 for failure, see Vincent et al., 1989). The results of van der Meer and Vincent are not applicable for design as:

- They are based on a limited number of 2D tests only;
- They represent an average value (and not a lower limit, which appears more reasonable for design purposes);
- They do not include any safety margins (which are essential for a proper armour layer design with single layer armour units).

Corresponding critical stability coefficients for Xbloc were determined by the DHI in 2003 ($H_s/\Delta D_n$ = 4.1 for start of damage and $H_s/\Delta D_n$ = 5.5 for failure, see Muttray et al., 2005). As for Accropode these stability numbers are not applicable for design (see above).

The definition of acceptable damage levels (either N_{od} or N_d) for single layer armour units is mainly of academic interest. Accropode and Xbloc are designed for zero damage under design conditions. Any damage under design conditions is indicating potential problems with armour unit size, armour unit placement, toe design, crest design etc. In case of damage the design shall be reviewed and re-tested. Both armour units shall be further tested for overload conditions (i.e. design wave height increased by 20%). Only minor damage (i.e. less than 3% rocking units and less than 1% displaced units within a range of $\pm H_D$ (design wave height) from design water level) is accepted for overload conditions.

Accropode and Xbloc armour shall be placed on 1:1.5 or 1:1.33 slopes. If necessary the units can be also applied on 1:2 slopes. The following stability numbers shall be used for concept design :

- Accropode: $H_s/\Delta D_n$ = 2.7 and 2.5 for trunk sections (non-breaking and breaking waves) and $H_s/\Delta D_n$ = 2.5 and 2.3 for roundhead (non-breaking and breaking waves);
- Xbloc: $H_s/\Delta D_n$ = 2.8 for trunk sections (non-breaking and breaking waves) and $H_s/\Delta D_n$ = 2.6 for roundhead (non-breaking and breaking waves).

The corresponding K_D coefficients refer to a 1:1.33 slope. The slope angle does not affect the stability of Accropode or Xbloc armour. If the Hudson formula is used for design (in conjunction with the proposed K_D coefficients) the slope shall be 1:1.33 (regardless of the actual slope!).

As the stability of Accropode and Xbloc is not affected by the slope, the Hudson formula is not appropriate for these units. It might be confusing to provide K_D coefficients for Accropode and Xbloc, as these coefficients suggests that (a) the Hudson formula shall be applied and (b) the effect of slope on armour unit stability is properly described by the Hudson formula. The latter is definitely not the case.

We would prefer to use stability numbers (2.7, 2.5 and 2.3 for Accropode and 2.8 and 2.6 for Xbloc) for concept design and to provide no information on corresponding K_D coefficients to the CRESS users (in order to prevent improper use of the Hudson formula). It might be further useful to add a note that the term “breaking waves” does not refer to wave breaking on the breakwater slope but to a depth limited situation at the breakwater toe (i.e. wave breaking on the foreshore and depth limited waves at the structure).

It should be noted that a 10% reduction on stability numbers for steep foreshore slopes (or 33% reduction of K_D coefficients) shall be considered as a rough guidance. The recommended reduction is mostly based on a limited number of project specific studies and is not yet substantiated by systematic model test or field measurements. Confirmative model tests (2D and 3D tests) are strongly recommended for situations with depth-limited wave heights in combination with steep foreshore slopes.

Situations with frequent occurrence of near design conditions (typically depth limited design wave conditions that are associated with a very flat exceedence curve for extreme near-shore wave heights) will also require a careful armour layer design. A reduction of design stability numbers will be appropriate in most cases.

It should be finally noted that the stability of Xbloc and Accropode has been tested only for typical concrete densities (about 2300 – 2400 kg/m^3). The hydraulic stability of high density single layer armour units is uncertain and most probably not correctly predicted by the stability number. As the stability depends mainly on interlocking (and not on armour unit weight) the effect of high density concrete might be overestimated. CRESS users should get at least a warning if they use untypical concrete densities for interlocking armour units.

References:

Muttray, M.; Reedijk, J.; Vos-Rover, I.; Bakker, P. (2005): Discussion of paper "Placement and structural strength of Xbloc and other single layer armour units". Proc. of the Int. Conf. on Coastlines, Structures and Breakwaters 2005, ICE, London, UK.

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