APPLICATION OF CUBES IN A SINGLE LAYER

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Abstract

The application of Cubes in a single layer is an innovative solution under investigation since 1998 (Van Gent & Spaan, 1998; d'Angremond *et al*, 1999; Van Gent *et al*, 1999, 2001; Van Gent 2003; Rock Manual, 2007; Van Buchem, 2009). Using these studies shows that Cubes in a single layer are feasible and potentially economically competitive with the other single layer blocks (*e.g.* Accropode™, Core-loc™ and Xblocs® and undoubtedly economically competitive with double layer blocks (Antifer and Tetrapod).

Physical model tests with cubes consisting of normal-density concrete or high-density concrete indicate that it is feasible to construct top-layers with Cubes in a single top-layer; *i.e.*, damage occurred for significantly higher values of $H_s/\Delta D$ if units in a single top-layer are applied. If for single top-layers approximately 10 times less damage (number of displaced units) is accepted than for a double layer of Cubes, the performance of the top-layers was found to be similar with respect to the stability under equal loading conditions (see Van Gent *et al* 1999).

One of the reasons for the competitiveness of single layer Cubes compared to interlocking armour units, is the simplicity of fabrication and placement. This competitiveness of single layer Cubes with the double armour layers is the lower amount of concrete.

From the design to maintenance of the structure, the key parameters for comparison between Cubes in a single layer and the other single and double layers blocks are:

- Design
  - Breakwater geometry (slope, crest height, toe protection, depth of the structure, *etc.*)
  - Design wave conditions
  - Stability numbers
  - Porosity / packing density
  - Vulnerable areas
    - Toe
    - Crest
  - Cost (fabrication and placement complexity and concrete consumption)
- Laboratory tests
  - Stability parameters (displacements and extractions for design and overload wave height)
  - Overtopping
- Construction
  - Fabrication
  - Placement
- Maintenance

In the paper each parameter listed above will be addressed and compared to different types of armour units. The essential information from existing studies will also be summarized.

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Finally, information on two structures with single layer Cubes will be discussed: (a) Punta Langosteira (Spain) in which most of the temporary roundheads consisted of single layer Cubes, and (b) Boa Vista (Cape Verde) in which the main part of the trunk and the roundhead of the breakwater consist of single layer Cubes. See also Figure 1.

The Punta Langosteira breakwater has a length of more than 3 kilometers. Due to its long length and the severe wave climate (with a design wave height higher than H_s=15 m), it was constructed by stages with the main construction efforts during the summer and temporary roundheads protecting the unfinished breakwater during the winter. The use of single layers cubes was apparently cost-effective. The breakwater at Boa Vista was designed with single layer Cubes in the roundhead based on economic evaluation of the construction costs. The paper will provide more information on these two practical cases.

Figure 1. Model tests for temporary roundheads with single layer Cubes at Punta Langosteira (left) and single layer Cubes roundhead at Boa Vista (right).

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