Stability of High Density Cubes in Rubble Mound Breakwaters

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ABTRACT

The stability number for rubble mound breakwaters is a function of several parameters and depends on unit shape, placing method, slope angle, relative density, etc. In this study two different densities for cubes in breakwater armour layers were tested to determine the influence of the density on the stability.

INTRODUCTION

The effect of changing the density of the used material was investigated by only a very few studies in the past, although the densities of the used materials in Hudson's tests were between 2146 kg /m^3 and 3076 kg/m^3. In order to get more information about the influence of changing the density, more experiments were recommended in the literature.

Normal concrete density is 2.4 t/m^3, but increasing the density of units (for the same loading conditions) will reduce the required size of the armour units according to stability formulas.

It is very difficult to find large rock material and it may also not be economic to use normal density concrete armour units. Because of the following reasons, stable but smaller size armour units can be required for breakwaters: 1-Environmental impacts due to stone quarries, 2-Economical effects (due to) increasing concrete blocks, 3-Climate change and increasing waves requiring heavier armour units, 4-Esthetics of armour layers, 5-Increasing stability and decreasing concrete volume, 6-Minimizing of manufacturing and construction site costs.

Ito et al. (1994) did some experiments with high density Tetrapodes between 17.8 and 42.8 kN/m^3. The authors suggested a relationship between K_D and the specific gravity where K_D decreases with increasing specific gravity. On the other hand, the stability of high density armour blocks was found to be significantly affected by scale effects due to very small units.

Van Gent et al. (2001) did tests with high density cubes (almost 40 kN/m^3) in a traditional double top-layer and single top layer. They revealed that high density cubes are as stable as normal density cubes; i.e., damage occurred for the same or higher values of stability number in double layer case.

Hoe and Cox (2018) also investigated high density concrete units for conventional breakwaters.

EXPERIMENTAL SETUP AND PROCEDURES

An experimental research was carried out in the wave flume of the Coastal and Harbor Engineering laboratory at Yildiz Technical University. The flume has 26 m in length, 1 m in width and 1 m in depth. The channel is equipped with a piston type wave generator that has an active reflection compensation system.

Normal and high density concrete cube armor unit breakwater models for a trunk section were tested to provide insight into their behavior. The nominal diameters for both normal and high density cube models were 40 mm to avoid the scale effects. Densities in the tests were 24.0 kN/m^3 and 31.5 kN/m^3. The breakwater model was placed on a horizontal foreshore. The slope of breakwater was 1:1.5. The underlayer consisted of stones with a nominal diameter of 19 mm. The packing density of the blocks was kept 59 % by using the double irregular placement method for both normal and high density cubes. Three different water depths of 0.45, 0.55 and 0.65 m were studied to reflect the stability of cubes.

A total of 11 irregular wave conditions with a JONSWAP spectrum were selected for the tests. Wave conditions were measured at six different locations. One wave probe was placed in front of the structure toe, one close to the wave board and four were in constant water depth with known spacing to determine reflections. The peak wave steepness was kept around 0.04 for both normal and high densities cube block tests.

Before each test series the structure was rebuilt. The blocks and the rocks were placed by hand. Each test lasted about 1000 waves. Damage was cumulative for each test series. Relative damage (N_0) was determined by using a visualization technique; before and after each run digital photos were taken from a fixed location perpendicular to the slope and also damage levels (S) were determined using bed profilers. Relative damage was determined by counting the displaced armor units from the reference area (SWL $\pm$ H_s) where the selected design wave height was 24 cm.

In this study, heavy concrete production with a targeted density of 31.5 kN/m^3 was made by using barite aggregate. Castings in different mixing ratios designed to achieve the desired density were realized and the density criterion, which is the main target, was achieved. The optimum mixing ratio was chosen in this way and in heavy concrete production a barite aggregate with 0-5 mm grain size, CEM II 42.5 R type cement and the super plasticizer were used. In the mixture design, the water/cement ratio was determined as 0.55 and the super plasticizer ratio was determined as 0.44%.

CONCLUSIONS

Normal density cube block tests agree with Van der Meer (1987) results. The experimental results show that the stability of high density blocks were found to be more stable and the damage initiation for high density blocks started at higher stability numbers compared to normal density cubes.

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