CHAPTER 147

ARMOUR BLOCKS AS SLOPE PROTECTION

By

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Introduction

Dolosse blocks were first described in 1966 by Merrifield and Zwamborn in a paper to the 10th Coastal Engineering Conference held in Tokyo. They reported a block whose design weight was one-fifth to one-sixth that of natural stone to resist the same wave height. The reaction of the profession was surprise and perhaps a little disbelief that the new block could have such a high K_D value. A considerable amount of testing followed in a number of hydraulic laboratories. Quite a lot of work was done at the Hydraulics Research Station at Wallingford and some interesting points came to light. The paper discusses how wave period and angle of attack affect block stability and suggests a way in which engineers might approach the problem of design of breakwaters.

The effect of wave period

The equation normally used to describe the performance of armout units is the Hudson equation:-

$$W = \frac{w_r \, H^3}{K_D \, (S_r - 1)^3 \cot \theta}$$

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W = weight of armour units in lbs

w_r = unit weight of armour unit lbs/ft^3

H = design wave height - ft

S_r = specific gravity of armour unit relative to water

θ = angle of breakwater to horizontal

K_D = stability coefficient

The Hudson equation does not include any allowance for wave period. During an investigation carried out for the design of Dolosse for the High Island Breakwater in Hong Kong, various slopes of breakwater were subjected to waves of different periods. Having selected a wave period the wave height was increased until failure occurred. A definite influence of wave period was observed and this is illustrated in Fig 1, which refers to tests carried out with 5.7 ton Dolosse on a 1:2 slope. Although more experiments are necessary, enough has been done to show that the observed period dependence is real and a possible explanation for it is as follows. As the wave period increases the wave tends to surge on to the protective layer rather than break. This sets up high velocities over the surface layer. It is suspected from watching many tests with Dolosse that although they are very stable to plunging breakers acting normal to the slope, their weakness lies in their inability to resist the drag caused by this surface flow.

Type of failure

The advantage of a properly designed tipped-stone breakwater is that as the wave heights build up, the extent of the damage will occur gradually. This is not the case with Dolosse. Approaching the state of serious damage small changes in wave height will produce large changes in damage - considerable rebuilding rather than repair being necessary to the breakwater.

An attempt has been made in Fig 2 to illustrate the difference in behaviour of Quarry stone, Dolosse and Tetrapods. It demonstrates that what would be acceptable damage for Quarry Stone would be very serious damage for a Dolosse breakwater; Tetrapods occupying an intermediate position. (It should be noted that strictly comparative data was not available to make the analysis - averaged values from a number of sources were therefore used.) The indications are that any increase of stability which can be brought about by an open form of block with a high voids ratio and designed to interlock will result in a reduction of the margin of safety as failure is approached.

Engineers when they design breakwaters are faced with the choice between a number of blocks and rightly suspect that the performance is adequately described by one number. It would help if all results were reduced to a common form as we have attempted to do here. The correct block for a particular situation could then be chosen.

Fig 2 also shows that the K_D ratios (Dolos/rock) decrease as the percentage of damage is increased. At failure, when the movement of large numbers of blocks is involved, the assembly is fluidised by the passage of water through the layers and the benefit of interlocking and friction disappear. The only restraint to block movement is then the weight. It follows that sophisticated blocks should only be used with a large factor of safety. Keep well away from the serious failure situation by designing a block weight which gives little damage at extreme wave heights. Even so, the advantages of a high K_D factor will still be available to give an economical design.

The effect of angle of attack

It is commonly assumed that breakwaters are more stable to oblique wave attack since the wave heights are reduced by refraction and the armour units are effectively on a reduced slope. Experiments with quarry stone support this view. There is reason to believe that such an improvement in stability might not occur with blocks that are susceptible to drag forces. To check the possible effects a short series of tests were carried out in a wave tank (Fig 3).

The Dolosse breakwater which was constructed on a framework could be readily turned at angles to the direction of wave approach. Regular waves were increased in steps at each angle until the number of removals was such that failure was imminent. Fig 3 shows that the overall stability of the blocks decreased up to an angle of 60^{o} and then improved dramatically.

The explanation is similar to the one given earlier for period dependence. In breaking at an angle to the slope some flow takes place along it and this coupled with velocities up the slope due to the wave break or surge causes high velocities and hence high drag. The increase in stability found above 60^{o} is due to adverse effects of surface flow being overtaken by the benefit of wave height reduction. The rapid improvement again stresses that the difference in wave attack between acceptable damage and failure can be small.

Conclusions

(a) Tests have shown that wave period affects the stability of Dolosse.

(b) The way in which failure builds up should be an important factor in design.

(c) The angle of attack of waves significantly affects the stability of a breakwater armoured with open type blocks having high drag coefficients.

(d) Serious consideration should be given to adopting a uniform method of presenting test results so that direct comparisons can be made between various types of block.

Acknowledgements

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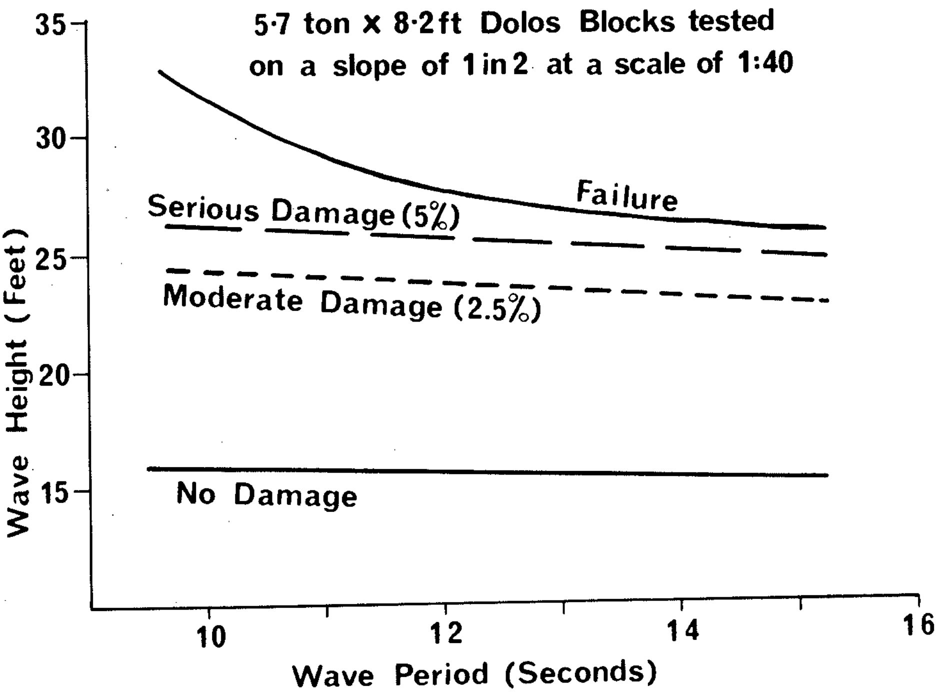

FIG. 1 Effect of Wave Period

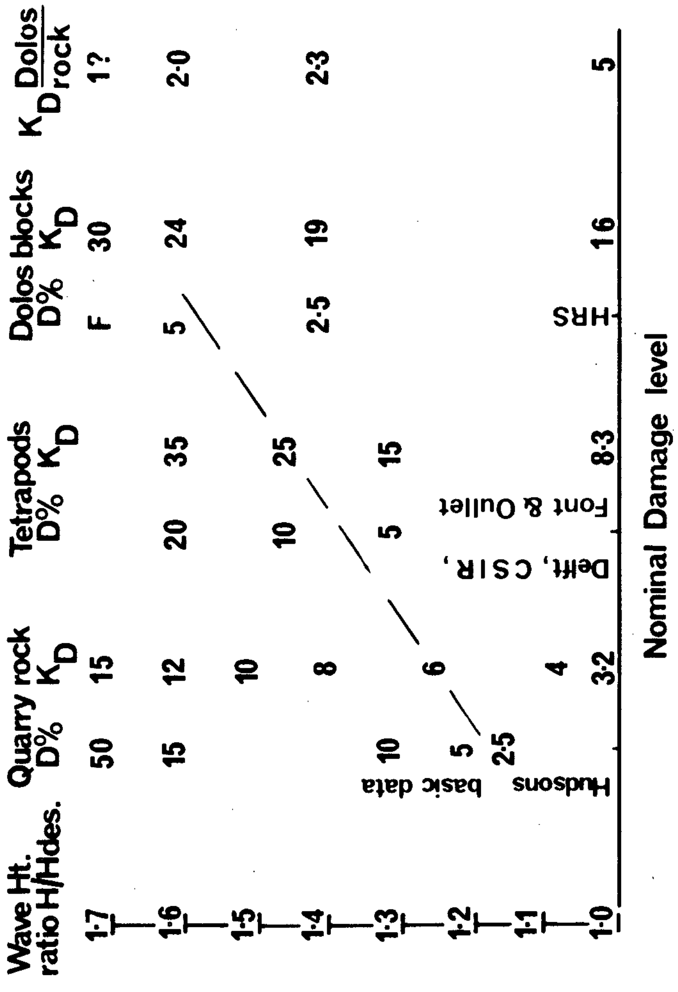

FIG. 2 COMPARISON OF DAMAGE TO ARMOUR BLOCKS

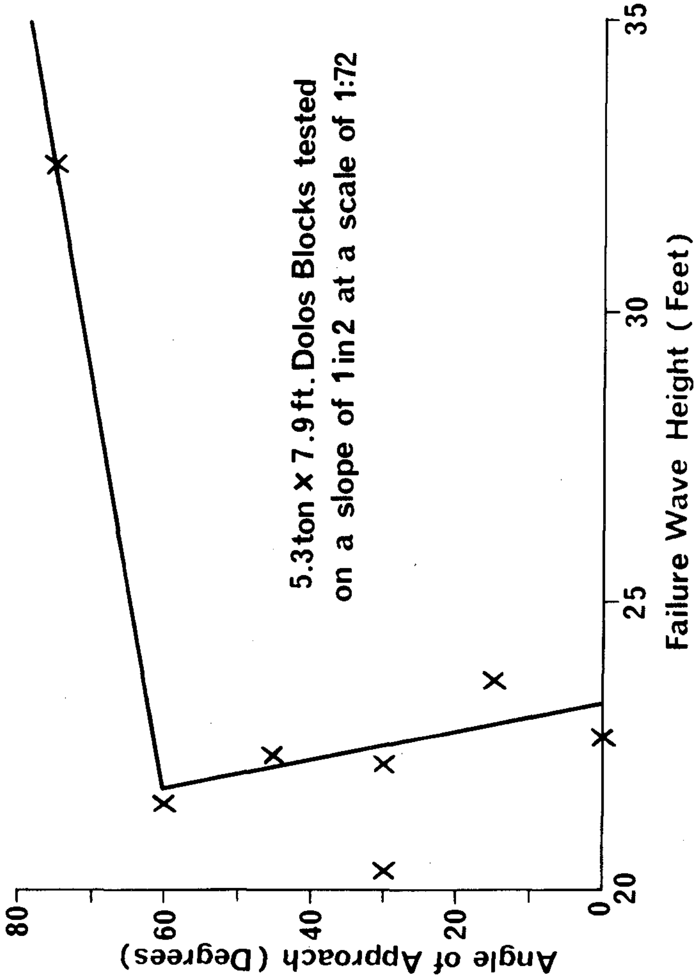

FIG. 3 Effect of Angle of Approach