BIZERTE-ZARZOUNA FISHING HARBOUR

TUNISIA

ACCROPODE(R) BLOCK DROPPING TESTS

July 1984
1. INTRODUCTION

The contracting group CAMPENON BERNARD CETRA/ALI MHENI has been appointed by the Tunisian Ministry of Equipment (Directorate of Air and Maritime Services) to build the new fishing harbour of Bizerte at the Zarzouna site, to the east of the existing harbour of Bizerte.

The overall layout of the new harbour, designed by SOGREAH-SCET Tunisia, provided for the construction of two protective breakwaters, the configurations of which were optimised on a mathematical model. The design provided for a facing constituted by ACCROPODE(R) blocks of three different sizes (4 m³, 6.3 m³ and 9 m³).

The manufacture of these blocks, which was the subject of a contract for license concession and technical assistance between SOGREAH and the contracting group, began on 3rd March, 1983.

Each set of shells (14 sets in all) produced on average one block per day. It was possible to envisage placing of the protective blocks on the main breakwater immediately on acceptance by the Administration of the breakwater core, toe mound and protective underlayer.

The first 6.3 m³ blocks were placed on 24 August 1983, at the level of the western roundhead of the northern breakwater. Once the placing team had got into its stride, the placing rate reached about 60 blocks per day.

With a placing schedule of one day per week, the first phase of protection of the main breakwater (that is excluding the crest works) was completed on 25 April 1984.

The present report gives an account of the dropping tests with 6.3 m³ ACCROPODE(R) blocks, which were performed on 26 April 1984.
2. TEST INSTALLATION

2.1 CRANE

The crane used for these tests was a LIMA 2400. This crawler-type crane, with a capacity of about 800 t.m, equipped with a 120 ft lattice-work jib, had been used to place all the ACCROPODE(R) blocks on the breakwater, and was also subsequently to be used to place the quay blocks.

Dropping of the ACCROPODE(R) blocks was obtained by disengaging the drum and releasing the brakes. The first tests, carried out with six-line reeving, were affected by substantial friction, both through the reeving pulleys and on the crane drum. Moreover, the reeving pulleys had a tendency to twist, so that the maximum dropping speed was quickly attained. The reeving was therefore reduced to two lines for the rest of the tests.

The drops obtained with this arrangement proved to be quite satisfactory, and the crane does not seem to have suffered, whether from the sudden rapid rotation of the drum or from the jerks in the jib caused at the moment of impact of the blocks.

2.2 POINT OF IMPACT

The tests were performed on the breakwater core.

The part of the structure on which the tests took place had been subjected to very heavy lorry traffic and crane movements, and was well consolidated (this impression was confirmed by measurements of settlement).

The dropping tests were performed in two stages, the block first of all being dropped on the quarry run (0-1000 kg) constituting the core of the breakwater, then on a parallelepiped concrete block of dimensions 2.25 x 2.25 x 1.40 m.

2.3 SLINGING

The slings used were the same as for placing of the blocks (30 mm diameter and coupled without eyes).

The blocks were lifted by the upper anvil, the hook being in one of two axes relative to the block:
in one case the impact was effected on the central protuberance opposite the hook,
in the other case the impact was effected on one of the protuberances forming the lower anvil.

2.4 BLOCKS USED

The tests were carried out with two blocks of 6.3 m³ nominal volume, complying with the technical specifications for manufacture.

3. TEST PROCEDURE

When it had been noted that the blocks were subjected to no damage when dropped on the core of the breakwater, regardless of the dropping height, testing was continued by dropping the block on the parallelepiped concrete block described above.

The blocks were dropped from increasing heights, starting again with the lowest height each time partial breakage of the block occurred. A graph of dropping time as a function of height was established (see figure 1), by interpolation from a series of observations, taking into account the error in use of stopwatch. Assuming the dropping heights to be exact, the speeds at the moment of impact were assessed graphically, and it was thus possible to deduce the equivalent free dropping heights.

Figure 1
### 4. OBSERVATIONS

The observations are presented in tabular form hereunder:

<table>
<thead>
<tr>
<th>Point of impact</th>
<th>Estimated height (m)</th>
<th>Weight loss (%)</th>
<th>Accumulated loss (%)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core of breakwater</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>The block suffered no damage, but it was noted that the six-line reeving had the effect of significantly slowing down the drop. The dropping speed soon reached its peak. The kinetic energy of the block is absorbed by deformation of the quarry run.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Concrete block</td>
<td>0,50</td>
<td>-</td>
<td>-</td>
<td>The dropping height is progressively increased. Breakage of the central protuberance occurs with ( H = 10 ) m but the dropping time is about 4 s.</td>
</tr>
<tr>
<td></td>
<td>1,00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2,30</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8,00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10,00</td>
<td>5 %</td>
<td>5 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8,00</td>
<td>-</td>
<td>5 %</td>
<td>The block is slung in the other direction. Breakage of the protuberance sustaining the impact occurs at a dropping height equivalent to that of the preceding test. The breakage area is identical.</td>
</tr>
<tr>
<td></td>
<td>12,00</td>
<td>5 %</td>
<td>10 %</td>
<td></td>
</tr>
</tbody>
</table>
### FIRST 6.3 M³ BLOCK - TWO-LINE REEVING - DROPPED ON CONCRETE BLOCK

<table>
<thead>
<tr>
<th>Dropping time (s)</th>
<th>Estimated height (m)</th>
<th>Estimated speed (m/s)</th>
<th>Equivalent free drop (m)</th>
<th>Weight loss (%)</th>
<th>Accumulated loss (%)</th>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.21</td>
<td>0.50</td>
<td>3</td>
<td>0.50</td>
<td>-</td>
<td>-</td>
<td>No damage.</td>
</tr>
<tr>
<td>0.29</td>
<td>1.00</td>
<td>4.5</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
<td>The second protuberance, fissured in the first phase of testing, breaks off.</td>
</tr>
<tr>
<td>0.34</td>
<td>1.50</td>
<td>5</td>
<td>1.20</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.60</td>
<td>2.30</td>
<td>5.80</td>
<td>1.70</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.67</td>
<td>2.80</td>
<td>6.20</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>0.91</td>
<td>3.00</td>
<td>6.40</td>
<td>2.10</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1.07</td>
<td>4.00</td>
<td>7.40</td>
<td>2.80</td>
<td>2 %</td>
<td>12 %</td>
<td>Part of one of the protuberances of the anvil breaks off.</td>
</tr>
<tr>
<td>1.12</td>
<td>6.00</td>
<td>8.50</td>
<td>3.70</td>
<td>23 %</td>
<td>35 %</td>
<td>The block breaks at the base of the anvil. Its residual weight is more than 60 % of the initial weight.</td>
</tr>
</tbody>
</table>

![Diagram](image.png)

*He = 2.50 m
He = 3.70 m*
<table>
<thead>
<tr>
<th>Dropping point</th>
<th>Measured time (s)</th>
<th>Estimated height (m)</th>
<th>Estimated speed (m/s)</th>
<th>Equivalent free drop (m)</th>
<th>Energy dispersed in chock (tf.m)</th>
<th>Accumulated energy (tf.m)</th>
<th>Weight loss (%)</th>
<th>Accumulated loss (%)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core of breakwater</td>
<td>1.69</td>
<td>10</td>
<td>10</td>
<td>5.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>1</td>
<td>4.5</td>
<td>1.00</td>
<td>15</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.56</td>
<td>1.5</td>
<td>5</td>
<td>1.20</td>
<td>18</td>
<td>33</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.62</td>
<td>2.2</td>
<td>5.6</td>
<td>1.60</td>
<td>24</td>
<td>57</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.90</td>
<td>3.2</td>
<td>6.60</td>
<td>2.20</td>
<td>33</td>
<td>80</td>
<td>2 %</td>
<td>2 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.11</td>
<td>4.5</td>
<td>7.60</td>
<td>3.00</td>
<td>44</td>
<td>124</td>
<td>-</td>
<td>2 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.23</td>
<td>6.3</td>
<td>8.60</td>
<td>3.80</td>
<td>57</td>
<td>181</td>
<td>2 %</td>
<td>4 %</td>
<td></td>
</tr>
<tr>
<td>Concrete block</td>
<td>1.52</td>
<td>7</td>
<td>8.90</td>
<td>4.00</td>
<td>61</td>
<td>242</td>
<td>-</td>
<td>4 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.89</td>
<td>11</td>
<td>10.20</td>
<td>5.30</td>
<td>80</td>
<td>322</td>
<td>-</td>
<td>4 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.07</td>
<td>15</td>
<td>12</td>
<td>7.30</td>
<td>111</td>
<td>433</td>
<td>12 %</td>
<td>16 %</td>
<td></td>
</tr>
</tbody>
</table>

The ACCROPODE block presents no significant degradation. It seems that the kinetic energy of the block is almost entirely absorbed by deformation of the breakwater core. There should be no problem within the limits of dropping height imposed by the crane.

- No damage suffered.
- Fissures appear in the protuberance.
- The fissured part breaks away from the block.
- No damage.
- Another big piece breaks off from the block.
- The extremity of the protuberance having broken off, the strength of the block has increased.
- Half of the upper anvil breaks off.
5. THE ACCROPODE(R) COMPARED TO THE OTHER MAIN ARTIFICIAL BLOCKS

The test procedure used calls for two reservations:

. the small number of ACCROPODE(R) blocks subjected to these tests does not allow precise quantitative information to be determined,

. the procedure does not cover the risk of breakage due to fatigue, although this is perhaps the most frequent cause of breakage of blocks, subjected to rocking movements on the facing.

However, it is possible to make a qualitative comparison of the approximate results obtained by the present tests with those of tests performed with other types of artificial block.

5.1 CUBIC BLOCKS

Tests were performed at Sines with cubic blocks of different size (1). The following table sets out an extract of the results obtained, with blocks of 9 tf and 27 tf. Refer to document (1) for precise indication of procedure used.

<table>
<thead>
<tr>
<th></th>
<th>9 tf</th>
<th>27 tf</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V ) (m/s)</td>
<td>5</td>
<td>3,4</td>
</tr>
<tr>
<td>( n_c )</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>( n_f )</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

\( n_c \): number of impacts before fissures appear

\( n_f \): number of shocks before breakage.

5.2 TETRAPOD BLOCKS

Numerous dropping tests have been performed during the 30 years of use of the Tetrapod technique.

The different test installations adopted have the effect of diversifying the results.

The dropping heights generally adopted in order to obtain breakage are less than one metre.
Tests were carried out at Sète -FRANCE- in September 1983 with 8 m³ Tetrapod blocks (2). Four blocks were subjected to the tests. Breakage in each case occurred after three or four drops through a height of a few tens of centimetres on a non-deformable concrete surface. It is to be noted that the quality of the concrete, checked on core samples, was proved to be perfectly satisfactory for these blocks.

5.3 DOLOS BLOCKS

Tests were carried out at Sines (3) with 42 tf dolos blocks.

Breakage occurred with dropping heights of between 0.05 and 0.25 m depending on the nature of impact. Furthermore, it is to be noted that the tests carried out by Burchardt (4) enable estimation of the critical dropping height (causing breakage) at between 0.09 and 0.16 m for dolos losses of 1.5 and 5.4 tf.

It is also important to note that static tests have been carried out in the USA with fibre-reinforced concrete (5). By contrast with conventional steel reinforced blocks, the appearance of fissures is significantly delayed, and it would seem that the use of fibres, whether or not of the metal type, brings significant improvements as regards both abrasion and resistance to fatigue. It nevertheless appears, despite these improvements, that the dolos presents an excessive fragility due to its shape, and that the risk of breakage on the facing remains (6).

6. RESULTS AND CONCLUSIONS

Tests of breakage of 4 m³ ACCROPODE(R) blocks were carried out on the work site in Sète harbour in 1980. These tests, performed with a loader, showed the strength of the block, but the testing method applied did not enable any quantitative information to be derived.

On the other hand, the tests carried out at Bizerte clearly demonstrate the following characteristics:

- The strength of the ACCROPODE(R) block is significantly greater than that of the other blocks that are designed to interlink or hook on to each other (Tetrapod, Dolos, Stabit, Dinosaur...). This is explained by the massiveness of the protuberances and the progressiveness of their connection to the central core.

- The breakage occurs progressively. Weight losses are generally low by comparison with the unit weight of the block, in marked contrast to what generally happens to other types of block. Moreover, the breakage of one protuberance, further increases the strength of the block.
Thus it appears that the ACCROPODE(R) block differs significantly from the other artificial blocks used for protective armours of maritime structures:

1. the massive shape of the block makes it intrinsically strong;
2. the $K_D$ coefficient used for preliminary sizing of the blocks gives unit weight values that are practically equivalent to those of grooved cubic blocks, thus giving a high degree of weight-induced stability;
3. the placing of the blocks in a single layer limits the rocking movements, hence also the risk of breakage due to repeated shocks;
4. the breakage of an ACCROPODE(R) block on the facing, assuming that such breakage were to occur despite the substantial safety margin already demonstrated, would in no way threaten stability of the facing, since it would not notably decrease the unit weight of the block.

It may also be noted that the scale model tests undertaken by SOGREAH or in numerous other laboratories have shown that even if a gap is deliberately created in the armour (by removing one, two or even three blocks), this tends to close up naturally by settlement of the armour. In the tests carried out to date, there have been no cases where the underlying rocks (assumed to be correctly sized) are sucked out through the armour and washed away.

The overall stability of an armour formed with artificial blocks depends on two factors:

1) **Stability of the blocks under wave attack**

This stability may be assessed with a fairly high degree of accuracy by laboratory tests. The tests using the ACCROPODE(R) technique, whether general tests or tests for specific projects, have been sufficiently numerous for the capacities of the block in this respect to be correctly assessed.
2) **Perennity of the actual blocks**

The fragility of the blocks on the scale model is by no means representative of that of the real-size blocks. The tests performed to date with a view to improving this representativeness have not yet proved fully satisfactory.

At present, therefore, only full-scale or large-scale tests would seem to be capable of giving satisfaction.

The tests carried out at Sète and at Bizerte enable the ACCROPODE(R) block to be situated relative to the other types of artificial block.

In conclusion, the ACCROPODE(R) block seems to be an effective compromise between:

- the solutions using grooved cubic blocks, which present satisfactory safety provided that they are correctly sized, but which are relatively disadvantageous from the point of view of cost, especially for protection of roundheads,

- and the solutions using artificial blocks of sophisticated shape, in respect of which the criterion of fragility has hardly been taken into account if at all, and the behaviour of which in full scale applications would seem to differ significantly from the behaviour in scale model tests.
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Total commitment at all levels enabled successful implementation of the tests under optimum conditions, as regards both the time required and the testing methods used.
BIZERTE

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PHOTOGRAPHS OF
THE DROPPING TESTS

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Crane used for the tests.

Test installation: the sling is the same as that used for placing the blocks.
The dropping heights are increased progressively.

Characteristic breakage surface.
Strength increases as the volume of the protuberances decreases.

After a complete series of drops, the block has retained 70% of its original weight.