Hydro-morphological study
Tagus Estuary

Additional work III

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1. INTRODUCTION

This report deals with two alternatives of the new Bugio-Trafaria Coal Terminal, located midway between the alternatives 2 and 3, which were already discussed in our reports of April 1982. Alternative 4 is a terminal without a connection to Bugio Lighthouse, while in alternative 5 a connection is made between the terminal and the lighthouse.

In the first chapters of this report the wave-climate and the shore protection is discussed, while in the last chapters the current pattern and the morphological changes are discussed.
2. WAVE-HEIGHTS AT THE TERMINAL LOCATION

A reanalysis of the wave penetration calculations for the new terminal lay-outs (alternative 4 and 5) showed that there is nearly no difference between the new berth location and location 8 (see our report of April 1982).

Wave periods are not influenced at all by this small shift of the terminal location, so fig. 2, 6 and 7 of our report of April 1982 are also valid for the shifted location.

The wave-directions are completely determined by refraction, thus all waves will come from directions of 270-275 degrees.

The wave-heights at the berth are a little bit lower than they were for the West location. Therefore we expect the following wave climate:

<table>
<thead>
<tr>
<th>waves higher than</th>
<th>occurrence in % of time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50 m</td>
<td>30 %</td>
</tr>
<tr>
<td>0.75 m</td>
<td>15 %</td>
</tr>
<tr>
<td>1.00 m</td>
<td>4 %</td>
</tr>
<tr>
<td>1.50 m</td>
<td>3 %</td>
</tr>
<tr>
<td>2.00 m</td>
<td>2 %</td>
</tr>
</tbody>
</table>
4. EXTREME WAVE-HEIGHT NEAR BUGIO

In order to be able to design the protection around the terminal, the extreme wave climate near Bugio has to be determined. The basis for this determination is also fig. 1. However, waves may reach Bugio from several directions. 52% of the waves are expected to reach Bugio. For long waves a refraction-coefficient of 0.6 will be applied, while short waves will have a refraction-coefficient of 1.0. Thus, for the "100-year wave":

\[
10^{-3} \times \frac{100}{52} \times \frac{100}{85} = 2.26 \times 10^{-3} \Rightarrow H = 12.0 \times 0.6 = 7.2 \text{ m}
\]

or

\[
10^{-3} \times \frac{100}{52} \times \frac{100}{14} = 1.13 \times 10^{-2} \Rightarrow H = 10.8 \times 1.0 = 10.8 \text{ m}
\]

For the "50-year wave":

\[
5 \times 10^{-3} \times \frac{100}{52} \times \frac{100}{85} = 1.13 \times 10^{-2} \Rightarrow H = 10.8 \times 0.6 = 6.5 \text{ m}
\]

\[
5 \times 10^{-3} \times \frac{100}{52} \times \frac{100}{14} = 5.65 \times 10^{-2} \Rightarrow H = 9.0 \times 1.0 = 9.0 \text{ m}
\]

Because of the depth near Bugio-lighthouse the wave-height will be restricted. So, the calculated extreme wave will not occur because of wave-breaking. This means that for both the "50-year wave" as well as the "100-year wave" a height of approx. 8 m should be used.
5. PROTECTION ON THE WEST-SIDE OF THE TERMINAL

For alternative 4 (no connection to Bugio) the waves at the west-side are approx. identical to the waves on the north, i.e. a "50-year wave" of 4.5 m besides that their height is limited by the waterdepth. If a rubble-mound protection is made on this side, a design wave of 4.5 m might be applicable. If a solution with a beach is chosen, additional protection of the beach with pile-groins is required. Suppletion once in several years is probably necessary. The quantity of suppletion is very difficult to estimate without detailed calculation. It might be a quantity of 100 000 m³ every five years.

For alternative 5 (closed connection to Bugio) the waves near the terminal are identical as described above. Near to Bugio the wave-height will be more. For this case a combined solution with rubble-mound and beach may be favourable. Near the terminal a rubble-mound can be constructed with a design wave of 4.5 m. The beach section has to be protected with pile-groins. It is expected that in this solution nearly no sand suppletion is required.
6. PROTECTION AT THE SOUTH-SIDE OF THE TERMINAL

It is not useful to determine the exact wave-height at the south side of the terminal in detail, because this wave-height is very much influenced by local refraction on the new coast. When the beach has the correct shape, the wave-height is not very important. The beach will get the correct shape automatically by nature. It will be some curved shape. Detailed calculations can give an answer to the question what shape the final shape of the beach will be, but in this stage of the study it is not useful to make these calculations. A protection with a beach (and a small row of artificial sand dunes) is a very stable coastal protection, if the sand cannot be moved away by longshore currents. In this case the beach is completely stable because of the curved shape. There is no possibility for the sediment to get lost. There is only a supply of new sediment from the south. In our opinion the southern protection of the terminal can be made with a beach only. This is a very cheap and stable solution. No additional groins are required, nor a frequent sediment suppletion.
9. MORPHOLOGY OF THE AREA AROUND THE TERMINAL

The influence of terminal with a closed connection to Bugio is identical to alternative 2 and needs therefore no further explanation. In case of no connection with Bugio, there will be a strong flood-current through the Goladas. This current will cause an erosion between the terminal and Bugio lighthouse. During ebb there will not be such a current.\textsuperscript{31}

The consequence of this phenomenon is that the Goladas are eroded and that sediment will settle on the slope of the Tagus main channel. The siltation will not cause any problem, because this sediment will be transported to the sea very quickly.

The erosion of the Goladas, however, may cause more serious danger to the stability of the terminal. After a few years a flow channel will be formed. The flow in this channel will affect the western slope protection of the terminal. Because the water is deeper, also a more severe wave attack may be expected. A third problem is that a beach at the south side is not completely closed, and that sediment may get lost through the Goladas. This will make the southern slope more expensive, this slope might even be endangered.
alternative 4

scale 1 : 107777
  erosion of 500 cm or more
  erosion of 250 cm
  sedimentation of 500 cm or more
  sedimentation of 250 cm

Fig. 2. Siltation calculated with a $D_{50}$ of 5 mm