

## Erosion of the Coastline

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### ABSTRACT

For several decades now, the erosion of the coasts bordering the salt fields at Aigues-Mortes and Salin-de-Giraud (South of France) has been increasing. An annual erosion of 10–30 m is seen in some places, and the beach and its dunes no longer provide natural protection for the saltworks against the invasion of the sea.

The reason for this considerable erosion lies in the control of the course of the Rhône by numerous dams which, by controlling the flow, greatly reduce the formation of alluvial deposits which this torrential river used to bring with each flood, now trapping them in the various basins created by the dams.

On the basis of periodic measurements made since 1959 over more than 25 km of coastline, a scientific method has been developed to check the erosion phenomenon. This method defines the type of structure to be installed to stop erosion and to stabilise the coastline. In the case of the saltworks at Salin-de-Giraud, the measures adopted involve the installation of dikes, the section, length and spacing of which are determined by the method. In 1990, the first battery of 21 dikes was installed. These dikes, 150–175 m apart, alternate between long structures (90 m in the sea) and short (50 m in the sea). Over two years of experiments, not only has the coast stabilised, but an average increase of 9 m has also been seen. This paper describes the studies carried out and published in 1990.

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### INTRODUCTION

Since 1744, the Camargue coast of southern France, a region situated to the west of the mouth of the Rhône river, has been receding constantly. An acceleration of this erosion process has been observed since 1930, due mainly to the massive decrease in sediments deposited by the Rhône since hydroelectric dams were commissioned to regulate the flow of the river.

Since 1982, the coastline has receded by an average of 5.40 m each year, over a length of 15 km, with some stretches receding by between 10 and 30 m annually.

In response to this threat, Compagnie des Salins du Midi et des Salines de l'Est, which operates the Salin-de-Giraud saltworks (11,000 hectares) and the Aigues-Mortes saltworks on this coast, endeavoured to find the most effective and suitable means, taking into account the specificities of the sector and urgency of the situation, to protect itself against this natural erosion which could in the long term have destroyed the salt-producing capacities of these two saltworks.

The Salin-de-Giraud saltworks is violently lashed by the sea (east-south east sector). A west-to-east countercurrent created by the Rhône prevents the normal transit of sediment from east to west and creates an alternative transit. The objective is therefore to trap the flows of sediments by perpendicular comb-like "dams". Moreover, in the Mediterranean, semi-diurnal tides occur which can reach heights of 0.50 m; this elevation of the sea level is amplified by an elevation of 1 m due to the heavy sea swell and to the specific coastal topography at this location.

The technique of sea jetties, the effectiveness of which has already been demonstrated on the coastline where the neighbouring Aigues-Mortes saltworks is located, was selected to provide stabilisation and protection, these structures being combined with a reinforcement of sea-front protection, behind the dune line (Figs. 1 and 2).

### CONSTRUCTION TECHNIQUE USED FOR THE JETTIES

#### Installation of the geotextile

The stability of the structure on soils with low

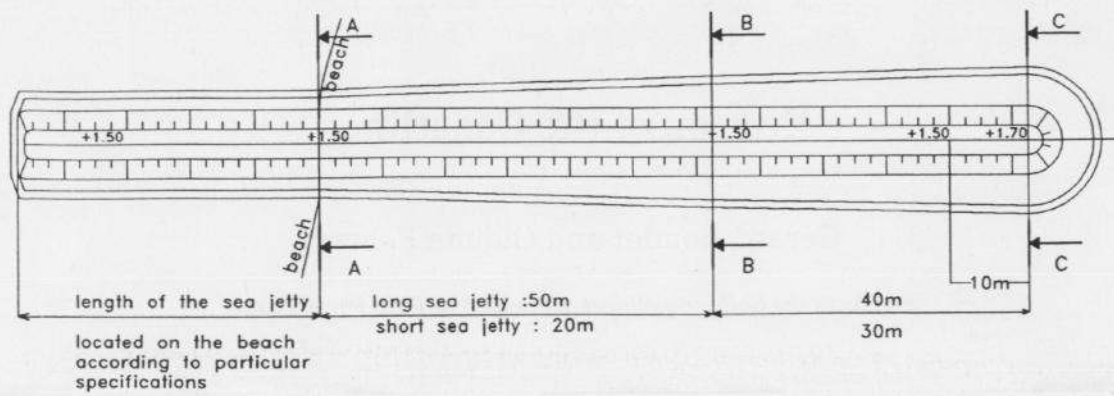
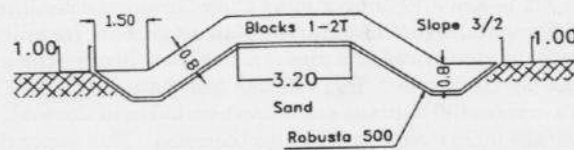
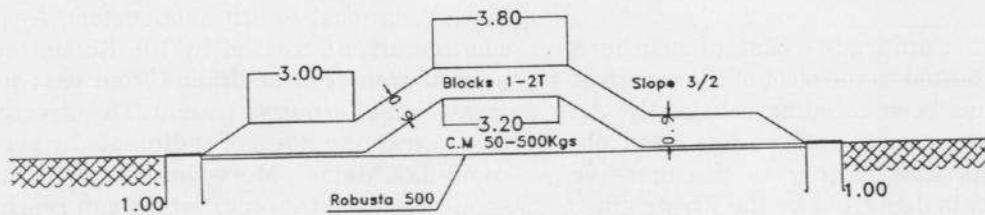


Fig. 1. Aerial view of jetty. Values expressed in NGF (National French Geographic values). Woven polypropylene treated to resist ultraviolet rays. Traction resistance:  $Tr = 100 \text{ kN/m}$ .

CROSS SECTION A-A



CROSS SECTION B-B



CROSS SECTION C-C

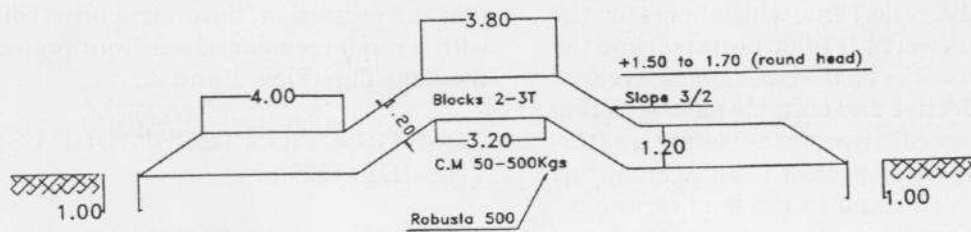


Fig. 2. Cross sections of jetties.



Fig. 3. Sea jetty: creating the core and the "terraccette".



Fig. 4. Sea jetty: creating the shell.



Fig. 5. Sea jetty: upper part of the shell.

load-bearing capacities (sand and clay) is ensured by installing a geotextile membrane in contact with the ground. It acts both as a filter and as a mechanical reinforcement for distributing stress. The stone bedding rests on this support.

#### Creating the core

The core or body of the structure consists of rock fill varying between 50 and 500 kg per unit (Fig. 3).

#### Creating the "terraccette"

A "terraccette" (1–3 t stone blocks) is installed over a width of 2–5 m, all around the submerged portion of the structure (Fig. 3). Its function is to reduce the energy of the swell on the round head of the structure and prevent the lateral destabilisation of the jetty by the return current in conditions of undertow.

#### Creating the shell

The shell, in calcareous hardpan blocks, with a porosity of between 40 and 60%, protects the structure from the direct action of the swell. These blocks, weighing between 1 and 2 t for the shore and sea parts, and between 2 and 5 t for the round head, make up the external portion of the jetty (Figs. 4 and 5).

The jetty's characteristics are calculated so that the structure can resist the stress of a 3 m swell.

The round head is located at level +1.50 to 1.70 m, NGF (normes géographiques françaises) over a length of 10 m. The upper part of the shell has a flat width of 3.80 m, which ensures satisfactory stability of the entire structure and allows the entry of a mechanical digger for repairs.

#### CONSTRUCTION TECHNIQUE FOR FRONTAL DIKES (Fig. 6)

##### The core

The core or body of the structure is made from materials excavated on site. This material is generally a mixture of sand and clay; clay is recommended.

##### Laying of the geotextile

A geotextile membrane is laid over the dyke's core to prevent deterioration, either by wind erosion or waves (Fig. 7).

##### Creation of the geotextile protection

On the sea side, protection is by stone bedding of between 1 and 2 t. The upper part of the dyke is covered by a 0.15 m thick layer of crusher material. On the pond side, the geotextile is protected from the sun's rays by a covering of sand or earth and, if possible, by vegetation as well (Fig. 8). The final level of the dyke is +2.10 m NGF.

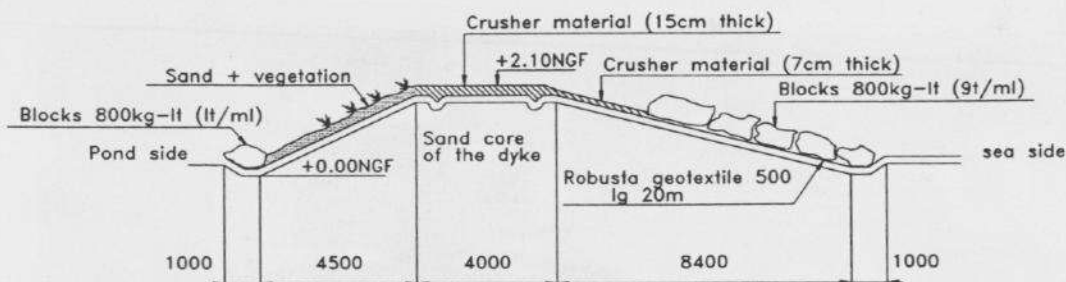


Fig. 6. Technical construction of frontal dykes (profile).



Fig. 7. Frontal dyke: creation of the geotextile protection.

### CHARACTERISTICS OF THE PROTECTION SYSTEM

The length and spacing of these structures has been determined by an optimization calculation, as the correct positioning of the jetties has proved to be a decisive factor for the effective protection of the coastline.

The solution adopted consisted of alternating long jetties (90 m at sea) (Fig. 9) with short jetties (50 m at sea), spaced 200 m apart. The long jetty catches the shifting sandy area, while the short jetty protects the coastline between the two long jetties. Obviously, depending on the conditions affecting each sector, the characteristics may have to be altered. Each sector must be studied individually.

### CONCLUSION

Since 1987, the creation of protective jetties on coastlines has made it possible to reverse the erosion process, with an average gain of nine meters on the protected sector.

Given this favourable and encouraging situation, the Compagnie des Salins du Midi et des Salines de l'Est has decided to maintain the sea jetty technique for the stabilisation of areas yet to be developed.

### REFERENCE

Caillaud, A., Boudet, G., Gieulles, D. and Briand, O., 1990. Le littoral de Salin-de-Giraud — Evolution et programme de travaux de stabilisation. 1st Eurocast Symposium, July 1990, Marseille (France), p. 729. (in French).

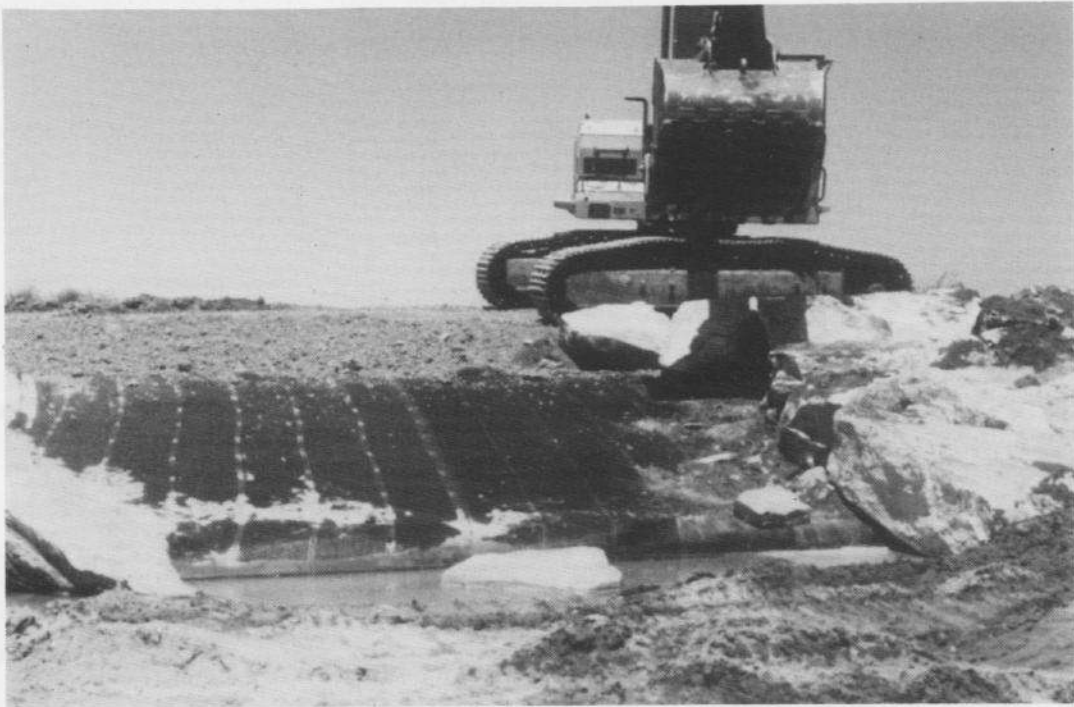


Fig. 8. Frontal dyke: overall view, with the upper part made of crusher material.



Fig. 9. Long jetty: overall view.