CHAPTER 193

TO RETREAT IN ORDER TO BETTER FIGHT : LITTORAL PROTECTION OF SHINGLE BEACHES IN THE NORTH OF FRANCE

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Abstract

Rather than endeavouring to protect a shoreline under severe waves attack, on the northern coast of FRANCE, a new solution a retreat landwards up to 800 m. With a slight retreat (180 m), the orientation of the new shoreline is drawn according to the dominating wave climate and enables the stabilization of the beach. A larger retreat (800 m) could allow the re-estuarisation of a valley. These solutions are tested on a physical movable bed model.

1. INTRODUCTION

Several parts of littoral in the North of France, constituted of chalky cliffs and shingle beaches are suffering today severe erosion, due to past human action : extraction of shingle for industrial purpose, construction of seawards harbour break waters interrupting littoral transport.

Previous responses of coastal engineers to this problem have been to construct classical seawalls or groynes, with unequal issue, problems usually shifting downcoast. Today, on the most critical site, annual shingle renourishment is employed : this is a soft, but onerous method, with bleak outlook, as the renourishment disappears downcoast in winter, during storms.

This most exposed site lies at the outlet of a valley, a 1 km indentation between the cliffs, with the beach lined landwards by a sea front road (fig. 1). Rather than protecting at any cost the present shore, with ineffective long term perspective, a new solution considers a retreat of the shore line in the valley. This draw back could be realized in two ways :

- either a slight retreat at the entrance of the valley,

- or even a re-estuarisation of the valley, with the sea entering landwards up to 800 meters.

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Fig I: Map of the site

Beyond the response to present problem, this approach integrates long term tendancies, as the annual recession of 0.20 m of surrounding cliffs exposing seawards the present sea front road, and possible sea level surelevation due to greenhouse effects.

This innovative solution, with strong local impact - destruction of the sea front road, partial intrusion of the sea in the valley - is tested and optimized on a physical movable bed model.

2. SEDIMENTOLOGICAL BACKGROUND

As a general manner, shingle beaches differ from sandy beaches by a steeper equilibrium slope and their mode of transport restricted to the swash zone, landward of the breaker line (MUIR WOOD, 1970).

In the North of France, likewise, shingles created from the cliff erosion lay down at the foot of the cliffs along the 140 km of the littoral and build up as a beach 20 to 30 meters wide, with an equilibrium slope of 10 %. Due to the westerly dominating wave climate, it exists an easterly littoral transport of 20 000 m³ per year. As the annual production of shingle from cliff erosion is also 20 000 m³, the sedimentary budget was well balanced in the past.

But, since the beginning of this century, various coastal developments as harbours breakwaters have deeply disturbed this natural transit, causing the breaking up of the shingle line into accumulation of dead stocks to the west of the breakwaters and its disappearance on the eastern parts. Quarrying of shingle for industrial purpose has also contributed to weaken the shingle line : half of the 5 millions m³ of the stock existing at the beginning of the century has disappeared in that manner.

In some areas, as Criel sur Mer, one of the most critical site, the annual easterly departure of shingle reaches, in spite of existing groynes, is 15 000 m³ per year, while the natural transit, cut down to 1000 m³ per year, can not feed the beach in a satisfactory way.

Therefore, since the last ten years, artificial shingle renourishment has relieved the nature, supplying the beach by lorries on an amount of 10 to 15 000 m³ per year in an attempt to fill up the deficit. This is a soft but onerous method, with ineffective long term perspective, as the renourishment disappears downcoast in winter, during storms.

Innovative planning policies, to save the beach while reducing drastically renourishment budget required to be tested on a physical movable bed model (TEISSON and al, 1989).

3. THE PHYSICAL MODEL

Bathymetry and shoreline have been represented in a 28×33 m tank, at an undistorded scale of 1/150.

Shingle of 30 mm mean diameter (D_{50}) is satisfactorily represented by bakelite of 1.5 mm, a lightened artificial material. After preliminary test with uniform granulometry, extended granulometry measured in the prototype (5-50 mm) has been set up in the model in order to reproduce the effects of sorting.

Sand is also simulated by another artificial material; at the present time this sand is passing in front of the site; it is expected to deposit in the future in the new sheltered area. The tank is fitted out with a mobile random wave generator, and tide generator. Measurements are carried out by digital waves gauges and limnimeters and by an automatic bottom probe sensor for bottom evolution.

Calibration of the model has been performed in two steps :

- to seek for the sedimentological time scale from the situation in the past, i.e. a stable beach with a littoral transport of 20 000 m³/year,
- to verify and reproduce present erosion problems.

For that purpose, random waves from various directions respecting wave climate, tide level with associated storm surges, are reproduced in the tank, in order to simulate evolutions up to 15 years in the future with the new lay out.

4. TESTS AND RESULTS OF PLANNING POLICIES

4.1. Bounded shore line retreat

The purpose of the planning policies is to adapt the beach line with the present situation, characterized by a very weak natural sediment supply. The idea is therefore to destroy the sea front road, badly orientated and to draw a new shore line well adapted to the westerly dominating wave climate.

We extended for shingle beaches the concept of static equilibrium bay, developed by SILVESTER in the 70's for sandy beaches, using the latest results of HSU et al. (1989). In stable condition, the tangential section downcoast is parallel to waves crests approaching the coast from offshore; the incoming waves will refract and diffract into the bay and break simultaneously, arriving more normal to the coast along the whole peripheries (fig. 2).

These results have been used to define theoretically a so called logarithmic spiral beach shape in the valley (fig. 3). Tests on the physical movable bed model have enabled to optimize the maximum identation in the valley to 180 m, bounded by a sea wall. The part of the beach sheltered in the valley, with an initial replenishment of 40 000 m³ of shingle is fully stable (fig. 4) : vertical cross sections of the beach after 6 and 12 years (fig. 5) show very little evolution. Sand, presently passing in front of the site, tends to deposit at the toe of the shingle beach. Annual renourishment could be carried back to 2500 m³, six times less than now, devoted to the eastern part of the beach below the cliffs, protected by a lengthened easterly groyne.

4.2. Estuarization of the valley

This most ambitious project (fig. 6), after destruction of the sea front road leaves the sea to intrude the valley; topography of this flat valley lies 1 meter below the highest tide level. At the beginning of the century, during a major storm, the sea invaded the valley 2 km landwards. Nowadays, estuarization would be limited to 800 m by a sea wall, to protect the city.

One of the main point of interrogation is the behavior of the soft, water saturated meadows under the waves attacks : new equilibrium slope, transition time. This aspect cannot be reproduced on the physical model, in the absence of similitude laws. An expertise has therefore been conducted from geological surveys (fig. 7), to deliver a first shape of this estuary (LAFOND, 1990). This high perched estuary, with a small tidal prism, has been set up on the physical model. Waves will diffract and vanish behind the western chalky cliff (fig. 8) : erosion of the meadows by waves would be limited to the first 300 meters. Upstream, topography of the valley would remain unchanged, forming a high marsh, irregularly flooded, only for the 10% highest tides. Downstream, consolidated soil below the present road and shingle beach would act as a barrier and limit the thickness of the eroded layer to 4 or 5 meters. Behaviour of shingle and sand has been surveyed over 15 years : littoral transport appears too weak to form a westerly spit. Superficial deposits of sand are noticeable at the mouth of the estuary.



Definition Sketch for Bay in Static Equilibrium



 R/R_0 versus θ for varying β

Fig.2: Characteristics of bays in static equilibrium (from HSU and al, 1989)



Fig.3: Layout of the shoreline retreat. "Logarithmic spiral" beach shape after optimization test. Position of section C and M on Fig.5



Fig.4: Shore line retreat. New bathymetry of the shingle beach after 6 years. Automatic data acquisition with the bottom probe sensor on the physical movable bed model.





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Fig. 6 Estuarisation planning



Fig.7: Longitudinal section of alluvial forms in the valley



Fig.8: Agitation survey (in meters) in the physical model in the case of estuarisation. Storm conditions, highest high water level.

5. CONCLUSIONS

Thus, littoral protection of this site reflects the evolution in coastal engineering state of mind : from hard solutions as groynes, then soft approach as beach nourishment, and finally a retreat to build up a new equilibrium shore line.

This new shore line, rather than fighting endless against the sea, is well adapted to the depletion of littoral transport and waves attack.

This approach as a retreat appears valuable when no worthwhile patrimony has to be safeguarded landwards.

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