# CHAPTER 35

## THE CREATION OF AN ARTIFICIAL BEACH IN LARVOTTO BAY - MONTE CARLO PRINCIPALITY OF MONACO

by

Louis Tourmen
Sogreah
Grenoble - France

### 1. INTRODUCTION

One of the features of a recent big Monaco Government modernisation scheme was an artificial beach in Larvotto Bay at Monte Carlo, which was to offer first-class bathing and amenities matching the very high standard of urban development planned for the area. Most of the Monaco coast is rocky and very steep, and the only places with a gradual slope down to the sea were a few very inferior beaches the waves had formed with widely varied materials from local builders' rubble dumps.

### 2. THE LARVOTTO SHORE BEFORE DEVELOPMENT

In some of the small bays between rocky headlands such as the Rock of Monaco, Pointe Faucignane and Pointe la Vigie, sediment deposits cover the rock to varying degrees. Most of them are not yet fully stable and have either been formed by local erosion or have built up from rubble The old Larvotto beach was one of these (Fig. 1).

The developed part of the Larvotto shore is between the reclaimed areas of the Sporting Club and Le Portier. It is about 500 metres long. As figure 2 shows, the slope of the old beach was about 10 per cent out to a depth of about 4 metres, and was fairly even all along this stretch of coast. A kind of shelf with a much flatter slope then followed out to about 8 metre depth, varying in width from about 120 metres at the Le Portier end to 230 metres at the Sporting Club (these being the distances from the datum level water line to the 8 metre depth contour) Beyond the 8 metre line the sea bed slope is about 10 per cent.

Old Larvotto beach was divided into compartments by short groynes reaching down to the waterline. The beach materials included lumps of rock up to several kilogrammes in weight, shingle and sand. Beyond the waterline the bed consisted almost uniformly of shingle over a wide size range, followed further out mainly by sand of locally varying coarseness and patches of seaweed beyond depths of 7 or 8 metres.

The local sea bed features confirmed the assumption that Larvotto beach had formed from materials dumped on the shore year after year over a very long period of time, for very little inshore sediment drift occurs in the area, and certainly not enough to have had any appreciable effect on the configuration of the sea shore. Most of Princess Grace Avenue is built on a backfill embankment for example, and the occasional damage it has suffered due to collapsing confirms that this stretch of shore has not always been absolutely stable. Before development, the Larvotto shore had been substantially built up by massive dumping of material, especially at the Portier end, and this had increased its stability accordingly.

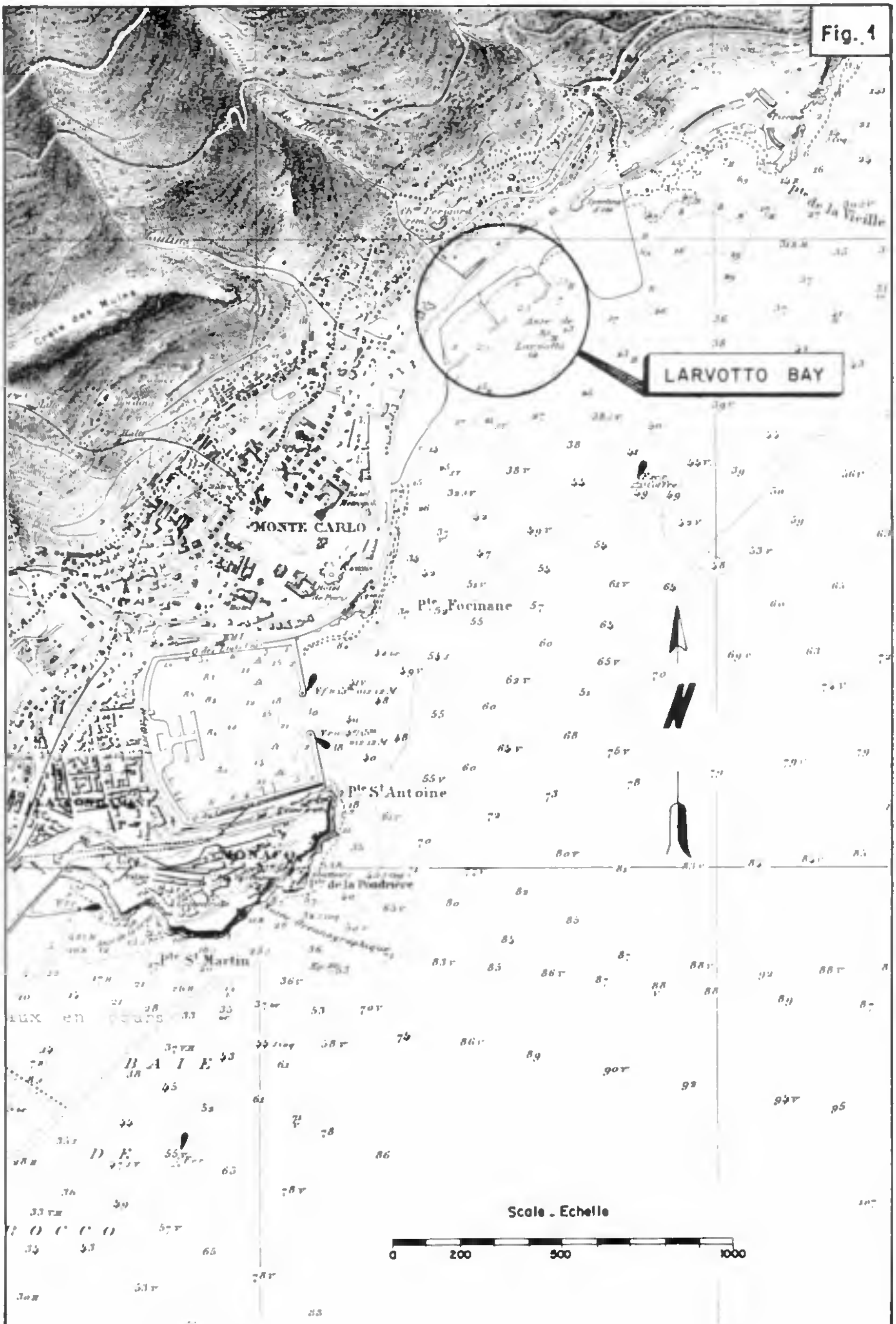


Fig. 1
LARVOTTO BAY
MONTE CARLO
Pte Focinane
Pte St Antoine
Pte de la Poudrière
Ile St Martin
BAIE
DE
MONACO
Scale . Echelle
0
200
500
1000

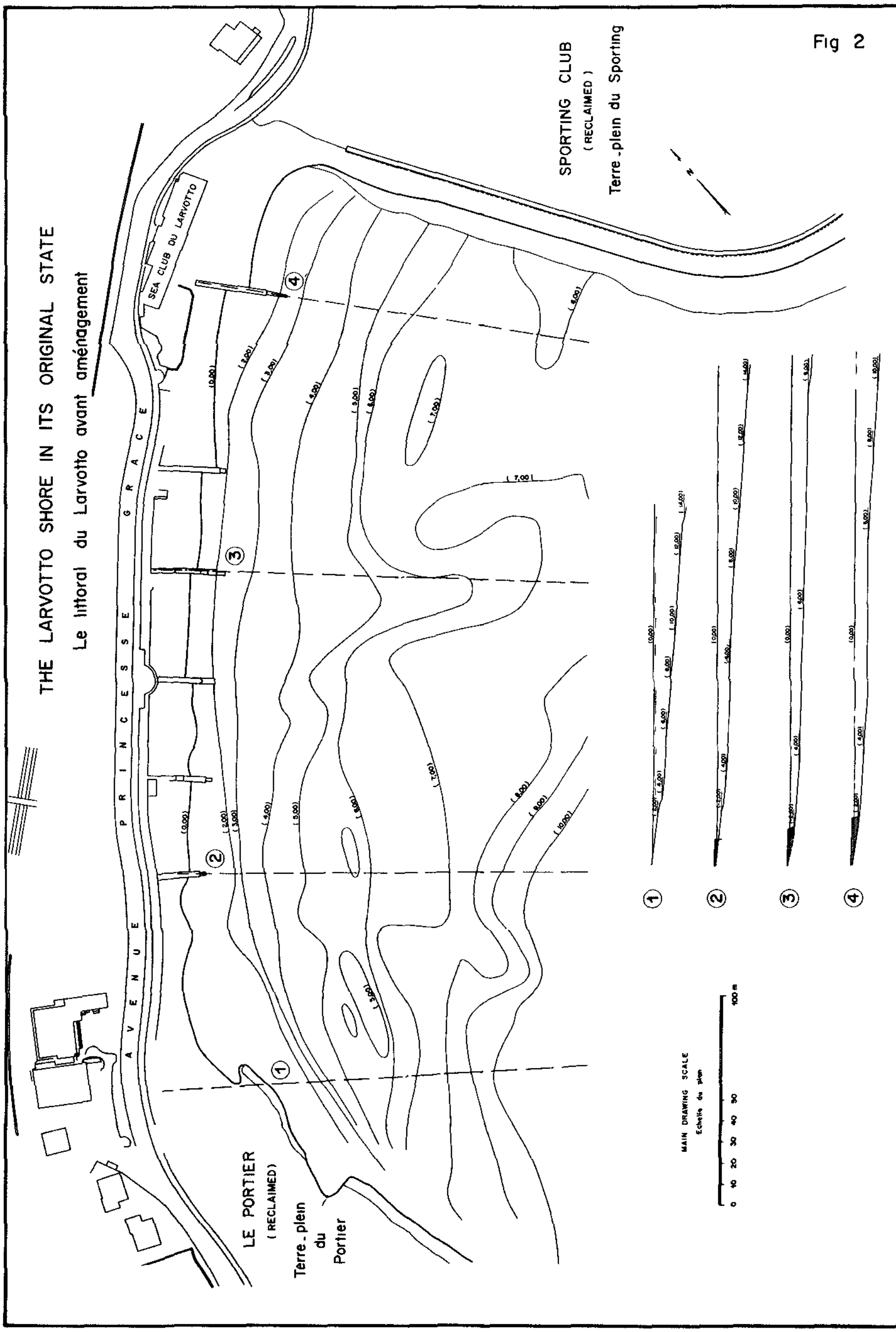

THE LARVOTTO SHORE IN ITS ORIGINAL STATE
Le littoral du Larvotto avant aménagement
AVENUE PRINCESSE GRACE
SEA CLUB DU LARVOTTO
SPORTING CLUB
( RECLAIMED )
Terre _plein du Sporting
LE PORTIER
( RECLAIMED )
Terre _plein du Portier
MAIN DRAWING SCALE
Echelle du plan
100 m

Fig 2

## 3. SEA LEVEL AND WAVES

The French Mediterranean coast has a tide range which is so small that it is insignificant for practical purposes Atmospheric conditions sometimes cause an abnormal rise or fall in level (though more seldom the latter). For example, a strong east wind can cause rises of up to 50 centimetres, but in relatively calm weather the water level can be considered to generally lie around 40 centimetres above datum.

From information supplied by the Principality of Monaco Public Works Department, wave conditions in the vicinity of Monaco harbour (Fig. 3) can be described as follows :

The prevailing wave frequency direction is from the east-south-east sector, with comparatively short-period waves (5 to 7 seconds) and maximum heights around 3 metres.

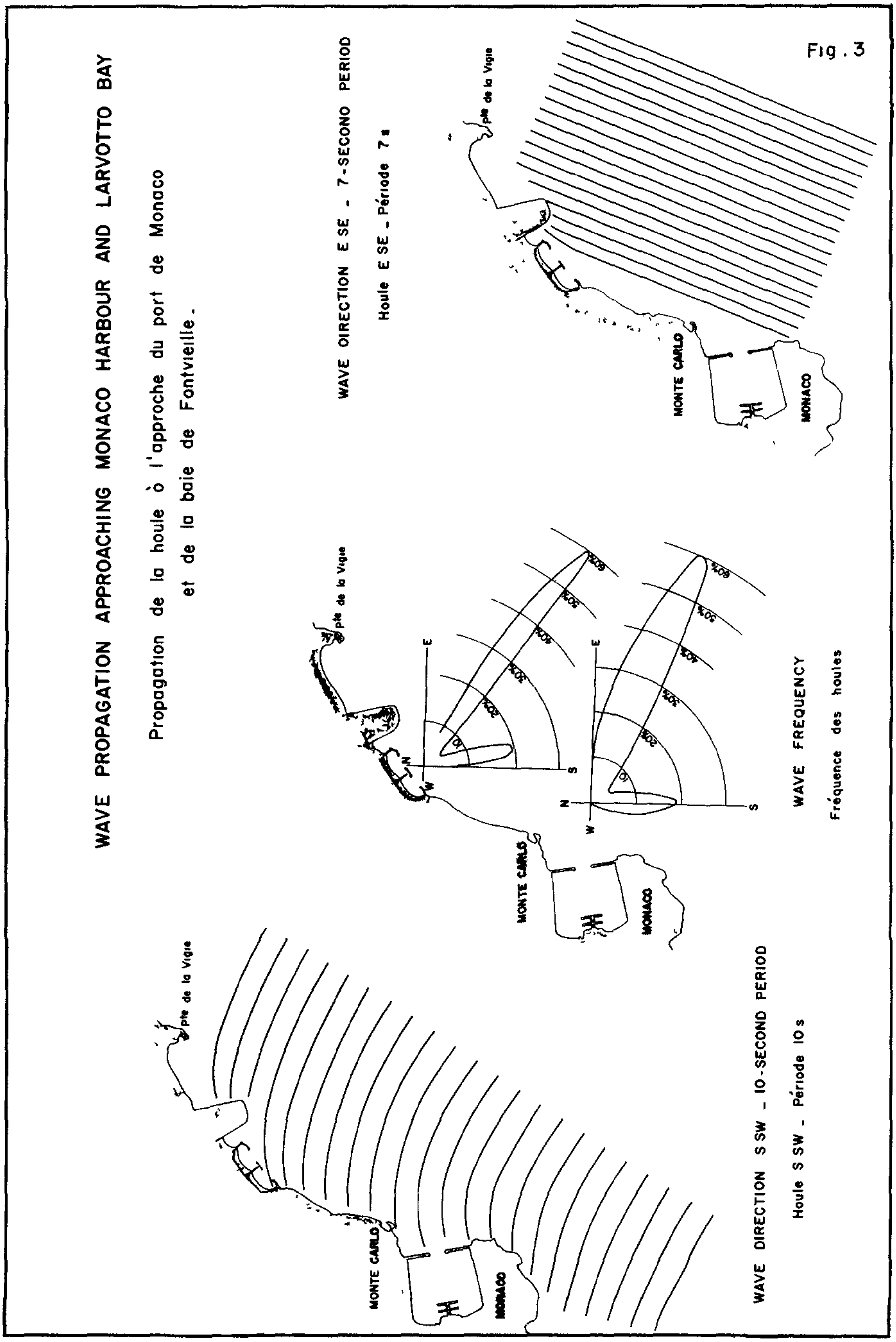
The prevailing wave height direction is from the southerly sector (south-south-easterly to south-south-westerly at sea), with longer periods (7 to 10 seconds) and maximum heights around 4 or 5 metres.

Propagation diagrams have been plotted for these various prevailing wave directions in order to show how the sea bed affects the wave crest directions in the immediate vicinity of Larvotto Beach. These diagrams are shown in figure 3, from which it is seen that although the effect of the sea bed tends to close the angle between the prevailing wave frequency and height directions, this angle is still quite large near the Larvotto Bay shore. In other words, waves must be reaching this shore from many very different directions, and this assumption is borne out by local beach evolution near the groynes, where the sediment is seen to drift to and fro depending on the incoming wave direction. It is considered that wave heights and periods off Larvotto Beach do not differ very much from those off Monaco harbour, except perhaps for the south-south-westerly waves. The refraction diagram for these in figure 3 shows that their orthogonals spread out a little, denoting some loss of wave height.

## 4 THE AIMS OF THE PROJECT - These were as follows :

### a. Widening of the shore seawards

The planning scheme for the Larvotto urban district provided for the reclamation of an appreciable area from the sea. A platform was to be built up to 5 metres above datum level on the seaward side of Princess Grace Avenue, ending in a vertical step designed to accommodate a row of shops along the beach front. The beach itself was to be about 30 metres wide to the water's edge. The whole project was based on this feature.


WAVE PROPAGATION APPROACHING MONACO HARBOUR AND LARVOTTO BAY
Propagation de la houle à l'approche du port de Monaco
et de la baie de Fontvieille.
WAVE DIRECTION E SE _ 7-SECOND PERIOD
Houle E SE _ Période 7 s
Fig. 3
Pte de la Vigie
MONTE CARLO
MONACO
WAVE FREQUENCY
Fréquence des houles
N
S
E
W
10
20%
30%
40%
50%
60%
WAVE DIRECTION S SW _ 10-SECOND PERIOD
Houle S SW _ Période 10 s

b. Sea Club Landing facilities

The Public Works Department had asked for a groyne to be built at the north-east end of the beach so as to provide a sheltered embarkation and landing area for the passengers of small craft.

c. Maximum beach extension

The project was to provide for the maximum possible beach area consistent with its general framework.

## 5. DESIGN PRINCIPLES - These were as follows :

a. The need to build up the sea bed

As mentioned in paragraph 2 the slope of the sea bed out to a depth of about 4 metres off Larvotto Beach was about 10 per cent, as consistent with the submerged beach material consisting of various sizes of shingle. The comparatively fine new beach materials provided for in the project could only be expected to remain stable under attack by the comparatively strong local waves, if placed so as to form an average slope consistent with their grain size and generally flatter than 10 per cent. In other words, it was necessary to correct the slope of the natural bed in order to ensure the stability of a new beach of fine material , this meant building up an underwater shelf on the sea bed with backfill, with a containment structure at its seaward end designed to withstand wave attack and sloping steeply down to the natural sea bed beyond. The effect of this structure on the incoming waves was expected to be quite considerable, especially in making them break.

The purposes of the shelf and its containment structure were thus as follows :

(i) To ensure that the beach settled down with a cross-sectional shape consistent with the size of its materials.

(ii) To make the biggest waves break and thus to reduce wave energy dissipation on the beach.

b. The need for groynes dividing the beach into compartments

As we have seen, the waves reach Larvotto Beach from a wide range of directions. The artificial beach material will tend to drift along the shore, therefore, and without special precautions this could modify the width of the beach to the point of affecting its amenities and possibly also causing a permanent loss of beach material. Groynes dividing a beach up into compartments are an effective way of preventing longshore sediment drift by containing the beach materials, and it was considered that at least two such groynes were required for a beach the size of Larvotto. Thus, the new Larvotto Beach consists of three self-contained compartments which are considered adequately safe from waves for normal practical purposes.

c. <u>The need for wave-diffracting structures</u>

It was considered that wave diffraction by separate offshore breakwaters running roughly parallel to Larvotto Beach would be most effective in stabilizing the artificial beach material for the following reasons :

(i) They would substantially reduce wave energy dissipation on the beach by stopping some of the incident wave energy.

(ii) By diffracting the waves, they would also substantially reduce the effects of changes in incident wave direction on the beach configuration.

Incidentally, a point to note in this connection is that the finer a beach material the stronger the case for incident wave diffraction.

A further effect of these breakwaters was that they would enable the length of beach at datum level to be increased by an appreciable amount, which was one of the aims of the project, and in fact this is precisely what has happened in practice for the beach has stabilized with a more or less marked curved outline.

## 6. THE BEACH-BUILDING MATERIAL

The problem of finding a suitable material for Larvotto Beach was a very stricky one indeed. A systematic exploration was made for prospective borrow areas - some a considerable distance from Monaco - but in the end, economic considerations led to the choice of local dolomite chippings ranging from 3 to 8 millimetres in size. This rather unusual material for a beach had sharp edges, but tumbling wear tests on a 'Los Angeles' machine had shown that they would soon wear smooth and produce a material with an attractive appearance and not at all uncomfortable underfoot. Figure 4 shows the results of these attrition tests for 3 to 8 millimetre and 5 to 15 millimetre chippings.

It was hoped that the waves would fairly soon wear the sharp edges of the chippings smooth. It was realized that it would be necessary to periodically 'turn the beach over' so as to ensure that all the material went through this process in time, but this was not expected to be difficult as the beach would have to be levelled with earthmoving equipment before each summer season anyway, and this would be a good time to do the job.

From the wear test results in figure 4, it can also be hoped that normal permanent wear of the beach material - that is to say more than just the wearing-down of the sharp edges - will be slow and that it will not be necessary to add fresh material to the beach too often.

## 7. INFRASTRUCTURE (Fig. 5)

The three offshore breakwaters running parallel to the beach vary between 80 and 100 metres in length with gaps of about 80 metres between them, which are filled in under water by a containment structure topping at 2.5 metres below datum level.

Behind these works, which are set in 6 to 10 metres of water, the sea bed has been built up with quarry run levelled off at 2.5 m below datum level, and the beach has been subdivided into three compartments by groynes built of concrete blocks.

## 8. PLACING THE BEACH MATERIAL

When the beach compartments were ready the beach material was gradually added, being tipped on the shore and spread roughly by bulldozers. The beach was then left to settle down naturally under wave action.

80,000 cubic metres of chippings were placed on the beach, including 34,000 cubic metres in the middle compartment and 46,000 cubic metres in the west compartment.

Very little material was added to the east compartment as it was mainly intended to provide landing facilities for small craft.

## 9. RESULTS OBTAINED

Work on the beach started early in 1965. Part of the beach was opened in 1966 and the whole job was completed in 1967, and the beach has since proved very popular with bathers. The improvement clearly shows up in the photographs in figure 6 of Larvotto Bay 'before' and 'after'.

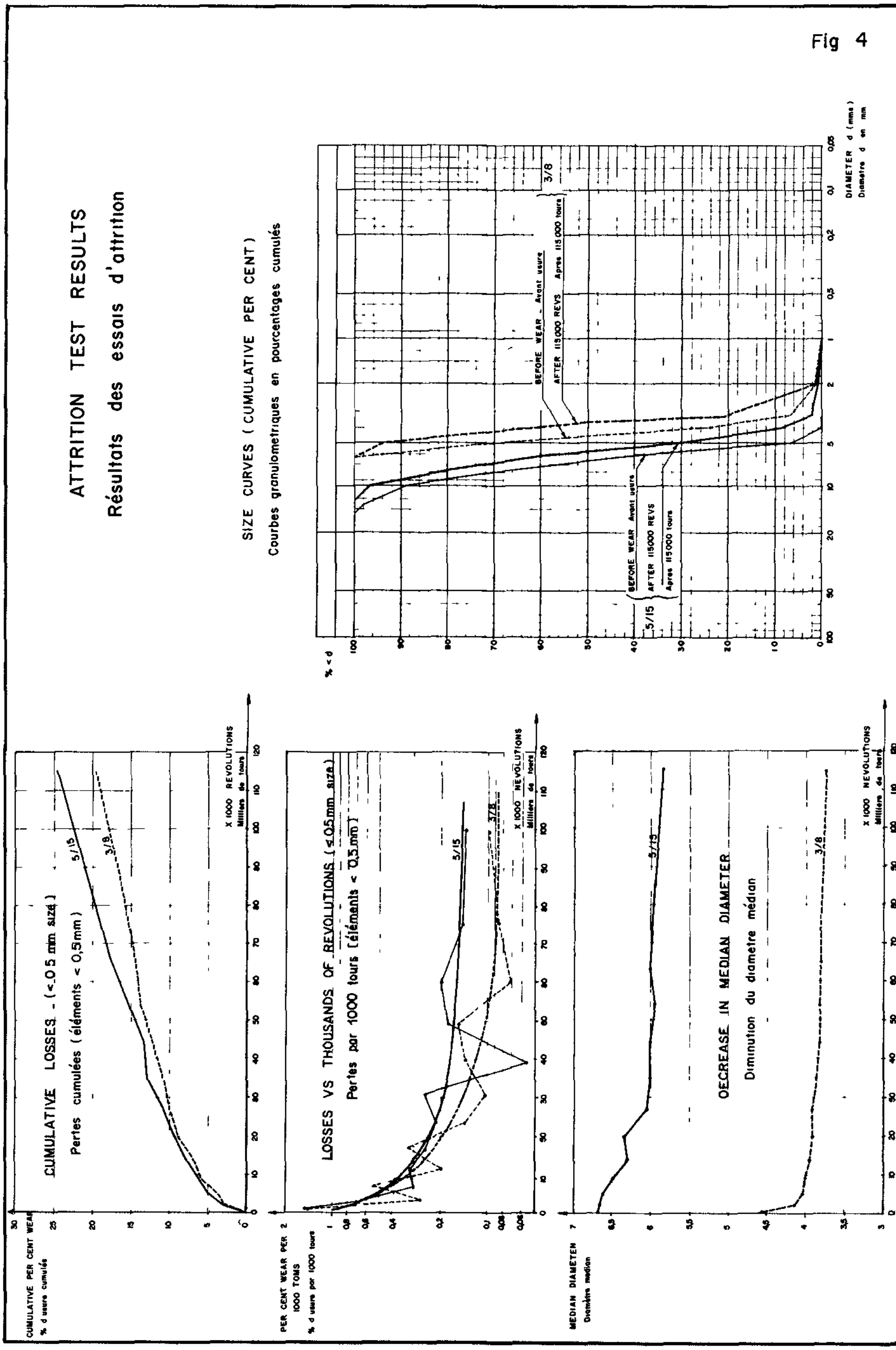


Fig 4
ATTRITION TEST RESULTS
Résultats des essais d'attrition
SIZE CURVES ( CUMULATIVE PER CENT )
Courbes granulometriques en pourcentages cumulés
% < d
DIAMETER d (mms)
Diametre d en mm
BEFORE WEAR - Avant usure
AFTER 115000 REVS Apres 115 000 tours
5/15
3/8
CUMULATIVE LOSSES (< 0.5 mm size)
Pertes cumulées (éléments < 0,5mm)
CUMULATIVE PER CENT WEAR
% d usure cumulés
LOSSES VS THOUSANDS OF REVOLUTIONS (< 0.5mm size)
Pertes par 1000 tours (éléments < 0,5mm)
PER CENT WEAR PER 1000 TOMS
% d usure par 1000 tours
DECREASE IN MEDIAN DIAMETER
Diminution du diametre médian
MEDIAN DIAMETER
Diamètre médian
X 1000 REVOLUTIONS
Milliers de tours

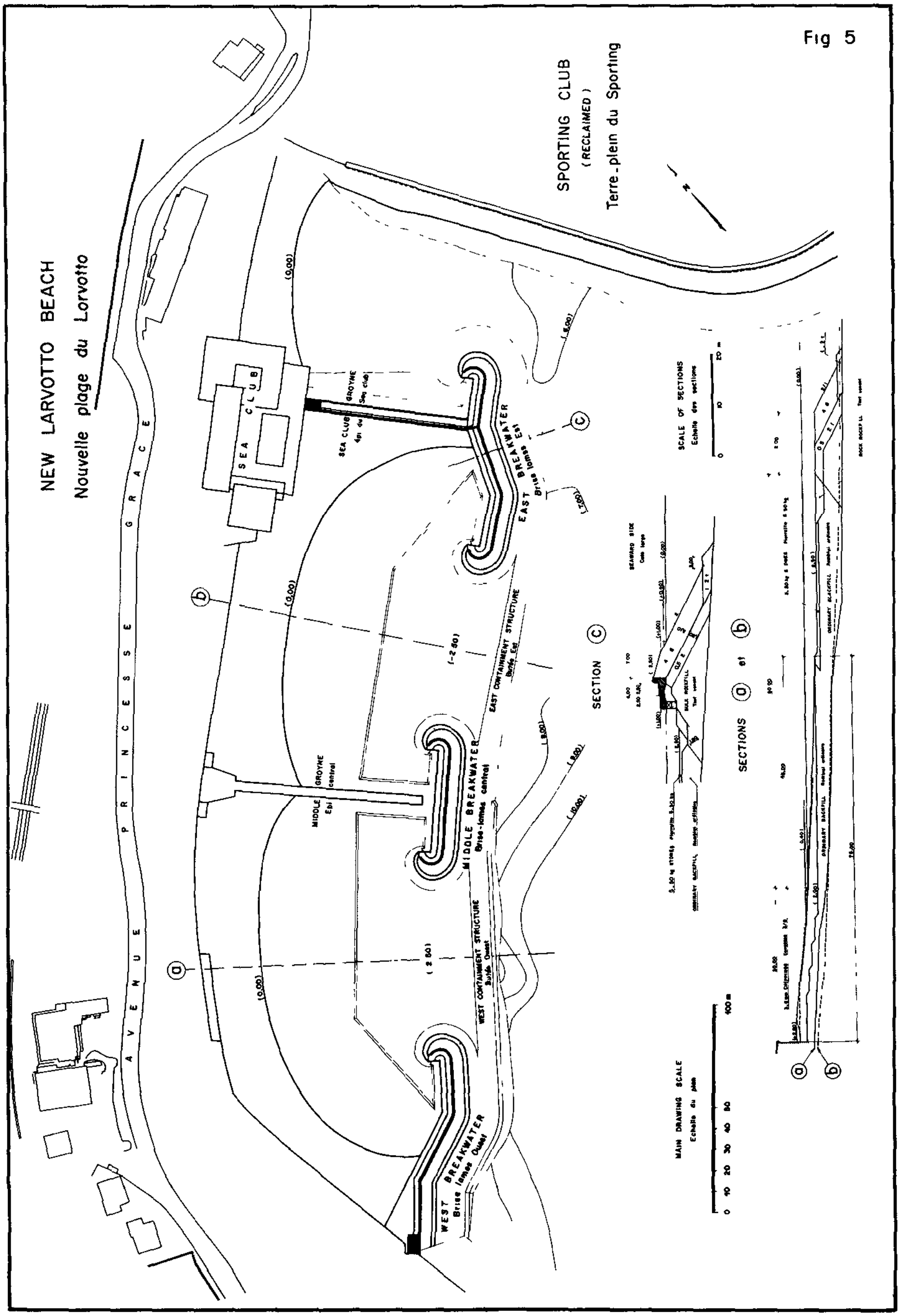


Fig 5
SPORTING CLUB
( RECLAIMED )
Terre_plein du Sporting
NEW LARVOTTO BEACH
Nouvelle plage du Lorvotto
AVENUE PRINCESSE GRACE
SEA CLUB
EAST BREAKWATER
Brise lames Est
MIDDLE BREAKWATER
Brise-lames central
WEST BREAKWATER
Brise lames Ouest
EAST CONTAINMENT STRUCTURE
WEST CONTAINMENT STRUCTURE
MIDDLE GROYNE
Epi central
SECTION c
SECTIONS a et b
SCALE OF SECTIONS
Echelle des sections
MAIN DRAWING SCALE
Echelle du plan

Fig. 6


Artificial beach of Larvotto _ Plage artificielle du Larvotto
MONACO

Now, two years later, close inspection has shown that the materials washed by the waves are gradually wearing smooth as expected. The beach is turned over once a year to make sure that all its materials are gradually exposed to this natural process of attrition.

In addition, the plan outline of the beach has developed into something very similar to the theoretical one predicted from the wave diagrams. At its narrowest, the new beach represents some 50 metres won from the sea. Its slope is about 10 per cent near datum level, which is still quite steep, but as it is directly due to the angular shape of the chippings it should flatten off in time as their edges wear smooth and they move more freely under wave action.

With regard to the lose of material due to permanent wear, that is to say beyond the initial stage of the corners wearing smooth, it is still too soon to say exactly how this will develop. From observations so far it seems unlikely that over-frequent additions of make-up material will be required, and beach upkeep costs may therefore be expected to remain low.

In conclusion, the Larvotto Beach Project shows how crushed chippings can provide an attractive solution to the beach material problem where sand of a suitable grain size is not economically available.