ZURRIOLA BEACH EVOLUTION TWO YEARS AFTER NOURISHMENT

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Abstract

First results about the behaviour of the nourishment done at Zurriola beach, Vasc Country, Spain, have been obtained, by means of the data acquired during 2 years monitoring. The general conclusion appoint to a good agreement with the previous physical model results: in spite of a small percentage of sand is lost, the beach is "self kept ". A rough evaluation of losses has been done, helping us to predict the future maintenance to do. The topography and bathymetry of the beach do not help to a easy modelling by means of mathematical models.

Introduction: The Nourishment Project

Zurriola beach, located in Gros neighbourhood of San Sebastian, in the North of Spain, has been progressively disappearing along this century, mainly due to the advance of the city over the beach. Its reconstruction project, tested at 1992-93, was based on the construction of the prolongation of the embankment Urumea river breakwater and a nourishment of the beach, with an urban promenade of 1100m. on the interface with the city.

The project begun at 1993(1), and $1*10^6$ m^3 of sand were used, that was borrowed form a submarine area close the 15 Kms from the beach. The grain size was .33mm. and the final slope was 0.013.

It ended at March-95, with a total cost of $13.3*10^6$ECUS(1996). After this moment the evolution of this new beach is being studied. Directional waves, tide and currents data are recorded simultaneously with monthly bathymetry,

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topography and grain size data acquisition surveys.

Figure 1: The layout of the beach before and after the nourishment.

<u>Field data acquisition survey:</u>

The information acquisition survey incorporated data of directional waves, tides, currents, bathymetry and topography for both submerged and emerged areas of the beach, completed by remote sensing of the dry beach. Since July-1995 the monitoring is being carried out. Four control profiles have been measured to obtain the beach evolution, employing DGPS. The closure depth for the noticeable sand movements was initially estimated at 15 metres depth but due to discrepancies between successive surveys, the number of control profiles and its final depth were modified adding other 4 with a total length prolonged till 25m. depth (May97)

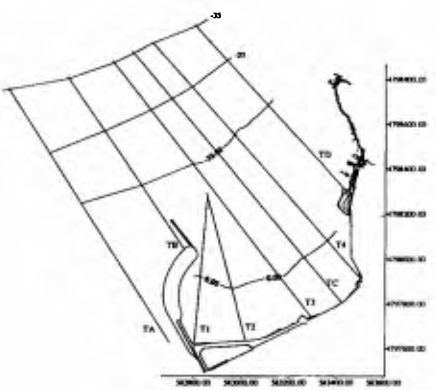

Figure 2: Final scheme of "control profiles": T1 to T4 (initial scheme) and Ta, Tb, Tc and Td control profiles added and prolonged at May97.

The sea weather conditions have been studied with 2 in situ systems:

1. First at all a S4DW EMCM that was deployed at a point located on the

T3 control profile, 1.5 metre over the bottom which is 11 metre deep.

2. At May-97 a Directional Waverider Buoy(DWB) has been deployed at 37 metres depth outside the Zurriola Bay.

Estimation of deep water storm conditions was done using the information provided by a Wavescan Ocean - Meteorological Directional Buoy (named EMOD-1) located at 600 metres depth, 40 miles north-west away.

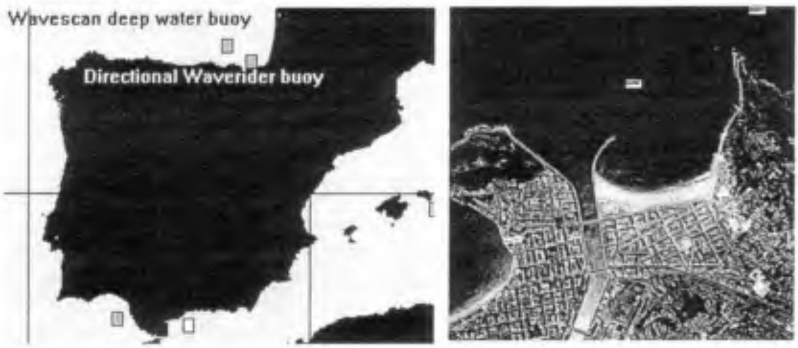

Figure 3: A) Buoy locations at studied area. B)Detailed zone of San Sebastian with the S4 and Datawell buoy situations.

The characteristics of Wave data acquisition survey were as follows(2):

EMOD1: Time series of 2048 points, 0.5 seconds sampling period, every 3 hours. Spectral process with 32 freedom degrees, without overlapping.

DWB: Time series of 1536 points, 0.78 seconds sampling period, every 1 hour. Spectral process with 24 freedom degrees, without overlapping.

S4DW: Time series of 4096 data points, 0.5 seconds sampling period, every 3 hours. Spectral process with 64 freedom degrees, without overlapping

Equipment S4DW provides the tidal data, that have been used for the bathymetry data corrections, and the current data.

The coverage of data during all the monitoring duration that began at June-1995, reaches more that the 80%. Specially the amount of information of the DWB is done better that the 95% since its installation at 19th-June/1997.

Bathymetry and topography data surveys were initially scheduled as monthly but the rough sea conditions do not enable to be realised every month.

The chosen methodology that is based on measurements only along same previous selected control profiles to optimise the balance between cheaper total costs and better knowledge of the short term temporal evolution, has allowed us to reach a big total amount of data of the 81% (36 monthly surveys done over 37 possible) tacking into account the temporal coverage. This point allows us to get a good base to estimate the beach evolution.

The selection of the closure depth (CD) was obtained from the Harllemeier's criteria (CERC, Shore Protection Manual, 1984):

$$d_1=2.H_s(p=0.50).12.\sigma(H_s) \quad \text{and} \quad d_2=2.H_s(p=0.137) \qquad [1]$$

The data taken from the EMOD-1 Data Base allow us to propagated the selected sea conditions from deep waters to 30 metres depth, obtaining d_1=27.2 m and d_2=12 m. for the Zurriola Bay external border. Due to that a CD of 15 m. was initially taken, but the successive comparisons of volumes for summer conditions evidenced that it should be greater. At May-97 it was enhanced till CD=25 m.

By other way it was added 4 control profiles more in order minimise the errors produced by the interpolation between them. All the features are produced because the extreme roughness of the bottom as its mobility. As a test point it was observed visually that the depth for the installation point of the S4DW varies 1.2 metres on 1 month at the moment to be done the monthly maintenance operations.

The grain size surveys were done every 3 months and they also reflected the high mobility of the bottom, specially along the river moth area and the extreme of the breakwater due to the currents created by waves diffraction.

Finally the remote optically observation of dry beach by means of a PC controlled camera allow us to contrast the results obtained from topography surveys as estimate the greater effects done by storms on the sandy and promenade areas.

Physical and mathematical modelling

First at all the Zurriola Regeneration Project was previously studied by REF-DIF propagation numerical model (3) to evaluate the best solution. At 1993 It was modelled by means a movable bed physical model to study the best choice for the groin to be constructed (4). The input data for deep water conditions, obtained from EMOD-1 buoy was H_s=9.3 , T_p=16 s, γ=7 , s_{max}(Mitsuyasu)=20, Θ_m(Incoming)=NW.

Evolution of control profiles in their swash and surf zones shows appreciable variations as it is presented on the picture 4. The behaviour of the beach + groin system was enough satisfactory but appointed a lost of sand that would appear in the future.

The area is too difficult to be mathematically modelled in order to employ shoreline and cross shore evolution models. But it was studied thé the local behaviour of the beach, appearing a very active zone with big rip-current effects after storms, corresponding with the T3 control profile.

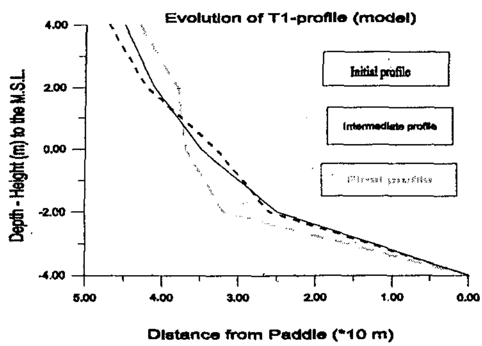

Figure 4: Experimented evolution of the T1 control profile by means the Physical model under storm conditions

<u>Beach evolution: Shoreline position and width of dry beach</u>

The shoreline evolution has been estimated taking into accunton data from the measured control profiles and its crossing point with zero level. The figure 5 shows the evolution along the monitoring period, from August-95 to February-98.

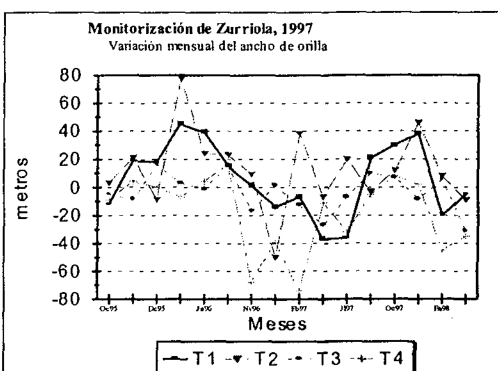

Figure 5: Monthly evolution of dry beach width (reference: August-95)

Maximum variations of 130 metres appear on T2 profile, while the minimum is on the T3 profile. The evolution along the year looks like the general rules, but it is dominated by other effects that masks it; the more important could be the movement of sand done by the local authorities focussed on the aesthetic aspect and leisure use purposes. This conclusion has been obtained doing the comparison with Monthly Averaged Waves, estimated at the no - surpassing levels of 50%, 84%, 97.7% and 99.87%, figure 6.

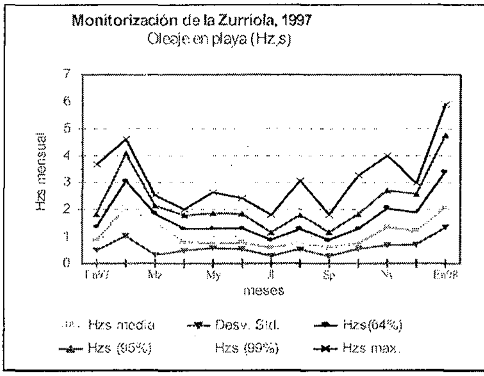

Figure 6: Time evolution during 1997 of Sea Wave conditions close to the beach. Data from S4DW equipment. Values corresponding to no - surpassing probability for Significant Wave Height Hzs , averaged along every month.

The more active zone, Profile T2, coincides with those that exhibit the rip currents effects after storms. This events fit well to the results from the numerical wave propagation model.

<u>Beach evolution: Volumetric variation of wedge sand</u>

Due to the two different used schemes of control profiles there are 2 zones to establish the evolution of the sand wedge (figure 7):

-Reduced area: comprised between the –15 metres bathymetric line, the breakwater and the cost line, that includes the zero depth contour line of the beach and the cliff of Ulia Mountain.

-Enhanced area: comprising from 25 metres depth contour line, the river mouth and the cost line.

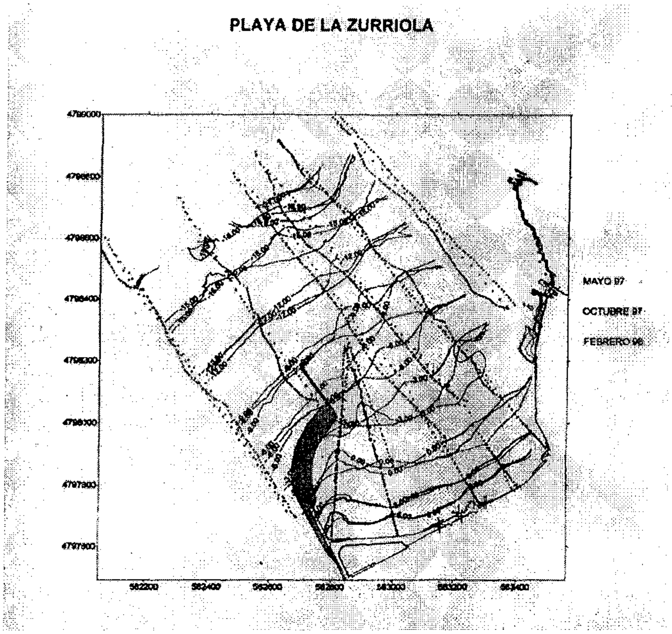

Figure 7: Enhanced area used to study the evolution of the wedge sand, after May-97. The reduced area is constraint to the inner part of the beach located between the breakwater, the 15 meters depth contour line and the coast line.

The evolution recorded along the 2-years monitoring is presented on the figure 8 for the period between Jnauary97 to February98.

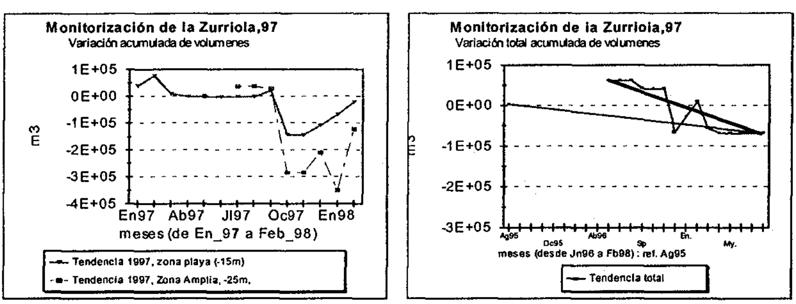

Figure 8: A) Relative evolution of Sand wedge, referenced to Reduced area (continuos line) and enhanced (dashed line).

B) Absolute variation from the beginning of monitoring(narrow line)corresponding to 2-years and for Ag96-Ag97 period.

Estimate of sand balance and tendencies

The evolution is not continuos during all the monitoring period. For the **reduced area**, where the information volume is greater, it was recorded an accretion of 46.000 m^3 during the period Ag95 to Ag96, while the lost of sand from Ag96 to Ag97 has been evaluated as 110.000 m^3. The general tendency could be assumed is about –60.000 m^3 for the 2-years period.

The **enhanced area** shows greater variations due to the inclusion of the river mouth. For the period between the beginning of working with this area, May97, to February98 the total amount of lost sand has been about 124.000 m^3 but the maximum sand losses, located between September and October 1997, has been about 312.000 m^3, while the maximum accretion is about 227.000 m^3 (dated between January to February 1998) after the biggest storm recorded since last 5 years (5).

These data show the high degree of mobility that the bottom has in this area. The factors that do that are:

1) The existence of the river mouth that acts as a sand reservoir. This fact is also proved because the relative high grain size that has been measured in this area:

Average: 2.6 mm , Sorting : 1.43 mm (October 97)

" : 0.14 mm , " : 0.4 mm (July-97).

2) The layout of this area that provides losses of sand from the studied area toward the east , outside of the Zurriola Bay.

Estimate of errors of the used control profiles schemes

The magnitude of figures before mentioned drive us to do an estimate of the errors that the methodology employed could have.

One of the source of errors to eliminate is the consideration of extrapolated areas, far of data. It produces extra data added by the working program, that have to be eliminated. These areas have been previously "blanked", as it can be appreciated on the picture 7, between the more external control profiles and the cost line.

First at all keeping in mind the wave data obtained by the buoys, we can assume that the movement of sediment during summer must be very short, specifically for the period from June to August, 1997. Due to that the variation recorded must be errors of the methodology. The evaluation of that are about 22.000 m^3 for the reduced area and about 45.000 m^3 for the enhanced one.

Secondly the gap between the control profiles can produce a source of errors directly proportional to that gap. Due to that it have to be greater for the used scheme with 4 profiles (before May97) than the used after, but it must increase with the area size. After May 98 it has been done a big density survey, with separation between points less than 10 metres along tracks (perpendicular to the cost) and less than 20 metres laterally to the track. The 3-D surface obtained has been cut by the control profiles and the new surface has been compare to the previous one. The estimated errors are about the following figures:

-Reduced area scheme (with 200 metres gaps and CD=15m): 10.000 m^3

-Enhanced area scheme (with more profiles, 100 metres gap, CD=25m):16.500 m^3

It is clear to deduce that the figures obtained by the reduced scheme are not so good to obtained an accurate estimate of sand balance, although the tendency could be taken as a draft conclusion. In opposite the figures deduced by the enhanced area and its scheme are more accurate and show an more approximated reality of the evolution.

Conclusions

- The main objective of the nourishment done was to recover an open space for social and leisure uses that the citizens had lost. This objective has been achieved with this reconstruction and opens new possibilities to the city.
- The control profiles scheme previously used with gap close to 200 metres, is not enough dense and wide to produce good estimation because the rough conditions of the sea, the mobility of the bottom and the quality of abruptness of the bottom surface. In the opposite the second scheme is enough good to produce a draft estimation of nourishment evolution.
- The order of the errors on the evaluation are about 35.000 m^3. If all the volume of the wedge sand is taken in mind (13.000.000 m^3), it is about 3 $^0/_{00}$.
- The beach experiences a little tendency to loss sand as it was predicted by the physical model. The evaluation of this tendency is about 30.000 m^3 per year, but it is a primary draft estimation because of factors like the amplitude of time dependent variations, with very high excursion during the year, and the errors .
- There are zones with high tendency to loss sand in the middle of the beach , profile T3, where rip currents happen after storms. In the same way the area close to the end of breakwater shows high mobility due to diffraction effects.
- Because aesthetic questions the layout of the beach, and specially the coast line contour and the dry beach surface, is man-made modified in order to obtain a good aspect for citizen uses. This character must be kept into consideration for all the urban beaches, and this disables to employ these to

calibrate numerical models.

- The presence of a river mouth modifies the evolution, doing an "open" character to the ensemble.

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