An Innovative, Non-Structural Solution to Beach Erosion: Costs Less and Delivers More Benefits

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More than 50% of the 3,250 km of Italian beaches experience a severe erosion (1991 estimate) which has been fought by coastal engineering since the last century. In respect to beach nourishment, hard structures were favored due to the availability of low-cost rocks from quarries and due to the lack of tradition in sand dredging which is related to the absence of river and estuary navigation. As a consequence, hard structures along the Italian beaches -such as breakwaters, seawalls and groins- protect over 330 km of shoreline.

These solutions have though often induced downdrift beach erosion; a valuable coastal environment was therefore lost. A benefit-cost analysis, not in use at that time, would have proved the lack of sense of this strategy. These problems have in recent years brought to the use of soft techniques in coastal restoration (e.g. beach nourishment) and inspired some researchers to find solutions in order to resume beach areas where breakwaters and seawalls had been constructed. In addition, cost-effectiveness analysis is now proving the advantages of these solutions.

Marina di Pisa is a seaside resort located on the southern side of the Arno River delta (Figure 1). The severe erosion characterizing the area is a consequence of the reduction in the Arno River sediment load from ca. 5,150,000 cubic meters/year between the XVI and the XIX centuries, to the estimated 1,910,000 cubic meters/year in the last 50 years. Beach erosion began during the mid-XIX century at the delta apex and gradually spread laterally, following a well known cuspate delta erosion model. Beach erosion has been free to develop along the uninhabited northern side of the delta. Since 1850 the shoreline has retreated of approximately 1.3 km reaching local peak values of approximately 20 m/yr between 1993 and 1997. Along the southern side, Marina di Pisa saw its first coastal defenses (groins) by the end of last century, when a shoreline retreat of approximately 100 meters endangered the new-born village. Different types of breakwaters of rock rubble/boulder construction were built during this century in order to stop shoreline retreat and to defend the town and the coastal highway from overwash during storm events. Today, offshore breakwaters run for 2.5 km from the river mouth southward and a continuous seawall protects the coastal highway (Figure 2). In addition, a few groins divide the protected coast into five cells of different size (Figure 3-top). As a result, more than 5 km of hard structures defend 2.5 km of coastline.

Nevertheless, although shoreline retreat was stopped in front of the town, erosion rates increased southward and offshore the breakwaters. A 1997 bathymetric survey indicates that the 7 m isobath runs at the foot of the breakwaters. Wave reflection over the breakwater induces undertow erosion and scouring together with the offshore dispersion of sediments that no longer reach the southern beaches where new groins rise every year. In addition, breakwaters need periodic maintenance work to keep up with lowering and collapsing.

In 1996 an innovative project of coastal restoration was initiated by the local Authority (Comune di Pisa). The project's aim is to prevent offshore dispersion of the southward longshore sediment transport, to quit building hard structures and to gradually return to a more natural coastal landscape where hard structures had been constructed in the past. This is to be obtained by razing the breakwaters to mean low water (M.L.W.) and by covering the existing seawall with an artificial gravel beach in order to dissipate wave energy and to prevent overwash (Figure 3-bottom). Laboratory wave channel experiments were performed at the University of Florence; these proved that, even under extreme wave conditions, a well designed fill with gravel is able to prevent overwash on the coastal highway and to restore a beach large enough to support a more competitive tourist industry (Figure 4).

In the meantime the Public Work Ministry, responsible for the seaside resort defense, had to maintain two breakwaters rising their berm from 2 to 3.5 m above M.L.W. for a total cost of 3 billion Italian Lire (ITL) (approximately 1.8 million USD). This kind of maintenance is necessary, for each breakwater, approximately every 10-15 years in order to balance structure lowering.. Breakwaters maintenance is not coherent with the new project and a different solution to defend Marina di Pisa was presented to the Ministry by the local Authority. For this project, a specific laboratory wave channel experiment was performed; this consisted in gradually testing breakwaters lowering as well as doing artificial filling with gravel. A cost effective solution was found by razing the breakwaters to M.L.W. and dumping the surplus rock boulders at the offshore toe of the structure thus decreasing its external slope and reflectance and increasing its stability. In addition, artificial filling with gravel was tested by gradually increasing the volume in order to find the optimum value of 100 cubic meters/meter of coastline. The total cost for this solution was estimated to be 2.2 billion ITL (approximately 1.3 million USD). Data on the stability of gravel beach nourishment are not available in literature; however, above mentioned laboratory experiments suggest a long durability. A detailed monitoring of the beach nourishment will give enough data to perform an accurate cost-effectiveness analysis.
As a result, in addition to the direct economic gain (0.8 billion ITL; 0.5 million USD), a 30 meter wide gravel beach will be obtained. Its value is estimated to be approximately 30 billion ITL (17.6 million USD) assuming a value of 2 million ITL (1.2 thousand USD) per square meter of beach, based only on a 10% yield for beach umbrellas and deckchairs rental. The economic value of the new coastal environment is expected to rise as a consequence of the sea water quality improvement due to the increase in water circulation, and because of the restoration of a more natural landscape. This will provide the chance of enjoying the sunset on the Ligurian Sea rather than behind a 3.5 meter high rock mound!

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Figure Captions:

Figure 1. Location map of the study area.

Figure 2. Seawall and breakwaters at Marina di Pisa.

Figure 3. Present coastal configuration (top) and proposed restoration project (bottom) [project by P. Aminti, G. Berriolo, G. De Filippi, J. Oneto and E. Pranzini].

Figure 4. Bird eye view of the future landscape (drawing by J. Oneto).