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EXTENDED ABSTRACT

Integrated model for beach nourishment design, post-nourishment monitoring and beach-maintenance refills

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Basic concepts

The poster attached to this volume presents the characteristics of a new model for beach nourishment interventions and some of its applications and tests related to the case of Ladispoli beach (Latium coast, Italy). The Grain-size Nourishment Model (GNM) gives assistance to the overall beach-recovery project: from the optimization of the nourishment design, to the post-intervention monitoring studies, to the project of beach maintenance by periodic sediment refills. However, the main task of the model concerns the simulation of different types of nourishment interventions virtualized through input variables. The outputs consist of 3D scenarios that contain the elements forecast by the model for the nourishment design. The process of prediction does not incorporate anything from other methods (Van De Graav et al., 1991; Larson et al., 1999; Pranzini, 1999; Capobianco et al., 2002). In fact, the model ignores the widely used concept of equilibrium profile (Dean, 1991; Pilkey et al., 1993) and rejects the assumption of other sedimentological techniques which concerns the granulometric reconversion of the borrow sands in the native ones by wave-washing processes (Krumbein and James, 1965; Dean, 1974; James, 1975; Hobson, 1977). Unlike classical engineering approaches, the GNM predictive process excludes parameters referred to the local hydrodynamic regime, assuming that this information is indirectly contained, at least in part, in the granulometric and topo-bathymetric data used in input.

The model adopts sedimentological criteria which imitate the mechanism of beach progradation evaluating the effects of the borrow material's grain-size characteristics over the cross-shore morphodynamic profile, since shoreline advance and nourishment volumes are strongly dependent on the profile form (Dean and Yoo, 1992). In particular GNM assumes, according to the null-point theory (Cornaglia, 1989; Bowen, 1980; French, 2005), that each borrow fraction, as a function of its size, is redistributed by waves on specific zones of the beach-shoreface profile, determining along it different rates of deposition from which the morphology of the post-intervention depends. For virtualizing this sediment redistribution the model uses a principle of grain size similarity: accumulating the volume associated to each borrow fraction on coastal zones where the analogous native fractions are resident before nourishment. The sum of the resulting sediment "layers" (one for each borrow fraction) reconstructs the artificial deposit above the pre-nourishment morphological surface and the individual attributes of this deposit are the elements forecast by the model, which therefore derive from only one process of prediction. Equations for this process are reported in Tortora (2008a) and a version of the software operating in 2D is available online (Tortora, 2008b).

Typical nourishment scenarios by the model show transitions between three main cases, which are predicted when the borrow sands are similar in grain-size characteristics to the average sediment originally resident: 1) on the entire beach-shoreface profile; or 2) on the upper portion of this profile; or 3) on the lower portion. According to these cases, the forecast artificial deposit changes in geometry and in depocenter position, developing in the first case along the entire profile, in the second as a sedimentary body attached to the older coast, and in the third as a submerged body. Shoreline advance and beach-seafloor morphology change consequently, according to the so-called nonintersecting, intersecting and submerged profiles (Dean, 2002). Contrary to other techniques that approximate the profiles by an equation (USACE, 2002), GNM predictions include morphological details (berm, bars, troughs, etc.) that are often important for volumetric estimations.

During the model's development, the following issues were taken into consideration in an attempt to resolve them: a) few models operate in 3D, and 3D methodologies represent the future frontier for coastal modelling; b) many models used for beach nourishment are not fully adequate because they were in origin designed for other purposes; c) the division of processes in nourishment studies (nourishment design, monitoring of reconstructed beach, plan for beach maintenance) typically requires different methodologies rather than an integrated method; d) the majority of the existing models are based on engineering approaches, and only a few are based on criteria more confident for geologists.

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Model characteristics

The Grain-size Nourishment Model operates in three distinct ways (module A, B and C): one predicts the effects of the nourishment; one manages post-intervention monitoring data; and the other furnishes predictions, calibrated with real data (monitoring), for beach-maintenance refills. Each module imports, elaborates and exports topo-bathymetric and grain size data organized into grid matrices (46x40 nodes) covering the littoral in exam. In particular, its characteristics are described by a grid matrix with elevation-depth data and by a package of granulo-metric grids, one grid for each size fraction, which together reconstruct on each grid node a grain size frequency distribution. So a total of 1840 virtual samples and the same number of elevation-depth measures are used for describing the beach-shoreface surface. Input for Module-A predictions is the description (grids) of the pre-nourishment surface. Module B, instead, imports the description of each surface detected during the post-nourishment monitoring period. Comparing these surfaces changes in sedimentary balance, morphology, seafloor sediment distribution and other aspects can be rapidly obtained. Comparing real and forecast features, the errors in predictions can be highlighted and used for calibrating the model for subsequent predictions by module C (beach-maintenance refills). Inputs for this module are the grids related to the last monitoring survey.

The two predictive modules (A and C), very similar, operate by three distinct procedures of calculation, which act in sequence (see poster: Panel 1). The nourishment simulations are manoeuvred tanks to three variables by which different types of intervention can be virtualized: the shoreline advance requested in the project; the grainsize frequency distribution of the available borrow material; the depth of closure. Each forecast scenario includes the following information: beach and shoreface morphology (topo-bathymetric map); shoreline position; geometry (isopach map) of the artificial deposit; geographic distribution of sedimentological parameters (mean size, sorting, percentage of sand and mud) and of singular or aggregated size fractions; sediment amount for the intervention. Scenarios for more than one preliminary nourishment hypothesis can be compared in order to choose the best solution for the live project (see poster: Panel 2). For the transparency of this solution, sensitivity and uncertainty propagation analyses are requested as a final step (Capobianco et al., 2002).

Applications and tests

The three modules of GNM have been applied, a posteriori, to the nourishment that occurred at Ladispoli beach in April 2003. Modules B, A and C were used respectively: 1) to ascertain the post-nourishment evolution of this beach; 2) to test the model by comparing real and forecast features as well as to identify the cause of the inconveniences following this intervention; 3) to correct these inconveniences by planning a small re-nourishment. Processes by module B (Panel 3, Section 1) show that at the end of the nourishment works the artificial deposit had a volume 367,000 m^3, and one year later it was reduced to 287,000 m^3 due to the sediment lost for lateral spreading. In one year, waves drastically reshaped the artificial deposit through erosion of the beach and redeposition of the eroded sands on the middle shoreface, where a trough-bar system parallel to the shoreline formed. The shoreline retreated by 30-50 m, equivalent to 190,500 m^3 lost from the dry beach. Drastic changes in geographic sediment distribution also occurred after nourishment, especially on the beach and upper shoreface zones where sediment size remarkably decreases. Results by module A lead to these conclusions: the forecast scenario for Ladispoli intervention encourages the use of the model showing many features in common with real post-nourishment evidence (Panel 3, Section 2); and, alternative scenarios for different types of borrow materials suggest that the cause of the beach erosion following the 2003 intervention was in the sands used, too fine for the equilibrium on and near the beach (Panel 3, Section 3). Processes by module C (Panel 3, Section 4) indicate an easy recovery of Ladispoli beach through a small re-nourishment (152,700 m^3) with medium-fine sands quarried from the Tuscany continental shelf (Tortora, 1994).

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