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Editorial[☆]

1. The project

The relation between wave climate, beach erosion, beach defence, habitat changes and beach value, which clearly exists and is highlighted by several EU research experiences, suggests the necessity of an integrated approach to coastal defence problems examining beside structure stability and construction problems, hydro- and morpho-dynamic effects, environmental effects (biological colonisation of the structure and water quality), societal and economic impacts (recreational benefits, swimming safety, beach quality). This issue aims at presenting some results of this difficult cultural integration process.

The DELOS project was originated by two observations.

- LCSs can cause strong currents with significant impacts on beach morphology and safety of swimmers due to heavy wave breaking and overtopping.
- The coastal defence with artificial structure has reached along some stretches of the European coast such an intensity that their environmental effects, not adequately documented in the past, deserve now a special attention.

In conclusion, the overall objective of DELOS was to promote effective and environmentally compatible design of low crested structures (LCSs) to defend European shores against erosion and to preserve the littoral environment and the coast economic development.

Specific objectives and methods were:

- to provide an inventory of existing LCS and a literature-based description of their effects;
- to analyse LCS hydrodynamics, structure stability and effects on beach morphology by surveys on specific sites by laboratory experiments and numerical modelling;
- to investigate the impacts of LCS on biodiversity and functioning of coastal assemblages by observations and field experiments;
- to develop a general methodology to quantify benefits for "Integrated Coastal Zone Management" based on Contingent Valuation monetary values in different European countries;
- to provide local authorities with validated operational guidelines for the design of LCS based on the achieved knowledge of LCS hydrodynamics and stability, water circulation, beach morphology, impacts on coastal assemblages, human perception and related economic effects.

DELOS offered the possibility to achieve these aims through integrated collaboration among engineers, coastal oceanographers, marine ecologists, economists and political institutions, involving 18 partners from 7 European countries and end users.

2. This issue

The present issue is specifically dedicated to socio-economic, ecological and engineering results obtained from LCSs analysis within DELOS project.

[☆] This Special Issue is dedicated to present the major scientific results of socio-economic, engineering and ecological studies carried out within the EU funded RTD project *Environmental design of low-crested coastal defence structures* (DELOS; contract EVK3-CT-2000-00041; http://www.delos.unibo.it).

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The first paper (Polomé et al.) deals with justification of the construction of LCSs for beach protection from an economic point of view by the value of the beach. As other environmental and/or non-marketable assets, the value of the beach cannot be obtained as for marketable ones from the price paid for exchange; values of enjoyment were obtained from surveys carried out within DELOS following the Contingent Valuation Method.

The structure design shall account for the preferences that people expresses; in our case preferences were in favour of:

- submerged structures for aesthetic reasons;
- groins for water quality and recreational activities.

The technical opinion expressed by interviewed people was in general in favour of the actual intervention, expressing more the appreciation of defence action than a convinced technical opinion.

A Benefit Transfer Function was prepared with coefficients calibrated on several data regarding the value of enjoyment of tourist beaches. This function can provide at least the order of magnitude of the value, substituting direct valuation for the least critical cases where benefits and costs add up to clearly different values.

The following paper (Lamberti et al.) describes the study sites monitored and analysed during the project (Pellestrina IT, Lido di Dante IT, Altafulla ES, Lønstrup DK, Elmer UK) and presents an inventory of the characteristics of the European LCSs compared to a worldwide scenario including Japan and USA experiences. Site-monitoring improved the knowledge of morpho-dynamic evolution at different space and time scales in presence of different intervention type and provided ground-truth data for subsequent analyses (Sumer et al., Zyserman et al. and Jimenez et al.[1]).

Experiments were carried out within the project in three laboratories aiming at extending and completing existing available information on waves and currents interaction at LCSs with respect to a wide range of engineering design properties both in 2D and 3D conditions; Kramer et al. describes the experimental set-up and the test conditions, recalled by several paper in the issue.

[1] To appear in a later issue of Coastal Engineering.

The following group of papers describe hydrodynamic processes taking places at LCSs by means of empirical analyses and numerical modelling. Lara et al. represent velocity and turbulence distribution around and inside LCS by means of a 2DV and a 3-D numerical integration of Reynolds Averaged Navier Stokes equations. A previous paper describes the development and validation of the 2DV model with DELOS laboratory data; the model is used in this case as a descriptive tool providing insight into details that can be hardly documented by measurements; effects of breakwater geometry on the wave breaking-induced flow pattern at the structure are investigated. The 3D model is compared with experiments and provide a detailed description of the flow near the roundhead. Van der Meer et al. analyse empirically wave transmission and reflection based on a very wide data-base: 2300 tests including wave basin tests with oblique wave attacks. Caceres et al. analyse the overtopping process and circulation around the structure and near the shoreline induced by overtopping by means of a numerical Q3D model comparing currents occurring with and without the overtopping flow.

Numerical modelling is becoming a standard description tool. Johnson et al. compare different numerical models through the simulation of waves and currents in the vicinity of submerged breakwaters reproducing DELOS test conditions. They provide an updated breaking model and calibration for the case of relatively steep and permeable bed. Bellotti and Brocchini analyse the implementation of the swash zone boundary condition for wave resolving and wave averaged models and discuss the role of the condition on the surf zone hydrodynamics. Zyserman et al. analyse the morphological response of the adjacent seabed to currents induced by LCSs, in particular close to roundheads and at the gaps between structures. Mechanisms responsible for the erosions highlighted by prototype and laboratory observations are examined by means of coastal area numerical modelling tools. Jimenez et al. analyse shoreline evolution in presence of LCSs through a numerical one-line model, highlighting the key role of the relative structure freeboard.

In general models are able to accurately predict most important processes as overtopping (Caceres et al.), transmission and current intensities (Johnson et al.), flow inside the breakwater (Lara et al.), far-field morpho-dynamic response (Zyserman et al. and Jimenez et al.).

The stability of the structure and local erosion at structure toe are the main themes of the contribution of Burcharth et al.[2] and Sumer et al.. The first presents consideration on LCSs stability in shallow water based on DELOS laboratory data and prototype experience, analyses the critical problem of the filter between armour and sea bed and presents considerations relative to LCS construction. The second summarizes the results of an experimental study on trunk and roundhead scour at submerged breakwaters due to streaming induced by reflected waves or to the breaker jet, and compares these results with prototype observations, to derive general recommendations for toe protection.

Papers 13 to 15 analyse the interaction between LCSs and the biological environment. The first analyses intertidal and subtidal infaunal assemblages and mobile fauna, based on results obtained in DELOS study sites in Spain (Mediterranean Sea), in Italy (Adriatic Sea) and UK (English Channel and Atlantic Ocean). The following paper investigates the abundance, diversity and distribution of living organisms growing on LCSs in relation to their design and environmental setting; the influence of design features on epibiotic communities is examined, suggesting criteria to make LCSs more environmentally sound and to allow targeted management of diversity and abundance of natural living resources. The last paper of this group examines the effect of LCSs construction on coastal ecosystems both at local scale (changes to the native assemblages of the areas) and regional scale (species diversity). Design criteria are suggested to mitigate specific impacts on the environment.

Ecological effects of LCS are remarkably site-specific reflecting the complexity and variability of natural systems and environmental conditions characterising the site (Moschella et al.). Generally LCSs produce an increase in biodiversity and generate inshore sedimentation that negatively affects the landward soft bottom habitat (Martin et al.). During LCS design attention should be addressed to (Airoldi et al.):

- promote the development of salubrious areas in the protected zone by increasing the water flow through the structures;
- reduce to the minimum LCS single element and global length to avoid unpredicted large-scale effects and community changes;
- increase structure stability, minimise maintenance works and manage human usage to facilitate settlement/persistence of algae and marine invertebrates and at the same time reduce the ephemeral presence of green algae;
- avoid siltation and scouring near the structure, for instance by increasing toe berm width, since they disturb abundance and composition of epibiotic assemblages;
- increase armour geometric complexity and heterogeneity at any scale, since they promote settlement of organisms and enhance diversity, i.e. prefer rough surfaces with pores and irregular unit shape to regular and smooth blocks;
- assure structure submergence at low-tide, or at least submersion at any tidal cycle, to avoid consequent exsiccation of colonising organisms.

The most significant global result of the project consists of Design Guidelines for LCS construction, covering economic, social, ecological and engineering aspects, to be published by Elsevier in 2006. The design method proposed by the Guidelines is presented in the last paper by Zanuttigh et al. through an example application to a project study site.

3. Conclusion

Tools are available to designers to ensure structural stability of LCSs. Moreover tools are available, mainly in the form of numerical models, to describe with technically sufficient approximations the wave and current system induced by LCS; most of these models are commercial. The effects on beach morphology can be qualitatively derived from a probability weighted average of initial rate of erosion/sedimentation caused by the different

[2] DOI:10.1016/j.coastaleng.2005.10.023. To appear in a later issue of Coastal Engineering.

wave-tide conditions; better results can be obtained with the use of morphological area models that represent the progressive evolution of the bathymetry and its effect on waves, currents and sediment transport.

Most environmental conditions (waves, currents, turbulence, sediment suspension) on the barrier can be reconstructed with these numerical tools; the same is not true for the effects on the biological assemblages growing on/in the barrier because this reconstruction has not been done in a sufficient number of cases to draw verified or empirical conclusions.

Correlations among hydrodynamic conditions and assemblages were determined based on the project study sites; they need however verification or extension for a general application.

The widespread diffusion of defence works was shown to be the cause of the dispersion of some hard bottom species, but no clearly negative effect could be observed in the studied cases due to this dispersion.

The defence of beaches is economically justified where the beach is visited by a sufficient number of persons, or the beach is part of defence system of immobile investments carried out on the backshore. The average value of enjoyment attributed to the beach environment ranges normally between 10 and 20 € per daily visitor; the higher values apply to summer bathing visitors and the lower to the other type of visitors.

Further research is needed to provide a reliable quantitative description of the effects of structures on the coastal sedimentary and biological environment, as well as on the value attributed to these assets by the involved human communities.

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