SCACR2019 – International Short Course/Conference on Applied Coastal Research
Engineering, Geology, Ecology & Management
9th – 11th September 2019 – Bari, Italy

COASTAL EROSION MITIGATION THROUGH EJECTOR DEVICES APPLICATION

A. Bianchini[1], A. Guzzini[2], M. Pellegrini[1], C. Saccani[2], M.G. Gaeta[3] and R. Archetti[3]

Paper topic: Coastal engineering, oceanography, geology & ecology

1. Abstract

To mitigate coastal erosion and harbors siltation several selective strategies are currently available. Among the traditional solutions, an innovative device, i.e. the "ejector", characterized by low operative costs, no environmental impact and able to simultaneously counteract both phenomena, was designed and experimentally tested in laboratory and in field by the University of Bologna starting from 2002. Based on the Venturi's effect, in fact, the device moves sediments from their original position into the basin to another desired position ensuring many advantages such as, but not limited to i) a continuous 24/7 operation, ii) no environmental impact, iii) low operating costs, and iv) benefits to local economies maintaining harbors able to be sailed for all the year. After the technical description of the technology, the demo plant designed and built in the harbor of Cervia (Italy) is completely analyzed.

2. Introduction

It is neither simple nor trivial to identify the best strategy to preserve coasts areas. In fact, there are many different factors that must be taken into consideration such as environmental, social and economic ones. In addition, due to the local specificity of coastal environment, the adopted solution cannot be simply replicated to other coastal areas. Although the difficulties, a clear strategy to manage and to oppose destructive phenomena along the 356.000 km of coasts is required as soon as possible.

Among these, coastal erosion represents a global problem in which a redistribution of sand from the beach face to offshore occurs resulting in a loss of surface and so in serious economic and social damages for the local population (Zhang et al., 2014). In fact, even if coasts areas continuously change due to coastline dynamics and human activities as schematized in (ISPRA, 2008), faster modifications occurred in last years. In particular, it results that almost the 20% of European coasts, i.e. 20.000 km, suffered of serious erosion requiring immediate interventions by the Authorities (Eurosion project, 2004). Also in Italy more than 2.300 km of coasts, i.e. the 30% of the total, are subjected to erosion resulting in a yearly surface loss estimated equal to 15 km^2 of surface area as reported by ISPRA's document. To counteract the phenomenon several strategies were developed and applied during the years such as hard/soft protection measures, accommodation, beach nourishment, managed retreat or sacrifice areas (Lamberti et al., 2005; de Jonge and Neal, 2018; Gracia et al., 2018; Williams, 2018) that were estimated to reach an annual expenditure of 5,4 billion euros/year in 2020 in accordance to Eurosion project's results.

In addition to coastal erosion, siltation also represents a big issue for coastal areas management negatively affecting the human activities of local communities like maritime transportation and tourism (Bianchini et al., 2019). In fact, resulting from a balance between drag force and weight, sediments are mainly deposited where low velocities of stream verify, i.e. at harbor entrance.

[1]Department of Industrial Engineering (DIN) – University of Bologna, Via Fontanelle 40, - 47121 Forlì, Italy. augusto.bianchini@unibo.it, marco.pellegrini3@unibo.it

[2]Department of Industrial Engineering (DIN) – University of Bologna, Viale del Risorgimento 2, - 40136 Bologna, Italy. alessandro.guzzini2@unibo.it, cesare.saccani@unibo.it

[3]Department of Civil, Environmental, Chemical and Materials Engineering (DICAM) – University of Bologna, Viale Risorgimento, 2 - 40136 Bologna, Italy. g.gaeta@unibo.it, renata.archetti@unibo.it

For sediments are mainly deposited where low velocities of stream verify, i.e. at harbor entrance. For these reasons, the sustainable management of ports and channels should also include sediment management as one of the relevant topics. As for coastal erosion, several strategies were proposed and applied in the past to avoid basins and approaches siltation. Among these, dredging technology is the most common one. Being applicable in a broad range of applications with different production rates and working depths, dredging technologies can be divided in mechanical and hydraulic depending on operation principle (Vlasblom, 2003). However, a different approach able to reduce the environmental impacts and to minimize and standardize costs is required to move towards a sustainable sediment management in harbor areas. Anyway, the replacement of traditional solutions, considered as well-known, reliable and widespread technology, is usually opposed by involved stakeholders. Strong arguments are so required to justify the introduction of innovative approach such as, for example but not limited to, i) the need of more competitive approach in smaller marinas and channels, ii) the elimination of periodic interventions to restore the desired water depth with continuous and less impactful restorations, iii) the interference with other nautical activities and iv) the growing attention to the environmental impact of dredging (European Commission, 2000, 1999).

Furthermore, a limitation in the currently applied strategies is that nowadays coastal erosion and siltation are managed separately. To achieve this evolving step, several alternative strategies was proposed through the years (Bianchini et al., 2019). Among these, an innovative device, called the “ejector”, was designed and experimentally tested in laboratory and in field by the University of Bologna starting from 2002. Moving away the sediments that are depositing in the basins, the “ejector” technology aims to restore the natural flow of sediments altered by human activities and infrastructures. Furthermore, based on its working principle, the sediments can also be continuously moved in those areas affected by coastal erosion without environmental impact (Bianchini et al., 2014).

Therefore, justified by the potentials, the paper aims to present the main experimental and field performances of the technology. In the first part, the “ejector” technology is explained and other plant auxiliaries described. In the second part, instead, the demo plant located in Cervia harbor and the integrated numerical modelling are respectively shown and described. Finally, conclusions deriving from the demo plant experience are reported.

3. The ejector technology

Similar to the jet pump concept, the ejector technology is based on the transfer of momentum from a high velocity primary jet flow to a secondary flow even if several differences are present such as the converging section instead of a diffuser, the radial nozzles positioned circularly, the absence of the mixing throat due to the open section chamber configuration realized (figure 1).

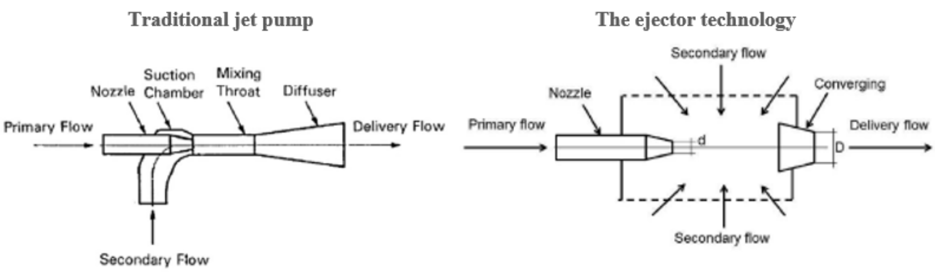

Figure 1. Comparison between traditional jet pump (left) and the ejector technology (right).

Based on the Venturi’s effect, an increase of the dynamic pressure and a decrease of static pressure occur along the nozzle ensuring the suction of the secondary flow that consists of a suspended mixture of seawater and sediments, i.e. the slurry, produced by the high pressure seawater jets from the radial nozzles. Finally, another converging section increases dynamic pressure to discharge the material at a defined distance from the location of the ejector overcoming the exiting pressure drops.

Figure 2. The ejector technology (Bianchni et al., 2014): 3D design (left) and laboratory tests (right).

As shown, no moving parts and no electrical cables are present in the core of the technology minimizing maintenance activities and so operative costs. Although the simplicity of the device, auxiliaries are required for the operation of the plant such as submersible borehole pumps, that pressurize the seawater to be supplied. Mechanical filters are also suggested upstream the device to avoid the entrance of marine flora and fauna within the interstices due to the geometrical tolerances and so nozzles obstruction. Flow regulating and manual valves are the other noteworthy elements. Nevertheless, a sophisticated control system is required to efficiently control the plant as the case of Cervia.

Many benefits can be achieved by the implementation respect to traditional systems. In particular, the most remarkable is that, working with the sediments that naturally come to a certain area, the plant does not add or remove the sediment from that area. Therefore, it is not a dredging activity and so, in accordance to the Italian normative, no authorization is required. Furthermore, placed on the seabed (as well as the pipelines), no barrier against navigation is expected during operation.

4. The demo plant in Cervia

Based on the positive experimental results in laboratory, the "*Life Marinaplan Plus*" project was started the 3rd of October 2016. The project, which total cost results 2,519,245 € of which the 57.7% founded by the European Commission, foresees the realization of 8 main actions (technical, communication, management) including i) the realization of a preliminary onfield test (completed on July 2017), ii) the design, realization (completed in June 2018) and operation of a sand by-passing plant at the Cervia port channel inlet, iii) the techno-economic and environmental assessment of the technology.

Due to the periodically occurrence of siltation phenomenon, the Italian marina of Cervia (lat. 44°16', long. 12°21') was selected for the application of the innovative strategy. Due to the presence of port infrastructure, the natural flow of sediments is strongly influenced resulting in the deposition of sediments at the entrance. However, thanks to the ejectors (figure 3) sediments are bypassed to the discharge direction mitigating the erosion phenomenon occurring in the south area.

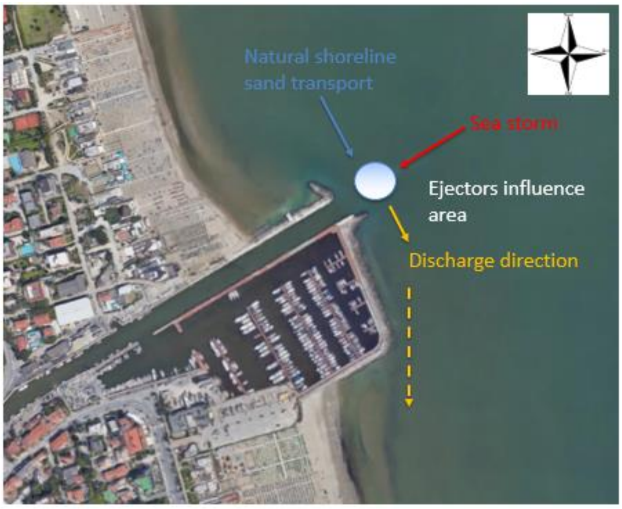

Figure 3. The harbor of Cervia. As shown, ejector restore the natural movement of sediments from North to South that it is currently impeded by the port infrastructure.

The demo plant consists of two identical modules with 5 ejectors each one as shown in the schematic P&ID where it has to be highlighted the high level of redundancy and so of availability expected (figure 4). Pressurized water is fed to each module by dedicated submersible water pumps that can be controlled remotely by inverter in accordance to plant operative protocol. Downstream to the pumps two autopurging disk filters are installed (filtration grade over 400 micron). For monitoring and control purposes, the several data are continuously monitored like as pumps outlet pressure, pressure loss on the filters, water flowrate for each ejector. Wind velocity and direction are also measured and recorded by a local meteorological station to be used as input for plant control during the years. Finally, two cameras are installed for the video monitoring of the harbor channel inlet and of the filtering cabin as an additional input for plant control.

Figure 4. Plant P&ID (left) and some pictures taken during the installation (right).

Contemporary with experimental activities, coupled wave - hydrodynamics simulations were elaborated in order i) to help in the prediction of the areas at risk of sediment accumulation and ii) to optimize the control of the ejectors in relation to the sea conditions. The scenarios' based approach by means of multiple-nesting modelling system (Samaras et al., 2016; Gaeta et al., 2016) aims to establish an efficient and computationally reasonable method for the operational use. The implemented methodology comprises the following steps:

1. *Set-up of the numerical model*. Detailed bathymetry of the Cervia port and navigation channel on April, 2019 were used. The unstructured mesh was implemented with two different densities for the resolution, from 5 m (close to the port) up to 200 m (offshore). MIKE21 by DHI was used to implement the approach and investigate its operational use for the management of the ejectors system.
2. *Scenarios definition on the basis of the meteocean climate of the study site*. Collected data from buoy and gauges between 2007 and 2019 were used to define the dataset for scenarios' runs considering 5 aggregated parameters, divided in number of classes, consisting on wave height, period and direction, sea level and outlet discharge.
3. *Running of simulations for each scenario*. The defined scenarios were used (in sequence) as boundary conditions for the model runs, resulting in an extensive data set of wave and hydro-morphodynamics features on the entire computational domain. The wave-hydrodynamics patterns of the site were numerically obtained: spectral and hydrodynamics modules were coupled to simulate all the possible scenarios.
4. *Storage of the numerical results for the entire computational domain*. Data are properly stored in NetCDF files.
5. *Extraction of local data.* Operatively, once obtained the forecast weather offshore Cervia from National or Regional Forecating system, a query algorithm implemented in Matlab will provide sea conditions at the port entrance, which can help to optimize the control of the ejectors.

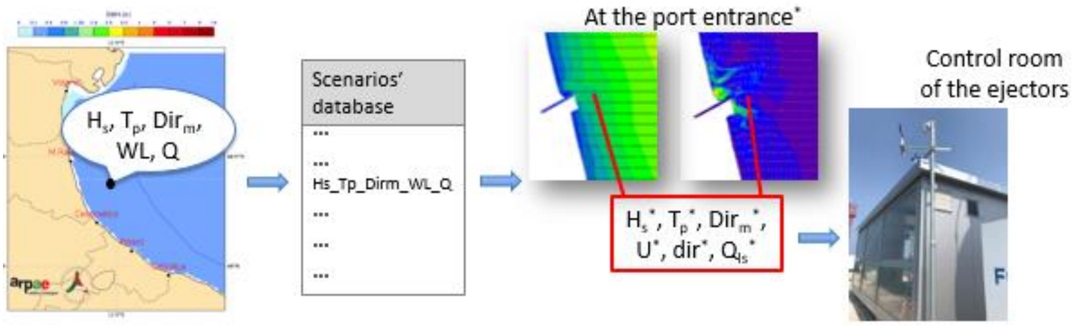

Figure 5. Modelling chain for Cervia harbor.

5. Conclusions

Although the positive results obtained during preliminary tests, monitoring actions are required to verify the economic sustainability of the ejectors technology with particular attention to maintenance. Also the environment impact on the local marine flora and fauna due to the 24/7 operation should be carefully evaluated to evaluate.

However, the best performances of the plant should be searched optimizing control procedures. Therefore, no trivial control logic should be expected. For the purpose, process data measured by in field instruments are considered essential to evaluate operation ranges, energy consumption and the presence of trends/anomalies so to optimize operative costs ensuring the maintenance of a defined depth at the entrance of the basin. Also environment data can help the best control of the plant increasing sediments transportation potential as a function of the expected sand movement following meteorological phenomena.

To highlight the technological content of the proposed solution, in addition to the instrumentation also a dedicated modeling chain was developed. The scenarios' based approach by means of coupled wave-hydrodynamics model is of the essence in the framework of an operational system – response speed. The combination of the specific interpolation method with an adequately high number of defined scenarios is deemed to deliver the best performance overall due to its simplicity. The approach could represent a valid tool in the management of the ejector system giving a possible contribution in the coastal mitigation due to their sediment movimentation at the port entrance.

Thanks to the combination of monitoring actions and implemented modelling, it will be also possible to evaluate the coastal erosion mitigation potential of the demo plant installed in Cervia.

References

Bianchni, A., Pellegrini, M., Saccani, C., 2014. Zero environmental impact plant for seabed maintenance, *4th International Symposium on Sediment Management* (I2SM).

Bianchini, A., Cento, F., Guzzini, A., Pellegrini, M., Saccani, C., 2019. Sediment management in coastal infrastructures: Techno-economic and environmental impact assessment of alternative technologies to dredging. *Jornal of Environmental Management*, 248, pp. 1-17.

de Jonge, V.N., Neal, W., 2018. How to make Integrated Coastal Erosion Management a reality. *Ocean & Coastal Management*, 156, pp. 290-299.

European Commission, 2000. Directive 2000/60/EC.

European Commission, 1999. Directive 1999/31/EC.

Eurosion project, 2004. Living with coastal erosion in Europe: Sediment and Space for Sustainability.

Gaeta, M.G., Samaras, A.G., Federico, I., Archetti, R., Maicu, F. and Lorenzetti, G., 2016. A coupled wave – 3D hydro- dynamics model of the Taranto Sea (Italy): a multiple-nesting approach. *Natural Hazards and Earth System Sciences*, 16 (9), pp. 2071-2083.

Gracia, A., Rangel-Buitrago, N., Oakley, J.A., Williams, A.T., 2018. Use of ecosystems in coastal erosion management. *Ocean & Coastal Management*, 156, 277-289.

ISPRA, 2008. Coastal areas. *Annuario 2008*, pp. 257-292.

Lamberti, A., Archetti, R., Kramer, M., Paphitis, D., Mosso, C., Di Risio, M., 2005. European experience of low crested structures for coastal management. *Coastal Engineering*, 52 (10-11), pp. 841-866.

Samaras, A.G., Gaeta, M.G., Miquel, A.M. and Archetti, R., 2016. High resolution wave and hydrodynamics modelling in coastal areas: operational applications for coastal planning, decision support and assessment. *Natural Hazards and Earth System Sciences*, 16 (6), pp. 1499-1518.

Vlasblom, W., 2003. Dredging equipment and technology - Central Dredging Association. URL https://dredging.org/content/content.asp?menu=1000_53.

Williams, A.T., 2018. The management of coastal erosion. *Ocean & Coastal Management*, 156, pp. 4-20.

Zhang, K., Leatherman, S.P., Douglas, B.C., 2014. Global Warming and Coastal Erosion. *Climatic Change*, 64, pp. 41-58.