Management of waste in Civil engineering: a new decision support software for the reuse of dredged sediments

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Keywords: dredged sediment, sediment treatment, optimization software, decision-making tool, costs, environmental impact.
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Dredging and cleaning campaigns in harbors are essential to ensure their quality of service, leading to the production of over 600 Mm^3 of sedimental waste per annum worldwide (Kasmi, 2016). However, regulations on the management of sediments are increasingly constraining due to the presence of pollutants such as polycyclic aromatic hydrocarbons and heavy metals. To minimize the adverse environmental impact of dredging operations, alternative management methods, as opposed to traditional ones such as immersion, need to be found to overcome this issue. As the field of civil engineering consumes large amounts of natural materials while the risk of depletion is real, sediments represent a potential substitute for natural materials. Nevertheless, sediments shall be properly treated before reuse in civil engineering works to improve their environmental and mechanical properties (Zentar, 2012) and used following the environmental, technical and economic requirements of the project.

In this context, a new open-source software was designed, aiming to the optimization of the treatment process and incorporation of dredged sediments as secondary raw materials for civil engineering applications such as road application, concrete, dike or agricultural spreading. One case study based on real data was then implemented in the software for the optimization of sediments to be used in road construction.

The optimization process embedded in the software is composed of three modules: input data, optimization parts, and displaying of the optimal solution (Figure 1). In the input data module, the user fills in information about the project, the sediments, the raw materials, the treatment center and the storage center, which are required for the computation and the launching of the simulation. GPS coordinates of all elements are, for example, crucial data to be indicated, as the geolocation allows calculating distances and costs related to transportation. In that way, the overall cost of the project can be precisely assessed.

In the optimization module, all the constraints related to the project are mathematically modeled. Indeed, to be used as raw materials, sediments may undergo several treatments before use to fulfil various environmental, technical and economic constraints. Technical and environmental requirements such as contaminants and organic matter amounts, the granulometry, the compressive strength or geotechnical characteristics, are specific to each application and defined according to current regulations. These constraints are modeled in the software by linear or nonlinear mathematical equations and the effect of available treatments (chemical, thermal, electrokinetic, etc.) is also taken into account. While the user has defined the desired threshold values of each parameter, and depending on the input data, the optimization computation can be carried out.

Finally, in the solution module, the detailed optimal solution which satisfies better the environmental requirements at a lower cost is proposed and displayed. Details include the selected materials, the proportion of each constituent of the mixture, the treatment centers and the applied treatments, the impacted parameters, the resulting environmental and technical properties of the mixture and the detailed associated costs.

A real case study was performed as a test of the software, based on a road construction project located in Lille, France and according to French standards. Three sediments (A2, B2, C3) dredged from three different rivers of the north of France were physically and chemically characterized, and used. Software inputs concerning them were the GPS coordinates of their capture points, the water content, the organic matter content, the absolute density of the solid grains, the particle size analysis, the methylene blue value, the liquidity limits and the pollutant levels. Other information was also inserted such as elements about treatments (type, impacted parameters, costs, etc.), treatment and storage centers GPS coordinates and acceptability limits.

Based on the input data, the software proposed a mixture combining the three sediments A2 (5.29%), B2 (22.57%) and C3 (2.43%) with two natural sands M1 (22.17%) and M2 (44.52%) as the optimal solution that best corresponds to the environmental and technical constraints and for the lower cost (Figure 2). To get the organic matter content of the sediments to decrease under the acceptable bound of 3% (SETRA 2000) and lower the pollutants concentrations for road application, treatments centers T1 and T2 were also proposed.

In this contribution, a new decision support software for the optimization of the treatment and the reuse of dredged sediments in civil engineering was presented. This software takes into account the type of application and environmental, technical and economic constraints modeled as mathematical equations to be solved, and proposes an optimal low-cost solution. It was shown to be valid upon the simulation of a road construction real case study.

References

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Figure 1. Architecture of the software operations.

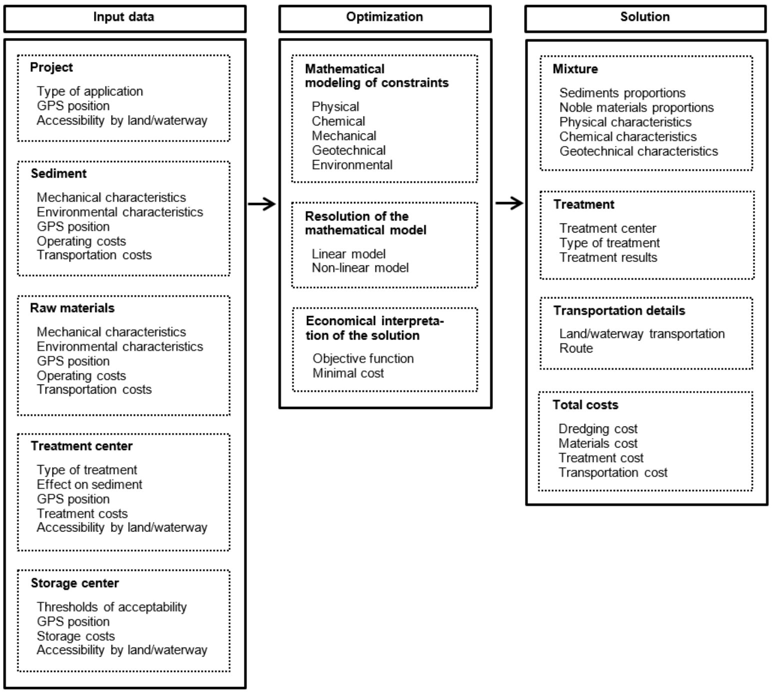

Figure 2. Proposed optimal solution computed by the software.