Solid foundations for dredging projects

Land reclamation projects offer a means of expanding living space, which is essential to meeting the needs of the growing global population, but effective defensive structures are required first. Alexander Rohe tells us about the MPM-DREDGE project's work in developing a numerical tool to model soil-water interactions.

A number of land reclamation projects have been completed over the last few years, including Hong Kong's new international airport, the artificial Palm Islands just off the Dubai coast and Rotterdam harbour, all of which were built on land reclaimed from the sea. All were extremely complex, large-scale projects which involved displacing large volumes of water and soil, an area which forms the primary research focus for the MPM-DREDGE project. “We are aiming to develop numerical tools for engineers in order to model large deformations of soils in contact with water,” explains Alexander Rohe, the project coordinator. While dredging companies hold deep technical expertise and knowledge of soil-water interaction, Rohe believes that they would benefit from the sophisticated numerical tools the project is developing. “Dredging companies have highly experienced operators on their vessels, who are familiar with the local situation. They know the environment and they know the soils, but that can be improved in a scientific way,” he says.

The starting point in this is a deep understanding of soil composition. Soil in coastal areas is mainly quite sandy, and is liable to being eroded by the movement of water. “During water flow the water can erode the soil, so the sand can be carried away with the water. Then the impact of waves on the shoreline, or on dykes, can cause erosion and affect structures, like for example flood defences,” outlines Rohe. Dredging of soil can cause further disruption; the project is developing a numerical software tool for dredging companies, aiming to model the impact of soil-water interactions, covering both solid and fluid mechanics. “Traditionally the disciplines of soil mechanics and hydraulics were rather separated – because one is a solid and one is a liquid. They were usually seen as two different fields of study, and separate companies were focusing on these aspects,” says Rohe. “The novelty of this new software is that it can cover both fields of engineering – so both solid mechanics as well as the fluid mechanics.”

Industrial application

Researchers are focusing on three major applications of this software related to the dredging industry. The first is the use of geocontainers, which are often used to provide added protection for harbour entrances from the sea, or for shore protection. “These geocontainers are like large bags filled with sand, with dimensions of maybe 50 metres x 20 x 10. They are dropped onto the sea floor and stacked up to protect the area behind against the waves,” explains Rohe. These geocontainers are likely to significantly deform when they are dropped into water, which Rohe says is an important consideration for the dredging company. “The water flows through the soil in the bag and around the side of it – as such it influences how the bag deforms and how it settles onto the sea bottom,” he points out. “This will also play a role in determining how strong these bags need to be and how many of them you would need. So the better you are able to install them, to drop them, then the less construction material you will need. That's a key driver of this research.”

The second major application of the project's research is in modelling liquefaction, the process by which a solid becomes a liquid. When the amount of water in a particular area of soil increases to a critical degree, then the surrounding sand will lose its strength and flow away. “If the amount of water in a formation of soil on a slope changes, whether due to currents, waves, or to an inclination of the slope itself, then this slope can become unstable. The slope will then fail, so it will...”
be liquified, and it will flow into the sea. This process can happen very quickly,” says Rohe. The project’s work is also relevant to modelling erosion processes; the tool is designed to help dredging companies understand how their operations will affect soil-water interactions, and tailor their work accordingly. “With this software tool you can establish parametric studies, and you can identify the significant influences on the process itself. Then you can focus your investigations on these particular parameters, and develop a more efficient and robust design,” continues Rohe.

Land reclamation
This is of course crucially important to land reclamation projects, which must be built on solid foundations, particularly in flood protection and offshore applications like oil and gas. The project is working with four European dredging companies involved in offshore applications, and researchers are collaborating closely with industry in the development and eventual validation of the numerical tool. “We will try to identify their needs, and we will get some data from them, to validate our work,” says Rohe. The validation of the tool involves work on several different levels. “We will thoroughly test the individual parts of the software with known mathematical solutions. That’s possible only for very simple cases – the next step would be to compare it to laboratory experiments,” says Rohe. “For example, you could apply some water flow to a one metre high column of sand, and see how the sand grains behave. This can be simulated with the developed software, and then we compare the experimental data with our numerical data.”

The next step will be to compare the numerical results with field data. Beyond the project’s immediate objectives, and the testing and validation of the software tool, Rohe believes there is scope for further development. “This research is only a first step towards a more general design tool – this is quite a novel tool – in which you can model both solids and liquids. There’s a lot of work to be done to make this tool attractive for engineering companies, and it will also be important to provide training and education to engineers in using these sophisticated models,” he says. The goal within the project is to prove the applicability of the software to the three applications that have been identified; beyond this initial objective, new questions arise. “Can we use the software for similar problems, which are slightly different in terms of soil properties?” asks Rohe. “It could be not only sand, it could also be other types of soils, or other ways of water interacting with soils. Currently we are mainly focusing on liquefaction and erosion processes, but in future we could also think about other problems.”