Port expansion through land reclamation

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When you sail into Rotterdam's Europort and see the new Maasvlakte 2, enter the Khalifa Port and Industrial Zone Project (KPIZ) in Abu Dhabi or visit Hong Kong's container terminals, it's hard to imagine that these areas were once simply wide expanses of water. These port expansion projects are just a few of the many infrastructure developments that owe their existence to the wonders of dredging and land reclamation.

Land reclamation is land that seemingly appears out of nowhere. And how do dredging contractors create something from nothing? These mega-infrastructures are in fact the domain of engineers specialised in the planning, design and construction of land reclamation using hydraulic fill. And such constructions are only possible because of the dredging industry's innovative and intensive work, both theoretical and practical, into the characteristics of hydraulic fill. Without suitable hydraulic fill, land reclamation for port expansions would not be possible.

Yet, despite its economic importance, a thorough study of hydraulic fill has long been overlooked in the literature of dredging - until now. Only recently, after several years of rigorous research and writing, with contributions from a score of highly respected engineers, is hydraulic fill getting the attention it deserves.

The recently published book, Hydraulic Fill Manual for Dredging and Land Reclamation Works (2012) was guided into existence under the stewardship of the Construction Industry Research and Information Association (CIRIA) and CUR Building & Infrastructure. Its two editor-experts in the field, Jan van 't Hoff and Art Nooy van der Kolff clearly and comprehensively tackle the complexities of hydraulic fill operations.

What is hydraulic fill?

Hydraulic fill is the process where sediment or rock excavated by dredgers from the seabed or other borrow areas, is transported and ultimately placed into the designated reclamation area. For each of these phases of excavation, transport and placement, a hydraulic filling method is used, meaning that a soil and water mixture is created to facilitate dredging, transport or placement of the fill material. The fill material is then placed as a mixture of the fill (sand) and water into the reclamation site.

But this is the simple mechanics. Before a land reclamation project can commence, months or often years of research are invested in determining the best possible work methods and the availability and suitability of the hydraulic fill. The question that has to be asked is: Will the hydraulic fill be able to bear the buildings, the cranes and other infrastructure for the newly developed/extended port?

How to build a land reclamation site

To begin with, the foundation of constructing a safe reclamation site is collecting a wide range of data. Data collection includes desk studies, field work and laboratory testing. It means gathering bathymetrical and topographical data and geological and geotechnical information in both the borrow and reclamation areas. Add to that hydraulic, meteorological and environmental data and then follow this with reporting on soil and rock classifications and descriptions using various internationally accepted standards.

This data is used during the pre-construction, construction and post-construction stages. Geostatistical methods will be used to develop models of the borrow and reclamation areas. All this information can ultimately be applied to an environmental impact assessment, which in most countries is a requirement in order to get work permits.

Choosing the right equipment

Choices also need to be made about the appropriate dredging equipment. This includes equipment used for acquiring the hydraulic fill, for transporting it and for placing it.

Each type of equipment, trailing suction hoppers, cutting suction dredgers and barges, pipelines and pumps, has different characteristics that determine the suitability for a particular type of soil, rock, sediment in a particular setting and accounting for the waves and swell, the currents and water temperature.

Where is the borrow site and how far away is the reclamation site? How deep is the water? Are you dredging in a busy shipping channel or a quiet waterway? These and many other questions

Brazil Superporto do Açu development

All photos courtesy of IADC/Terra et Aqua

Trailer rainbowing hydraulic fill

Soil consolidation using vertical drains

Soil compaction using bulldozers

must be asked, answered and factored into the project operations to determine the feasibility and cost calculation for the project.

Not all sand is equal

High on the list of priorities when considering the feasibility of a land reclamation project is selecting a borrow area. Since not all sand is equal, evaluations have to be made and these are based on the availability, the suitability and the quality of the potential fill material. The nature of the fill and its in-situ characteristics will influence the type of equipment, the means of transport, the method of reclamation and the possible need for ground improvement techniques.

Landfills are preferably constructed with well-graded quartz sands. But suppose that sufficient, good quality fill material located at a reasonable distance from the land reclamation site is not available. Then what? Are alternative materials available and more realistic? Sometimes the next best cost-effective solution is to improve the properties of what is available and accessible.

Land reclamation platform for the new Khalifa port, Abu Dhabi

When ground improvement is necessary

That said, repairing or improving non-compliant fill is not always easy and can be a challenge, time consuming and costly. On the other hand, under certain circumstances, repair or improvement may be the next best solution. For instance, the use of vertical drains or vibratory, dynamic or explosive compaction with or without admixtures can be acceptable.

Other methods may be soil replacement to improve the subsoil, stone columns, sand compaction piles and/or geotextile encased columns. The choices are highly technical and demand good engineering guidance by experts as each of these methods must be studied in a case-by-case, site-specific calculation.

Consider the future use of the reclaimed land

One clear engineering rule applies: match the anticipated loading response of the fill mass to the requirements imposed by the future use of the reclaimed land. That is the function within the technical boundaries of the project. These technical boundaries should be reasonable, measurable and feasible.

This means that if you are building or expanding a port, consider the functional requirements, such as the heavy machinery, cranes and buildings as well as road traffic that will be coming and going on the site. Then consider the boundary conditions. What is the nature of the soil and subsoil? What is the likelihood of earthquakes, flooding or other natural events? Then consider the uncertainties, failure probabilities and safety margins.

Guaranteeing the quality of the fill

After the completion of a filling operation, the reclaimed land must be able to guarantee the stability of the structures to be built upon it will be completely trustworthy. Uncertainties and failure probabilities will always be present however, and to minimise risks a design must determine safety margins. Predictions and calculations should focus on performance criteria that consider stress-induced deformations, liquefaction, drainage capacity and protection against flooding and erosion.

The quality of the reclamation will all come down to the basic properties of the fill mass: its strength (bearing capacity and slope stability), stiffness (settlement), density (resistance to liquefaction), permeability (drainage capacity) and the elevation of the fill mass (as a safety against flooding).

Determining these factors requires specific engineering knowledge and is far from simple. And the consequences of not doing due diligence can be severe. The failure to evaluate these properties can result in poor quality fill material. And poor quality fill material can cause serious problems, resulting in dangerous unstable foundations for a reclamation area.

Hydraulic fill is complex

A land reclamation project is a complex process and clearly not an overnight happening. To address all the aspects of a hydraulic fill project demands highly qualified engineers as well as the full commitment of clients, consultants, technical and financial advisors. It demands technical expertise, contractual expertise and extensive planning from all parties. Dredging contractors and sub-contractors have a wealth of skills and information that can make an enormous contribution to this process.

This brief survey is the tip of the iceberg. And it comes with a caveat: you may not know what you do not know about hydraulic fill. If you are thinking about a land reclamation project to build a new port or expand an existing one, think about finding a good team of engineers who can lead you through the maze of requirements to reach a successful outcome. And never underestimate the importance of getting the right hydraulic fill for your project.

The new Khalifa Port and Industrial Zone (KPIZ), Abu Dhabi was a large-scale design, that included the relocation of Port Zayed from central Abu Dhabi to Al Taweelah.

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ABOUT THE AUTHOR

Photo by Jim Wilson

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ABOUT THE ORGANISATION

The International Association of Dredging Companies (IADC) is the global umbrella organisation for contractors in the private dredging industry. It is dedicated to promoting the skills, integrity and reliability of its members, as well as the dredging industry in general. IADC has over one hundred main and associated members. Together they represent the forefront of the dredging industry. IADC's mission is to inform the world about the economic, social, technological and environmental benefits of dredging; improve the international business climate for the private dredging industry; promote fair contract conditions and fair competition; promote worldwide the Standards of Professional Conduct which form the basis for all members' operations; and present the industry's attractive career opportunities.

ENQUIRIES

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