Design of coastal infrastructure; a look at the basics

J. Overbeek, Delta Marine Consultants bv (Singapore Branch), Singapore

Coastal infrastructure, as referred to in this article, includes the full range of features, from jetties and quays, breakwaters and groins to beaches and shore protection. The actual design of each particular type of structure and facility is very different but all design work is reliant upon the same basic environmental data. In addition the usual statement 'garbage in, garbage out' holds true here also.

In this short article we will try and highlight some of the more important considerations in relation to the risks associated with environmental data by reference to several recent projects as examples.

Coastal developments

When the development of coastal infrastructure is considered, be it a 'new' beach or an oil terminal, it appears self-evident that environmental factors such as currents, waves and winds together with geotechnical conditions at that location are important starting points for the knowledge base for the development.

The environmental conditions influence stability of the coastline, type of foundation, levels of platforms or breakwaters, loads on structures, movements of vessels, environmental impact and the like. All are important factors in determining the technical and economical viability of a development or facility.

Though many developers would openly acknowledge that they fully realise the importance of the foregoing aspects, it is our experience that few appreciate the magnitude of the influence of environmental factors. In addition we have found that amongst those who do, there is a significant spread in the degree of client risk that they would be willing to assume arising from adverse influence of environmental factors on design.

Sample case A

There was a request to review the environmental data and its interpretation for a greenfield project in Indonesia. An impressive factual data report and interpretation report were submitted which on first glance looked well performed.

Though in certain respects this impression was correct, a significant problem was that the measurements were taken outside of the monsoon season and that the statistical analysis therefore did not incorporate these, leading to a significant under-estimation of the maximum wave height. This fact would either lead to periods of down-time or required the construction of a breakwater to reduce this downtime. Both were equally unacceptable to client.

Environmental modeling

Though there are planned developments in or near existing facilities or in established ports where significant amounts of data are available equally, often this is not the case. At green-field development sites or in developing ports detailed data may be unavailable, insufficient or subject to change. Recent examples from our experience include a project on Java in Indonesia where no local measurements are available despite the presence of nearby facilities, and a project in Singapore where, due to the ongoing land reclamation, no hard data is yet available on the situation that may result from the final configuration of the land. In both cases mathematical modeling was used to determine the design currents, waves and winds for the projects.

An example of failed slope protection in a coastal development project.

Sample case B

A major port project in Asia, during its FEED stage, was 'moved' several kilometers along the coast for apparent good reasons. The client was however unwilling to invest in additional soil investigation at the new site and decided to prepare the EPC tender based on the available data.

The lack of this data led to the refusal of reputable contractors to assume the risks of the ground conditions and others were not prepared to bid.

Apart from the cost involved in the process it lead to considerable delays in the project start-up.

Sample case C

For a major new terminal development in Singapore the current profiles near the berth were very important for several reasons, including navigation. Extensive numerical modeling was carried-out with a calibrated model to determine current speeds, directions and possible operating windows.

Though the models and studies are not fully conclusive they have focused attention on possible problem areas and influenced the design and decision making process of client and authorities leading to acceptance of the project by the latter.

Statistical analysis and theoretical (mathematical) models have a relatively long track record and in many cases have demonstrated that they can be as dependable as forecasting tools but their accuracy is highly dependant on the quantity, quality and time-span of the input data. Clearly the quality and reliability of the results can at best only be as good as that of the input data. As the wave, current and wind output of these exercises is generally used as the input for other models or studies, such as navigation studies or downtime assessments any significant error in the results from mathematical models could have considerable impact on the long term viability and cost of the development considered.

Data and data collection

Currents, water levels and waves indicate daily, monthly, yearly and even longer cycles. In some locations the variations are small over any of the periods considered and a relatively short duration of observations may be sufficient to make reasonable predictions for the future. In other locations the minimum recommended duration of the period of observation as would enable accurate prediction would be at least one year. In certain situations it may also be argued that one year would not be sufficient.

A measurement campaign of several months to a year is a costly exercise and generally also forms a problem for clients wishing to make decisions on a (relatively) short time frame. This apart from the fact that such a campaign in a remote site can easily lead to loss of equipment, for a variety of reasons. Data corruption due to various reasons is also not unheard of.

Long(er) term data is available from sources such as ship observations and, more recently, satellite measurements but are, almost by definition, limited in their level of detail and/or duration. As a result they can be used to model and simulate data for a larger area but are not necessarily well-suited for detailed predictions near the project. Similar to the above geotechnical data, which is sometimes provided, can be scattered and limited in detail and is not always suited for all purposes i.e. sufficient data for a pile design may not be sufficient for settlement calculations or sedimentation transport studies, or vice versa.

Risks

Many more issues could be added to the above mentioned items and it would certainly be possible to provide further elaboration but it is necessary to consider the question: "Why bother about them in the first place?" The answers to this question include: Risk and Uncertainty.

If the reader has already reviewed the sample cases included in this article it is hopefully clear that the risks can have several dimensions, from initial contractual risks at several levels to long term risks associated with operability and perhaps also reputation of the parties.

Two of the main problems faced by the consultant are the perception of such risks within the client organisation and the immediate pressure(s) of project budgets. The cost and time involved in performing studies and investigations are easily quantifiable whereas the advantages or savings that might be gained are often not, even in hindsight as, unless two 'versions' of the project are realised, no direct comparison is possible. This difficulty is most clearly notable in advance of such studies and sometimes also following the study when probabilities are involved.

When designing coastal infrastructure in particular the concept of the 'return period' is a particular issue. When a design wave with a return period of say 1/100 years or more is mentioned a not uncommon reaction is 'but the design life is only x years' or similar remarks. Few people, including many engineers, have more than a passing familiarity with statistical analysis and fully appreciate the chances and risks associated with the probabilities of occurrence. Moreover, remembering the adage: "There are three kinds of lies: Lies, damned lies and statistics," statistical data and by extension probabilistic design is not always trusted. If the data that forms the basis of the statistics may furthermore be potentially flawed or otherwise insufficient to be reliable the adverse risks are significantly increased but are even less quantifiable.

It is not the intention of this article to provide a discussion on statistics or risk assessment but it is hoped that the foregoing and the examples make it clear that lack of (reliable) data can be a serious problem. Engineers, though often considered unimaginative, are often able to 'make do' with whatever limited information is available and produce something that looks wholly realistic and reasonable but there is a limit to which a responsible engineer can go. The consultant should make the potential consequences of lack of data as clear as possible to a client and the client should be open to discuss such issues before finally deciding to take the risk to 'make do.'

ABOUT THE AUTHOR AND THE COMPANY

J. Overbeek is the branch manager of Delta Marine Consultants bv (Singapore Branch).

Since its formation more then twenty five years ago, **Delta Marine Consultants** (DMC) has been focused on the various aspects of civil engineering connected with the boundary between land and all bodies of water. Their experience of ports and harbours has developed throughout this period along with expertise of many different engineering problems. Whilst operating worldwide as an independent Consultant, within parent company Royal BAM Group, DMC have also become very familiar with many forms of Design & Construct projects, including engineering Procurement and Construction, Build, Operate, Transfer and the like. DMC is able to operate as an effective partner of choice whatever the preferred form of contract.

ENQUIRIES

Delta Marine Consultants bv Singapore Branch
6001 Beach Road #10-06 Golden Mile Tower
Singapore 199589
Tel: + 65 62943033
Fax: + 65 62999283
Email: info@dmc-singapore.com.sg
Website: www.dmc.nl