Effects of breakwater in the civil engineering field construction essay

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Problems of erosion, reduction in shorelines, disappearance of beaches, and environmental impacts have led to the recession of many economies around the world. To

resolve, engineers have devised man made structures like breakwaters and piers to address a variety of coastal problems such as shelter, fishing, docking and coast line

recession. While these problems are resolved, new ones emerge when breakwaters and jetties are constructed in the areas. Clearly, breakwater engineering and related civil engineering fields are still at their rudimentary level, despite the fact that these structures have been in use since age old. In the following study, the researcher carries out investigation into the hydrodynamics of breakwaters, and their engineering aspects, with the view to gain insight into their importance to civil engineering fields. The researcher aims to explore, evaluate and analyse the impact of breakwaters on engineering professions, and ways that their knowledge limits or opens up new channels for engineering innovation. The results are compiled, and the researcher concludes that breakwater engineering has great scope in contributing to civil engineering knowledge, provided that its design and applications are researched further.

Chapter 1 Introduction

Background and Rationale

A coast is a geological system that is subject to constant movement and change. Shorelines, beaches, and coastal areas in effect affect human lives, and vice versa. The diverse and complex nature of the coastal system is the result of processes involving waves, tides, currents and winds that affect the geological state of the coast in an attempt to keep a balance between land and water. However, these are not the only factors that influence and shape coastlines. Human activities for economic and social purposes contribute towards its modifications. Natural processes, coupled with human intervention, contribute towards erosion, sedimentation, and accretion (Hsu, Lin, and Tseng 2007). In fact, according to French (1997), human activities bring about changes that influence the environment adversely by creating new habitat and decreasing environment stability.

Though not all changes affect the environment adversely, nevertheless the natural processes are affected by the unnatural conditions. Coasts and estuaries are not indifferent towards human intervention where a range of variations in their structure and environment can alter the geological, oceanological and marine system therein. Added to this status is the fact that coasts have become the ideal place for human population, industrialisation, commercialisation transportation etc. Human has, in effect, taken over to develop coastal areas to act as shelters, ports, docks, and for numerous other activities. The pressure for benefitting human lives has inevitably changed the environment drastically towards degradation. To compensate, a host of management strategies have been undertaken to operate, manage and sustain coastal areas, to control the activities and maintain a balance between nature and mankind (d'Angremond and van Roode 2004).

One of these management control methods is building of breakwaters and jetties. Jetties and offshore breakwaters are man made structures designed to protect coastal areas from the natural and unnatural recession of the shoreline. Breakwaters are usually built parallel to the shore or at an angle to direct serious wave action from its destructive impact on the shoreline. Jetties, on the other hand, are built with the purpose to prevent erosion of the inlet or harbour area. Offshore breakwaters provide shelter as they are built based on wave refraction and diffraction (Putnam and Arthur, 1948). Similarly, groins are structures built to face seawards and at an angle to slope at the same angle as the normal beach. Groins are built at an elevation above datum to act as the stabilising structure and to increase the width of the beach by arresting the shore drift in part or as a whole (Paige 1950).

Apart from these, coastal areas are subjected to geological problems such as natural processes including coastal erosion, deposition, sedimentation, tsunami, tidal

waves etc. These require human intervention to protect and conserve human and natural habitat. For these purposes, an engineering field called coastal engineering has been introduced in the academic arena for enhancing the knowledge and skills of professionals to develop coastal areas with minimal damage to the natural and man made environment.

Coastal engineering involves developing and protecting existing coastal protection work with the view to predict future natural coastal processes. Comprehending the nature and value of coastal processes, enables engineers to devise plans and strategies to protect these processes better.

Moreover, knowledge of the coastal condition helps professionals in the field to construct, facilitate and execute better breakwater construction. Breakwater construction is a field that is directly related with coastal engineering.

However, it also has close relations with other engineering fields like geology, construction, environment and computer engineering. It is within this context, that the

researcher shall be investigating the importance of breakwater engineering and the ways it affects the engineering field.

Aims and Objectives

The aim of this dissertation is to investigate how breakwaters and their construction affect various civil engineering fields. The objective is to:

a. Identify the various civil engineering fields that breakwaters affect

b. Evaluate how breakwaters impact civil engineering professionals; and

c. Study how the knowledge of breakwater construction adds to the skill knowledge of engineers

Scope and Limitations

The research, in essence, is not a pure scientific empirical study, but rather an exploratory one. The researcher is aware that in exploring the dynamics of breakwater

engineering, he/she will have to link civil engineering techniques and skills, which makes it a successful defence structures for both, humans and marine life. In this context, the study shall limit its discussion to the various fields breakwater construction entails, and shall not delve extensive into any particular field which concerns its engineering perspectives, such as marine life or construction engineering. However, it will touch upon these topics byway, to enumerate on its role and effects on the engineering field. Audience readers shall find the study insightful and enlightening as it would provide the numerous aspects that coastal engineering of breakwaters impact. However, academics and scholars shall find the content of the study limiting as it shall not be holistically technical. Fellow students shall find the dissertation a good stepping stone for furthering their research into areas of specialisation like geological engineering, construction engineering and so on. Nevertheless, the dissertation shall aim to address the social and scientific aspects of breakwaters.

Outline of Dissertation

To accomplish the above objectives, the researcher shall endeavour to carry out the study in the following manner:

Chapter 1 shall introduce the background and the rationale for the study.

Chapter 2 shall provide the theoretical background based on an extensive literature review on the aspects of the study outlined above.

Chapter 3 shall outline the methodologies considered and the rationale for the chosen research approach.

Chapter 4 will be the analysis segment in which the researcher shall evaluate the data gathered, and discuss with the aim to acquire conclusive results.

Chapter 5 shall be the conclusion to the research, offering insights gained from the research, summarising whether the researcher has accomplished the objectives or not, and perhaps some recommendations for future research.

Chapter 2 Literature Review

Introduction

Breakwaters and similar coastal structures are human interventions, which are exposed to strong waves, currents and other marine processes. The construction of such

structures needs to be enduring, as well as fitting, with the natural environment. The design and construction of breakwaters and interrelated structures indicate that

knowledge of pure engineering alone is not practical. In fact, it requires consideration for various empirical and theoretical knowledge for its design. To the extent of this

knowledge, the researcher is of the view that civil engineering relating to large scale hydraulic structures has developed considerably. According to d'Angremond and van

Roode (2004), coastal problems of erosion, tides and currents have existed since the beginning of civilisation. However, the management of these movements and problems have gained considerable attention today due to the commercialization and population of coastal areas around the world. For these reasons, problems such as sea level rise, tidal asymmetry, sedimentation budget etc. need to be tackled. These are carried out through careful coastal defence and management practices, and engineering skills, which shall be discussed in the following sections.

Coastal Engineering

Ocean waves are generated by wind and propagated from the ocean towards the shoreline. The orbital motions of wave kinematics influence the depths and heights of the ocean bed. Near shore ocean beds are greatly impacted by the velocities and the wave strengths. As a result, sediment beds often change in topography due to continuous impact of the fluid forces of waves. Sedimentation response or impact is negligible, but, in effect, compound the problem of sediment transportation to and away from the local beach. The scale, depth, and extent of the influence of the waves on the beach may and may not result in coastal degradation. For these reasons, detailed investigation on the continental shelves, fluid dynamics, near shore motion and variation of ocean topography are required in order to monitor and maintain the natural barrier to land. When the problems of natural erosion and sedimentation become too great to manage, measures like construction of barriers, submerged shoals, breakwaters and artificial headlands are undertaken to sustain the environment (Birbena et al 2006). Construction of this nature is triggered by defence planning, storm handling and flood prevention. In fact, coastal defence system and management require formation of framework for projects to be planned, investigated and implemented to meet the needs of the environment and its people. These are the civil aspects of coastal engineering (French 1997).

Not only this; structures like breakwaters also require continuous monitoring and protection work to predict future performance. This is carried out through coastal

engineering processes such as modelling to estimate the changing environment and angle of repose of shorelines, site investigation to study the cycles of hydrographic and marine life status, as well as processing these to build a profile for the shorelines on which breakwaters are constructed. For example, in Iskander et al’s study (2007), the authors studied and developed a monitoring model for studying coastal structure along the El Agami area of Egypt. The study indicates that where breakwaters exist, shoreline fluctuates, marine life is impacted, as well as wave hydraulics. Coastal engineers need to record and study the gradual change that takes place due to the presence of breakwaters. Issues concerning wave distribution, shoreline sand composition, coastal calibration, marine survey, and effect on the harbours’ population are taken into account. Apart from these, breakwaters also affect the coastal structure such as villages, ports, or other such human activities (Iskander et al 2007).

Furthermore, coastal engineers also need to ensure that the construction of breakwaters and estuaries does not adversely affect human activities as a result of design fault of these structures. For example, in Donnell et al’s article (2006), the authors indicate that the breakwaters on Tedious Creek estuary on the shoreline of Chesapeake

Bay in Dorchester County, MD caused substantial damage to local vessels than the benefits it provided for its shelters. The setup of breakwaters is aimed at protecting the boat dock and public piers from storms, but, in reality, the project’s design fault has resulted in under performance, both in functionality and structure to benefit the locals. It is in instances such as these that coastal engineers need to be ascertained of the need and importance for breakwater structures. Similarly, breakwaters can also result in beach morphology that effectively negates the protection objective when breakwaters are constructed with limited knowledge applied relating to practical engineering. Accurate study of the shore area through cross shore distribution, long shore sedimentation transport rates and performance of breakwaters in advance, as well as using model calibration and validation, hydrodynamic module, wave modules etc. could positively affect the performance of the structures. Therefore, coastal engineers are responsible for studying the wave conditions, down drift side, expected erosion and current patterns behind submerged breakwater, to gauge incident waves. These mechanisms, according to Ranasinghe and Sato (2007), can relatively influence the function and utility of breakwaters’ function. Thus, coastal engineering is greatly influenced by the type and design of breakwaters structures.

Construction engineering

Breakwaters and such coastal structure construction combine design and functionality with the view to protect the coastal area. The design process is similar to structural design of buildings as it entails paying attention to functional requirements, limitations of the state of the structure, exposure, construction phases and occurrence of natural conditions. Breakwaters also require considerations for knowledge of construction materials including quarry stone, concrete blocks, caissons and similar types of materials to apply to its construction. Equipments for both floating and rolling breakwaters too need to be studied and related to the specificity of the breakwaters' site, function and design. The development of breakwaters also requires functional and structural monitoring of performance, with enduring characteristics. According to Camfield and Holmes (1995), coastal structures like breakwaters and jetties are influenced by long periods of water level changes. They need to be built parallel to the entrances, in an attempt to stabilise entrances and safe navigation. Construction along the shore should be carried out with the direction of the channel in mind, to prevent migration of channel thalweg, rapid shoaling and erosion of the coastline (Morang 1992 qt. Camfield and Holmes 1995). This is because construction of jetties and breakwaters often creates a new equilibrium for the tidal system. For this purpose, surveys of adjacent shorelines, natural bypass and the material that may ebb tidal activities need to be carried out for effective construction of the structures aligned with the regional dynamic and hydraulic processes. Construction engineering approach such as cross sectional relationship of inlet and tidal prism, as well as depths of the jetties and breakwaters, and water flows are studied before finding the ideal balance between performance, flow conditions, and natural marine activities.

Knowledge of construction material, as mentioned earlier, is imperative for choosing and designing breakwaters to complement the need of the local landscape and environment. Since breakwaters are made up of rubble mounds or caissons or are concrete filled, knowledge of construction material adds to the skills required for developing structures for dispersing wave currents to minimise impact, as well as conserve energy from wave hydraulics where possible (Arena and Filianoti 2007). Not only this; new construction material knowledge also provides an edge over the design and planning of the breakwater armour unit. Reedijk et al (2008), for example, indicate that the development of Xbloc by Delta Marine Consultants in 2001 has innovated armour concepts in terms of designs, tests and prototypes. Xbloc are concrete blocks designed to armour shore protection and are being used in breakwater construction actively by engineers today. Muttray et al (2003), in their study of the suitability of Xbloc in breakwater construction, indicate that Xbloc are shaped to suit the harsh environmental conditions of waves, and such hydraulic activities. When placed interlocked with each other, Xblocs not only reduce concrete volumes, but also achieve the stability required for achieving breakwaters impact from wave loads and damage (Muttray et al 2003; Reedijk et al (2008). Added to this fact is the cost of layering breakwaters with Xbloc, which is significantly reduced as compared to other armour blocks.

Furthermore, coastal protection design and construction require development and use of probabilistic design tools to gauge uncertainties, prediction of wave impact, as

well as structure stability. One of the main concerns for construction engineers is that the structures can sustain its functionality for coastal protection, regardless of the wave conditions and transformations of water bodies. The basic premise is that wave transformation in foreshores and offshore areas cannot be relied upon through model designs. In fact, it requires construction engineers to have knowledge of coastal shores by using prediction models for wave transformation to study the effect of wave height, setup and distribution before designing the breakwater and jetty structures (Muttray et al 2001; Coduto 1999). Consideration for these aspects would help design structures to achieve its long term goals, as well as retain beach composition from long shore transport processes.

Analytical engineering

Breakwaters are constructed based on engineering approaches and processes that exploit the nature of wave parameters and hydraulics. According to Huizinga (2003), breakwater engineering often fails after 5 to 10 years as a result of poor design. Engineers fail to grasp the concept of breakwater designs and modelling, which uses propagation of water around of breakwater with the assumptions that water is the ideal fluid and incompressible. Waves are small in amplitude and can be analysed using the linear wave theory. Their flow is usually rotational, which can be analysed through Laplace equations. Breakwater’s depth is constant and its dynamics are determined by diffraction, refraction or reflection (Huizinga 2003).

Diffraction analysis takes into account of the water height, and the interaction of breakwater and waves. The wave energy is assumed to disperse as the waves come into contact with breakwater structures, which could be understood using linear diffraction theory. In this context, a rubble mound breakwater is a diametric form, with certain density and diameter designed to disperse wave motion. The velocity of the waves is retarded by its action, in contact with the breakwater. The change in direction of the wave affects the sediment supply, composition, wave properties, topography, and breakwater properties. Therefore, the variables in the breakwater interaction change in response to the caisson. The underlying assumption set forth is that the physical movement of breakwater is associated with the wave action, the permeability of the breakwater surface, seabed composition and response of the breakwater over a long period of time (Huizinga 2003; Twu and Chieu 2000).

Alternatively, wave reflection and wave run up is the model for analysing breakwater through a cross section and slopes. In this method of engineering, wave reflection is determined by the 3 guage method. Wave conditions comprise of relative depth, height, steepness, and breaker index. Measurement of wave conditions is accomplished by analysing its reflection at the seaward direction when the wave surface comes into contact with the structure and foreshore. The water surface comes into contact with the breakwater as a toe and an anti knot. The wave run up and run down impact the breakwater’s wave resistance. When engineers analyse the efficacy and effectiveness of breakwater, they study the angle of the incident wave, as well as its reflection coefficient, to determine the impact of regular wave action. The analysis is critical for gauging the significance of wave run up and run down on breakwater surfaces, and inevitably its longevity. This is achieved by using the higher order wave theory for assimilating waves and horizontal seabed asymmetry. Furthermore, wave reflection measurement is determined by its dynamics such as local wave height, wave pressure, wave energy dissipation and wave penetration into the structure (Muttray and Oumeraci 2002). How waves break or non break is dependent on the breakwater slope and the reflection set for critical wave incident impact (Clyne and Mullarkey 2008).

These analytical approaches are various forms of analytical engineering, which are engaged to evaluate the strength, longevity, efficacy and effectiveness of the breakwater functionality. Alternatives in analytical engineering, therefore, help construction of the breakwaters more effective, as they establish the baseline for stabilisation potential, as well as extend the life cycle of the structure (Wiegel 1962).

Environment engineering

Breakwaters and jetties are engineering solutions to resolve the problem of erosion and sedimentation of shorelines. These are constructed with the view to sustain

the shoreline, and in turn benefit the local human communities. Just as breakwaters and jetties affect the hydraulic system of the areas, they also produce long and short term impacts on marine life. Hydrodynamic conditions, sedimentation patterns, wave motion, physical and chemical factors tend to alter the composition and nature of the habitat. Not only this; the habitat tends to change in its characteristics and life cycle due to the change induced by the presence of breakwaters. No doubt, there is an imperative relationship between biological life form and breakwater structures. Even though breakwaters are developed with the objective to provide shelter to marine life, as well as harbour for human activities, the type of alleviation, shoaling and access to aquatic floral and faunal also gets impacted when breakwaters are constructed without careful monitoring of quality, composition and marine lifecycle. In fact, construction of breakwaters for creating inlets often results in floral and faunal morphology of marine life due to the quality of sand, water chemical properties and the wave action. Water temperature, with variation through seasonal change, substantially affects the fish population, as well as other marine life forms. For example, the components of macrozoobenthos, algaes and polychaetous worms' densities change (increase/decrease) according to the increasing or decreasing water depth. Thus, construction of breakwater tends to adversely affect the micro constituents of marine biology (" Biological effects of breakwater construction" 1985).

At times, colonisation of fishes within the vicinity is affected due to the elevated turbidity's and suspended solids concentrates near the breakwater. Moreover, maintenance of the depth of entrance to the area, and exposure of the same, can alter the sustenance level of fish populations. By streamlining the natural sand bypass, the morphological performance can be improved to simulate waves, currents and sediment transport, which corresponds with the marine life processes (Broker et al 2007). The reliability of the effect of breakwater calibration process ensures that the constructed structure does not hinder marine life forms. For this purpose, marine engineering knowledge, combined with the breakwater development know how, can help local engineers to establish dynamic coastal structures to fit within the parameters of the natural environment.

Risks and failures

While it is clear that breakwaters have their own functionality and utility for which they are used to sustain beach line sustainability and continuity, they are also risky. The utility and functionality of breakwaters and jetties depend on the model, material and simulation upon which they have been based. Measurement for their horizontal and

vertical fluid velocities, breakwater composition (porous or non porous), energy dissipation rate and modification intensity, all contribute towards its impenetrable nature. However, any variation and standard deviation in the design such as surface elevation, velocity variation, calibration, and structure permeability can result in its wear and breakage. According to Kobayashi et al (2007), breakwater permeability can affect its situation in the beach zone, effectiveness in eliminating serious wave impact and structural longevity. In fact, breakwater transformation as a result of wave load, pressure and velocity can lead to shattering. This is dependent on the design of the breakwater and its sensitivity and test against breaker ratio. Steepness of seaward slope, wave breaking motion, and wave parameters greatly influence the structure, to the extent of predicting its durability (Kobayashi et al 2007).

In fact, Oumeraci et al (2006) are of the view that analysis of saturation due to liquefaction phenomena in sand gravity structure tends to increase the risk of structural failure. Vertical breakwaters, especially, are vulnerable to permanent deformation of the subsoil, which leads to irreversible strains at the peak stress level. As a result, breakwaters’ structures can give way to wave load induced by the fluctuation in pressure along the seabed and the pore pressure in the concrete itself. Failure of such monumental nature affects the stability, composition, and cyclic mobility.

Failure is also the result of the nature of the breakwater structure, whether it is designed for offshore or onshore coastal defence. It is greatly influenced by the depth,

and nature of the sand composition underneath the seabed upon which the breakwater is constructed. The relative density of the sand, pressure of the fluid, as well as storm yield, all contribute towards its endurance (Oumeraci et al. 2001).

Apart from these physical risks and failures, breakwaters are also vulnerable in terms of their effect on marine life forms. Changing chemical composition due to

displacement of fauna colonisation, as well a toxicity of the structures along the sediment banks, can result in breakwater biota fluctuations. While the human benefits of

breakwaters last for 5 to 10 years, the long term effects of marine life cycle and fishery can alter the nature of the coast altogether if careful engineering approaches are not undertaken for the construction of breakwaters (“ Biological effects of breakwater construction” 1985).

Conclusion

The above discussion has been carried out with the view to provide an overview of the relationship between breakwater construction and its impact on engineering fields. While engineering is a vast discipline, in this study the researcher has included engineering fields related to the construction of breakwaters and their maintenance. The discussion indicates that breakwater structures are not merely coastal construction monuments, but have multidimensional impact on the physical, biological and human

life. For this purpose, engineering and designing of these structures need to be analysed, planned and implemented with care, for its impact.

Chapter 3 Research Methodology

The nature of research problem determines the choice of its methods. Before one chooses the research method, its objectives, audience and underlying assumptions should be justified. The methodologies are then weighed and evaluated to justify for its choice. The theoretical perspective of the study should provide the background reality, as well as the constituent for increasing reader's knowledge. Within these dimensions epistemology is " concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate" (Crotty 1998). The epistemology, therefore, allows the researcher to decide the application and the underlying academic literature that is required for adding knowledge to the " existing consciousness." Generally, there are two options objectivism and constructionism. The objectivistic approach entails the investigation of existing knowledge and spanning it to extend its consciousness. The aim is to discover the objective truth. On the other hand, the constructionist approach entails the research which requires interaction with the world, and finding the truth in the process.

Underlying the constructionist approach is the premise that research endeavours need to explore views from multiple angles before deciding on the objective truth. This approach is grounded in the qualitative methodology (Crotty 1998 qt. Levy 2006). Alternatively, researchers in the applied field usually conduct research based on quantitative methods that entail action research and evaluations for studying particular aspects and issues. The premise for choosing action research is to endeavour to capture the reality with certain degree of control on the phenomena under research. Although, the nature of the coastal engineering field mandates that research activities be subject to quantitative empirical methods whereby researchers carry out extensive action research strategies and processes.

However, in this case, the researcher has opted for the qualitative approach as it complements the nature and topic under discussion. Whereas the study of breakwater is pragmatic, the exploration of its connection and impact on the engineering field is qualitative in nature. Furthermore, to understand the implications of breakwaters and

their effect on civil engineering profession, investigation into the subjective views of experts within the field is required, rather than engaging in empirical research to achieve its findings.

Having said that, the researcher is also aware that qualitative research requires a paradigm for basing the enquiry. According to Gummesson (2000), " a paradigm is a very

general conception of the nature of scientific endeavours within which a given enquiry is undertaken" (p. 18). It is a world view which allows the researcher to base his/her

research outcomes and understanding. Research paradigms can be divided into positivist, which is characterised by the world as the external dimension and must be researched through facts and fundamental laws, and by studying concepts through sampling. On the other hand, the phenomenological paradigm involves the social construction of the subject, and characterised by the understanding of the totality of the situation by investigating the issue through established phenomena. For the current study, the researcher shall adopt the phenomenological paradigm for analysing the effect of breakwaters on the engineering field. The rationale is based on the premise that even though through the course of discussion some technical and practical aspects shall be discussed, the analysis shall regard the ideology, decision logic and utility behind breakwaters and their link with civil engineering fields. While the researcher is aware that the phenomenological paradigm is not suited for engineering and scientific research, he/she also has the understanding that research of this qualitative nature