CLASSIFICATION OF SEAWALLS AND THEIR FAILURE: AN OVERVIEW

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ABSTRACT

The effects of seawalls on beaches and coastal dynamics have not been well documented in the literature. The purpose and function of coastal structures, especially seawalls, have often been misunderstood, as in some cases, seawalls lead to coastal erosion, contrary to protecting the shoreline for which they are generally constructed. Seawalls have been reportedly causing changes in the nearshore process, specifically the sediment dynamics by affecting the onshore/offshore and, to some extent, the longshore sand transport. Therefore, it becomes pertinent to understand the basic guidelines for the construction of a seawall to make sure more informed decisions are made on their installation. This paper discusses the effects of seawall on beaches, gives guidelines for the construction of a rubble-mound seawall and the various factors contributing to the failures of seawalls.

Keywords: Seawall, effectiveness of seawall, design guideline, impact of seawall, failure

INTRODUCTION

Seawalls are free-standing structure related to flood or shoreline retreat prevention. Are commonly made of the concrete material in order to overstand sliding and overturning moments. The main element for design is the crest elevation, being wave overtopping and wave run-up the main driver parameters considered for estimation. Seawalls are often the engineering tool that is employed to protect coastal structures that are threatened by shoreline erosion. Shoreline erosion presents a major problem in California and many other states. Sea level rise compounds the problem. While the shoreline has historically receded and advanced, erosion has become exacerbated by human's efforts to control California's rivers and to divert their waters for public and private use. Dams, highways, coastal structures, and other development in coastal watersheds prevent or retard the transportation of sand to the coast. This phenomenon only becomes recognized as a problem when valuable resources that have been placed near the shoreline become threatened by storms as their sand buffer erodes. Seawalls are expensive, and fixing a seawall freeboard at too large a value has a financial penalty and is unnecessarily damaging to the natural environment owing to the increased impact of the structure on its surroundings. On the other hand, if the crest of a seawall is set too low then there are potential problems with structural safety and flooding from wave overtopping. Hence, it is important to strike the correct balance between satisfying the structural and functional requirements of the project, avoiding unnecessary expense, and having undesirable impacts on the surrounding environment. Three categories of response are employed in response to a local shoreline erosion problem: 1) hard stabilization, such as seawalls, 2) soft stabilization, such as beach replenishment, and 3) relocation of threatened buildings. As implied, the hard stabilization alternative involves armouring the beach to stabilize it or hold it in place. The most common and widespread coastal engineering tool for

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hard stabilization is the seawall. A seawall is a structure built on the beach parallel to the shoreline. Seawalls can be large or small, high or low, and constructed of a range of materials including wood, plastic, concrete, rock, construction rubble, steel, old cars, aluminum, rubber tires, and sandbags. Coastal erosion is a problem faced by all the coastal population in different parts of the world. With a long coast of about 7500 km, the subject of coastal erosion and control in India assumes great importance. This problem calls for the protection of houses, cultivable lands, valuable properties, monuments etc. in the coastal belt. The solution to this problem involves scientific analysis of the same with a view to devise methods for preventing and/or minimizing the damage due to erosion caused by the destructive forces of the waves. It is well known that the erosion of a coast is mainly due to the action of waves in addition to the currents set up by the oblique attack of waves. Erosion of the cost depends on many factors like storm waves, nature of the beach, beach material and the shape of the coast, tidal level changes, movement and quantity of the littoral drift material. Human interference is also an important factor causing coastal erosion. The best natural defence against erosion is an adequate beach on which waves expend their energy. However, provision of an adequate beach is rarely possible due to economic reasons. The resort has, therefore, to be taken to provide appropriate engineering structures such as seawalls, revetments, anti-sea erosion bunds, groins, offshore breakwaters, etc. to prevent beach erosion. Seawalls, revetments and groins are structures located on the beach, while offshore breakwaters are located away from the beach. Since waves are the prime cause of beach erosion, it is natural that the protective methods are evolved to dissipate the energy of waves either by absorbing this energy on the beach or by dissipating/diverting the same before the waves approach the beach.

TYPES OF SEAWALLS

This large coastal protection structures can be built using different types of construction materials such as rubble-mound, granite masonry, or reinforced concrete. Seawalls are commonly built and run along the shoreline to prevent coastal structures and areas from the detrimental influence of ocean wave actions and flooding which are driven by storms. There are various arrangements or configurations that might be employed includes curved face seawall, stepped face seawall, rubble-mound seawall and vertical seawall. Others are gravity, steel sheet pile and concrete block seawall.

Curved Face Seawall

Curved face seawall is designed to withstand high wave action effects. Foundation material loss, which might be caused by scouring waves and/or leaching from overtopping water or storm drainage underneath the wall, is avoided by employing sheet pile cut off wall. Moreover, the toe of the curved face seawall is built from large stones to decrease scouring. Figure 1 shows curved face seawall with its components.

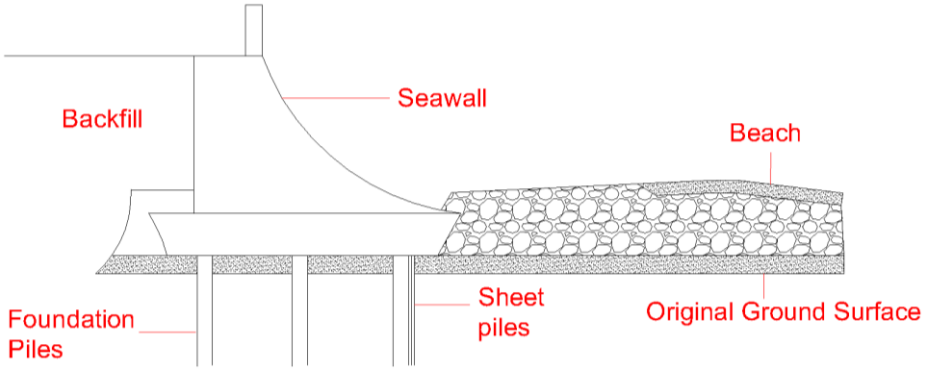

Figure 1. Seawall with curved face configuration

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Stepped Face Seawall

Stepped face seawall is used to oppose or resist moderate wave actions. Reinforced concrete sheet piles with tongue- and- groove joints are employed to construct this type of seawall. The spaces which are created between piles is either filled with grout in order make sand proof cut off wall or install geotextile fiber at the back of the sheet pile to form a sand-tight barrier. Applying geotextile is beneficial because it allows seeping water through and consequently prevents accumulating hydrostatic pressure. Figure 2 shows an example of a stepped face seawall with its components and details.

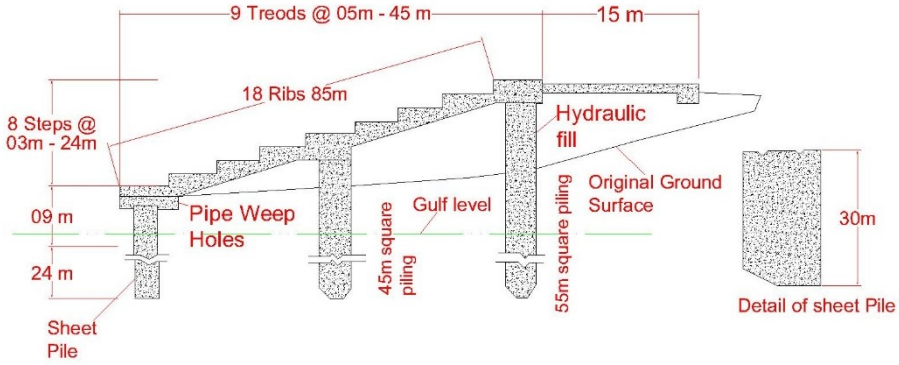

Figure 2. An example of a stepped face seawall and its components

RUBBLE-MOUND SEAWALL

Design and construction this type of seawall configuration might be easier and cheaper. It can resist substantially strong wave actions. Despite scouring of the front beach, quarry stone comprising the seawall could be readjusted and settled without causing structural failure. Figure 3 provides components of the rubble-bound seawall. The rubble-bound seawall dimensions are determined based on site conditions.

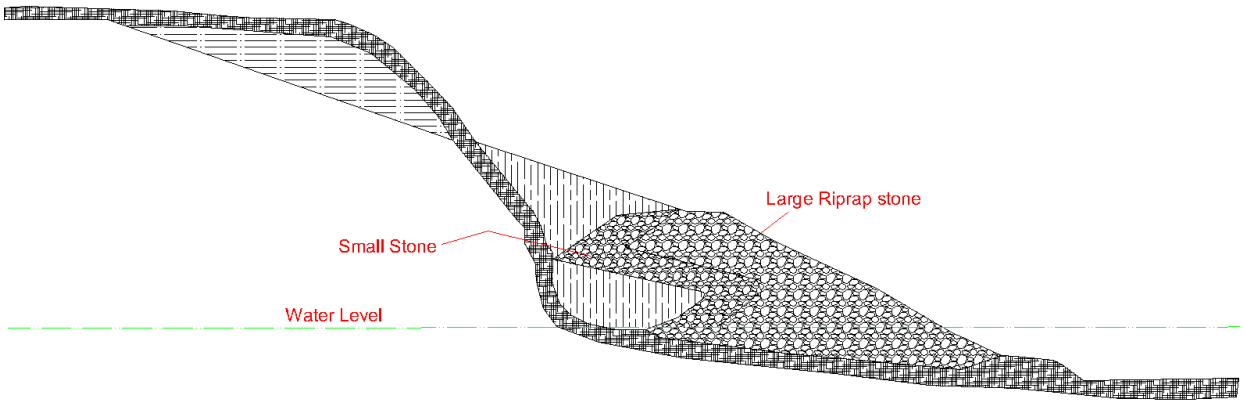

Figure 3. Rubble Mound Seawall

Seawalls' Effectiveness

Seawalls, if properly designed and constructed for a particular situation, are effective at saving beachfront property, provided the severe disadvantages they impose are acceptable (Pilkey et. al., 1996). They can be effective in protecting beachfront property from a retreating shoreline and, if high enough and strong enough, can protect a backshore area against the onslaught of storm waves. They may retain a low fill, but they are intended primarily to withstand and to deflect or dissipate wave energy. If a community's only priority

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is to preserve beachfront buildings then seawalls will effectively accomplish that goal. Seawalls protect only the land immediately behind them, offering no protection to fronting beaches. Scientists, coastal residents, and most coastal engineers (though not all) agree that seawalls degrade beaches. This and other significant disadvantages that seawalls impose are discussed in the following section.

Merits and Demerits of Seawalls

The merit of Seawalls: Construction of a seawall may be expensive but it can be an effective coastal management solution and can be planned to keep in mind the various positive features compared to other engineering methods. The construction of a seawall provides for increased coastal defense besides providing opportunities for sightseeing and recreation. Seawalls are strong defenses that are durable even in increased energy environments and last longer than other engineering methods. Some of the merits of seawall are listed below:

i. Offers the highest protection to property in short-term
ii. Lifespan of up to 50 years
iii. Effectively halts erosion locally

The demerit of Seawalls: The construction of Seawalls involves high costs besides dissolving the beaches and making them nonfunctional for beachgoers. It is important to determine whether the construction of a seawall is beneficial and worthy of the high costs involved. Seawalls may not be a pleasing sight and ruin the landscape of the sea. The construction of seawalls can destroy the formation of intertidal beaches and wetlands that form naturally near the shoreline.

i. Erosion can continue where scheme ends in unprotected areas
ii. Needs careful maintenance to prevent concrete shrinkage, debonding and micro-fracturing
iii. Ongoing maintenance costs
iv. Waves reflecting off the wall scour the beach, and this can cause greater erosion problems downdrift.

IMPACT OF SEAWALLS ON BEACHES

Beaches are an incredibly dynamic system that are affected both by watershed processes such as natural erosion of the hills that supply sand to the beach and by oceanic conditions such as wave climate and sea level rise. Beaches are a precious resource for many reasons; they are an extremely popular form of recreation, they provide a natural buffer against storm surf and they are an important habitat for birds, turtles and many other species. Due to impacts on watersheds and sea level rise many beaches in the world are eroding. Natural beach erosion does not reduce the size of the beach. Instead, the beach tends to march towards the land. There is no problem with the health of the beach unless the beach erosion begins to encroach man-made development. Responding to beach erosion by the creation of seawalls can temporarily protect development, but ultimately results in the loss of the beach. The following points elaborate more on the impact of seawalls on the beach.

- Passive erosion -"Wherever a hard structure is built along a shoreline undergoing long-term net erosion, the shoreline will eventually migrate landward beyond the structure. The effect of this migration will be the gradual loss of beach in front of the seawall or revetment
- As the water deepens and the shoreface moves landward…. While private structures may be temporarily saved, the public beach is lost. This process of passive erosion

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appears to be a generally agreed upon result of fixing the position of the shoreline on an otherwise eroding stretch of coast, and is independent of the type of seawall constructed."

- It is evident that passive erosion will eventually destroy the recreational beach area unless this area is continually replenished. Excessive passive erosion may affect the beach profile such that shallow areas required to create breaking waves for surfing are lost.
- Placement loss – Seawalls are placed on the beach. In many cases, construction of seawalls is on the beach, which is public property. This is a taking of extremely valuable public property.
- Active Erosion – Refers to the interrelationship between wall and beach whereby due to wave reflection, storm surf zone narrowing and a thousand other processes the wall may actually increase the rate of loss of beach. This is site-specific and dependent on sand input. There are varying opinions on if this effect actually exists. However, as watchdogs of the coast, until there is overwhelming evidence that this effect is not significant, this represents yet another reason to avoid constructing seawalls.
- Public access impacts – these can be a result of passive erosion, placement loss or active erosion. Seawalls built on eroding beaches will lead to the loss of access. Most beaches in Rincón are undergoing erosion.
- Visual/aesthetic impacts – Seawalls are ugly and detract from simple pleasures as a walk on the beach.
- Economic issues – local, state or federal subsidies or construction to protect private property or insurance coverage. Construction is performed on State or Municipal land. The public has never been compensated for this loss of valuable property.
- Loss of sand supplied by the eroding coastline that is armoured. This sand is lost from the system because seawalls prevent the naturally occurring erosion to supply additional sand to beaches. This natural erosion also creates additional space for the beach to stay wide.
- The most important thing to remember is that a seawall is never built to protect the beach. Rather, it is built to protect property, structures or a cliff from erosion.

GUIDELINE FOR THE DESIGN OF SEAWALLS

Design considerations of rubble-mound

For coastal protection works, rigid structures should normally be avoided and the flexible structures, which dissipate energy, should be adopted. In case of rigid structures, if unavoidable, may be provided with slope and vertical face should, in any case, be avoided. The vertical face leads to the reflection and scouring and subsequent failure of the wall. The vertical rigid retaining wall is normally mistaken with the seawalls. However, it should be kept in mind that the function of the seawall is to dissipate the wave energy and allow the formation of beach in front of it. As such, the sloping rubble-mound seawall is the most suitable type of seawall. The rubble-mound seawall is generally designed to consist of three layers. Viz. core, secondary layer and an armour layer (Fig.4). A minimum of two layers of stones (units) in the armour and second layer is always necessary. While the thicknesses of these layers are determined by the size of stones used, the levels including that of the core are determined based on maximum water level, design wave height, wave run-up, permissible overtopping and method of construction.

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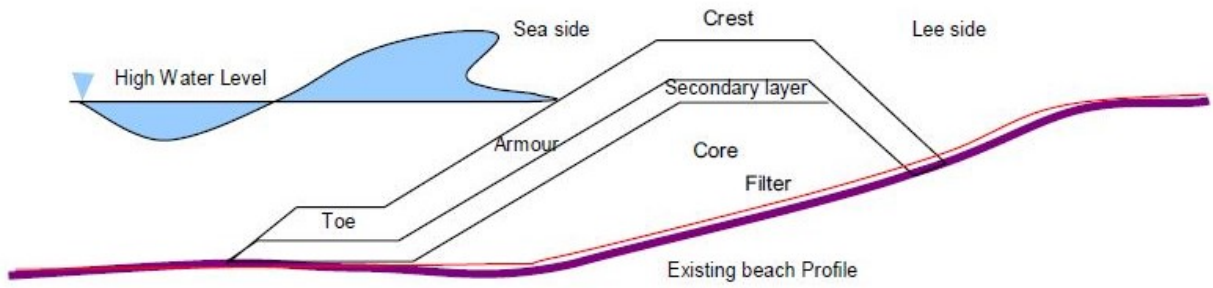

Figure 4. Typical section of a seawall

The usual steps needed to design adequate and efficient rubble-mound seawalls are:

i. Determine the water level range for the site.
ii. Determine the wave heights.
iii. Determine the beach profile after the storm condition/monsoon.
iv. Select the suitable location and configuration of the seawall.
v. Select suitable armour to resist the design wav.e
vi. Select size of the armour unit.
vii. Determine potential run-up to set the crest elevation.
viii. Determine amount of overtopping expected for low structures.
ix. Design under-drainage features if they are required.
x. Provide for local surface runoff and overtopping runoff and make any required provisions for other drainage facilities such as culverts and ditches.
xi. Consider end condition to avoid failure due to flanking.
xii. Design toe protection.
xiii. Design filter and under layers.
xiv. Provide for firm compaction of all fill and back-fill materials. This requirement should be included in the plans and in the specifications. Also, due allowance for compaction must be made in the cost estimate.
xv. Develop cost estimate for each alternative.
xvi. Provision for regular maintenance and repairs of the structure.

For more information and formula related to general guidelines and criteria related to the seawalls, sea waves, onshore, planning, and constructions of seawalls refer to references: (Sadeghi, 2004, 2007, 2007a, 2007b, 2013), (Nouban, 2016) (US Army Coastal Engineering Research Center, 1980), (US Army Corps of Engineers, 2011), (Sadeghi, and Nouban, 2013), (Nouban, F. et al., 2016).

Causes of Seawalls Failure

There are many causes of seawall failure. Some are preventable with regular maintenance and others, such as unexpected harsh weather conditions, are unavoidable. Whenever seawall damage occurs, it is vital to seek repairs or replacement immediately from a qualified professional.

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Causes of Seawall Failure Include:

i. Poor maintenance.
ii. Lack of inspection to detect problems early.
iii. Placing loads atop the soil supported by the seawall.
iv. Shallow building foundations placed too close to the wall.
v. Changing water flow and trapping large quantities of water behind seawall.
vi. Changing cover depth of anchor system, which diminishes seawall the anchor's capacity.
vii. Raising elevation and load beyond seawall design limits.
viii. Driving heavy vehicles and/or equipment too close to seawall.
ix. Using materials that can't withstand harsh, corrosive marine environments.
x. Corrosive Nature of Marine Environments.

CONCLUSION

The main purpose of a seawall is to serve as a form of structural defence to control shoreline erosion. Different types of seawall can be used to achieve this purpose depending on the site conditions. Determination of water level, wave heights and the beach profile are some of the usual steps taken in order to design a typical seawall. Placement loss, active erosion and passive erosion are some of the ways which a seawall impacts the beach. Several factors such as poor maintenance, corrosive nature of the marine environment, lack of inspection to detect problems early, placing loads atop the soil supported by the seawall can cause seawalls to fail.

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