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Specifications and types of seawall structures needed to protect beaches from sand erosion and storm disasters

Khosro Zehro

Faculty of Civil and Environmental Engineering, Near East University, Nicosia, Mersin10, Turkey

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ABSTRACT

When someone decides to buy a house or any other estate near the shoreline, they do not think that in future nature will impact the value of their asset significantly. Further to the risks of hurricanes or any other natural hazards (such as tsunami), waves are gradually shifting the coastlines by displacing soil from a location to various areas. In recent decades, coasts have been affected by a significant deterioration due to weather conditions, waves, and coastal soil erosion. Hence, it needs precise environmental consideration, and preserves coasts for leisure, specifying reasons that promoted effective technologies from immersed structures to coastal nourishing. Therefore, by constructing sea-walls should prevent shoreline environments, especially the mechanism of sedimentation, long-shore transfer of sand, altering the coasts to the significant proportion which results from weathering and sea waves sever. In this paper, an overview submitted to the kinds of seawalls and specifications needed to sustain the seawalls. There explained the positive and negative effects of seawalls on coastal area, and the required factors to enhance seawalls stabilization against overturning and sliding failure. Also, the developed types of seawall structures have been identified that, in addition to the more practical vertical model, the stepped, rubble-mound, and curves have also been designed. It is recommended to coastal structure designer and engineers, in the pre-construction stage should precisely be studied on the coast situation and weathering conditions in the area, that is essential to make sustainable decisions and designs for construction of these structures.

1. INTRODUCTION

By potential risks from storms and other environmental disasters, coastlines have gradually transformed, materials eroding and moving from certain areas to others (Luo, 2014). The storms are; hurricanes, tropical storms, typhoons, tornadoes, winter storms, and cyclones, resulting in casualties, their investment loss, and coastal environment hazards. The lower sedimentary shores have lesser flooding resistance (Liu et al., 2019).

Temperature change, rising sea levels, and patterns of rainfall are results of the natural climate cycle. Consequently, rising sea levels and both the average level of water and wave height will increase during the utmost weather conditions. This process induces erosion of soils from shores resulting in beach intrusion and the impact on human activities (Jin et al., 2015).

Anything built on the shoreline is known as coastal structures and constructed explicitly to the protection of the shoreline. This kind of structural system is designed to withstand waves, scouring, and beach erosion. Coastal designs were considered recently, such as a barrier between shore and sea, a global issue. Over decades to stop the rate of erosion, coastal defence implemented a fence (commonly seawalls) formed a critical requirement (Church et al., 2013).

A structural treatment such as groins, seawalls, embankments, jetties, and levees has been a conventional coastal disaster prevention mechanism, especially preferred in the expansion of urban concentration near seas, between much different sustainable developments, widely considered (Davlasheridze & Fan, 2019). Nearly 60 per cent of the population is resident in coastal regions, and about 100 kilometres in the coastline (Perkol et al., 2018).

Seawalls include self-supporting structures relating to the prevention of flooding or coastline retreats, and constructed mostly on coasts parallel to the coastline and usually prepared of reinforced concrete to overcome

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sliding or moments by overturning. The necessary design part is the elevation of the crest, becoming over-topping of waves and run-up of the waves.

Erosion was a natural coastal process that can be short-term, long-term or periodic that is caused by factors as rises of sea level, losses of supplied sediments, wave behaviour changes. Fortunately, there are other strategies in coastal engineering that support or avoid continued shorelines erosion which classified in various ways, according to Kraus (1988) study such as:

- Hard stabilizations; include some enduring rigid structures by a fixed position, like as; groins, seawalls, and suspended breakwaters,
- Soft stabilizations; refilling of the shores,
- Retreats and relocations; peoples transferred from near beaches to other locations to allow the process of natural recovery for the coast.

The seawalls construction has many limitations, which can be related to climate and conditions of the sea like the significant height of the wave, the average speed of the wind, and continually heavy rainfall (Yoo et al., 2013). By considering different techniques, it proved that the rubble-mound type of seawalls construction is the cheaper type than others, which with ordinary workers, could construct it without using any machine. One more positive aspect is the extension of construction year after year, regarding funding availability (Manu et al., 2015).

The main objective of this study is to identify the four types of seawall structures and their importance in protecting beaches from erosion that necessary for people's infrastructure investment safety assurance results from disasters near the coasts. Moreover, it explains the factors affecting the sustainability of these structures and preventing them from failure probabilities.

2. METHODOLOGY

The study's information was collected by the literature review of the recent coastal researches, and their investigation about climate conditions, erosion, design of seawall structures, and stability needed for structures.

3. COASTAL STRUCTURES

Shore structures used in the shore protection plans with the purpose of protecting beach erosion and hinterland flooding. Other purpose includes protecting basins and entrances of harbours from waves, stabilizing inlet channels, and protecting water outfalls and intakes (Burcharth & Hughes, 2003). Table 1 explains the different kinds of shore structures and their functions.

Table 1. Some common types of coastal structures and their functions

Kind of structure	Aims and functions
Seawall	Protection of structures and land from Overtopping and flooding. Reinforcing of certain areas of the shore profile
Breakwater	Sheltering harbours entrances and basins, and intakes of water from waves. Dissipation the energy of wave and wave reflections back to the sea
Groin	Protecting shore erosion. Reducing long-shore transportation of sediments.
Jetty	Stabilizing channels at river entrances and inlets. Protecting storms disaster.
Revetment	Protection of coasts from erosion. Reinforcing certain part of shore profile
Sea dike	Prevent sea flooding energy from low-lying shore areas. Separating coastline from hinterland by structures with high impermeability.
Bulkhead	Maintain soil and preventing of behind soil sliding. Reinforcing the bank of the soil.
Nourishment of beaches and construction of duns	Preventing shore erosion and protection from flooding. Artificial infill of shores and dune materials that eroded with waves in place of natural supplies.

4. SEAWALLS

Seawalls are usually coastal structures, which are adjacent to the seashores. The fundamental roles of these structures are, to inhibit marine areas erosion from flooding and prevention of the constructed building structures near the shore. To create seawall structures, different materials are used, including concrete, gabion, cribs filled by stone, casting concrete in the site, precast blocks, and prefabricated segments. The seawalls types can be constructed in the vertical, curved, rubble-mound, or stepped surface. In certain situations, large structure by suitable foundations and practical toe support needed to overcome and control the damage of significant wave effects (Sadeghi & Al-Othman, 2019).

Sea walls become factors of their-self demolition if they not properly construct. The sea waves will crush versus it, while decline its front face, strive to remove the shore soil in its base, transferring of these soils, if not kept down, forces the wall to be undermined and collapse. Sea walls not constructed to decrease soil sedimentation only, but they protect industrial factories, bridges, railways, and roads from attacking by waves and storms. As also resist flooding damage on low lying areas (Williams et al., 2016).

Sea wall installed in the coastline at a specific location that changes the hydrodynamic status by interacting with repetitive sea waves. By controlling soil erosion from cutting off sea walls, typical sediments supplied when

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waves which impact sea wall reversed down, scouring the wall's toe as an outcome (Pilkey & Cooper, 2012).

Sea walls construct to reduce the wave's power and soil erosion that already exposed shorelines. The appropriate design for the sea wall and its types depends on location-specific features such as erosion processes around it (Balaji et al., 2017).

5. TYPES OF SEAWALLS

The different details or types of the seawall are used to construct along with the coastline structures such as vertical, curved, rubble mound and stepped seawall. Others include the gravity, seawalls made by concrete blocks, and the piles made by sheets of steel.

5.1. Vertical seawall

Vertical-face sea walls generally consist of materials like blocks of stone, mass concrete, and RC, and it can construct as interlock walls by using concrete, wood piling, and steel. Another form of the vertical wall can install using rock-filled as a sizeable concrete wall that behaves like retaining walls against materials behind them (Balaji et al., 2017).

Vertical face sea walls often constructed in situations that are subjected to such wave power. Non-breaking static waves arise during flood effects where it rolls upward and downward not horizontally. This wave promoting can cause serious risk to the seawall in the wall toe. Fig.1 shows the detail of vertical face seawall (Williams et al., 2016).

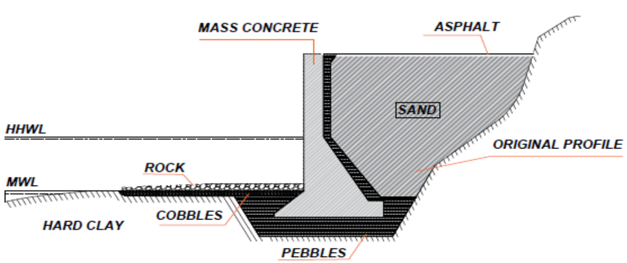

Fig. 1. Vertical front seawall

5.2. Curved face seawall

The curve face model will prevent walls from wave overtopping and protect walls' toes effectively. Curved face sea walls attempt to redirect all the risky wave power, results from reflected energy of waves and considerably reduced downdrafts (Vijayaraghavan et al., 2018). Curved types seawall constructed to protect the impact of the intense action of waves. By using piles' sheet cut off seawalls can prevent the loss of materials in the foundation around, resulted in waves' scouring, eroding from water overtopping, and floods drain below the wall (see Fig. 2). Additionally, to reduce waves' scouring, the toe section of the curve face wall is constructed by big stones (Sadeghi et al., 2018).

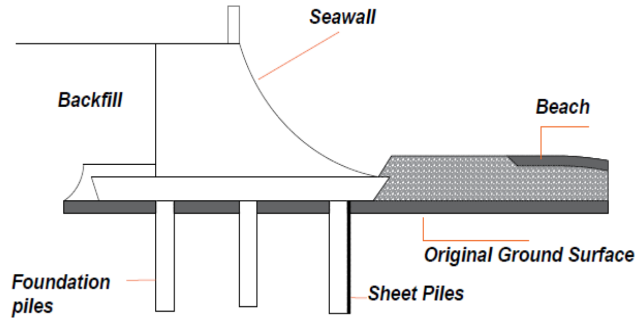

Fig. 2. Seawall with curved face configuration

5.3. Stepped face seawall

Stepped types of the seawall are designed to resist and reject moderate action of waves. Reinforcing concrete sheet pile used in the construction of these kinds of seawalls (see Fig. 3). The areas that built between sheet piles are mostly filled by grouts to maintain sand cut off or installation of geotextile fibres at the sheet piles' back, to generate a sand-tightened barrier. Installing geotextile is helpful since it facilitates water flowing through and thus prevents the development of hydrostatic pressures (Sadeghi et al., 2018).

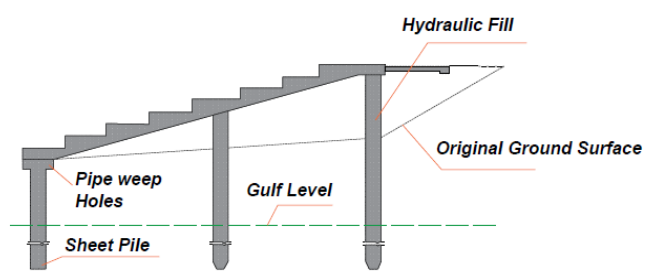

Fig. 3. Stepped face seawall

5.4. Rubble-mound seawall

These kinds of seawalls were cheaper and easier for construction and designing and could protect the energetic action of waves substantially (see Fig. 4.).

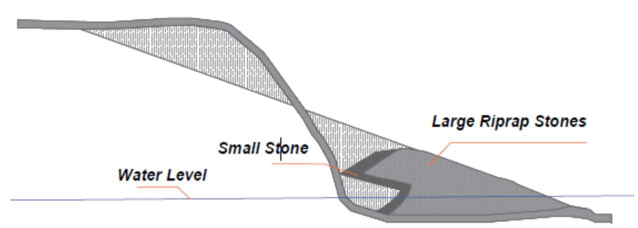

Fig. 4. Rubble-mound seawall

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Mound form of seawalls built by using rip rap or revetments, and usually in less requiring applications used, where erosion process with low energy occurs. The least rate of exposure means the lower bulkheads' cost and revetments' sandbag. These are serving to shores' armour and reduce erosion, also can either be waterproof or porous form, allow the filtering of water after the dissipation of the waves' power (Vijayaraghavan et al., 2018).

6. FACTORS AFFECTING FAILURE IN SEAWALLS

According to Wang et al. (2012) and the site investigators, the damaged mechanism of seawalls' failure can be divided into two kinds: the collapse of the introversion, and dispersion collapse. The sea walls structures failure is strongly related to mortar hydrodynamic effects and invalidation. Different types of geotechnical or structural occurrences of failures are as following:

- Hydraulic uncertainty (primary armour depletion),
- Overtopping leads to scouring of seawalls' crest,
- Scour or erosion at the toe,
- Liquefaction (action of waves decreases sand bearing capacity, allowing the armour to submerge),
- Inside erosion (material losses of inside the wall),
- Central instability, it is unusual for rock wall builds.

Some types of common failures reported by surveying in the UK with coastal authorities shown in Table 2 (Thomas & Hall, 2015).

Table 2. Different kinds of damages

Seawall damages	No. of occurrences
Collapse	16
Disintegration of concrete	9
Armouring uplift	3
Armour removal in revetments	19
Erosion in toe	63
Abrasion	16
Wash-out filled materials behind seawalls	10
Cracking in concrete	2
Settlement	2
Promenades damage	4
Corrosion	3
Partial failure in crest	26
Outflanking	3
Concrete spalling	2
Failure in structural members	5
Landslip	5
Total	188

Increasing seawalls exposure with a rising water level during time is going to affect the overtopping, hydraulic stabilization, and toe scouring as the sea wall experienced. In the study by Mulcahy et al. (2017), it explained that changing climate could also directly impact the vulnerability of seawalls by:

- Rising seas' level,
- Increasing storms surge,
- Increase in the height of waves,
- Unpredictable geo-morphological impacts due to climate change.

7. STABILITY OF SEAWALLS

Based on various factors like sea walls weight, the different applied force upon seawalls, as well as the resistance of foundation soil and back-fill materials, the rotation of seawalls could be toward shore or the seaside. The seawall's stability verified by implementing the equilibrium limit method regards the safety factor against sliding toward shores or overturning toward shore's failure modes. Based on the moving relationship between the water in pores and particles of soil, two conditions considered, i.e., the first one is free-water, and the second is the water that restrained (Rajesh & Choudhury, 2016).

There are a lot of strategies that could be placed in a way to enhance seawall's ability. Some alternatives outlined by the "climate change adaptation guidelines in coastal management and planning" (Engineers Australia, 2012). That including (but does not restrict to):

- Retreat or permit occurrence of erosion,
- Exposure reduction by raising the volume of the upper shore,
- Develop further layer of bigger armour unit in front of seawalls, to enhance the armour unit stability,
- Placement of further stones on the crest, expanding the width, and raising the height of the crest leads to minimizing the damage of overtopping,
- Use the best practical design and integrate elements that will enable to maintenance in the future (Tomlinson et al., 2016).

8. POSITIVE AND NEGATIVE EFFECTS OF SEAWALLS ON COASTS

While coastal areas undergo erosion deterioration, for controlling the effects of shore losses and damage of storms, using different strategies. Measures of Soft stabilizing involve coast and re-nourishment of the dune, which tend to remain as temporary, however significantly expensive. Measures of hard maintaining like as; seawalls, groins, and jetties effectively prevent coast properties deteriorate. However, they have some negative effects on beaches, as explained in Table 3 (Beatley et al., 2002; Rizkalla & Savage, 2011).

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Table 3. Advantages and disadvantages of hard stabilization structures to coasts

Advantages	Disadvantages
Inhibit marine areas erosion from flooding	Seawalls restrict access to seawater
Prevent losses of the beaches	Seawalls become unattractive
Seawalls protect sand interchange between the coast and dune, which attempts to disperse the energy of waves by storms	Seawalls generate a false security sense in unsafe areas and increase high-density construction development
Prevention of the constructed structures near the shore	Seawalls cause amusement beaches degradation
As also resist flooding damage on low lying areas	Seawalls almost always cause rubble and make swimming risky
Seawalls behaves like re-taining walls against materials behind them	Seawalls mainly benefit landowners only

9. CONCLUSIONS

By inducing changes in natural weathering, expected to increase the disaster's repetition and potentially cause enormous human and financial losses. Almost all investigators and decision-makers are incredibly interested in developments related to different alternatives for coastal modification, such as the development of protection structures. This alternative was a conventional method of adapting to locations in which precious resources will be in damage. Besides that, no empirical study about how the public perceives these protection structures.

Seawalls are the most common marine structures, and their construction depends on the sea's natural conditions more than shore effects. Working on the construction of seawalls during extreme sea conditions will result in a reduction in work performance, construction quality, and safety of workers and construction equipment. The seawall's fundamental role is to act as a kind of protection structure to prohibit the erosion of the coasts. Based on the conditions of the site, various seawall types can be constructed to attain this objective. Due to the diverse relationships between natural erosion and coastline nutrition, it may receive incorrect data in measuring erosion in the coastal area.

In brief, the studies aided in highlighting and identifying the conditions of the common seawalls and confirming that creating proper walls do not need to extra reconstruction. Sea walls help to improve the infrastructure of the community's safety against extreme erosion by storms. The study revealed that standard designs for the seawall structures were aligned with the performance of the structure's requirements.

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest.

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