Technology Fact Sheet for Adaptation

Construction of Groins & Sea Walls [i]

Construction of Groins & Sea Walls

42. Sector: Coastal

43. Technology characteristics

43.1 Introduction to construction of hard structures such as sea walls (revetments) or storm surge barriers and closure dams:

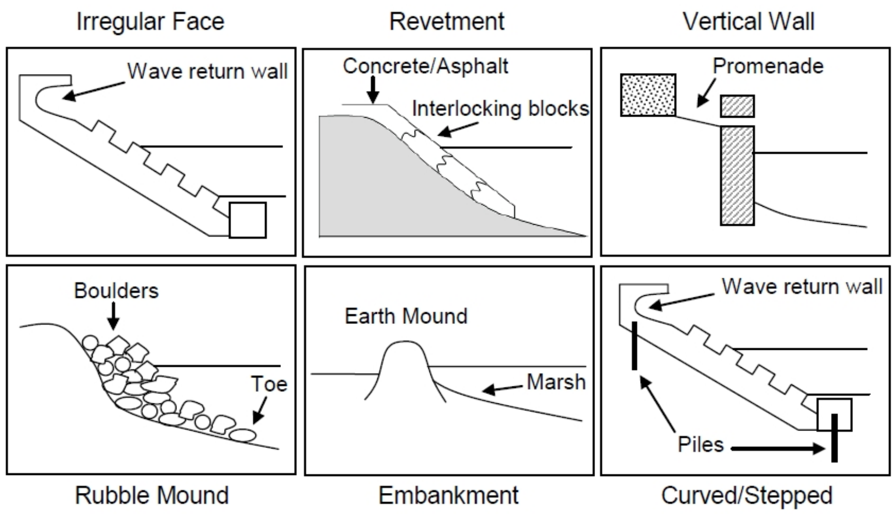
Seawalls are hard defense structures which are built parallel to the shoreline in coastal areas which are subjected to erosion due to sliding of soil as a result of high wave action and coastal flooding. The physical form of these structures is highly variable; seawalls can be vertical or sloping and constructed from a wide variety of materials. They may also be referred to as revetments. The description of this technology originates from Linham and Nicholls (2010). Sea walls are frequently used in locations where further shore erosion will result in excessive damage, e.g. when roads and buildings are about to fall into the sea and they are often built as a last resort, most are continually under severe wave stress. Seawalls usually have a deep foundation for stability. Also, to overcome the earth pressure on the landward side of the structure, 'deadmen' or earth anchors can be buried upland and connected to the wall by rods (Dean & Dalrymple, 2002). However, while they prevent further shoreline erosion, they do not deal with the causes of erosion (French, 2001). Seawalls will provide protection against water levels up to the seawall design height. In the past the design height of many seawalls was based on the highest known flood level (van der Meer, 1998).

Global climate change has already begun to have serious impacts on socio-ecological systems around the world. Increased average temperatures have set in motion a variety of forces that are producing rises in sea levels globally and, in a number of specific locales, they promise to have serious impacts in both proximate (decades) and distant (centuries) futures. Most recent scientific assessments of global climate change indicate that sea level rise will have significant impacts on coastal environments and their biotic communities, including human settlements Oliver-Smith (2009).

According to the estimates done in 1990 by the IPCC Coastal Zone Management Sub Group Sri Lanka's coastal belt could be categorized in to following types (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990), in Sri Lanka, total city water front length and harbour length that needs protection are respectively 4820km and 1.6 km respectively. Cost for protection of above areas from erosion due to high wave action and storm surge is reported as US$M 1,860 and 37 respectively. With the new harbours, which are under construction in Hamabanthota and in the eastern coast of Sri Lanka the cost of construction has exceeded the cost indicated above. Proposed defenses constructed for above purposes (especially for Industrial area and harbours) are raising of low lying outer dike areas by 1 m; strengthening of quay walls by raising or construction of sea dikes. For such constructions unit cost have been estimated as 15 M$/km^2. Current construction costs for hard defense structures were not available to be included in this report, although several attempts were made to obtain them from respective organizations. Therefore the estimates for this report was made using the values given by IPCC (1990) with relevant alterations considering the depreciation of the Sri Lankan rupee against the US$ in 2011.

2.2 Technology Characteristics/Highlights

Seawalls range in type and may include steel sheetpile walls, monolithic concrete barriers, rubble mound structures, brick or block walls or gabions (wire baskets filled with rocks) (Kamphuis, 2000). Some typical seawall designs are shown in Figure 1. Seawalls are typically, heavily engineered, inflexible structures and are generally expensive to construct and require proper design and construction supervision (UNFCCC, 1999).



Hard, concrete structures are typically replaced by revetments and embankment-type structures in more sheltered environments

Figure 1: Variation in design type of seawalls. Source: Adapted by Linham and Nicholls (2010) from French, (2001)

From the above structures recommended by French (2001), rubble mounds constructed using granite boulders is the commonest in Sri Lanka. However during the tsunami they neither protected the coastal infrastructure within the coastal belt of Hikkaduwa, which has been previously altered due to anthropogenic activities such as coral mining for lime industry Plate 1. Therefore revetments, vertical walls and the sea walls with irregular face with a wave return wall would be the hard defense structures that could be considered as most suitable for coastal belts that needs protection from high wave action and storm surge. Furthermore, as indicated in the Figure 2, if they could be coupled with soft barriers. If such soft barriers could be artificially transplanted within the irregular depressions on the hard defense structures or if they could be designed to give a terraced appearance, such structurs will enhance the effect of hard structures against wave action. Such strctures should be experimentally tested especially in coastal areas such as Hikkaduwa where corals and sea grass beds are naturally occurring.

Plate 1: Disturbed revetments & groins in the Southern Coastal belt of Sri Lanka during tsunami (2004)

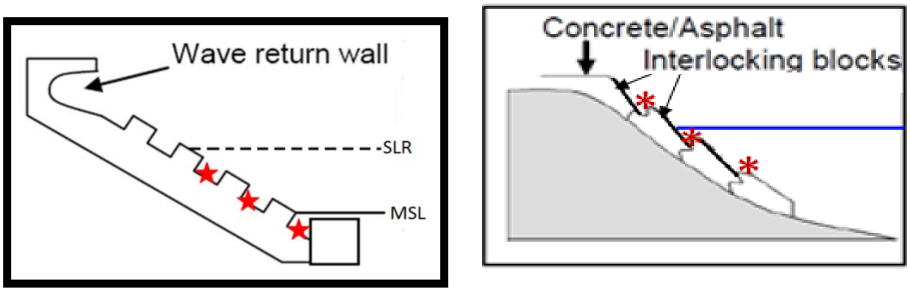


Figure 2: Modified drawing of a sea wall with a structure that helps the return of the waves could be used as a hard substratum to establish artificial coral beds (Source: Adopted from French, 2001). Places within an irregular faced sea walls ( ) and on the revetments with interlocking blocks ( ) sea walls suitable to fix the tiles with transplanted corals or plots with sea grasses considering the water level due to sea level rise. MHWS- MSL- Mean sea level; SLR- Water level at sea level rise

2.3 Institutional/ organisational requirements

- Coast conservation department should collaborate with engineers and marine scientists from research & academic institutions when designing most suitable hard defense structures for preventing coastal erosion and coastal inundation.

- Funds should be made available for research on construction of sea walls and revetments with suitable designs to accommodate soft barriers and to explore the possibilities of using low cost but strong constructions which could stand the forces of strong waves.

44. Operations and maintenance

44.1 Endorsement by experts

- Construction of groins & revetments have been already implemented by the CCD.
- Coral transplanting and sea grass replanting technologies are adopted independently and their applicability and incorporation in to hard structures should be experimentally tested to obtain the endorsement of experts.

44.2 Adequacy for current climate

- Currently, sea walls groins have been constructed along the coasts close to urban areas, harbours, anchorages etc.
- During monsoonal periods certain areas of the western southern and north western coasts are badly affected due to strong waves and currently CCD is promoting the construction of groins and revetments to prevent coastal erosion and it is given higher priority than to the rehabilitation of soft barriers such as rehabilitation of mangroves for reduce impacts from wave action and coastal inundation in North and western coasts of Sri Lanka (Personnel communication by a CCD official)

44.3 Size of the beneficiary group

- All coastal communities living in the urban areas in the vicinity of eroding coastal belts especially in the western, southern and south-western coasts of Sri Lanka and close to harbours.

- Those who are involved in construction of hard defense structures

- Tourist hotel owners and beach resort owners.

- If coral transplanting (establishment of artificial reefs) and sea grass planting could be incorporated in to the designing of hard defense structures it would improve the biodiversity and therefore fisher communities and those involved in ecotourism will benefit out of such project.

4. Costs

4.1 Cost to implement adaptation options

A study by Linham et al. (2010) indicates that the unit cost of constructing 1 km of vertical seawall is in the range of US$0.4 to 27.5 million, which depend on the height of sea wall required with respect to the wave height. Variation in costs between projects is a result of numerous factors, such as:

- Design height is a major factor affecting costs per unit length of seawall. Height affects the volume of materials required for construction and the build time
- Anticipated wave loadings will affect how resilient the structure needs to be; deeper waters and exposed coasts cause higher wave loadings which will mean the structure needs to be more robust, thus higher costs
- Single or multi stage construction; costs are lower for single stage (Nicholls & Leatherman, 1995)
- Selected seawall design and the standard of protection desired. Certain design features will increase costs and more robust seawalls will be more costly
- Construction materials (e.g. rubble blocks, pre-cast concrete elements, metal, soil, etc.)
- Proximity to and availability of raw construction materials
- Availability and cost of human resources including expertise

Maintenance costs are another significant and ongoing expense when a hard defence is selected. These costs are ongoing for the life of the structure and are therefore likely to result in significant levels of investment through a project's lifetime. Continued investment in maintenance is highly recommended to ensure defences continue to provide design levels of protection (Linham et al., 2010).

According to the estimates done in 1990 by the IPCC Coastal Zone Management Sub Group Sri Lanka's coastal belt could be categorized in to following types (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990), in Sri Lanka, total city water front length and harbor area that needs protection are respectively 124 km and 1.6 km^2 respectively. Cost for protection of above areas from erosion due to high wave action and storm surge is reported as US$M 1,860 and 37 respectively. With the new harbours which are under construction in Hamabanthota and in the eastern coast of Sri Lanka the cost of construction has exceeded the cost indicated above. Proposed defenses constructed for above purposes (especially for Industrial area and harbours) are raising of low lying outer dike areas by 1 m;

strengthening of quay walls and protection of petrochemical areas by raising or construction of sea dikes. For such constructions Unit cost have been estimated as 15 M$/km^2. Current construction costs for hard defense structures were not available to be included in this report, although several attemps were made to obtain them from respective organizations. Therefore the estimates for this report was made using the values given by IPCC (1990) with relevant alterations considering the depreciation of the Sri Lankan rupee against the US$ in 2011

Length of the coast line required protection from hard defense structures	-127 km
Total cost estimated in 1990 (IPCC, 1990)	-US$M1897
Total cost calculated to 2011	-US$M2846
Cost per km^2 of sea walls as estimated in 1990	-US$M15
Cost per km^2 calculated for 2011	-US$M22.5
Cost per m^2 in 2011	-US$ 22.5

44.4 Additional costs to implement adaptation option, compared to "business as usual"

- If the sea walls and revetments are modified with applications of coral transplants and establishment of sea grass plots considering the expected sea level rise as shown in Figure 2, respective additional costs should be added.

45. Development impacts , indirect benefits

Seawalls provide a high degree of protection to the coastal belt against coastal flooding and erosion and also they protect the infrastructure within the coastal zone. They will also fix the boundaries between the sea and land, if they are appropriately designed and properly maintained. Seawalls also have a much lower space requirement than other coastal defenses such as dikes, especially if vertical seawall designs are selected. In many areas land in the coastal zone is highly sought-after; by reducing the space requirements for coastal defence the overall costs of construction may fall. The increased security provided by seawall construction also maintains hinterland values and may promote investment and development of the area (Nicholls et al., 2007b). Moreover, if appropriately designed, seawalls have a high amenity value – in many countries, seawalls incorporate promenades which encourage recreation and tourism.

When considering adaptation to climate change, another advantage of seawalls is that it is possible to progressively upgrade these structures by increasing the structure height in response to SLR. It is important however, that seawall upgrade does not compromise the integrity of the structure. Upgrading defences will leave a 'construction joint' between the new section and the pre-existing seawall. Upgrades need to account for this weakened section and reinforce it appropriately.

45.1 Economic benefits

45.1.1 Employment

- This project will provide employment opportunities to person involved in coastal construction sector
- Small & medium scale entrepreneurs will be able to establish new industries within the coastal belt due to the reduced risk to infrastructure from coastal erosion & inundation, which will provide self employment opportunities and employment for others
- Expansion of tourist hotels will also provide more employment opportunities

45.1.2 Investment :

- Investment on new enterprises by coastal communities
- Although there is no direct investment involved, due to protection provided by coastal dikes to coastal structures and properties of coastal communities and business establishments, it is an indirect investment due to reduction of costs for rehabilitation and maintenance of coastal structures which will be damages due to wave action and coastal inundation in the absence of hard defense structures .

45.2 Social benefits :

- Income
  - Improvement of socioeconomic status of coastal communities due to reduction in loss of land, properties and infrastructure and also due to availability of more land for establishment of new business enterprises and tourist hotels.
  - Increase income of persons involved in construction and maintenance of sea walls..
- Education
  - Improvement of knowledge on effect of hard defense structures against strong wave action and erosion.
  - Provide opportunities for undergraduate and postgraduate students to carry out research projects to improve the quality of and reduce the cost of hard defense structures and on the possibility of incorporating soft defense mechanisms to enhance the effects of hard constructions
- Health
  1. Improved security of coastal dwellings will naturally improve the health conditions of coastal communities

45.3 Environmental benefits

- Sea walls provide a high degree of protection against flooding in low-lying coastal areas. They often form the cheapest hard defense when the value of coastal land is low (Brampton, 2002).

- The sloped seaward edge of a dike leads to greater wave energy dissipation and reduced wave loadings on the structure compared to vertical structures. This is achieved because the seaward slope forces waves to break as the water becomes shallower.

- Wave breaking causes energy dissipation and is beneficial because the process causes waves to lose a significant portion of their energy. Because the waves have lost energy, they are less capable of causing negative effects such as erosion of the shoreline.

- By reducing wave loadings, the probability of catastrophic failure or damage during extreme events is also reduced.

- With the sea level rise, surface area available for settlement of benthic marine organisms will be increased and it will improve the coastal biodiversity.

4.2 Social benefits :

- Income
    - Improvement of socioeconomic status of coastal communities due to reduction in loss of land, properties and infrastructure due to coastal erosion and inundation.
    - Increase income of persons involved in construction and maintenance of sea walls/revetments will improve their socioeconomic status
- Education
    - Provide opportunities for research based studies for persons who are involved in designing sea walls and revetments.
    - Improvement of knowledge on the effect of hard defense structures against coastal erosion and inundation, when coupled with soft defense structures,
- Health
    - Improved security of coastal dwellings will naturally improve the health conditions of coastal communities

4.3 Environmental benefits

- Sea walls provide a high degree of protection against rough sea conditions and flooding in coastal cities and harbours.

- Protect coastal agriculture from salt water intrusion and inundation

- Prevent sedimentation in coastal marine sensitive ecostystems

6. Local context

6.1 Opportunities & Barriers

- **Opportunities**
  - For coastal scientists, coastal engineers, marine biologists, coastal zone managers will get a very good opportunity to cooperate and to use their knowledge and experience to construct sea walls with an ability to stand the wave heights reported from different coastal belts, using, using locally available material.
  - Academics and researchers will get an opportunity to conduct useful scientific research to develop low cost techniques to construct sea walls and revetments.
  - Sri Lanka will get an opportunity to make possible contributions to find solutions for local, regional and global problems that may faced due to climate change.
  - These structures help to increase the land area available for construction of infrastructure for tourism and other coastal industries.

6.2 Barriers

- High cost incurred on coastal constructions, etc.
- Low inputs by the government on coastal & marine science research and education, due to ignorance of the importance of marine science education and the cost incurred for marine science education.
- Sri Lanka is depending on the foreign exchange earnings from tourism and the hard barriers will not allow free access to the beaches and such constructions will affect the natural scenic beauty of the Sri Lankan beaches
- These structures may affect the ecological balance of ecosystems in the intertidal zone as they prevent the free movement of certain organisms. Especially they might affect the migratory circuits of diadromous species.
- If the construction of these walls do not take the extreme conditions of the tidal variations and wave heights, during such events sea water enters the land may not freely return and affect the ground water salinity of adjacent coastal areas, which was observed in the wells of the coastal belt of Sri Lanka after the 2004 tsunami.
- In estuaries, seawalls also cause changes to the area inundated by the tides thus, reducing the available area for occupation by water on a high tide. With the same volume of water flowing into the estuary, the level of the water after seawall construction will be higher. This may mean areas in front of the defence remain submerged longer and by greater depths. In turn, this is likely to affect the distribution of vegetation and could increase tidal range upstream of the defence (French, 2001).

- Seawalls also reduce beach access for handicapped people and for emergency services. This can be problematic if the beach fronting such structures is to be used for recreation. (Linham, 2010)
- Although seawalls prevent erosion of protected shorelines, where the seawall ends, the coast remains free to respond to natural conditions. This means that undefended areas adjacent to the wall could move inland causing a stepped appearance to the coast (French, 2001)

a. Time frame

	Year 1 divided to 4 quarters				Year 2 divided to 4 quarters				Year 3 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Selection of sites and feasibility studies	X	X										
Construction of dykes			X	X	X							
Monitoring						X	X	X	X			
Depending on the success application to more coastal areas									X	X	X	X

b. **Acceptability to local stake holders:**

- If successful following stakeholders will support the programme
  1. Coastal property owners
  2. Tourist hotels
  3. Small & medium scale enterprise owbners

7. References

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[i] **This fact sheet has been extracted from TNA Report – Technology Needs Assessment Reports For Climate Change Adaptation – Sir Lanka. You can access the complete report from the TNA project website http://tech-action.org/**