Technology Fact Sheet for Adaptation

Construction of Sea Dykes [i]

Construction of Sea Dykes

38. Sector: Coastal

39. Technology characteristics

39.1 Introduction to construction of sea dykes

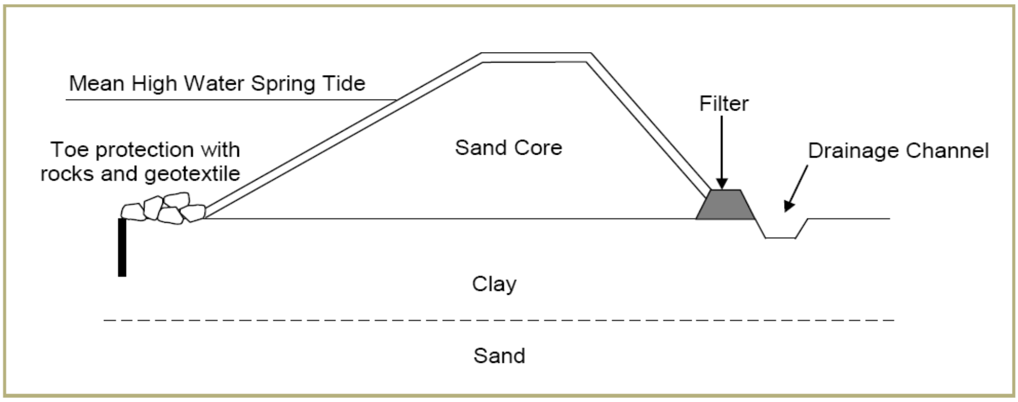
According to the estimates done in 1990 by the IPCC Coastal Zone Management Sub Group Sri Lanka's coastal belt could be categorized in to following types (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990) and areas under each type and the cost for providing necessary protections are also given in Table 1

Table 1: Types of Coasts available in Sri Lanka, respective areas &cost for providing necessary protections as estimated in IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990.

Coast type	Length km/Area km^2	Cost US$M
Coast length ("crow")	990 km	
Low Coast Length	4820 km	1,446.0
Total City water front length	124 km	1,860
Beach length	30 km^2	203
Harbour area	1.6 km	37
Total		3,545

The primary function of sea dikes is to protect low-lying, coastal areas from inundation by the sea under extreme conditions (Pilarczyk, 1998a). Dikes are not intended to preserve beaches which may occur in front of the structure or any adjoining, unprotected beaches. These structures have a high volume which helps to resist water pressure, sloping sides to reduce wave loadings and crest heights sufficient to prevent overtopping by flood waters. They may also be referred to as dykes, embankments, levees, floodbanks and stopbanks., et.al., 1999). Dikes have been extensively utilised as flood defenses in the Netherlands over the past several hundred years. Dikes are widely used to protect low-lying areas against inundation in many countries including Sri Lanka. After the tsunami incident in 2004 such dykes have been constructed along the coastal belt subjected to sever damage. Although it has been successfully protecting the landward properties, it prevents the travelers along the coastal to enjoy the scenic beauty of the sea and the beaches of Hikkaduwa. A number of zones can be distinguished on the seaward slope of a sea dike. The base of the dike, up to MHW will be regularly submerged and will experience constant, low-level loadings. The zone above MHW can be heavily attacked by waves, but the frequency of this occurrence reduces as you move further up the slope. Toward the dike crest, above the design water level, the structure should only be subjected to wave run-up.

Dikes 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.



39.2 Technology Characteristics/Highlights

Figure 1 : Cross section of a typical sea dike (Linham et al. 2010)

Figure 1 shows a cross-section of a typical dike, which is predominantly earth structure consisting of a sand core, a watertight outer protection layer, toe protection and a drainage channel. These structures are designed to resist wave action and prevent or minimise overtopping.

Typical dikes employed by the Dutch use following design guidelines will be the most appropriate for eroding coastal belts of Sri Lanka as they are giving a more natural appearance compared to concrete sea walls erected along the coast.

- Sloped seaward face at a gradient of between 1:3 to 1:6 – Reduce wave loadings
- Sloped landward face at a gradient of between 1:2 to 1:3 – Minimises land use and maximises stability
- Impermeable cover layer – this is usually composed of clay but is sometimes supplemented by asphalt. It serves to protect the sand core (Barends, 2003) Toe protection – used as supplemental armour for the beach and prevents waves from scouring and undercutting the structure (Pilarczyk, 1998b)
- Dike core usually composed of sand to ensure that water that does enter can drain away.
- The core provides support for the cover layer and gives the structure sufficient volume and weight to resist high water pressures (Barends, 2003)
- Drainage channel – allows any water which does enter the structure to drain away, therefore ensuring the structure is not weakened by water saturation (Barends, 2003)
- A number of zones can be distinguished on the seaward slope of a sea dike. The base of the dike, up to MHW will be regularly submerged and will experience constant, low-level loadings. The zone above MHW can be heavily attacked by waves, but the frequency of this occurrence reduces as you move further up the slope. Toward the dike crest, above the design water level, the structure should only be subjected to wave run-up.

If such dikes could be constructed with suitable modifications at the base of the dike towards the seaward slope to attach tiles transplanted with corals and to given an appearance of a terraced structure to enhance growth of sea grasses (figure 2), such dikes could play a more natural role during high water levels due to sea level rise. Sea level rise is a slow phenomenon and if the dykes are designed in a manner , that they will be best adapted to allow benthic marine organisms to settle on it with the gradual sea level rise these dykes will provide a better adapted structure for protection from erosion and inundation.

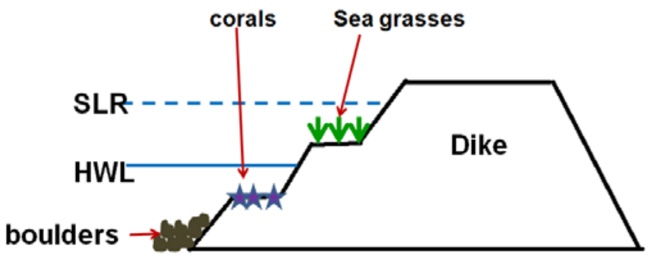


Figure 2: Proposed design of a dyke with the landward aslope having a terraced structure to enable transplanting corals and establishing seagrass plots during high water levels (HLW) and sea level rise (SLR). This would gradually enhance the settlement of more adaptive (temprrature tolerant marine benthic organisms)

39.3 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 dikes with low cost locally available material and for possible reinforcing their effect by association with soft defense mechanisms (coral transplanting, sea grass replanting, etc.)

40. Operations and maintenance

40.1 Endorsement by experts

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

40.2 Adequacy for current climate

- Currently, dikes have been established in eroding low coasts and they have made a very high impact in controlling erosion and inundation in such areas (e.g. Hikkaduwa, Peraliya, etc.) .

40.3 Size of the beneficiary group

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

- Those who are involved in construction of hard defense structures

- Tourist hotel owners and beach resort owners.

- If coral and sea grass growth could be promoted it will improve the biodiversity and therefore fisher communities and those involved involved in ecotourism will benefit out of this project.

41. Costs

Construction of a 1 m high sea dike with following dimensions have incurred a unit cost of 0.4MUS$/km (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990)

Height :1 m
Top width :4 m
Slopes :1:4
Cross Section :8m^3/m
Bottom width :12m
Construction material: local materials by hydraulic crane and bulldozer; slope protection; asphalt penetrated stone

4.1Cost to implement adaptation options

Dikes to be constructed are expected to have a height of 1m from the Mean High Water level (MHW). According to Linham et al.(2010), construction cost of dikes can range from US$ 1-7.6 million/ km length depending on their global location. According to IPCC Report of the Coastal Zone Management Subgroup (1990), Sri Lanka is having a total Low-Coast Length of 4820km (Low-coast “crow” length = 990km) and for its protection 1,446.0 MUS$ is required and also the total cost for protection of low coasts of the low middle income groups and for Asian Indian Ocean Countries to which Sri Lanka belongs, have been estimated as 33.7 & 23.6 Billion US$ respectively. Considering the above information cost for construction of a dike of 1 km length, 4m crown width, 12m foot width and a height of 1m was taken as 1.6 MUS$ and estimates were carried out.

Total Low-coast length - 4820km
Total cost for construction of dikes as estimated in 1990(IPCC,1990) - US$M 1,446.0
Cost/m of coast line as estimated in 1990 - US$ 300
Cost/m as calculated for 2011 - US$ 450
If the base width,crown width & the height of the dike are 8m, 4m and 1m respectively
Area of land covered by 1m length of dike along the coast -12m^2
Therefore cost per 1m^2 of the dike constructed along the low coast **- US $ 37.5**

4.2 Additional costs to implement adaptation option, compared to “business as usual”

- With the increase of sea level dike heightening is needed and costs for such modifications should be included whenever they are necessary.

- If the dikes 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.

5 Development impacts , indirect benefits

5.2 Economic benefits

5.2.1 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

5.2.2 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 it is an indirect investment due to reduction of costs for rehabilitation and maintenance of coastal structures and properties.

5.3 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 dikes will improve their socioeconomic status
- **Education**
  - 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

5.4 Environmental benefits

- Dikes 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

6 Local context

6.2 Opportunities & Barriers

6.2.1 Opportunities

6.2.1.1 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 find solutions to possible coastal erosion and inundation due to expected sea-level rise within the coastal belt of Sri Lanka, using locally available material.

6.2.1.2 Academics and researchers will get an opportunity to conduct useful scientific research to develop low cost techniques to construct dikes.

6.2.1.3 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.

6.2.2 Barriers

- High cost incurred on coastal constructions, coral transplanting, 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.

6.3 Status

Technology for dike construction using locally available material, associated with rock revetments and geotextile lining is currently being used in low coasts.

6.4 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

6.5 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/**