APPENDIX L

FAILURE MECHANISMS AND PROTECTION OF DIKE SLOPE AND DIKE TOE

L.1 Principal mechanism of sea dike and revetment failure in Vietnam

Fig. L-1 illustrates common failure mechanism for sea dikes. Note that the occurrence of a certain mechanism will sequentially result in others, and consequently leads to dike breach. For example, the foreshore erosion or dike toe erosion will cause the instability of toe structures or dike toe. This instability will result in the instability and failure of the revetment if no remedial solutions are adopted. Consequently, under the impacts of waves, unprotected dike slopes will be eroded. The erosion continues until the dike body is entirely destroyed, leading to dike failure.

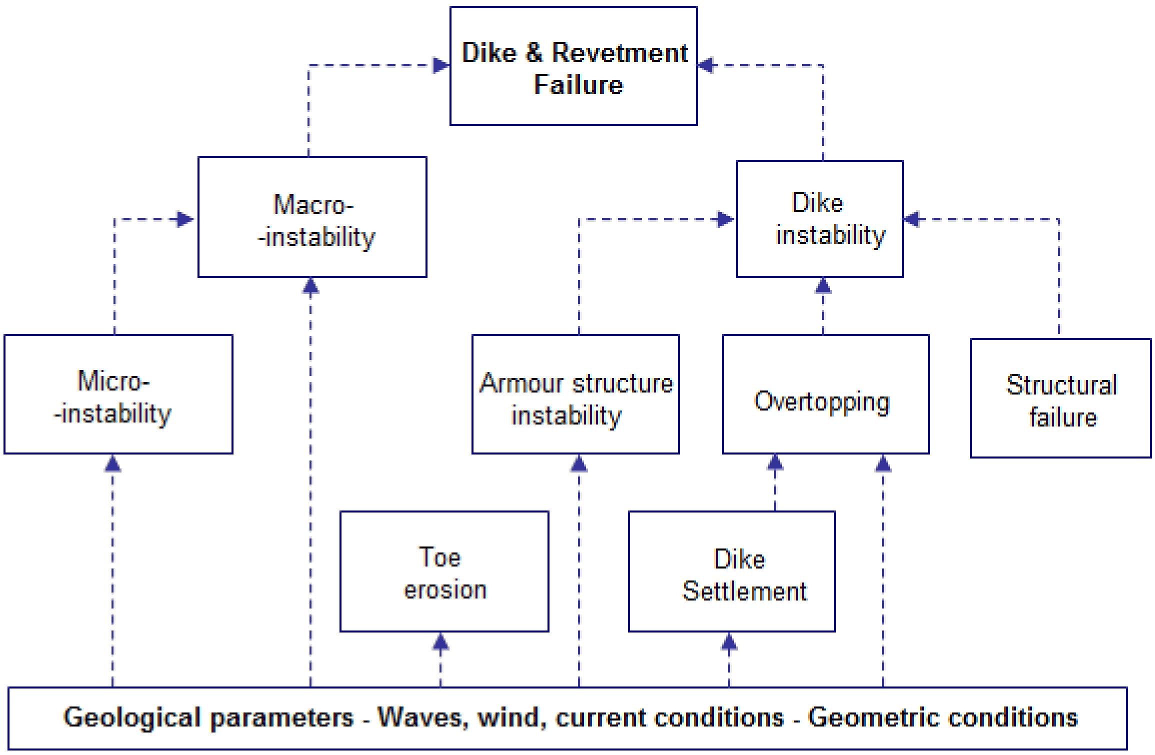
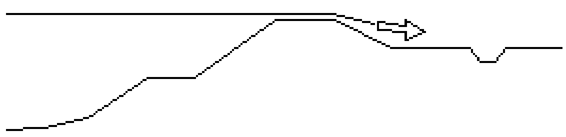
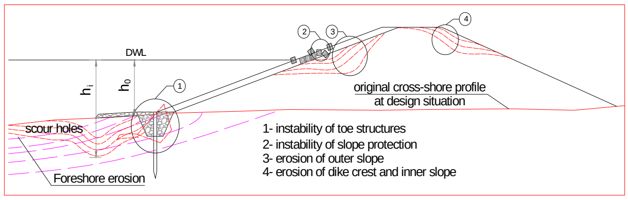


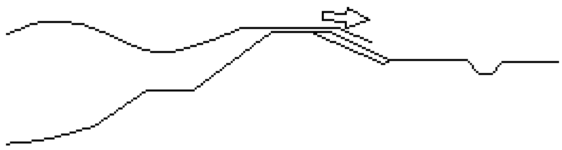
Figure L-1. *Diagram of dike & revetment failure*



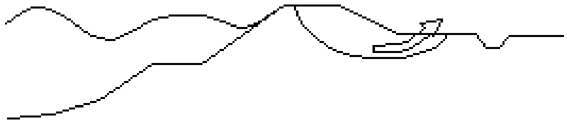
(1) Overflow



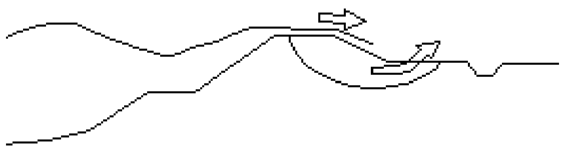
(3) Instability of toe protection structures due to foreshore erosion and local erosion of dike toe



(1a) Overtopping; resulting in erosion of crest and inner slope

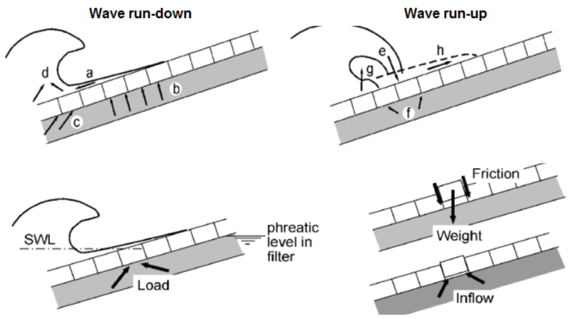


(4) Inner slope sliding



(1b) Overtopping; resulting in inner slope sliding

(5) Outer slope sliding



(2) Instability of outer amour structures/dike slope and body erosion

(6) Internal erosion; piping

Figure L-2. *Typical failure of sea dike*

In the following sections, details of common failure mechanism of sea dike and revetment system in Vietnam will be given.

L.1.1 Wave overtopping

Wave overtopping is the dominant mechanism of sea dike failure in Vietnam, as most of sea dikes are overtopped during storms and flood, even in the long-lasting monsoon period.

The cause of this failure is the great amount of overtopping water or higher water level resulting in the overflow:

+ Current velocities on dike slopes are very high, up to more than 4 m/s, causing the failure of amour structure or grass layer on dike slope and consequently, leading to inner as well as outer slope sliding;

+ When overtopping dike crest, the seepage occurs and causes the liquefaction of dike body. If the compactness is insufficient, the seepage flows will disintegrate the soil gradually and lead to the complete failure of dike body.

In general, the higher overtopping discharge will cause more severe damage. The damage extent depends on construction quality in terms of compactness, types of soil, initial moisture content of the core and dike height.

In the areas where the foreshores lower, when the water depth increases, wave height in combination with high tide and storm surge will cause overtopping with higher discharges. In case the dike body is composed of sandy soil covered by a layer of heavy soil (with common thickness of 0,5m), the overtopping water will wash the covering layer and following sand grains out of the dike body; as a result, the inner slope will fail and the dike breach is initiated seawards.

In case of high waves with no overtopping, the seepage may occur if the requirements of embankment during construction are not met; the seepage flow through the dike body can carry soil grains landwards. More and larger grains will be moved by stronger flows, resulting in the failure of inner slope.

The failure of dike slope usually starts from the crest in case of relatively good quality of embankment. However, the entire slope can also fail if it is saturated with water.

Landward overtopping usually occurs in the areas from Quang Ninh to the North of Thanh Hoa, but seaward overtopping is a common mechanism in the Central region during the main floods.

L.1.2 Slope sliding

Slope sliding occurs when the dike slopes do not meet the safety standards against sliding, i.e. the safety factor against sliding of sea dike is less than the allowable value as per design standards.

Inner slope sliding is mainly caused by wave overtopping and seepage, which saturates or liquefies the embankment soil. The inner dike toe may also be eroded in case of weak toe protection, and as a result the weight of the entire slope will cause sliding. The mechanism of outer slope sliding is similar to that of inner slope, but the external loads are more complicated. The causes of outer slope sliding include:

L.1.2.1 Wave impacts

Waves have great impacts which can cause the erosion of beaches, foreshores and sea bed, as well as the instability and breakage of shore protection structures.

In fact, the mechanisms of dike and revetment failure caused by waves are as follows: the pressures of wave run-down on the revetment toe will wash out sand grains seawards, resulting in the toe erosion. These grains are swept back and exert impacts on dike slope, causing the erosion and failure of revetment.

Process of wave breaking, run-up and run-down will cause the dynamic water pressures on foundation soil and the revetment. Positive wave pressures on dike slope during wave run-up will be exerted into the saturated embankment, pushing the water in the stressed region aside and changing the stress state of soil skeleton. In case of wave run-down, the outer water level is lowered, causing the water pressure difference between the foundation soil and outer surface of revetment – it is the negative wave pressures exerted on the revetment base and tend to break the bond of soil skeleton. These processes form dynamic force couples, causing the instability of revetment structures and the washout of soil grains which lead to the failure of dike and revetment. This is also the cause of outer slope sliding under the impacts of waves.

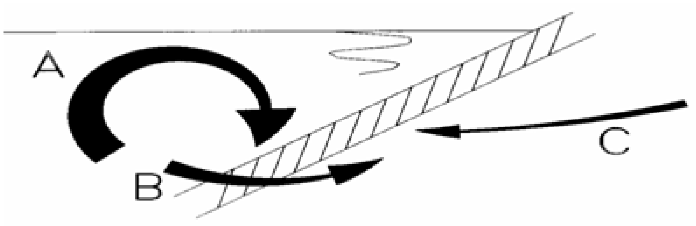


Figure L-3 *Interaction of external and internal loads on the revetment*

where,

A – Impacts of waves and currents;

B - Interactive impacts of external and internal loads;

C - Internal loads caused by potential energy of ground water level;

Due to the impacts of outward seepage flow after the wave retreat, in case of no geotextile or poor quality of inverted filter layer not meeting the requirements of construction, soil grains will be washed out gradually through the openings, forming the irregularly hollow regions in the soil body under the revetment and causing the revetment to deform and to fail.

L1.2.1 Water levels

In case of low water level, waves exert great pressures on the dike toe and cause the failure of dike slope and toe, leading to the collapse of the toe, loss of underlying amour layers, or the washout of soil grains from the embankment; and consequently the dike slope will collapse. The impacts of positive wave pressures can also cause the settlement of the revetment.

Due to the beach erosion under the impacts of strong waves and nearshore currents, sediments are carried away; consequently, the foreshore sinks and the dike toe is eroded, causing the collapse of revetment and dike. In case of sandy dike body with insufficient compactness, continuous impact of waves with great intensities can causes the liquefaction of sand, which is then carried by the seaward flows, also resulting in the collapse of revetment and dike.

Nearshore waves and currents carry sediments away and lower the foreshore, causing the instability of seaward dike toe, while wave overtopping and wave run-down increase the pressures and cause the instability of outer slope. In case of mean tidal water level, the foreshore erosion decreases gradually until the water level rise under normal conditions of weather. However, in case of stormy period or wind direction perpendicular to the coastline, the local erosion will occur.

When the tidal water level is high, the impacts of waves and current on dike toe are insignificant. However, these impacts become much greater at the regions close to design water level with the combination of strong wind, high waves and high tides during storm; they can cause highly severe damage in case of poor and insufficient reinforcement.

L.1.3 Dike toe erosion

Dike toe withstand the frequent impacts of waves and current, therefore these factors must be taken into consideration in the study of dike toe erosion.

L.1.3.1 Wave impacts

Waves break during the propagation from deep-water to shallow-water areas, causing serious impacts on the structures. According to research results, there are 60-80% of breaking wave energy exerting direct impacts on the dike toe. Waves and currents erode the foreshore surface, and cause local great sinking during storm, leading to the erosion and collapse of dike toe, and the instability of the entire dike profile.

L.1.3.2 Nearshore currents

Nearshore currents carry the sediments on the foreshore surface out of the study area is the cause of sediment loss and foreshore sinking. If the erosion continues until the foreshore elevation is close to the base level of revetment toe, it will fall or collapse completely, resulting in the slope sliding. The frequency of erosion process or the rate of local scour formation during storm depends on wave height, wave direction, water depth, bathymetry and geological conditions in the study area.

L.1.3.3 Common types of dike toe failure

Common types of dike toe failure in Vietnam include:

- Settlement of dike toe, resulting in the breakage and collapse of revetment;
- Collapse of dike toe due to the erosion of dike slope;
- Dike toe is separated from the revetment due to settlement;
- Breakage of toe structures due to wave impacts;
- Dike toe is exposed as the foreshore elevation is lower than the base level;
- Damage to dike toe due to human impacts ;

L.1.3.4 Causes of failure

Main causes of dike toe failure are as follows:

- Main dimensions of dike toe (width, depth etc.) cannot withstand the actual impacts from the sea;
- Dimensions and shape of dike toe elements (stone, concrete structures etc.) do not meet the technical requirements;
- Insufficient treatment of foundation resulting in the settlement, erosion etc.;

- Poor quality of filter layers; the erosion of soil causes dike toe failure;
- Construction of dike toe does not meet all of the technical requirements.

L.1.4 Failure of slope amour layers and dike crest structures

The failure process of slope amour layers and dike crest structures under the impacts of overtopping waves are explained as follows:

- As the weight of amour elements is smaller than the periodic wave pressures on dike slope, these elements can be lifted out of the slope, initiating the failure;

- If the wave impacts continue, the following amour elements will be separated from the dike slope;

- Underlying layers will also be washed out due to overtopping waves resulting in scours on dike slope. Furthermore, the seepage will cause the saturation of the dike body and initiate the sliding;

- The erosion of crest surface and slope armour layer is mainly caused by overtopping flow with velocities of 4-5 m/s: grass layers come off and then the dike body is eroded or saturated with water, leading to the inner slope sliding;

- Outer and inner slope sliding due to the loss of armour layers can occur simultaneously; and as a result, the “dike breach” will occur faster.

L.1.5 Settlement on soft soil foundation

Common types of failure of dike foundation and dike body are as follows:

L.1.5.1 Damage and instability due to the settlement and collapse of foundation

This type of failure is found in case of soft soil foundation with thick layers, especially at the locations where the thickness (H) is greater than average width (B) of the dike profile (H > B) and the shearing resistance of foundation soil hardly increase with reference to the depth. The pressure of embankment soil column is greater than the limited bearing capacity of the soft soil at the dike base.

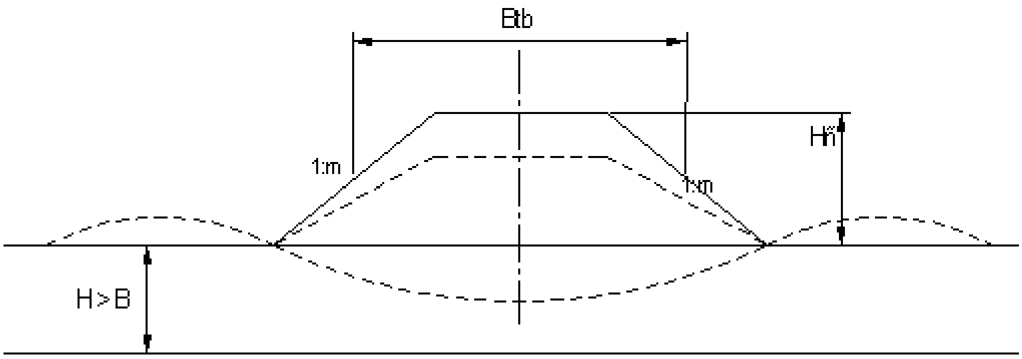


Figure L-4 *Simulation of dike foundation failure due to settlement within loading range*

L.1.5.2 Foundation failure due to horizontal soil emergence

This type of failure is usually found in case of soft soil foundation with thickness (H) is much smaller than the average width (B) of dike profile (H < B), and there are relatively better underlying soil layers.

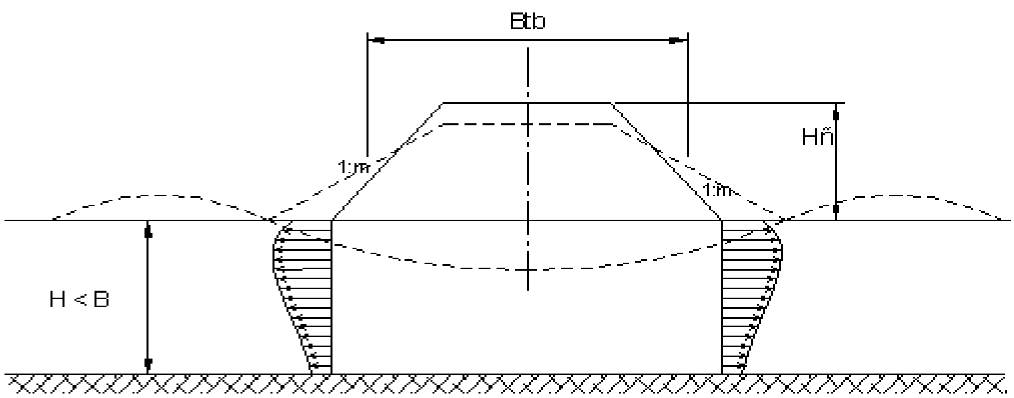


Figure L-5 *Failure model of foundation due to horizontal soil emergence*

L.1.5.3 Failure of dike foundation and dike body due to deep sliding

This is the common types of failure for dike and earth dam. Depending on the characteristics of foundation and embankment soil, the severe sliding circles can go through the embankment and foundation, especially in case of soft soil foundation; or only the embankment.

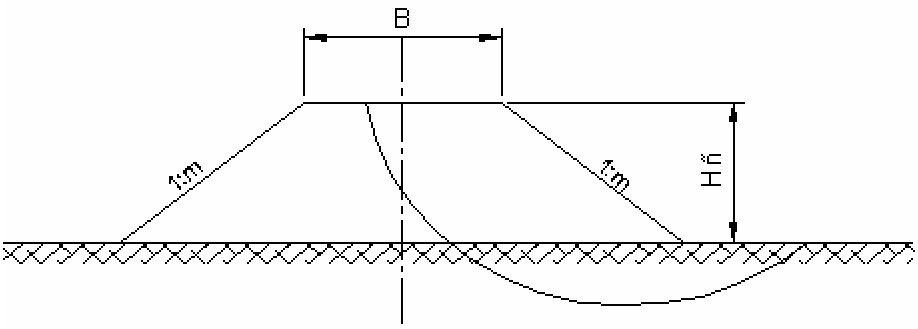


Figure L-6 *Deep sliding circle going through the embankment and dike foundation*

L.1.6 Failure of structures located on dikes

Structures located on dikes include sluices, combination of sluice and bridge, subterranean structures, especially the dike-crossing sluices. Possible failure includes:

+ Failure of sluices gate resulting in the erosion of foundation due to the leakage of water from the river to the sea and vice versa, and causing the collapse of sluice walls or headwalls;

+ The connection between concrete parts of sluices and earthen parts of the embankment is broken due to the leakage and cracking formation in the contact surface, resulting in the flow inside the dike body and leading to the failure after the sluices.

+ The failure of sluice foundation also cause the internal erosion or piping due to the difference between outer and inner water level, which is the cause of sluice base collapse and the breach of dike in the proximity of sluices.

L.1.7 Erosion of natural sea dikes/sand dunes

Sandy beaches and sand dunes are located mainly in central areas from the South of Thanh Hoa to Quang Nam. The combination of waves and storm surge causes severe erosion of sandy beaches, mainly due to the cross-shore currents. According to Bruun, storm surge itself can cause the erosion of sand dunes by 60m in case the sea level rise is 1m. If storm surge is combined with high waves and no solution is adopted to protect the sandy beaches and sand dunes, the range of erosion will become larger.

Mechanism of sandy beach erosion includes:

- Wave run-down with relatively high velocities carry the sand grains with poor bonding away, especially in case of saturation;

- When submerged (due to storm surge), the bonding between sand grains is broken and as a result, sediments will be carried by the currents with relatively high velocities.

- Apart from the impacts of sea water, wind-induced transport of dry sand is also relatively common in case the nearshore wind velocity is much greater than those in the hinterland.

L.1.8 Chemical impacts of marine environment

The corrosion of marine materials includes electrochemical and chemical processes when sea water contains Cl^- ion and SO_4^{2-} ion. Content of dissolved salt in sea water is about 34 – 35 ‰. NaCl has the highest ratio, approximately 77 - 79%, followed by MgCl which accounts for 10,5-10,9%, $MgSO_4$ accounting for 4,8%, $CaSO_4$ accounting for 3,4 - 3,6% and other types of salt. These types of salts can trigger chemical reactions with minerals, rocks, concrete, reinforced concrete, steel etc. and consequently, these materials can be corroded chemically.

In case of metal structures, the corrosion of the elements such as sluice gates occurs in 3 separate zones:

(1) Emerged or dry zones: enduring chemical corrosion in sea water; however, the rate of corrosion depends on the humidity and content of chlorine and sulfate ions in sea water;

(2) Zones under impacts of tidal fluctuation: enduring the most severe corrosion. The rate of corrosion can be much greater than that in other zones;

(3) Completely submerged zones: enduring electrochemical corrosion and the rate of corrosion is less than that in the zones under impacts of tidal fluctuation.

Not only metal, other materials can also be corroded, such as paving stones on revetment surface; apart from mechanical impacts of waves, chemical and weathering processes due to sunlight can also round the stones, which can then roll on the dike slope and piled up at the dike toe.

L.1.9 Impacts of marine creatures

There are some types of marine creatures which usually stick to the surface of wood, metal, concrete and other rigid materials and secrete the substances which can decay these materials. The most common creature is *Crassostrea gigas* (or Japanese oyster) sticking to the sluice walls, not only obstructing the flow, but also secreting the excretion which can degrade the concrete.

Natural factors do not exert impacts independently or separately. Only long-lasting impacts of tides, nearshore currents, saline water, marine creatures can cause certain degradation of durability, damage, erosion or failure. However, impulsive pressures of waves can promptly cause the partial damage or even the collapse of sea shore and its amour structures.

L.1.10 Negative human impacts

Exploitation of nearshore sand, gravel, deposit and coral reduces the quantity of sediments supplementing the beach, resulting in the coastal erosion. The exploitation of sand for construction material has increased the foreshore degradation and causes the toe erosion, leading to the revetment failure and dike breach.

L.2 Details of some dike slope protection elements

L.2.1 Slope armour elements with self-joining and array-linking patterns

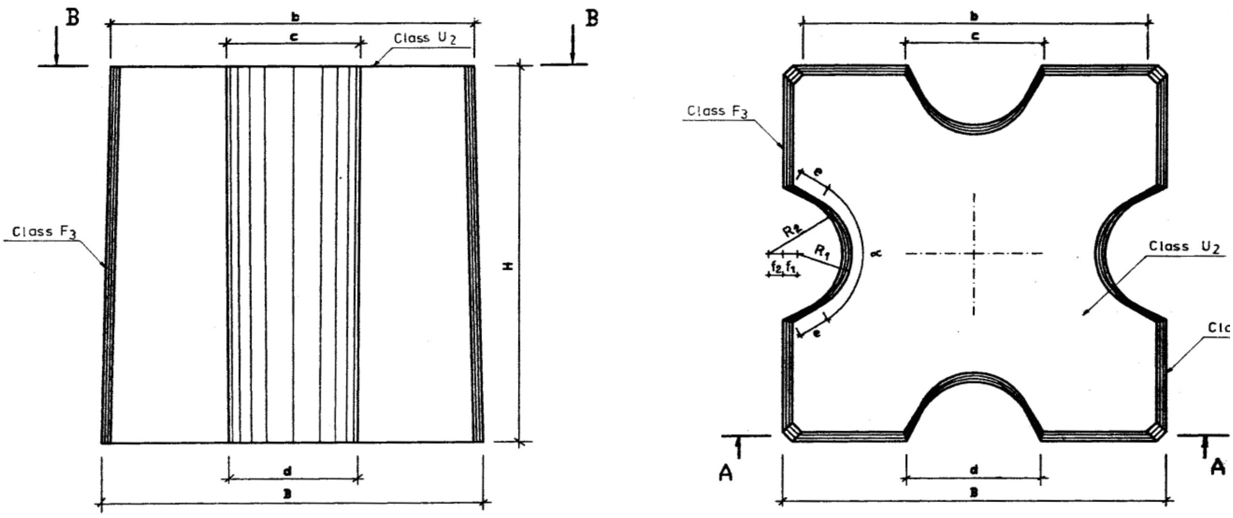
Fig. L-7, L-8 and ***L-9*** illustrate some types of precast concrete slope armour elements with self-joining and array-linking patterns and their common specifications.

(a) Notched faces concrete blocks (Empty Block)

(b) TSc-178 blocks

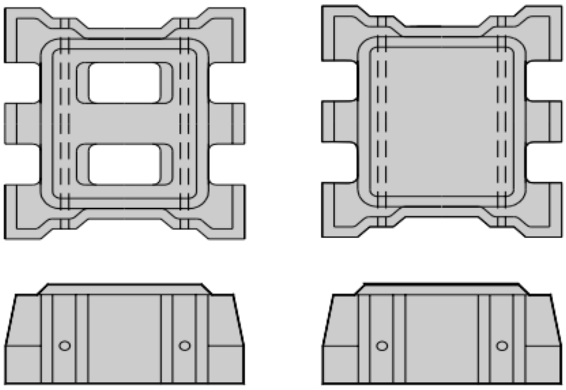
(c) Rectangular blocks with positive-negative joining pattern

Figure L-7 *Some types of precast concrete slope armour elements with self-joining and array-linking patterns*



Weight	B	b	H	c	d	e	a	R_1	f_1	R_2	f_2	∝	Volume (m^3)	Area (m^2)
10T Blocks	1800	1700	1750	750	750	144.5	50	350	0	250	0	120	4.17	13.60
15T Blocks	2000	1900	2000	704	704	156	1800	315	50	315	0	120	6.25	16.00

Figure L-8 *Notched faces concrete blocks (EMPTY BLOCK or AntiFer®)*



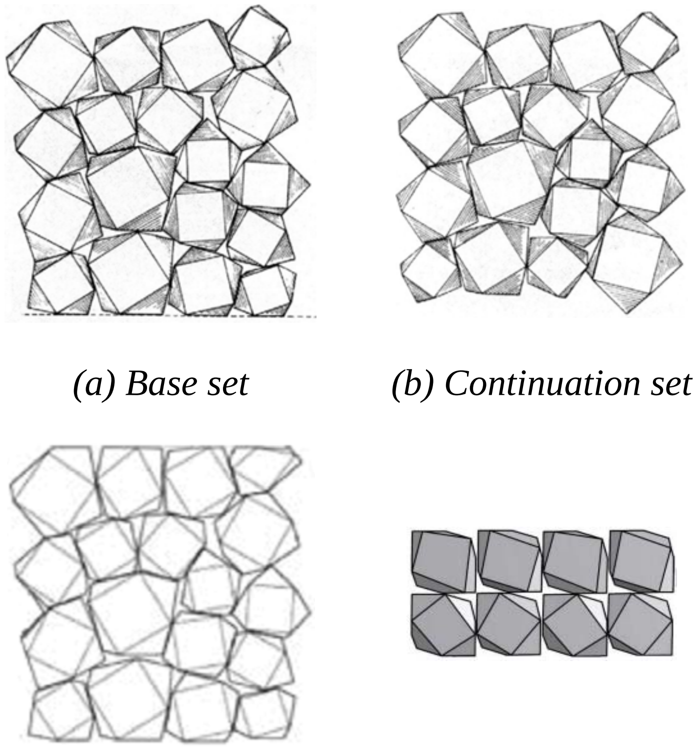
Technical specifications GreenFlex®:		150	180	185	215	305	445
Concrete block							
Length	mm	340	340	340	340	340	340
Width	mm	400	400	400	400	300	300
Height	mm	85	110	95	110	150	225
Block weight	kg	19	23	23	27.2	29	42
Open block		•	•				
Closed block				•	•	•	•
Concrete quality	NEN	7000	7000	7024	7024	7024	7024

Figure L-9 *Precast GreenFex®concrete block*

L.2.2 Column-typed slope armour elements

L.2.2.1 Basalton® and Basalton-ECO® blocks

Basalton® is a typical precast column-typed concrete blocks, including standard and ecological types (or *Basalton-ECO®*) for the purpose of ensuring the environmental-friendly characteristic of sea dikes (see ***Fig. L-10***).



(a) Base set *(b) Continuation set*

(c) Corner set *c) End set*

Figure L-10. *Types of Basalton® layouts*

Weight and other specifications of Basalton® is given in ***Table L-1*** and ***Fig. L-11***.

Table L-1 *Weights of Basalton® blocks*

Height *(cm)*	*15*	*20*	*25*	*30*	*35*	*40*	*45*	*50*
Weight *(kg)*	***310***	***433***	***554***	***654***	***736***	***880***	***990***	***1038***

Basalton Standard Columns			
Name	Total height of column in mm	Density 2.3 (compacted concrete)	
		t/m^2	m^2/t
STD 15	150	0.312	3.21
STD 20	200	0.416	2.40
STD 25	250	0.521	1.92
STD 30	300	0.628	1.59
STD 35	350	0.710	1.41
STD 40	400	0.811	1.23
STD 45	450	0.912	1.09
Small variations in size & weight may occur			

(a) Specifications of standard Basalton®

Basalton Eco Columns			
Name	Total height height of column in mm	Density 2.3 (compacted concrete)	
		t/m^2	m^2/t
ECO 15+	200	0.375	2.67
ECO 20+	250	0.480	2.08
ECO 25+	300	0.590	1.69
Small variations in size & weight may occur			

(b) Specifications of Basalton-ECO®

Figure L-11 *Specifications of standad Basalton® and Basalton-ECO®*

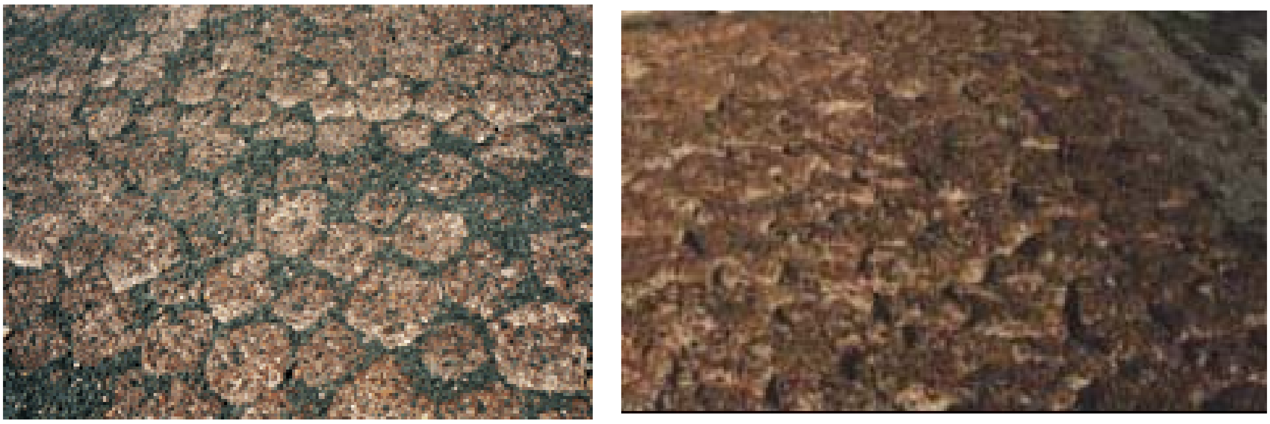


Figure L-12 *Basalton-ECO® blocks*

L.2.2.1 Hydroblock® and Hydroblock-ECO®

Hydroblock® is another typical type of precast column-typed concrete blocks, also includes 2 common types: standard Hydroblock® and Hydroblock-ECO® (see ***Fig. L-13***).

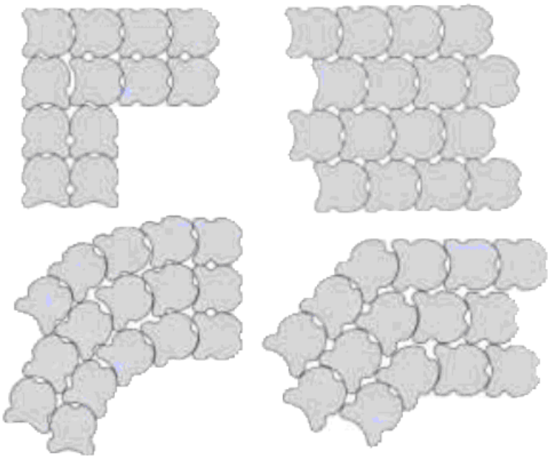


Figure L-13. *Linking patterns of Hydroblock®*

Specifications of Hydroblock® are shown in ***Table L-2.***

Table L-2 *Specifications of Hydroblock®*

TECHNICAL SPECIFICATIONS						
Type	Block height (cm) *)	Block weight (kg) **)	Open space (%)	Weight (kg/m²)	Block height (inches)***)	Block weight (Lb)
HYDROBLOCK® 15 (15 + ECO)	15 (18)	19	12-15	300	5.9″	41.9
HYDROBLOCK® 20 (20 + ECO)	20 (23)	25	12-15	400	7.9″	55.1
HYDROBLOCK® 25 (25 + ECO)	25 (28)	31	12-15	500	9.8″	68.3
HYDROBLOCK® 30 (30 + ECO)	30 (33)	38	12-15	600	11.8″	83.8
HYDROBLOCK® 35 (35 + ECO)	35 (38)	44	12-15	700	13.8″	97.0
HYDROBLOCK® 40 (40 + ECO)	40 (43)	50	12-15	800	15.7″	110.2
HYDROBLOCK® 45 (45 + ECO)	45 (48)	57	12-15	900	17.7″	125.7
HYDROBLOCK® 50	50	63	12-15	1000	19.7″	138.9

*) The block height of the ECO-coated Hydroblock® can only be approximated because of the open structure of the top.
**) Relative density: 2.28 (different relative densities available on request).
***) Ecotops add a height of approximately 2″ to block height.

In fact, blocks of this type can be arranged discontinuously on dike slope in order to give the best efficiency of wave run-up attenuation and wave energy decay (see ***Fig. L-14***).

Figure L-14. *Discontinuous placement of Basalton® on dike slope*

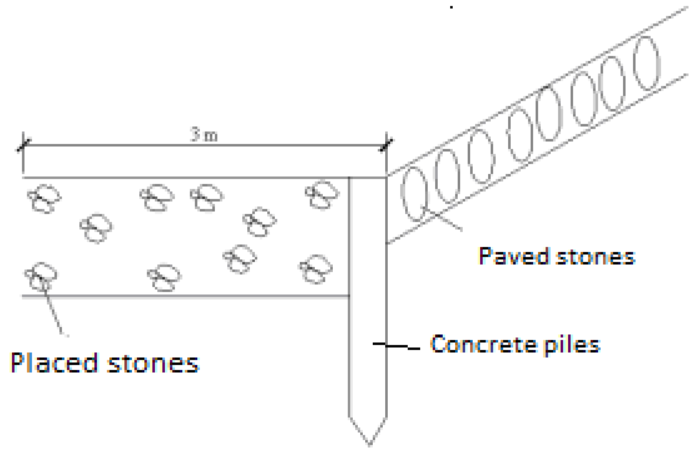
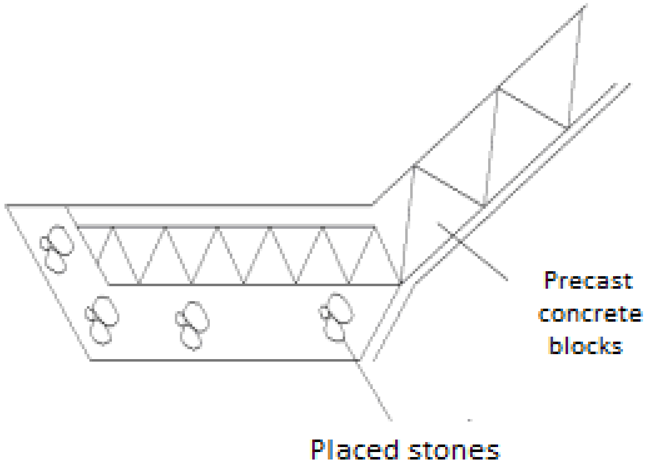
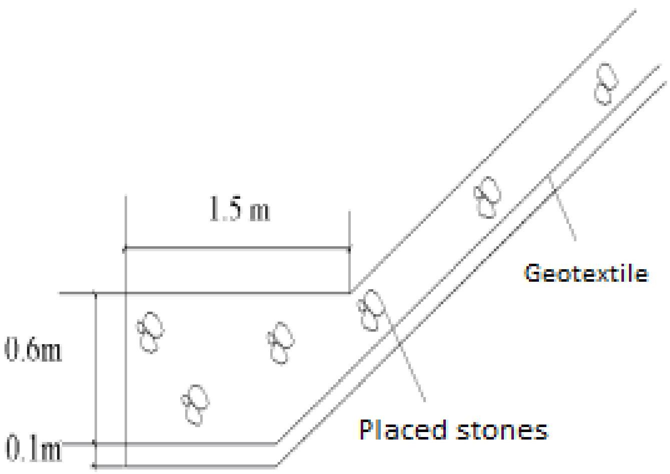
L.3 Details of dike toe protection structures

Table L-3 *Summary of structural types and materials of dike toe protection in Vietnam*

Structural types and materials of dike toe protection	Ratio (%)
Placed quarry stone	45,4
Grouted quarry stone	18,2
Placed quarry stone + paving concrete blocks	11,4
Sheet pile (steel/ concrete)	6,8
Concrete cylinder	6,8
Gabion	4,5
Riprap	2,3
Piles	2,3
Others	2,3

Table L-4. *Types of common dike toe protection structures in Vietnam and their application conditions*

(According to Centre for Hydraulic Science and Technical Deployment, 1999)

No.	Composition	Appication conditions
1		- Topography: abrupt change of beach (with stepped formation); - Geology: soft soil; - Impacts from the sea: insignifcant erosion; weak nearshore current; - Materials: in situ; - Construction: manually in dry or submerge conditions.
2		- Topography: foreshore in front of dike toe; - Geology: soft soil foundation; - Impacts from the sea: insignifcant erosion; weak nearshore current; - Materials: in situ; - Construction: manually in dry or submerge conditions.
3		- Topography: foreshore in front of dike toe; - Geology: soft to medium soil foundation; - Impacts from the sea: insignifcant erosion; weak nearshore current; - Materials: in situ; - Construction: manually in dry or submerge conditions.

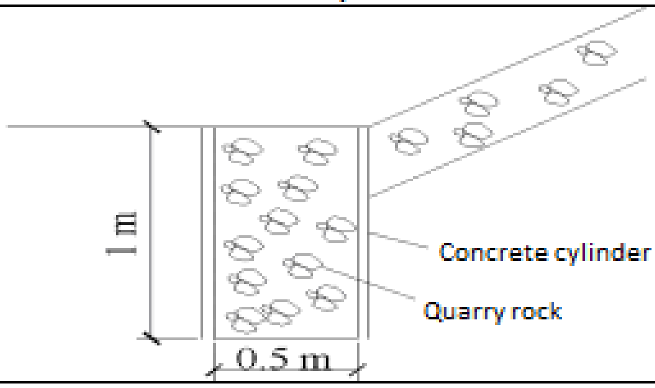
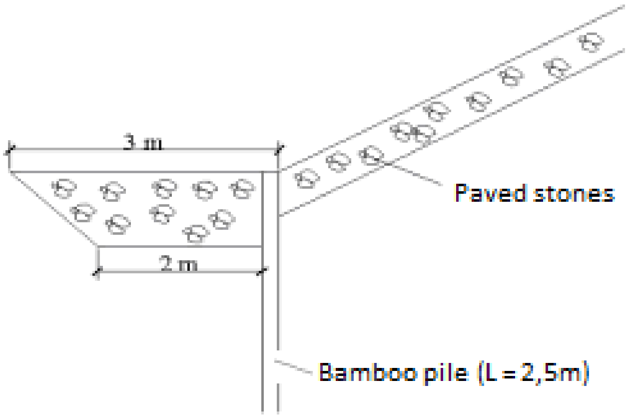
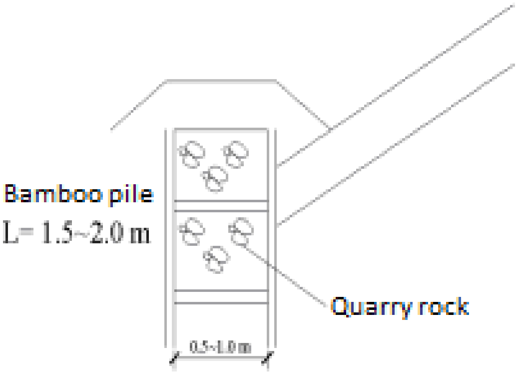
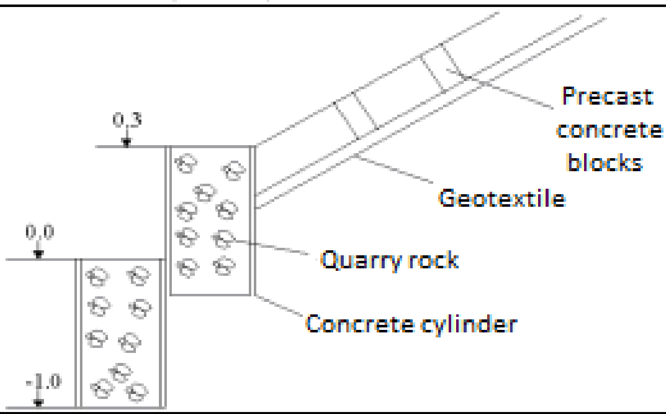
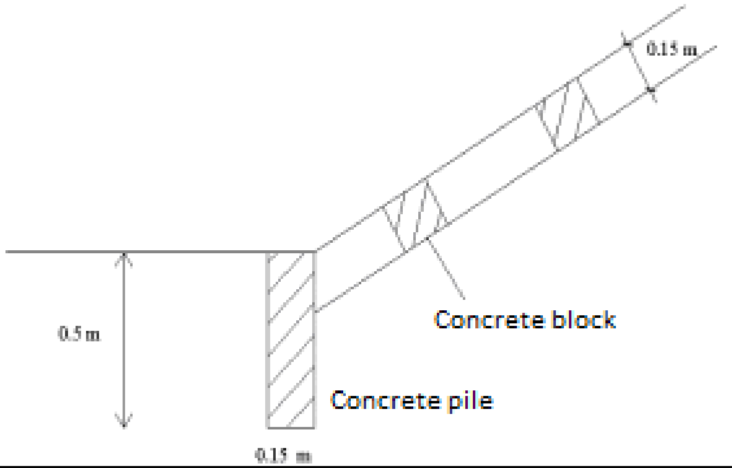
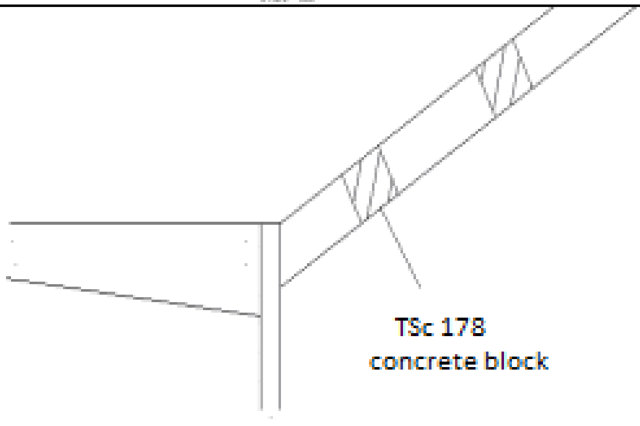
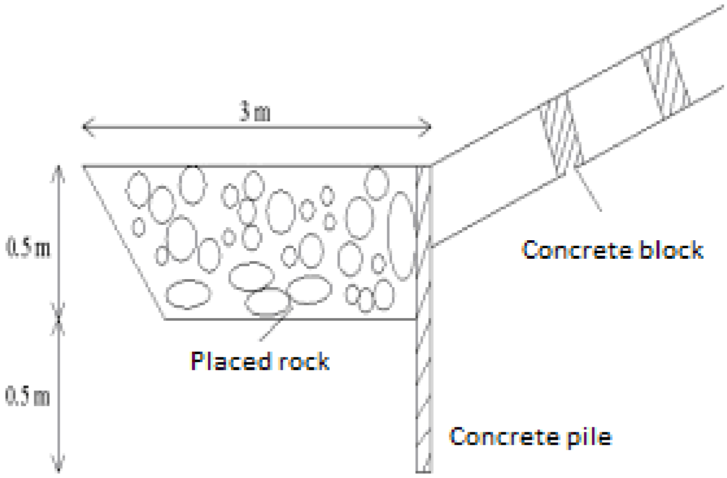
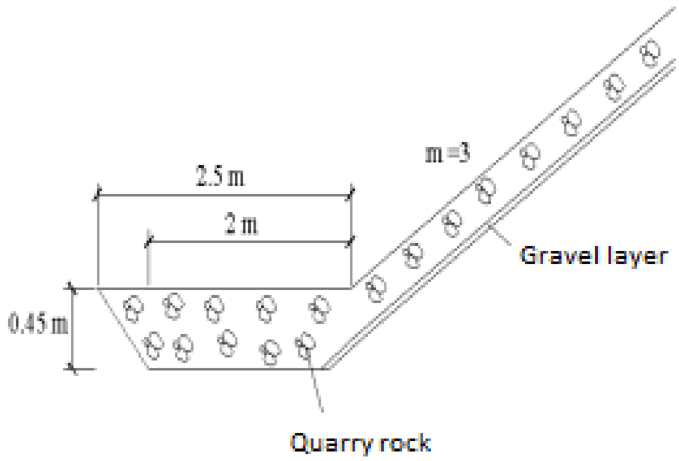
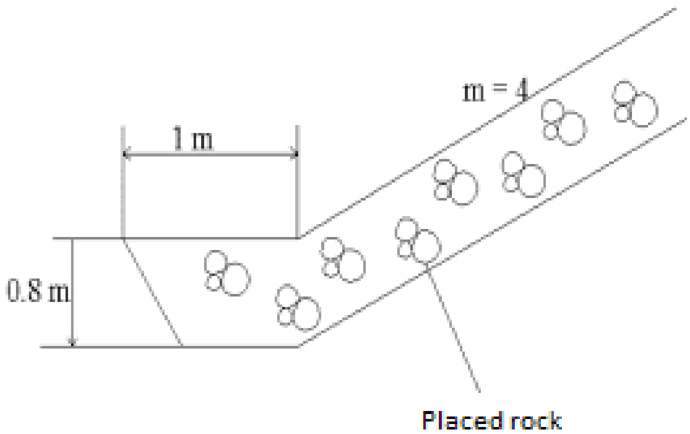
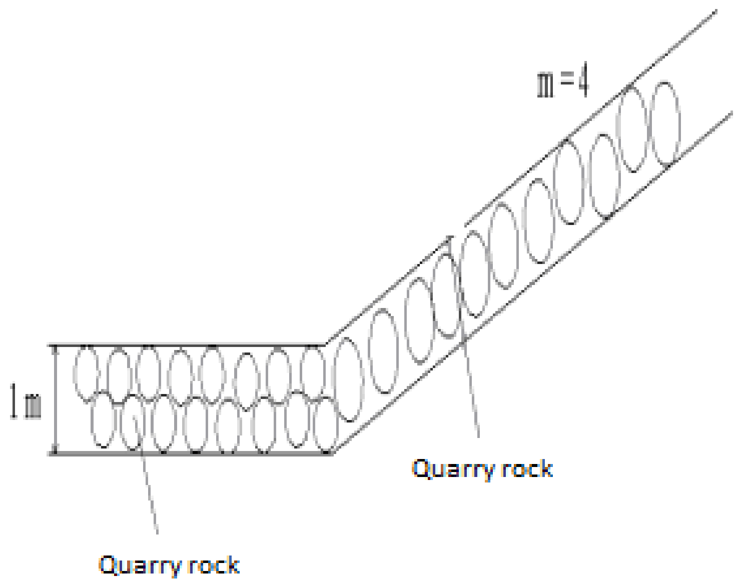
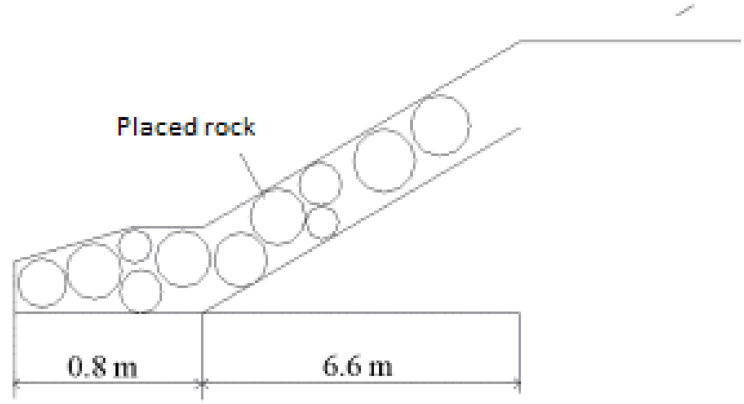
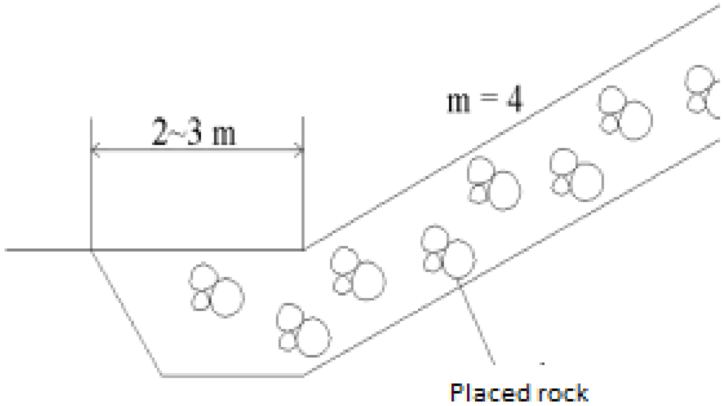
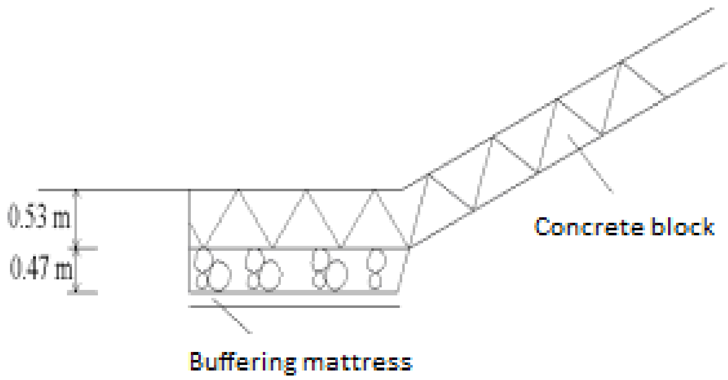
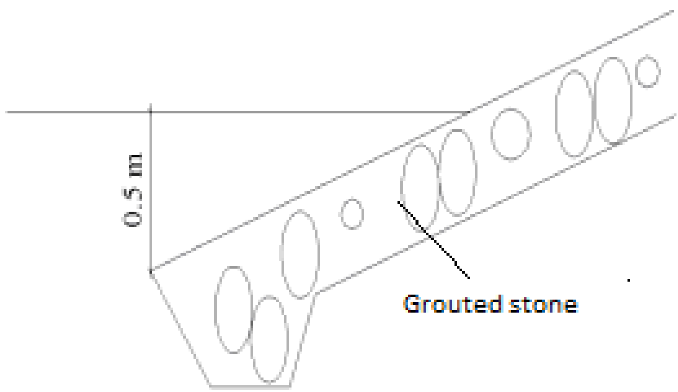
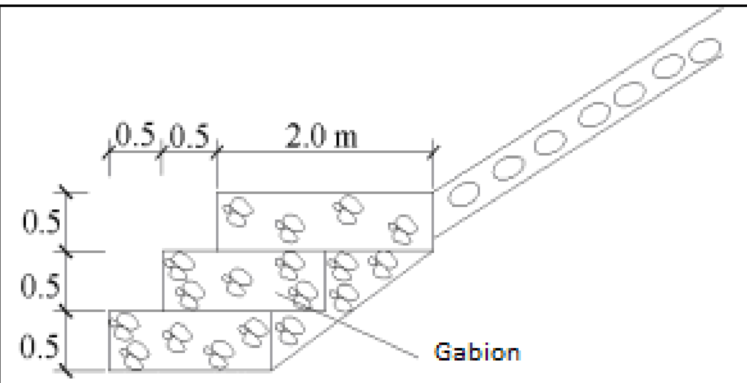
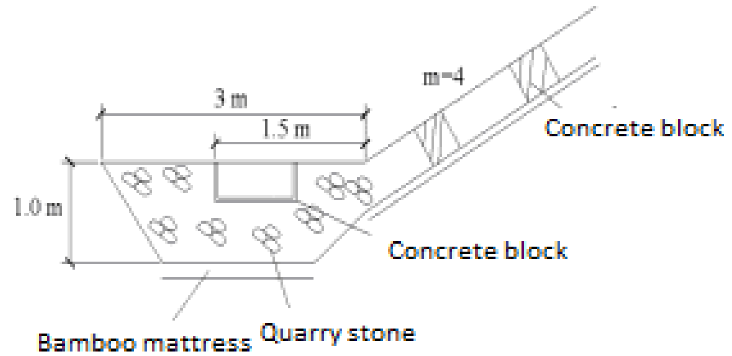
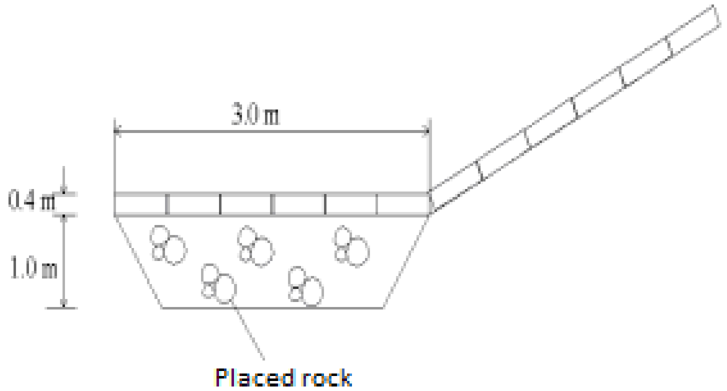
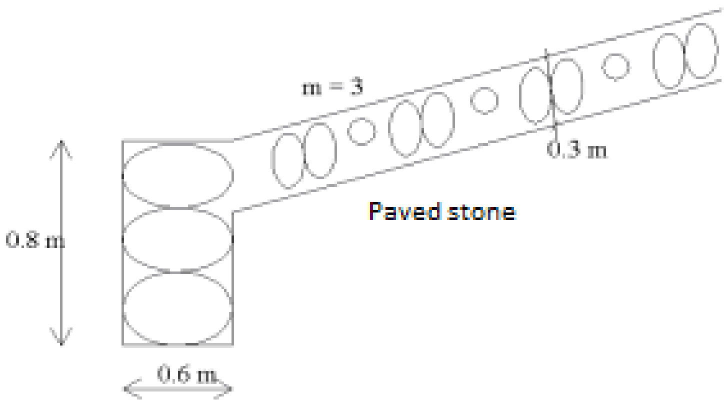
No.	Composition	Appication conditions
4		- Topography: stepped formation; - Geology: weak sandy foundation; - Impacts from the sea: severe erosion, strong nearshore current; - Materials: combination of concrete and in situ materials; - Construction: manually in dry or submerged conditions.
5		- Topography: stepped formation, severely eroded foreshore; - Geology: soft and weak foundation; - Impacts from the sea: severe erosion, insignificant nearshore current; - Materials: in situ; - Construction: manually in dry conditions.
6		- Topography: abrupt change of beach (with stepped formation); - Geology: soft and weak - Impacts from the sea: insignificant erosion, weak nearshore current; - Materials: in situ; - Construction: manually in dry or submerged conditions.
7		- Topography: stepped formation, severely eroded foreshore; - Geology: soft and weak sand; - Impacts from the sea: severe toe erosion, strong nearshore current; - Materials: concrete and in situ materials; - Construction: manually and mechanically in dry or submerged conditions.

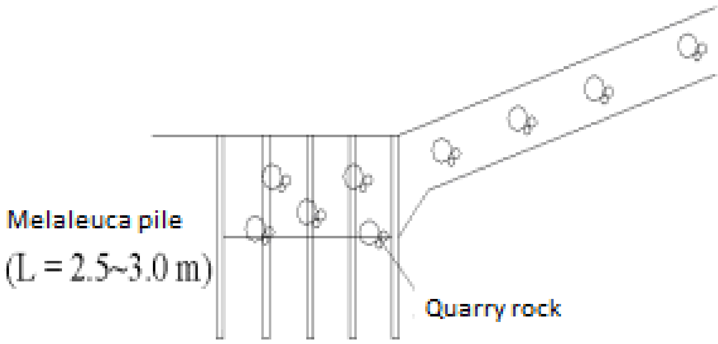
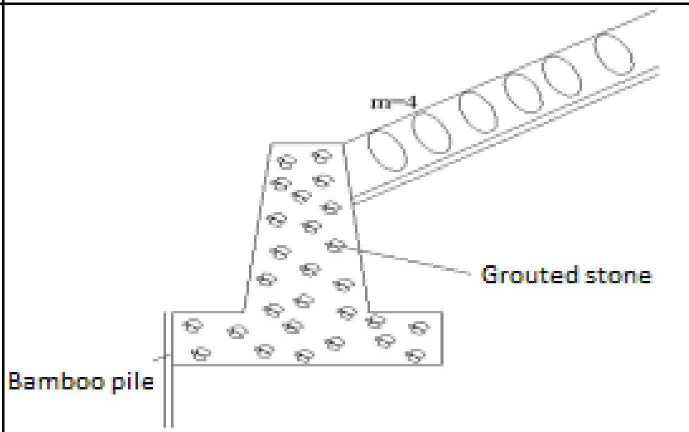
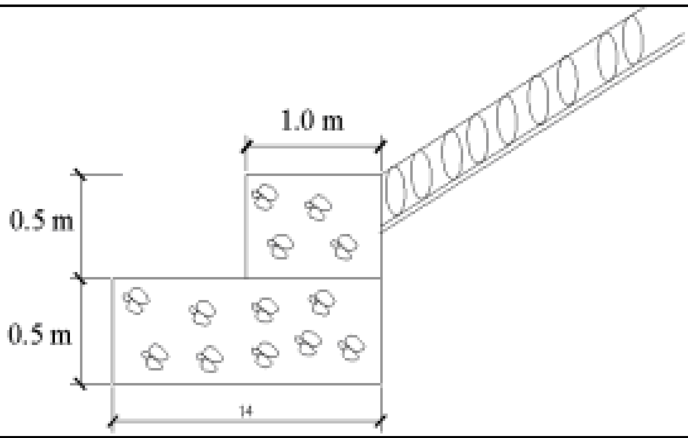
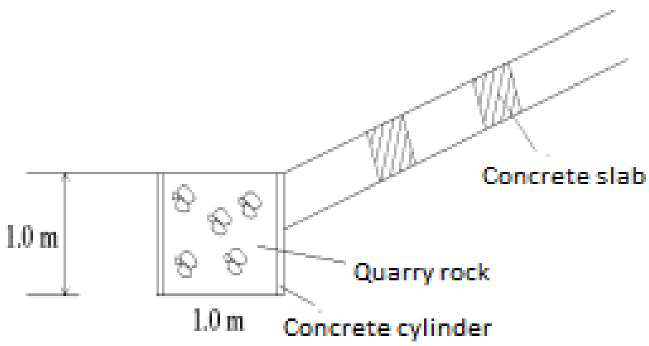
Table L-5. *Summary of common types of dike toe protection in Vietnam (according to Centre for Hydraulic Science and Technical Deployment, 1999)*

No.	Composition	Description
1		- Name: My Trung Revetment; - Location: Quang Ninh - Quang Binh; - Structural type: concrete elements; - Material: concrete; - Status: data not available
2		- Name: Tran Phu Revetment; - Location: Nha Trang City; - Structural type: steel sheet pile, TSc 178 concrete block; - Material: steel sheet pile; - Status: data not available
3		- Name: Van Ly Revetment; - Location: Hai Hau - Nam Dinh; - Structural type: concrete pile, grouted stones;

No.	Composition	Description
4		- Name: PAM Revetment; - Location: Quang Ninh; - Year of construction: 1998 - Structural type: manually placed stones; - Material: quarry rock; - Status: good
5		- Name: Co Vay Revetment; - Location: Xuan Thuy - Nam Dinh; - Year of construction: 1998 - Structural type: un-grouted paved stones; - Material: quarry rock;
6		- Name: Van Chan Revetment; - Location: Cat Hai island - Hai Phong city; - Structural type: un-grouted paved stones; - Material: quarry rock;

No.	Composition	Description
7		- Name: Do Son Revetment; - Location: Hai Phong City; - Structural type: un-grouted paved stone; - Material: quarry rock.
8		- Name: Hai Thinh Revetment; - Location: Hai Hau - Nam Dinh; - Structural type: paved stone; - Material: quarry rock. - Year of construction: 1985
9		- Name: Van Ly C15-C21 Revetment; - Location: Hai Phong City; - Structural type: concrete block and quarry stone; - Material: concrete, quarry rock. - Year of construction: 1989
10		- Name: Sea dike No. 7; - Location: Thai Binh; - Structural type: grouted stone; - Material: quarry rock.

11		- Name: Hai Hau Revetment; - Location: Nam Dinh; - Structural type: gabion (with quarry rock); - Material: gabion with quarry stones.
12		- Name: Danh Chau, Ba Non Revetment; - Location: Hai Hau - Nam Dinh; - Structural type: bamboo filter layer, quarry rock, concrete blocks - Material: concrete, quarry stone, bamboo; - Year of construction: 1995
13		- Name: Van Ly Revetment; - Location: Nam Dinh; - Structural type: concrete block, placed stone; - Material: concrete, quarry rock; - Year of construction: 1989
14		- Name: Quan Muc Revetment; - Location: Hai Phong City; - Structural type: grouted stone; - Material: quarry rock; - Year of construction: 1998

<table>
<tr><td>15</td><td>
</td><td>- Name: Vinh Long Revetment;
- Location: Vinh Long;
- Structural type: bamboo pile and quarry stone;
- Material: quarry rock, melaleuca tree</td></tr>
<tr><td>16</td><td>
</td><td>- Name: Cua Lo Revetment;
- Location: Nghe An;
- Structural type: retaining wall, bamboo pile;
- Material: quarry rock, bamboo</td></tr>
<tr><td>17</td><td>
</td><td>- Name: Tu Hien Revetment;
- Location: Phu Loc - Hue City;
- Structural type: Gabion with quarry rock;
- Material: gabion with quarry rock,
- Year of construction: 1997</td></tr>
<tr><td>18</td><td>
</td><td>- Name: Y Vich Revetment;
- Location: Thanh Hoa;
- Structural type: concrete cylinder, quarry stone;
- Material: concrete, quarry rock.</td></tr>
</table>

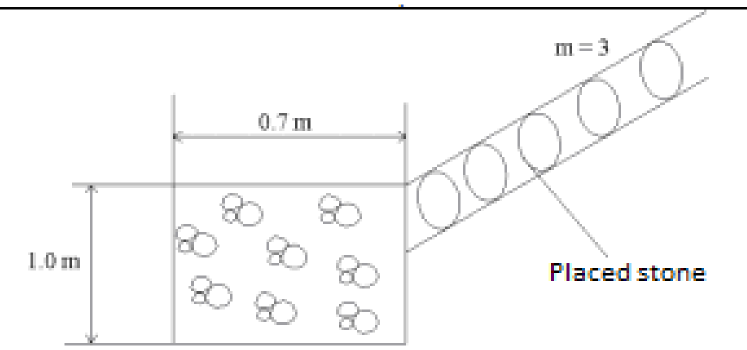
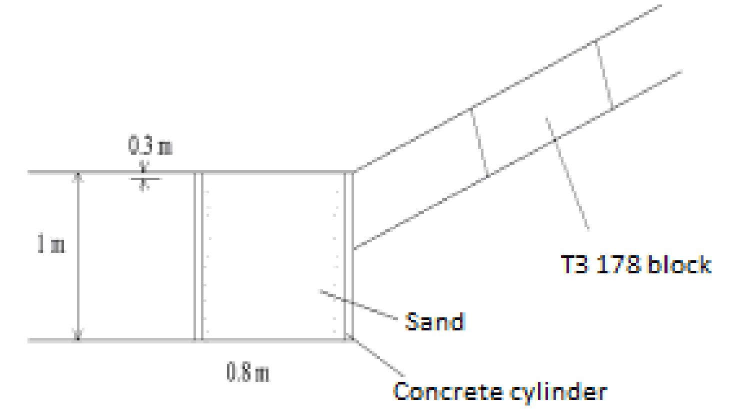
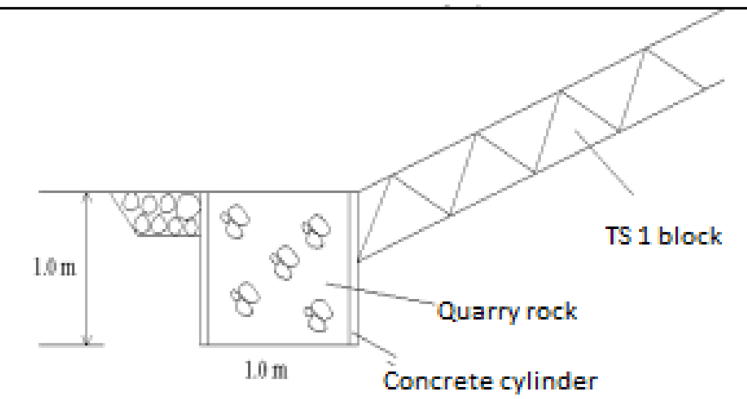
<table>
<tr><td>19</td><td></td><td>- Name: Nghia Phuc Revetment;
- Location: Nam Dinh;
- Structural type: large quarry stone;
- Material: quarry rock</td></tr>
<tr><td>20</td><td></td><td>- Name of revetment: Left bank of Nhat Le river;
- Location: Quang Binh;
- Structural type: concrete cylinder;
- Material: concrete, sand.</td></tr>
<tr><td>21</td><td></td><td>- Name: Co Vay Revetment;
- Location: Xuan Thuy - Nam Dinh; Do Son - Hai Phong City;
- Structural type: concrete cylinder, quarry stone;
- Material: concrete, quarry rock</td></tr>
</table>

Figure L-15. *Types of inner dike slope protection. Left: Vetiver planted on inner dike slope with no structural toe protection. Right: grass planted in grouted stone framework, dike toe is protected by grouted stone longitudinal beam.*

Figure L-16. *Types of inner dike slope protection using grass layers and steel sheet piles*