A Manual for Protection of Agricultural Coastal Lands in Malaysia

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The purpose of this manual is to compile available information on the design of sea dyke works for protecting agricultural lands at the West Coast in West Malaysia. Many alluvial lowlands, lying below high-tide water level, are distributed widely at the West Coast. Although earth bunds have been constructed to prevent coastal wave actions and invasion of sea water, they have often induced coastal erosion and heavy damage on agricultural lands.

The receding coast line of the alluvial lowlands has been believed to be a simple erosion phenomenon so far, but in this manual it is shown that the receding occurs due to a scouring caused by dynamic process, as evidenced by a field model of rock dyke constructed.

Based on the results obtained with the model, a new method of designing and construction are proposed. For example, a mechanized construction of foundation without piles, and an estimation of dyke safety on the basis of safety factors.

Scouring and erosion

The author found out that the receding coast line phenomenon in alluvial clay regions was quite different physically from that in sandy coasts.

Transport and sedimentation of soil particles are predominantly attributed to flocculation of clay fraction. When cohesive material is immersed under tidal water, its properties are changed to become erodible.

In this section, the author sammarizes a new simple method to discriminate between scouring and erosion, based on the results of many case studies carried out in Malaysia over a long period of time. The outline is described in Table 1.

Table 1. Differences between scouring and erosion

No.	Key Subject	Scouring	Erosion
1	Main forces effecting	Momentum	Continuity
2	Extent of receded area	Localized	Wide
3	Period of occurrence	Short	Long
4	Complex or monotonous action	Complex	Monotonous
5	Transformation of main forces at the time of action	Wave breaking	Current
6	Difference in response	No time lag	With time lag
7	Active limit power of breaking	Maximum value	Mean value
8	Location of stability point in the profile	Toe of dyke	Off-shore
9	Effect on neighboring regions	Receding or no change	Accretion or transitive status

1) Momentum or continuity

Receding of coast line follows the drift of water. Scouring can be explained to develop with momentum relations. This mechanism seems to have a dynamic term, $F=m(v^2/2g)$. On the other hand, erosion is considered to occur with continuity relations between input and output forces in the field, as can be expressed by a static formula like $ds/dt=I-O$, where s=deposition or erosion volume, I= input force or material, and O=output force or material.

In case of scouring, dominant factor is only wave forces, but for erosion tidal current also has to be considered.

2) Micro scale or macro scale

Scouring phenomenon occurs concentrically at a narrow belt of beach line. It occurs initially at the intersection area of radial flow at a river mouth and a beach line, and then it develops and expands.

Erosion is developed in much wider areas from the place of high tide to that of low tide, covering a large extent of area, i.e. in a macro scale.

3) Scouring occurs during a short time of monsoon season, while erosion develops every day, but very slowly for a long period of time: almost invisible in a short time observation. Its progress speed and features are influenced by the rate of agricultural development and nourishing properties of delta in the hinder land.

4) Complex motion or monotonous action

Scouring is related with combination of forces such as waves, drifting logs and shells.

Erosion occurs in association with water quality change.

5) Dominant force

At the time of wave breaking, impact forces of wave action turn into scouring forces.

Erosion follows rip current flow of movables like colloidal soil or shell.

6) Difference in response

According to the field studies, scouring develops immediately without time lag when a flood runoff exceeds a certain critical amount during the monsoon season.

Erosion occurs some time later with the time lag of peaks from those of flood, rain fall or monsoon.

7) Limit power of breaking

Naturally, input forces are variable and irregular. As for the value of critical breaking force, scouring phenomena are dependent on the maximum value within a series of powers, but erosion is affected by the mean value of powers.

8) Stability point in the profile of topography

Usually a coastal profile has a certain stable point between beach line and offshore. In case of scouring, the stable point exists at the place, which is in front of dyke toe and is keeping constant water depth along shore line, but in case of erosion, it locates offshore as a fixed point over years.

9) Relation of neighbouring region

If we consider two adjoining regions with a river in between, scouring was found in both regions, but erosion took place in one of them and in the other we will see an accretion of beach line.

To identify scouring or erosion in the alluvial lowlands of marine clay regions, coastal profile survey by actual measurements has to be continued for several years, as shown in Fig. 1. When scouring is a main factor for receding coast line, the receding proceeds keeping a certain critical elevation of land, and this elevation once eroded never recovers. When such survey results are not available, field investigations by the use of boat (observation of land from sea side) are needed.

By filling up the columns of Table 1, the final judgement of phenomenon, scouring or erosion, can be made.

For the successful designing of bunds and

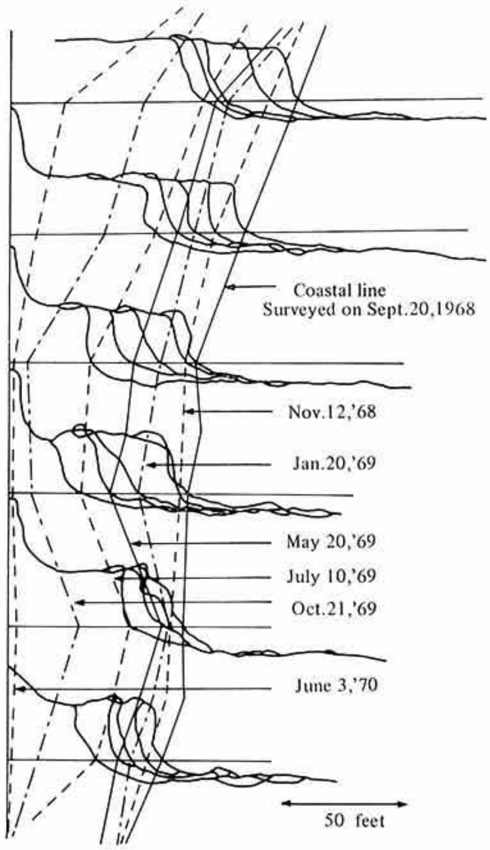


Fig. 1 Receding of coast line with time and vertical cross section of land

agricultural development of the delta, the following two items should be kept in mind:

(1) For the erosion control, countermeasures covering a wide area is required first of all. To get uniform improvement of the whole tideland, attention must be paid to the equilibrium relation between input material such as silt and output material induced by wave and current forces.

Recommended examples of countermeasures are off-shore breaker and groin, which are built at an off-shore area as distant as possible from the receding coast line.

While there is a well-developed theory about the erosion of sandy coasts, little knowledge is available regarding the resolution and suspension of clay in the erosion of clayey lands.

(2) For the design of scouring control, at least the following two main information specific to a given area must be obtained: stability profile and equivalent profile against wave and tidal forces in front of dykes, because scouring mechanism causes settlement, deformation, localized scouring, localized piping and shell accumulation at the toe of the dykes. To overcome these scouring forces, design concept should be concentrated to make a local transition zone, instead of cnsidering the treatment of a wide area as in the case of erosion control.

Design and construction example

In the past, many kinds of trial measures have been taken based on many authorities proposals in Malaysia.

Attempts to plant Apiapi trees among the existing mangroves, to drive staggered rows of Bakau piles to reinforce earth bunds, and to construct groin, gabion wall, gabion groyne with filter membrane were so far done.

Those however retarded the erosion to a certain extent but did not solve the problem permanently.

For design concept of bund, it is necessary to have a clear grip on the relationship between input (hydraulic wave forces) and topographic outcome.

The design concept of bund is summarized as follow:

(1) alternation or modification of the wave forces so as to be balanced with the topographic results.

(2) harnessing or taking advantage of natural forces to get the equilibrium.

(3) dissipation of wave force and protection of earth bund.

At first we should consider the problems of structure scale which is balanced with irrigation and drainage works, because coastal bund are one of those facilities and its functions have close relation to others.

As to the durabilities of structure it is also required to consider the balance with other farmland conservation works.

The scale of structure must be evaluated

Table 2. Kuala Battu Paht tidal condition 1974

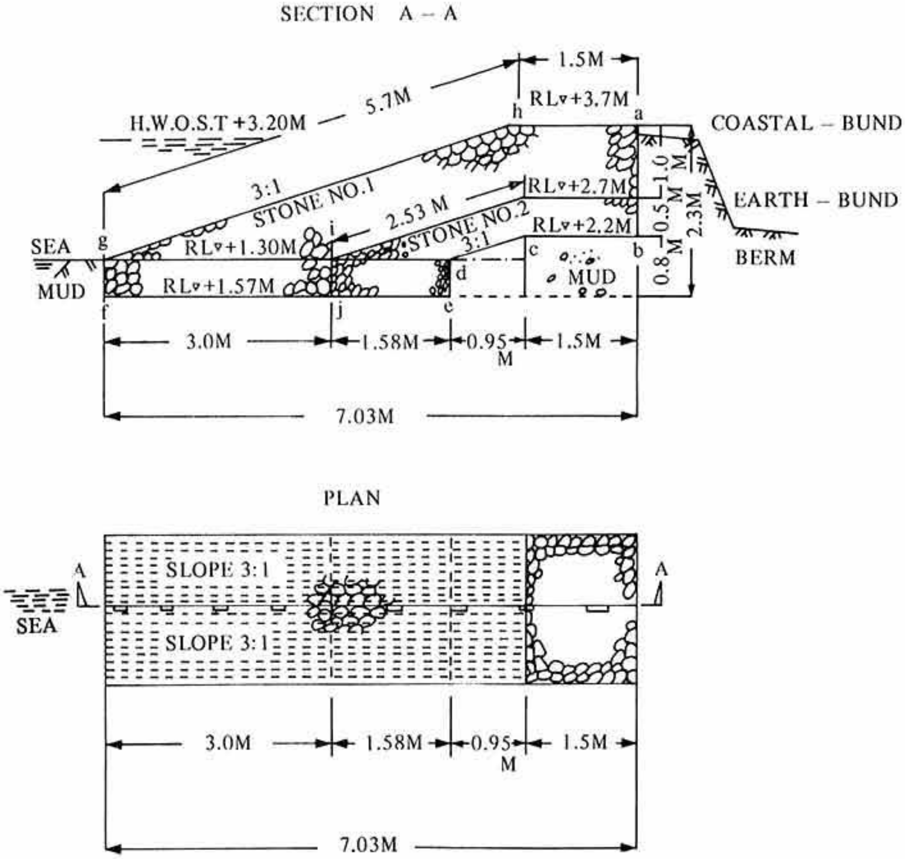
Tide range m-unit	March 3		June 6		Sept. 9		Dec. 12	
	N	F%	N	F%	N	F%	N	F%
3.0 over			5	4.3 4.3	2	1.72 1.72	6	5.0 5.0
3.0—2.8	5	4.2 4.2	6	5.1 9.4	5	4.3 6.02	7	5.8 10.8
2.8—2.6	9	7.5 11.7	3	2.5 11.9	12	10.3 16.32	4	3.3 14.1
2.6—2.4	9	7.5 19.2	9	7.6 19.5	10	8.6 34.42	6	5.0 19.1
2.4—2.2	10	7.6 26.8	11	9.3 29.0	11	9.5 34.42	13	10.7 29.8
2.2—2.0	9	7.5 34.3	12	10.0 39.0	7	6.0 40.42	15	12.4 42.2
2.0—1.8	6	5.0 39.3	11	9.3 48.3	3	2.6 43.02	8	6.6 48.8
1.8—1.6	4	3.3 42.6	1	0.8 49.1	5	4.3 47.32	3	2.5 51.3
1.6—1.4	6	5.0 47.6			3	2.6 49.92		
1.4—1.2	2	1.7 49.3			2	1.7		
1.2—1.0	4	3.3 52.6	3	2.5	6	5.2	6	5.0
1.0—0.8	9	7.5	18	15.3	9	7.8	14	11.6
0.8—0.6	10	8.3	12	10.1	10	8.6	12	9.9
0.6—0.4	9	7.5	19	16.1	13	11.2	16	13.2
0.4—0.2	13	10.8	8	6.8	13	11.2	10	8.3
0.2—0.0	11	9.2			2	1.7	1	0.8
0.0—(—)0.2	4	3.3			3	2.6		
Total:	120		118		116		121	

Note: N . . . No. of occurance of tide
F . . . Frequency of occurring tide height shown in the leftmost column
Lower values denote accumulation of frequencies

from the probability view points. For this purpose, the method based on the frequency occurrence of tide height is very convenient. An example is shown in Table 2. Standard section of rock type design is shown in Fig. 2.

It was noted that bund design and construction were done with no wave absorber mechanism. To make up a perfect design, the following requirements must be satisfied; 1) wave absorbing properties and 2) complete seepage cutoff.

Block material used is stones with the smaller grades from 2 to 6 inch overlayed by the bigger blocks from 10 to 14 inch. A slope



Detail of stone
Stone No. $1\phi=(10.24''-14.17'')$. $W_1=(119=322)$ Lb
Stone No. $2\phi=(2.5''-6.00'')$. $W_2=(1.43-18)$ Lb
Fig. 2 Typical cross section of stone bund

of 3 : 1 on the seaward side is used to provide stability and to provide sufficient area for waves to be dissipated.

The toe is depressed well into the ground in anticipation of ultimate lowering of the seabed.

The earth bund behind the rock mound is built up with soil excavated from the area behind the bund where drainage canal was to be constructed to a consolidated height of Reduce Level(R. L) +9.00 feet to contain the HWOST of R.L+7.00 feet. Alignment of coastal bund is determined so as to be parallel to the contour line of the off shore topology.

In order to avoid non-uniform and concentrated settlement, a particular consideration was given in designing the base, i.e., length and volume of the base structure (GDEF) were designed so as to be able to compensate effects of localized settlement, sliding, and deformation of the bund.

No other treatment such as replacement of sand bed, sand piling or piling of Bakau piles and the use of any other special materials was given.

The present design of wave breakers has been drawn up into two sections, the one part is ijfgh and the other is hijedba as shown in Fig. 2. Scouring and deformation of the toe are allowed to occur at the part ijfg. Settlement of the toe is anticipated with the resultant change in shape with shearing at the edge of the filter, thereby forming a staggered formation.

The hinder portion, the part abcd, of the breaker remains standing and performs as the main wave absorbing mechanism.

The design was made to enable automatic compensation should any damage occur: the damage would be automatically compensated by materials of the neighbouring areas of the bund.

Results of construction

The sections designed for a trial in this model study have so far proved to be satisfactory, and the settlement of the rubble blocks observed, 12–18 inch, was within the range of expectation.

Concerning the determination of allowable critical limit of risk, based on evaluation of design, or allowable time limit for the reduction of functions of the bund, only some terms can be anticipated at present, but final conclusions regarding other terms, still remaining unsolved, have to be obtained by collecting data for a longer period of time.

In West Malaysia, the typical feature of the disappearance of coastal lands is that which occurs by the combination of wave action and driftwoods. An example is shown in Plate 1. To oppose this motion, stone weight should be designed to be more than sufficiently enough: at least three times of stone weight calculated by the Hudson's formula.

According to the Hudson's formula, stone weight can be calculated as follows:

$$W=\frac{K \cdot Wr \cdot f^3 \cdot H^3}{\left(\frac{Wr-W}{W}\right)^3 (f \cdot \cos\theta-\sin\theta)^3}=K' \cdot H^3$$

$$K'=\frac{K \cdot Wr \cdot f^3}{\left(\frac{Wr-W}{W}\right)^3 (f \cdot \cos\theta-\sin\theta)^3}$$

Stone weight is a function of wave height H. If wave height increases from H (without driftwoods) to $H+\Delta H$ (equivalent to the effect of driftwoods) the stone weight becomes as shown below:

Plate 1. Stone bund contructed against scouring action of sea

$$(W+\Delta W)-W=K(H+\Delta H)^3-K \cdot H^3$$
$$\therefore \quad \Delta W \fallingdotseq 3 \cdot K \cdot H^2 \cdot \Delta H$$
$$=(K \cdot H^3+3K \cdot H^2 \cdot \Delta H+\ldots)-K \cdot H^3$$

In order to realize the final stable cross section of dyke under the actual conditions or to get the indicative terms of subjects related to future maintenance, it is necessary to survey dyke elevation and deformation of the cross section. However, the most important work is how to utilize these results for future works.

For this problem, dimensionless expressions are arranged in this manual. Therefor this value can be used to compare any other similar problems in other districts.

Usually coefficient of variance can be expressed as follows:

$$C=\sigma/x=\sqrt{(X_i-\bar{X})^2/n-1}\Big/(\Sigma X_i/n)$$

For each section, C value was about 0.03. The measuring sites were a, h, between h and g, and g in Fig. 2, and the measurements were made with 20 meter interval along the alignment. Time interval of the measurements was 10 days in the first year, and 1 month in the succeeding 2 years.

For the scientific studies on receding coast line and better development of lowlands in coastal regions, the following proposals will be made in place of the conclusion:

1) To improve the designing of wave breakers

to a higher level, experimental determination of critical velocity of water flow to change soils into colloidal state must be carried out.

Critical soil shearing force against wave action or water flow can be measured either in the field or by laboratory experiments.

2) Experimental formula regarding the wave impact forces combined with timber motions, generated during the wave breaking must be developed.

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