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A CASE STUDY ON STRENGTHENING OF TIDAL EMBANKMENT OF BRACKISHWATER AQUAFARM BY SEDIMENTARY PROCESSES IN SILT CAGE

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ABSTRACT

The earthen embankments of brackishwater aquafarms often suffer extensive damages caused as a result of erosion by tidal impacts and owing to unequal settlement of foundation soil since the embankments of brackishwater farm are mostly constructed on slushy and permeable bases commonly encountered in deltaic regions where soils have usually poor bearing capacity. Permeable silt cages as erosion control measure have been tried to counteract the erosive forces of tidal flows by sedimentation of silt loads carried by tidal waters. The silt cages worked with success in reducing the tidal stresses on the embankments and helped in strengthening the embankment. During a period of 15 months, 1.08 m sedimentation inside the cage helped in making the berm wide and strong which in turn controlled further erosion and the dyke could be saved.

INTRODUCTION

THE EARTHEN embankments of brackishwater fish ponds are vulnerable to extensive damages caused as a result of erosion by tidal water and by other agencies. The problem of embankment failure mostly by tidal erosion is common in deltaic regions of West Bengal, since the soils normally found in these regions are predominantly silty or silty-clay in nature with comparatively lower percentages of sand. The surface layer of the soil mostly consists of very fine coherent silt with fairly high plasticity index and low liquid limit.

The embankment also fails as a result of uneven settlement of foundation soil as the beds are mostly slushy and permeable with relatively poor bearing capacity. Construction and maintenance of closure dyke running across a narrow stream or secondary creek become a real problem since in such conditions dyke has to rest on extremely slushy and unstable base. Sometimes water percolating underneath the dyke makes the condition worse and perfectly unsafe for supporting huge weight of the dyke.

In river training work different types of protective structures such as embankment type solid spurs, light and heavy permeable type spurs, groynes, *etc.* are usually constructed, depending upon the characteristics of river flow, for flood control and stabilising the bank against erosion (Joglekar, 1971). Similarly floating cages, flexible and permeable screens are some of the erosion control structures which have reportedly been used in bank protection on some of the turbulent rivers in India (Weller, 1970). The two way flow pattern in tidal rivers and channels is much dependent on tidal amplitudes and currents which are somewhat complex in nature and unpredictable. No specific information are available on the method of protecting embankments running across such tidal rivers and channels.

Studies were undertaken on the method of protecting and strengthening eroded portion of an earthen embankment of brackishwater fish farm running across a tidal channel in lower Sunderbans area by sedimentation in silt cages. The result of the observation is embodied in this communication.

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MATERIALS AND METHODS

The protective dyke of the brackishwater fish farm was constructed on the canal bank leaving a clear margin of 15 m between the dyke and the tidal creek for safety of the dyke. Some portion of the dyke had to be constructed across a deep narrow creek which served as a natural drainage outfall before the dyke was constructed. The dyke was made sufficiently wide and strong to counteract the tidal impacts. Bamboo pilings were done at the dyke edge to prevent soil slipping (Wheaton, 1942).

Specifications of the dyke

Crest width = 1.20 m
Base ,, = 13.80 m
Height ,, = 3.60 m
Side slope (canal side) = 2 : 1
-do- (farm side) = 1.5 : 1
Free board = 0.60 m

Mechanical composition of the dyke materials.

Sand = 20%
Silt = 58%
Clay = 22%

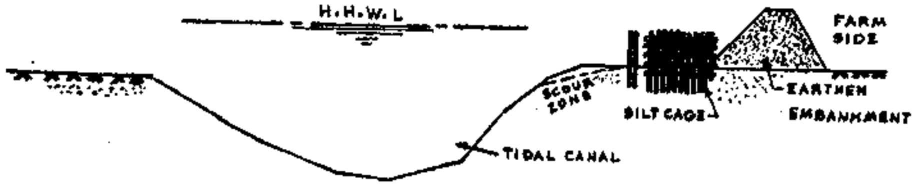

FIG. 1. The tidal canal and location of the silt cage.

Even with all precautionery measures taken the portion of the dyke constructed over the natural drainage breached several times chiefly due to undermining of the base and scouring at the bed.

The hydro-morphological conditions of the adjoining tidal creek showed a general proneness of carrying silt both in suspension and rolling. With a view to impart stability to the susceptable base of the embankment depositing silt carried by the tidal waters, suitable design of a permeable silt cage in the form of a vertical screen similar to hanging spur or permeable spur measuring, 15.4 × 8.0 m covering three sides of the damaged portion of the dyke on the creek side was framed and installed.

The principal materials used in building the cage were straight *garan* poles (*Ceriops roxburgiana*, Arn) and brushwood stalks, being mangrove vegetation grow abundantly in the Sunderbans. The woods are hard and durable and are used by the local people for building cheap dwelling houses. The physical properties of *garan* are as under:

Weight: 880 kg/m^3, Horizontal 15.6 kg/cm^2.
Shear: Along grain 22.1 kg/cm^2.
Compression: Parallel to grain 112.5 kg/cm^2
Perpendicular to grain 65.4 kg/cm^2
Modulus of elasticity—1,08,262 kg/cm^2

The *garan* poles of average length 2.7 m and 10 cm in diameter were driven into the bed to a depth of 1.2 m leaving 1.5 m above the ground and the stalks were closely spaced in two parallel rows with 15 cm gap in between, which was thoroughly filled up and inter-twined with branches of trees and brushwoods. One more row of protective fence was installed in the depression and where the bank was steep. The screens were secured by lashing horizontal timber poles at close spacings. A narrow opening was left in the middle of the front screen and a gauge fixed in the cage for recording monthly deposition of silt. Observations were made on tidal amplitudes, water temperature, silt concentrations, rainfall and sediment depositions. Fig. 1. depicts the position of the silt cage in the scouring zone of tidal canal and the dyke.

RESULTS

The average tidal fluctuations in the canal adjoining the farm ranged between 1.63 and 2.80 m. With the periodic variations in the tidal range, the tidal currents correspondingly changed both in strength (velocity) and direction. In the rectilinear tidal propagation the velocity increased gradually from slack conditions to a maximum and again gradually reversed through maximum in other direction to zero. The hourly variations in velocity and discharge in the tidal canal are given in Table 1.

TABLE 1. *Hourly variation in velocity and discharge of the tidal canal*

W.L. (m) at every half an hour interval	Velocity of flow (m/sec.)	Discharge (cum/sec.)	H.H.W.L. (m)
0.46	0.25	1.06	+2.66
0.92	0.31	3.20	
1.17	0.52	4.54	
1.52	0.85	6.92	
1.96	1.05	9.75	
2.30	1.20	12.25	
2.50	1.30	14.50	
2.62	1.40	14.85	
2.64	1.42	15.10	
2.66	1.40	15.00	
2.65	1.30	14.30	
2.60	1.00	14.00	

The canal cross-section as in Fig. 1 shows that the canal was comparatively deeper at the farm embankment side than at the mid-stream and the depth was found gradually increasing in subsequent observations because of more flow and tidal stresses in the region resulting in scouring and undermining of the canal bank. But because of greater inertia of the deeper mass of water, high water slack was observed earlier along the bank particularly at the fences of silt cage which helped on stilling the flow considerably and hasten the sedimentation process in the cage and silting around the immediate vicinity of the cage.

The sediment carried by tidal currents was mainly silt and little percentage of clay transported in suspension. A lesser amount of sandy sediment was also transported as bed load. The dense and coarser sandy elements were usually carried near the bed and its concentrations were found higher during the initial phase of the rising tide, whereas the fine materials (particle size 0.002 mm and above) were distributed in the water column from second hour onwards till after the commencement of the high water slack. Silt concentrations in the tide water in general varied from 54 mg/litre in the surface to as high as 1,150 mg/litre at a depth of 2.50 m during the tidal phase, some of the finer particles with low concentration of about 30 mg/litre and particle size less than 0.002 mm remained in colloidal form in the water column because of their low settling velocities and turbulence in the tidal flows.

Hydrological observations, silt concentrations in tide water and silt deposition in the silt cage are presented in Table 2.

Sediment deposition

The water of the creek was generally turbid during monsoon months, and the sedimentation in the cage was relatively more during these months. The freshwater run-off owing to rainfall from the adjoining catchment and forest lands acted as a source of sediment and the sediment dispersions mechanism increased the suspended sediment load high in the creek water. The surface washings from the adjoining alluvial lands consisting of a fair percentage of clay matter and transported in suspension into tidal water became cohesive and flocculate under saline water influence.

Because of ionic changes in the clay particles, they have the property to collide and stick together in salt water environment. The colliding and sticking forces in the particles are supplemented by turbulence in the tidal flow acted upon by wind which promote rapid binding among the particles and thus become large size floccules to settle to the bottom at a faster rate. It was due to this reason that sedimentation in the cage was observed as high as 22 cm in a month when rainfall and run-off were also quite high.

Biological activities mainly by suspension feeders and primary producers either algae or sessile plant had some role in promoting sedimentation in addition to deposition of free floating forest organic mass which settled down during low water phase within the cage. The metabolic pathways of organic matter deposition usually do not lead to complete mineralization and the concentration of dissolved organic matter in interstitial water is greater. A part of the dissolved material undergoes chemical condensation reaction in the sediment leading to compounds with a higher molecular weight, the so called humic matter. This condensation process normally leads to redeposition of organic matter which forms a third organic component in the sediment resistant to decomposition (Postma, 1981). However, the volume of sediment load thus deposited could not be estimated separately.

TABLE 2. *Water temperature, rainfall, sediment concentration and deposition, etc.*

Month	Water temperature (°C)	H.H.W.L. (av.)	Rainfall (mm)	Estimated sediment concentration in tide water (ppm)	Estimated sediment deposition in the silt cage (cm)
September 1973	28.2	2.25	1,681	1,380	22
October	29.4	2.38	630	720	12
November	29.0	2.43	363	360	6
December	24.2	2.15	nil	220	2
January 1974	22.2	2.50	nil	200	2
February	22.8	2.35	nil	200	2
March	26.0	2.32	442	600	6
April	28.6	2.40	28	320	4
May	30.6	2.22	615	660	8
June	30.2	2.13	252	520	5
July	29.2	2.30	537	840	9
August	28.6	2.95	1,228	1,110	10
September	28.0	2.85	1,347	1,200	12
October	28.2	2.45	350	840	6
November	28.0	2.40	nil	400	2

Estimated total depth of sediment deposition = 1.08 m.

Estimated total volume of sediment load in the silt trap = 129.73 cu. m.

Observation on sediment depositions in the cage showed that in a period of 15 months it was possible to raise the canal bank at the edge of the earthen embankment to a height of

1.08 m by sedimentation as the rate of deposition exceeded erosion. The berm thus formed by siltation was observed perfectly stable, withstood the tidal thrusts and lasted in its true profile for a few years more after the experiment was over, and served as an effective safeguard against dyke erosion.

Needless to say some soil lost as washings from the adjoining embankment had definitely gained access into the silt cage and deposited on the bed. The estimated volume of soil deposit contributed as embankment washings was 28.64 cu. m whereas the remaining volume of silt load of 101.09 cu. m in the silt cage must had been trapped and deposited in the silt cage by detention and dampening the velocity of tidal flow and flow energy in and around the silt cage structure.

The actual expenditure incurred for fabricating the silt cage is presented below.

Cost of *garan* poles 10 cm dia— 700 Nos., bamboo 1 No. and binding ropes *etc.*	..	Rs. 221.00
Transportation and labour charges for erection	..	Rs. 47.00
Total	—	Rs. 268.00

Therefore, the field trials showed the possibility of employing silt cage method as a low cost structure for strengthening the tidal embankment.

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