STUDY ON PROACTIVE BREACH OF SUBMERSIBLE EMBANKMENT FOR ITS SUSTAINABLE MAINTENANCE IN HAOR ARREA

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ABSTRACT

Haor is a naturally formed large bowl shaped depression found in the northeastern region of Bangladesh. It is a mosaic of wetland habitats, which consist of rivers, canals and ponds. During dry season a large area of Haor is utilized as paddy field to cultivate seasonal rice called Boro crops. Also some water pockets remain in some area serving as habitat for fishery. Boro crops have the greatest importance as the agricultural production supports local economy in the region. Boro crops are harvested from late April to early May during which Haor region frequently experiences flash floods. During 1975-1990 a series of Submersible Embankments projects were launched under Bangladesh Water Development Board (BWDB) to protect Boro crops from flash floods. As embankments are designed to submerge during monsoon flood season, it requires reinforcement work every year and that has been financial burden to local communities. This thesis study presents hypothetical approach of "fuse levee" which protects Boro crops against flash floods but breaches naturally for seasonal monsoon floods. By allowing more spaces to control water flow it would minimize the difference of water level between Haor and river and thereby reducing erosion at overtopping. Through numerical analysis of possible scenarios it is found that fuse levee can facilitate water flow into Haor and consequently reinforcement cost of embankment can be reduced as much as 40 to 50 %, indicating that the suggested approach may contribute local community in terms of sustainable management of embankments.

Keywords: Haor, Submersible Embankment, Fuse Levee, Water balance model

1. INTRODUCTION

The northeastern region of the Bangladesh is known for Haor. Haor is a mosaic of wetland habitats including rivers, streams, canals, and Beel (local name of pond), which serves as wetland ecosystem as well as irrigation land. Since Haors exist on flood plains, they are subject to extensive inundation caused by seasonal monsoon flood. While Haors are subject to inundation, flood has an important aspect in terms of agricultural land, fishery, and local ecosystems.

Haors are naturally formed bowl-shaped depression, and they are formed as a result of peripheral faulting. During monsoon flood seasons Haor submerges completely under the water, but during dry seasons, Haors becomes dry land and utilized to cultivate of Boro crops. And it is usually surrounded by submersible embankment (SE), which is low height embankment that submerges completely under water during monsoon flood. SE is constructed in order to protect Boro crops from the pre-monsoon floods, which occur during harvesting period, from 1st April to 15th May. SE requires maintenance work and a lot of money spend for maintenance work every year.

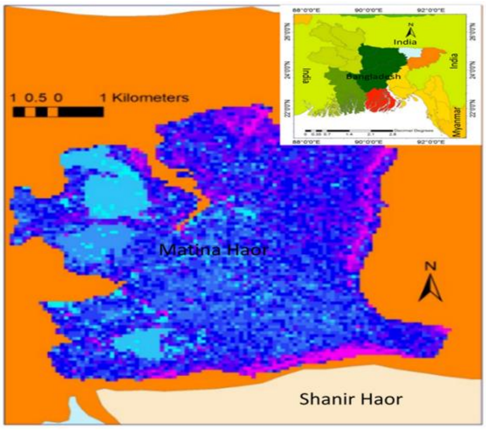

Figure 1: Matian Haor, Sunamganj

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The objectives of this thesis study is to propose effective measures to reduce the annual operation and maintenance cost of SE by adopting appropriate countermeasures while protecting Boro crops from the pre-monsoon floods. Matian Haor is selected as a target area as an experiment of sustainable management of SE.

2. THEORY AND METHODOLOGY

2.1 Fuse levee concept

In this study artificial breach of embankment is considered by introducing fuse levee. Fuse levee can be considered as non-permanent embankment that can resist to certain water level, but it will wash out a certain water level or pressure. It is intended to create space in SE allowing water flow into the Haor in shorter time. By doing so, the difference of surface water level between river and Haor is reduced and overtopping shall be reduced, which can then avoid erosion on embankment. Different types of fuse levee are considered for their size and shape.

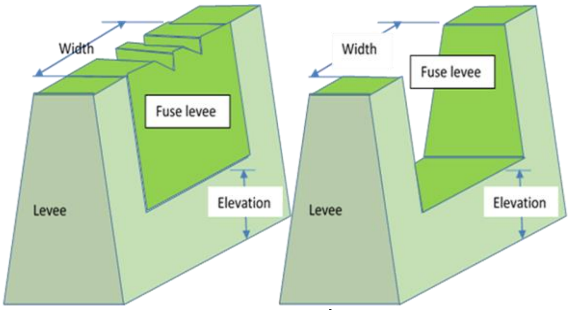


Figure 2: Fuse levee

2.2 Water Balance Model (Pond model)

Presently river water enters into the Haor through a regulator gate, but in many cases the regulator gate is not sufficient to control water inflow and overtopping occurs. When overtopping happens, the most of the erosion occurs in the levee. The levee erosion is related to the velocity of water flow crossing over embankment and its time duration. The velocity of overtopping depends on the difference between Haor water level and river water level. If the water level difference can be reduced as much as possible less erosion shall occur. While the discharge into the Haor depends on the water level, the Haor water level depends on the discharge and area of Haor. It is assumed here that they do not affect each other within short time. Equation to express changes in Haor water level after time dt can be written as:

$$dh_h = \frac{Q_{in}(t)}{A(t)}dt \tag{1}$$

Where, dh_h is changes in Haor water level at dt time. $Q_{in}(t)$ and $A(t)$ are inflow and area of Haor at time of t.

2.3 Pipe Flow Method

When river water flows into the Haor through regulator, it can be considered that its state can be simplified and expressed as flow through pipe (hence the formulation is called Pipe Flow Method). The head loss equation through a pipe is the base of this equation. In the equation, Manning's equation is used to relate different parameters. The discharge equation through regulator gate is

$$Q_{in} = \left(i^{\frac{1}{2}} R^{\frac{2}{\sqrt{3}}} B \frac{hr+hh-2Zb}{2}\right)\frac{1}{n\sqrt{k}\, f(h)} \tag{2}$$

Where h_r is river water level (m), h_h is the Haor Water level (m), l is the length of regulator (m), B is the width of regulator gate (m), R is the Hydraulic radius (m), Z_b is the datum height of regulator bottom (m), K is the coefficient of energy loss, n is the Manning coefficient, i is the surface slope.

2.4 Critical Flow Depth Method

When the river water rises rapidly in the Haor area, overtopping happens on the SE crest. The velocity of overtopping water can be considered to have critical velocity. The underlying equation here is this critical velocity and also the energy conservation equation. The equation of overtopping discharge on the levee is

$$Qhc = B\left(\frac{2}{3} * (hr - Zbe)\right)^{\frac{3}{2}} \sqrt{g} \quad (3)$$

Where, B is the width of fuse levee (m), h_r is river water level (m), Z_{be} is the datum level of levee bottom, g is the acceleration of gravity (m/sec^2) and Q_{hc} is the overtopping discharge (m^3/sec).

2.5 Estimate of Erosion

The equation to estimate erosion is related to the overtopping velocity and hence the erosion coefficient is given as proportional to the overtopping velocity.

$$\frac{dzb}{dt} = -\alpha \sqrt{\frac{2}{3} g(hr - Zb)} \quad (4)$$

Where, h_r is the river water level (m), Z_b is the embankment level (m), E is erosion rate (m/sec), α is the non-dimension Erosion coefficient, V_c is the critical velocity (m/sec), and g is gravity (m/sec^2). α is the erosion coefficient, which value is calibrated by trial and error. Initially the value of α is given as 0.00001, which is equivalent to actual damage.

2.6 Scenario Analysis of Fuse Levee Geometry

Fuse levee with large cross section would reduce the erosion on embankment, but at the same time it would increase the cost to renovate fuse levee. To identify most effective cross sectional area of fuse levee, a series of simulation analysis with varying width and height of cross section are considered (Table 1).

Table 1: Different geometry of fuse levee

Width (m) / Height (m)	550	600	650	700	750	800
2.9	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
2.4	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
1.9	Case 13	Case 14	Case 15	Case 16	Case 17	Case 18

The renovation cost of fuse levee changes according to corresponding volume of the fuse section. For analyzing the effectiveness of fuse levee, total cost for renovating fuse levee and SE are compared. The most effective fuse levee should balance fuse levee cost and main levee restoration cost while protecting Boro crops from flash floods.

3. DATA

3.5 Data Collection

Three types of data are used in this study. They are topographic data, hydrologic data and levee survey data. In topographic data Digital elevation model (DEM) needed. River water level are used as hydrological data. Embankment cross sectional elevation, distance and damage length is used as survey data. Topographic data is required to calculate area and volume of Haor. To calculate the volume of Haor we use the DEM of Haor. A new projection system was evolved from the UTM, and that is known as Bangladesh Transverse Mercator (BTM) projection system. The BTM system has been introduced since 1992. The digital map of Bangladesh has been generated using this projection system. The study area is heavily affected by river flood water and therefore hydrological data is required for understanding the causes of damage. The required river water level data was collected from BWDB through personal communication. The available river water level data is from 2005 to 2011. These data use for simulation.The available survey data of the SE is longitudinal and cross sectional data. The longitudinal profile data is used to calculate the damage of SE. To compute the damage of SE different type of levee construction item rate is required. These necessary item rate is collected from the BWDB schedule book which is updated at 2014-15 financial year under the Sylhet operation and maintenance circle of BWDB, Sylhet district.

4. RESULTS AND DISCUSSION

At first a simulation analysis was done for the 2011 flood because total maintenance cost of SE and flood water level data were available this year, which makes it possible to calibrate the model. First simulation was done for present condition, in which only regulator gate is used for controlling inflow. Erosion coefficient was calibrated so that simulated renovation cost becomes equivalent to the actual cost. After calibration, erosion coefficient was 0.00001. The simulation results of 2011 are shown in Fig. 3.

In Fig 3 the blue line shows the river water level and the red line shows the water level in Haor, in which only regulator gate is used to control inflow. The black color straight line shows the SE level. In the simulated present condition overtopping happens. If the SE keeps provision of different size of fuse levee, we can see that the Haor water level is increasing with respect of increase the size of fuse levee. After installing fuse levee, overtopping could be avoided. Before overtopping of river water the Haor water level reaches to the river water level. Here different width of fuse levee used for simulation, but their bottom level was kept same. The orange line shows the simulated hydrograph with fuse levee having 800m width and 2.9m height. Water level inside Haor rises faster than other fuse levees because it has a bigger cross sectional area than other fuse levees. The deep blue line shows the smallest width of fuse levee, which size is 500 m width and 2.9 m height and this is the smallest of all. In this case the rise of water level is slower than the others. Therefore, we can say that if we use bigger cross sectional area for fuse levee, the Haor will be filled with water rapidly. Consequently, the number of overtopping on submersible embankment can be reduced.

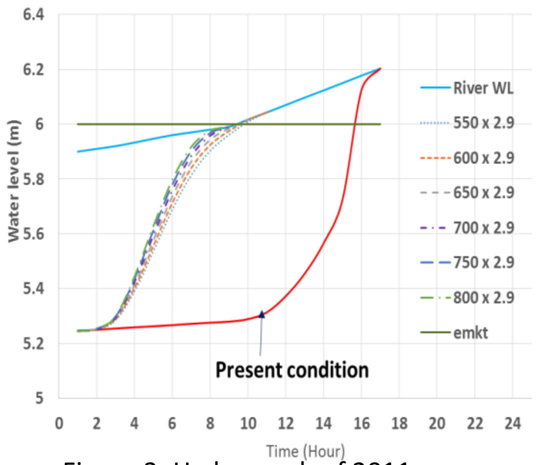


Figure 3: Hydrograph of 2011

Fig 4 shows cost comparison. In this analysis, we show 18 cases from all scenarios (Table 1) and 18 cases are numbered according to the fuse levee size. Fig. 3 shows the simulated cost for case 1-18 in 2005, 2007-09 and 2011. From the scenario analysis it is difficult to identify the most appropriate case (i.e. most effective fuse levee) because their costs show minor differences, however from the graph it can be seen that, the cases13 to 18 show lower cost of fuse levee reconstruction. For the cases 1 to 18 their cost does not change because their cross sectional areas are identical. However the total levee maintenance cost changes because damages vary with floods in different years. From 2005 to 2009, we can see the case 13 shows the lowest cost. It is noted here that, case 18 shows the lowest maintenance cost for the 2011 simulation but we don’t consider this one because it does not happen for other years’ flood.

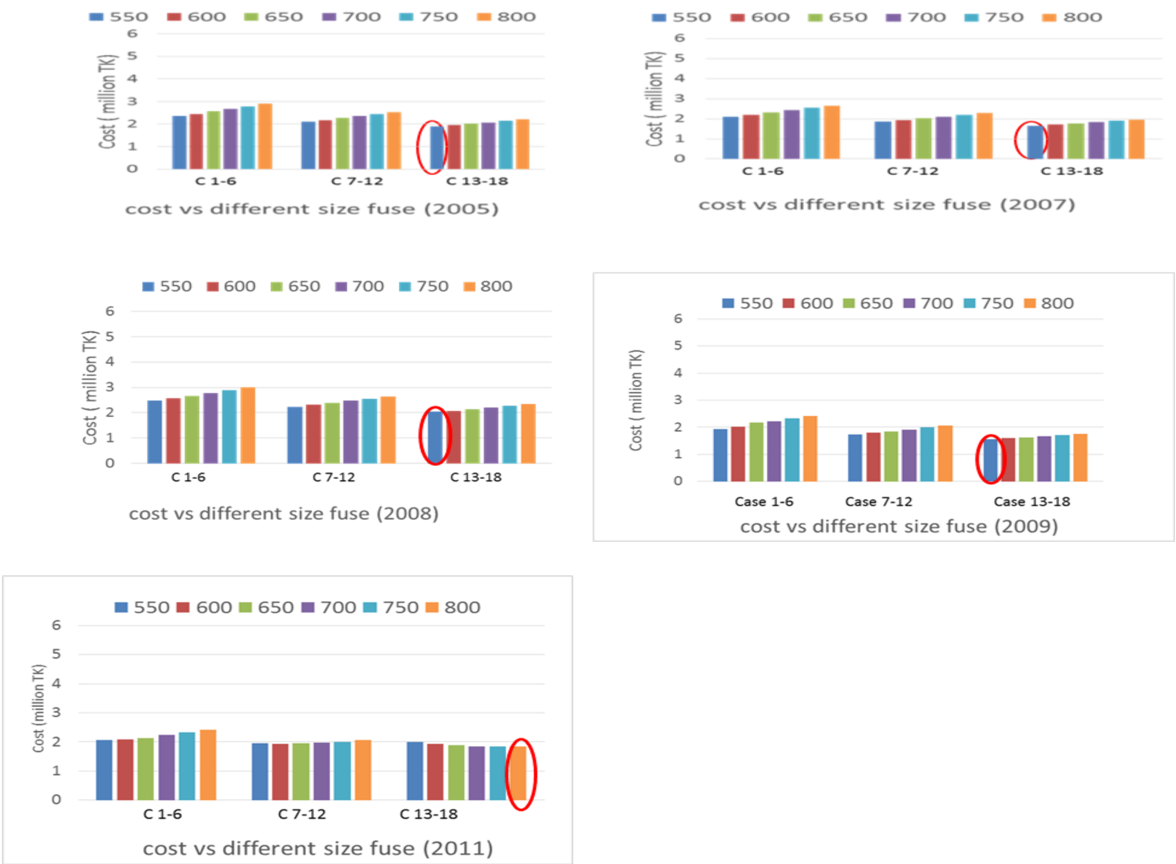
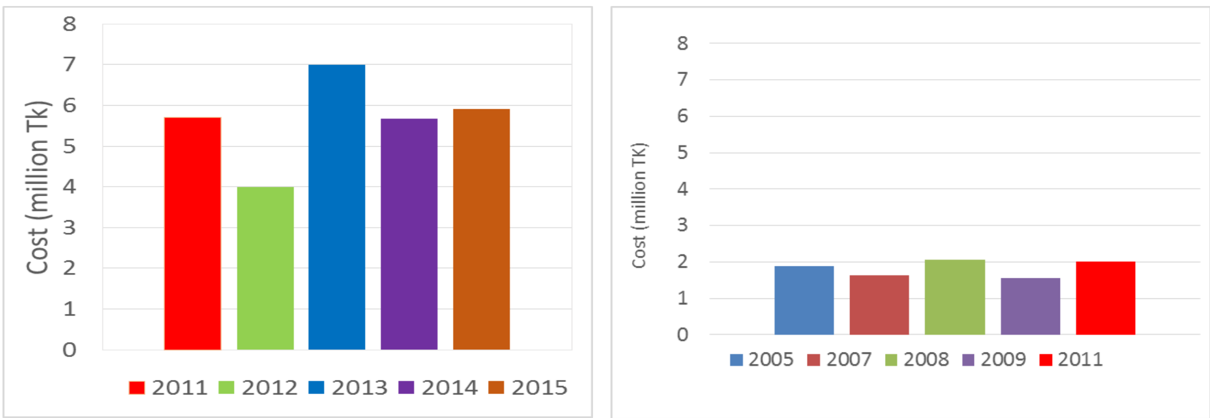


Figure 4: Cost comparison of case 1 to case 18 for flood 2005, 2007-09 and 2011

For the simulated cost for the cases 1 to18 for flood from 2005 to 2011, the case 13 shows the lowest cost for most of the years. Therefore, from considered scenarios, most effective cross section of the fuse levee is found as case 13, which dimension is 550 m width and 1.9 m height.



Actual cost

Simulated cost for case 13

Figure 5: Cost comparison of actual cost and proposed fuse levee simulated cost

Fig. 5 compares of actual cost and simulated cost of the proposed fuse levee (550 m width and 1.9 m height). In Fig. 5, the averaged actual annual maintenance cost is almost 6 million Tk while the simulated average maintenance cost is about 2 million Tk, which indicates that installation of fuse levee could have reduced 40%-50% of annual restoration cost of SE.

5. CONCLUSIONS

Haors have vital importance in Bangladesh as they produce Boro crops. Although SE has the great contribution to protect Boro crops from the flash flood, SE requires maintenance work. Currently approximately 6 million Tk is spent annually for restoring SE for Matian Haor. In this study, we proposed sustainable method to reduce maintenance cost SE by introducing fuse levee to Matian Haor as a numerical experiment. It is found that presently the drainage system of Matian Haor might be inadequate to control water inflow and therefore it may allow frequent overtopping causing damages on embankment.

We considered water balance of Haor. If we can increase Haor water level earlier, right after finishing harvesting Boro crops, the damage of submersible embankment can be reduced. In order to achieve such idea, hypothetical fuse levee, which will be artificially breached at a certain water level or pressure, is considered. A model was developed for simulating water balance and effectiveness of fuse levee was evaluated through scenario analysis. Considering water balance of Haor the model provide present condition and estimate the damage cost. I calibrate the model by changing erosion coefficient parameter so that the simulated cost and the actual cost becomes compatible. I found the past year's flood water level by this model. It is observed that in existing condition huge damage occurred which cost represents previous year expenditure quite well. By using fuse levee it was shown that damage of SE could be reduced and the maintenance cost was reduced up to from 40 to 50%. Hence the fuse levee is more effective countermeasures to reduce the damage of SE.

To improve the socioeconomic condition of this area, proper management of SE and reduce the damage to Boro crops is required. For proper management of submersible embankment, the main priorities is to reduce the damage of SE. The fuse levee will be able to reduce the maintenance cost of submersible embankment, so it will be great contribute in our economy.

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