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AN INVESTIGATION ON FAILURE OF EMBANKMENTS IN BANGLADESH

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ABSTRACT

The study presents the results of case histories on failure of embankments in Bangladesh based on the field visits to the embankments sites, collected data and information on failure of embankments necessary data related to embankments construction practice obtained from available publications and soil conditions of the breached embankments in Bangladesh. Efforts have been made to discuss briefly the causes of embankment failure and its possible remedial measures. Two recent failures of embankments that occurred in the year 2007 are taken into consideration for a detailed study. For each case, embankment failure mechanism, construction method used for the embankments, soil conditions, embankment geometry and water levels are collected and analyses are made for slope stability with and without water storage conditions. Soil samples collected during field visits are analyzed. On the basis of the results of analyses and discussions, it is concluded that the major causes of failure of earlier embankments are identified as breach of the embankment, cutting by public, overflow, erosion, seepage and sliding. Other causes were poor planning, design and faulty construction. The cause of failure of all the flood control embankments in the year 2007 could be attributed to erosion and sliding of embankment materials due to river encroachment and mitigation. Slope stability analyses of the Padma and Jamuna flood control embankments revealed that the country side slopes of both the embankments are not at all stable during the monsoon when the water level is high. The Jamuna flood control embankment is not stable even before and after the monsoon period because the factor of safety calculated for the country side slopes are less than that of the recommended one. Of the two cases studied detailed in this research articles, it is observed that there are substantial differences between the cross sections shown in the actual designs that existed near to the failure locations. A close investigation of the above two cases indicates that no protective measures such as mattressing, stone pitching, concrete layers, artificial or natural reinforcement like grassing, soil-cement layer are made to prevent the embankments from rain splash, water current, waves, storm surges, and other natural calamities and destructive forces. It is recommended that the embankments should be constructed by following the proper design and construction procedure, and be protected by using some forms of reinforcements or surface covering/treatment.

INTRODUCTION

Construction of earthen embankments, their repairing and rebuilding for flood control, irrigation and drainage have been the history of Bangladesh since time immemorial. Institutional steps for embankments construction started with the creation of the East Pakistan Water and Power Development Authority (EPWAPDA) in 1959. After the independence of Bangladesh, the Bangladesh Water Development Board (BWDB) is the principal executive agency for construction, operation and maintenance of embankments in order to save lives and properties from natural disasters such as main river floods, flash floods in the east and northeast of the country, and saline intrusion in the lower delta. Over the last few decades, more than 13000 km of earthen embankments have been constructed because of their cheapest form to protect people's health, homes, agricultures and city dwellers from flooding. Along with this, some other constructions such as 7555 km of coastal embankments, 3674 km of irrigation canals, 3204 km of drainage channels, 7907 km of hydraulic structures like sluice gates and culverts, 1082 pump houses and 2 barrages are made. River embankments protect lives and property from inundation during the monsoon. Sea embankments of the offshore islands and coastal zones provide safeguard against the intrusion of saline water and devastation associated with repeated attacks of tidal surges and cyclonic storms (Hossain, *et al.* 2007).

To minimize the impact of natural disasters as well as to achieve the aim of embankment construction in Bangladesh, sustainable and cost-effective operation for maintenance of these embankments is utmost necessary. It is evident that the earthen embankments in Bangladesh are overwhelmed with multi-facetted problems. These are not only unsuccessful to serve the purpose for which they are constructed but also create many other new problems. Usually the earthen embankments are breached easily due to rainfall splash, animal actions and the human interferences. Embankments in haor areas of the eastern part and river embankments of the main land are subjected to turbulent water currents and changes in river courses. The problem is acute in offshore islands and coastal belts where the embankments are in addition exposed to erosion by sea waves and tidal fluctuation of water levels. The estimate prepared by BWDB in 1984 shows that about 1200 km of bank length of rivers were subjected to erosion, 565 km of which faced severe erosion problems. The instability in river regime coupled with huge discharge and sediment load cause erosion, scouring and also deposition, and thus a chain action proceeds (BWDB 1987).

As per the latest information available, it is found that 441 projects/sub-projects are either fully or partially damaged due to the severe floods of 1998. The process of erosion gradually destroys the shore lands/riverbanks, foreshore areas/berms and successively the earthen embankments that engulfing the plain agricultural lands, habitats and many important installations. Other constructions vulnerable to rain and flood damage include about 7000 km of national highways, 90000 km of feeder roads and millions of homestead flat forms. The failure of embankments in Bangladesh is almost a recurring phenomenon and thus, continuing every year. In 2007, a lot of earthen embankments, river banks, agricultural and forest land on terraces and hill slopes are subjected to erosion just at the start of the monsoon. Soil eroded each year from the earthen embankments becomes accumulated in rivers, reservoirs, harbors, estuaries and other water bodies and therefore, disrupting the water transportation system, shrinking fish habitat and affecting surface water storage capacity and ground water recharge. Consequently, these phenomena deteriorate the overall economy and environment of the country. The volume of silt deposited in Bangladesh every year including the silt received from across the border amounts to more than 2.70 million cubic meter. Thus, failure of earthen embankments creates a double disaster such as 1) sudden breach of embankments destroying lives, crops, agricultures, poultry, fisheries and many other things, and 2) it creates simultaneous accumulation of silts in the river beds and floodplains. A map of Bangladesh showing the river systems and floodplains is given in Fig.1.

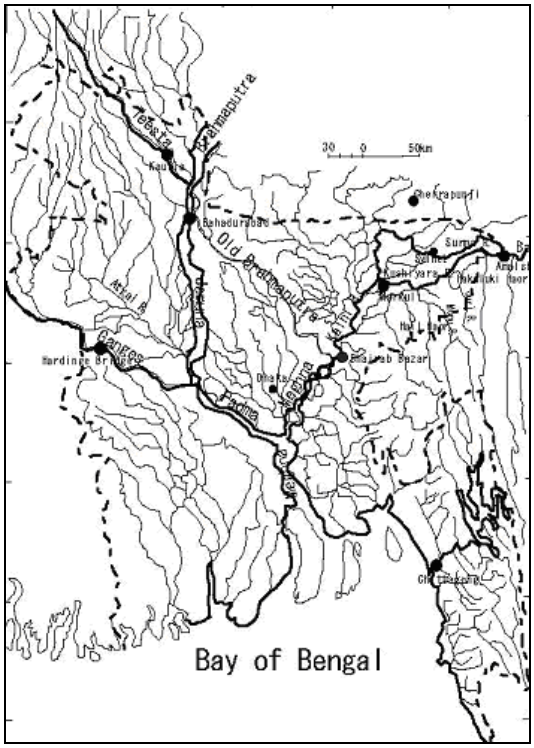

Fig.1. Map of Bangladesh showing the location of failure of embankments

Although the failure of embankment is very common news in Bangladesh, unfortunately very little or no study is available that has been adequately analyzed the main reason of such failure except an incomplete research work that can be found in BWDB 1987, Saifullah 1988, Islam 1994 and Hoque and Siddique 1995. For the interest of the overall economy of embankment construction and environmental conservation in Bangladesh, a research project is undertaken in the Division of Environmental Science and Technology of Mie University. The present research article reports the results of an investigation into the causes of damages of some flood embankments in Bangladesh in order to make possible remedial measures to reduce the embankment failure in the country. The following two locations are selected for a detailed study in this research article, such as 1) Jamuna flood control dam

at Talukderpara in Shariakandi upazila, Bogra and 2) Padma river embankment at Rajbari which are breached in the year 2007. The failure locations are being shown in Fig. 1.

METHODOLOGY, FIELD VISIT AND DATA COLLECTION

Various types of information on embankment failure such as geometry, soil conditions, river position, flood water levels, construction procedure, materials used, hydraulic and hydrologic condition are collected from different sources for instance, local people of the areas of embankment failure, officials of BWDB, contractor connected to the design and construction of the embankments.

To understand the engineering and physical properties of the embankment materials, samples from the failed location are collected and analyzed. The cross-sections of the embankments are drawn in order to investigate the geometry of the failed embankments, stability of slopes and other parameters. The analyses of stability of the failed embankments are performed by the determinate method because of its ease in calculation, accuracy and handiness in application to the field with and without water storage conditions. The main feature of this method is that it calculates the factor of safety of a slope based on moment equilibrium of simultaneous blocks dividing the whole slope into two major blocks of left and right sides as shown in Fig.2.

Where, H_i is the horizontal component of internal force and V_i vertical component of internal force both are acted at the vicinity of *i-section* owing to the self-weight of the right-side soil-block when considering the free-body of left side soil block. In the same way, considering the free body of the right-side soil-block, the H_i and V_i are acted in the opposite direction due to the reaction of the left-side soil-block. The self-weight of right-side soil-block is denoted by W_{ir}. The center angle formed by the lines connecting to the center of the arc and the point which is the cross-section of slip line and acting line of W_{ir} is denoted by α_{ir}., The horizontal distance between the *i-section* and the acting line of W_{ir} is denoted by X_{ir} and the vertical distance between the point of action of internal forces and the slip line is given by L_i. Alike the right-side soil-block, the parameters W_{il}, α_{il}, X_{il} are also defined in the case of left-side soil-block.

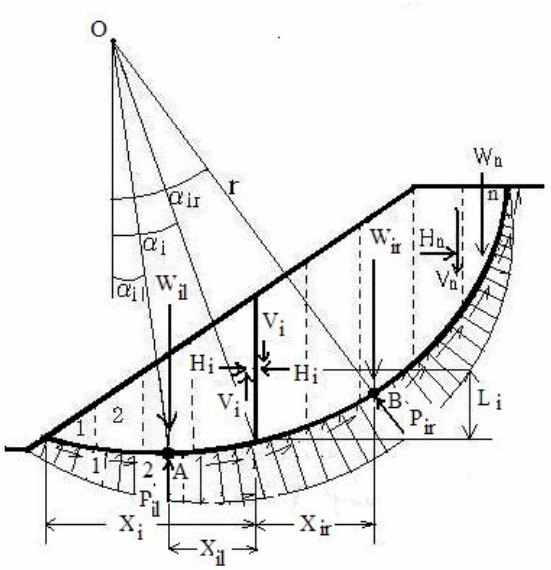

Fig.2. Stability analysis by determinate method

Another feature of this method is that the point of action of internal forces to the slip circle (L_i) is common for both left and right group. The radius of the circular arc is defined by *r*. The horizontal distance between the bottom edge of the slip circle and *i-section* is defined as X_i and the center angle formed by the line passing through the cross-section of *i-section* and slip-line with the vertical direction is defined as α_i. The details of this method can be found elsewhere (Hossain and Inoue, 2007).

By using the determinate method, the factors of safety of the failure section are calculated by the following equation.

$$F_S = \frac{\{H_{n-1}\sin\alpha_n + (W_n - V_{n-1})\cos\alpha_n - u_n l_n\}\tan\phi' + c' l_n}{(W_n - V_{n-1})\sin\alpha_{n-1} - H_{n-1}\cos\alpha_n} \quad (1)$$

where, n indicates the number of vertical slices, ϕ' indicates effective angle of internal friction and c' indicates effective cohesion of soil. Here, H is Horizontal force component, V is the vertical force component, W self weight of slice, α is angle to the center of the circle, u is the pore water pressure and l is the base length of the slice along the circle.

Failure of Jamuna Flood Control Embankment

The failure of Jamuna flood control embankment is shown in Fig.3. Over 150000 families have been affected due to the threat of Jamuna right bank flood control embankment at Talukderpara in Shariakandi upazila in May 2007 in Bogura. The daily star on May 2, 2007 reported that the local Union Parishad (UP) member Mr. Shahadat Hossain

Dulal said his house is likely to be devoured within a few days if erosion continues unabated. He said a major portion of the flood control embankment at Talukderpara point would be eroded within a short period if the erosion is not checked immediately.

Fig.3. Jamuna flood control embankment in Bogura, The Daily Star 2007/05/02

Local people have apprehended damage of scores of houses. A large number of houses along the embankment eroded last year. The BWDB Sub-Divisional Engineer (SDE) Engr. Zahural Haque said more than 150000 families might be affected in Dhunat and Sharikandi upazila if erosion could not be checked without further delay. If the erosion continues in such a speed the flood control embankment may be washed away within a week. Engr. Zahural Haque said the department already invited a tender to protect the embankment at Talukderpara point. But fund was not allotted timely. A portion of Chandanbaisa hard point eroded last year which had been built to protect Chandanbisa and adjacent areas including part of Talukderpara. But the eroded point was not being repaired due to fund constraint. An amount of Tk 80 lakh is required to repair the hard point while Tk 99 lakh is required to protect the embankment at Talukderpara point.

Damages of Padma River Embankment

The damage of Padma river embankment at Rajbari is shown in Fig.4. Nearly 50 km Padma river embankment at Rajbari from goalando to pangsar sengram has been damaged in June 2007due to heavy current of padma river water that flooded and come from upstream part. This beribad at Rajbari was breached in 2004 causing numerous damages of lives and agricultures. Then, huge amount of money was being spent to repair the beribad in 2005 and 2006. It required about Tk.650 lakh for filling, repairing and reconstruction of the embankment. However, because there were lot of fault and complaints in the repair and reconstruction works, this beribad is now in great threat especially in the rainy season. Approximately 60 unions and 14 lakhs peoples within the beribad in Rajbari are passing their days with great fear and danger of flash flood owing to the sudden breach of the embankment. The villages of daulotdia, debgram, ujanchor, ratandia, kalikapur, bbahadurpur, habampur, sawrail, and kasaba as well as thousand of houses and families already destroyed near the Padma bank in just one week due to the thrust of water current.

Fig.4. Padma river embankment damages at Rajbari., Naya Digonta 2007/06/16

RESULTS AND DISCUSSIONS

Some of the recent failures of embankments, name of the regions or location of failure, name of the embankments and date of breached are summarized in Table 1 and Table in monthly basis for the year of 2007, respectively.

Table 1. Recent failures, regions, name of embankments, date of breach for the month of May, 2007

Sl. no.	Region/ District	Name of embank-ment	Date of breach	Damages
1	Sharia-kandi, Bogura	Jamuna l embank-ment	2-May-07	Over 1,50,000 families have been affected
2	Patua-khali, Baufal	Baufal Embank-ment	18-May-07	12 villages flooded and 2000 acres land damaged

It is evident that most of the embankments are failed in the month of May and June, the months which are the start of monsoon of the year 2007. Among 6 cases reported in this paper, two embankments are failed in May and another four embankments are failed in June indicating that the failure of the embankment increases with the increase of rainfall and thrust of river water current. It is observed from this table that a lot of damages such as lives, land, agriculture, roads, houses and fisheries are occurred in 2007 during just two months period indicating continuous disruptions and damages due to failure of many embankments and effect of floods. Some of the physical properties of soils of the failure locations of Jamuna and Padma river embankments are depicted in Table 3. The coefficient of permeability of soil of the failed sections of Jamuna and Padma river embankments are obtained as 0.35×10^{-6} and 0.42×10^{-6} cm/sec, respectively.

The dry density, specific gravity, optimum water content and angle of internal friction of both soils are given in Table 3. The particle size distribution data given in this table showed that the soil of Jamuna dam consists of 58% sand, 44% silt and 8% clay, and the soil of the Padma river embankment composed of 44% sand, 43% silt and 13% clay indicating that both the soils can be classified as non-plastic SC group according to the unified classification system. On the basis of the properties of soils obtained, it can be said that the soils are fairly suitable for embankment construction according to the Indian Standards (Punmia 1981). However, the soils are also suitable to move easily with the impact of rain splash and current of water if it expose to rain and river flow without any surface protection or reinforcement.

Table 2. Recent failures, regions, name of embankments, date of breach for the month of June, 2007

Sl. no.	Region/ District	Name of embank-ment	Date of breach	Damages
1	Cox's bazaar, Teknaf	Cox's Bazar Cross Dams	5-Jun-07	Damages 150 houses, 40 fishermens nursing
2	Dhaka, Gabtoli	Gabtoli Mitford connectin g Embank ment	11-Jun-07	Connecting road damaged
3	Sirajgon j, Khosbar i	Jamuna River Khosbari Embank ment	13-Jun-07	Nearly 1200 meters breached
4	Rajbari, Rajshah i	Padma river embank ment	June 16. 2007	Nearly 50 km has been damaged

Table 3. Some of the physical properties of soils of the failure locations of Jamuna and Padma river embankments.

Soil Properties	Jamuna dam at Talukderpara, Shariakandi, Bogra	Padma river embankment damages at Rajbari.
Dry density, t/m^3	01.38	01.43
Optimum water content, %	14.30	13.50
Specific gravity	02.63	02.64
Cohesion, kN/m^2	05.71	06.35
Angle of internal Friction, degree	18.21	16.32
Sand, >75μm (%)	58.00	44.00
Silt, 5-75μm (%)	44.00	43.00
Clay, <5μm (%)	08.00	13.00
UCS classification	SC	SC

The damages and number of deaths of people owing to effect of major floods and embankment failure after the independence of Bangladesh to date are shown in Fig.5. It is evident that every year almost two-thirds of the country inundated in the monsoon and thus breached of embankments and relevant disruptions as well as damages caused were enormous. Bangladesh, being located at the GMB delta of the three mighty rivers (the Ganges, Meghna and Brahmaputra), is vulnerable to flooding every year during the monsoon. Flood has become frequent natural disaster in Bangladesh since long before resulting in failure of hundreds of embankments causing homeless of thousands of people. As a result the affected people are becoming poorer day by day. After the independence of Bangladesh, the maximum deaths of people occurred in the year 1988 although the flood in 1998 was extreme in the history of Bangladesh. In 1998, almost 80% of the country was inundated that damaged most of the houses, paddy fields and hundreds of kilometers of road-cum-flood embankments of rural Bangladesh.

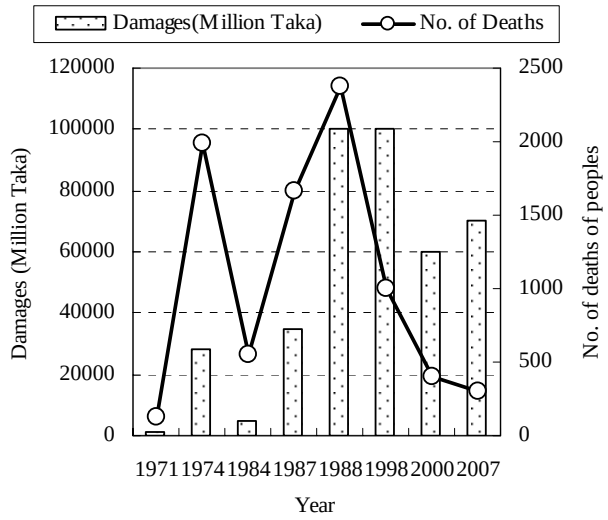

Fig. 5. Damages and number of deaths of peoples after independence of Bangladesh due to effect of flood and embankment failure

Recent floods in 2007 caused many failures of embankments and river banks, and damaged a lot of things along with deaths of many peoples in just two months. This is because the country usually tried to deal with the short term consequences of flood and embankments. However, in order to cope with the persistent situation of flood and consequences of embankment failure, Bangladesh has to think seriously about the long-term strategy regarding the flood control procedure and embankments construction methods. In Fig. 5, it can be observed that the number of deaths of people is getting to reduce in the recent years as compared to earlier despite the damages are enormous. This clearly indicates the alertness and awareness of government and the people of Bangladesh about the flood and flash flood due to the sudden breach of earthen embankments. Nonetheless, this phenomenon can not be considered enough and necessary steps in this direction especially protection of earthen embankment from failure should be taken into account urgently.

In order to make useful investigation regarding the failure of embankments, the stability analyses of the failed sections of the Jamuna and Padma flood control embankments are performed. The factor of safety for the country side slopes of each embankment section having a circular slip circle using the determinate method described above are summarized in Table 4. It can be seen from this table that the factors of safety for country side slopes of Jamuna flood control embankments under both the conditions such as with and without water storage are less than the recommended factors of safety of 1.5. In the case of Padma river embankment, the factor of safety without water storage is more than the recommended factor of safety, however, for water storage conditions, the factor of safety is less than the recommended one. This indicates that the country side slopes of Padma river embankment is not stable during the flood period in monsoon and the Jamuna flood control embankment is not stable even during the non-flood period when the water level is low.

Table 4. Summary of the results of slope stability analyses for the failed sections of Jamuna and Padma flood control embankment

Embankment failed	Type of analysis	Water storage condition	Factor of safety	Recom-mended factor of safety
Jamuna flood control embankment	Effective stress analysis	Without water storage	1.45	1.5
		With water storage	1.27	1.5
Padma river embankment	Effective stress analysis	Without water storage	1.55	1.5
		With water storage	1.35	1.5

It should be noted here that about 20% budget of Bangladesh is being spent every year for the flood control embankments but it does not solve the problem permanently due to erroneous construction and wrong planning. It is feared that unless serious steps are taken to correct this way of construction and planning, embankments and flood problem of Bangladesh are plausible to turn into even worse with time and achieve eventually devastating magnitude. Although the construction of earthen embankments is an established practice in Bangladesh for protecting people's health and homes, such construction without proper attention towards the improvement of properties of the construction materials and methods of construction may incur huge extra cost through conservative design or failure.

CONCLUSIONS AND RECOMMENDATIONS

The major causes of failure of earlier embankments are identified as breach of the embankment, cutting by public, overflow, erosion, seepage and sliding. Other causes were poor planning, design and faulty construction. The cause of failure of all the flood control embankments in the year 2007 could be attributed to erosion and sliding of embankments materials due to river encroachment and mitigation. The cause of failure of Padma and Jamuna river embankments could be attributed to gradual erosion of embankments material owing to migration of the rivers and thrust of water current. Slope stability analyses of the Padma and Jamuna flood control embankments revealed that the country side slopes of both the embankments are not at all stable during the monsoon when the water level is high. The Jamuna flood control embankment is not stable even before and after the monsoon period because the factor of safety calculated for the country side slopes are less than that of the recommended one. Of the two cases studied detailed in this research articles, it is observed that there are substantial differences between the cross sections shown in the actual designs and that existed near to the failure locations. A close investigation of the above two cases indicates that no protective measures such as mattressing, stone pitching, concrete layers, artificial or natural reinforcement like grassing, soil-cement layer are made to prevent the embankments from rain splash, water current, waves, storm surges, and other natural calamities and destructive forces. Therefore, some forms of erosion are occurred in most of the cases. Based on the results and discussions above, it is felt that the embankments should not only be constructed by following the proper design and construction procedure but also be protected by using some forms of reinforcements or surface covering/treatment.

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