STUDY OF FLOOD EMBANKMENT DETERIORATION OF OMCHHU

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Abstract

Omchhu basin has a catchment area of about 22.52 km^2. Omchhu runs across the heart of Phuentsholing town with tremendous discharges during monsoon. Past events of floods along Omchhu posed considerable losses and damages. The construction of embankment in 2001 have aided in reducing the damages, however the flood embankments along Amochhu and Omchhu still suffers greater deteriorations. The main causes for the deteriorations are intense rainfall, slope instability, high river bed incision rate, shorter span of river width and the quality of embankment protection works. A proper engineered, efficient and effective protection works are desired.

A proper concept on embankment construction, rectification of existing structures and determination and monitoring of embankment deterioration factors are essential. Field investigations and inspections with photographic evidences were used to determine the deteriorating factors. River survey using total station (TS06) was extensively carried out along the simulation stretch to get the cross sectional details for the design. The iRIC software (Nays2D Flood) was used to simulate flood for the identification and determination of flood prone areas. Therefore, this study is oriented to determine the maximum flood level that have occurred in Omchhu in order to suggest appropriate embankment protection works so that the Phuentsholing City remains safe and protected from any future flood events. The factors that leads or contributes to the deterioration of embankments are studied such as scour prediction and slope instability problems.

A brief geotechnical studies and laboratory test on soil and bed materials were also carried out to study the subsoil characteristics and to determine the parameters required for scour depth computation and design. Proper rectification to the existing embankments and design of new embankments at flood prone areas are suggested incorporating the factors causing embankment failure.

Key Words : *Embankment, Flood simulation, iRIC, Geo-bags, apron, DEM and Scouring.*

1. INTRODUCTION

Floods are the natural and recurrent phenomena causing unusual destruction to human society and the environment . Flooding is one amongst the most devastating natural hazards in the world claiming more lives and causing tremendous damages to the properties and infrastructures. Floods also cause severe bank erosion if the river banks are fragile and not protected against the heavy flood discharges.

In Bhutan, floods of varying magnitude affect some or most parts of our country, almost every year due to different climates and rainfall patterns. Of late, in the year 2000, some areas which were not traditionally prone to floods experienced severe inundation, especially in western parts of Bhutan. The devastating flood at Phuentsholing along Omchhu in 2000 had caused damage to property and people residing around the area and at the downstream of the catchment area. It is still a concern to the industrial estate and residential areas along Omchhu flood plain. As per "Compendium of Guidelines in the field of Flood Management" prepared by Ganga Flood Control Commission (GFCC), Patna, the floods have been classified as follows:

(i) *Low flood:* If water level in the river during monsoon rises higher than usual in other seasons.

(ii) *Medium flood:* When the water level in the river rises to the extent that crops in the adjoining areas are submerged and populated areas are encircled with flood waters and the flood waters overflow the river bank, with flood frequency of 1 in 10 years.

(iii) *High flood:* Any flood level of the river, which is higher than the danger level (i.e. level of the river which will damage crops and property of the people) and which corresponds to return period of more than 10 years.

2. OBJECTIVES

- Determine factors causing embankment deterioration in Om Chhu Basin.
- Simulate Floods using IRIC software and determine flood prone zones in Phuentsholing City.
- Identify and suggest Rectification and other engineering solutions.

3. METHODOLOGY

The main steps involved for the study of flood embankment deterioration were collection of data, soil test, survey and simulation of flood using **International River Interface Cooperative** (iRIC) software to determine flood prone areas in order to provide protective measures for the embankment along Om chhu.

Data used for desk study were mostly based on the maps from Phuentsholing city and DGM prepared by the Geological Survey of India and satellite imageries. The following table shows the data used and the sources from where the data were obtained.

Table : Data type and their sources

Sl. No	Data Type	Sources
Spatial Data		
1	DEM(10 m resolution)	Department of Geology and Mines
2	Satellite Image	Google Earth
Hydrological Data		
1	Rainfall Data & Base flow Data	Department of Hydro-met services MoEA, Thimphu
Survey Data		
1	Survey maps	Phuentsholing City Co - operation

Figure 1: Study Area

Area of Interest (Om Chhu Basin)

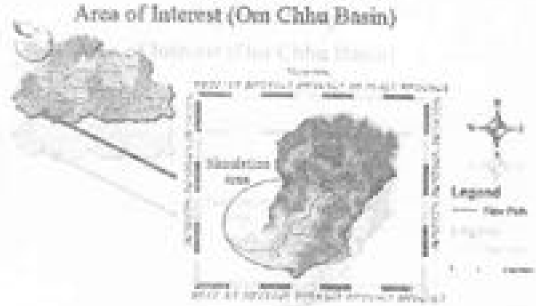
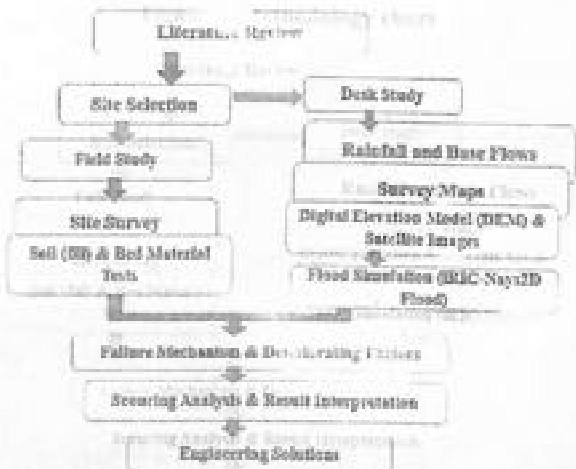


Figure 2: Methodology chart



3.1 Embankment Deterioration factors

Factors affecting embankment deterioration are often geographically specific. There are several factors that accelerate deterioration of river embankment. Some factors such as rainfall indirectly deteriorates embankment whereas factors such as Peak discharge, type of embankment foundation, rate of scouring, Seepage, moisture content and soil types directly contributes to embankment deterioration.

When the water content of the soil in embankment increases beyond optimum moisture content the soil become more unstable which is then more susceptible to collapse or damages.

Those factors that affects Omchhu embankment (deteriorates) are

1. Peak Discharge / Design Flood.
2. Velocity of flowing water.
3. Toe scouring.
4. Material of Embankment.
5. Foundation of Embankment.
6. Rainfall.

3.2 Laboratory tests

Embankment protection works such as retaining walls, gabion walls, etc. fail due to improper assessment of effect of subsoil or foundation soil characteristics. In order to determine the subsoil characteristics we have conducted various tests in the laboratory such as sieve analysis to find the gradation of soils, moisture content determination, specific gravity test, compaction test to determine maximum dry density and optimum moisture content of the soils. From the right and left embankments, we have collected twelve soil samples in total from different places which were dug to the depth of 1metre each.

3.3 Site Survey

The survey was carried out using t tal station (TS 06). The main purpose of surveying was to acquire the cross section and topography. It was then used to evaluate the cross section of the river and design training structured.

3.4 Flood simulation

For simulation of flood iRIC software application, particularly the Nays2D component is used in this project. The International River Interface Cooperative (iRIC) software application is an integrated software environment for river simulation. In the comprehensive iRIC software application, data can be compiled for river analysis solvers, rivers can be simulated and results can be visualized.

Data used for flood simulation were prepared from topographical map, satellite image (Google Earth), and Digital Elevation Model (DEM) using ArcGIS 10.1. The parameters used in this study have been selected based on the field verification as well as the review of related literatures.

Figure 3: iRIC operation flow chart

3.4.1 Out put visualization

The output depth profile and velocity is shown below. The maximum depth was found to be 6.85 m and maximum velocity to be 2.68 m/s.

Figure 4: iRIC output of depth profile of Omchhu

Figure 5: iRIC output of velocity profile with arrow of Omchhu

Figure 6:iRIC output profile showing areas prone to floods.

3.5 Scouring analysis

Scour is one of the major causes of failure for stream and river projects. It is important to adequately assess and predict scour for any stream or river design. Designers of treatments such as barbs, revetments, or weirs (that are placed on or adjacent to streambeds) must estimate the probable maximum scour during the design life of the structure to ensure that it can adjust for this potential change.

Pemberton and Lara (1984) suggested that regime equations provided by Blench (1970) and Lacey (1931) could be used to predict general scour in natural channels.

These regime relationships may be expressed as:

$Z_t = K\, Q_d^a\, W_f^b\, D_{50}^c$;ouring calculations

Sl. no.	Q(m3/s)	K	W(m)	D50 (mm)	Z(m)
1	221.6	0.162	56.20	10	0.314
2	221.6	0.162	34.48	12	0.426
3	221.6	0.162	33.50	7	0.461
4	221.6	0.162	44.81	5	0.394
5	221.6	0.162	44.80	5	0.394
6	221.6	0.162	38.06	5	0.439
7	221.6	0.162	37.36	7	0.429
8	221.6	0.162	42.81	5	0.406

4. Result and Discussion

From the soil tests, past evidences, flood simulation and site visits we concluded that many factors are associated to long term and short term deterioration of the embankment. Factors like rainfall which can affect the embankment instantaneously due to high infiltration rate causing erosion should be checked by levees. The guidelines for levees in Japan suggests that the gentle slope of 3H:1V should be maintained but the revised guidelines in Korea suggests that the slope should be maintained between 2H:1V to 3H:1V after the study of damages from the large floods, Typhoon 'Rusa' and 'Maemi' in 2002 and 2003, respectively.

In the long run, rainfall may lead to rise in ground water table which may fail the embankments due to under seepage and piping. During high floods in monsoon seasons the scour rate will be high in Omchhu basin as the width of channel is narrow.

The training structures that are currently installed in the Omchhu are not effective against toe scouring which was found to be long term as well as short term deteriorating factor. The RCC retaining walls are scoured in the base and also the chunks of retaining walls lying and dangling in the river foresights future instability as toe scouring is not checked properly. Therefore, stone pitching at a gentle slope of 2H: 1V and also for the same slope geo-textile bags which are cost effective are good techniques to check toe scouring.

The fill material of the embankment is mainly coarse grained sand which can be scoured easily as in the case of area near archery ground which has subsidized by the combination of scouring and seepage.

5. Countermeasures / protection works

1. Stone pitching

The area near the vegetable market was prone to flood after simulation in iRIC. Although current retaining wall has a height enough to protect the area, toe scouring poses risk of future subsidence and failure of the wall. Hence to counter the scouring a simple stone pitching design is provided below for that cross section.

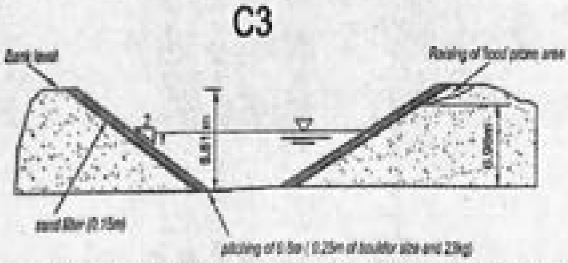


Figure 7: Area C3 designed for stone pitching against toe scouring at a slope of 2H: 1V

The design of typical bank revetment has been provided with weight of boulders as 22.349kg, size of boulder 0.25m, and thickness of pitching as 0.6m.

2. Pitching by geo textile bags

The area near the archery ground has subsided due to rapid incision and toe cutting of the embankment (Thapa, Tshering, & Wangdi, 2010). The area which has scoured is not protected, which poses risk to the stability to the area near the archery ground which is used by people for recreational purposes. Hence a simple design of geo textile bag is calculated as per specifications with the following properties. Size of geo textile bags= 1.1m X 0.7m X 0.15m,

Weight of bags= 126kg, material used in bags: fine sand (0.02mm – 0.01mm), thickness of geo bag pitching: 0.3m.

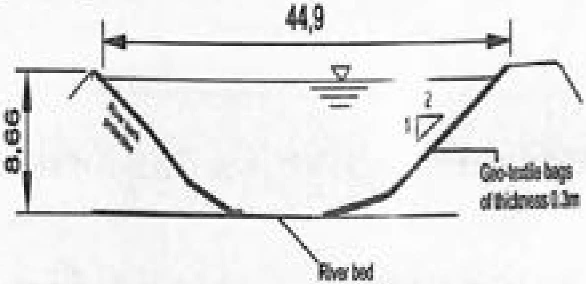


Figure 9: Area C3 designed for stone pitching against toe scouring at a slope of 2H: 1V

Geotextile bags of 126 kg filled weight are stable against near bed velocities of up to 2.9 and 2.6 m/s on slopes of 1V:2H and 1V:1.5H respectively. Geotextile bags provide high stability against currents. The main reason is the substantial difference in shape: flexible geotextile bags lying flat on the bank show high resistance to flow forces (Oberhagemann & Hossain, 2010).

3. Gabion wall with mattress apron

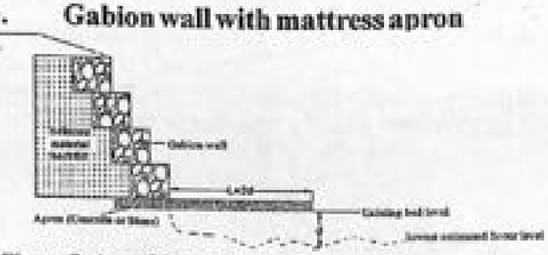


Figure 8: Area C3 designed for stone pitching against toe scouring at a slope of 2H: 1V

The existing training structures must be supplemented with apron (concrete or stone) which is effective against scouring.To tackle the problems of excessive toe scouring the above measure can be adopted.

6. CONCLUSION

From the soil tests, past evidences, flood simulation and site visits we concluded that many factors are associated to long term and short term deterioration of the embankment. Scouring is the most predominant factor that deteriorates or weakens the embankment in upstream side of Omchhu and the existing training structures. Other factors like seepage and high discharge during rainfall also contributes to the failure of embankments.

Not only rainfall affects the embankment instantaneously due to high infiltration rate but also causes erosion. In the long run, rainfall may also lead to rise in ground water table causing embankment failure due to under seepage and piping. During high floods in monsoon seasons the scour rate will be high in Omchhu basin as the width of the channel is narrow. From the geotechnical test results, it was found out that the fill materials of the embankment as coarse grained sand with high moisture content indicating low strength. That could be the reason for slope instability problems causing erosion, seepage and scouring as in the case of areas near archery ground which has been subsidized.

Therefore, incorporating all the deteriorating factors mentioned above, proper training structures must be constructed in the upstream areas of Omchhu basin. The training structures that are currently installed in the Omchhu are not effective against toe scouring which was found to be long term as well as short term deteriorating factor. The RCC retaining walls are scoured in the base and also the chunks of retaining walls lying and dangling in the river foresights future instability as toe scouring is not checked properly.

Therefore, stone pitching at a gentle slope of 2H: 1V and for the same slope geo-textile bags which are cost effective and effective against scouring would be recommended. Proper embankment design with provisions for drainage must also be taken into account by the city planners in future. Flood simulation using iRIC (Nay2D Flood) helped us in identifying the flood prone areas. After identifying and prioritizing the critical areas, protection works of the embankment were suggested and designed accordingly.

7. RECOMMENDATIONS

1. The DEM data of higher resolution gives better accuracy in case of flood simulation.
2. The extension file .tpo should be modified accordingly after vigorous site validation which requires accurate survey data.
3. Apart from the rainfall data of Phuentsholing town as a whole, a separate gauge station for each catchment area is required for accurate evaluation of flood discharge.
4. Department of hydro-met services or any other agencies related to hydrology needs to update and keep records of hourly rainfall data that would be useful for any hydrological related studies and research and the rainfall data required for flood simulation should have minimum record of 30 years.
5. Existing training structures should be supplemented with secondary training structures to check against toe scouring. The most innovative and cost effective measures such as stone pitching and geo-textile bags would be better options for the city planners to look upon.

8. CONCLUSION

Of all the factors listed above, scouring is the most predominant one that deteriorates or weakens the embankment in upstream side of Omchhu and the existing training structures. On the other hand, factors like seepage and high discharge during rainfall also contributes to the failure of the embankments. Therefore, proper training structures must be constructed in the upstream areas in case there is further development of town on the upstream part of the Omchhu.

The geotechnical tests were carried out to study the properties and characteristics of the fill materials of the embankment. The result shows that the materials are coarse grained sand having low strength and high moisture content. It could be the reason for slope instability problems causing erosion, seepage and scouring. Therefore, proper embankment design with provisions for drainage and proper training structures should be considered by the city planners in future.

Flood simulation using iRIC (Nay2D Flood) helped us in identifying the flood prone areas. After identifying and prioritizing the critical areas, protection works of the embankment were suggested and designed accordingly. Discharge computation for the year 2000 also helped us in the design of training structures.

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