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## TECHNICAL PAPERS

# Effectiveness of Multiple Groynes In Bank Protection Works

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## Abstract

*Groynes are widely used in Bangladesh for bank protection, river training and navigational purposes. In bank protection works it is generally practiced to construct more than one groyne to get better results. More than one groyne has a combined hydro-dynamic effect which affects the thalweg, bankline shifting, flow field etc. In any cases if multiple groynes are suggested to construct and if it is not done properly, then the problem arises thereof are briefly described in this paper as an example of Kushtia town protection from the erosion of the Gorai river.*

## Introduction

Bangladesh is a land of rivers interlaced by numerous tributaries and distributaries of the three great river systems: the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna. We have an agro-based economy and most of the important cities, towns, business centre and so many important structures are situated on the bank of the major rivers of the country. In almost every year bank protection works are carried out to protect the river bank erosion, of which groyne is a widely used type of structure.

Groynes are the embankment type structure constructed transverse to the river flow, extending from the bank into the river. That is why they may also be called transverse dykes. They are constructed in order to protect the bank from which they are extended, by deflecting the current away from the bank.

Spurs/groynes can be different types based on the materials and method of construction, shape of the groynes, functional points of view, etc. such as submersible and non-submersible groyne, straight groynes, T-head groynes, hockey shaped groynes, bell mouth groyne, attracting type, repelling type etc. Different model studies and its recommendation and the protective measures taken for the protection of Kushtia town are described in the following discussion. A short description of the characteristics of the Gorai river are given below.

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The Gorai

The river Gorai is a large spill distributary channel of the Ganges and flows following a sinuous path, through the alluvial plains of Gangetic delta consisting of fine sand and silt. The Gorai taken of from the Ganges near Talbaria and flowing towards south for 243 km and falls into the Bay of Bengal. The river has a different names at different parts of it's course. The upstream part is known as the Gorai then it flows by the name Madhumati and further down it is taken the name Balehswar at Kachua and falls into the Bay of Bengal through the Haringhata estuary. In the monsoon the river carries huge amount of discharge and sediment load and the river course has a general tendency of instability, channels are constantly migrating laterally which results formation of many meander loops, latter cutoffs and consequently many oxbow lakes along the of the channel (RRI, 1993).

**Discussion**

The Gorai takes off from the river Ganges near Talbaria and the Kushtia town is situated on the right bank of the river at about four miles downstream of Talbaria. In 1972, severe bank erosion was noticed at the right bank of the Gorai River near the Kushtia town. Then the Hydraulic Research Laboratory was requested to carry out physical model study for the protection of the Kushtia town and after that River Research Institute conducted physical model studies several times as the erosion continued due to partial implementation of the recommended works. These are described here subsequently.

**1972**

Due to severe erosion of the right bank of the Gorai river, Hydraulic research laboratory was requested to carry out the scale model study for the protection of the Kushtia town. After scale model investigation two nos. of T- head groynes ( groyne no.1 and 2 of shank length 500 ft and T head 400 ft), as shown in the Figure 1, were recommended to construct in one year for the protection of Kushtia town from the erosion of the Gorai river (HRL, 1972).

After this recommendation only groyne no.2 was constructed in 1973.

**September 1979**

As a results after some years heavy erosion was taken place upstream of groyne no.2 and consequently RRI was requested again in 1979 to carry out the model studies for the protection of Kushtia town. After scale model investigation 900 ft length of brick revetment at the right bank, upstream of proposed groyne no.1 including groyne no.2 were recommended to prevent the bank erosion.

**December 1979**

In November-December, 1979 additional model studies were conducted for groynes and spurs as another alternative of revetment to reduce the cost. Accordingly after model tests it was recommended that one groyne (groyne no.1) of 250 ft shank and 400 ft T - head on the right bank at cross-section no.2 and second groyne (groyne no. 3) of 300 ft shank and 300 ft T head which was about 1600 ft above the existing groyne no.1 as shown in Figure 2, to be constructed to protect the Kushtia town. It was also recommended to excavate a diversion channel to facilitate the construction work (RRI, 1979).

**1985**

In the year 1985 BWDB took up the construction work of groyne no.1 and Project Director Gk Irrigation and Rehabilitation project requested RRI to carryout the model study on emergency basis to suggest whether the size and location of the proposed groyne no.1 recommended in December 1979 (Report #55) is still effective or to be modified. It was also requested to study whether the proposed groyne no. 3 is still required or not as the thalweg has been changed and a big char was developed at its proposed location.

During model study it was found that the proposed size and location of groyne no.1 recommended in December 1979 (Report #55) will be quite effective and no modification is necessary. In order to retain the newly formed char at the right bank of the river upstream of groyne no.1, it is necessary to construct one permeable spur, 800 ft long as shown in Figure 3. Alternatively to retain the newly formed char, a bell mouth spur of length 400 ft at 1100 ft downstream of cross-section no.4 as shown in Figure 4 may also serve the above purpose and this will be more economical and a permanent one (RRI,1985).

After this recommendation groyne no.1 was constructed in 1985.

**1988**

But erosion further continued. RRI was requested again by the Project Director, G.K. irrigation and Rehabilitation project, BWDB, Kushtia to carry out the fresh model study to comment whether the proposed spurs as suggested in April 1985(Report #84) or any other protective measures which will be effective in view of the fact that the configuration and thalweg of the river have been greatly changed. Consequently, after model tests it was recommended to construct one T- head groyne(groyne no.3) at 150 ft downstream from cross-section no.2 and one bell mouth spur at 800 ft upstream from cross-section no.3 as shown in the Figure 5, will suffice for the purpose of the Kushtia town protection (RRI, 1988).

A comparison of model tests recommendation in different years and the protective measures implemented in the field for the protection of Kushtia town are shown in the Table below:

Table:

| Year | Model tests recommendation | Protective measures taken in the field |
|---|---|---|
| February 1972 | Two nos of T-head groyne(Groyne no.1 and groyne no.2 of shank length 500 ft and T head 400 ft) as shown in figure 1 | Only groyne no.2 was constructed in 1973 |
| September 1979 | 900 ft length of brick revetments in the right bank, u/s of proposed groyne no.1 ( including groyne no.1) | |
| December 1979 | Groyne no.1 of 250 ft shank and 400 ft T-head, groyne no.3 of 300 ft shank and 300 ft T-head as shown in figure 2. It was also recommended to excavate a diversion channel to facilitate the construction work. | |
| April 1985 | Groyne no.1 of 250 ft shank and 400 ft T-head as recommended in December 1979 to be constructed.<br>and<br>one permeable spur of 800 ft length as shown in figure 3<br>or<br>A bell mouth spur of 400 ft length as shown in figure 4 | Only groyne no.1 was constructed in 1985 |
| December 1988 | One T-head groyne(groyne no.3) of shank length 400 ft and T-head 360 ft and one bell mouth spur of 400 ft length as shown in figure 5. | |

## Conclusion

Groyne in series has a combined hydrodynamic effect. At the starting of the erosion, after model study two nos. of T-head groynes were suggested to construct (HRL, 1972) for the protection of the Kushtia town from the erosion of the Gorai river. But it was not constructed according to the recommendation. Only one groyne (groyne no.2) was constructed after this recommendation in 1973 and as a result in the next years erosion continued. As a result according to the necessity model studies were carried out several times for the protection of the Kushtia town. So it is obvious from the above discussion that if two nos. of T- head groynes (groyne no.1 and groyne no.2) were constructed in one year as recommended then the cost of bank protection works, the sufferings of the inhabitants and the loss of the valuable lands, several times model study could be avoided and reduced significantly. So to overcome the adverse effect of the partial works, it is always suggested to construct all the groynes in one hydrological year, as multiple groyne has a combined hydrodynamic effect on the thalweg, flow field, bankline shifting etc.

## Acknowledgement

This paper has been prepared based on the data and information of various report for the physical model studies carried out at Hydraulic Research Laboratory, Dhaka and River Research Institute, Dhaka. The author likes to thank those research personnel, whose efforts were essential and helpful to carry out the model studies. Thanks are also due to the Water Development Board to take initiative and funding to study the models at this Institute.

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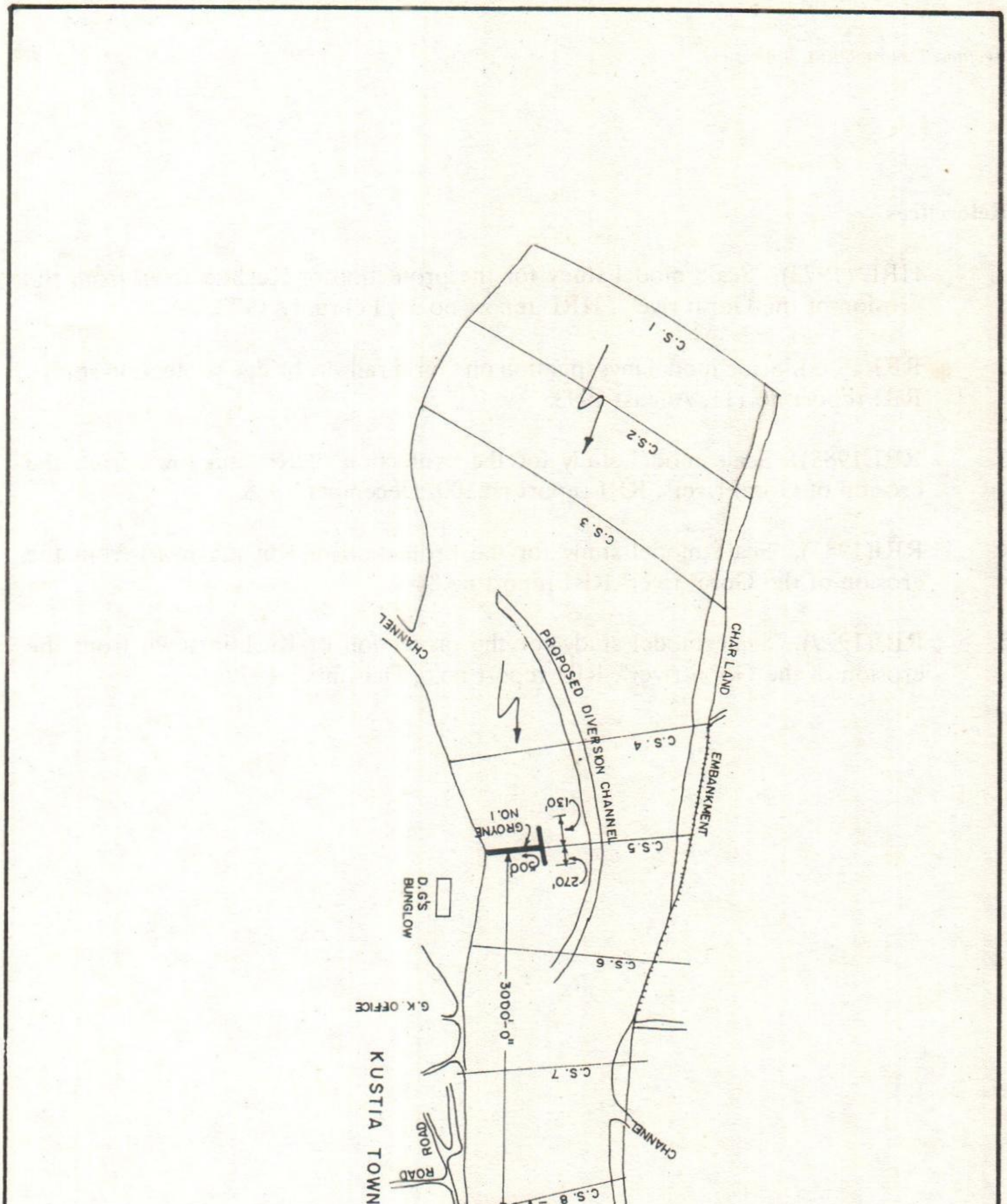


FIG. 1 : LOCATION OF PROPOSED GROYNE

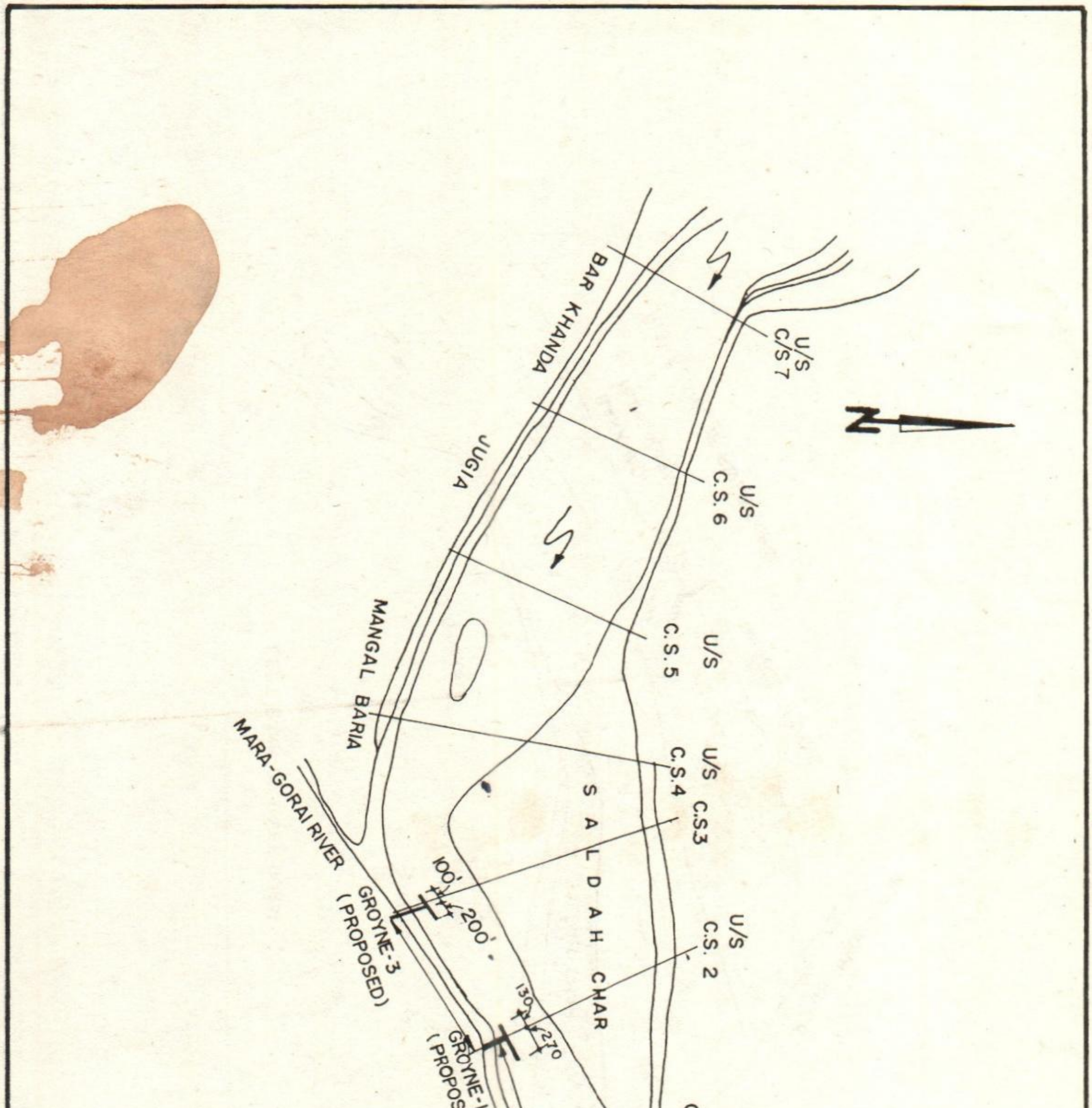


FIG. 2 : LOCATION OF PROPOSED GROYNE

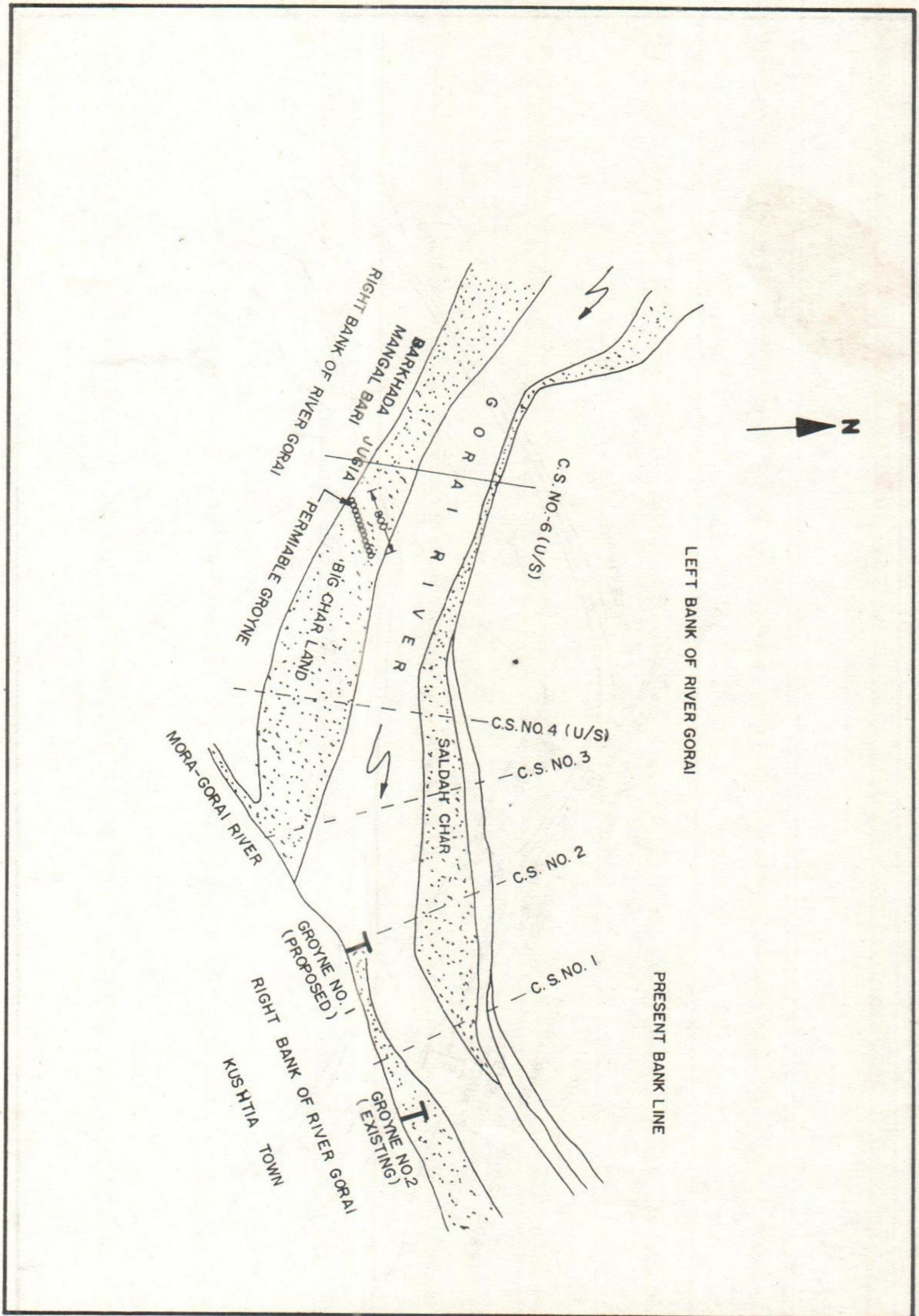


FIG. 3 : LOCATION OF PERMIABLE GROYNE

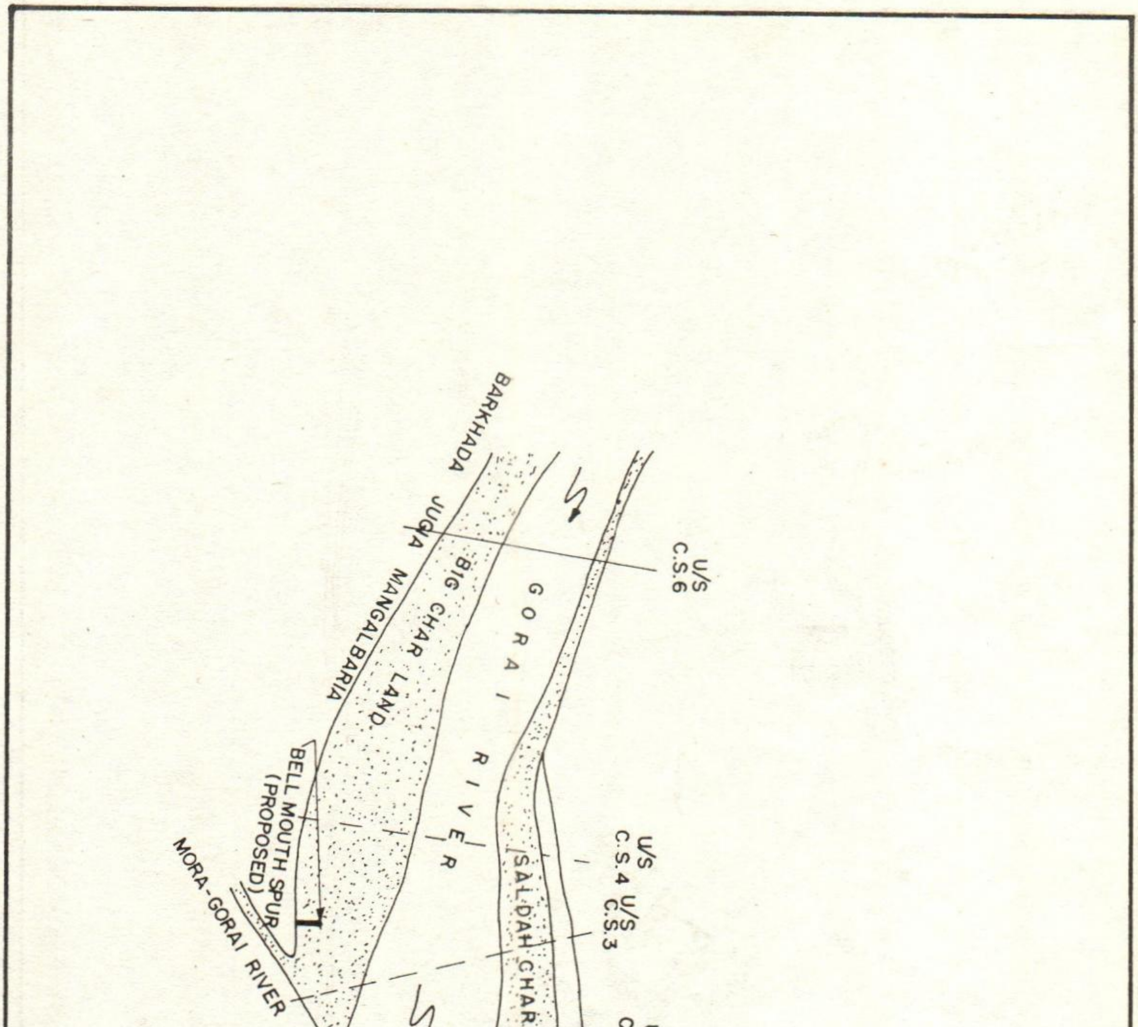


FIG. 4 : LOCATION OF BELL MOUTH GROYNE

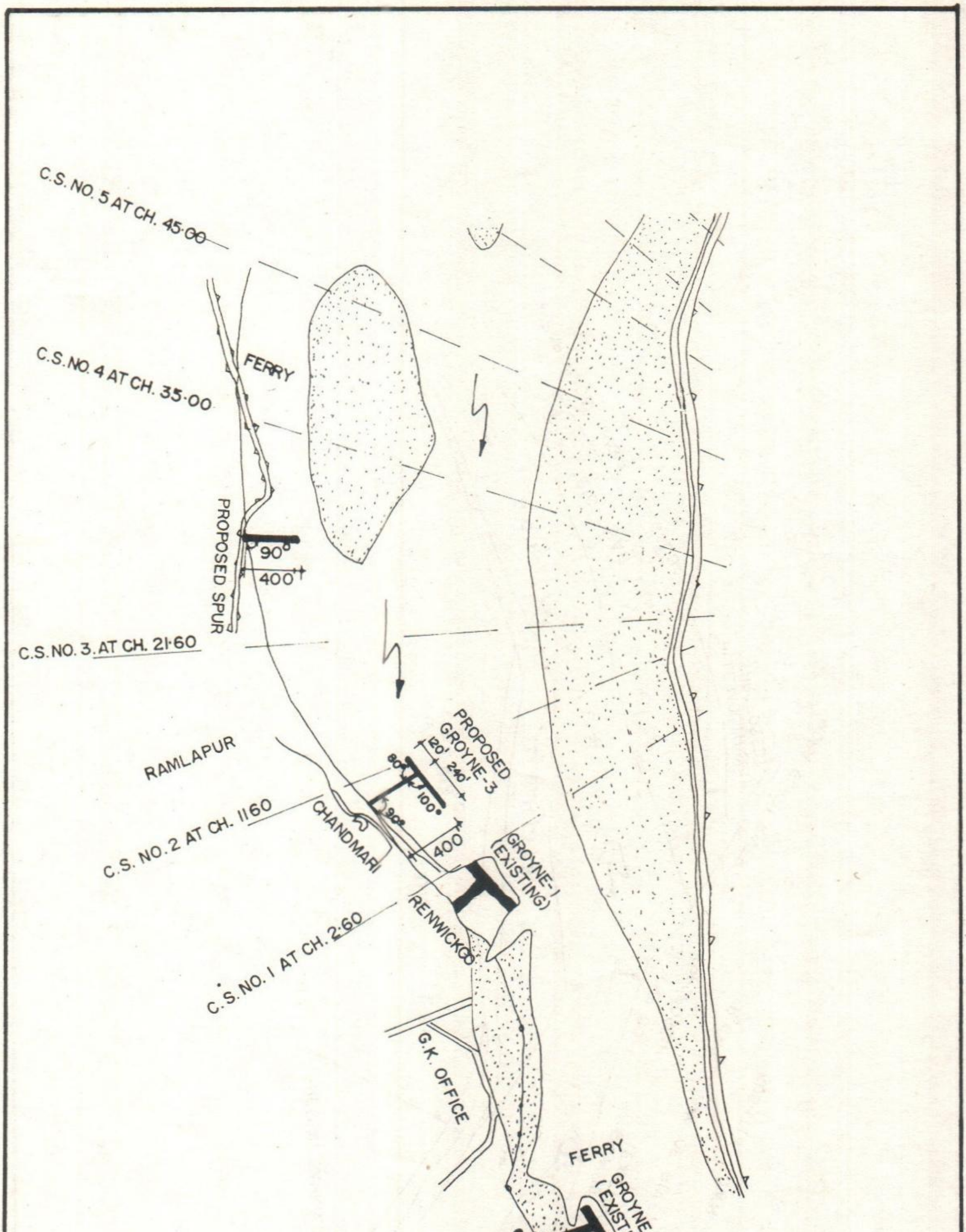


FIG. 5 : LOCATION OF PROPOSED GROYNE

# A Physical Model Study for Investigating Stability of West Guide Bund of Jamuna Multipurpose Bridge

Md. Abu Hena Mostofa Kamal[1]

**Abstract**

*This Model was designed and planned to investigate the extreme flow velocities and local scour around the guide bund and to verify the stability of boulders against design discharge for various planforms of the approach channels. Scour around the bridge pier was also investigated in this study. The model was operated with two conditions, one was scour condition to investigate local scour and another was Froude's condition to investigate flow fields and extreme flow velocities near the guide bund.*

## Introduction

The Jamuna Multipurpose Bridge Project is one of the largest projects ever made in Bangladesh. It includes a bridge of 4.8 kilometre length and some major river training works for guiding the flow to pass under the bridge safely. The river training works comprise of East and West guide bunds having length of more than 2 kilometres each and two hard points near Sirajganj and Bhuyanpur, upstream of the bridge. The Jamuna is a braided river. The design discharge for the bridge is selected as 91,000 $m^3/s$. The average water surface slope varies within 5 cm - 9 cm per km. The morphology of the Jamuna is very lively. Forecasting of probable morphological changes which may occur near the guide bunds is of immense importance in terms of safety and future maintenance of the river training works.

The present study deals with the aspects of West Guide Bund(WGB) where about 5 km of the river reach covering the river training works with partial width of the river is reproduced.

## Objectives of Model Study

This study aims at the following objectives:

a) To check detailed flow fields and the extreme flow velocities near the west guide bund for present planform of approach channel.

b) To forecast possible morphological changes near the guide bund for present and future planforms of the guide bund.

c) To verify the stability of the stone/boulders against design discharge of the guide bund.

d) To investigate the possible scour development arround the bridge piers.

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## Methodology of the Study

### Model Set-up

About 5 km x 1.2 km river reach covering the total length of guide bund and part of the west channel closure have been reproduced in the model. The left and right boundary of the model are derived from the flow lines found in overall fixed bed model. The layout plan of the sectional model is shown in **Figure 1.** To supply steady state flow two rectangular sharp crested weirs have been installed at the upstream end of the model. To maintain water level at four well gauges, to ensure uniform flow into the stilling basin and to maintain a constant water level, eight tail gates have been installed in the model.

### Basic Data for Modelling

Topographical data for the model study were collected from various sources and listed in **Table 1.**

**Table 1:** Bathymetric data

| Type of data | Sources of data | Date/Period | Remarks |
|---|---|---|---|
| Bathymetric survey, Flow conditions, Scour patterns | SWMC | Oct-Nov,'95 | Available within the area of 15 km upstream and 5 km downstream of the bridge |
| Bathymetric survey, Water level | FAP-24, DHI/SWMC and 2-D Math model | July11-13,'95 | Only at the bridge location |
| Bathymetric survey,Design of west channel closure of WGB | CSC | June-Nov 19?5, February 1996, April 1996 | Available within 8 km area covering the bridge location |

### The Main Parameters and Scale ratios

The main characteristic parameters and their scale ratios are given in **Table 2.**

For the simulation of local scour holes and changes in the bed geometry the model was partly fixed and partly movable. $D_{50}$ & $D_{90}$ for model and protype are 0.18 mm & 0.29 mm and 0.19 mm & 0.26 mm respectively. Therefore the ratio between protype and model roughness was not unity. To minimize the scale effect model discharge was increased depending on the schield's coefficient.The required velocity for the initiation of the bed load transport was calculated as 0.37 m/s (using Van Rijn formulae).

### Measurements in the Model

In all tests discharge, corresponding level, flow velocities ,flow lines and scour depths were measured. The development of scour with time have also been recorded.

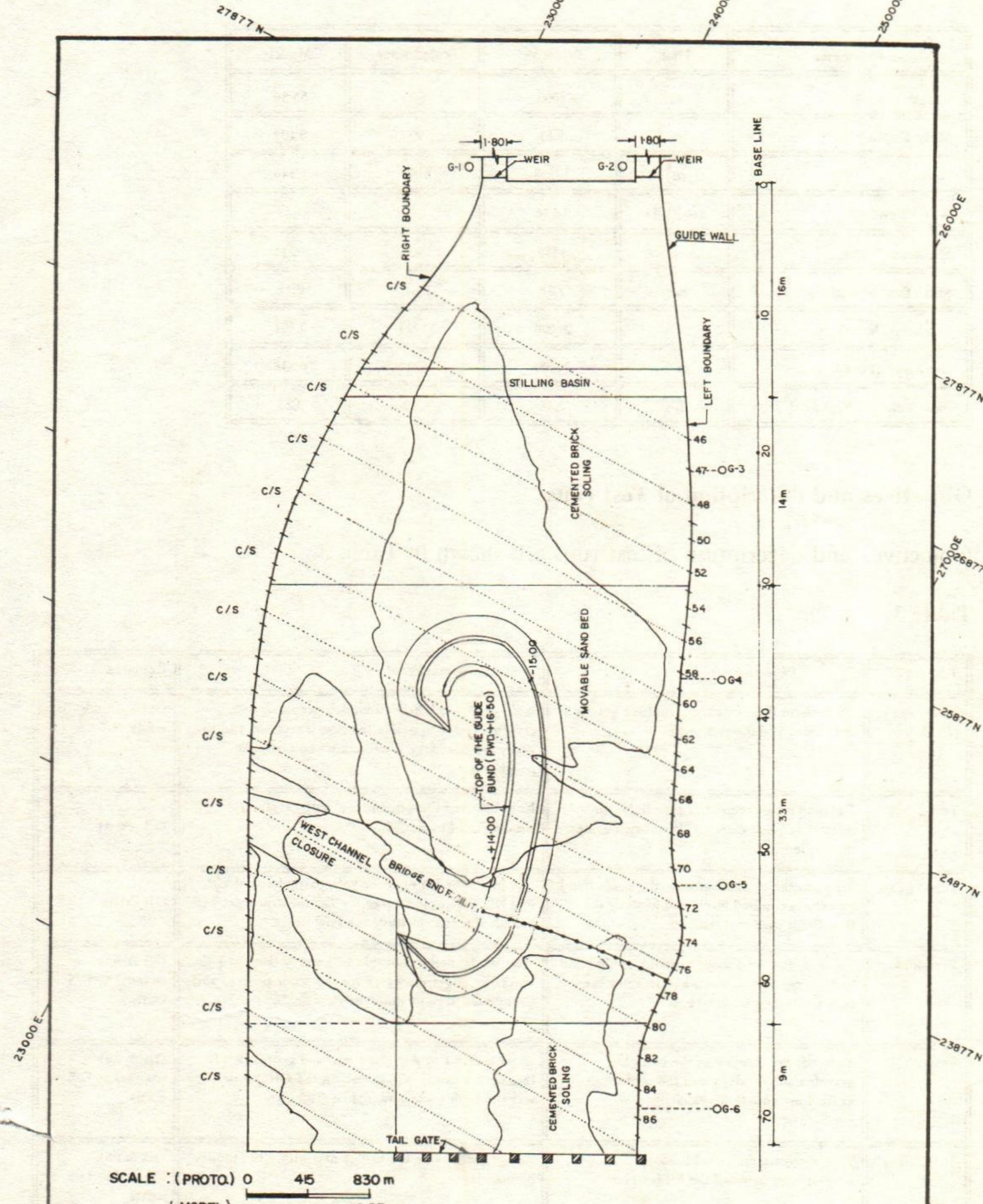


FIGURE NO. 1

**LAYOUT PLAN OF SECTIONAL MODEL OF WEST GUIDE BUND OF JAMUNA MULTIPURPOSE BRIDGE PROJECT**

**Table 2:** The main parameters and scale ratios

| Parameter | Unit | Prototype | Scale Factor | Model |
|---|---|---|---|---|
| Length | m | 5000 | 90 | 55.56 |
| Mean Depth | m | 9.63 | 90 | 0.107 |
| Area | $m^2$ | 10920 | 8100 | 1.348 |
| Water Level | m+PWD | 14.36 | - | - |
| Maximum Width | m | 1450 | 90 | 16.11 |
| Mean flow Velocity(scour) | m/s | 2.38 | 6.41 | 0.37 |
| Discharge(Scour) | $m^3/s$ | 26000 | 51921 | 0.501 |
| Discharge (Froude's) | $m^3/s$ | 26000 | 76843 | 0.338 |
| Flow Velocity (Froude's) | m/s | 2.38 | 9.49 | 0.25 |

**Objectives and description of Test runs**

Objectives and description of test runs are shown in Table 3.

**Table 3:**

| Test No | Objective | Description | Remarks |
|---|---|---|---|
| Test-1 (T1) (Calibration Test) | To confirm the hydraulic similitude between the model and the prototype | Non- distorted fixed bed model prepared with cement plaster to define the flow directions and to verify the discharge distribution and hydraulic roughness . | Guide Bund(GB) exists |
| Test-2(T2) | Detailed measurement of flow fields on normal bed and extreme flow velocities near the guide bund. | Non distorted fixed bed model with careful simulation of hydraulic roughness. | GB exists |
| Test-3 (T3) | To study the local scour near the guide bund and change in bed levels and to study the flow fields over scoured bed. | The model bed is movable with partly fixed at U/S and D/S. Higer discharge for the scour process and Froude dischrge to study the flow fields. | GB exists |
| Test-4(T4) | To study the local scour near the guide bund and change in bed levels and to study the flow fields over scoured bed. | The model bed is movable with partly fixed at U/S and D/S. Higer discharge for the scour process and Froude dischrge to study the flow fields. | GB & link channel at D/S exists |
| Test-5(T5) | To verify the stability of the boulders/ gravels used as slope and toe protection against extreme flow velocity. | Gravels of #4 to #16 sieve size and geotextile of thin cotton cloth was placed on the GB. Model was run both lower and higher discharge. | GB & link channel at D/S exixts |
| Test-6 (T6) | To investigate the possible scour development arround the bridge piers. | Bridge piers along the bridge axis within the model boundaries. | GB & link channel at D/S exixts |

**Findings of the Test Runs**

The interpretation of test results are mainly focused on the following:

**Flow velocities**

It was noticeable that major flow passed into the dredged trench in front of the guide bund and it accounts for about 57% of the total model discharge. The maximum flow velocity around the guide bund occurs near the upstream edge of the guide bund and its position was in the distant of 1588 m upstream from west end pier & 85.5 m from the perimeter of the guide bund. The maximum flow velocity was 3.92 m/s. The ratio between the maximum to average velocity in a cross section perpendicular to flow direction was found to be as 1.64.

It was important to note that the magnitude of flow velocities gradually declines to zero towards the upstream of closure. This indicates that the guide bund will provide dead water protection to the closure. A rotational flow was observed along the upstream end of the guide bund and finally this flow combines with the main flow in front of the guide bund.

The flow velocity distributions at the upstream chars were high enough to cause possible char erosion. On the other hand, flow velocity measured on the downstream chars were not higher than that of upstream. Because some of flow diverted towards the main channel at the downstream of the guide bund. Velocity along the closure just downstream were tend to zero. Due to construction of a link channel between downstream of the guide bund and west channel, flow velocity found in the channel ranged from 0.86 m/s to 3.56 m/s.

**Flow Lines**

From the tests it was obseved that major flow concentrated toward WGB and passed into the dredged trench near the guide bund. As a result thalweg had been shifted toward the guide bund. The northern tip of the guide bund was experienced rotational flow which led to erosion at that location.

**Local scour and change in bed level**

The scour depths around the guide bund were important with respect to stability of the slope and would be used to design the toe level for launching apron. The deepest point of the dredged trench was -15 m+PWD as per design. Maximum scour and deposition near WGB at different cross-sections were collected and shown in **Table 4**. The test result under scour investigations were summerized and described as follows:

* Considerable sediment transport from the upstream chars were observed

* Ripples were formed in the middle of the cross sections toward downstream. The process was found to be very slow. It caused deposition of sediment and raised the bed level where initial topography was not very high.

* After equilibrium bed was reached, final bed levels around the WGB had not exceeded - 15 m+PWD.

* Sedimentation occured at the toe of the slope of the guide bund which mean slope was flat enough.

* Sedimentation occured at the immediate downstream of the closure.

* Appreciable bed scouring had been occured at southern corner of the guide bund where initial bed levels were high and the maximum scour depth was found to be 16.11 m at a distance of 427.5 m away from the guide bund. On the other hand,sedimentation was noticable at deepest areas near the downstream of WGB.

**Table 4:** Maximum scour/deposition near WGB along cross-sections in tests T3, T4 and T5

| C/S # | Test T3 | | | Test T4 | | | Test T5 | | |
|---|---|---|---|---|---|---|---|---|---|
| | D | I | F | D | I | F | D | I | F |
| 61 | 126 | 16.5 | 8.9 | 171 | 13.1 | 9.1 | 171 | 13.1 | 6.8 |
| 62 | 270 | 6.6 | -1.5 | - | - | - | 315 | 8.1 | 1.7 |
| 63 | 459 | 3.7 | -4.7 | 459 | 0.8 | -5.1 | 234 | 2.1 | -5.8 |
| 64 | - | - | - | 311 | 7.9 | -6.2 | 131 | -6.5 | -2.2 |
| 65 | 419 | 12.7 | 8.2 | 464 | 16.1 | 12.9 | 149 | -8.5 | -4.7 |
| 66 | 275 | -2.4 | -7.3 | - | - | - | 94.5 | -1.4 | 8.0 |
| 67 | 216 | -4.9 | -11 | 396 | 12.9 | 6.3 | 36 | 0.7 | 11.6 |
| 68 | 248 | -8.3 | -14 | 248 | -8.3 | -11 | 113 | -2.5 | 6.5 |
| 69 | 248 | -1.5 | -12 | 248 | -4.7 | -14 | 68 | 2.2 | 9.3 |
| 70 | 261 | -6.5 | -13 | 261 | 7.6 | -9.2 | 126 | -1.2 | 4.1 |
| 71 | 288 | -0.6 | -11 | 288 | 4.0 | -8.3 | 288 | 4.0 | -8.3 |
| 72 | - | - | - | 275 | 4.8 | -10 | 275 | 4.8 | -8.1 |
| 73 | 279 | 11.1 | -3.3 | 279 | 3.0 | -12 | 279 | 3.0 | -8.6 |
| 74 | - | - | - | 338 | 9.4 | 4.2 | 293 | 4.8 | -4.7 |
| 75 | 338 | 16.0 | -4.8 | 360 | 7.8 | 2.8 | 315 | 2.1 | -5.1 |
| 76 | - | - | - | 131 | -2.9 | 2.6 | 131 | -2.9 | 8.9 |
| 77 | 360 | 8.9 | -0.6 | 356 | 3.5 | -4.7 | 252 | -11 | -5.6 |
| 78 | 194 | -8.4 | 1.1 | 239 | -12 | -2.2 | 239 | -12 | -2.0 |
| 79 | 212 | -8.4 | -3.8 | 212 | -9.2 | -2.4 | 212 | -9.2 | 0.0 |
| 80 | - | - | - | 212 | -8.1 | -1.1 | 167 | -4.4 | 3.0 |
| 81 | 356 | -12 | -0.2 | 176 | -13 | -3.3 | 252 | -13 | 1.7 |
| 82 | 657 | -8.7 | 2.2 | 207 | -6.9 | 3.7 | 162 | -0.9 | 13.4 |
| 83 | - | - | - | 427 | 12.8 | -3.3 | 398 | 12.8 | -0.7 |
| 84 | - | - | - | 113 | -6.2 | 10.2 | 158 | -3.3 | 11.8 |

D- Distance from perimeter of the WGB(m)
I- Initial bed level(m+PWD), F- Final bed level(m+PWD)

Test wise simultaneous scour and deposition at cross-section #74 were plotted and shown in **Figure 2.**

**Stability of stone/boulders**

Prototype stone/boulders used as slope protection and also used on the launching apron as toe protection were scaled according to their specific gravity and size and placed accordingly in the model. To verify the stability of stone/boulders the tests were carried out with higher(501 l/s) and lower (338 l/s) discharges. The maximum velocities around the guide bund were recorded and deepest scour holes were measured to check the stability of armour materials on slope.

In this test it was observed that the stone/boulders remain intact. Only damages were occured at the toe of the slope at about 500 m upstream of the bridge axis where maximum velocity was 3.92 m/s and deposited to immediate downstream.

**Scour around bridge piers**

In the model, fourteen numbers of piers had been provided as per design covering the model width of the river. Scour depths around the piers were measured and maximum scour depth 15.08 m corresponds to bed level of -19.5 m+PWD was found around the pier #46 which was located at a distance of 400 m away from WEP along the bridge line. Scour depths around the other pier were laid within the range of 1.71 m to 8.73 m.

**Conclusions**

The model study lead to the following general conclusions:

a) High flow velocity occurs around the guide bund and the maximum velocity was observed as 3.92 m/s at the northern tip of the west guide bund, while a minimum velocity of 3.21 m/s was observed at the southern corner of the guide bund.

b) Flow tend to concentrate at the southern tip of the guide bund and the dredged trench in front of the guide bund also tends to attract the flow.

c) Spreading out of the flow on leaving the bridge site was noticeable.

d) The maximum lowering of bed level near the guide bund was up to 14.55 m+PWD.

e) A flow channel was likely to be developed downstrem of the guide bund.

f) The dredged trench in front of the guide bund had been widened and its left side slope had been flattened due to erosion.

g) Sedimentation and/or deposition occured on the lower end of the slope of the guide bund.

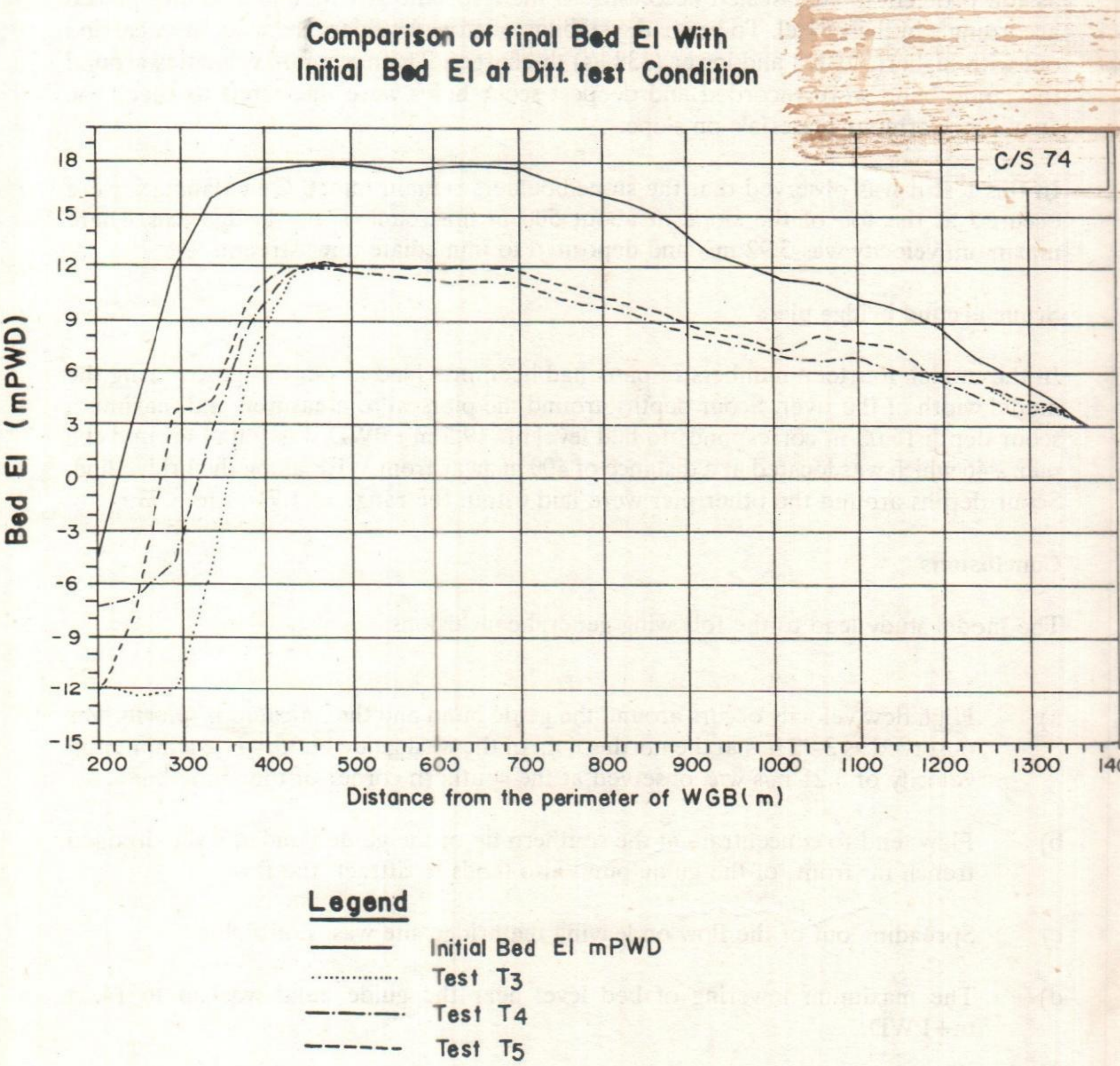


**Figure no. 2 : Test wise comparison of bed levels along c/s # 74**

h) The armour material was stable upto a velocity of 3.92 m/s. Special precautions should be taken for the locations where higher velocities might occur.

i) The flow field in the vicinity of the guide bund was complex.

j) The minimum bed level around bridge pier was found to be -19.5 m+PWD

**Acknowledgement**

The author would like to thank all officers and stuff of River Research Institute those are involved in this study directly or indirectly.The financial support provided by the Jamuna Multipurpose Bridge Authority is greatfully acknowledged.

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## Some Data Screening Techniques and an Application to The River Gumti

**Engr. Md. Abul Kashem**[1]

**Abstract**

*The data screening which gives an absolute measure of the quality of data is essential for the proper identification of errors of hydrological and hydraulic data. Hydrological data should be stationary, consistent, homogeneous and independent for modelling or frequency analysis. This paper deals with the application of some data screening/ assessment techniques for the analysis of hydrological data (annual maximum discharge ) of the Gumti River. Some comments on the findings are also included in this paper.*

### 1.0 Introduction

The data screening which gives an absolute measure of the quality of data, is the root of proper analysis and the solution of water related problems, in which a number of uncertain parameters is involved. Hydrological time series may exhibit trends referred to as inconsistencies or non-homogeneities, where inconsistencies result from changes in the amount of systematic error associated with recording of data, such as those arising from changes in instrumentation or observational practices; and non-homogeneity is defined as a change in the statistics of the data set which are caused by natural or man-made changes. Hydrological data should be stationary, consistent, homogeneous and independent for modelling or frequency analysis.

Tests for homogeneity, stationarity, persistency, consistency and trend of the hydrological data [ annual maximum (extreme) discharge] recorded at the station Comilla for 28 years [Tab-1.1]. Here Comilla [23°-28′ N and 91°-15′E] is the border station of the Gumti River after its entrance into Bangladesh from the Indian Hilly Province of Tripura[Fig.1.1].

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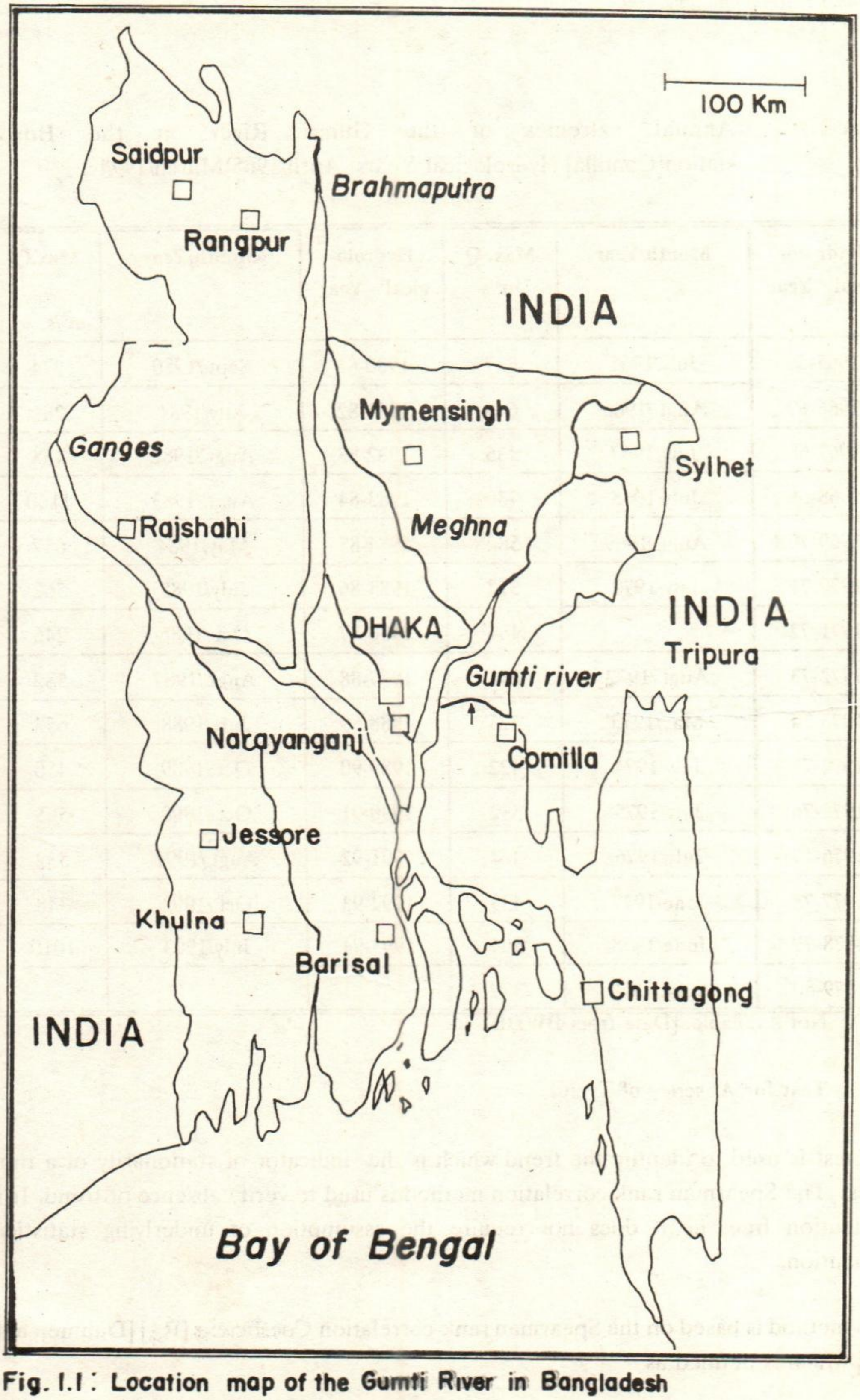


Fig. 1.1: Location map of the Gumti River in Bangladesh

Table-1.1: Annual extremes of the Gumti River at the Border station[Comilla].Hydrological Years: April/1965-March/1994

| Hydrological Year | Month/Year | Max. Q $m^3/s$ | Hydrological Year | Month/Year | Max.Q $m^3/s$ |
|---|---|---|---|---|---|
| 1965-66 | July/1965 | 537 | 1980-81 | Sept./1980 | 274 |
| 1966-67 | Augt./1966 | 649 | 1981-82 | July/1981 | 281 |
| 1967-68 | July/1967 | 436 | 1982-83 | Augt./1982 | 488 |
| 1968-69 | July/1968 | 730 | 1983-84 | Augt./1983 | 1160 |
| 1969-70 | Augt./1969 | 580 | 1984-85 | May/1984 | 657 |
| 1970-71 | July/1970 | 372 | 1985-86 | July/1985 | 562 |
| 1971-72 | - | N/A* | 1986-87 | Oct./1986 | 246 |
| 1972-73 | Augt./1972 | 241 | 1987-88 | Augt./1987 | 582 |
| 1973-74 | May/1973 | 425 | 1988-89 | July/1988 | 653 |
| 1974-75 | July/1974 | 422 | 1989-90 | Oct./1989 | 450 |
| 1975-76 | July/1975 | 552 | 1990-91 | Oct./1990 | 505 |
| 1976-77 | July/1976 | 464 | 1991-92 | Augt./1991 | 532 |
| 1977-78 | June/1977 | 439 | 1992-93 | Oct./1992 | 348 |
| 1978-79 | June/1978 | 504 | 1993-94 | July/1993 | 1010 |
| 1979-80 | Augt./1979 | 370 | | | |

* N/A:- Not Available. [Data from BWDB]

### 1.1 Test for Absence of Trend

This test is used to identify the trend which is the indicator of stationarity of a time series. The Spearman rank-correlation method is used to verify absence of trend. It is distribution free, i.e.,it does not require the assumption of underlying statistical distribution.

This method is based on the Spearman rank-correlation Coefficient [$R_{sp}$] [Dahmen and Hall] which is defined as

$$R_{sp} = 1 - \frac{6 \sum_{i=1}^{n} (D_i^2)}{n\,(n^2 - 1)} \tag{1}$$

where

n = total number of data

i = chronological order

D = $Kx_i - Ky_i$

$Kx_i$ = the rank of data as observed

$Ky_i$ = the rank of the same data in ascending order

The null hypothesis $[H_0]$ of no trend is tested with the statistic [Student's t-distribution]:

$$t_t = R_{sp} \left[ \frac{n - 2}{1 - R_{sp}^{\;2}} \right]^{0.5} \tag{1.1}$$

where $t_t$ = Student's t-distribution at the confidence level $\alpha = 5\%$ [2-tailed test] and [n-2] degree of freedom [v]

The critical region, U of $t_t$ at a significance level of 5% [two-tailed], is bounded by :

$$\{-\infty, t\{v, 2.5\%\}\} \cup \{t\{v, 97.5\%\}, +\infty\}$$

The time series has no trend if the $t_t$ is not in the critical region or if:

$$t\{v, 2.5\%\} < t_t < \{v, 97.5\%\}$$

The test results of trend analysis [Spearman] for annual maximum [extreme] discharges of the Gumti River are:

Total no of data n= 28

The value of t is found as $t_t = 0.846$,

Now,for degrees of freedom v= 26,the boundary limits are $t_{2.5\%} = -2.053$ and $t_{97.5\%} = 2.053$ [for the 5% level of significance (two-tailed)]

From the result, it is clear that the null hypothesis $[H_0]$ is accepted, i.e. $t_{2.5\%} < t_t < t_{97.5\%}$.

So, the probability of $t_t$ is not in the critical region. Hence, there is no significant trend in the time series of discharge.So the time series is stationary.

### 1.2 Tests for stability of variance and mean

To test the stability of variance and mean, which is an indication of the homogeneity and stationarity of the time series, the F-test for stability of variance and t-test for stability of mean is used [Dhamen and Hall].

#### 1.2.1 The F-test for stability of variance

The F or Fisher distribution is the distribution of the variances-ratio of samples from a normal distribution. Also, the F-test or Fisher-distribution gives an acceptable indication of stability of variance of the sub-sets of the time series even if the samples are not from a normal distribution . The test statistic is the ratio of the variance of two split, non-overlapping, sub-sets of the time series.

The null hypothesis is tested with the statistic [F-test]:

$$F_t = \frac{s_1^2}{s_2^2} \qquad (2)$$

where,

$F_t$ = Fisher or F distribution

$s_1^2$ = variance of the first sub-set

$s_2^2$ = variance of second sub-set

The standard deviation can be computed from the following equation:

$$S = \sqrt{\frac{\sum_{i=1}^{n} (x_i^2) - (\sum_{i=1}^{n} (x_i))^2/n}{n-1}} \qquad (2.1)$$

where $X_i$ is the observation and n is the total number of data.

The critical region [rejection region], U at a significance level of 5% [two-tailed], is bounded by:

$$\{0,F\{v_1,v_2,2.5\%\}\} \cup \{F\{v_1,v_2,97.5\%\}\}$$

where $v_1 = n_1-1$ is the degrees of freedom for the first sub-set, and $v_2 = n_2-1$ is the degrees of freedom for the second sub-set, and $n_1$ and $n_2$ are the number of data in each sub-set. If the variance of the time series is stable a pooled estimate of the standard deviation, S, can be used in the subsequent test for stability of the mean if:

$$F\{v_1,v_2,2.5\%\} < F_t < F\{v_1,v_2,97.5\%\}$$

The test results for the stability of variance of the time series (F-test) of annual maximum discharges of Gumti River are:

Total no of data n= 28
Number of data of sub-set 1= 18
Number of data of sub-set 2= 10
Degree of freedom for the first sub-set-1 $v_1=17$
Degree of freedom for the second sub-set-2 $v_2=9$
Standard deviation for the first sub-set $S_1=205.31$
Standard deviation for the second sub-set $S_2=205.53$
The value of F is found as $F_t=0.846$,

Now,for degrees of freedom $v_1= 17$ & $v_2= 9$,the boundary limits are $F_{2.5\%} =0.374$ and $F_{97.5\%}=3.57$ [for the 5% level of significance (two-tailed)]. From the test results, it is clear that the null hypothesis [$H_0$] is accepted, i.e. $F_{2.5\%}<F_t<F_{97.5\%}$.

But the difference in number of data in sub-sets is eight, and the second moment [variance] of the first & longer sub-set is almost equal to the second moment of the second & shorter sub-set which may be due to recording of two high floods within the last ten years. However, the probability of $F_t$ is not in the rejection region, and therefore, the variance of the time-series of discharges is stable.

**1.2.2 The t-test for stability of Mean**

The t-test for stability of the mean compares the computed means of two non-overlapping sub-sets of the time series but the sub-sets of the time-series should be the same sub-sets as those for the F-test for stability of variance.

The null hypothesis $[H_0]$ is tested with a suitable test statistic[Dahmen and Hall]:

$$t_t = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} * \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \qquad (2.2)$$

where

$x_1$ = mean of the first sub-set
$x_2$ = mean of the second sub-set
$n_1$ = number of data in the first sub-set
$n_2$ = number of data in the second sub-set

The critical region,U, for the 5% level of significance [two-tailed], is bounded by:

$$\{-\infty, t\{v,2.5\%\}\} \cup \{t\{v,97.5\%\},+\infty\}$$

where $v = n_1 - 1 + n_2 - 1$, degree of freedom.

The mean of the time series is considered stable, i.e. the null hypothesis is accepted, if:

$$t\{v,2.5\%\} < t_t < t\{v,97.5\%\}.$$

The test results for the stability of mean of the time series (t-test) of annual maximum discharges of Gumti River are:

Total no of data n= 28
Number of data of sub-set $n_1 = 18$
Number of data of sub-set $n_2 = 10$
Degrees of freedom $v = 26$
Mean for the first sub-set $x_1 = 205.31$
Mean for the second sub-set $x_2 = 205.53$
The value of $t_t$ is found as $t_t = 0.846$,

Now, for degrees of freedom v= 26,the boundary limits are $t_{2.5\%} = -2.053$ and $t_{97.5\%} = 2.053$ [for the 5% level of significance (two-tailed)].

From the result, it is clear that the null hypothesis $[H_0]$ is accepted, i.e. $t_{2.5\%} < t_t < t_{97.5\%}$. But the first moment [mean] of the first and longer sub-set is smaller than the first moment of the second and shorter sub-set which is may be due to the same reasons mentioned above. However, the probability of $t_t$ is not in the rejection region, and therefore, the mean of the time-series of discharges is stable.

Now from both F-test for stability of variance and t-test for stability of means of the time series of discharges, it has been found that the variance and the mean of the time-series are stable. Therefore, the discharge data of the Gumti river can regarded as homogeneous and consistent.

### 1.3 Test for Absence of Persistence

To verify the independence of a time series, i.e., the absence of persistence, the serial-correlation coefficient for lag 1 was used as suggested by Dahmen and Hall(1990) and this reads:

$$r_1 = \frac{\sum_{i=1}^{n-1} (x_i - \bar{x}) * (x_{i+1} - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})} \quad (3)$$

where

$\bar{x}$ = mean of the time series
$x_i$ = an observation
$x_{i+1}$ = the following observation
n = total number of data

The value of $r_1$ should fall between the upper confidence limit [UCL] and the lower confidence limit [LCL]. The critical region, U, at the 5% level of significance is defined as:

$$\{-1,(-1-1.96(n-2)^{0.5})/(n-1)\}U\{(-1+1.96(n-2)^{0.5})/(n-1),+1\} \quad (6.6)$$

where the first term indicates the lower confidence limit and last term indicates the upper confidence limit. This is also called Anderson test for independency of the time-series[Dahmen and Hall,].

From the analysis, the first serial coefficient of the time series of annual maximum discharges was found about 0.13.

Also, for n=28, the boundary limits are:

upper confidence limit for $r_1$ ; UCL[$r_1$]= 0.333
lower confidence limit for $r_1$ ; LCL[$r_1$]=-0.407

Here, -0.407<0.13<0.333, i.e., $LCL[r_1] < r_1 < UCL[r_1]$. So the first serial correlation coefficient is between the confidence limits. So there is no persistence in the time series of discharges and hence, the discharge data of the Gumti river are independent.

## 1.4 Resumé of tests result and Conclusion

From the Spearman's test for trend, the F-test for stability of variance and t-test for stability of means of the time series of discharges, it has been found that there is no significant trend in the time-series, and the variance and the mean of the time-series are stable. The collected hydrological data [discharge] at Comilla station can therefore be regarded as stationary, consistent, and homogeneous.

Also, from the Anderson test, it has been found that the discharge and water level data are independent, and hence, there is no persistence in the time series of discharges.

Hence,it is concluded here that the discharge data of the Gumti River at Comilla station have passed all tests successfully, and are suitable for modelling or frequency analyses.

## 1.5 Recommendation

These data screening techniques should be an example for checking the quality of hydrological and hydraulic data for other river.

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# Effectiveness of Cement Concrete Blocks Against Failure of Coastal Embankment: A Case Study of Bhola Town Protection

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Md Abul Ala Moududi[2]

## Abstract

*This paper describes the performance of cement concrete (C.C.) blocks used as revetment for the protection of coastal embankment against erosion due to tidal current and wave action. Various coastal embankment projects at different locations of coastal areas in Bangladesh were undertaken to protect valuable land and property from the adverse effects of natural disasters like floods, cyclones, storm surges etc. Among them, a case study on Bhola district town protection was carried out at River Research Institute (RRI) to find out the optimum solution by means of physical model investigation. Revetment in the form of C.C. blocks were designed as a bank protection structure. The study aims at finding out optimum slope and length of launching apron of the revetment and also to find out alternative design which enables to control erosion caused by current and waves. Also stability of C.C. blocks against wave was investigated in this study.*

## Introduction

Coastal areas in Bangladesh are mainly divided into three parts (Pramanik, 1983): such as Eastern zone, Middle zone and Western zone. The middle zone i.e. the Meghna deltaic plain is an active deltaic region which draws almost the entire flux of the Ganges-Brahmaputra-Meghna river system. This plain has been identified as consisting of fluvial, fluvio-tidal and tidal units. The coast line of Bangladesh with coastal inlets and hydro-morphological divisions is shown in Figure-1.

Bangladesh is densely populated country and most of the people are living in the river and coast sides. The coastal area of Bangladesh is vulnerable to devastation caused by cyclonic storms and associated storm surges. The country is experiencing catastrophic floods, cyclonic surges every in few year and make hazards to the life and property directly.

Bhola town as well as Bhola island is located at very adjacent to the sea, surrounded by Shahbajpur and Tentulia channels and is being threatened by severe erosion of west bank of Shahbajpur channel due to both ebb current and tidal waves generated from the sea. This area is characterized by alluvial deposition and erosion.

As a part of Bhola town protection from the erosion of Shahbajpur channel, C.C. blocks of 40 cm cubes were designed to use as revetment for bank protection. The purpose of providing revetments is to prevent failure of the bank soil due to hydraulic loads created by waves, currents, and drawdown of the water level. The type of possible failure mechanism depends on the nature of the soil which shows certain characteristics to resist

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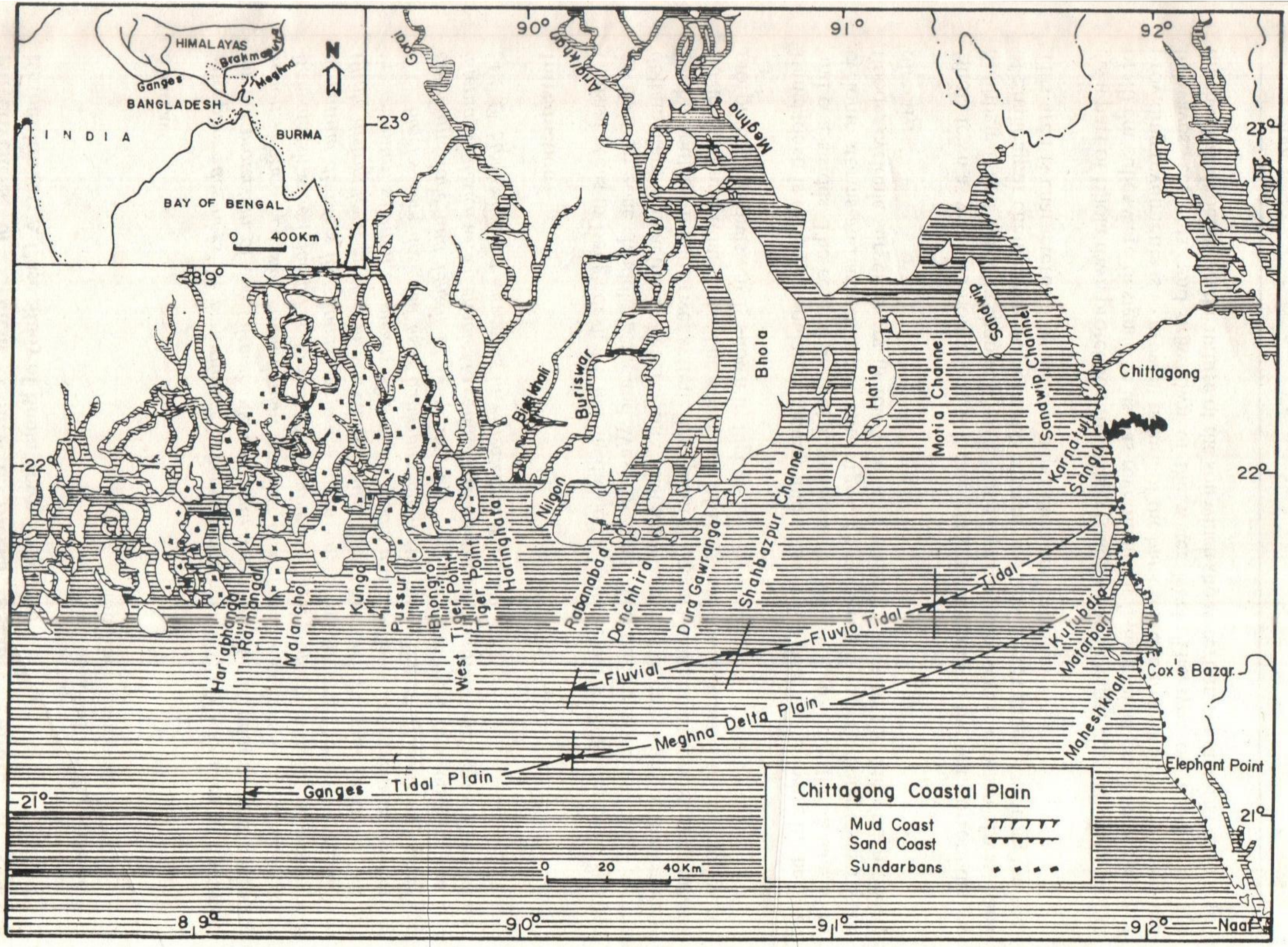


FIGURE NO.1: THE COASTLINE OF BANGLADESH WITH COASTAL INLETS AND HYDRO-MORPHOLOGICAL DIVISIONS various modes of failure. The function of the revetment is thus to reduce the hydraulic load acting on the soil and possibly to help to stabilize the soil. The most precise assessment of subsoil conditions and hydraulic loads created by water motion in the form of waves, currents required for the design of revetment of sufficient stability. Revetment is constructed above the design water level or in very shallow water where its toe is likely to be exposed to intense wave and current faces during storms. For these reasons, its toe warrants special protection. If a revetment is overtopped, even by minor splash, the stability can be affected.

The effect of C.C. blocks for this specific protection works was investigated by means of physical model study. The study comprised of two components, viz. river models (one overall and one sectional movable bed) and wave model. In sectional river model, stability of blocks against maximum current and maximum scour have been evaluated. In wave model, stability of C.C. blocks against waves were investigated. Both models were designed based on Froude's model law.

This paper attempts to provide a comprehensive interpretation of the modelling results and to find out the efficiency of C.C. blocks as a coastal bank protection based on analysis of results.

**The study area**

Shahbajpur channel is located in the tide influenced southwestern part of Bangladesh. Recently, the water discharge has increased in Shahbajpur channel causing serious erosion along right bank. The area is located at the west bank of Shahbajpur channel and north part of Bhola district and adjacent to the Bhola town which is shown in Figure-2. The latitude and longitude of the project lies between $22^0 40'$N to $22^0 45'$N and $90^0 35'$E to $90^0 40'$E in the lower Meghna estuary. Severe bank erosion is being experienced at Nasirmajhi to Kalikirti due to tidal bore and cyclonic surges.

In the dry season there is a reversing of the flow in the river at the flooding hours. During flood season, only ebb current occurs. Water flows directly during ebb tide. Discharge at Shahbajpur channel during August-September is recorded as high as 1,40,000 $m^3/s$ where average is 35,000 $m^3/s$.

**Data acquisition**

For setting up the model, following data was collected from different sources and listed in Table-1.

Tide height during dry and flood season are 1.5 m and 2.0 m respectively in Shahbajpur channel. River flow velocity recorded as 1.75 m/s to 3.8 m/s. Wave celerity varies between 1.5-3.5 m/s. The tidal amplitude is dampened by the river flow. One tidal period was selected for the study. The tidal variation is dominated by diurnal/semidiurnal tidal components, the two successive tidal periods being almost identical. Rivers are characterized high discharge during ebb tide and decreased by about 50% during flood tide.

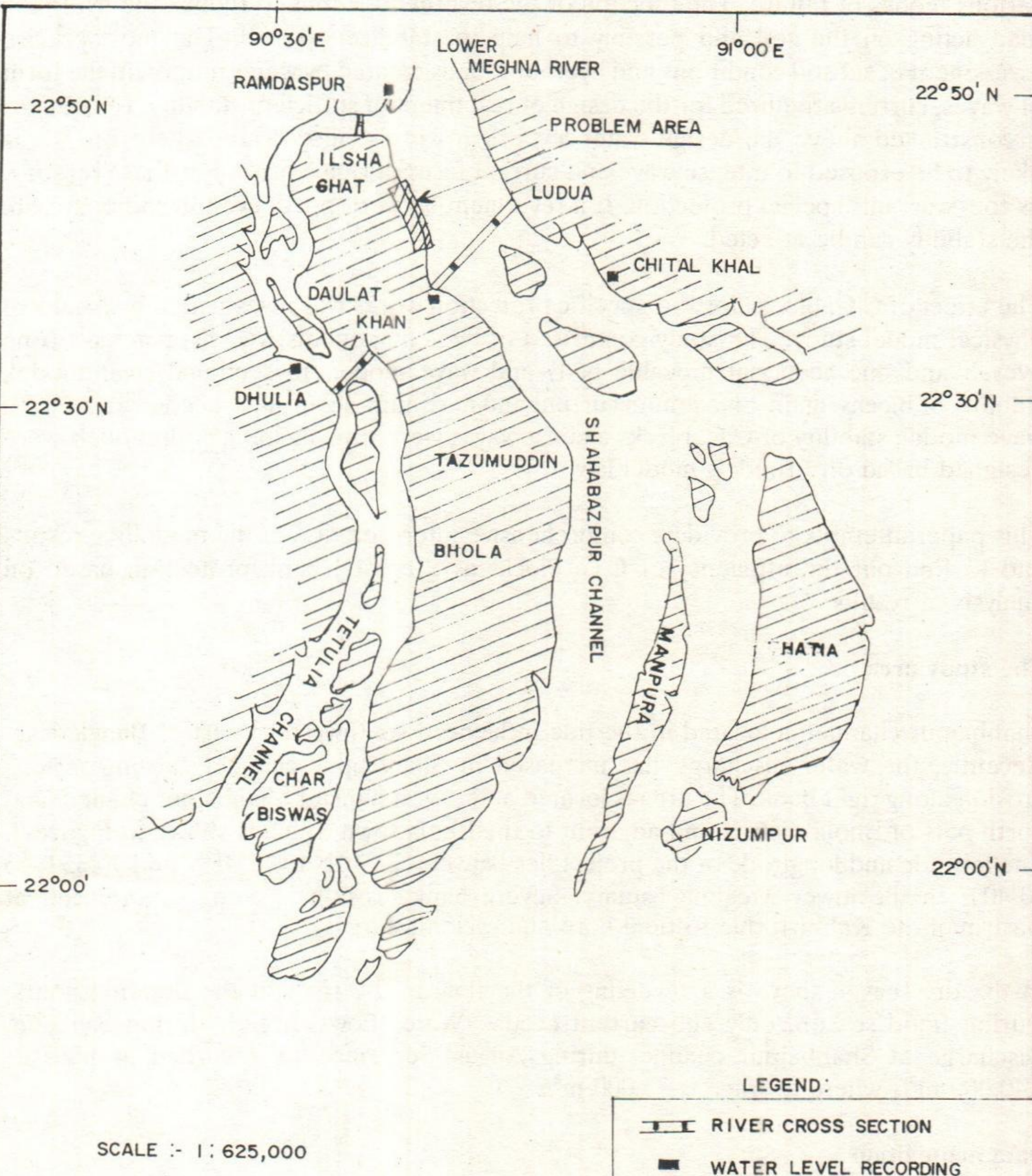


FIG. NO. 2

INDEX MAP

BHOLA DIST. TOWN PROTECTION PROJECT

Bank is made of mixture of loose sand ($D_{50}$=0.054 mm) and traces of silt and unstable against velocity.

Table-1:

| Type of data | Source of data | Date/period | Remarks |
|---|---|---|---|
| Bathymetric survey | Survey & Study Division,BWDB | October 1993 | 6 km x 6 km area were surveyed from the west bank of Shahbajpur channel |
| Hydrological data | Survey & Study Division,BWDB | October 1993 | |
| Weather data | SPARRSO Meteorological Office, Dhaka | 1987-1993 | |
| Tidal data | Previous study report of Bhola erosion and Feasibility report on the project | | |
| Bank material data | Survey & Study Division,BWDB | October 1993 | |
| Design of revetment works | BWDB, BholaW.D. Division | 1994 and 1995 | |

BWDB - Bangladesh Water Development Board
SPARRSO - Space Research and Remote Sensing Organization

**Model set up and scale ratios**

For this case study, three models were constructed. Firstly, an overall model covering 6 km x 6 km of problem area has been reproduced with a distorted scale of Horizontal 1:250, Vertical 1:100 at the RRI's open air space based on bathymetric survey data, 1993 with a view to identify the most vulnerable areas of erosion and to obtain the flow lines to select the left boundary for the sectional movable bed model in the open air space and wave model in the indoor wave basin.

Secondly, 4 km x 0.75 km area have been reproduced in open air space with undistorted scale of 1:100 to investigate the flow pattern and local scour around the proposed revetment works. The length and width of the river reach are selected from the flow lines of overall model. Also most vulnerable area sensitive to both wave and current was identified. Finally, 800 m x 400 m area at Nasirmajhi have been reproduced in the wave basin with undistorted scale of 1:40 to verify the stability of C.C. blocks against incoming waves.

**Discharge calculation for model**

In prototype, actual discharge into the Shahbajpur channel was not available because there were no gauging stations for discharge measurements. However, there were two water level recording gauges at the upstream and downstream of the study area.

The Bhola island is separated by two channels viz, Shahbajpur channel in the east and Tentulia channel in the west. These two channels were originated from the lower Meghna. Discharge through the lower Meghna was considered to determine the flow through Shahbajpur channel. For the study, highest water level ever recorded was considered to see the extreme hydrodynamic impact. Discharge through Shahbajpur channel was found 1,40,000 cumec considering highest recorded flood in 1988. Since bank erosion is being taken place along west bank of Shahbajpur channel. A total 6 km width of the river from the eroded bankline was surveyed and bed levels along the cross-sections at a regular interval were recorded. Water surface slope was calculated from the recorded water levels at the upstream and downstream of the problem area. Cross-sectional bed levels and the calculated slope were used to calculate prototype discharge by spread sheet. The estimated theoretical discharge for the overall model was found 57,067 $m^3/s$. Discharge for the sectional movable bed model was calculated as 30,000 $m^3/s$ and 4000 $m^3/s$ for wave model in the same procedure.

**Flow velocity**

The prototype mean velocity, 2.5 m/s and maximum velocity, 3.5 m/s around the proposed protective works were found.

**Wave characteristics**

Surface waves generally derive their energy from the winds. A significant amount of this wave energy is finally dissipated in the near bank region and causes erosion. Waves generated in this region can be of simple harmonic type. Waves are the major factor in determining the geometry and composition of river bank in the extreme coastal zone and significantly influence the planning and design of bank protection measures. Water waves are of paramount importance in the solution of bank protection measures. Wind generated waves produce the most powerful forces to which coastal structures are subjected. Wave characteristics are usually determined for deep water and then analytically propagates toward structure. A given structure might be subjected to breaking, non-breaking and broken waves during different stages of tidal cycles. The wave action a structure is subjected to may also vary along its length at a given time.

**Wave calculations**

The speed at which waveform propagates is termed the phase velocity or wave celerity, C. Since the distance travelled by a wave during one wave period is equal to one wave length, the wave celerity can be related to the wave period and length by,

$C=L/T$.....(*i*)

An expression relating the wave celerity to the wave length and water depth is given by,

$C= \sqrt{[(gL/2\pi) \tanh(2\pi d/L)]}$....(*ii*)

From equation (*i*), it is seen that equation (*ii*) can be written as:

$C= gT/2\pi \tanh(2\pi d/L)$....(*iii*)

So, L=98 m, when d=11.52 m and d/L= 0.1175, which means that transitional wave occurs.

When d/L>0.5, deep water wave, when d/L<0.04, shallow water wave and when d/L ranges between 0.04 to 0.5, transitional wave occur.

The values $2\pi/L$ and $2\pi/T$ are called the wave number,k and the wave angular frequency,ω respectively. From equations (*i*) and (*iii*) an expression of wave length as a function of depth and wave period may be obtained.

$L= gT^2/2\pi \tanh(2\pi d/L)$....(*iv*)

In deep water, $\tanh(2\pi d/L)$ approaches unity and equations (*ii*) and (*iii*) reduce to $C_0=\sqrt{(gL_0/2\pi)}=L_0/T$ and $C_0= gT/2\pi = 1.56T$ m/s.

When the relative water depth becomes shallow, i.e. $2\pi d/L<1/4$ or $d/L<1/25$ equation (ii) can be simplified to $C=\sqrt{(gd)}$.

The wave period, wave length and the wave amplitude are calculated from the established formulae as follows:

The wave period, $T_s$ have been calculated by the following formula:

$$T_s = 8.6 \exp \frac{R\Delta P}{9400}\left[1+\frac{0.145\,\alpha\,V_F}{\sqrt{U_R}}\right] \quad \ldots\ldots\ldots\ldots (v)$$

where,

R = Radius of maximum wind in km (taking 26 km for coastal area)

$\Delta P$ = Pressure drop in mm of Hg = 25.5

$V_F$ = average forward speed in m/s = 3.1

$U_R = 86.5\%\ U_{max} + 50\%\ V_F$ ( where, $U_{max}$ = maximum gradient wind speed 10 m above the water surface in m/s)

$U_R$ = Maximum sustained wind speed in m/s

$\alpha$ = a co-efficient depending on forward speed = 1.0(for slowly moving hurricane)

Maximum wind speed can be found using the following equation :

$$U_{max}=0.447\,[\,14.5\sqrt{\Delta P}-0.31\,Rf\,]$$

where, f= Corioli's co-efficient = $2\omega \sin\phi$ = 0.201

where, $\omega$ =angular velocity of earth = $2\pi/24$ rad/hr, $\phi$ = latitude=$22.6^0$

Hence, $U_{max}$ = 32 m/s

So, $U_R$ = 29.23 m/s (105 km/hr)

Putting the values in equation (*v*), then we get

$T_s$ = 10 sec in prototype equals 1.58 sec in model

The wave height, H at the toe of the structure can be found from the following equation:

$H = K_s * H_0$ ..............(*vi*)

where, $H_0$= deep water significant wave height,m and deep water wave length, $L_0$= $1.56T^2$ =156 m

Alternatively, approximate wave period may be obtained from

$T=12.1\sqrt{(H_0/g)}$.....(*vii*)

$$Where,\ H_0=5.03 \exp \frac{R\Delta P}{4700}[1+\frac{0.29\,\alpha\, V_F}{\sqrt{U_R}}] =6.76\ m$$

$$K_s=\sqrt{\frac{1}{(\tanh\frac{2\pi d}{L})(1+\frac{4\pi d}{\sinh\frac{4\pi d}{L}})}} = 0.295$$

where, $K_s$ = shoaling co-efficient

Putting the values in equation (vi), we get

Wave height, H = 2 m in proto which equals 0.05 m in model

Shallow water wave occurs at the toe of the embankment where average water depth, d=1.98 m and d/L = 0.013

The wave length, L is calculated using the following equation :

$L = CT$

where, wave celerity, $C = (gd)^{1/2} = 4.4$ m/s

Now, L = 44 m in proto equals 1.1 m in model

The still water level (SWL) +4.52 m PWD is used in determining wave forces on the structure.

**Model boundary conditions**

For this study, three general and one specific boundary conditions were considered.

1. An upstream boundary condition at the inflow of the model i.e. discharge distribution.

2. Downstream boundary condition at the outflow of the model i.e. water level at the downstream.

3. Lateral boundary of the model which is flow lines.

**Specific boundary condition**

1. Designed incoming wave train generated from sea side was maintained in the model at either side of the C.C. blocks.

**Model calibration**

The main objective of the model calibration is to find a geometric and dynamic similitude between the model and prototype. A representative section has been chosen in both ebb end flood tide conditions to compare the hydraulic parameters such as flow fields, average flow velocity, flow patterns satisfying upstream and downstream boundary conditions of the model.

**River Model tests**

The model is operated in both ebb and flood tide conditions. The overall objective of this study were : to test the effectiveness of proposed protective works (C.C. blocks) against river current, scour and wave actions.

Firstly, the flow lines were derived and upstream flow velocity were measured in the overall model to satisfy the boundary conditions in the sectional model. Then the proposed revetment was tested in sectional movable bed model. In this study, 30,000 $m^3/s$ equivalent model flow of 300 litre per second (lps) was allowed to pass into the model and was tested by varying the length of launching apron for different morphological conditions. Scour pattern around the revetment and behaviour of bankline shifting in different tests were investigated. Simulated C.C. blocks were used as revetment works in the model. The proposed revetment was found stable against the maximum current and maximum expected scour around the structure. It may be pointed out that the revetment was designed for minimum bed level of -17.0 m+PWD, whereas the value was found as -17.8 m+PWD in the model which tends to close to the design value. To prevent scouring action for additional 0.8 m, extra launching apron need to be provided.

The proposed revetment was designed to withstand against extreme velocity of 3.5 m/s. After careful simulation of the prototype conditions in the model, the observed maximum flow velocity around the structure is found as 3.1 m/s which lies within safe limit. The revetment is tested with 50% launching apron to optimise its length. But the test revealed that the launching apron was not adequate to withstand against possible scour.

**Wave model tests**

In the model, both ebb tide and flood tide conditions were investigated. Maximum erosion takes place during ebb tide because water flows from upstream to downstream with extreme velocity. The flood/ebb ratios are generally higher in the model than in the prototype because of some oscillations were expected in the model.

The periodic incoming waves were generated by an electrically driven flat wave board on the either side of the protective works at a distance of 7.0 m in the model which equals 280 m in prototype from the right bank at Nasirmajhi. Only a critical portion of the revetment at Kalikirti was reproduced in the model to investigate the stability of proposed C.C. blocks. The location was selected based on the extreme severity with respect to wave actions on the embankment slope experienced in the field and the distance between the wave flap and the revetment was chosen to accommodate four numbers of wave length per cycle for getting better wave actions.

The model was operated in flowing condition with wave generated from the sea side. Total six tidal cycles consists of three ebb tide and three flood tide were introduced in the model according to calculated wave parameters. The average time period for each tidal cycle in the model was 6 hour 13 minutes. Time period 10 sec was adjusted in the model. Model waves are monochromatic and do not reproduce the variable condition of nature. But, nevertheless, these were compatible to the prototype irregular wave trains.

Simulated C.C. blocks were placed on both slope and launching apron. Waves were generated from the either side of the revetment and blocks were kept expose to wave attack. The model was operated for about 6 hrs and displacement of blocks were counted. Blocks were tested for various slopes and designs and the results were compared with each other. It may be noted that for first series, three layers of blocks were placed on slope and five layers as a launching apron for toe protection. In all the tests, launching apron remains intact, only displacement occurred at the slope. The tests revealed that slope 1:2 is unstable. Also slopes 1:3 and 1:4 did not show a good result. Therefore, the designer modified the design where one layer blocks were used on slope instead of three and three layers on the launching apron instead of five. Blocks were then tested with slopes 1:2 and 1:3. The result was found better for 1:3 than 1:2. Hence, the slope 1:3 was taken as first option but the blocks must be interlocked. For getting optimum results from the wave study, the designer then refined the design for slope 1:3 providing vertical filter drains at 5 m apart with a view to allow no or little displacement of blocks. The revetment was tested with the new design and the outcome of the test appeared that the revetment is stable against waves which was taken as second option. Geotextile filters were used beneath the blocks in both options to prevent hydraulic failure. From the analysis of results for both investigations, these two alternative options were recommended for implementation.

**Stability of C.C. blocks under wave action**

Damages are invariably done on the point of wave breaking. The most important factor which does influence stability of blocks on slope is wave breaking point. Designers can have a choice to shift the breaking point of waves by varying the slopes. It is desirable that the wave breaks on the berm and this is why curved face sea walls with little or no slopes are practiced to ward off damages against severe eroding forces. The breaking point is an intermediate point in the breaking process between the first stages of the instability and the area of complete breaking. Headar(1965) suggested that the breaking process extends over a distance equal to half the shallow wave length. In practice C.C. blocks are also used on the slopes against severe wave actions but blocks must be interlocked such that blocks can withstand in the face of severe wave attack. Allowance for relief of hydrostatic uplift pressure generated by wave action should be kept by Geotextile filters along with gravel filtering and open asphalt grouting at the top. The stability of blocks largely depend on:

- Foundation condition
- Exposure to wave actions
- Weight of C.C. blocks
- Wave breaking point

Empirical formula was developed by Pilarezyk(1990) for the calculation of the specific size or the thickness of protection units exposed to wave attack:

$$D \geq (H_s.\xi^b)/(\Delta m.\psi_u.\Phi.\cos\alpha)$$

Where,

$D=$ thickness of protection unit,m

$H_s=$ significant wave height,m

$\Delta m=$ relative density of a system unit

$\Phi=$ stability factor

$\psi_u=$ system determined stability upgrading factor=1.0

$\alpha=$ slope angle in degree

$\xi=$ breaker similarity index $=\tan\alpha[H_s/L_0]^{0.5} = 1.25.T_s.\tan\alpha/\sqrt{(H_s)}$

$L_0$= wave length,m = $gT^2/2\pi$
$T_s$= average wave period
b= an exponent=0.5-1.0

Calculation shows that $\phi$=4.48 which lies within the acceptable limit of 1.9 to 5.3.

Alternatively, Hudson (1953, 59, 61a and 61b) carried out extensive research based on model test to determine the stability of blocks and developed the following formula:

$W=W_r.H^3/[K_D(S_r-1)^3\cot\theta]$

Where,

W= Weight in Newton
$W_r$= Unit weight in $Kg/m^3$
H= Wave height at the structure, m
$S_r$= Sp. gr. of C.C. blocks
$\theta$= angle of structure
$K_D$= Stability co-efficient

Hence, Stability Number, $N_s= (K_D\cot\theta)^{1/3}$

Blocks are found stable also satisfying the stability criteria according to this approach.

**Conclusions**

Coastal structures must be designed to satisfy the criteria such as, structural stability, functional performance, environmental impact, life-cycle cost and other constraints which add challenge to the designer's task. Structural stability criteria are most often stated in terms of the extreme conditions which a coastal structure must survive without sustaining significant damage. Only structural stability were investigated in the present study.

In practice, vertical, curved-face, stepped-face and sloping face seawall, revetments, bulkheads, breakwaters etc. are used for coastal protection. Of them, the stability of revetment in the form of C.C. blocks were examined through model tests. As far as revetment was concerned, comparisons between different types of structures were not made but alternate design of revetment works were evaluated and compared with each other. Based on these comparisons, two alternatives were recommended. It may be concluded that C.C. blocks in the form of revetment for certain slopes were stable against waves and currents and can effectively be used for coastal bank protection like other hard materials. The stability can only be verified by physical model tests.

The model was not run with variable flood hydrographs and simultaneous wave propagation due to limitations of physical model. However, the model was operated for steady uniform flow and the results may have affected a little. This limitation can not be avoided.

**Acknowledgement**

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# A Study of Engineering Aspects of Soils of the Polder Areas of Bangladesh and Finding out Some Correlations with Shear Strength and Some Index Properties

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**Abstract**

*This paper describes the engineering properties of soils for the polder areas of Bangladesh. Also some correlations between shear strength and index properties of soils of those polder areas have been established. It is found that shear strength decreases with the increase of natural water content and liquidity index, whereas shear strength increases with the decrease of compression index. The relationships may be helpful for designing any structures within respective polder areas.*

**Introduction**

Bangladesh is a land of rivers and all of the rivers flows into the Bay-of-Bengal. Due to erosion and sediment deposition almost every year one side destroy of the river and another side create. So, many lands reclaimed in this respective areas. In this regard, different projects like coastal embankment rehabilitation project, land reclamation projects and different number of polder projects is undertaken every year for development of polder areas.

The embankments around the polders prevented tidal flooding and salt intrusion. Drainage sluices construct in the embankments to drain the run-off from local rainfall by gravity on surrounding tidal rivers. So, for overall development of polder areas, the aforesaid projects is undertaken.

In the development projects,different types of construction of structure is to be built. Since all the construction of structure is to be built on soils, in that case soil properties is an important aspects of construction of structure. One of the most controversial engineering properties of soils is its shear strength. In this goal, this study has been made and some correlation have been established with shear strength and index properties of soils of different polder projects of Bangladesh which will help to compare the results of other construction of structure of same areas.

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**Geological Background**

The landform of Bangaldesh is constituted by the alluvial deposit of sediment that has been transported from the Himalayan and sub-Himalayan region to its present location by water and deposited in a wide range throughout the areas of Bangladesh. The main streams of rivers which still carrying on this process, are the Ganges, the Brahmaputra, Meghna, Teesta. Gumti etc. As the soils of Bangladesh comprised of alluvial deposit varying from gravel to fine grained soil material, the stratified arrangement of soil materials mainly depends on the fluctuation of the stream velocity. Thus in the upper region of Bangladesh the soil is a mixture of coarse and fine grained soils like boulders, gravels, sand, silt and clay and in the lower region is obviously a deposit of fine grained soils like sand, silt and clay. In the western region of the country the soils mainly consists of sand, silt and clay deposits.

**Engineering Properties of Soils**

Soils of different polder areas of Bangladesh are tested and analysed in Soil Mechanics Division under Geotechnical Research Directorate of River Research Institute, Faridpur. Various engineering properties of soils of Patuakhali, Bogra, Chittagong and Cox's Bazar polder areas are presented in Table 1. Location of these polder areas are shown in Figure A.

It is found from the study that the types of soil of the polder areas are $c$-$\phi$ soil. The shear strength has been calculated by Mohr-Coulomb equation as follows:

$$S = c + 6\tan\phi$$

Where, $S$ = Shear strength expressed in $kN/m^2$

$c$ = Cohesion expressed $kN/m^2$

$6$ = Effective normal stress expressed in $kN/m^2$

$\phi$ = Angle of internal friction expressed in degree

The values of 6 is to be taken from the respective soil testing reports of polder areas done by River Research Institute (RRI).

The liquidity index $I_L$ has been calculated from equation

$$I_L = N.W.C.\text{-}LL/PI$$

Where, $I_L$ = Liquidity index expressed in (%)

N.W.C. = Natural water content expressed in (%)

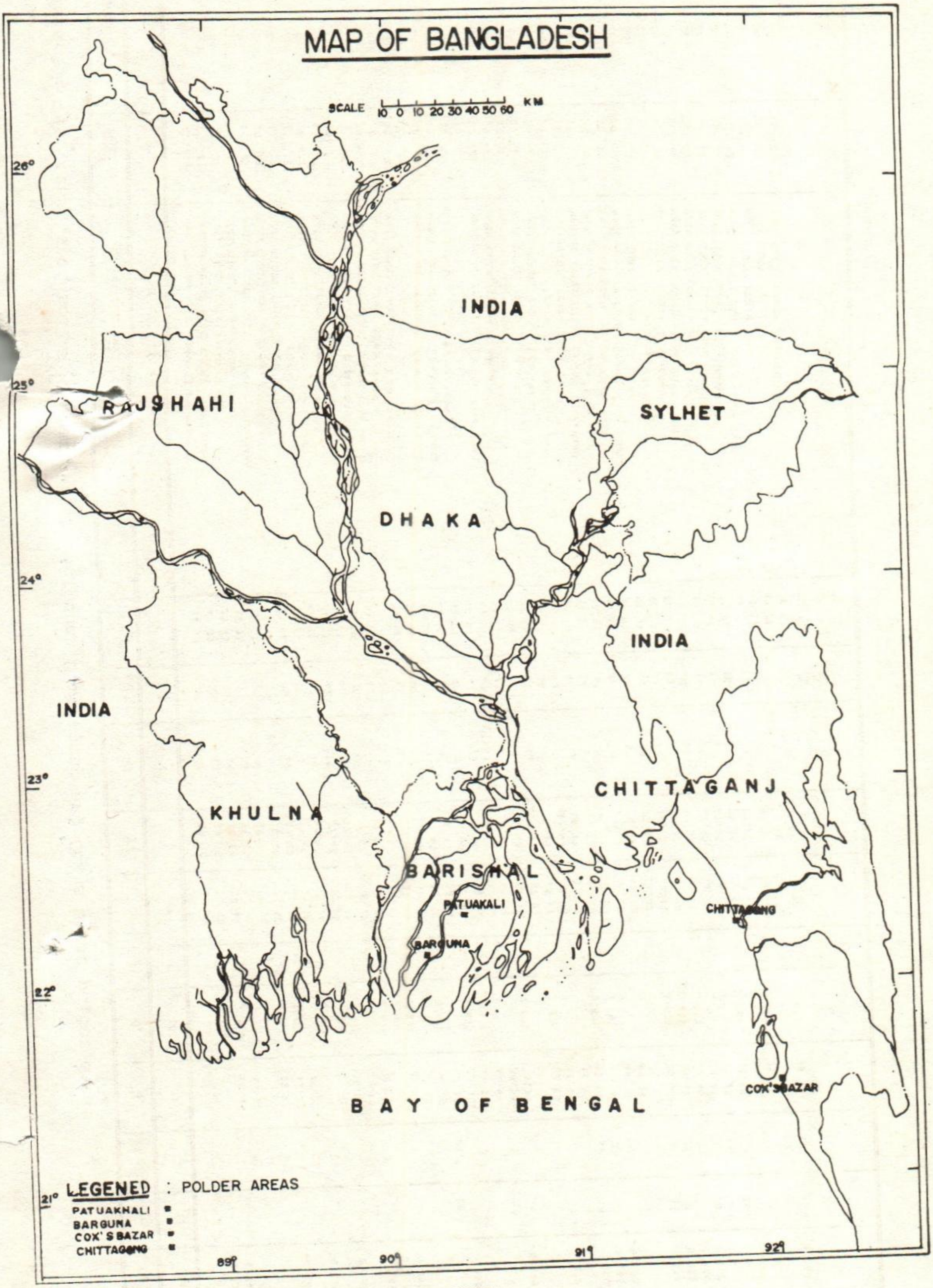


FIG. A : LOCATION OF POLDER AREAS IN BANGLADESH

Table-1 : Test results of soils of Patuakhali, Borguna, Chittagong and Cox's Bazar polder areas

| Polder | Depth | Classification | N.W.C. | LL | PI | $\gamma_w$ | $\gamma_d$ | $I_g$ | $G_s$ | $q_u$ | Q | c | $C_c$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1. Patuakhali | 20'-22' | Very loose SILT, some fine sand | 34.77 | N | P | 18.79 | 13.93 | - | - | - | 27 | -2 | - |
| 2. -DO- | 20'-22' | Medium stiff SILT, trace fine sand | 42.82 | 39 | 12 | 18.10 | 12.68 | - | 2.675 | - | - | - | 0.237 |
| 3. -Do- | 20'-22' | Soft Silt, trace fine sand | 38.43 | 41 | 14 | 16.84 | 12.16 | - | 2.674 | 68.46 | - | - | 0.248 |
| 4. -Do- | 20'-22' | Soft SILT, trace fine sand | 35.81 | 39 | 13 | 15.49 | 11.52 | - | - | 44.30 | 22 | 8 | - |
| 5. -Do- | 25'-27' | Medium stiff SILT, trace fine sand | 35.01 | 35 | 9 | 19.00 | 14.08 | - | - | - | - | - | - |
| 6. -Do- | 20'-22' | Soft SILT, trace fine sand | 29.52 | 37 | 9 | 18.18 | 14.42 | - | - | 62.82 | - | - | - |
| 7. -Do- | 15'-17' | Soft SILT, trace fine sand | 3[illegible].33 | 42 | 14 | 17.22 | 12.77 | - | 2.671 | 40.22 | - | - | 0.220 |
| 8. -Do- | 15'-17' | Loose SILT, little fine sand | 32.81 | N | P | 17.65 | 13.19 | - | - | 26.90 | 22 | 7 | - |
| 9. -Do- | 20'-22' | Very soft CLAY, trace fine sand | 44.82 | 46 | 20 | 17.73 | 12.24 | - | 2.675 | - | - | - | 0.201 |
| 10. -Do- | 15'-17' | Soft CLAY, trace fine sand | 38.33 | 42 | 17 | 17.43 | 12.58 | - | - | 13.65 | - | - | - |
| 11. -Do- | 20'-22' | Soft CLAY, trace fine sand | 37.43 | 43 | 19 | 17.93 | 13.03 | - | 2.675 | 36.66 | - | - | 0.202 |
| 12. -Do- | 25'-27' | Loose SILT, little fine sand | 24.08 | N | P | 18.95 | 15.27 | - | - | 31.96 | 30.5 | 3 | - |
| 13. -Do- | 20'-22' | Medium stiff CLAY, trace fine sand | 33.00 | 42 | 17 | 15.42 | 12.04 | - | 2.678 | - | 12 | 3 | 0.265 |
| 14. -Do- | 20'-22' | Soft SILT, trace fine sand | - | 41 | 14 | 17.57 | 12.61 | - | 2.672 | - | - | - | 0.303 |
| 15. -Do- | 15'-17' | Very soft CLAY, trace fine sand | 37.16 | 41 | 20 | 17.36 | 12.69 | - | 2.674 | 41.43 | - | - | 0.290 |
| 16. -Do- | 30'-32' | -Do- | 34.85 | 40 | 18 | 17.26 | 12.80 | - | - | 22.11 | - | - | - |
| 17. -Do- | 20'-22' | Medium stiff CLAY, trace fine sand | 34.11 | 42 | 17 | 17.67 | 13.17 | - | 2.676 | 35.29 | - | - | 0.160 |
| 18. -Do- | 15'-17' | Medium stiff SILT, trace fine sand | 29.90 | 36 | 8 | 16.41 | 12.64 | - | - | 62.16 | 26.5 | 25.5 | - |
| 19. -Do- | 20'-22 | Stiff SILT, trace fine sand | 40.99 | 40 | 11 | 16.99 | 12.43 | - | 2.670 | 53.30 | - | - | 0.310 |
| 20. -Do- | 10'-12' | -DO- | 40.94 | 42 | 13 | 17.77 | 12.61 | - | - | 49.75 | - | - | - |
| 21. -Do- | 10'-12' | Medium stiff CLAY, trace fine sand | 44.54 | 47 | 21 | 16.62 | 11.50 | - | - | 61.84 | - | - | - |
| 22. -DO- | 20'-22' | Soft CLAY, trace fine sand | 39.29 | 45 | 19 | 17.47 | 12.54 | - | - | 34.55 | 8 | 10 | - |
| 23. -Do- | 15'-17' | Medium SILT, trace fine sand | 40.63 | 35 | 8 | 17.13 | 12.79 | - | 2.672 | 73.38 | - | - | 0.215 |
| 24. -Do- | 25'-27' | Soft SILT, trace fine sand | 39.06 | 42 | 13 | 17.92 | 12.89 | - | - | 20.97 | - | - | - |
| 25. -Do- | 20'-22' | Stiff SILT, trace fine sand | 31.29 | 36 | 9 | 17.70 | 13.48 | - | 2.670 | 53.83 | - | - | - |
| 26. -Do- | 20'-22' | Soft CLAY, trace fine sand | 41.43 | 42 | 20 | 17.03 | 12.04 | - | - | 32.15 | 11 | 17 | 0.172 |
| 27. -Do- | 15'-17' | Soft SILT, trace fine sand | 40.72 | 40 | 12 | 16.77 | 11.92 | - | - | 38.39 | - | - | - |
| 28. -Do- | 15'-17' | Medium stiff SILT, trace fine sand | 34.27 | 36 | 9 | 18.75 | 13.97 | - | 2.670 | 53.83 | 33 | 10 | 0.260 |
| 29. -Do- | 20'-22' | Medium dense SILT, some fine sand | 25.32 | N | P | 18.71 | 12.93 | - | 2.669 | - | 27 | 10 | 0.146 |
| 30. -Do- | 20'-22' | Very soft CLAY, trace fine sand | 40.50 | 45 | 19 | 17.17 | 12.19 | - | 2.676 | 16.28 | - | - | 0.308 |
| 31. -Do- | 30'-32' | Medium stiff CLAY, trace fine sand | 29.83 | 41 | 17 | 18.38 | 14.12 | - | - | 80.24 | - | - | - |
| 32. -Do- | 20'-22' | Soft CLAY, trace fine sand | 41.64 | 44 | 19 | 18.04 | 14.02 | - | - | - | - | - | - |
| 33. -Do- | 15'-17' | Soft CLAY, trace fine sand | 41.39 | 53 | 26 | 17.55 | 12.41 | - | 2.676 | 25.41 | 6 | 15 | 0.334 |
| 34. -Do- | 15'-17' | Soft CLAY, trace fine sand | 35.11 | 43 | 19 | 18.32 | 13.56 | - | 2.639 | 36.29 | 13 | 15 | 0.229 |
| 35. -Do- | 20'-22' | Very soft CLAY, trace fine sand | 39.89 | 46 | 20 | 17.36 | 12.41 | - | 2.685 | 10.46 | 3 | 7 | 0.210 |
| 36. -Do- | 25'-27' | Soft CLAY, trace fine sand | 38.79 | 41 | 16 | 17.65 | 12.72 | - | 2.70 | 27.48 | 2 | 20 | 0.267 |
| 37. -Do- | 40'-42' | Soft CLAY, trace fine sand | 36.45 | 39 | 16 | 17.85 | 13.08 | - | - | 27.20 | - | - | - |
| 38. -Do- | 30'-32' | Soft CLAY, trace fine sand | 37.68 | 46 | 20 | 17.25 | 12.53 | - | 2.684 | 29.69 | 1.5 | 28 | 0.205 |
| 39. -Do- | 10'-12' | Medium stiff CLAY, trace fine sand | 37.74 | 40 | 16 | 17.22 | 12.50 | - | 2.660 | 57.74 | - | - | 0.367 |
| 40. -Do- | 15'-17' | Soft CLAY, trace fine sand | 43.38 | 45 | 20 | 17.82 | 12.43 | - | 2.667 | 25.15 | - | - | 0.305 |
| 41. -Do- | 20'-22' | FINE SAND, trace silt | 37.38 | N | P | 17.78 | 12.96 | - | - | - | 29 | 8 | - |
| 42. -Do- | 15'-17' | Soft SILT, trace fine sand | 38.77 | 40 | 12 | 17.60 | 12.69 | - | 2.670 | 25.39 | 10 | 32 | 0.260 |

Table-1 (Continued):

| Polder | Depth | Classification | N.W.C. | LL | PI | $\gamma_w$ | $\gamma_d$ | $I_g$ | $G_s$ | $q_u$ | Q | c | $C_c$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 43. Patuakhali | 20'-22' | Soft SILT,trace fine sand | 34.12 | 36 | 11 | 18.72 | 13.96 | - | - | 42.37 | 22 | 14 | - |
| 44. -DO_ | 15'-17' | Soft CLAY,trace fine sand | 35.62 | 46 | 20 | 18.82 | 13.87 | - | 2.678 | 41.80 | 8 | 28 | 0.293 |
| 45. -Do- | 20'-22' | Soft CLAY,trace fine sand | 40.97 | 43 | 19 | 17.86 | 12.67 | - | 2.680 | 30.37 | 3 | 15 | 0.321 |
| 46. -Do- | 15'-17' | Soft SILT, little fine sand | 34.13 | 33 | 9 | 18.71 | 13.95 | - | 2.667 | 24.71 | 22 | 11.5 | 0.290 |
| 47. -Do- | 15'-17' | Soft SILT, little fine sand | 35.01 | 39 | 12 | 18.74 | 13.88 | - | 2.672 | 31.50 | 32.5 | 14 | 0.194 |
| 48. -Do- | 15'-17' | Soft CLAY,trace fine sand | 42.39 | 50 | 24 | 16.43 | 11.54 | - | 2.674 | 28 | 25.5 | 16 | 0.407 |
| 49. -Do- | 15'-17' | Loose SILT, trace fine sand | 33.81 | N | P | 17.65 | 13.19 | - | 2.671 | - | 22 | 7 | 0.245 |
| 50. -Do- | 15'-17' | Medium stiff CLAY, trace fine sand | 35.40 | 40 | 18 | 17.40 | 12.85 | - | - | 71.58 | - | - | - |
| 51. -Do- | 20'-22' | Very soft CLAY, trace fine sand | 44.82 | 46 | 20 | 17.73 | 12.24 | - | 2.675 | 13.65 | - | - | 0.291 |
| 52. -Do- | 15'-17' | Soft CLAY,trace fine sand | 38.88 | 42 | 17 | 17.47 | 12.58 | - | - | 36.66 | - | - | - |
| 53. -Do- | 20'-22' | Soft CLAY, trace fine sand | 37.43 | 43 | 19 | 17.93 | 13.03 | - | 2.675 | 31.96 | - | - | 0.202 |
| 54. -Do- | 25'-27' | Loose SILT, little fine sand | 24.09 | N | P | 18.95 | 15.27 | - | - | 30.5 | 3 | 20- | - |
| 55. -Do- | 20'-22' | Medium stiff CLAY,trace fine sand | 28.14 | 42 | 17 | 15.42 | 12.04 | - | 2.678 | - | 12 | 21 | 0.265 |
| 56. -Do- | 20'-22' | Soft SILT,trace fine sand | 39.32 | 41 | 14 | 17.57 | 12.61 | - | 2.672 | 41.43 | - | - | 0.303 |
| 57. -Do- | 20'-22' | Medium stiff CLAY,trace fine sand | 32.08 | 43 | 19 | 17.25 | 12.98 | - | 2.676 | 67.07 | - | - | 0.325 |
| 58. -Do- | 20'-22' | Very soft CLAY, trace fine sand | 38.54 | 44 | 18 | 18.06 | 13.45 | - | 2.670 | 22.44 | - | - | 0.265 |
| 59. -Do- | 20'-22' | Soft CLAY, trace fine sand | 39.46 | 45 | 20 | 17.70 | 12.69 | - | 2.668 | 19.76 | - | - | 0.240 |
| 60. Borguna | 20'-22' | Stiff CLAY, trace fine sand | 30.95 | 48 | 24 | 18.89 | 14.42 | - | - | 134.10 | - | - | - |
| 61. -Do- | 20'-22' | Soft CLAY,trace fine sand | 37.12 | 38 | 14 | 17.39 | 12.67 | - | 2.672 | 35.50 | 5 | 29 | 0.285 |
| 62. -Do- | 20'-22' | Stiff SILT, trace fine sand | 23.40 | 37 | 10 | 17.86 | 14.25 | - | 2.674 | 128.34 | - | - | 0.215 |
| 63. -Do- | 20'-22' | Soft CLAY, trace fine sand | 40.08 | 40 | 17 | 17.24 | 12.30 | - | 2.673 | 28.87 | 3 | 48 | 0.330 |
| 64. -D0- | 20'-22' | Soft SILT, little fine sand | 37.20 | 38 | 13 | 19.32 | 13.40 | - | - | 36.84 | - | - | - |
| 65. -Do- | 15'-17' | Stiff CLAY,trace fine sand | 30.64 | 45 | 19 | 19.62 | 15.02 | - | 2.675 | - | 7 | 72 | 0.162 |
| 66. -Do- | 20'-22' | Soft SILT, trace fine sand | 32.80 | 38 | 12 | 17.67 | 13.06 | - | 2.671 | 25.66 | 19 | 16 | 0.210 |
| 67. -Do- | 20'-22' | Soft SILT, trace fine sand | 36.19 | 39 | 12 | 17.83 | 13.09 | - | 2.672 | 35.29 | 25 | 40 | 0.290 |
| 68. -Do- | 15'-17' | Soft SILT, little fine sand | 36.43 | 41 | 14 | 17.91 | 13.13 | - | 2.678 | 22.97 | 4 | 13 | 0.258 |
| 69. -Do- | 30'-32' | Soft CLAY, little fine sand | 35.94 | 45 | 20 | 18.08 | 13.30 | - | - | 29.32 | - | - | - |
| 70. -Do- | 20'-22' | Soft CLAY, trace fine sand | 45.00 | 49 | 23 | 17.21 | 11.87 | - | 2.679 | 25.79 | 2 | 26 | 0.330 |
| 71. -Do- | 30'-32' | Soft CLAY, little fine sand | 41.14 | 42 | 22 | 17.92 | 12.70 | - | - | 30.00 | - | - | - |
| 72. -Do- | 25'-27' | Soft to medium stiff CLAY, trace fine sand | 39.00 | 45 | 22 | 18.00 | 12.93 | - | 2.675 | 33.89 | 2 | 26 | 0.324 |
| 73. -Do- | 10'-12' | -Do- | 44.20 | 47 | 21 | 18.05 | 12.02 | - | 2.670 | 32.75 | 7 | 28 | 0.296 |
| 74. -Do- | 20'-22' | Very soft CLAY, trace fine sand | 44.34 | 46 | 21 | 17.43 | 12.10 | - | 2.675 | 12.10 | 2 | 6 | 0.333 |
| 75. -Do- | 15'-17' | Very soft CLAY, trace fine sand | 43.57 | 48 | 19 | 17.52 | 12.20 | - | 2.675 | 12.20 | 3 | 7 | 0.317 |
| 76. -Do- | 30'-32' | Medium stiff CLAY, trace fine sand | 38.35 | 50 | 23 | 18.89 | 13.65 | - | - | 78.50 | - | - | - |
| 77. -Do- | 15'-17' | Very soft to medium stiff SILT, trace fine sand | 42.04 | 45 | 17 | 18.26 | 12.68 | - | 2.677 | 52.43 | 4 | 11 | 0.257 |
| 78. -Do- | 25'-27' | Medium stiff CLAY, trace fine sand | 46.55 | 46 | 20 | 16.39 | 11.43 | - | 2.676 | 71.76 | 5 | 40 | 0.437 |
| 79. -Do- | 20'-22' | Soft to medium stiff CLAY, trace fine sand | 43.26 | 47 | 22 | 17.79 | 12.42 | - | 2.676 | 42.56 | 5 | 25 | 0.375 |
| 80. -Do- | 30'-32' | Soft CLAY, some fine sand | 36.87 | 43 | 18 | 18.18 | 13.28 | - | - | 29.55 | - | - | - |
| 81. -Do- | 15'-17' | Medium stiff SILT, trace fine sand | 42.09 | 42 | 14 | 17.47 | 12.30 | - | - | 51.78 | - | - | - |
| 82. -Do- | 20'-22' | -Do | 38.14 | 38 | 8 | 17.66 | 12.78 | - | 2.670 | 24.16 | 4 | 23 | 0.275 |
| 83. -Do- | 15'-17' | Very soft CLAY,trace fine sand | 41.04 | 40 | 20 | 17.67 | 12.53 | - | 2.675 | 17.86 | 1 | 17 | 0.310 |
| 84. -Do- | 30'-32' | Soft CLAY, trace fine sand | 41.97 | 43 | 21 | 17.82 | 12.55 | - | - | 24.70 | - | - | - |

Table-1 (Continued) :

| Polder | Depth | Classification | N.W.C. | LL | PI | $\gamma_w$ | $\gamma_d$ | $I_g$ | $G_s$ | $q_u$ | Q | c | $C_c$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 85. Borguna | 16'-18' | Very soft CLAY,trace fine sand | 45.78 | 49 | 24 | 18.59 | 12.75 | - | 2.681 | 18.14 | 6 | 13 | 0.258 |
| 86. -D0- | 26'-29' | Very soft CLAY,trace fine sand | 43.70 | 48 | 23 | 17.63 | 12.27 | - | 2.679 | 14.31 | 2.5 | 16 | 0.378 |
| 87. -Do- | 15'-17' | Very soft to soft SILT,trace fine sand | 42.86 | 45 | 17 | 17.70 | 12.39 | - | 2.676 | 36.28 | 5 | 8 | 0.375 |
| 88. -Do- | 20'-22' | Very soft to soft SILT, trace fine sand | 37.84 | 40 | 13 | 18.52 | 13.54 | - | 2.667 | 40.87 | 7 | 7 | 0.192 |
| 89. -Do- | 20'-22' | Medium stiff CLAY, trace fine sand | 32.25 | 43 | 18 | 18.75 | 14.18 | - | 2.671 | 81.04 | 6 | 474 | 0.252 |
| 90. -Do- | 15'-17' | Very soft CLAY,trace fine sand | 38.38 | 45 | 19 | 17.79 | 12.64 | - | - | 23.81 | - | - | - |
| 91. -Do- | 15'-17' | Soft CLAY, trace fine sand | 39.77 | 40 | 16 | 16.95 | 12.10 | - | 2.675 | 35.86 | 3.5 | 32 | 0.280 |
| 92. -Do- | 20'-22' | Very soft SILT, trace fine sand | 40.62 | 45 | 16 | 18.27 | 12.99 | - | 2.670 | 22.50 | 22 | 13 | 0.350 |
| 93. -Do- | 20'-22' | Soft SILT, trace fine sand | 39.37 | 45 | 17 | 17.86 | 12.81 | - | 2.670 | 41.66 | 31 | 21 | 0.245 |
| 94. -Do- | 20'-22 | Medium stiff SILT,trace fine sand | 33.06 | 39 | 13 | 16.61 | 12.48 | - | 2.671 | - | 31 | 20 | 0.266 |
| 95. -Do- | 20'-22' | Soft CLAY, trace fine sand | 45.80 | 44 | 18 | 17.74 | 13.33 | - | 2.675 | 34.10 | - | - | 0.368 |
| 96. -Do- | 20'-22' | Very stiff SILT, trace fine sand | 35.15 | 37 | 10 | 18.53 | 13.81 | - | 2.670 | 67.85 | - | - | 0.370 |
| 97. -Do- | 15'-17' | Soft CLAY,trace fine sand | 40.83 | 46 | 20 | 17.28 | 12.27 | - | 2.676 | 28.62- | 2 | 19.9 | 0.242 |
| 98. -Do- | 10'-12' | Medium stiff CLAY,trace fine sand | 33.20 | 45 | 19 | 17.57 | 13.19 | - | - | 69.10 | - | - | - |
| 99. -Do- | 15'-17' | Medium stiff CLAY,trace fine sand | 35.78 | 47 | 17 | 17.86 | 12.81 | - | 2.670 | 41.66 | 31 | 21 | 0.245 |
| 100. -Do- | 20'-22' | Medium stiff SILT, little fine sand | 37.54 | 42 | 20 | 17.14 | 12.60 | - | 2.675 | 55.86 | 5 | 30 | 0.285 |
| 101. -Do- | 25'-27' | Stiff CLAY, trace fine sand | 33.32 | 34 | 8 | 17.86 | 12.98 | - | 2.668 | 55.00 | 13 | 45 | 0.225 |
| 102. -Do- | 25'-27' | Soft SILT, trace fine sand | 32.28 | 43 | 14 | 17.80 | 12.43 | - | 2.672 | 28.24 | 26 | 8 | 0.271 |
| 103. -Do- | 15'-17' | Soft SILT,trace fine sand | 43.19 | 45 | 20 | 17.88 | 12.24 | - | - | 42.57 | 26 | 3 | - |
| 104. -Do- | 15'-17' | Soft CLAY, trace fine sand | 40.73 | N | P | 18.13 | 14.82 | - | 2.665 | 39.99 | 3 | 18 | 0.312 |
| 105. -Do- | 20'-22' | Medium dense SILT and CLAY | 22.29 | 42 | 18 | 18.62 | 14.02 | - | 2.676 | - | 35 | 17 | 0.110 |
| 106. -D0- | 15'-17' | Stiff CLAY, trace fine sand | 32.86 | 42 | 18 | 18.62 | 14.02 | - | 2.676 | 95.80 | - | - | 0.0.210 |
| 107. -Do- | 10'-12' | Stiff CLAY,trace fine sand | 33.86 | 42 | 19 | 19.62 | 15.02 | - | 2.675 | 98.44 | - | - | 0.210 |
| 107. -Do- | 10'-12' | Medium stiff CLAY, trace fine sand | 53.06 | 70 | 37 | 16.02 | 10.47 | - | 2.672 | 70.56 | 3 | 46 | 0.575 |
| 108. Chittagong | 15'-17' | Soft CLAY, trace fine sand | 35.11 | 43 | 19 | 18.32 | 13.56 | - | 2.639 | 36.29 | 13 | 15 | 0.229 |
| 109. -D0- | 20'-22' | Very soft CLAY, little fine sand | 39.89 | 46 | 20 | 17.36 | 12.41 | - | 2.685 | 10.46 | 3 | 7 | 0.210 |
| 110. -D0- | 25'-27' | Soft CLAY, trace fine sand | 38.79 | 41 | 16 | 17.65 | 12.27 | - | 2.70 | 27.48 | 2 | 20 | 0.267 |
| 111. -D0- | 40'-42' | Soft CLAY, trace fine sand | 36.45 | 39 | 16 | 17.85 | 13.08 | - | - | 27.20 | - | - | - |
| 112. -Do- | 30'-32' | Soft CLAY, little fine sand | 37.68 | 46 | 20 | 17.25 | 12.53 | - | 2.684 | 29.69 | 1.5 | 28 | 0.205 |
| 113.Cox's Bazar | 35'-37' | Soft CLAY, trace fine sand | 45.24 | 47 | 20 | 17.94 | 12.35 | - | 2.676 | 26.66 | 1.5 | 18 | 0.390 |
| 114. -Do- | 30'-32' | -Do- | 41.63 | 47 | 22 | 16.90 | 11.93 | - | - | 31.75 | - | - | - |
| 115. -Do- | 40'-42' | Soft CLAY, trace fine sand | 46.75 | 48 | 21 | 16.75 | 11.40 | - | - | 42.86 | - | - | - |
| 116. -Do- | 20'-22' | Soft CLAY AND FINE SAND, trace organic matter | 36.49 | 43 | 17 | 17.33 | 12.70 | - | 2.674 | 23.61 | 2 | 24.5 | 0.291 |
| 117. -Do- | 15'-17' | Very soft CLAY,trace fine sandand organic | 44.13 | 57 | 27 | 17.08 | 11.85 | - | - | 15.30 | - | - | - |
| 118. -Do- | 10'-12' | Very soft CLAY, trace fine sand and organic | 50.42 | 61 | 32 | 16.38 | 10.84 | - | 2.658 | 31.41 | 3 | 9 | 0.364 |
| 119. -Do- | 13'-15' | Soft CLAY, some fine sand,trace organic | 38.87 | 47 | 24 | 16.50 | 11.90 | - | 2.672 | 31.81 | 5 | 81 | 0.375 |
| 120. -Do- | 18'-20' | Medium stiff CLAY, some fine sand,trace organic | 41.33 | 47 | 21 | 17.51 | 12.39 | - | 2.674 | 55.92 | 6 | 92 | 0.295 |
| 121. -Do- | 18'-20' | Soft CLAY, some fine sand | 35.37 | 42 | 20 | 18.02 | 13.31 | - | - | 45.62 | - | - | - |
| 122. -Do- | 05'-07' | Very soft ORGANIC CLAY, litte fine sand | 56.70 | 76 | 37 | 16.32 | 10.41 | - | 2.659 | 20.46 | 8 | 87 | 0.275 |
| 123. -Do- | 21'-00' | Soft CLAY AND FINE SAND,trace medium sand | 28.85 | 32 | 13 | 18.68 | 15.43 | - | - | - | 16 | 2 | - |
| 124. -Do- | 20'-22' | Soft FINE SAND,some medium sand,some clay | 20.50 | 27 | 8 | 20.12 | 16.70 | - | - | - | 20 | 8 | - |
| 125. -Do- | 15'-17' | Soft SILT, trace fine sand | 36.70 | 31 | 11 | 17.79 | 13.01 | - | 2.672 | 27.28 | - | - | 0.210 |
| 126. -Do- | 20'-22' | Very soft to medium stiff SILT,trace fine sand | 38.19 | 40 | 13 | 17.19 | 12.44 | - | 2.672 | 21.38 | 3 | 24 | 0.302 |
| 127. -Do- | 35'-37' | Very soft CLAY, little fine sand | 40.18 | 42 | 19 | 18.08 | 12.90 | - | - | 20.44 | - | - | - |
| 128. -Do- | 40'-42' | Soft CLAY, trace organic trace fine sand | 45.75 | 55 | 26 | 17.40 | 11.95 | - | 2.668 | 25.41 | 8 | 19 | 0.480 |

Notations used in Table -1 :

N.W.C = Natural water content expressed in %

LL = Liquid limit expressed in %

PI = Plasticity index expressed in %

$y_w$ = Wet unit weight expressed in $kN/m^3$

$y_d$ = Dry unit weight expressed in $kN/m^3$

$I_g$ = Loss-on-ignition expressed in %

$G_s$ = Specific gravity

$q_u$ = Unconfined compressive strength expressed in $kN/m^2$

o = Angle of internal friction expressed in degree

c = Cohesion expressed in $kN/m^2$

$C_c$ = Compression index

LL = Liquid limit expressed in (%), PI = Plasticity index expressed in (%)

Relationships are established between different soil parameters using the available data and these are described below:

1. **Shear strength vs. natural water content :**

Correlations are established between shear strength and natural water content of silt and clay soils which shows that shear strength decreases with the increase of natural water content. The relationships are shown in Figure 1 & 2 which can be expressed by the following equations:

S = -6.10 * N.W.C. + 301.08 (For silty soil)

S = -1.03 * N.W.C. + 75.10 (For clayey soil)

2. **Shear strength vs. liquidity index :**

Shear strength and corresponding liquidity index values for different polder areas are collected from the available reports at RRI and shown in Table 2.

The values of shear strength of silt and clay soils of different polder areas are plotted against corresponding liquidity index and shown in Figure 3 & 4. These figures show that shear strength decreases with the increase of liquidity index. These figures yield two equations as follows:

$S = -2.32 * I_L + 260.906$ (For silty soil)

$S = -0.308 * I_L + 54.19$ (For clayey soil)

3. **Compression index vs. shear strength :**

The values of compression index of silty soils of different polder areas are linearly related to shear strength and may be expressed by the following equation:

$C_c = -0.0002 * S + 0.271$

The relationship is graphically presented in Figure 5.

The values of compression index of clayey soils are plotted against shear strength and shown in Figure 6. This figure shows that the compression index is slightly increased with increase in shear strngth. The relationship is expressed in the following form:

$C_c = 0.0001 * S + 0.320$

**Table-2 :** Calculated shear strength (S) and liquidity index ($I_L$) from the respective soil testing reports of River Research Institute(RRI)

| Polder areas | S | $I_L$ |
|---|---|---|
| 1. Patuakhali | 22.15 | 60.08 |
| | 146.65 | 23.75 |
| | 36.35 | 107.15 |
| | 279.32 | 80.77 |
| | 31.31 | - |
| | 32.28 | 58.47 |
| | 8.45 | 69.45 |
| | 21.89 | 85.88 |
| | 29.69 | 58.40 |
| | 20.46 | - |
| | 52.13 | 89.75 |
| | 108.80 | 82.91 |
| | 41.56 | 48.10 |
| | 17.30 | 89.32 |
| | 30.36 | - |
| | 213.63 | 66.75 |
| | 103.53 | 68.29 |
| | 29.97 | - |
| | 25.84 | - |
| | 33.90 | 18.47 |
| 2. Borguna | 15.80 | 67.35 |
| | 28.05 | 82.61 |
| | 28.07 | 72.73 |
| | 37.80 | 86.67 |
| | 6.55 | 92.09 |
| | 8.14 | 76.68 |
| | 15.04 | 82.59 |
| | 49.55 | 103.25 |
| | 32.26 | 83.00 |
| | 28.30 | 100.64 |
| | 17.34 | 86.58 |
| | 17.94 | 81.30 |
| | 10.42 | 87.41 |
| | 12.71 | 83.38 |
| | 62.16 | 112.56 |
| | 37.09 | 92.31 |
| | 71.34 | 72.63 |
| | 149.35 | 61.00 |
| | 192.19 | 53.38 |
| | 221.54 | 54.31 |
| | 21.54 | 74.15 |
| | 37.02 | 43.90 |
| | 85.96 | 56.60 |
| | 29.82 | 78.50 |
| | 8.17 | 101.36 |
| | 20.10 | 78.65 |
| | 296.51 | - |
| | 51.37 | 54.22 |
| 3.Chittagong | 10.41 | 68.88 |
| 4.Cox's Bazar | 21.21 | 66.13 |
| | 29.68 | 73.00 |
| | 10.19 | 47.83 |
| | 29.92 | 75.77 |
| | 28.59 | 18.75 |
| | 27.33 | 86.07 |

These statistical relationships are summerized and shown in Table 3.

**Table-3 :** Soil parameters and statistical relationship of polder soils.

| Soil parameter | Soil | Statistical Relationship |
|---|---|---|
| S vs. N.W.C. | Silt soil of polder areas<br>Clay soil of polder areas | S =-6.10 *N.W.C+301.08, r=0.4<br>s(S)=78.01 s(N.W.C)= 5.14<br>S =-1.03 *N.W.C,+75.11, r=0.3<br>s(S)=21.71 s(N.W.C.)=5.89 |
| S vs. $I_L$ | Silt soil of polder areas<br>Clay soil of polder areas | S =-2.32 *$I_L$ +260.91, r =0.5<br>s(S)=87.55 s($I_L$)=14.23<br>S = -0.31* $I_L$ + 54.19, r=0.2<br>s(S)=21.70 s($I_L$)= 16.99 |
| $C_c$ vs. S | Silt soil of polder areas<br>Clay soil of polder areas | $C_c$ = -0.0002 * S +0.27, r=0.3<br>s($C_c$)=0.06 s(S)=98.84<br>$C_c$ =0.0001 * S + 0.320, r=0.02<br>s($C_c$)=0.090 s(S)=22.08 |

**Notations used in Table-3**

S = shear strength

N.W.C. = Natural water content

$I_L$ =Liquidity index

$C_c$ = Compression index

r = Correlation coefficient

s(S)= Standard deviation of shear strength

s(N.W.C.)= Standard deviation of natural water content

s($I_L$) = Standard deviation of liquidity index

s($C_c$) = Standard deviation of compression index

**Conclusions**

The engineering properties of c-Φ soils of polder areas of Patuakhali, Bogra, Chittagong and Cox's Bazar are analysed and relationships between shear strength versus natural water content, liquidity index and compression index are established. These relationships may be useful to determine any unknown soil parameter knowing other parameters which can be used for designing any small structures within the polder boundaries.

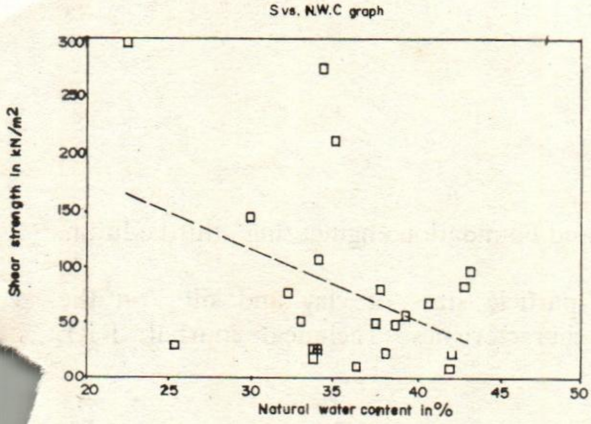


Fig-1 : Relation between shear strengh and natural moisture content of silt soils of polder areas.

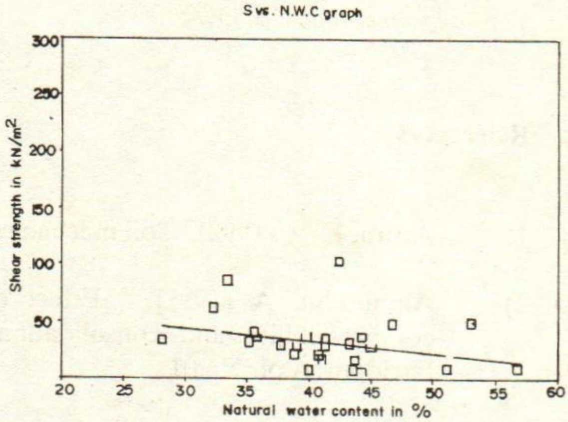


Fig-2 : Relation between shear strenght and natural moisture content of clay soils of polder areas.

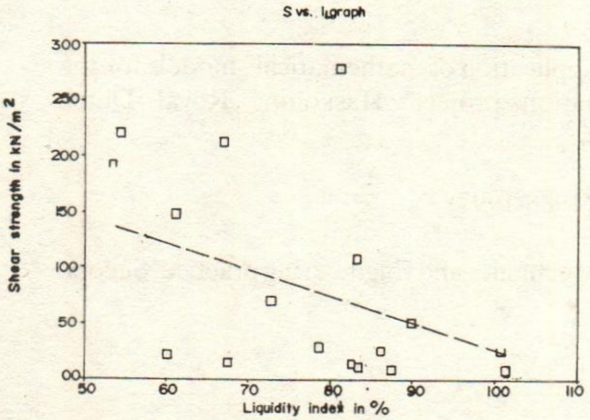


Fig-3 : Relation between shear strength and liquidity index of silt soils of polder areas

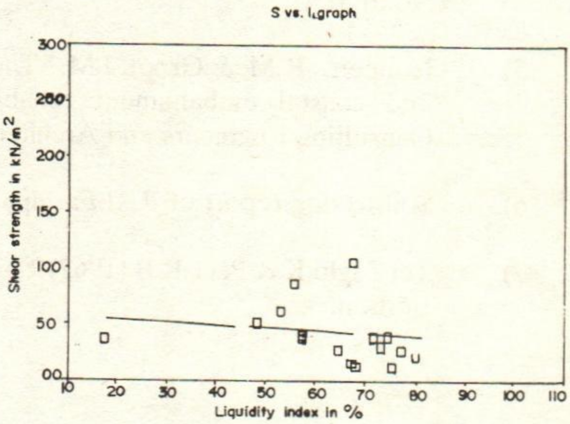


Fig-4 : Relation between shear strength and liqidity index of clay soils of polder areas.

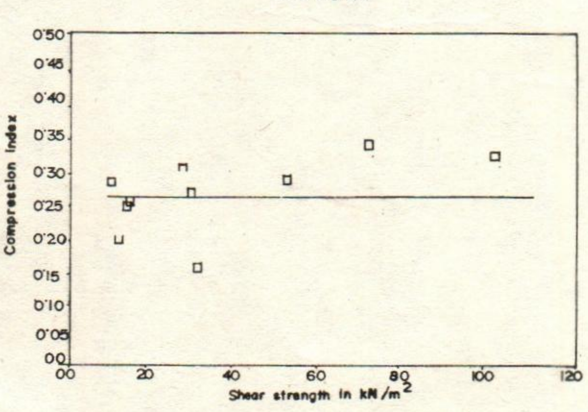


Fig-5 : Relation between compression index and shear strength of silt soils of polder areas.

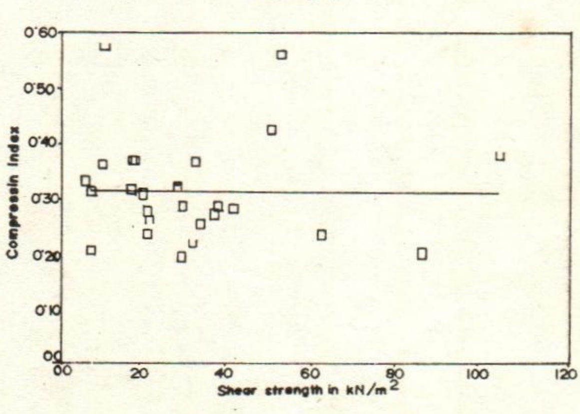


Fig-6 : Relation between compression index and shear strength of clay soils of polder areas.

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# Scale Modelling: a Case Study of Groynes for the Protection of Kazipur Area from the Erosion of Jamuna River

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**Abstract**

*This paper presents the results of scale model investigation for the protection of Kazipur area in the Sirajgonj district from the erosion of Jamuna river. Bangladesh Water Development Board (BWDB) proposed one T-head groyne of length 1650 m for the protection of about 6.5 km area. The behaviour and effectiveness of the proposed T-head groyne was studied and the effective length, location and orientation were optimized by carrying out physical model studies at River Research Institute (RRI). Three numbers of T-head groyne of length 300 m,200 m and 200 m were recommended from technical and economic point of view after extensive studies.*

**Introduction**

Kazipur is situated on the right bank of Jamuna river under Sirajgonj district and located at 25 km upstream of Sirajgonj town. Kazipur thana head quarter is situated just on the eroding right bank of Jamuna river with many permanent installations. Schools, colleges, hospital, godown, post office etc. within the thana head quarter are under threat due to the continuous bank erosion of Jamuna river. This causes unmitigable losses of properties and unbearable sufferings to the people and the continuous bank erosion threatens the whole area to be devoured by the river.

Bank erosion extends from ch.140 km to ch. 146 km covering a river reach of about 6 km. A flood embankment was constructed by BWDB along the right bank to save these areas from the devastation of the Jamuna, but due to the continuous bank erosion, this flood embankment is also under threat and some parts of the embankment have already been washed out.

Fig.1 shows the bank line shifting of Jamuna river at Kazipur from 1985 to 1995, from which one can easily visualize the nature of devastation of bank erosion. Realizing the facts and to save the valuable land and Thana head quarter with installations, BWDB had planned to undertake a project for the protection of that area and decided to construct a T-headed groyne to stop continuous bank erosion of the Jamuna at Kazipur and formally proposed to RRI to carry out a scale model investigation to find out a viable solution. This study is a part of that project.

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**Objectives of the Model Study**

The objectives of the present model study were as follows:

1) To check the effectiveness of the groyne proposed by BWDB

2) To suggest a suitable means to combat erosion at Simla

3) To furnish design parameters such as velocity, scour depths etc. for the finalization of design of the river training works.

**Collection and Assessment of Data for the Model**

Hydrological division of BWDB records both discharge and water level data at Bahadurabad and only water level is measured at Sirajgonj. Bahadurabad is located at 74 km upstream from Kazipur while Sirajgonj is located at 25 km downstream. As per requirement of RRI, Morphological division of BWDB collected river bathymetry and carried out a plain table survey to prepare a index map of the river reach to be modelled. About 4.0 km of the river width was considered during data collection.

Frequency analysis have been carried out to determine the discharges and corresponding water levels and only water levels for different return periods at Bahadurabad and Sirajgonj respectively.The values of discharge and corresponding water level for 100 years return period at Bahadurabad were found as 91,000 cumecs and 21.26 m+PWD respectively and water level at Sirajgonj was found as 14.95 m+PWD.

The average water surface slope of Jamuna is about 7.5 cm/km and thus the water level at Kazipur for 100 years return period is 16.83 m+PWD. In the model, about 3.0 km of the river width was reproduced and the discharge and corresponding water level within this width for 1 in 100 years flood were estimated as 37,000 cumecs and 16.83 m+PWD respectively.

**Design of the Model**

Design of the model is an iterative approach which deals with a lot of possibilities and limitations and leads to the vicinity of an optimum solution. If the model is properly designed and verified, the results obtained from the model study may be transformed easily to prototype and can be used successfully in the field. In the scaling procedure, Froude's model law was used. To meet the requirement of the study, a distorted and an un-distorted sectional model were decided to be constructed in the open air model bed of RRI. To accommodate the model within the model bed and to get sufficient water depth for convenient measurement of velocity, scour etc. a distorted model scale of 1:200 (horizontal) and 1:65 (vertical) and an un-distorted model scale of 1:100 were selected. The characteristic design parameters are shown in Table-1 and the following simulation criteria were verified.

**Table-1: Characteristic design parameters**

| Parameters | Prototype | Scale factor | Model |
|---|---|---|---|
| Length(m) | 6500 | 200 | 32.5 |
| Width(m) | 3000 | 200 | 15 |
| Average depth(m) | 5.92 | 65 | 0.09 |
| Discharge(m3/s) | 36000 | 104809 | 0.343 |
| Cross-sectional area($m^2$) | 20618 | 13000 | 1.586 |
| Average velocity(m/s) | 2.10 | 8.062 | 0.26 |
| Critical velocity(m/s) | 0.40 | 1.74 | 0.23 |
| Reynold's number | 201158 | 8.17 | 24632 |
| Froude's number | 0.28 | 1.0 | 0.28 |

**(a) Simulation of flow pattern and flow velocity in the model**

1) Fulfillment of the Froude's model law

According to the Froude's model law, the Froude's number in the model and prototype should be equal. Froude's number is given by the following equation

$$F=\frac{V}{\sqrt{gD}}$$

Equating the Froude's number in the model and prototype the velocity ratio has been calculated as

$$V_r=\sqrt{D_r}=8.06$$

Velocity in the model, $V_m$=0.26 m/s

$$Q_r=A_r\,V_r=h_r D_r\sqrt{D_r}=104809$$

Discharge in the model=343 *l/s*

2) Turbulent flow in the model

Depending upon the Reynold's number, the flow in the river can be classified as laminar and turbulent. In laminar flow the viscous force is dominant and in the turbulent flow the effect of viscous force is small. In laminar flow, R<500 and and in turbulent flow R>2000 and in the transitional zone 500<R<2000. Most of the river flow is turbulent and thus to simulate flow pattern, the flow in the model should also be turbulent.

The Reynold's number can be defined as

$$R=\frac{VD}{\nu}$$

Here, $\nu$=Kinematic viscosity=$0.95*10^{-6}$

Reynold's number in the prototype

$$R_p=\frac{2.1*5.92}{0.95*10^{-6}}=13086316$$

Which confirms turbulent flow in the prototype

Reynold's number in the model

$$R_m=\frac{0.26*0.09}{0.95*10^{-6}}=24632$$

Which confirms turbulent flow in the model

3) Rough turbulent flow in the model

According to the equivalent roughness height, the flow can be classified as hydro-dynamically smooth and rough. In hydro-dynamically smooth flow, the thickness of the viscous sub-layer($\delta$)is greater than the roughness height($K_s$)and viscous force may affect the velocity distribution. And thus to avoid this effect, the flow in the model should be rough turbulent i.e hydro-dynamically rough.

**(b) Simulation of roughness in the model**

As the material distortion was allowed in the model, the quantitative equalization of roughness in the prototype and model was not possible, but effort was made to ensure similar pattern and forms of roughness in the prototype and model. As for instance, the form roughness dominates and controls flow distribution in the prototype and thus the form roughness should also dominate in the model. The roughness due to viscosity is negligible in the prototype and this should also happen in the model.

### (c) Simulation of scouring in the model

In the design purpose, the maximum possible anticipated scour around the hydraulic structure after its construction in the domain of a river is normally demanded. Thus in the present model study, importance was mainly focused on the local scour. Local scour occurs as a consequence of local disturbances to the flow. Due to that disturbance, the flow field and shear stress distribution change and a vortex system is developed which causes local erosion to the river bed. As Jamuna river carries sediment laden water, the model was designed corresponding to the live bed condition.

Many Researchers worked on the local scour around the bridge piers and it was found that scour depth at an obstacle becomes independent of flow velocity when the average flow velocity is greater than the critical velocity of the sediment for initiation of threshold motion. However, in the model study of Flood Action Plan (FAP)[1], it is opined that the scour depth becomes independent of flow velocity if $V_m > 2V_{cr}$. This means that the maximum scour depth does not depend on the flow velocity in the model if $V_m > 2V_{cr}$, where $V_m$ is the average flow velocity and $V_{cr}$ is the critical velocity. Only the time period in which this maximum scour depth will be reached, will decrease if the model flow velocity increases. The critical flow velocity for the initiation of bed load movement can be calculated from the following equation (L.C. Van Rijn, 1984):

$$V_{cr} = 0.19\,(D_{50})^{0.10}\,Log\left(\frac{12\,R_b}{3\,D_{90}}\right)\ for\ 100 < D_{50} < 500\ \mu m$$

$$V_{cr} = 8.5\,(D_{50})^{0.60}\,Log\left(\frac{12\,R_b}{3\,D_{90}}\right)\ for\ 500 < D_{50} < 2000\ \mu m$$

Critical velocity in the prototype is

$$v_{crp} = 0.19\,(0.00018)^{0.10}\,Log\left(\frac{12*5.92}{3*0.00026}\right) = 0.40\ m/s$$

Critical velocity in the model is

$$v_{crm} = 0.19\,(0.000185)^{0.10}\,Log\left(\frac{12*0.09}{3*0.000284}\right) = 0.25\ m/s$$

Thus the material available at RRI's model bed was used and the model was designed for live bed condition and model discharge for simulating the local scour can be calculated as follows:

$V_{ms}=1.4*V_{cr}=1.4*0.25=0.35$ m/s

So, $Q_{ms}=A_m*V_{ms}=1.586*0.35=0.555$ cumecs =555 l/s

That is why, the each test of the model will be run for two discharge in the concecutive days. In the first day, the model will run for the discharge calculated from velocity simulation, and flow velocity, flow lines etc. will be recorded. In the 2nd day, the model will run for the discharge calculated from scouring simulation and scour depth around the groynes will be measured.

**Model Construction**

An open air model bed of RRI with the area of 60 m x 30 m was selected. The river reach of 6.5 km from C/S-13 (Ch.140 km) to C/S-51 (Ch.146.5 km) and the width of 3.0 km of the river from the right bank line of 1995 were reproduced in the model. The model was a sectional model and the mid river boundary was constructed in such a way that no flow separation would be occurred during model operation. The movable bed extended from C/S-15 to C/S-49 and was constructed according to the recent bathymetry. The upstream part (from weir to C/S-15) and the downstream part(from C/S-49 to C/S-51) of the model bed were fixed. The fixed bed was constructed with cement plastering over one layer of flat brick soling. Tail gates each having a length of 1.8 m were installed at the downstream end of the model along the C/S-51 to regulate water level in the model. Two point gauges were constructed and the distance between these two gauges was about 10 m in the model. During model operation water level was measured with these point gauges and the water surface slope was found out. A pipe line was linked with the model to feed water from the down stream before each test in order to keep model bed intact prior to supply discharge.

**Operation of the Model**

The water supplied to the model from a constant head sump. The water passed over a 1.78 m long sharp crested weir. A good number of hollow bricks were placed accross the cross section at upstream. These bricks distributed the flow uniformly over the entire width of the model and also helped in dissipating the excess energy of the flow.The water then passed over the sand bed and discharged over the radial tailgate, and returned to the sump. The design model discharge and corresponding head over the weir were measured using the Rehbock's formula.A well gauge installed upper side of the weir was used to measure the water depth flowing over the weir.The water head corresponding to desired discharge was fixed up first,then the flow was allow to flow over the weir. The tailgates were then so adjusted that the water surface slope and the bed slope were resonably the same.

Depth averaged point velocity was measured with an A-OTT type (vertical axis) propeller current meter. Where the depth was insufficient to measure velocity with this current meter, surface velocity was measured using surface floats and the average velocity was found out by multiplying with the factor of 0.85.

Flow lines were recorded to identify the flow directions and surface floats (wax ball) were used in this purpose. In each test, the float was dropped at specific distances(500 m, 750 m, 1000 m, 1250 m, 1500 m) from the right bank along the C/S-13 to d/s and the distances of the float in each cross-sections from the right bank were recorded.

Scour depths at some selected points around the groynes were measured with a sounding rods at time interval of 15 - 30 minutes. Bed levels around the groynes were measured after each test with levelling instruments.

**Calibration of the Model**

In a sectional model where whole width of the outflanking channel is not considered, three boundary conditions namely upstream boundary condition, downstream boundary condition and lateral boundary condition are necessary to be satisfied. Boundary conditions are normally adjusted in the model comparing with measured prototype information.The setup of the model were verified for velocity distribution and water level. The measured discharge distribution of Jamuna at or near the upstream limit was not available and the model was calibrated against computed discharge distribution at C/S-17. Table-2 shows comparison between computed and measured depth averaged flow velocity at C/S-17.

Table-2: Comparison of computed and measured velocity at C/S-17

| Distance from R/B in m | Computed velocity in m/s | Measured velocity in m/s | Percentage of error |
|---|---|---|---|
| 50 | 1.00 | 1.05 | -5.00 |
| 200 | 1.80 | 1.86 | -3.33 |
| 400 | 1.48 | 1.37 | +7.43 |
| 650 | 1.00 | 1.14 | -14.oo |
| 1000 | 1.24 | 1.32 | -6.45 |
| 1500 | 2.66 | 2.66 | 0.00 |
| 1950 | 2.74 | 2.48 | +9.49 |

**Test Results and Discussion**

Eight different test runs were carried out in the distorted model. Test no.1 was conducted with existing condition (with no groyne) prevailed in the field & the model was calibrated in this test. Velocity measured in this test were compared with the velocities from next tests to check the reduction of near bank flow velocity. Five flow lines were recorded and will be compared with the flow lines from next tests to asses the influence of proposed groyne on flow direction. The flow lines have a tendency to move toward the right bank at the downstream indicating severe bank erosion in the downstream areas which justifies the correct similitude of flow pattern in the model because severe bank erosion took place ( Fig.1) in those areas during last flood. Test no. 2 was carried out with the groyne proposed by Bangladesh Water Development Board (BWDB). Velocities at the downstream of this groyne were tremendously reduced upto C/S-40. Velocities from C/S-41 to the downstream were much more to cause bank erosion. The flow lines still had a tendency to move toward the right bank at the downstream. The flow direction remained unchanged inspite of construction of a groyne at C/S-29. Another groyne may be necessary to reduce the flow velocity in the region of C/S-41 to the dowstream and to change the converging tendency of flow in the said areas. During each test run depth averaged flow velocity at different cross-sections (presented in Table-3), flow lines (presented in Figures 2 & 3) and scour depths (for undistorted model test) were measured. Tests ( T-2 to T-8) were carried out with the groyne(s). In the distorted model, location, length, alignment, spacing etc. of the groynes were finalized. However, the scouring around the groynes were investigated in an undistorted model and the duration of that test was 8 hours.

Test no. 3 to 6 were conducted with two groynes named as G-1 and G-3 constructed at ch.142 km and 144.7 km respectively with the changes of length of shank and T-head of the groynes. In these tests it is seen that the near bank flow velocities in C/S-41, 42 & 43 were higher to cause bank erosion. To reduce the ersion tendency, it was decided to construct another third groyne named as G-2 at ch. 143.5 km.

Test no. 7 & 8 were conducted with three groynes. In test no. 7 the near bank flow velocities were within the acceptable limits. But to economize the solution, necessary modification was made to the groynes.The results of Test no. 8 was found satisfactory and finally accepted, and the groynes tested in this test were recommended to construct in the field for the protection of Kazipur area from the erosion of Jamuna river. Velocities around groynes G-1, G-2 & G-3 are presented in Table 4a, 4b & 4c . Layout and locations of the recommended groynes are shown in Fig. 4 & 5.

Another test was carried out for undistorted model with the same horizontal and vertical scale of 1:100. In this case the same things as like in test no. 8 were reproduced. In this test only the scour arround the groynes was measured and is shown in Table 5a, 5b & 5c.

**Conclusions & Recommendations**

Test no. 8 was produced best results in comparison with the other tests. The three groynes proposed in this test were supposed to be sufficient to save bank erosion from C/S-29 to the some distance downstream of C/S-44. The near bank flow velocities were quite low to cause bank erosion and near bank flow were fairly shifted towards the middle of the river. The distance between the groynes G-1 & G-2 was 1350 m which is about 4 times of the shank length of groyne G-1 and G-2 & G-3 was 1200 m which is about 6 times of the shank length of groyne G-2 and the groynes proposed in this test

Table-3: Depth averaged flow velocity from T-1 to T-8

| c/s no | Velocity (m/s) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Distance from right bank (m) | | | | | | | | | | | | | | | | | | | | | | | |
| | 100 | 200 | 300 | 100 | 200 | 300 | 100 | 200 | 300 | 100 | 200 | 300 | 100 | 200 | 300 | 100 | 200 | 300 | 100 | 200 | 300 | 100 | 200 | 300 |
| | T-1 | | | T-2 | | | T-3 | | | T-4 | | | T-5 | | | T-6 | | | T-7 | | | T-8 | | |
| 17 | 2.0 | 2.1 | 1.9 | 1.7 | 1.7 | 1.8 | 1.7 | 1.8 | 1.9 | 1.6 | 1.6 | 1.8 | 1.7 | 1.6 | 1.8 | 1.7 | 1.7 | 1.6 | 1.7 | 1.7 | 1.8 | 1.7 | 1.7 | 1.8 |
| 18 | 1.3 | 2.0 | 2.2 | 1.3 | 1.3 | 1.5 | 1.4 | 1.3 | 1.5 | 1.4 | 1.3 | 1.4 | 1.3 | 1.3 | 1.4 | 1.3 | 1.3 | 1.2 | 1.4 | 1.6 | 1.7 | 1.3 | 1.6 | 1.8 |
| 19 | 1.7 | 2.1 | 2.1 | 1.3 | 1.7 | 1.5 | 1.3 | 1.9 | 1.5 | 0.9 | 1.5 | 1.8 | 1.4 | 1.8 | 1.4 | 1.4 | 1.6 | 1.5 | 1.3 | 1.8 | 1.9 | 1.4 | 1.8 | 1.9 |
| 21 | 1.5 | 1.9 | 1.5 | 0.0 | 0.8 | 1.4 | 0.0 | 1.1 | 1.4 | 0.0 | 0.6 | 1.5 | 0.0 | 1.0 | 1.5 | 0.0 | 0.9 | 1.5 | 0.0 | 0.9 | 1.5 | 0.0 | 0.8 | 1.8 |
| 26 | 1.9 | 1.9 | 1.8 | 1.1 | 1.4 | 1.5 | 1.1 | 1.5 | 1.7 | 0.8 | 1.1 | 1.4 | 1.1 | 1.5 | 1.5 | 1.2 | 1.5 | 1.5 | 1.1 | 1.5 | 1.7 | 1.2 | 1.5 | 1.8 |
| 28 | 2.3 | 2.1 | 2.1 | 0.7 | 1.1 | 1.7 | 0.8 | 1.2 | 1.8 | 0.9 | 1.2 | 1.8 | 0.7 | 1.1 | 1.7 | 0.6 | 1.2 | 1.5 | 0.7 | 1.2 | 1.7 | 0.0 | 1.0 | 1.8 |
| 30 | 2.8 | 1.8 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 |
| 32 | 1.5 | 2.8 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 |
| 34 | 1.3 | 1.4 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 1.7 | 2.5 |
| 38 | 1.7 | 1.8 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 1.9 | 2.1 |
| 40 | 1.9 | 2.1 | 1.9 | -0.7 | 0.0 | 0.7 | 0.7 | 0.0 | 0.7 | 0.0 | 0.0 | 1.3 | 0.0 | 0.7 | 1.4 | 0.0 | 0.9 | 1.8 | 0.0 | 0.0 | 0.8 | 1.4 | 1.8 | 2.2 |
| 41 | 3.3 | 2.1 | 1.6 | 0.0 | 0.9 | 1.4 | 0.0 | 0.9 | 1.4 | 0.7 | 1.5 | 1.3 | 0.9 | 1.1 | 1.6 | 1.1 | 1.5 | 1.8 | 0.0 | 0.4 | 1.2 | 0.0 | 2.1 | 2.4 |
| 42 | 2.3 | 2.1 | 2.3 | 1.3 | 1.7 | 2.0 | 1.1 | 1.7 | 1.7 | 1.2 | 1.6 | 1.7 | 1.3 | 1.4 | 1.7 | 1.5 | 1.6 | 1.7 | 0.0 | 2.3 | 2.5 | 0.8 | 2.6 | 2.1 |
| 43 | 2.0 | 2.1 | 2.5 | 1.4 | 1.8 | 1.8 | 1.2 | 1.2 | 2.0 | 1.3 | 2.0 | 2.1 | 1.4 | 1.2 | 1.9 | 1.1 | 1.5 | 1.9 | 1.4 | 2.1 | 2.8 | 1.4 | 2.7 | 2.1 |
| 44 | 2.2 | 2.2 | 2.2 | 1.8 | 1.7 | 1.7 | 0.0 | 2.9 | 3.4 | 0.0 | 0.0 | 3.2 | 0.0 | 0.0 | 2.6 | 0.0 | 0.0 | 0.0 | 0.0 | 2.8 | 2.9 | 0.0 | 2.9 | 2.5 |
| 45 | 2.1 | 2.6 | 2.7 | 1.8 | 2.3 | 2.3 | 0.0 | 1.1 | 0.9 | 0.0 | 1.3 | 3.0 | 0.0 | 0.0 | 2.1 | 0.0 | 0.0 | 0.0 | 1.9 | 2.4 | 2.5 | 1.8 | 2.4 | 2.6 |
| 47 | 2.8 | 2.7 | 3.1 | 2.0 | 2.6 | 2.3 | 0.6 | 2.8 | 2.5 | 0.6 | 2.6 | 2.9 | 0.7 | 2.1 | 2.9 | 0.0 | 0.0 | 3.3 | 1.8 | 2.6 | 2.1 | 1.9 | 2.5 | 2.8 |
| 50 | 2.8 | 3.1 | 3.1 | 3.1 | 2.7 | 2.7 | 1.0 | 2.6 | 2.8 | 0.9 | 2.9 | 3.2 | 0.9 | 2.7 | 2.6 | 0.5 | 2.4 | 2.6 | 2.4 | 2.8 | 3.2 | 2.8 | 2.8 | 2.8 |

Note: (-) sign indicates eddy

## Table-4(a): Velocity around the groyne G-1

Velocity in M/s

| Distance from the shank axis in m | Distance from T-head axis in m | | | | | | |
|---|---|---|---|---|---|---|---|
| | -100.0 | -50.0 | 0.0 | 50.0 | 100.0 | 200.0 | 300.0 |
| -300.0 | | 1.7 | 2.1 | 2.5 | 2.2 | 2.3 | 2.4 |
| -200.0 | | 1.5 | 2.2 | 3.6 | 2.5 | 2.3 | 2.0 |
| -100.0 | | 0.8 | | 4.2 | 3.1 | 2.4 | 2.4 |
| -50.0 | | 0.5 | T-head axis | 4.1 | 3.0 | 2.2 | 2.3 |
| 0.0 | Shank axis | | | 4.0 | 2.9 | 2.7 | 2.3 |
| 50.0 | | 0.0 | | 3.9 | 3.2 | 2.6 | 2.2 |
| 100.0 | | 0.0 | | 4.2 | 3.4 | 3.0 | 2.3 |
| 200.0 | | 0.0 | 2.8 | 4.0 | 2.5 | 2.9 | 2.6 |
| 300.0 | | 0.0 | 2.5 | 3.8 | 2.3 | 2.9 | 2.4 |

## Table-4(b): Velocity around the groyne G-2

Velocity in M/s

| Distance from the shank axis in m | Distance from T-head axis in m | | | | | | |
|---|---|---|---|---|---|---|---|
| | -100.0 | -50.0 | 0.0 | 50.0 | 100.0 | 200.0 | 300.0 |
| -300.0 | 0.9 | 1.8 | 2.0 | 2.0 | 2.5 | 2.3 | 1.8 |
| -200.0 | 0.8 | 1.7 | 1.9 | 2.2 | 2.6 | 2.3 | 1.9 |
| -100.0 | 0.4 | 1.6 | 2.0 | 2.9 | 2.8. | 2.4 | 1.8 |
| -50.0 | 0.0 | 0.8 | T-head axis | 3.4 | 2.7 | 2.6 | 2.0 |
| 0.0 | Shank axis | | | 3.6 | 2.9 | 2.5 | 1.9 |
| 50.0 | 0.0 | 0.0 | | 3.8 | 2.6 | 2.7 | 2.1 |
| 100.0 | 0.0 | 0.0 | 1.0 | 3.7 | 2.5 | 2.8 | 2.0 |
| 200.0 | 0.0 | 1.0 | 2.5 | 2.9 | 2.4 | 2.8 | 2.3 |
| 300.0 | 0.0 | 1.5 | 2.5 | 2.6 | 1.9 | 2.0 | 1.9 |

## Table-4(c): Velocity around the groyne G-3

Velocity in M/s

| Distance from the shank axis in m | Distance from T-head axis in m | | | | | | |
|---|---|---|---|---|---|---|---|
| | -100.0 | -50.0 | 0.0 | 50.0 | 100.0 | 200.0 | 300.0 |
| -300.0 | 1.0 | 1.5 | 1.7 | 1.8 | 1.6 | 2.1 | 2.1 |
| -200.0 | 1.1 | 1.4 | 1.8 | 2.0 | 1.8 | 2.4 | 2.3 |
| -100.0 | 0.0 | 1.4 | 1.6 | 2.2 | 2.2 | 2.4 | 2.4 |
| -50.0 | 0.0 | 0.0 | T-head axis | 3.2 | 2.5 | 2.3 | 2.7 |
| 0.0 | Shank axis | | | 3.5 | 2.7 | 2.5 | 2.6 |
| 50.0 | 0.0 | 0.0 | | 3.8 | 2.8 | 2.6 | 2.6 |
| 100.0 | 0.0 | 1.0 | 1.7 | 3.6 | 2.6 | 2.7 | 2.7 |
| 200.0 | 2.7 | 2.8 | 2.5 | 2.8 | 2.9 | 2.8 | 2.6 |
| 300.0 | 2.2 | 2.7 | 2.6 | 2.6 | 2.9 | 2.9 | 2.7 |

Note: (-) sign indicates distance from the shank axis in u/s direction and distance from the T-head axis towards the river bank

## Table-5(a): Equilibrium bed levels around the groyne G-1

Bed Levels in M Pwd

| Distance from the shank axis in m | | | | | |
|---|---|---|---|---|---|
| | -50.0 | 0.0 | 50.0 | 100.0 | 150.0 |
| -200.0 | 7.20 | 5.20 | 7.20 | 8.20 | 9.00 |
| -150.0 | 8.00 | 2.80 | 8.00 | 7.50 | 8.00 |
| -100.0 | 7.50 | 0.80 | -5.60 | 5.60 | 8.00 |
| -50.0 | 11.30 | T-head axis | -21.20 | -1.20 | 7.80 |
| 0.0 | Shank | | -16.10 | -1.00 | 6.30 |
| 50.0 | 9.00 | | 0.30 | 2.00 | 4.80 |
| 100.0 | 16.00 | 6.50 | 2.80 | 6.50 | 6.00 |
| 150.0 | 11.30 | 7.80 | 7.30 | 7.30 | 4.70 |
| 200.0 | 11.30 | 9.00 | 8.20 | 7.30 | 5.30 |

## Table-5(b): Equilibrium bed levels around the groyne G-2

Bed Levels in M Pwd

| Distance from the shank axis in m | Distance from the T-head axis in m | | | | |
|---|---|---|---|---|---|
| | -50.0 | 0.0 | 50.0 | 100.0 | 150.0 |
| -200.0 | 8.5 | 7.8 | 6.0 | 7.4 | 12.6 |
| -150.0 | 7.5 | 7.0 | 5.0 | 7.3 | 12.3 |
| -100.0 | 8.3 | 5.7 | -4.0 | 1.0 | 7.5 |
| -50.0 | 7.8 | T-axis | -8.0 | -2.0 | 7.7 |
| 0.0 | Shank | | -7.3 | -1.5 | 7.0 |
| 50.0 | 8.3 | | -5.0 | -0.8 | 6.0 |
| 100.0 | 4.3 | -1.0 | -4.0 | -0.5 | 7.5 |
| 150.0 | 3.8 | 3.8 | 4.6 | 6.6 | 7.5 |
| 200.0 | 3.3 | 4.8 | 5.8 | 5.5 | 5.6 |

## Table-5(c): Equilibrium Bed Levels Around the Groyne G-3

Bed Levels in M Pwd

| Distance from the shank axis in m | Distance from the T-head axis in m | | | | |
|---|---|---|---|---|---|
| | -50.0 | 0.0 | 50.0 | 100.0 | 150 |
| -200.0 | 1.2 | 3.0 | 3.5 | 4.0 | 5.0 |
| -150.0 | 0.0 | 2.6 | 3.0 | 3.6 | 4.6 |
| -100.0 | 1.3 | 2.8 | 2.3 | 3.6 | 4.3 |
| -50.0 | 3.8 | T-axis | 2.0 | 3.3 | 2.3 |
| 0.0 | Shank | | -5.0 | 0.3 | -0.2 |
| 50.0 | 11.3 | | -7.0 | -0.7 | -0.2 |
| 100.0 | 15.8 | -6.0 | -3.0 | 0.3 | 1.0 |
| 150.0 | 7.6 | -3.2 | -0.2 | 0.0 | 1.6 |
| 200.0 | 6.8 | -1.2 | -1.5 | 0.7 | 1.6 |

Note: (-) sign indicates distance from the shank axis in u/s direction and distance from the T-head axis towards the river bank were economically justified. Thus the results of the Test no.8 were finally accepted and groynes constructed in this test will be recommended to construct in the field to save Kazipur area from the erosion of Jamuna river.

Length of falling apron can be decided from the equilibrium bed levels around the groynes presented in Tables 5a, 5b & 5c.

During model study, following area were found to be protected by the recommended groynes:

(a) River bank (in between the groynes G-1 & G-2) from C/S-29 to C/S-40 (about 1350 m)

(b) River bank (in between the groynes G-2 & G-3) from C/S-40 to C/S-44 (about 1200 m)

(c) River bank of about 700 m (downstream of G-3) from C/S-44 to the downstream

(d) Some distance upstream of the groyne G-1

Three groynes having a joint hydrodynamic effect should be constructed at the same time. The groynes should be perpendicular to the flow direction pointing from the head of the existing roads (see Fig.5). The groynes should be constructed before next monsoon because the model study was conducted on the basis of the river geometry/bathymetry collected in the post monsoon of 1995 and river geometry/bathymetry may be changed after the next monsoon.

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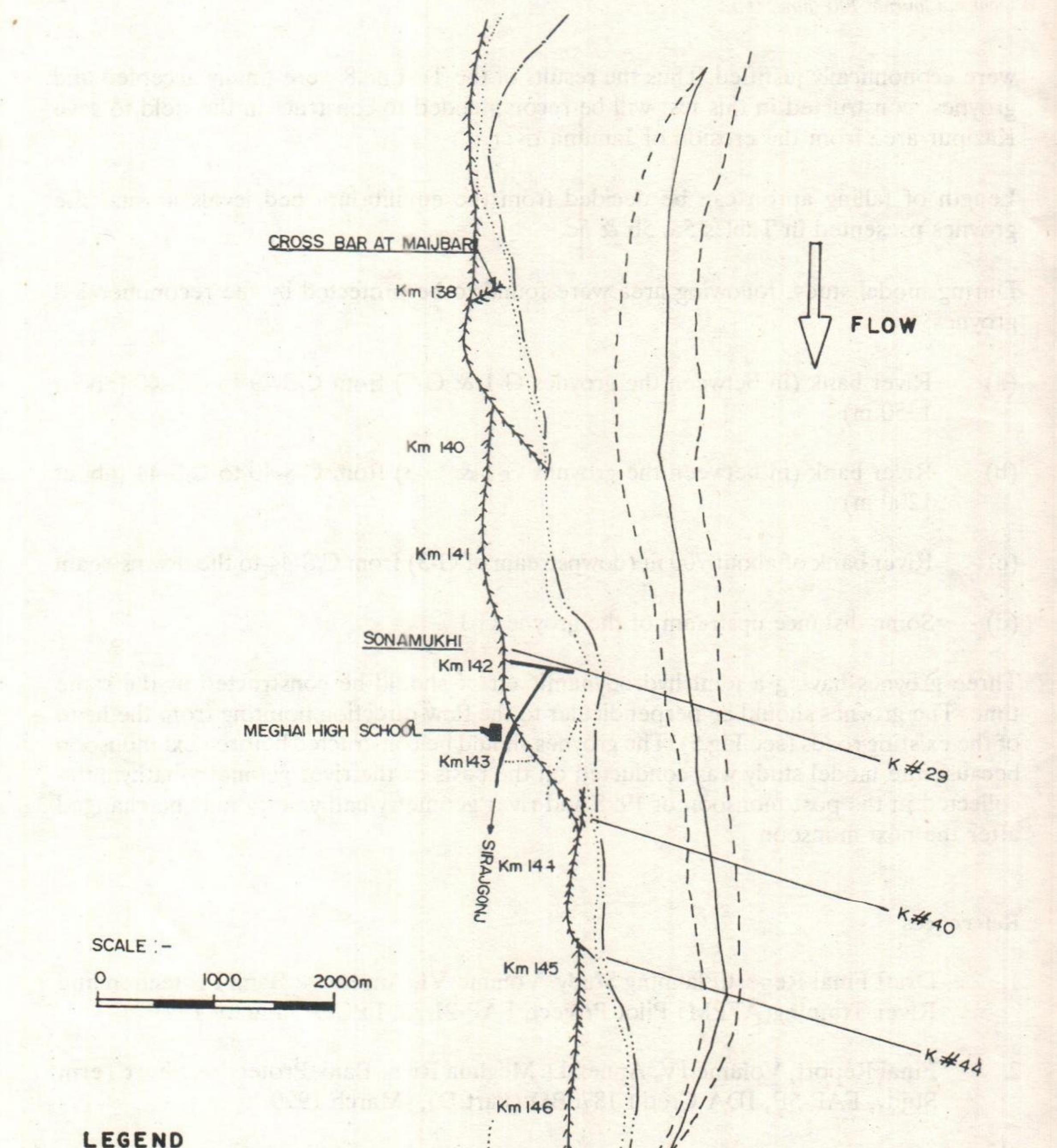


FIG. NO. 1 :- BANK LINE SHIFTING OF JAMUNA RIVER AT KAJIPUR

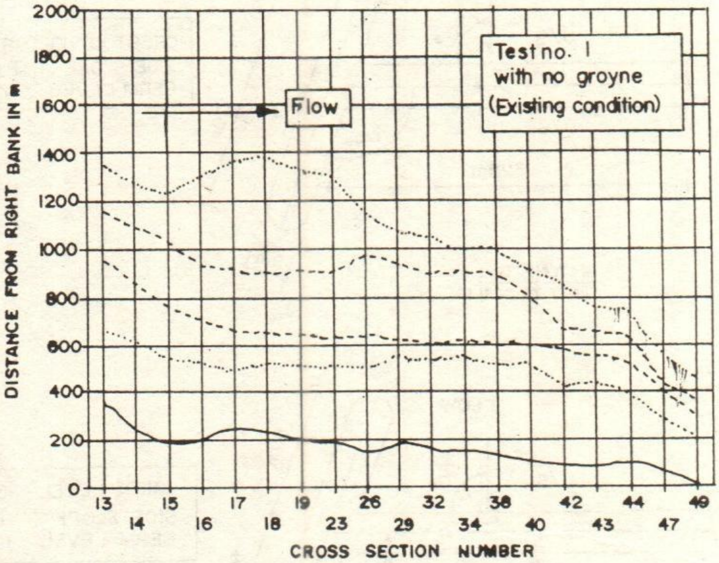


Fig. No. 2 : Flow lines in existing condition (with no groyne)

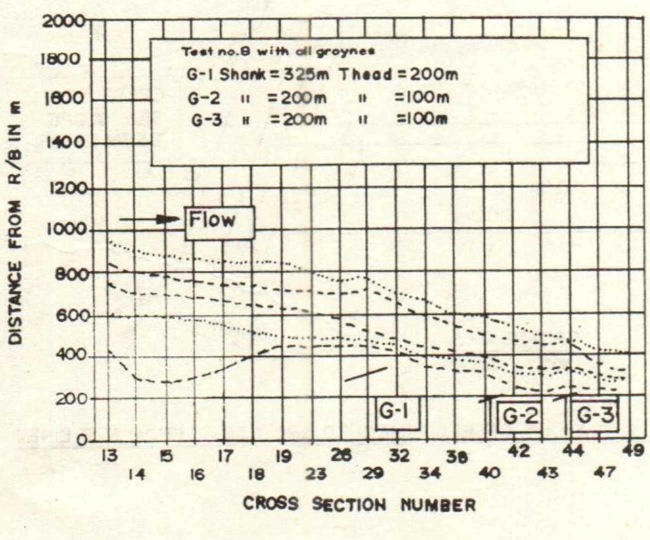


Fig. No. 3 : Flow lines in test no. 8

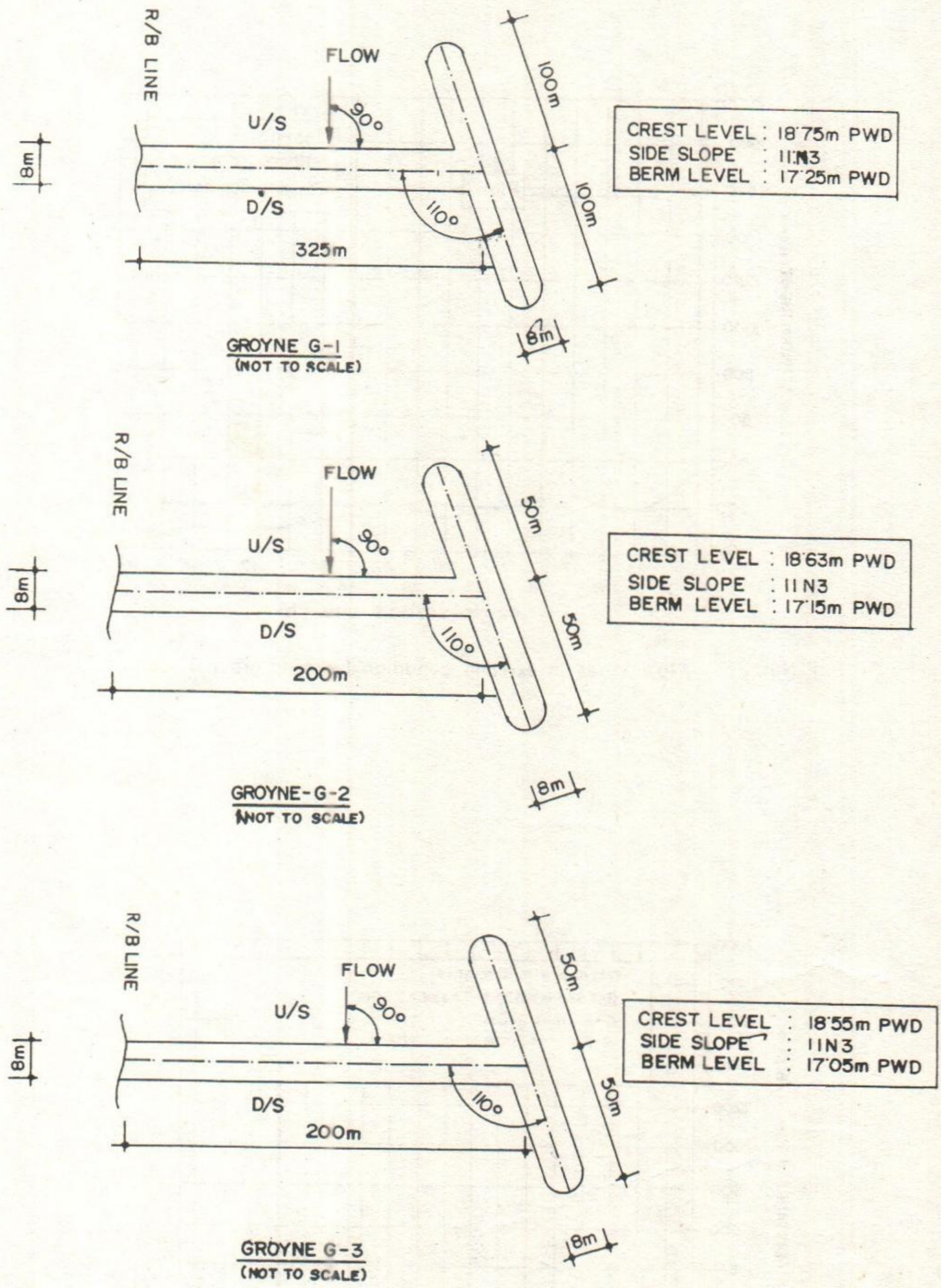


FIG.4 : LAYOUT OF RECOMMENDED GROYNES (FROM R/B LINE)

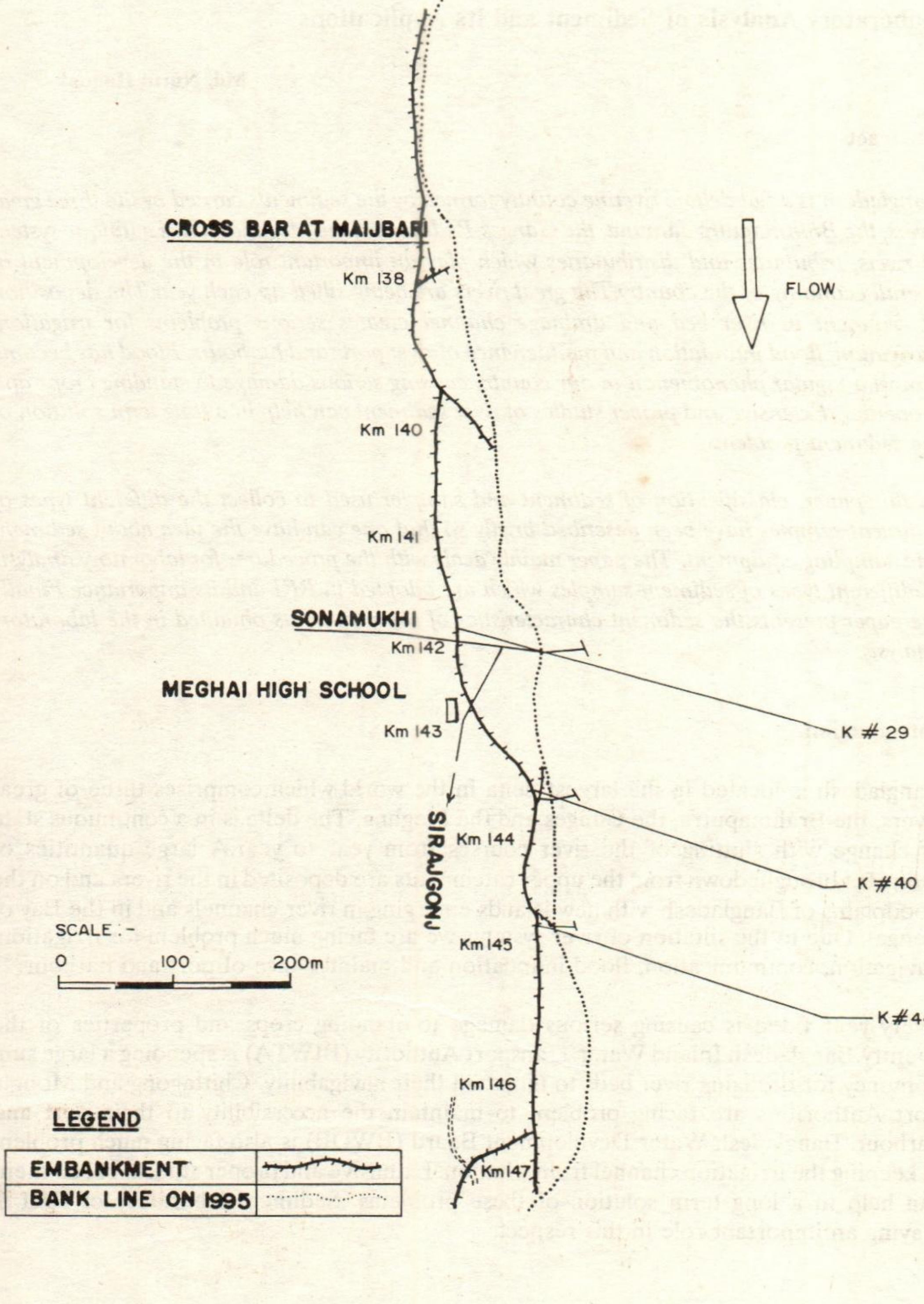


FIG. NO. 5 : LOCATION OF THE RECOMMENDED GROYNES

# Laboratory Analysis of Sediment and its Applications

**Md. Nurul Haque**[1]

## Abstract

*Bangladesh is a flat deltaic riverine country formed by the sediments carried by the three great rivers, the Brahmaputra-Jamuna, the Ganges-Padma and the Meghna. It has a unique system of rivers, tributaries and distributaries which play an important role in the development of overall economy of the country.The great rivers are being silted up each year.The deposition of sediment in river bed and drainage channel creates serious problems for irrigation, navigation, flood inundation and maintenance of river ports and harbours. Flood has become almost a regular phenomenon in our country causing serious damage to standing crops and properties. Extensive and proper studies of river sediment can·help in a long term solution of the sediment problems.*

*In this paper, classification of sediment and sampler used to collect the different types of sediment samples have been described briefly so that one can have the idea about sediment and sampling equipment. The paper mainly deals with the procedures for laboratory analysis of different types of sediment samples which are adopted in RRI and its importance.Finally the paper presents the sediment characteristics of some rivers as obtained in the laboratory analysis.*

## Introduction

Bangladesh is located in the largest delta in the world which comprises three of great rivers, the Brahmaputra, the Ganges and the Meghna. The delta is in a continuous state of change with shifting of the river courses from year to year.A large quantities of sediment brought down from the upper catchments are deposited in the rivers and on the floodplains of Bangladesh with new islands emerging in river channels and in the Bay of Bengal. Due to the siltation of river systems we are facing much problem for irrigation, navigation, communication, flood inundation and maintenance of port and harbour.

Every year flood is causing serious damage to standing crops and properties of the country.Bangladesh Inland Water Transport Authority (BIWTA) is spending a large sum of money for dredging river beds to maintain their navigability. Chittagong and Mongla Port Authorities are facing problem to maintain the accessibility to their port and harbour. Bangladesh Water Development Board (BWDB) is also facing much problem in keeping the irrigation channel from siltation. Extensive and proper studies of sediment can help in a long term solution of these problems. Sediment laboratory of RRI is playing an important role in this respect.

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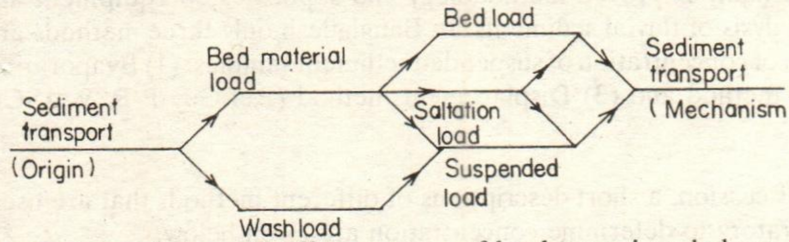
**Sediment transport mechanism and classification of sediments**

When the flow conditions reach the critical stage, that is when the value of the bed shear velocity just exceeds the critical value for initiation of motion, the bed material particles start moving by rolling or sliding in continuous contact with the bed. With the increase of bed shear velocity, the particles move along the bed by more or less regular jumps which are called saltation. When the value of bed shear velocity begins to exceed the fall velocity of particles, the sediment particles can be lifted to a level at which the upward turbulent forces will be of higher order that the submerged weight of the particles, as a result the particles may go into suspension. At any time a good number of bed particles may jump but eventually some of them return to bed again but by that time other particles go into suspension and the process goes on continuously. As a result depending on the magnitude of turbulence, the shape and size of the bed particle, some of them remain in suspension and move along with the flowing water.The main sources of sediment are the materials of stream bed and the fine particles which come from the catchment of the river. According to source, sediment can be divided into two groups namely bed material load and wash load.But according to transport mechanism sediment can be classified into three categories viz(1) bed load (2) saltation load and (3) suspended load.

The classifications have been shown below schematically( Jansen & others):




A short description of different types of loads are given below:

**Bed load**

Bed load is defined as sediment particles which move by sliding or rolling over and near the bed, generally in the propagating bed forms such as ripples and dunes(Tech.Bu.1026).

**Saltation load**

Saltation load is defined as sediment particles which make their journey by hopping and jumping as a result of higher value of bed shear velocity . These particles very frequently move as bed load and some times as suspended load.

**Suspended load**

Suspended load consists of sediment particles held in suspension by balancing their gravitational force with the upward forces due to the turbulence of the fluid. The suspended load may also include the fine silt particles which come from catchment area but not from stream bed and is called the wash load.

**Equipment used to collect different types of sediment samples**

Various equipment are available for collecting different types of sediment samples. In the developed countries many improved and sophisticated samplers have been designed for collection and measurement of different types of sediment. In our country Jabsco pump sampler, Binkley sampler, point-integrating sampler,depth-integrating sampler are used for the collection of suspended sediment samples. Hydro-core, US-BM-54, US-BM-60 and other Grab-type samplers are used for collection of bed material samples.
In Bangladesh, only Bed load Transport Meter of Arnhem is used for collection of bed load samples (Ref.ASCE **Report no 54)**

**Laboratory Analysis of Sediment:**

The main function of a sediment laboratory is to determine the concentration of suspended samples and to determine the particle size distribution of suspended sediment, river bed material and deposits associated with other surface water. The other functions of the sediment laboratory are the determination of specific gravity of sediment particle,specific weight of deposits and the amount of organic matter in the sediment . In advanced countries many improved methodology and sophisticated equipment are used for laboratory analysis of fluvial sediments. In Bangladesh only three methods are used for dètermination of concentration of suspended sediment samples: (1) Evaporation method (2) Filtration method and (3) Displacement method (Ref:Guy P R & ASCE Re.54)

In the light of above discussion, a short descriptions of different methods that are used in RRI sediment laboratory to determine concentration are given below.

**Evaporation Method**

In evaporation method, the sediment is allowed to settle to the bottom of the sample container, the clear liquid is decanted, the sediment is washed into a basin and then dried in an oven.Finally the sediment concentration is determined by weighing the sediment in a sophisticated balance.The main advantage of this method is the simplicity of equipment and technique but one of the disadvantages of this method is that when the sample contains naturally dispersed clay, the settling time make the method impractical.It is possible to coagulate the clay particle by using chemicals for shortening the settling time. But in case of testing a large number of samples, the process is lengthy.

**Filtration Method**

The filtration apparatus is connected with a vacuum pump by air tight plastic pipe to suck water from the sediment sample. In this method millipore filter paper of 47mm and pore size of 1.2 or 0.45 micron is used. Using this arrangement maximum six samples at a time can be filtered easily

**Displacement Method**

For some special studies, where the amount of sediment is considerable and consists mostly of sand, the displacement method may be used. In displacement method the formula for computation of sediment concentration is given by

$$c_d = \frac{W}{1 - S_w/S_s} \times 10^6 \text{ (mg/l)} \quad \text{(Ref: ASCE Re 54)}$$

where, W = difference in wt. of 100 ml cylinder with water only and water plus sediment
$S_W$ = Specific wt.of water, $S_s$ = Specific wt. of sediment

This method may be used with advantage of avoiding the problems of oven drying the sediment.

**Methods for particle size distribution of sediment**

Now a days in developed countries various improved methods are being used for determining the particle size distribution of suspended sediment and bed material samples. These are visual accumulation tube (V A tube) method, Bottom withdrawal tube (B W tube) method, pipet method, settling tube method, Hydrometer method etc. The hydrometer method is used only in case of cohesive bed sediment and soil samples but in case of sandy sediment, sieves of different opening dia are used. The methods mentioned above have their limitations. V.A tube is used for determining the particle size distribution of suspended sediment samples that contain only sand. Pipet, BW tube and settling tube methods are applicable for determining the grain size of the sediment samples that contain silt and clay (particle size less than .062 mm). The pipet method is based on the principle that the size distribution is determined by measuring the concentration of sediment at specific interval of time & depth such that the larger sizes will have settled at the pipet withdrawal zone in the settling medium. The theory for determining grain size distribution of sediment by settling tube and BW tube is same which based on the principle that the distribution is obtained from the quantity of sediment remaining in suspension after various settling times when the coarser sizes and heavier concentrations are withdrawn at the bottom of the tube.The theory of settling tube analysis is discussed briefly.

The grain size distribution based upon the settling velocity is given by the stoke's law as

$$W_f = \frac{(S_s - S_w)}{(18\,\nu)} g d^2 \qquad \text{(ASCE Re.54)} \qquad (1)$$

Where, $W_f$ = Settling velocity

d = Grain diameter

$\nu$ = kinematic viscosity = $10^{-6}\{(62.4/(42.2+T)\}^{3/2}(m^2/s)$

T = temperature, $g = 9.81\ m/s^2$

Ss = Sp gr. of grain, $S_w$ = Specific Gravity of water.

The time "t" for a grain with diameter "d" to fall from the top of the water column to the level of the outlet ( height h ) is given by $t = h/W_f$ (2)

Combining (1) & (2) the diameter of the grain "d" at fall distance h at time "t" is given by

$d = [18\,\nu/(S_s - S_w)g]^{1/2}.(h/t)^{1/2} = F.(h/t)^{1/2}$

Factor $F = [18\,\nu/(S_s - S_w)g]^{1/2}$

**Application of laboratory Analysis of Sediment**

The laboratory grain size analysis data of stream bed material and suspended sediment and concentration data of suspended sediment are very essential for planning any artificial reservoir by constructing dam or barrage for generating hydro-electric power or to provide water for irrigation purpose. Sediment concentration and particle size data obtained from laboratory analysis are almost indispensable for design of any hydraulic structure. In case of mathematical modelling and physical modelling, suspended sediment concentration data and particle size information of river bed are very essential(Ref. Kiff.P.R).

Concentration and particle size information are also needed to compute suspended sediment discharge, total sediment load and also in computation of sediment volume deposited in reservoir.

Similarly particle size information are also required for solution of any erosion and deposition problem.The transportation and deposition of sediment depend on the characteristic of flow as well as the physical characteristics of sediment such as concentration, sediment grain size, specific weight of sediment etc. So a planner and a design engineer must need information about the sediment characteristics at the time of planning and design of any hydraulic structure and in this respect only long term laboratory sediment analysis data can help them .

**Presentation of sediment analysis result**

The sediment and flow characteristics of different rivers of Bangladesh in respect of minimum and maximum values of water level, water discharge, sediment discharge, sediment concentration, flow velocity, have been presented in **Table-1.** Annual variation of sediment concentration and water discharge and those of water discharge with sediment discharges of rivers Surma at Sylhet, Kushiyara at Sherpur, Gorai at Gorai Rly. bridge, Brahmaputra at Bahadurabad and Ganges at Baruria have been presented graphically in **Figures 1a, 1b, 2, 3 & 4** respectively.

**Discussion**

The results presented in **Table-1** obtained from the laboratory study of sediment will give an idea about the range of variations of various parameters of different rivers of Bangladesh. In **Figures 1a & 1b** a relation between sediment concentration and water discharge with respect to days during the year 1995 of the river Surma at Sylhet and the river Kushiyara at Sherpur have been shown graphically. If anybody knows the water discharge at any date of the year he can determine the sediment concentration from the graph directly corresponding to known discharge. Similarly the variations of sediment discharge with water discharge of the river Gorai at Gorai Rly. Bridge, Brahmaputra at Bahadurabad and the Ganges at Barruria for consecutive four years have been shown in **Figures 2, 3 & 4** respectively. If one variable is known for a particular date the other unknown variable can be determined from the graph. So **Figures 1a, 1b, 2, 3, & 4** may be used as tools for determining one variable when the other is known.

**Conclusion**

A planner and a design engineer must have sound knowledge about sediment characteristic such as sediment concentration, sediment discharge, grain size of bed

**Table-1**: Comparison of parameters of several rivers for the year 1995

| Characteristics river | Water discharge in cumecs | | Suspended sediment discharge in kg/sec. | | Sediment concentration in PPM by wt. | | Water level in meter (PWD) | | Flow velocity in m/sec. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| Bogkhali at Ramu | 66 | 2 | 33 | 0.10 | 507 | 52 | 3.67 | 2.32 | 0.85 | 0.32 |
| Feni at Kaliachari | 419 | 4 | 346 | 0.20 | 825 | 49 | 9.73 | 4.10 | 1.36 | 0.26 |
| Gumti at Comilla | 550 | 3 | 2021 | 0.14 | 1770 | 47 | 12.10 | 7.08 | 1.38 | 0.10 |
| Halda at Punchpukuria | 77 | 0.4 | 18 | 0.02 | 233 | 50 | 11.21 | 4.07 | 1.52 | 0.15 |
| Howrah at Ganga-Sagar | 20 | 2 | 12 | 0.17 | 600 | 87 | 6.05 | 3.39 | 0.54 | 0.11 |
| Ichamati at Thandachari | 24 | 0.2 | 16 | 0.02 | 683 | 84 | 11.80 | 10.55 | 0.79 | 0.10 |
| Khowai at Shaistagonj | 148 | 4 | 145 | 0.46 | 983 | 115 | 11.98 | 9.25 | 1.31 | 0.40 |
| Kushiyara at Sherpur | 2357 | 58 | 1058 | 4.23 | 449 | 73 | 8.82 | 2.22 | 1.35 | 0.15 |
| Matamuhuri at Lama | 342 | 7 | 286 | 0.29 | 836 | 42 | 8.30 | 5.93 | 1.31 | 0.52 |
| Mathabhanga at Hatboalia | 208 | 2 | 139 | 0.12 | 670 | 60 | 12.06 | 7.13 | 0.9 | 0.2 |
| Muhuri at Parshuram | 183 | 0.52 | 116 | 0.18 | 633 | 35 | 12.42 | 9.80 | 1.36 | 0.13 |
| Sangu at Bandarban | 321 | 3 | 318 | 0.16 | 990 | 52 | 8.80 | 4.48 | 1.71 | 0.40 |
| Surma at Sylhet | 2060 | 4 | 1454 | 0.24 | 706 | 59 | 11.43 | 2.08 | 1.74 | 0.23 |
| Brahmaputra at Bahadurabad | 84244 | 4321 | 160286 | 432 | *4452 | *93 | 19.27 | 12.96 | - | - |
| Kaliganga at Taraghat | 1734 | 32 | 491 | 5 | *481 | *40 | 9.25 | 3.02 | - | - |
| Gorai at Gorai Rly. Bridge | 3928 | 24 | 12991 | 14 | *1653 | *34 | 11.75 | 5.03 | - | - |
| Modhumati at Kamarkhali | 3785 | 9 | 6136 | 1 | *1012 | *2 | 9.21 | 0.91 | - | - |

Note : * Only fines concentration.

material, bed load material, suspended material at the time of designing a hydraulic structure like barrage, drainage channel, irrigation canal, reservoir, flashing sluice, closure etc for proper design and planning.The data presented in the paper may help an engineer in planning phase of scheme. The laboratory methods of analysis of sediment mentioned and explained in the paper will help the persons those who work with the sediment.

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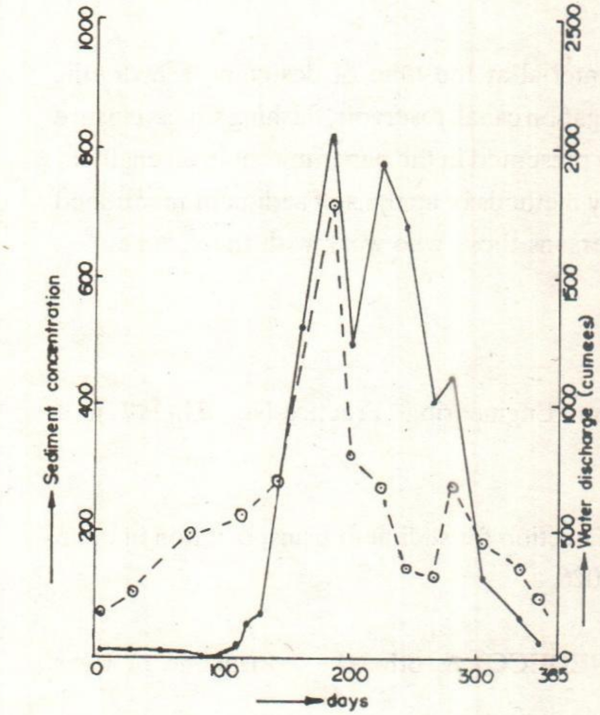


Fig.1a Surma at Sylhet during the year 1995

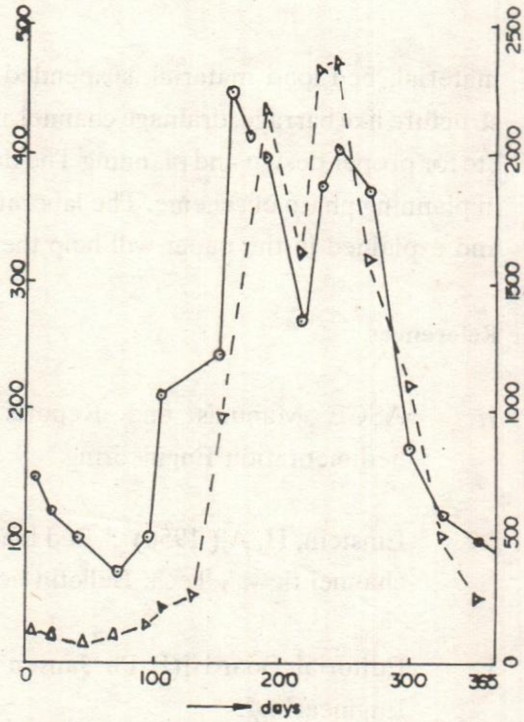


Fig.1b. Kushiyara at Sherpur during the year 1995

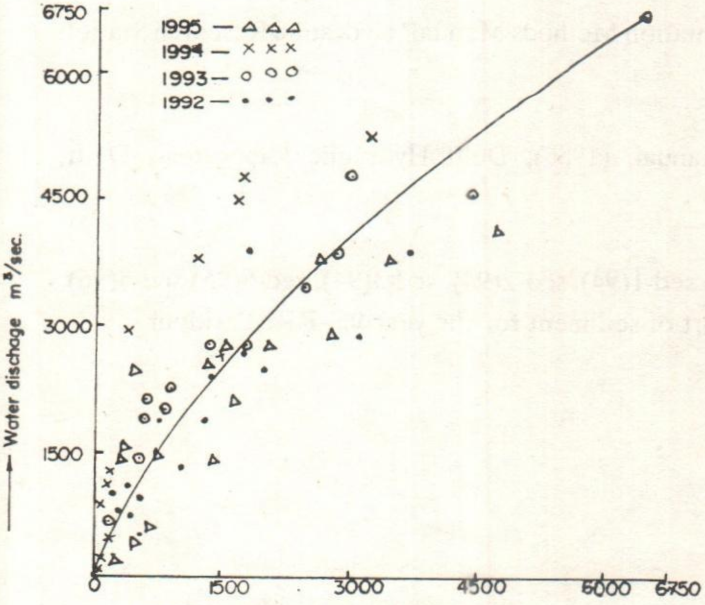


Fig-2: Gorai at Gorai RLy. Bridge for the years. 1995—92.

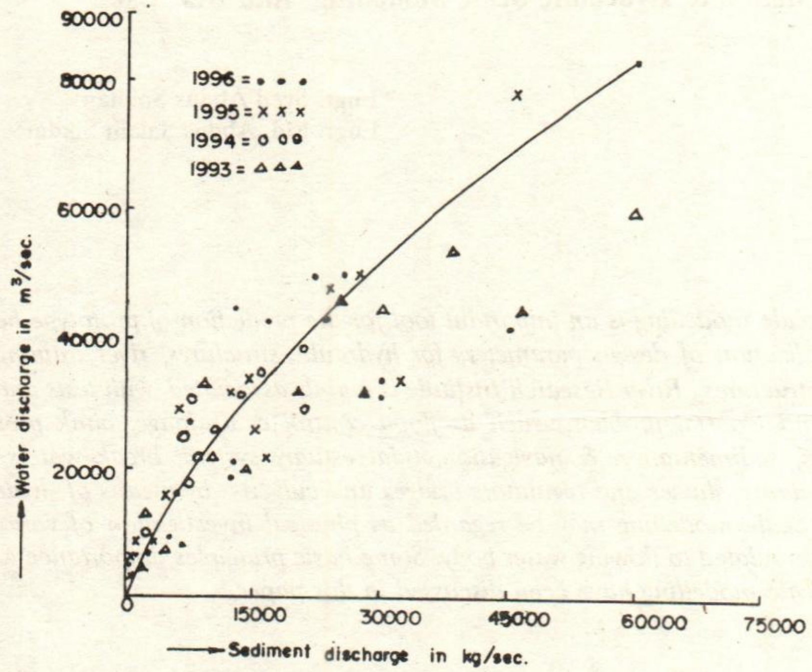


Fig-3 : Brahmaputra at Bahadurabad for the years. 1996—93.

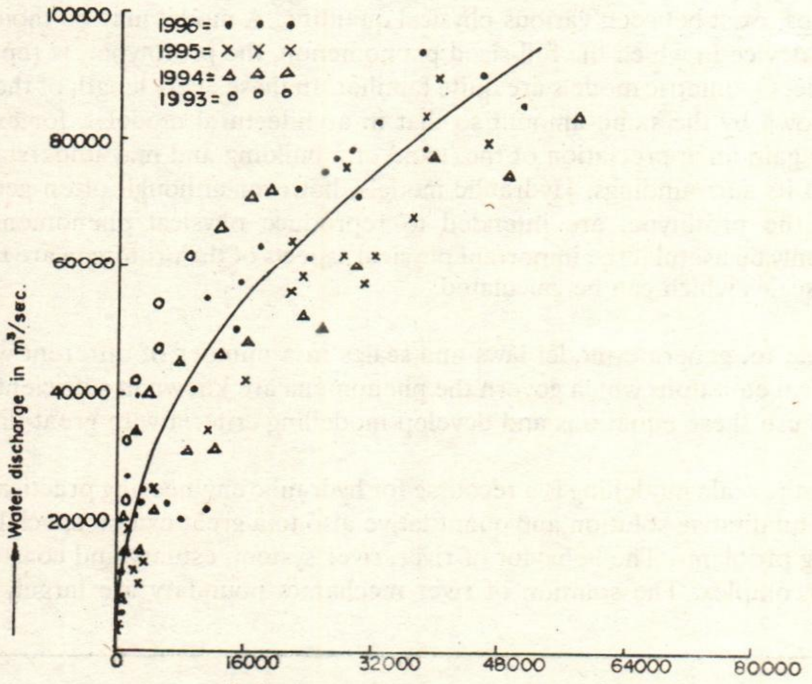


Fig-4 : Ganges at Baruria for the years. 1996—93.

# An Introduction to Hydraulic Scale Modelling And Its Use

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**Abstract**

*Hydraulic scale modelling is an important tool for the prediction of prototype behavior and for the finalization of design parameters for hydraulic structures, river training and bank protection structures . River Research Institute is mainly associated with tests and researches on River and Coastal problems such as flood control & drainage, bank protection and stabilization, sedimentation & navigation, tidal estuary system, break- waters, sea dikes, barrages & dams, sluices and regulators bridges and culverts by means of hydraulic Scale modelling. Scale modelling may be regarded as physical investigation of various physical phenomenon related to flowing water body. Some basic principles, importance and utility of hydraulic scale modelling have been discussed in this paper.*

## Introduction

A principal purpose of scientific research in engineering is to establish the exact relationships exist between various physical quantity. A model may be thought of as a prediction device in which the full-sized phenomenon, the prototype , is reproduced at a small scale. Geometric models are quite familiar. In these every length of the prototype is scaled down by the same amount so that in architectural models , for example the public may gain an appreciation of the 'look' of a building and may understand how it will fit into its surroundings. Hydraulic models, however although often geometrically similar to the prototype, are intended to reproduce physical phenomena and can therefore only be useful if the important physical aspects of the prototype are reproduced at certain scales which can be calculated.

It is possible to, generate model laws and scales in a number of different ways. If the mathematical equations which govern the phenomena are known in sufficient detail it is possible to use these equations and develop modelling criteria with great difficulty.

In that way the scale modelling is a recourse for hydraulic engineering practical problems to the best qualitative solution and quantitative also to a great extent, specially for river engineering problems. The behavior of river, river system, estuary and coastline is very erotic and complex. The solution of river mechanics boundary are largely guided by

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certain boundary conditions, which is very difficult to determine from the prototype conditions. But from the close observation to hydraulic phenomenon in the model, it is possible to determine these boundary conditions with acceptable accuracy.

**What is Scale Modelling**

The uses of scale modelling methods are seen in different fields. An architect at first resorts, makes a model of a building or any structure which he has dreamt before going to design it or make it in practice. Practically, all modern airplane design is based on wind tunnel experiments, in which models of planes or parts of planes are fixed in a conduit through which air is propelled at high velocities.

Scale modelling is a way of investigation of a system or a structure or an objective substance and prediction of its exact behavior of the actual system by making it into a greater or smaller shape by means of scaling up or down.

Thus scale modelling in hydraulic problem is to make a small physical representation of an overall system or a section of the problem area to get the possible post effects, the interactions of different physical phenomena, which would be in existence in the system.

**Basis of Hydraulic Scale Modelling**

The principles on which the scale modelling approach is made are based on the theory of hydraulic similitude. Two physical systems of different size in which one accurately reproduces the phenomena of the other, are called the similar systems. It may be noted that if the systems are of the same size one is called a relics of the other. So here is not the question of similarity because the two systems are the same in all respect. Similarity then occurs, only of one system accurately reproduces the other. This means that the same particular laws apply to both systems and that equations written for a system must be equally valid for the other.

Similarity is a general term, exists between model and prototype, may take three different forms: geometric, kinematic and dynamic.

- Geometric similarity implies similarity of forms. A model is geometrically similar to the prototype if the ratios of all homologous lengths in model and prototype are equal.

- Kinematic similarity implies similarity of motion. Kinematic similarity of model to prototype is attained if the paths of homologous moving particles are equal.

- Dynamic similarity implies similarities of forces. A model is dynamically similar to the prototype if it is kinematically similar and if the ratios of homologous moving masses and of the forms producing motion are respectively equal.

**Brief History of Hydraulic Scale Modelling**

There is an evidence that Leonardo da Vinci studied principles of hydraulic design by means of small models of structures and machines. Later, the model study became very popular and useful in the construction of modern ports and harbors around the world. In Bangladesh part of the British India, Asam Bengal railway made scale model study to the construction of chittagong port. The physical model for Hardinge bridge was conducted at poone, India. Later, a very famous Institute for Hydraulic Research was established at Poone.

Now a days, with the invention of computers, mathematical model study came into use. But it is not exactly the replacement of the physical model study. The physical model is still reliable and popular.

**Classification of Model**

Depending on scale condition, model may be classified into two types. a) Undistorted model and b) Distorted model.

a) Undistorted model : When all the geometric similarity requirements are fulfilled in a model or if a model is perfectly similar to its prototype then the model is said to be undistorted or true scale model. Results obtained from this type of model are quantitative and can be used successfully in the prototype problems.

b) Distorted model : In some model studies, particularly of open channel flow, geometric similarity would result in too small a depth of flow in the model . It is then necessary to make the vertical scale of the model larger than the horizontal scale. The model is then said to be distorted. For example, if one model has horizontal scale ratio is 1:50. Then the distortion factor should not be greater than 5. The lower the distortion factor, the greater the accuracy.

Again depending on model bed formation, model is said to be of a) Fixed bed model & b) Movable bed model .

a) Fixed bed model : Fixed bed model is designed with Froud's model law to hold strict dynamic similarity under the framework of rough turbulent flow. The fixed bed indicates that the sediment movement and bed forming processes are out of concern in designing this type of model.

b) Movable bed model : The name movable bed implies that in this type of model due attention should be paid to sediment transport, deposition and bed-forming processes. To fulfill the similarity requirements regarding bed load movement, it is normally found to use light-weight material such as backlite dust, coal dust, saw-dust etc.

**Theoretical Aspect**

In any hydraulic system, there are many inertia and active forces. But the presence of the number of forces and their degrees entirely depend upon the kind of fluid, the overall system, where and through which the fluid passes . In hydraulic engineering especially in open channel flow only the concerned fluid is water. Here, the force of inertia and the force of gravity can be considered to be the only forces which control the motion, when the similarity is made considering those two forces between model and prototype which is called Froudian similarity .Froudian similarity occurs when the ratio Froudes number in the model and Froudes number in the prototype is unity.

$$Fm=Fp$$

Where Fm= Froudes number in the model
Fp = Frodes number in prototype

Froude's number is defined as the ratio of inertia force to gravity force. Mathematically it can be expressed in the following way

$$F=\frac{V}{\sqrt{gL}}$$

where V = velocity , L characteristics length, in open channel it is hydraulic depth D.

**Scale Selection**

It is usually desirable in hydraulic model studies to express the ratio of all quantities involved in terms of geometric scale ratios.

Scale can be derived from Froude's model law (Rouse et. al. 1950) is given below:

$$\frac{V_m^2}{g_m L_m}=\frac{V_p^2}{g_p L_p}$$

where, $V_m$= Velocity in model
$V_p$= Velocity in prototype

$L_m$= Characteristic length in model or Hydraulic depth in open channel
$L_p$= Characteristic length in prototype or, Hydraulic depth in open channel
$g_m$ and $g_p$ are acceleration due to gravity in model and prototype

Then

$$\frac{V_r}{\sqrt{g_r L_r}}=1$$

i.e Velocity scale ratio

$$V_r=\sqrt{L_r} \qquad g_r=1$$

where

$$L_r=\frac{L_p}{L_m}$$

$L_r$= Length scale ratio and

$$V_r=\frac{V_p}{V_m}$$

Discharge scale can be derived from,

$Q_r= A_r V_r$
$Q_r=Lr^{5/2}$ for undistorted model
$Q_r=L_v L_r^{3/2}$ for distorted model,
Lv= Vertical scale ratio in distorted model

Time scale $T_r$ can be expressed

$$T_r=\sqrt{\frac{L_r}{g_r}}$$

if $g_r=1$, $T_r=\sqrt{L_r}$

**Points to be Remembered During Selection of Model Scale**

- Froude's number in the model and in the prototype must be the same to hold strict dynamic similarity.
- Flow in the model must be rough turbulent to avoid the effect of viscous force in the model.

- Depth of water in the model should be sufficient for convenient measurements of velocity and scour etc .

**Method of Construction and Testing**

For construction of model the following procedures are followed :

- A model bed is chosen which is made of fine sand or other finer materials like coal dust etc. Generally sand is used.

- A geometric scale is selected in such a way that the whole problem area is accommodated within the model bed with an optimum scale.

- Bathymetric data is converted to model dividing the prototype values by geometric scale ratios. Cross sections are reproduced in the model by inserting pegs into the sand bed and bed level are provided by levelling instrument.

- Normally co-ordinate method is used to make layout on the model bed with respect to two reference lines as X-axis and Y-axis.

- Some portion in the upstream and downstream is made with a fixed bed for velocity distribution and adjustment.

- Discharge and water level data are needed at a certain cross section for maintaining exact flow condition in the model. In the model Wel gauge is provided to maintain the water level. At least two wel gauges are required to determine the slope.

- Downstream tailgates are used to maintain the desired water level at the specified section.

- A supply sump and a delivery sump are needed to ensure continuous flow of water.

- A measuring device usually sharp crested weirs with point gauge are required to measure the inflow water.

- An approach channel is made to ensure uniform flow at the upstream boundary of the model.

- To verify the model measured prototype velocities are necessary along a certain cross section within the area to be modelled.

**Testing**

- Point velocities are measured at different points at a regular interval usually at 0.5 m interval in the model.
- Flow lines are recorded by float tracking. Wax ball, little bottles etc are used for float tracking so that they can move keeping a greater portion of their length below the water surface and consequently wind effect is reduced.
- To measure the local scour and deposition at different sections are chosen on and around the protective structure and the measurements are taken from a reference string at every hour until equilibrium scour is reached. Finally readings are converted to bed elevation in m PWD.
- Shape and size of the Scour is measured by depth contour.
- Water levels are measured from upstream and downstream well gauges to determine the water surface slope.

**Importance and Use**

The use of large hydraulic models to aid the solution of major problems in River engineering, and to assist in planning the development of estuaries, harbors and coastal areas, has increased considerably in recent years. As the engineering projects have become progressively more comprehensive, so have the associated models increased in size and complexity until today a model might cover a floor space of hundreds of square meters.

The principles of hydrokinetics developed mathematically are based on assumptions. But the accuracy of the results obtained by their application to practical engineering problems frequently depends on experimental data obtained in field and laboratory. From determined boundary conditions the hydraulic modeling can be used to have reliable solution from the mathematical treatment of the problem. Even some river related problems are still existing beyond the possibility of mathematical solution, such as behavior of three dimensional vortex in the vicinity of a local scour hole, but this problem can be understood and solved more accurately by hydraulic modelling.

**Conclusion**

The behavior of one place of a river may not be the same for the other places and also the behavior of one river must vary with the other river. Again any problem caused in one river reach can not be solved by the same experience applied to the other river with same problem. So, for solution of problems, the design parameters of hydraulic structures can be optimised by the help of scale modelling. Normally, hydraulic structures such as bridge, culvert, barrages, groynes, revetment etc, are constructed within the domain of rivers. These structures are very expensive. So, such important and expensive structures do not permit an error in design or misinterpretation of actually prevailed condition in the field. Therefore, with the help of hydraulic modelling within limited constraints, the possibility of misinterpretation of design parameters can greatly be reduced or even eliminated. Thus hydraulic modelling helps to avoid risk and financial losses which may arise from the failure of structure due to improper design.

Sometimes, hydraulic modelling helps to reduce the cost of a structure. Due to uncertainty of parameters, the designer keeps a large safety factor making the structure more expensive. But once the better understanding of the process and certain behavior of the design parameter is attained by hydraulic modelling, the designer can change or reduce the size, spacing and orientation etc. of the structure with confidence and consequently the cost will be reduced.

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# Environmental Pollution : A Scenario of Bangladesh

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## Abstract

*With the increase of population as well as industrial and agricultural activities in the world, the pollution problem is also increasing day by day. Particularly developing countries like Bangladesh, where the population density is very high and the industries and agricultural activities are growing without proper care of environment, the pollution problem is immense. The cause and nature of pollution in different compartment of environment as well as the impact of pollution on entire ecosystem is discussed in this paper.*

## Introduction

Pollution means the presence of undesirable substances in any compartment of environment such as air, water and soil. The cause of pollution is mainly due to the discharging of waste products or bye-products and harmful secondary products in the different compartment of environment from different anthropogenic i.e. human activities.

The earth has created million years ago. Although the existence of human beings is not as old the earth yet the presence of them has brought revolutionary changes on the earth. Man has proceeds through the ice age, the stone age, the medieval age, the age of renaissance and has stepped into twentieth century which can be regarded as the age of innovation and dynamism. It is this epoch man has invented medical and technical devices and has brought about major revolution in scientific development. With the constant creation and availability of new and better amenities such as housing, clean water and food. The life expectancy has increased while the mortality has drastically decreased leading to rapid increase of population in several folds In order to sustain this large population lots of lands for housing, food, fuel and timber are needed. More and more coal petroleum metal ores, bricks, cement fresh and clean water for drinking, domestic, industrial and irrigation water are being used. These are not only causing reduction of natural resources but also degrading our surrounding environments through extinction of wild life, pouring toxic chemicals including many non-bio-degradable one's in the different of environment such as water, air and soil. Now, the fundamental questions have been raised whether the globe could support the rapidly growing population and whether the technology itself is appropriate. So, pollution is now one of the main issue confronts our earth. But it seems that we are not fully aware of its results. Particularly in developing countries different types of chemicals, pesticides, industrial

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hazardous waste as well as domestic wastes are increasingly released into the different compartments such as water, air and soil that may adversely affect the interest of our future generation. So, environmental issues should be rather closely examined to ensure a better and balanced development so that the long range interest of mankind is not ignored.

**Environmental Pollution**

**Water Pollution**

Water is the most abundant and essentially required element in the earth. In pure state, it contains traceable amount of different dissolved minerals. As it is one of the best solvent of different elements and have unique physio-chemical characteristics so it gets easily polluted by dissolving different substances.

Water pollution means the presence of undesirable foreign substances either in dissolved or in suspended state which are harmful to life and reduce its utility value. The foreign matters in water normally present in three states such as dissolved, colloidal and suspended. Among them, impurities in the dissolved state are gases like $CO_2$ and $SO_2$ from atmospheric origin, cations like sodium, potassium, calcium, iron, arsenic and anions like chloride, sulphate, carbonate, nitrate from edaphic origin and decomposition products like hydrogen sulfide and methane etc. and colloidal and suspended contaminants like dusts, clay, sand, bacteria, viruses, algae, organic coloring materials from atmospheric, edaphic and biotic sources.

Physical state of aquatic pollution is in forms of color, turbidity, odor and temperature. Color of water is due to the presence of suspended/colloidal and dissolved particles in water known as apparent and true color respectively. The presence of algae in water causes green color of water. Excessive growth of algae which is known as eutrophication causes large variation of pH and dissolved oxygen in water resulting in fish killing. The excessive growth of algae also leads to increase the amount of dead materials results deficiency of dissolved oxygen as it is used by the decomposer organisms. Other suspended/colloidal particles like clay imparts apparent color of water and reduce light penetration into the water which affects oxygen regime of the water body. On the other hand, true color is due to the presence of dissolved particles like humic acids which is a decomposition product of organic matters, effluents from leather, carpet and textiles factories etc. These affects the light penetration in water body and normal functioning of the aquatic ecosystem. The color imparting ions are also chemically toxic in nature. Further, slightly colored water is not acceptable for domestic purpose whether polluted or non-polluted. Turbidity of water is mainly due to the suspended solids in water. Like coloring substances, it affects light penetration in water body and causes disinfection problems of pathogens organisms as they escape in the suspended solids. Odor and taste of water are mainly due to decomposition products of organic matters from sewage, dead plankton, higher form of plants and animals. and secondly from to waste discharges from industries which contain different types of chemicals. Generally chlorine is added to drinking water to disinfect it from bacteria and other microbes. This chlorine also has some effect on taste and odor of water. Again chlorides and sulphates of sodium, potassium, calcium, magnesium and iron cause odor and taste when the concentrations are increased in water. Like color, turbidity and odor temperature has also some negative impact on water quality. This effect is mainly due to the discharges from the industries, because most of the industries use nearby water bodies for cooling purpose. This results lowering of dissolved oxygen concentration as dissolved oxygen concentration in water decreases with the increase of temperature. In addition, the rate of decomposition of organic matters increases with the increase of temperature. So, rapid depletion of dissolved oxygen concentration results higher temperature. This causes problem not only for fishes and but also it may change the whole aquatic ecosystem. Again temperature stratification in a deep water body causes no circulation of water along vertical. In that case, the dissolved oxygen concentration in the *hypolimnion* will be less and that zone may turn into anaerobic and it may cause foul odor during upturning.

The cause of chemical water pollution is the presences of numerous types of substances such as different dissolved solids, acidity, alkalinity, $CO_2$ and other gases, metals like chromium, arsenic, lead, copper, iron, manganese, mercury, cadmium etc and anions like sulphate, nitrate, phosphate, chloride, fluoride, ammonia etc. Organic chemicals like sugar, starches, fat, protein are also causes pollution upon decomposition. In addition, different synthetic chemicals in form of pesticides, non-biodegrading chemicals and radio-active substances reaching water bodies are also causing pollution.

Acidity is the aggregate property of water due to the presence of several specific substances mainly dissolved $CO_2$. According to American Public Health Association (1985) it is a quantative capacity to react with strong bases and designated as pH as reported by Ambasht (1990). pH is one of the most important regulating factor in biological and bio-chemical reaction including decomposition of dead organic matters. The speed of reaction is also depends on pH. Normally most of the species in the aquatic environment are adopted in a narrow range of pH and a slight change in pH may adversely affect them. Sculthorpe(1967), as reported by Ambasht(1990), regarded that pH is even a more critical parameter than dissolved $O_2$ for survival of aquatic plant and fishes. At low pH water become corrosive, causes metal corrosion and subsequently release in the aquatic environment. pH of water is considerably affected by variety of industrial effluents such as detergents, solvents, acids, alkalines, salts and washing from agricultural industries etc. On the other hand, alkalinity is the property of neutralizing acids. It occurs in the ground water due to the presence of lime stone in the earth crust. In addition, phosphates, borates and silicates also contribute some alkalinity in water. Excess alkalinity causes encrustation on soil surface, if encrustation is heavy then it adversely affects plants.

Total dissolved solids are mainly inorganic minerals and some organic matters such as chlorides, carbonates, nitrates, phosphates and sulphates of different cations. Excess dissolved in water mainly causes taste in drinking water, salinity of soil, encrustation on soil surface on evaporation, scale formation on boiler and *eutrophication* in aquatic system.

The presence of organic matters particularly cause oxygen depletion in water. Because micro-organisms use oxygen for the decomposition of organic matters. If excess organic matters are present, it may cause anaerobic condition of the aquatic system. More organic matters means more organism, so water is more polluted. There are some organic matters mainly the synthetic organic one's which aren't decomposed by organisms and normally deposited on the bed of aquatic system.

Heavy metals are normally the main concern of water pollution. The density of metals greater than five are classified as heavy metals. Most of the heavy metals are present in water in small amounts. But the main sources of these heavy metals are different anthropogenic activities such as industrial wastes and other human activities and find their way in different water bodies thus enter terrestrial plants and man through food web. Most of the heavy metals such as mercury, cadmium, chromium, arsenic, lead, copper etc are very toxic. Even a lower concentration may cause serious problem to man, animal and plants. Mercury is a rather scare element in the earth crust but it is widely used in different industries such as battery, fluorucent lamps, thermometer etc and found in aquatic environment around many industrial big cities. It is very poisonous to all kinds of life. In 1953, the mercury pollution in form of methyl mercury which is soluble in water in minamata bay in Japan caused the death of 53 lives and several others paralysed. Lead is also a very poisonous and has a property of getting accumulated in increasing concentration in the body of organisms. It affects bone marro, formation of blood hemoglobin, and replace calcium bone. The sources of lead pollution in the atmosphere are automobiles, PVC pipes and batteries etc. Arsenic is also a quite toxic heavy metal reaching water bodies from mining activities, waste water of ceramic industries tanneries, fertilizer factories and pesticides. It is found both in inorganic and organic compounds such as sodium arsenate, arsenic tri oxide mono sodium methane arsenate which are widely used as herbicides and insecticides. Arsenic causes different problem in man and animals such as reduce apatite and body weight, stomach and skin disorder. Other toxic heavy metals such as chromium, copper and cadmium come to aquatic system from various industrial activities such as cadmium from electroplating, vinyl plastic, metallurgical industries and minewaste, chromium from tanneries, dyeing, electroplating and ceramic industries whereas copper from water supply pipeline, chemicals and pesticides. pollution of these heavy metal cause immense harm to both man and plant. Cadmium pollution causes hypertension, lung and liver cancer and retard growth of plants, hexavalent chromium which is very toxic in nature causes bronchial cancer, yellowing of leafs of wheat and paddy. Though certain amount of copper is necessary for plant and animal but excess cause harm such as retardation of growth.

Among the anions chlorides, phosphates, ammonia, nitrate, hydrogen sulfide have some damaging properties on water. Chlorides which are normally abundant in marine and coastal areas cause salty taste of drinking water when concentration exceeds 200 mg/l. High chloride content irrigation water gradually leads to accumulate salts and adversely affect soil property. Some derivatives of sulfur such as sulphates and $H_2S$ are the important constituents of hard water in form of calcium and magnesium sulphates. $H_2S$ causes foul odor and also toxic to organisms. Nitrogen in its different forms are also of much interest of aquatic system. Though it is an important constituents of all living things but the presence of excess amount causes pollution. Nitrogen fertilizer is used for food production but excess amount of fertilizer not only pollute surface water through agricultural run-off but also cause ground water pollution through infiltration. Agricultural runoff with high nitrogen content causes eutrophication of surface water. Ammonia in water is formed by decomposition of certain organic matters and hydrolysis of urea cause depletion of dissolved oxygen concentration of water upon oxidation. This is normally found in water body receiving wastewater from fertilizer factory. Nitrate is particularly toxic to babies which cause *methemoglobinenia*.

A large variety of chemicals have been used in agriculture to kill undesirable weeds, insects etc. These chemicals are collectively called pesticides such as organic phosphorus compounds, chlorinated hydrocarbons, arsenic compounds and rodenticides etc. These are synthetic compounds and most of them are non-biodegradable and very toxic in nature. The main sources of pesticides are surface runoff from agricultural fields, sewage and industrial effluents. Though these pesticides meant to kill a very narrow range undesirable organisms yet these are capable of harming other non-target organisms of aquatic ecosystem. Some of them are persistent like DDT and accumulated in the body aquatic organisms and reaches to the body of higher trophic level through food web. So, higher concentrations are found in the fat tissue of those higher organisms which is known as bio-accumulation. Bio-accumulation severely affects liver and brain and even it may cause death of lives.

In addition to the chemical compounds, the organisms like bacteria, virus and other higher animals are called pathogenic organisms and these organisms also cause pollution to the aquatic system. These are mainly come from external inputs such as sewage, effluent from sugarcane industries, paper and pulp industries. These pathogenic organisms like fecal coliform, fecal streptococcus, shigella etc cause dread diseases sometimes in the form of epidemics when infected water is used for drinking purpose.

**Air Pollution**

Atmosphere is the gaseous cover of the earth surface. It consists of mixture of gases such as nitrogen, oxygen, carbon di oxide. In addition, it contains numerous numbers of gases in trace and particulate matters such as dusts, pollen grains, bacteria and viruses etc. But in urban areas it is very difficult to get clean air. There are several foreign matters by human activities such as from industrial chimney, dump of decomposing waste, smoke from railway engines, automobiles, aeroplanes and radio active contaminants from nuclear fuel. Whenever these emissions mixed in air, it adversely affects life of plants, animal and human life and even the buildings and other properties by excessive concentrations, lethal or toxic nature, we regard it as a case of air pollution. Common gases those cause air pollution are $CO_2$, CO, nitrogen oxides, $SO_2$ etc. CO is one of the noxious gas is formed by the incomplete combustion of fossil fuels like coal, petroleum and other organic matters. Automobiles are the most common source of CO pollution. Other common sources are refineries, metallurgical operations and internal combustion engines. It is one of the major pollutant of man and other animal life because inhaled CO combines with haemoglobin of blood much faster than oxygen and cause severe problem in respiration and even death of life. On the other hand $CO_2$ forms from complete combustion of fossils fuel. Though it is used in photosynthetic process for the production of foods for the plants yet it has adverse effects on global climate. $CO_2$ and some other gases particularly the water vapor in the atmosphere has the ability to allow solar radiations to pass through and reach ground surface but on reradiation, the outgoing waves are held up by these gases. This causes increase in temperature of atmosphere resulting in melting of ice in poles and hydrologic cycle may be changed. This may cause rise in water level in the oceans. So, low lying areas near offshore may be inundated. This phenomenon is known as "Green house Effect". Other than $CO_2$ and water vapor, there are gases particularly CFC's play an important role on "Green House Effect". CFC's which are mainly used in refrigeration and plastic industries reacts with $O_3$ layer in the stratosphere causing depletion of $O_3$ layer thickness which acts as a shield to absorb ultra-violet rays of solar radiation.

$SO_2$ is the second most abundant gas to CO and accounting for 20% of air pollution. It is emitted into the atmosphere by some natural and mostly from man made sources such as thermal power plants, metallurgical operations, oil refineries etc. Coal and crude petroleum also contains some quantity sulfur compounds which is converted to $SO_2$ upon combustion. One of the most important air pollution of sulfur di oxide is reaction with atmospheric moisture and formation of sulphurous and sulfuric acids which come down to earth with rain water is known as acid rain. $SO_2$ is injurious to both man plant. It stings the eye, causes a burning sensation in throat and respiratory problems. It also adversely affects the plants such as growth, flowering, nutrient cycle, pollination and seed formation.

Nitrogen oxides collectively are called $NO_X$ are also common air pollutants. These are principally omitted from burning of fossil fuels such as petroleum and diesel and partly as a result of oxidation of atmospheric nitrogen under the high combustion temperature of the factory furnaces and oxidation of atmospheric ammonia by thunderstorm. Although the emission of $NO_2$ from coal burnt is less than $SO_2$ but it is higher in petroleum and diesel driven transport. High concentration NO2 is lethal as it combines with haemoglobin of blood thousand times faster than $O_2$ and cause internal bleeding, oxygen deficiency and possible pneumonia and lung cancer. Peroxytal nitrate or PAN is a secondary pollutant forming smog by the action of light on hydrocarbons and nitrogen oxides. The smog has found to be cause of death of human beings. In 1952, the death of 3 to 4 thousand persons were occurred in London. It is also very toxic to plants because it enters through stomata and reduce photosynthesis rate through injury of chloroplast, inhibition of electron transport and interference with enzyme system connected with photosynthetic activity. Again a yellow grey smog forms in presence of light between action of hydrocarbon and $O_2$ where $NO_2$ acts as an catalyst produce oxidized hydrocarbon and ozone. The resultant mixture of such photochemical reaction form smog . This smog is highly irritant to eye and throat. Persons having occupational exposure to $O_3$ suffers from reduced eye sight, chest pain, headache, chronic bronchitic asthma etc. It is abundant in a traffic jam places and in industrial areas.

Hydrocarbons like methane, ethane, propene, isobutane are also abundant in atmosphere. Though hydrocarbons in trace amount are useful for plants but in pollution load level it is injurious to plants. Hydrogen fluoride is also an important air pollutant comes from combustion process of fossil fuels and aluminum industries. Although the amount of hydrogen fluoride is far less compared to $SO_2$ but it is rated as pollutant because of its pollutant nature. Plant photosynthesis and respiration reduce and problems like chlorosis discolorisation are common injury due to presence of fluoride.

In addition to the gases, there are also several minute particles that keep floating all the times like pollen grains, fungal spores, bacteria, viruses, fine carbon particles produced from forest fires, soil dust, coal dust from factory chimney, cement dust asbestos dusts etc. The common name of these particulate matters is aerosol. The size of aerosol is below 1 micron. Larger than aerosol particles i.e. above 1 micron are called dust for solids and mists for liquids. Industrial activities, mining, metallurgical operations produce lots of metallic and non-metallic dusts such as lead, zinc, copper, cement, asbestos etc. Among the particulate matters causing air pollution, lead is on of the most poisonous element. It is used in petrol as an anti-knock element. Even a small amount of lead can be harmful to human particularly for young children, it affects brain. Asbestos is also proved carcinogenic to lung. Cadmium aerosols settle with rain on plants and through food chain it reaches man and animal. It causes several problems to man like cardiovascular problems and hypertension and in plant like chlorosis and root injury. Similarly, mercury and copper aerosols are also important pollutant cause air pollution.

**Soil Pollution**

Soil is the weathered top surface of the earth crust constituted by mineral matters (sand, silt and clay), organic matters in different composition(humus), micro-organisms(bacteria, viruses, fungi) mixed together and the pores are filled with water and air. Soil is the medium of anchorage and supply of nutrients for the plants and in turn plants are the ultimate source of food for the man and animal. So, soil is the basic and most important life support component of biosphere. But the soil is polluted in several ways such as by: air borne sources and by using excessive chemical fertilizer, pesticides etc. Air borne particles such as fumes emitted by factory chimney slowly deposited on the soil. Sulphur particles present in atmosphere responsible for acid rain resulting in lowering of pH of soil. Chloride, nitrogen oxides and other gaseous pollutant combines with water and pollute the soil.

Now a days a number of synthetic chemicals are used to prevent foods from different kinds of pests which are commonly known as pesticides. These are very toxic in nature and adversely affect the growth of soil micro-organisms which are responsible for the decomposition of organic matters present in soil matrix. This upset the natural rate of decomposition and soil fertility is badly affected.

**Scenario of Bangladesh**

Bangladesh is a densely populated country in the world. Per capita income of the people is also very low compared to the most of the countries of the world and more than half of the people are living below the poverty line. So, due attentions are not paying to the environment mainly due to financial constrains. But environmental pollution problems are increasing day by day with increase in development.

Most of the water bodies particularly those are situated near big cities such as Buriganga, Karnafuli, Bhairab and Surma etc are very polluted. In rainy season, the flow of the rivers/water bodies are high. So, water pollution is not so acute due to effect of dilution. But in winter season it is really a matter of concern as flow into the water bodies is very low. Domestic sewage and industrial waste effluents are being discharged into water bodies without treatment which causes rapid depletion of oxygen content in the water bodies. Even anaerobic condition prevails in some reaches of the water bodies. This results foul odor and scarcity of fishes in those reaches during winter season. Though, in the rainy season the effect of dilution abate water pollution, flood water spreads pathogens from untreated wastewater over a large area causes epidemic of diarrhoea, cholera, dysentery etc when drinking water is infected by the untreated sewage water. Fishes grown in polluted water or contaminated by inflow contamination may also ingest pathogenic bacteria and it may also cause of sickness. Some important parameters related to water quality are shown in Table 1.

Table 1: Guide line value of some important water quality parameters for drinking water and impacts if present in excess amount.(WHO Water Quality Guideline, 1993; Bangladesh Standards for Drinking Water, 1990.)

| Parameters | Guideline Values | | Impacts |
|---|---|---|---|
| | WHO | Bangladesh Standard | |
| Chloride (mg/l) | 250 | 200-600 | Taste, Corrosion. |
| Ammonia (mg/l) | 1.5 | | Odor, taste. |
| Iron (mg/l) | 0.3 | 1.0 (Urban area)<br>5.0 (rural Area) | Staining on laundry and sanitary. |
| Manganese (mg/l) | 0.1 | 0.5 | Staining on laundry and sanitary. |
| Arsenic (mg/l) | 0.01 | 0.05 | Skin cancer |
| Fluoride (mg/l) | 1.5 | 0.6 - 1.2 | Fluorosis in teeth. |
| Nitrate (mg/l) | 30 | 45 | Methemoglobinenia |
| Coliform (per 100 ml | <1 | <1 (max. 4) | Gastrointestinal diseases. |

In Bangladesh, most of the industries and chemical factories are operating without proper care of environment. These are discharging waste to the nearby water bodies with out treatment. This causes severe chemical pollution of the water bodies. This is not only affected surface water but also the ground water infiltrating through soil horizon. For example, the tanneries in Hazaribag in Dhaka city use chromium compounds for processing of leathers. Some chromium compounds used in leather processing find the way to the Buriganga river through wastewater effluent which causes severe pollution of the Buriganga river. Some of wastewater also infiltrates through soil. Investigation on ground water pollution of that area reveals that chromium pollution that infiltrates through soil is not yet reached to the water table due to the thick underground clay layer. But it is apprehended that once this pollution reaches the ground water, it will take long time to stop pollution even there is no infiltration of wastewater. Because the leaching of water through clay layer is very slow. This may result a horrible situation in Dhaka city as groundwater is the main source of water of about 10 millions of the city. Other industries are also polluting the water bodies indiscriminately and most of the cases the adverse effects go unnoticed because of limited availiblity of data. Farmers of our country are using fertilizer and pesticides indiscriminately to increase the food production. So, huge amount of fertilizer and pesticides are not only misusing but also polluting surface and ground water bodies through surface runoff and infiltration through soil respectively.

Most of the automobiles and industrial chimneys in Bangladesh have no environmental standards. These are releasing black smog in the atmosphere which may contain noxious gases like CO, nitrogen oxides which is very harmful to different life. These are also releasing harmful particulate matters in the environment but most of the cases there is no control. So exhaustion from these installation causes respiratory and other severe diseases which is more common in big cities. Most of the brick fields of our country are using coal for burning bricks which emits gas like $SO_2$ and nitrogen oxides in the atmosphere. Particularly, the Dhaka city is surrounded by several brick fields emit $SO_2$ and nitrogen oxides in the surrounding areas which is very harmful to man, animal and plants. So, people may suffer eye irritation, respiratory problems, heart diseases, diabetes, cancer etc. Solids wastes are also scattered in many open places in our country. This is not only cause the foul odors in the surrounding areas but also spreads pathogens and other harmful matters upon dry up.

Many climatic study suggest that Bangladesh could possibly a worst victim of *Global Warming* as the temperature of the globe is increasing with the increase in consumption of coal and fossil fuel. So, low lying areas near offshore i.e. two-third of our land may be inundated due to the so called *Green House Effect* though the per capita contribution of Green House Gases is one of the lowest in Bangladesh.

Overall soil quality of Bangladesh is also degrading due to indiscriminate use of fertilizer and pesticides. The mineral balance of the soil becomes distorted. Again the essential micro-organisms for decomposition of organic matter are also adversely affected by the use of excess fertilizer and pesticides.

## Conclusion

Most of the people of Bangladesh deprives of basic needs such as food, housing, education, Medicare facility etc. for survival. So, it is necessary to set up more industries to accommodate large number of unemployed people and to increase agricultural activities for growing more food. There will certainly have some impacts on the development activities. Now if stringent environmental regulations like developed countries are imposed, it will be very difficult to maintain such standards in the perspective of Bangladesh. Because enterprenuers will not be interested to invest because of additional costs of their products. But the environment have to be saved for existence. So, some pragmatic steps may be considered to reduce extent of pollution. Firstly, a flexible environmental regulation may be followed for different seasons, for example, the standards of different pollution discharges may be different in winter and rainy season because of higher dilution effect in later case. Secondly, regulations should be imposed in such a way that a nominal price have to be paid for treatment which may save the environment in a greater extent without hampering development activities. So that, a very less amount to be paid in future for the salvage of environment. Thirdly, more environmentally friendly development technologies should be promoted to save environment and last but not least is that a data base should be established for different environmental parameters. It will not only helpful to predict the extent of environmental damage but also to take possible protective measures.

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# Laboratory Investigation for the Estimation of Discharge Loss Due to Friction and Initiation of Sediment Transport in a Current Flume

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**Abstract**

*This paper discusses some basic theory of open channel flow and initiation of sediment transport in a current flume based on the results and findings of different tests carried out during a training course at Danish Hydraulic Institute (DHI) in Denmark participated by the author and other personnel from RRI. In the first part of the current flume study, the velocities at different depths were measured and their distribution profiles, bottom roughness, friction velocity, mean velocity and surface velocity were determined in order to compare measured discharge with known discharge. In the second part, the initiation of sediment transport in the current flume and possible scour around a pile structure was investigated. For a fixed bed flume the obtained results shows that friction on the sidewalls cannot always be neglected and the friction on both side walls are identical. The measured discharges were 12% and 3.5% higher than the read discharges in tests no. 1 & 2 respectively. Obviously, the latter appeared as better result. The loss of discharge due to friction on the side walls was found 7% compared to the discharge calculated from velocity distribution in the middle of the flume. For a mobile bed flume scour was developed much earlier with structure than without structure due to local increase of velocity around the structure.*

## 1. Introduction

The current flume study deals with some basic theorem of open channel flow and sediment transport. The main purpose of the first current flume study was to measure the velocities at different depths with known discharge, to draw velocity distribution profiles, to calculate bottom roughness "k", friction velocity "$U_f$", mean velocity "v" and to compare mean velocity with surface velocity and measured discharge with known discharge.

The purpose of the second test was to calculate Shield's parameter, and Reynolds number (R) in order to study the initiation of sediment transport in the current flume and to illustrate the mechanism of scour around a pile structure.

## 2. Description of the current flume

The flume was 22.45 m long, 60 cm wide and 100 cm deep having 22 sections. One side of the flume was fitted with glass plate to have clear view of inside of the flume.

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A recirculatory water system was fitted with the flume. The discharge Q was measured in the recirculated water pipe by means of magnetic flow meter.

During study 1 & 2, the bed of the flume was made of concrete i.e. the bed was fixed. After the first two tests, a sediment pit was introduced in the current flume. The dimension of the sediment pit as shown in Figure 7.

A recirculated water system fitted with the flume as in test no. 1 & 2 to see the initiation of sediment and to calculate $\theta_C$. After this test the sediment was again constructed and a pile construction was introduced in position I and position II to see the initiation of sediment and scouring which is shown in Figure 8.

## 3. Test results of current flume tests with fixed bed

### 3.1 Test No-1

Mini OTT current meter was fitted in the middle of the section of the flume as shown in Figure 1. Velocities were measured at different depths from the bottom.

Velocity distribution profile was drawn as shown in Figure 2. Bottom roughness "k", Friction velocity "$U_f$", Mean velocity "v" and theoretical discharge were calculated. The mean velocity of the theoretical velocity profile calculated from measuring points 1 & 4 (cf. Table 1) is 0.39 m/s resulting in a measured discharge, $Q=0.089m^3/s$. The discharge read on the flow meter is, however $Q_1=0.0795m^3/s$. This means that the discharge evaluated by velocity measurements is about 12% too high.

The measured velocities are presented in Table 1.

**Table 1:** Measured velocities

| Points | y (cm) | u (cm/s) |
|---|---|---|
| 1 | 03.2 | 32.4 |
| 2 | 08.5 | 37.5 |
| 3 | 13.5 | 39.1 |
| 4 | 18.5 | 39.9 |
| 5 | 23.5 | 39.6 |
| 6 | 33.5 | 39.5 |
| 7 | 22.8 | 39.8 |

### 3.2 Test No 2

Mini "OTT" current meter placed at a distance of 3 cm away from the right wall of the flume and velocities were measured at different depths with known discharge $Q_2$. Then the current meter was placed at a distance of 10 cm & 30 cm away from the right wall of the flume respectively as shown in Figure 3. Velocities were measured at different depths from the bottom as presented in Table 2.

**Table 2:** Measured velocities u in cm/s

| b cm / y cm | 3 | 10 | 30 |
|---|---|---|---|
| 3 | 20.7 | 22.9 | 26.3 |
| 5 | 22.6 | 25.6 | 28.6 |
| 10 | 25.7 | 28.2 | 31.3 |
| 20 | 27.1 | 30.4 | 32.5 |
| 30 | 26.9 | 30.1 | 32.0 |

Velocity distribution profiles are drawn as shown in Figure 4.

Bottom roughness "k", friction velocity "$U_f$", mean velocity "v" & theoretical discharge were calculated. The values of $U_f$, k & v are shown in Table 3.

**Table 3:** $U_f$, k & v for the theoretical profiles through points 1(y=3 cm) and 4(y=20 cm) in distances b=3 cm, b=10 cm & b=30 cm from side walls

| | b = 30 cm | b = 10 cm | b = 03 cm |
|---|---|---|---|
| $U_f$ (cm/s) | 01.31 | 01.58 | 01.35 |
| k (cm/s) | 00.03 | 00.27 | 00.19 |
| v cm/s) | 32.00 | 28.80 | 26.60 |

The velocity distributions in a horizontal plane are drawn in Figure 5 for the five water depths with y=3 cm, 5 cm,10 cm,20 cm & 30 cm. It has been admitted that the horizontal distribution profiles are symmetric, i.e. the friction of the two side walls is admitted to be identical.

In order to evaluate the global loss of discharge due to friction at the side walls, the horizontal velocity distribution of the mean velocity in the vertical velocity profiles has been drawn, cf. Figure 6.

The loss of discharge due to friction at the side walls is represented by the shaded area in Figure 6. The loss is evaluated to about 7% compared to the discharge calculated from the velocity distribution in the middle of the flume multiplied by the width of the flume.

The actual calculated discharge was $Q=0.077m^3/s$ and when compared with the discharge read on flow meter($Q_2 = 0.075m^3/s$) and it was observed that actual mean velocity and discharge were about the same as the theoretical mean velocity and discharge. The difference form measured and read discharge is of 3.5%.

## 4. Test results of current flume test with mobile bed

### 4.1 General

In order to investigate initiation of sediment transport, a sand pit was introduced in the test flume. The dimension of the sediment pit were:

Length: 1.0 m

Width: 0.6 m (width of the flume, depth=0.05 m)

The test layout is sketched in Figure 7.

After introducing the sand pit in the test flume, the following four test series were made;

**Series 1 :** The discharge in the flume was increased in steps beginning with small discharges. The sand in the pit was observed & the beginning of sediment transport was registered.

**Series 2 :** Repeating (for control) test series 1.

**Series 3 :** A pile structure with $\phi$ = 0.09 m was introduced in the sediment pit in position I (cf. Figure 8).

The discharge in the flume was increased in steps beginning with small discharges. The sand around the pile structure was observed & the scour around the pile was recorded.

**Series 4 :** As test series 3, but the pile structure was moved upstream to position II (cf. Figure 8)

### 4.2 Test results Series 1 and Series 2

The test series 1 started with Q = 0.010 $m^3/s$ and the discharge was increased in steps of 0.005 $m^3/s$. The first sediment transport was recorded for Q = 0.065 $m^3/s$ and the water depth D = 0.373 m. The sediment transport was very little & the discharge was still increasing. At Q = 0.075 $m^3/s$ & D = 0.372 m, the sediment transport was apparent & a velocity profile of the flow was measured.

From this profile, the friction velocity was calculated as:

$U_f$ = 0.0183m/s and v = 0.35 m/s. The Shield's parameter, $\theta_C$ = 0.069 and Reynold's number, R = 5.5 was calculated using the following equations:

$$\theta = \frac{U_f^2}{[(s-1)\,gd]} \quad \ldots\ldots\ldots\ldots(4.1)$$

$$R=\frac{(U_f d)}{\gamma}$$ . . . . . . . . . . . . . (4.2) ( Engelund and Hansen'1972)

Comparing with Figure 9, it is seen that the calculated point (*) is in the area where sediment is moving fast.

The first movement of sediment was observed during the test with Q = 0.065 $m^3/s$ & D = 0.373 m. The velocity profile has not been measured. To evaluate the friction velocity in this case, proportionality between Q and $U_f$ can be admitted since the water depth is almost identical in the two cases. By putting $Q_1$ = Q = 0.065 $m^3/s$, $Q_2$ = 0.075 $m^3/s$ and $U_{f2}$ = 0.0183 m/s, from the proportionality,

$$\frac{Q}{Q_2}=\frac{U_{f1}}{U_{f2}}$$

The value $U_{f1}$ = 0.0159 m/s was obtained and $\theta_1$ = 0.052 and $R_1$ = 4.8 was calculated using equations (4.1) and (4.2).

Comparing this point (x) with Figure 9, it is seen that it lies slightly above the critical curve indicated.

Series 2 was a check of series 1. The first sediment movement was observed with Q = 0.065 $m^3/s$ & the D = 0.371 m. The velocity profile was measured in this situation & is shown in Figure 10.

From this profile, the friction velocity was calculated as:
$U_f$=0.0148m/s, v=0.315 m/s and corresponding values of Shield's parameter and Reynold's number were found as $\theta$ =0.045 & R=4.4.

A check with Figure 9 found by Engelund (Engelund & Hansen 1972) shows that the value $\theta$ =0.045 is very close to the critical value $\theta_C$ = 0.04 which is the initial situation for the beginning of sediment transport.

### 4.3 Test results Series 3 & Series 4

The last 2 test series ( series 3 & 4) illustrated the scour around a pile structure as shown in Figure 8. Two positions of the pile structure were investigated in order to observe the scour pattern around & downstream of the pile structure.

The following was observed: Scour(sediment transport) is developing for discharge Q = 0.040 $m^3/s$. This is much earlier than without structure. The explanation is that the velocity around the structure is locally increased. This has been confirmed by measuring a velocity profile near the pile structure, cf. Figure 11.

The velocity profile is shown in Figure 12. The measured profile shows a clear local increase in flow velocity around the pile structure.

## 5. Conclusion

Laboratory investigation of a current flume was done at technical university of Denmark during the period attended by the author himself and other RRI personnel at DHI in 1989. It is concluded from the fixed bed current flume study that the friction on the side walls can not always be neglected. The friction of the two side walls of the flume is admitted to be identical. In test no.1 the measured discharge was found 12% higher than the observed discharge. The result of test no.2 was better as measured discharge was 3.5% higher than the observed discharge. The loss of discharge due to friction at the side walls is evaluated to about 7% compared to the discharge calculated from the velocity distribution in the middle of the flume.
The initiation of sediment (uniform sand pit of size 0.30mm) transport was observed at the value of $\theta = 0.045$ which is slightly above the critical value, $\theta_C = 0.04$ for Reynold's number R = 4.4. It can also be concluded from the mobile bed current flume study that the development of scour (Sediment Transport) is much earlier with structure than without structure. The explanation is that the velocity around the structure is locally increased.

**Acknowledgement**

The author is grateful to Doris Christiansen- Muhlestein, M. Sc. Civil Engineer, Ports & Marine Structures Department of DHI, Denmark for planning & supervision of the study. The author likes to thank the people of technical university of Denmark, associated with power supply, water supply & instrumentation works. The author would also like to thank the RRI personnel associated with the tests during training in Denmark.

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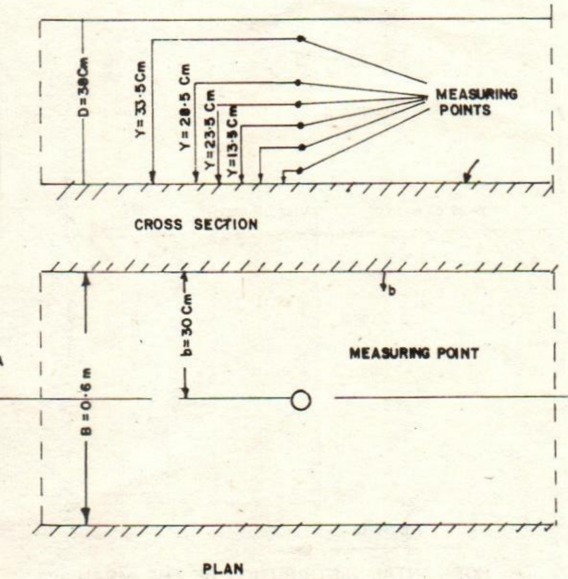



FIG. 1 : DEFINITION SKETCH OF MEASURING POINTS

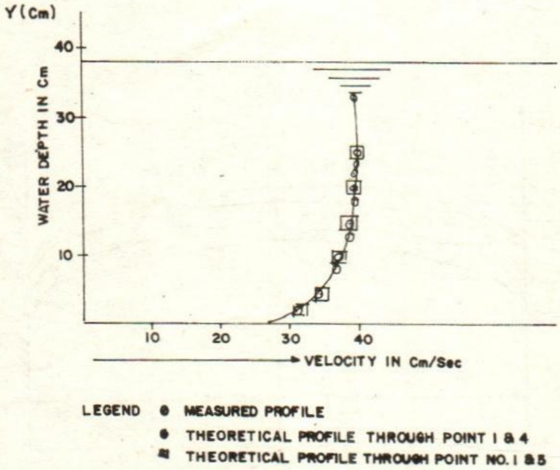



FIG. 2 : VELOCITY PROFILE

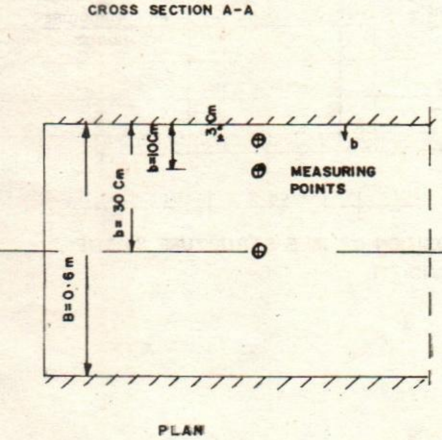



FIG. 3 : DEFINITION SKETCH OF MEASURING POINTS

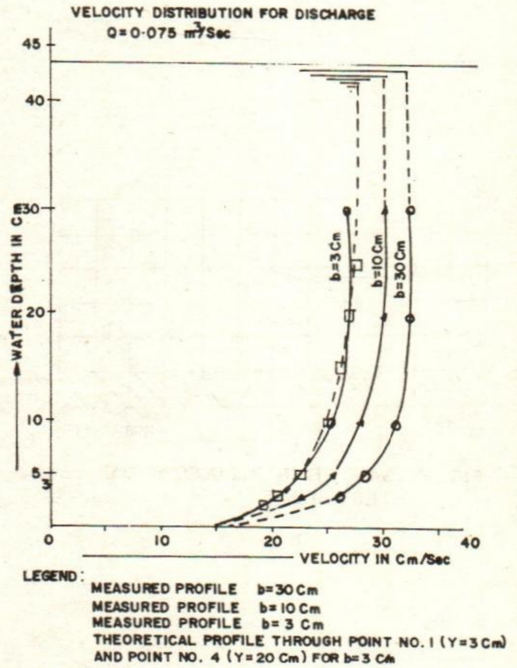



FIG. 4 : VELOCITY PROFILES FOR b=3Cm, b=10Cm & b=30 Cm

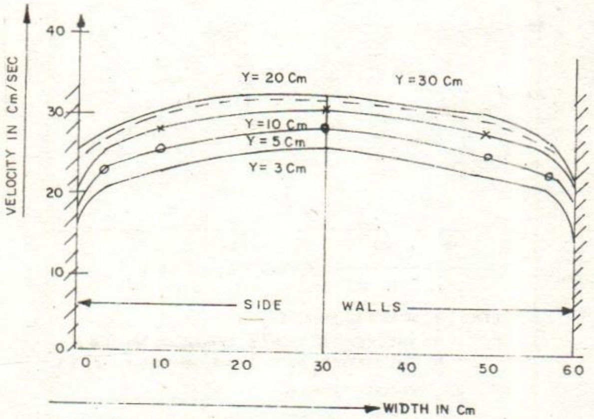



FIG. 5 : HORIZONTAL VELOCITY DISTRIBUTION IN THE FLUME

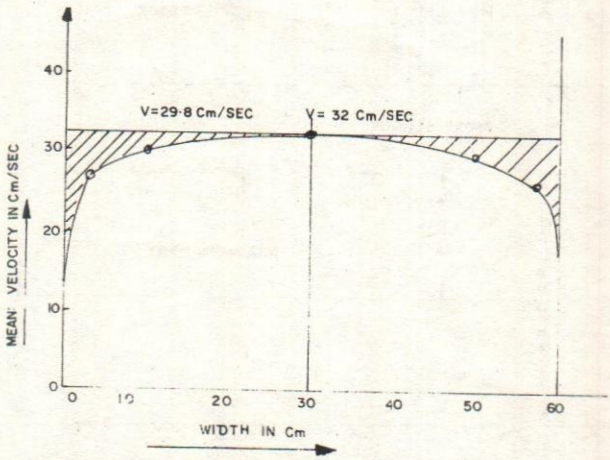



FIG. 6 : HORIZONTAL DISTRIBUTION OF THE MEAN VELOCITY

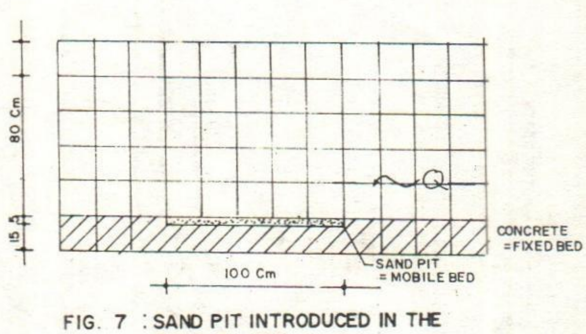



FIG. 7 : SAND PIT INTRODUCED IN THE TEST FLUME

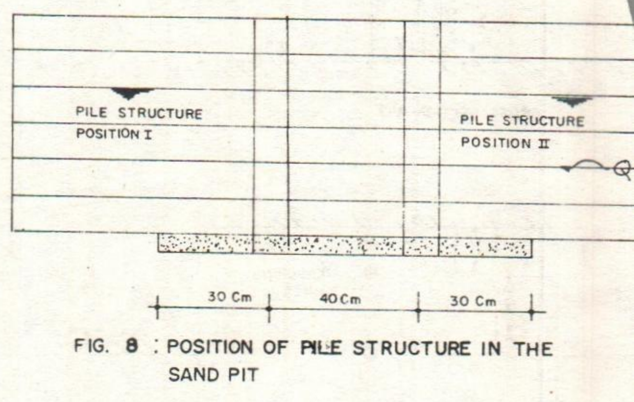
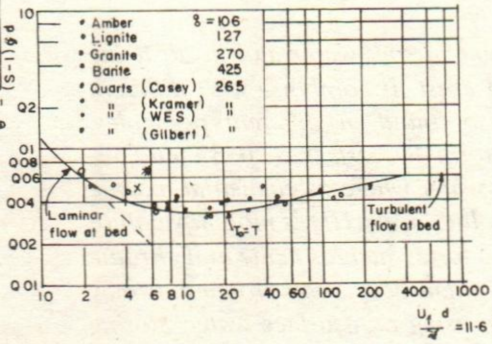



FIG. 8 : POSITION OF PILE STRUCTURE IN THE SAND PIT




IG. 9 : SHIELD PARAMETER θ VS. $U_f d/\nu$ ( FROM F. ENGELUND AND E. HANSEN, MONOGRAPH 1972).

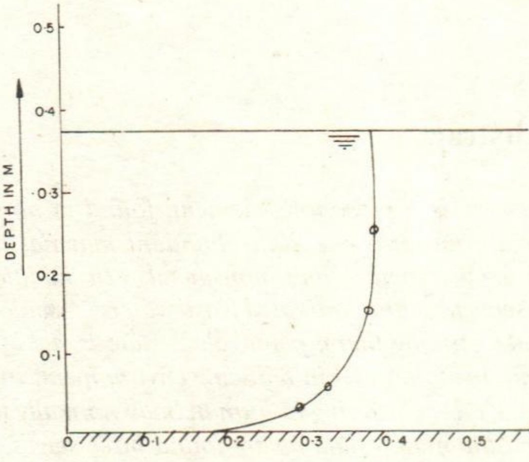



FIG. 10 : VELOCITY PROFILE Q=0·065 m³/S, D=0·371 m

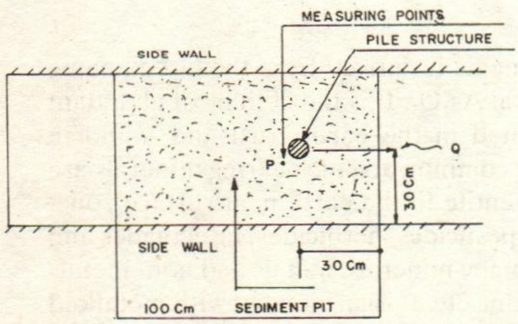



FIG. 11 : SKETCH OF POSITION P OF MEASURED VELOCITY PROFILE

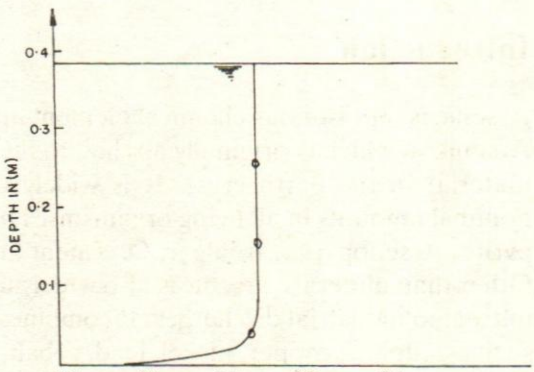



FIG. 12 : VELOCITY PROFILE IN POSITION P, Q=0·040 m³/S D=0·385m

# Arsenic Contamination of Ground Water : In Context of Bangladesh

Dr. Nilufa Islam[1]
Md. Mahbubar Rahman[2]

## Abstract

*Arsenic is a poisonous element, found in nominal amount in soil, water and in all living organisms. It is the 20th abundant material in the earth crust. It combines with different minerals, metals and non-metals. In addition it is also found in different pesticides, insecticides and untreated wastewaters. Arsenic in nature normally exists in 3-, 0, 3+ and 5+ state. Among them, pentavalent state is stable in aerated water where as elemental arsenic and arsine ($AsH_3$) in reducing environment. In aqueous solution, As(III) is more toxic than As(V). Its poisoning in human body normally found in two forms such as acute and chronic and the manifestations are found three stages. Not only human body, crop production may also be reduced for using arsenic contaminated water. By using rain/surface water, storing and filtering of arsenic contaminated water and taking balance diet the adverse effects of arsenic may be reduced. In Bangladesh, Arsenic contamination problem in groundwater particularly in the southern region of the country is probably due to arsenic rich deltaic deposition and hydraulic connections with contaminated regions of West Bengal province of India. The situation has already taken serious turn in Bangladesh. So, immediate measures should be taken to find a solution of this problem.*

## Introduction

Arsenic is a poisonous chemical element and the name is derived from the Greek name Arsenikon which is originally applied to the mineral $As_2O_3$. It is the 20th most abundant material in the earth crust. It is widely distributed in the earth crust and found in nominal amounts in all living organisms. The most common arsenic bearing minerals are pyrite, Arsenopyrite, Realgar, Orpiment and Tenentite in the earth near surface zone. Other than minerals, arsenic is also widely used in pesticides, herbicides, insecticides and untreated industrial discharges. It combines with many minerals, metals and non- metals such as sulphur, copper, nickel, lead, cobalt, iron, zinc etc. It is an element with metalloid characteristics behaving sometimes organic and sometimes as inorganic substances. High arsenic contamination is associated with volcanic deposits, deposit of alluvial lacustrine in semi-arid zone, geothermal system and mining areas of gold, uranium etc. and comes

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into groundwater through leaching and seepage. Normally the concentration of arsenic in groundwater is very low. But in recent years the level of arsenic in groundwater shows increasing concentrations in different parts of the world such as in Taiwan, Argentina, chile, U.S.A., Canada and Japan. The latest occurrence of arsenic pollution particularly in groundwater is found in the West Bengal province of India.

## Chemistry of Arsenic

Arsenic is occasionally found in its pure state in nature. Ordinary arsenic occurs in surface waters at a concentration less than 10 ppb. However, it is more frequently combined with sulphur, selenium, tellvium and as sulfo salts and arsenides of various heavy metals such as cobalt, copper, iron, nickel and tin as stated earlier. The original ore of arsenic is arsenical pyrite, FeAsS. It also forms a number of pentavalent arsenate minerals that have close geochemical relationship with phosphate and vandates with which it can form some isomorphic compounds. Arsenic sulphide and arsenic-tri-sulphide are found in hydrothermal veins and volcanic-sublimation. The numerous oxidic minerals of arsenic observed in the nature are as a result of oxidation of sulphide and arsenide deposits in contact with free atmospheric oxygen. The arsenic minerals are the most preponderant of the oxide minerals.

In surface water, arsenic compounds are mainly found owing to the disposal of industrial and municipal effluents and as a result of contact of aquatic systems with arsenic bearing minerals such as arsenical pyrites and soil containing arsenic pesticides and insecticides. Arsenic exists in nature in the 3-, 0, 3+ and 5+ oxidation state. Among them, pentavalent state is stable in aerated water whereas elemental arsenic and arsine ($AsH_3$) exist in reducing sediments. In more moderate reducing environment the trivalent state can also exists. Chelation with organic species may increase the solubilization of arsenic in natural waters, however, limited information on the existence of soluble chelates is available. Arsenic (III) is very toxic in aqueous solution where as arsenic (V) is known to be less toxic. Arsenic (V) can remove from solution most effectively by adsorption on activated solids but the efficiency of removal is substantially less for the As(III) state. So, one of the main mechanism affecting the distribution of arsenic in natural waters is adsorption from the solution phase to sediment.

Loehr and Plane (1968), as reported by Minear and Keith (1982) studied dilute solution of $As(OH)_3$ and concluded that As(III) exists primarily as the mononuclear species as $As(OH)_3$, $As(OH)_4$, $AsO_2OH^{2-}$ and $AsO_3^{3-}$. Everest and Popiel (1957) studied As(III)over a pH range of 6-13 and proposed the existence of poly nuclear species $As_3(OH)_{10}^-$ and $As_2(OH)_8^{2-}$ and the mononuclear species $As(OH)_3$, $As(OH)_4^-$ and $AsO_2OH^{2-}$. However, polymeric species are not expected to be significant in a very dilute solution also reported by Minear and Keith (1982). The major bio-chemical reactions of arsenic are coagulation of proteins, complexation with co-enzymes and uncoupling of phosphorylation. As(III) at high concentrations coagulate proteins possibly by attacking the sulphur bonds maintainging the secondary and tertiary structure of proteins (A.K. De 1990).

## Effect of Arsenic contamination

Arsenic poisoning occurs when its intake exceeds the limit of tolerance.According to the World Health Organisation guideline, the maximum permissible value of arsenic in drinking water was 0.05 mg/l. But recently it is lowered to 0.01 mg/l considering its toxic and carcinogenic nature. Most arsenic ingested is rapidly absorbed by the body in the stomach and intestine and enters the blood stream. It is converted into less toxic form in the liver and excreted with urine. When the amount of ingestion is greater than excretion, the arsenic accumulates in hair, nails, skins liver and bones. It is presumed that arsenic interferes with cellar metabolism causing different systematic changes (Haque, 1997).

Arsenic poisoning in the human body is normally found in two forms such as chronic and acute poisoning. Chronic poisoning occurs when small amount of arsenic enters a body repeatedly through food and water over a prolonged period of time whereas when a large amount of arsenic enters into the body within short time, It is known as acute poisoning. The symptoms of arsenic normally appears in three stages. In first stage there are dermatitis, keratosis, conjuntivites, bronchitis, gas- troenteritis. In second stage, it is peripheral Neuropathy, Hepatopathy, Melanosis, Depigmentation and hyperkeratosis and in third stage the manifestations are Gangrene in the limbs and Malignant dermatitis or skin cancer (Khaleque, 1997).

Though arsenic in trace amount is stimulatory for a good growth of plants yet it is toxic in high concentrations and excessive use of arsenic insecticides may indirectly cause iron deficiency (Ambasht 1990). Residence representative of World Health Organisation in Dhaka also is reported the rice production may be decrease 20% to 30% in order of magnitude due to use of arsenic contaminated water for irrigation.

## Remedy of Arsenic contamination

As earlier stated that the sources of arsenic contaminations are leaching and agricultural runoff from agricultural areas using pesticides, insecticides and geo-chemical reactions due to mining activities. In West Bengal province of India and in Bangladesh, the source of arsenic problem is probably same i.e. due to excessive use of ground water causes depletion of ground water level and cause leaching of arsenic from dehydrated arsenic rich layer contaminating the ground water aquifers. So, the ground water use of arsenic prone areas should be restricted and the use of surface/rain water may be encouraged. However, the quality of surface water should be an important consideration. Secondly, the drinking water should store overnight and then filter it with a clean cloth which may reduce arsenic concentration because the oxidation of arsenic due to storage also converts arsenite to arsenate which is less toxic. Thirdly, arsenic rich aquifers should be avoided during installation of tubewells. It is observed that arsenic diseases are more among the people suffer from malnutrition areas. So, experts suggested balance diet particularly vitamin A and C rich foods which increases arsenic metabolism thereby lessening arsenic deposition in the tissue by flashing it out with urine.

## Arsenic contamination in Bangladesh

The Arsenic contamination problem in West Bengal is one of the biggest arsenic calamity in the world reported so far. At the beginning, it was thought to be due to tubewell stainer, pestici-des, insecticides used in high quantity and arsenic containing minerals dumped locally during world war II. However, study revealed that groundwaters upto 30 to 40 feet don't show any arsenic pollution which indicates that arsenic containing insecticides and fertilizers may not be the source of arsenic pollution. But the tubewells having 70 to 200 feet depth contains arsenic. The study of soil and hydrological conditions revealed that a 450 km long layer of arsenic rich silt and clay between the depths of 70 and 200 feet below the surface. So, from geological point of view, it may be due to the fact that excessive withdrawal of groundwater triggering chemical changes deep under ground. It is believed the lowering of groundwater results oxidation of arsenic of pyrite minerals of dewatered zone and subsequently comes into the groundwater through leaching and seepage.

Khan et al (1995) reported that the western border districts of Bangladesh particularly the southern regions is very vulnerable to arsenic contamination. Because the sediments on both the sides of the border have same depositional characteristics and geological environment which is known as ganges delta. The subsurface regional gradient is to the south to south east. So, the aquifers of the contaminated zone of West Bengal province is probably hydraulically connected which is echoed in the groundwater arsenic concentration of different districts of Bangladesh. Districts of Bangladesh where arsenic contamination in groundwater is expected due to the same geological characteristics as that of the West Bengal province of India is shown in Figure 1.

According to the report on arsenic pollution in soils and water from the wooden poles of Rural Eletrification Board of Bangladesh (REB), it is reported that total arsenic concentrations in soils of pole stacked areas were 33 to 594 ppm with an average concentration of 237 ppm against the toxic level 20 mg/l, which are mostly retained within 30 cm from surface. Retention of As in surface soil may be due to the presence of organic matters and clay colloids, which adsorbed As and prevented its leaching to lower depths of soil. It is also reported that the dynamics of arsenic is not properly studied during investigation. Chromated Copper Arsenate (CCA) treated wooden poles are normally used in Bangladesh to protect it from insecticidal and fungicidal actions. This compound bounds to wood fibers by actions with wood sugars to form insoluble arsenate precipitate (Pizzi 1982, Anderson 1989) . But this compound may leach during drying if fixation with wooden fiber isnot appropriate again it may be decomposed by microbial activity particularly in the moonson causing huge relese of arsenic in the environment (Arsenic investigation committee,1996) .

World Health Organisation (WHO) recently reported that one fifth of the population of our country i.e. 23 million people are living on the edge, being exposed to arsenic contamination. Recently, Dhaka community hospital, in collaboration with School of Environmental Studies, Jadavpur University has surveyed groundwater of 32 districts in Bangladesh. Among these districts, arsenic has found above maximum permissible concentration (0.05 mg/l) in 27 districts whereas in one district it was above World

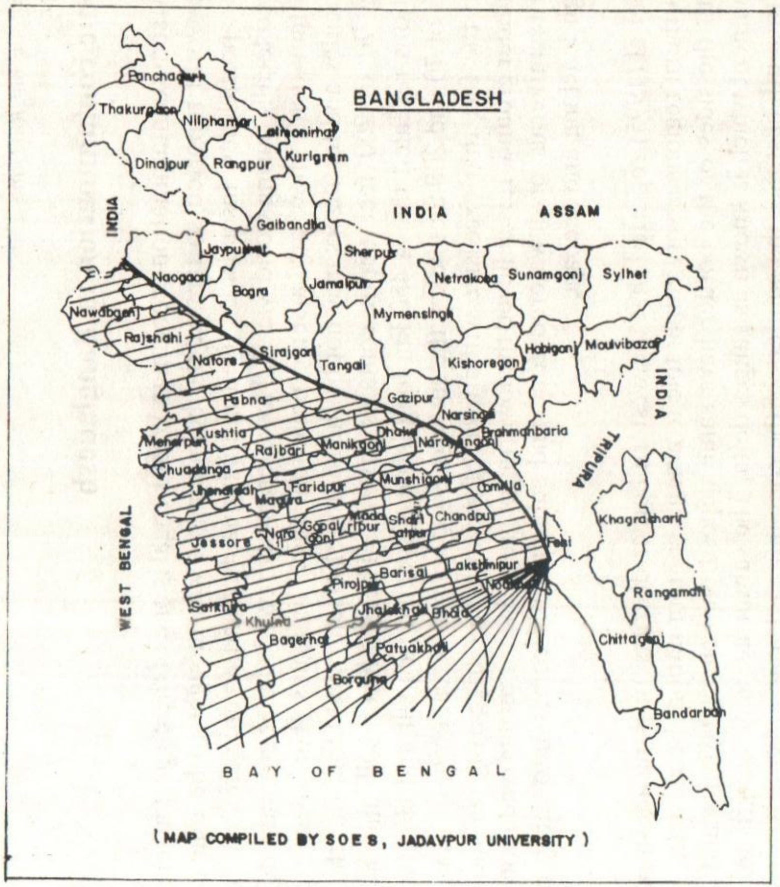


FIG. I : DISTRICT OF BANGLADESH WHERE ARSENIC IN GROUND -WATER IS EXPECTED

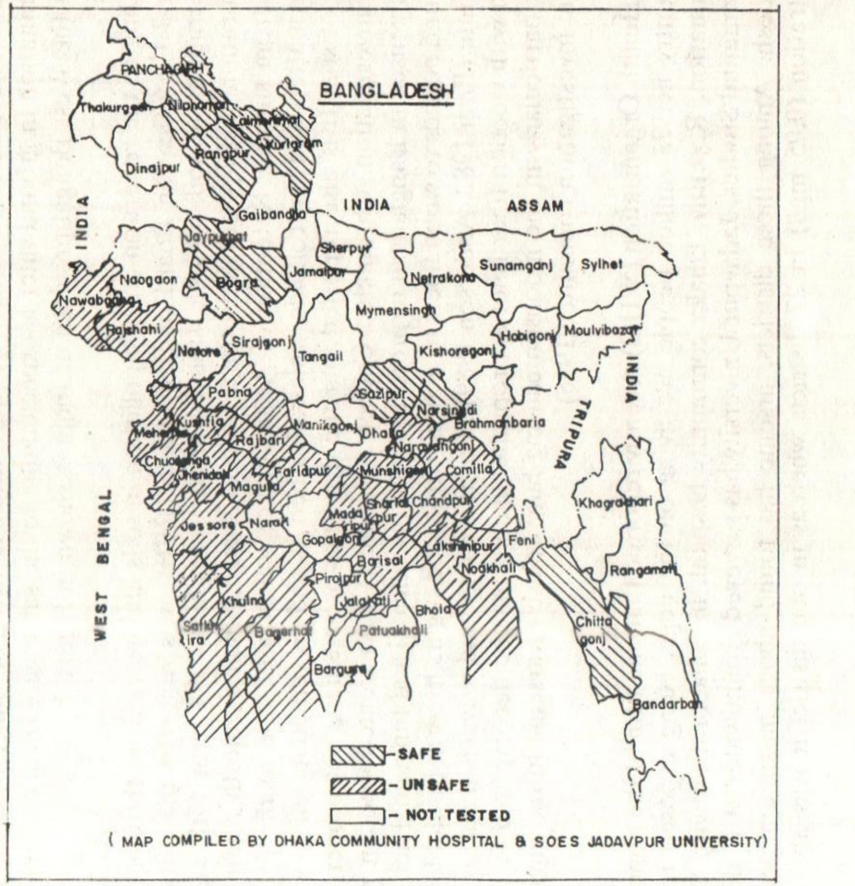


FIG. 2 : DISTRICT OF BANGLADESH WHERE WATER HAS BEEN TESTED FOR ARSENIC

Health Organisation (WHO) recommended value (0.01 mg/l) which is shown in Figure 2. Out of 28 districts so far surveyed, arsenic diseases related patients are found in 20 districts and in 18 districts, people are found with skin lesions such as Kustia, Chuadanga, Meherpur, Satkhira, Jhenidha, Chandpur, Laxmipur, Rajshahi, Nababgonj etc.

Table 1: Some results of arsenic concentration in ground water in different districts of Bangladesh (Khan, 1996).

| Name of Places | Concentrations (mg/l) |
|---|---|
| Court para (Kustia) | 0.135 |
| Majampur (Kustia) | 0.330 |
| Bheramara (Kustia) | 0.694 |
| Chudanga | 0.520 |
| Narayangonj | 0.388 |
| Nababgonj | 0.105 |

Table 2: Arsenic Concentration in Drinking water of Samta village under Sharsha thana in Jessore district (Dhaka Community Hospital,1997)

| Range of Arsenic concentration (mg/l) | Number of samples |
|---|---|
| Below 0.01 | 5 |
| 0.01-0.049 | 18 |
| 0.05-0.099 | 100 |
| 0.10-0.299 | 96 |
| 0.30-0.499 | 14 |
| 0.50-0.699 | 21 |
| 0.70-1.000 | 11 |
| Total | 265 |

## Conclusion

Ground water contamination by arsenic has already taken serious turn in Bangladesh. So, immediate steps should be taken to find the exact solution of this problem. It is important to initiate research projects for indepth analysis regarding sediments and water of aquifers those are hydraulically connected with the contaminated regions and arsenic dynamics in soil and water phase. In addition, other possible sources of arsenic pollution such as pesticides and insecticides which are widely used by farmers should be determined. Proper care should be taken in preserving and handling of the wooden electric poles are used by REB to avoid possible arsenic pollution, as suggested by the investigation committee. At this moment, arsenic related problems are getting importance only in public health sector but it is already reported that food production may reduce from 20% to 30% by arsenic. So, impact of arsenic on agriculture should be assessed as most of the farmers in our country depend on groundwater for irrigation and other pesticides and insecticides. The news media can play an important role in this regard through advertising, so that people become aware about the adverse effects of arsenic.

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