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BANK PROTECTION AND RIVER TRAINING (AFPM) PILOT PROJECT FAP 21/22

FINAL PROJECT EVALUATION REPORT

VOLUME V

Annex 8: The Revetment Test Structure; Design Report
Annex 9: The Revetment Test Structure; Procurement and Construction Report

DECEMBER 2001

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BANK PROTECTION AND RIVER TRAINING (AFPM)
PILOT PROJECT FAP 21/22

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MAY 2001

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BANK PROTECTION PILOT PROJECT
FAP 21/22

Important General Remark

The results presented and discussed in the Annexes of the Final Evaluation Report of the Bank Protection Pilot Project provides the state of the studies during the course of analysis and writing by the individual project partners. After a final review subsequent to the completion of the Annexes during the concluding stages of the Main Reports and the Guidelines and Manual some modifications and adjustments were felt necessary, also for covering more generalized structural measures in addition to the given case studies. For that reason, with respect to design formulae, recommended structure types, etc., reference should be made to the Main Reports and the Guidelines and Design Manual only.

DECEMBER 2001

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BANK PROTECTION PILOT PROJECT

FAP 21

FINAL PROJECT EVALUATION REPORT

ANNEX 8

THE REVETMENT TEST STRUCTURE; DESIGN REPORT

MAY 2001

FAP 21 - BANK PROTECTION PILOT PROJECT

FINAL PROJECT EVALUATION REPORT

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LIST OF ACRONYMS

ASTM	-	American Society for Testing Materials
BAW	-	Bundesanstalt für Wasserbau (Federal Institute for Waterways Engineering, Germany)
BRTS	-	Brahmaputra River Training Studies
BS	-	British Standards
BWDB	-	Bangladesh Water Development Board
CC	-	Cement Concrete
CNR	-	Compagnie Nationale du Rhône
DHW	-	Design High Water Level
DIN	-	Deutsche Industrie Norm (i.e. German Industrial Standard)
FAP	-	Flood Action Plan
FPCO	-	Flood Plan Coordination Organization
HFW	-	High Flood Water Level
IALA	-	International Association of Lighthouse Authorities
JTWC	-	Jamuna Test Works Consultants
PES	-	Polyester
PIANC	-	Permanent International Association of Navigation Congresses
PP	-	Polypropylene
PVC	-	Polyvinyl Chloride
PWD	-	Public Works Department (datum level)
RRI	-	River Research Institute
SHW	-	Standard High Water
SIGNI	-	Signs and Signals on Inland Waterways
SLW	-	Standard Low Water
SPT	-	Standard Penetration Test
SWMC	-	Surface Water Modelling Centre
WARPO	-	Water Resources Planning Organization

GLOSSARY

TERM	DEFINITION
bed protection	layered systems placed on filters on a horizontal surface as protection against hydraulic forces and scouring
char	island, sand bank and floodable area adjacent to the banks
common excavation	stripping, excavation or removal of any type of material on or near bank for construction pits or embankment revetments and bed protections, whether in dry or in wet condition
cover layer	outer protective layer of an embankment revetment or a bed protection
cushion layer	intermediate layer of an embankment revetment or a bed protection, i.e. the layer above a filter or sublayer and below the cover layer
dredging	removal of any soil by bank-sided or floating equipment below water level, irrespective of the method employed
earthworks	"common excavation" and "filling works"
executed design	design adapted to the prevailing local conditions, i.e. to construct the test structure completely in a dry construction pit well above SLW
fabric containers	synthetic fabric bags, mattresses or tubes filled various materials such as sand, bitumen sand, lean sand asphalt etc.
falling apron	multi-layer system of granular material placed directly on the existent subsoil or riverbed
filling	filling by suitable material and compaction of any land, for construction of embankments or groynes, filling and compacting of construction pits and excavations, back filling of structures, etc., to designed levels
filter	one-layer or multi layer system of well graded granular material or a geotextile or a combination of both
gabions	mattresses and rectangular baskets made from protected steel wire mesh and filled with loose material such as boulders, bricks etc.
geotextile	synthetic fabric (woven, non-woven, needle pinched) applied as a filter or used in tailored geotextile systems (mattresses, etc.)
GUIDELINES	Guidelines for Planning, Design and Implementation of River Training and Bank Protection Works, Consulting Consortium FAP 21/22, 2001

TERM	DEFINITION
hydraulic loads	forces due to action of water (hydrostatic or hydrodynamic)
khoa	brick chips, used as concrete aggregates and filter material
launching apron	integrated and articulating mattress system placed on prepared slopes above and below water or in horizontal excavation well above SLW
MANUAL	Design Manual River Training and Bank Protection Works, Consulting Consortium FAP 21/22, 2001
opening size	the dimension which corresponds to the average size of particles of which n % by weight are able to pass through a geotextile fabric
original design	the design of structure based on the recommendations of the Final Planning Study Report (Consulting Consortium FAP 21/22, 1993a)
permittivity	the permeability of a geotextile normal to the fabric per unit thickness of the fabric
revetment	layered systems placed on filters on a sloping surface as protection against hydraulic forces and scouring
rip-rap	layer of loose stones acting as cover layer in an embankment revetment, a bed protection or a falling apron
rock	any hard natural or artificial material requiring the use of blasting or mechanical tools for its removal
scour	removal of soil particles by current or wave induced shear forces
seepage	movement of water into or out of the river bank
soft material	all material, whether "suitable" or "unsuitable", but other than "rock"
soil migration	the transportation of the finer soil particles within a soil mass
sublayer	any layer between cover layer and filter
subsoil	naturally deposited or filled and compacted soil material on which an embankment revetment, a bed protection or a falling apron is constructed
suitable material	all material obtained from excavations within the site or from borrow pits and which is approved by the employer as acceptable for use in the works

TERM	DEFINITION
toe protection	systems to protect the toe of an embankment against instability due to erosion/scouring
top soil	top layer of soil containing a higher proportion of organic material
unsuitable material	any other than "suitable material"

LIST OF SYMBOLS

a_g	-	surface area of geotextile	(m^2)
B	-	coefficient for flow conditions	(-)
b	-	exponent	(-)
C	-	modulus of subgrade reaction	(N/m^3)
C_c	-	compression index	(-)
C_u	-	coefficient of uniformity	(-)
c	-	cohesion	(kN/m^2)
c'	-	effective cohesion	(kN/m^2)
c_u	-	undrained shear strength	(kN/m^2)
cc	-	cement concrete	(-)
D	-	dimension of cube	(m)
D	-	compactness (of non-cohesive soils)	(-)
D	-	specific size or thickness of protection unit	(m)
D_{eq}	-	equivalent thickness of geotextile mattress	(m)
D_n	-	grain size diameter corresponding to n % by mass of finer particles	(mm)
D_n	-	nominal thickness of protection unit	(m)
D_{n50}	-	nominal diameter of rip-rap	(m)
D_{10}	-	effective grain size	(mm)
d	-	water depth	(m)
d	-	thickness of mattress	(m)
d_b	-	thickness of cover layer of open stone asphalt	(m)
d_{n50}	-	grain diameter	(m)
g	-	acceleration due to gravity	(m/s^2)
H	-	layer thickness	(m)
H	-	height of the slope	(m)
H_s	-	significant wave height	(m)
h	-	water depth	(m)
i	-	hydraulic gradient in soil	(-)
K_h	-	depth factor	(-)
K_s	-	slope factor	(-)
K_τ	-	turbulence factor	(-)
k	-	reduction factor	(-)
k	-	wave number	(-)
k′	-	slope reduction factor	(-)
k_g	-	permeability of geotextile	(m/s)
k_s	-	permeability of soil	(m/s)
L	-	wave length	(m)
L_o	-	wave length in deep water	(m)
O_n	-	opening size of a geotextile	(μm)
P	-	wave impact	(N/m)
S	-	stiffness modulus of asphalt	(N/m^2)
T_z	-	average wave period	(s)
t_g	-	geotextile thickness	(m)
t_m	-	thickness of mattress	(m)
u	-	pore water pressure	(kN/m^2)
u	-	mean velocity	(m/s)

$\bar{u}$	-	depth averaged flow velocity	(m/s)
u_b	-	bottom velocity	(m/s)
u_c	-	local flow velocity	(m/s)
u_{des}	-	design velocity	(m/s)
u_s	-	surface velocity	(m/s)
u_{cr}	-	critical velocity	(m/s)
u_r	-	maximum current velocity	(m/s)
V	-	Poisson's ratio for asphalt	(-)
v	-	maximum flow velocity	(m/s)
W	-	weight	(kN/m)
W	-	weight of armour unit	(tons)
W_n	-	n % value of mass distribution curve of rip-rap stone	(kg)
α	-	slope angle of revetment	(degree)
β	-	strength coefficient	(-)
β	-	stability coefficient	(-)
β	-	angle of potential failure plane	(degree)
γ_s	-	specific weight of solid	(kN/m^3)
γ_w	-	specific weight of water	(kN/m^3)
γ'	-	specific weight of solid in submerged condition	(kN/m^3)
ΔH	-	head loss	(m)
Δm	-	relative density	(-)
Δp	-	increase in pressure	(kN/m^2)
ε_s	-	angle of internal friction of material	(degree)
ϕ	-	stability factor	(-)
ϕ	-	angle of slope	(degree)
φ	-	angle of internal friction	(degree)
φ'	-	effective angle of internal friction	(degree)
ξ_z	-	wave breaking parameter	(-)
ρ_c	-	specific gravity of concrete	(kg/m^3)
ρ_s	-	density of protection material	(kg/m^3)
ρ_w	-	density of water	(kg/m^3)
σ	-	total normal stress	(kN/m^2)
σ_b	-	asphalt stress at failure	(N/m^2)
σ'	-	effective normal stress	(kN/m^2)
τ	-	shear strength	(kN/m^2)
θ	-	angle of respose	(degree)
Ψ_{cr}	-	critical shear stress parameter	(-)
Ψ_{cr}	-	shields parameter	(-)
ψ	-	stability upgrading factor	(-)
ψ	-	permittivity	(m/s)

Other symbols are explained in the text at their utilisation.

SUMMARY

This Annex summarizes the procedures for the design of the Bahadurabad Revetment Test Structure. After an introduction (Section 1), the selection of the test site is described and the relevant design criteria are discussed in Section 2. The detailed design of the individual components of the revetment structure are presented in Section 3. The structure was split into several sections, each of which was built with different protective materials of mainly local sources.

The main executional constraints which were encountered were the land acquisition, the organisation of earth works (with the participation of local people) and the filling of the geotextile mattress systems with sand.

After its completion, the structure was attacked by the river during the monsoon flood in 1997 and again in 1998. The structure was monitored and only minor damages were encountered. It was concluded, that the design was suitable to withstand the occurring hydraulic loads and to stop the progressing bank erosion, despite extreme scour holes of up to about 30 m below water level.

1 INTRODUCTION

1.1 AIM OF THE DESIGN REPORT

The aim of the Bank Protection Pilot Project was to develop and to optimise design criteria and cost-effective construction and maintenance methods, which could ultimately serve as standard bank protection works along the Jamuna and other main rivers of Bangladesh. It was a pre-condition that such protection measures should take into consideration local customary methods and materials. The improved construction methods and strategies were to be verified for their effectiveness and future applicability through the Pilot Project.

The Project comprised the construction of test structures at three selected test sites. The implemented test structures included a groyne field (Kamarjani 1994/95) and two revetments (Bahadurabad 1995/97 and Ghutail 2001), bed protections, launching aprons and falling aprons. The functioning and efficiency of these test structures were monitored for several years after completion and modifications were implemented as appropriate.

The present Design Report deals with the Revetment Test Structures at Bahadurabad Test Site. Summarising and supplementing earlier reports, such as the Final Planning Study Report (Consulting Consortium FAP 21/22, 1993 a) and the Procurement and Construction Report, Test Site II, Bahadurabad (Consulting Consortium FAP 21/22, 1994 c), it shall highlight the

- selection of test site location;
- layout configuration of the test site;
- structural design assumptions and criteria;
- configuration of the revetment structure;
- associated embankment protection and erosion prevention measures;
- proposed and applied adaptations to the original structure, and
- basic recommendations for future standard designs.

The following subjects are to be seen in conjunction with this Design Report and are covered elsewhere in the Final Project Evaluation Report, namely

- construction methods [Annex 9], (Consulting Consortium FAP 21/22, 2001 j);
- construction materials [Annex 9], (Consulting Consortium FAP 21/22, 2001 j);
- construction equipment [Annex 9], (Consulting Consortium FAP 21/22, 2001 j)
- construction implementation schedule [Annex 9], (Consulting Consortium FAP 21/22, 2001 j);
- financial and economic evaluation [Annex 9 and Annex 12], (Consulting Consortium FAP 21/22, 2001 j and m);
- evaluation of monitored hydraulic loads on the structures [Annex 11], (Consulting Consortium FAP 21/22, 2001 l), and
- response of the river [Annex 11], (Consulting Consortium FAP 21/22, 2001 l).

1.2 HISTORICAL EXPERIENCE

The protection of riverbanks by revetments has been applied in several ways since generations around the globe. Revetments are usually employed in cases, where minor correction of the river's flow is required to achieve planform stability. These structures allow for a stabilisation of the riverbanks and can cope with deep scouring in front of the revetment, when proper toe protection is being provided.

The type of revetment can be manifold, but usually depends on locally available materials, custom and skill. Four basic categories can be established, namely

- natural bank protection using organic materials (which is not considered to be a somewhat permanent measure);
- self-adjusting structures using a range of single protection elements, such as rip-rap, stones, concrete blocks, etc.;
- flexible structures, such as articulating mattress systems of various kind, and
- rigid structures.

Design rules are available, which could be applied to normal river conditions. However, in particular the special behaviour of the Jamuna river does not permit the application of such rules without further ado.

Despite the fact that bank erosion is a permanent threat along the main rivers of Bangladesh, apparently no long tradition exists in bank protection works in this part of the Indian Subcontinent. Till the early sixties of the last century the bank protection measures along the major rivers in Bangladesh were practically restricted to measures upstream from Hardinge Bridge at River Ganges and some town protection measures, among others at Rajshahi and Sirajganj, where mainly local brick mattressing and some type of impermeable groynes were used to stabilise the riverbanks. Ongoing bank erosion would have called for urgent implementation of bank protection measures, which possibly could not be done due to budget constraints. It was only in the eighties that bank protection by revetment structures became more relevant, particularly after the floods of 1987 and 1988.

Some design rules have been developed over the decades for revetment structures as well as for scour protection measures which, however, cannot necessarily be transferred to the conditions of a braiding river such as the Jamuna. Even with the application of most modern computerised modelling and design tools there will always remain some trial and error approach in preventing bank erosion at the Jamuna river.

It must always be kept in mind, however, that whatever bank protection measure would be carried out, it will create a substantial interference with the natural flow regime of the river. The succeeding river response will certainly call for compensatory measures in the following years. Therefore, the planning of adaptation and supplementary measures must always be seen as an inseparable element of the respective project.

1.3 JUSTIFICATION FOR THE USE OF REVETMENTS

It was the focus of the Project to develop measures suitable to stop or at least to restrict bank erosion within selected areas along the Jamuna river. One of the technical options is to reduce the velocity of the river flow through artificial structures, such as groynes, to an extent that erosion of the natural and unprotected riverbanks is decreased considerably. The other option chosen was the protection of the riverbank by revetments suitably designed to withstand the forces of the river.

Within the Project scope the construction of the Revetment Test Structures was aimed to verify their applicability under particular conditions (e.g. with regard to the river attack, availability of land, site access), which, may be different to situations where the construction of groynes would be the more appropriate alternative.

The general advantage of revetment protection measures is (within the focus and aim of the Project strategies)

- ease of construction, utilising local construction capacity and capability;
- reasonable investment cost;
- except geotextile filter materials and factory-made mattress systems all other materials are of local origin and manufacture;
- materials can be ordered well in advance of implementation and kept in strategic stockyards;
- construction window can be maximised since construction is being carried out from flood plain level as per strategy of the Project. Early high floods can even be kept away from the site area by construction of temporary gunny bag dykes, and
- adaptation measures in the subsequent seasons are easy to implement. Launching and falling aprons as well as the upstream and/or downstream terminations may be strengthened if needed by dumping additional volume of protection material, etc.

2 THE BAHADURABAD TEST SITE

2.1 PRE-SELECTION AND VERIFICATION OF SITE LOCATION

In the Final Planning Study Report (Consulting Consortium FAP 21/22, 1993 a) the second test site of the Project was proposed at Bahadurabad, next to a place called Belgachha. Subsequently, the morphological changes since 1992 were monitored and the results and predictions presented in various update reports.

In early 1995 it was assessed that bank erosion during the flood of 1994 occurred at Bahadurabad Ghat and in an area 8 km downstream, but not at Belgachha. Since these morphological changes at the pre-selected site of Belgachha tended not to comply with the Project requirement of "certainty of attack", three alternative site locations were investigated in early 1995 (Consulting Consortium FAP 21/22, 1995 c), namely

- Bahadurabad, just downstream from the railway ghat (Kulkandi);
- Rasulpur/Balashi Port, further downstream from Kamarjani Test Site (west bank), and
- Chandanbaisa Bazaar.

A final decision about the location for the Revetment Test Structure of Test Site II was made on the basis of the report "Morphological Predictions for Test Site Areas and Selection of Test Sites" of September 1995 (Consulting Consortium FAP 21/22, 1995 d). According to the investigations the location of Bahadurabad Ghat was identified as a potential test site area under consideration of all relevant project demands. On September 10, 1995 FPCO (now WARPO) confirmed the location Bahadurabad-Kulkandi for implementation of the Revetment Test Structure.

2.2 PHYSICAL MODEL TESTS PRIOR TO IMPLEMENTATION

2.2.1 Model Tests at Faridpur

During the Study Phase (1992 till early 1993) of the Project physical model tests were carried out at the River Research Institute (RRI) in Faridpur, the results of which are compiled in Annex 14 to the Final Planning Study Report (Consulting Consortium FAP 21/22, 1993 k). The model investigations were conducted in the so-called "Bahadurabad Model" at a length scale of 1 in 60.

The Bahadurabad Model was to determine the following parameters:

- optimisation of the structure alignment;
- shape of the upstream termination of the revetment;
- flow pattern in front of the structure, and
- depth and location of scour along the structure face, and

Based on the first ten model tests, four supplementary model tests were carried out at RRI in the second half of 1993 after the start of the Test and Implementation Phase in order to verify the parameters for the layout at the assumed test site Bahadurabad-Belgachha. The supplementary tests were carried out at a length scale of 1 in 75 to also include the local scour hole near the downstream termination of the structure.

The respective detailed analyses are presented in Technical Report No. 1 (Consulting Consortium FAP 21/22, 1994 c), but the resultant recommendations for the original design of the Revetment Test Structure are summarised in the following subsections.

2.2.2 Model Tests in France

With the start of the Test and Implementation Phase supplementary physical model tests were carried out at the laboratories of CNR, Chanaz/France in 1993/94. These tests were aimed to develop an understanding of the behaviour of falling aprons of concrete blocks placed around groyne structures as well as at the toe of revetment structures in order to restrict the development of scour holes. These models were scaled 1 in 15 and 1 in 25. The results are compiled in Technical Report No. 4 (Consulting Consortium FAP 21/22, 1995 b), and the developed design guidelines were taken into consideration in the dimensioning of the falling aprons of the Revetment Test Structure.

2.3 LAYOUT CRITERIA FOR THE TEST STRUCTURE

2.3.1 Preliminary Remarks

The original configuration of the Revetment Test Structure was decided on the basis of the model tests referred to under Section 2.2. For reasons explained in more detail under Subsection 3.6.1 it was required to make adjustments to the originally assumed planning criteria, particularly with regard to the geometry of the upstream termination and the under water slope of revetments.

The criteria indicated in the following subsections have been applied to the original implementation design of the revetments. It should be noted, however, that the experience gained during the implementation of the test structure has demanded the adaptation of certain design assumptions. The monitoring of the structure's behaviour during the monsoon seasons after its construction would suggest also that an optimisation of the design assumptions for the revetments and in particular for the launching apron appear appropriate (see Chapter 4 and 6).

2.3.2 Length of Test Structure

The original test structure design presented in the Procurement and Construction Report, Test Site II, Bahadurabad (Consulting Consortium FAP 21/22, 1995 c) provided for seven test areas of about 100 m length each, plus test sections at the upstream and downstream termination. The total revetment length of the test structures was about 1,148 m, including terminations. In the final implementation of the modified Revetment Test Structure the overall length was reduced to about 780 m.

It should be noted that the aim of the Revetment Test Structure was not to test the configuration, i.e. the geometry of the structure but to test individual revetment types and their designs. Accordingly, the shape and length of structure served primarily the purpose to provide reasonably equivalent test conditions to each section of the test structure. Therefore, the chosen structure length does not claim to be measured in terms of optimal defined criteria, rather the structure length will have to be determined in consideration of its intended functioning, which may be

(a) a revetment, whether curved or parallel to the river, protecting a well defined area of interest;
(b) a guide bund type structure, or
(c) a hard point type structure.

For further information the Guidelines (Guidelines for Planning, Design and Implementation of River Training and Bank Protection Works, Consulting Consortium FAP 21/22, 2001 n) and the Design Manual (Design Manual for River Training and Bank Protection Works, Consulting Consortium FAP 21/22, 2001 o) may be consulted.

2.3.3 Upstream and Downstream Terminations

From the physical model tests it was recommended (Consulting Consortium FAP 21/22, 1994 c) to apply a radius of 450 m for the layout design of the upstream termination, possibly limiting the expected scour depth to 12 m to 14 m, instead of 18 m to 23 m in case of a 50 m radius, and reducing the risk that a long eddy would form near the termination.

With this configuration it was anticipated that an upstream river bank embayment depth of about 250 m could be accommodated.

The downstream termination has been designed at a radius of 50 m.

Due to the circumstances referred to under Subsection 2.3.1 the upstream geometry was subsequently adjusted for final project implementation, primarily to accommodate the Revetment Test Structure within a very limited area of land. Thereby the main radius along the embankment crest was reduced to 200 m, followed by 75 m. From three years' monitoring of the structure and the river's response it may be a tentative conclusion that such adjusted upstream geometry still produces acceptable results.

2.3.4 Orientation of Test Structure

The orientation of the test structure was arranged at a slight angle to the assumed river flow, which was decided to allow for a more or less uniform flow along the individual revetment test sections. An arrangement about parallel or even retreating towards downstream would have initiated flow separation and eddies along the test sections and would have made the evaluation of revetment properties a more difficult task. For standard structures the orientation needs to be carefully decided, well in consideration of the prevalent local situation and the predicted response of the river.

2.3.5 Connection to Existent Main Flood Embankment

The design of the Revetment Test Structure included the strong recommendation that the structure should be linked to a high level point in the hinterland to prevent from flow attack of the structure inner slope in case high floods and severe upstream erosion should tend to outflank the upstream termination point. This connecting dyke or embankment was planned to be protected by light revetment, either by grass or brick mattressing to ensure its sustainability.

This was again strongly recommended to the authorities in November 1999, but to the present, such connecting link was not constructed.

2.4 DESIGN CRITERIA

2.4.1 General

When deciding on the design parameters for any bank erosion prevention measure due regard must be given to the fact that the initial hydraulic and morphologic boundary conditions may be subject to change until the structure is finally implemented. Therefore, as a matter of principle, design parameters must always be chosen with an appropriate margin to allow final adaptation to the actual site conditions without significant deviation.

The Final Planning Study Report, in particular its Annexes 16, 17 and 21 (Consulting Consortium FAP 21/22, 1993 m, n and r), recommended the basic design criteria to be considered for dimensioning the revetments and underlying filter layers. These inputs were further elaborated and verified in consideration of the results of model test runs (see Subsection 2.2.1 and 2.2.2).

It should be noted that the design criteria for the dimensioning of the revetment structures at Bahadurabad Test Site apply only to these test structures, but for any future standard design the Guidelines and the Design Manual shall be consulted.

2.4.2 Water Levels

The design water levels were determined through water level frequency analyses carried out by FAP 25, (later: Surface Water Modelling Centre (SWMC). The frequency analysis covers a 25-years (1969-1995) period and showed the following results (Table 2.4-1).

Water Level	Reference to PWD	Reference to SLW	Return Period
Standard Low Water (SLW)	13.30 m+PWD	± 0.00 m+SLW	-
Standard High Water (SHW)	18.80 m+PWD	5.50 m+SLW	-
Design High Water Level (DHW)	21.10 m+PWD	7.80 m+SLW	25
High Flood Water Level (HFW)	21.40 m+PWD	8.10 m+SLW	100

Table 2.4-1: Design Water Levels Bahadurabad Test Site

Therein the High Flood Water Level (HFW) represents the statistical highest high water level for a 100-years return period, which is normally considered the design water level for bank protection measures in Bangladesh. For the purpose of the Bank Protection Pilot Project, however, the Design High Water Level (DHW) has been determined corresponding to the probability of reoccurrence within a 25-years period.

2.4.3 Design Crest Level

The crest level of the Revetment Test Structure had been decided in consideration of the assumed conditions for a 25-years return period as follows:

Design High Flood Level	21.10 m+PWD
50 % of Design Wave Height H_{25}	0.50 m
Surcharge for wave run-up	
and water level rise due to wind	0.40 m
Crest level (25-years situation)	22.00 m+PWD

This level satisfies also the High Flood Level of 21.40 m+PWD with a tolerable margin for wind surge. During the structure's monitoring period the maximum recorded water level was 20.5 m+PWD and overtopping of the embankment has never been observed.

2.4.4 Design River Bed Profile

The design riverbed profile has been evaluated at various cross-sections along with the test site area together with the profile used for the physical model tests. The range of evaluation river profiles is in Fig. 2.4-1.

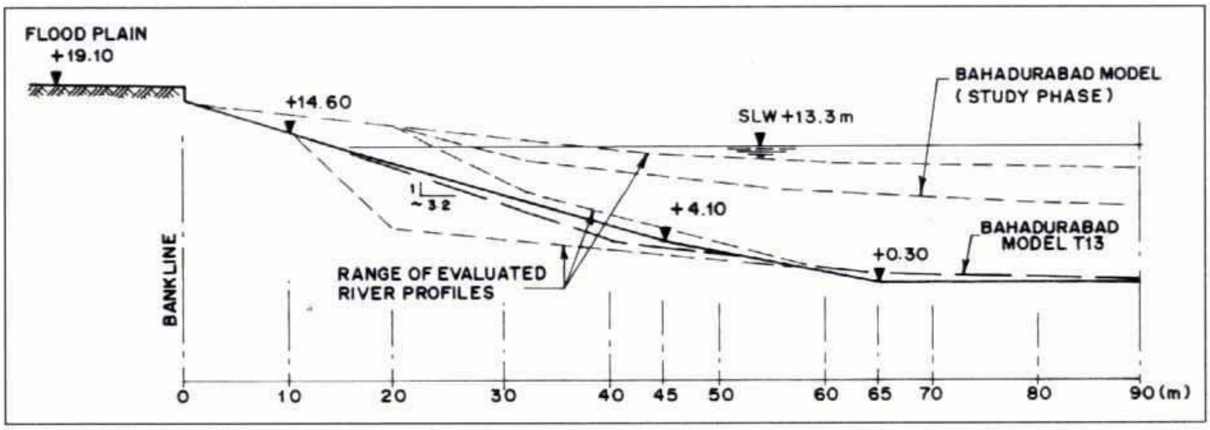

Fig. 2.4-1: Design River Bed profile

For the original design (design water depth associated with a river bed level at 8.30 m+PWD and at 3.80 m+PWD at the toe of the Revetment Test Structure) the final location of the structure could have been chosen without difficulties which could develop from profile variation. Except that additional dredging volume would have resulted in case the deep channel would be closer to the bankline, in which case the structure would have to be shifted further into the flood plain.

2.4.5 Hydraulic Loads

(1) General

The hydraulic loads on a revetment structure are characterised by the flow velocity and wave climate at the respective site location. Floating debris, that might be piling-up at the upstream termination of a revetment structure does not need to be considered since it is not expected to influence the flow velocities and subsequently the scour development along the structure.

(2) Design Flow Velocity

As design flow velocity the depth averaged flow velocity ($\bar{u}$) has been selected, which definition has universally been used in all design formulas and computations of the pilot project. Fig. 2.4-2 presents the general understanding of the definitions used, but a more elaborate presentation is contained in Annex 11 to the Final Project Evaluation Report (Consulting Consortium FAP 21/22, 2001 l).

Dependent on the location within a cross-section of the revetment or the scour protection to be dimensioned, the design flow velocity $\bar{u}_{des}$ has been determined according to the principles of Attachment 8. It should be noted that the results presented therein are not valid for the upstream termination area, where the flow field can be complicated due to flow separation and eddy formation.

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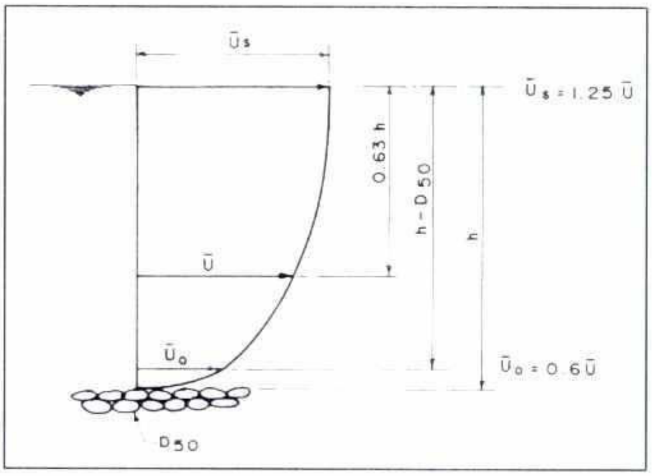

Fig. 2.4-2: Logarithmic flow velocity profile

For the original design of the Revetment Test Structure, i.e. the construction of under water slopes between 3.80 m+PWD and 8.3 m+PWD, the following has been evaluated:

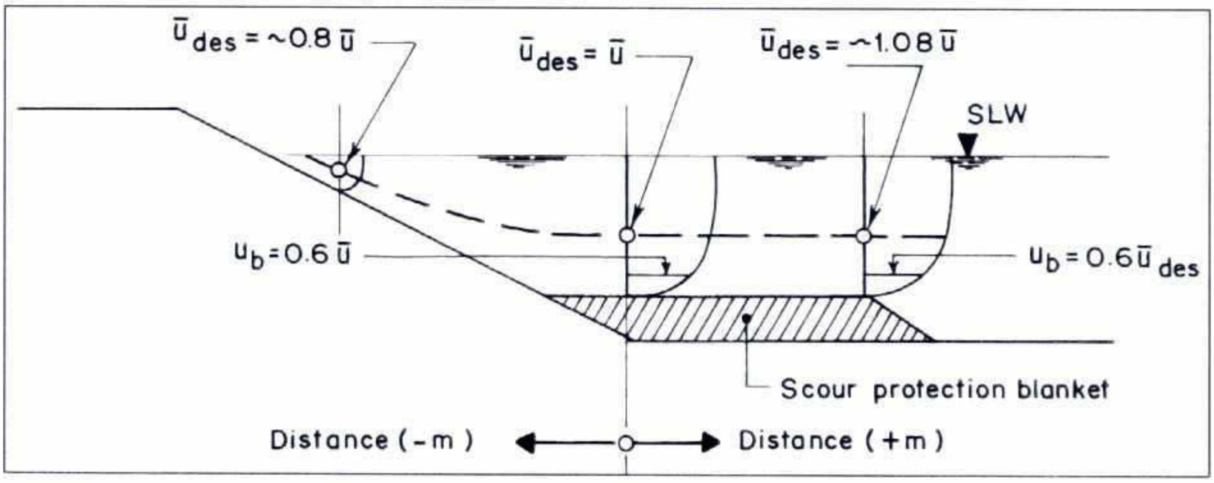

Fig. 2.4-3: Designation of Design Flow Velocity

For the location of Bahadurabad the depth averaged flow velocity (25 years return period) has been determined at $\bar{u}$ = 3.5 m/s. The design flow velocities at certain positions in front of the Bahadurabad test site are presented in Table 2.4-2.

In practice, a reduction of $\bar{u}_{des}$ along the revetment slope will not be of influence to the dimensioning of the revetment cover layers since wave loads will be decisive.

Distance from the toe of the revetment slope	Design Depth Average Flow Velocity $\overline{u}_{des}$ (m/s)	
	Revetment	Scour Protection
- 30 m	2.8	-
0 m	3.5	3.5
+ 12 m	-	3.6
+ 20 m	-	3.8
+ 30 m	-	3.85

Table 2.4-2: Design Flow Velocities ($\overline{u}_{des}$) for Bahadurabad Test Site

(3) Wave Loads

Waves are generated on the Jamuna river by wind during the tropical Norwesters, by cyclones and by passing of ships.

The occurrence of tropical cyclones is comparably low in the interior location and may be expected in this region once in 30 years only. Due to the test character of the structure and this rare recurrence, cyclonic storms have not been considered as a design criterion.

Important for the Jamuna river are the squalls during pre-monsoon (Norwesters) and post monsoon periods, which generate considerable waves on the river. Squalls are local disturbances causing substantial wind speeds thunderstorms, mainly occurring in the months of March to May, but also at other times of the year.

Detailed studies on the wind and wave conditions at the Jamuna river were carried out under FAP 1-project as well as in connection with the Jamuna Multipurpose Bridge Project, which were given due consideration in the Final Planning Study Report (Consulting Consortium FAP 21/22, 1993 a and j). Wave loads are normally decisive for revetment design, but the emphasises of this pilot project is related to studying the behaviour of revetments primarily under current attack. Therefore, a lower estimate within the band width of estimated design wave height has been considered.

Based on the analyses of wind generated waves for various wind conditions, water depths and fetch lengths at Bahadurabad Test Site (see Attachment 9), the following generalized wave parameters have been computed and compiled in Table 2.4-3.

Return Period (year)	**Design Wave Height** H (m)	**Wave Period** T (s)
5	0.8	3.0
10	0.9	3.3
25	1.0	3.5
50	1.2	3.8
100	1.3	4.0

Table 2.4-3: Design Wave Parameter at Bahadurabad Site

2.4.6 Vessel Traffic Loads

Inland waterway transport does not yet play an important role for the upper reach of the Jamuna river. Therefore, ship induced waves always have not been given consideration in the design assumptions for the test structures.

However, the proximity of the test structure to the railway ferry ghat at Bahadurabad raised concern during the design of the original test structure whether or not ship screw race could initiate additional or even extraordinary hydraulic loads to the revetment structures. Attachment 10 deals with this subject and it can be reported that during the structure's monitoring period no danger has been observed in this regard.

2.4.7 Design Scour Depth

According to the results of the physical model tests the deepest scour was expected to develop near the upstream termination of the test structure as shown in Fig. 2.4-4, which was considered in the final design assumptions.

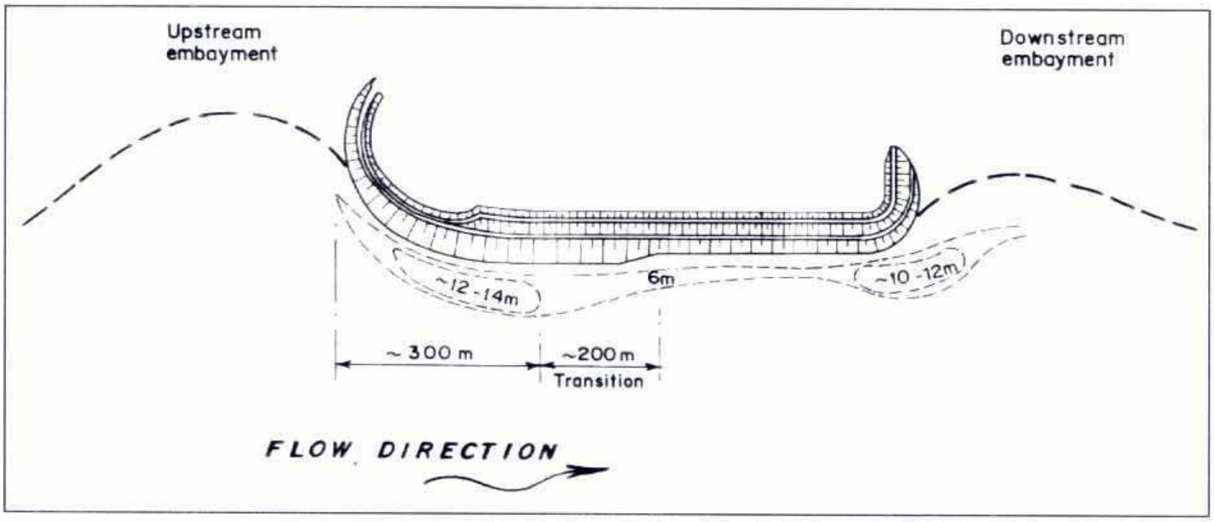

Fig. 2.4-4: Design Scour Depths along test structure

2.4.8 Subsoil Conditions

In 1992 subsoil exploratory works were carried out in the area of Bahadurabad/Belgachha up to about Bahadurabad/Kulkandi. It was understood that at the finally chosen test site location additional soil exploratory works and soil mechanical analyses would have to be carried out to verify the parameters to be applied to the slope stability analyses of the original design. It should be noted in this regard that due to the fact that a completely different design approach was taken for final implementation of the Revetment Test Structure in 1996 no supplementary soil investigations were carried out (see Section 3.6).

In 1992 a total of four exploratory borings with Standard Penetration Tests (SPT) and three cone penetrometer tests were carried out around Bahadurabad/Belgachha. The nearest boring to the test area Bahadurabad/Kulkandi was located about 2 km south of the anticipated location of the test structure.

The subsoil around Bahadurabad/Belgachha consists mainly of poorly graded silty sand with traces of mica and a content of silt between 9 and 21 % (mean value 13 %). Cohesive layers of clayey sandy silt to sandy silt (group CL to ML) were found as cover layers with thickness up to 5.5 m, but also as about 2 m thick layers down to a depth of 11.5 m below surface.

As per visual classification the plasticity of the clayey sandy silt and sandy silt was only low and according to the results of Standard Penetration Tests its consistency was medium to stiff.

Effective shear parameters of cohesive layers:

$\varphi' = 29°$ to $35°$

$c' = 0$ to $11.7\ kN/m^2$

According to the Standard Penetration Tests and the cone penetration tests the relative density of the silty sand with a coefficient of uniformity between 2 and 9 was only loose down to approximately 5.0 m. Below this level it was medium dense and at depths between 16 and 24 m medium dense to dense. The coefficient of permeability was estimated to be about $3 \cdot 10^{-5}$ m/s and the effective angle of internal friction without cohesion resulted in a value of: $\varphi' = 27.5°$

The ground water table at the time of field investigations was measured between 2.5 m and 3.3 m below surface.

Apart of these site specific investigations, the data obtained from various locations have been evaluated as presented in Table 2.4-4.

Despite the fact that the soil conditions along the investigated reaches of the Jamuna river may be considered somewhat uniform (within the context of structures in question), it must be a standard requirement for any structure design that the soil properties are being well determined on the basis of detailed subsoil explorations and mechanical laboratory tests.

	Flood Plain Level to 13.30 m+PWD	**13.30 m+PWD to 8.30 m+PWD**	**Below 8.30 m+PWD**
Soil classification	Clayey sandy silt to silty sand; (CL - ML)	Fine to medium sand, silty, partly clayey (SM)	Sand
Grain size distribution (mm)			
d_{60}	0.03 to 0.09	0.11 to 0.20	0.20 to 0.26
d_{50}	0.02 to 0.07	0.09 to 0.22	0.15 to 0.22
d_{10}	0.003 to 0.03	0.04 to 0.07	0.06 to 0.08
Coefficient of uniformity $U = \frac{d_{60}}{d_{10}}$	3 to 10	3 to 4	3 to 4
Coefficient of permeability (m/s)	-	$3 \cdot 10^{-5}$	
Angle of internal friction φ' (°)	25 to 27.5	27.5 to 32.5	
Cohesion c' (kN/m^2)	7 to 20		0
Unit weight/submerged unit weight γ/γ' (kN/m^3)	18/8		

Table 2.4-4: General subsoil data for filter and revetment design

2.4.9 Earthquake Loads

Earthquake loads possibly followed by liquefaction of soil had not been considered for the design of the test structures since their frequency of occurrence in Bangladesh is rather low.

3 DETAILED DESIGN OF THE REVETMENT TEST STRUCTURE

3.1 PRELIMINARY REMARKS

This Design Report differentiates between the "Original Design" and the "Executed Design", for the following reason:

According to the recommendations presented in the Final Planning Study Report (Consulting Consortium FAP 21/22, 1993 a) the Revetment Test Structure was to be implemented within sheltered waters of a dredged channel in front of Bahadurabad/Belgachha. Morphological changes in the area during the first period of the Project Implementation Phase required to decide on another location for the structure to best comply with the Project's site selection criteria (see Section 2.1 and Consulting Consortium FAP 21/22, 1995 d in this regard).

The "Original Design" referred to in this report means the design based on the recommendations of the Final Planning Study Report (Consulting Consortium FAP 21/22, 1993 a), which was lateradapted to the chosen test site location, i.e. construction of protected underwater slopes to 5 m below SLW and 9.5 m below SLW respectively, not within sheltered waters, but from the riverbank.

For several reasons the original design concept could not be implemented during the dry season 1995/1996. Consequently, the "Executed Design" means the design adapted to the prevailing conditions, namely to construct the Revetment Test Structure completely in a dry construction pit, well above SLW. The "Executed Design" is covered by Section 3.7 of this Design Report.

3.2 DESIGN PARAMETERS

The basic design parameters were chosen from Section 2.4 as follows:

- top level of earth dam according to Design High Water Level (DHW) and the assumption as per Subsection 2.4.3 equal to 22.0 m+PWD;
- crest width 7.5 m, with the intention to utilise this area as a strategic stockpile for boulders and concrete blocks, to be available for any emergency action during a season;
- embankment slopes 1 : 3;
- surface load on the entire crest area corresponding to a 1.5 m high stockpile of boulders within 5 m width;
- scour depth near the upstream end of the structure 12 m to 14 m and near the downstream end 10 m to 12 m (see Subsection 2.4.7) with an assumed slope of scour hole of about 1 : 2;
- subsoil characteristics as per Subsection 2.4.8;
- suitable material to be used for earth dam to be from borrow pits with maximum 5 % silt content for material with steep grain size distribution curve, or of 10 % for material with flat curves;
- layer-wise compaction of earth dam fill to achieve a degree of density corresponding to D = 0.60 to 0.75 (DIN 18126) determined by in-situ testing and the following computation:

  $$D = \frac{\max n - n}{\max n - \min n}$$

  max n = Degree of porosity of soil in loosest state, in the dry,
  min n = Degree of porosity of soil in densest state
  n = Degree of porosity of compacted soil, , and
- design of revetments and toe protection along the structure and around its heads to meet with the anticipated flow conditions detailed in Table 2.4-2 and a wave load corresponding to a wave height of H = 0.8 m and a wave period T = 3 seconds (see Table 2.4-3).

3.3 FILTER DESIGN

3.3.1 Preliminary Remarks

One of the tasks of the Project was to investigate the effectiveness and suitability of different filter materials, such as granular filters and geotextile filters (geosynthetics). The aspects of designing suitable filter materials are exploited in more detail in Attachment 11 to this Design Report.

3.3.2 Granular Filters

Granular filters included the following combinations:

- two-layer sand-gravel filter: 1. layer of sand – gravel, filter Type II
  2. layer of gravel – stone, filter Type III
- two-layer Khoa filter: 1. layer of sand – gravel, filter Type II
  2. layer of Khoa (chipped bricks of medium to coarse size)

The chosen grain distribution is presented in Fig. 3.3-1. It should be noted that for each and every situation the granular filter design must be adapted to the prevailing soil conditions and intermediate or armour layers.

Each of the individual filter layers was designed at 30 cm thickness, providing a minimum overall filter thickness of 60 cm.

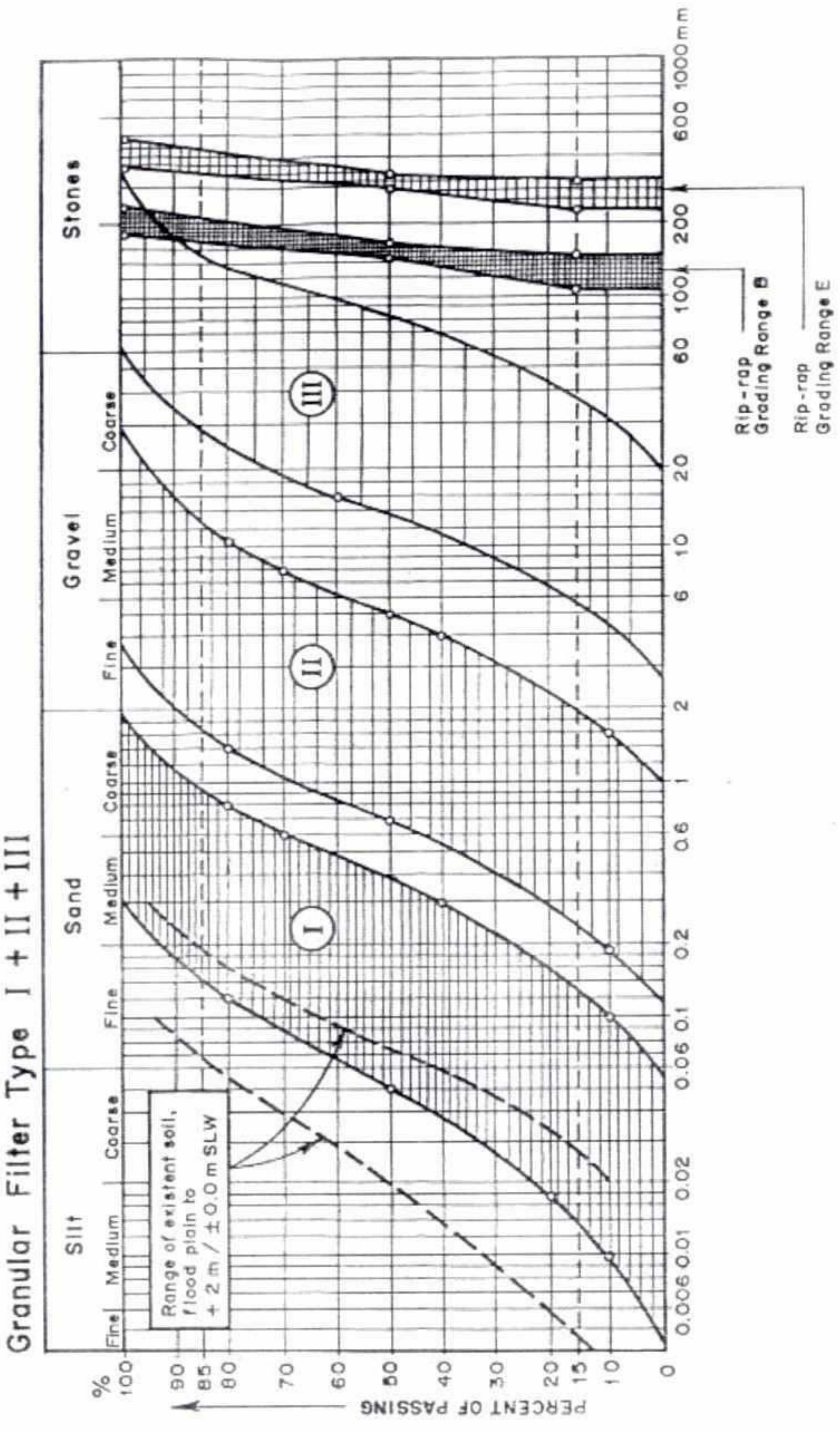

Fig. 3.3-1: Grain distribution of granular filter materials

3.3.3 Geotextile Filters

A total of ten different geotextile filters were selected and utilised within the test structure, to meet with the different subsoil classifications and application methods.

The soil classification applied for determination of different geotextile filter materials is presented in Table 3.3-1.

Grain Size (mm)	Range of Grain Sizes							
	Soil Type 1		Soil Type 2		Soil Type 3		Soil Type 4	
	min.	max.	min.	max.	min.	max.	min.	max.
d_{90}	0.5	63.0	0.125	2.0	0.06	2.0	0.02	1.0
d_{60}	0.5	10.0	0.125	0.5	0.06	0.5	0.012	0.06
d_{20}	0.125	2.0	0.125	0.5	0.06	0.125	0.006	0.06

Table 3.3-1: Soil classification for filter design

The assumed mean values of the coefficient of permeability (water) are:

- soil Type 1: $k = 4 \cdot 10^{-4}$ m/s
- soil Type 2: $k = 3 \cdot 10^{-4}$ m/s
- soil Type 3: $k = 6 \cdot 10^{-5}$ m/s
- soil Type 4: $k = 1 \cdot 10^{-9}$ m/s

Based upon the foregoing assumptions the individual types were determined in accordance with Attachment 11 hereto. Geotextile filter Type GF-3 has not been used in the works, but the original code of geotextiles has been retained in this report to avoid confusion when reading original design drawings.

(1) Geotextile Type GF-1

Geotextile Type GF-1 was designed to be used as revetment filter layer above and below low water level to soil of Type 4.

The filter have to be covered by protective layers of rip-rap or uniformly sized concrete blocks (dumped as well as placed in parallel rows) of more than 50 kg single weight, or brick mattresses or gabion mattresses of 25 cm to 40 cm thickness.

The material was selected as non-woven needle-punched geotextile with the following additional specification:

- effective opening size (BAW-method) O_{90}: 0.07 mm
- thickness: ≥ 2.0 mm
- area mass: ≥ 350 g/m²
- min. tensile strength as per DIN 53857
  - longitudinal: > 1200 N/10 cm
  - transversal: > 1400 N/10 cm
- min. elongation
  - longitudinal: ≥ 80 %
  - transversal: ≥ 50 %
- puncture resistance: > 600 Nm

- mechanical filtering capacity (soil Type 4)
  - max. quantity of soil passage: 300 grams
  - max. quantity of soil passage in the last test phase: 30 grams
- coefficient of permeability at a load of 2 kN/m²: $\geq 1 \cdot 10^{-7}$ m/s
- materials: preferably 100 % Polyester (PES) or 50 % Polypropylene (PP) 50 % PES

(2) Geotextile Type GF-2

Geotextile Type GF-2 was designed to be used as revetment filter layer above and below low water level and the soil to be retained had to meet the characteristics of soil Types 1 to 3.

The planned cover layers were of rip-rap or dumped concrete blocks of more than 50 kg per single weight. The material was selected as non-woven needle-punched geotextile with the following specification:

- effective opening size (BAW-method) O_{90}: 0.07 mm
- thickness: 2 mm < d < 5 mm
- area mass: $\geq$ 700 g/m²
- min. tensile strength as per DIN 53857
  - longitudinal: > 1200 N/10 cm
  - transversal: > 1400 N/10 cm
- min. elongation
  - longitudinal: $\geq$ 60 %
  - transversal: $\geq$ 50 %
- puncture resistance: > 1200 Nm
- mechanical filtering capacity (soil Types 1 to 3)
  - max. quantity of soil passage: 25 grams
  - max. quantity of soil passage in the last test phase: 2.5 grams
- coefficient of permeability at a load of 2 kN/m²: $\geq 1 \cdot 10^{-7}$ m/s
- materials: 100 % Polyester (PES)

(3) Geotextile Type GF-4

Geotextile Type GF-4 was selected to be used as revetment filter layer above and below low water level and the soil to be retained are soil Types 1 to 3.

The cover layers are of rip-rap or dumped concrete blocks of more than 50 kg single weight. The material shall be non-woven needle-punched with the following specification:

- effective opening size (BAW-method) O_{90}: 0.07 mm
- thickness: $\geq$ 5 mm
- area mass: $\geq$ 700 g/m²
- min. tensile strength as per DIN 53857
  - longitudinal: > 3200 N/10 cm
  - transversal: > 4700 N/10 cm
- min. elongation
  - longitudinal: $\geq$ 60 %
  - transversal: $\geq$ 50 %
- puncture resistance: > 1200 Nm

- mechanical filtering capacity (soil Types 1 to 3)
    - max. quantity of soil passage: 25 grams
    - max. quantity of soil passage in the last test phase: 2.5 grams
- coefficient of permeability at a load of 2 kN/m²: $\geq 1 \cdot 10^{-7}$ m/s
- materials: 100 % Polyester (PES)

(4) Composite Geotextile Type GF-5

Composite geotextiles are expected to prevent downslope migration of critical soils, which was to be expected in the reaches above SLW.

The composite material comprises of a geotextile filter mat corresponding with Type GF-1 or GF-2 and an attached coarse fibre layer, which had to fulfill the following criteria:

- effective opening size (BAW-method) O_{90}: > 0.3; < 1.5 mm
- thickness of additional layer d_m : 5 - 15 mm

The geotextile filter mat and the additional coarse layer are needle-punched together at the manufacturer's factory.

(5) Composite Geotextile Type GF-6

The description of above para (4) applies, but with the following criteria for the additional coarse layer:

- effective opening size (BAW-method) O_{90}: > 0.5; < 2.0 mm
- thickness of additional layer d_m : 5 - 20 mm

3.3.4 Resume

After the first years of monitoring the Revetment Test Structure it can be concluded that all granular filters as well as geotextile filters have performed well, except one type of composite filter, which did not sufficiently prevent downslope migration of critical soils.

The selection of heavier geotextile filters, such as types GF-3 and GF-4 was justified for the original design concept, which assumed the construction of under water slopes.

Using geotextile material is by far the fastest way to install a filter, which is important in view to the restricted construction windows, but the the present it need to be imported and hence foreign currency payments are involved.

3.4 DESIGN OF EMBANKMENT REVETMENTS

3.4.1 Slope Stability

With the design assumptions listed under Section 2.4 slope stability computations were carried out regarding to different loading and scouring conditions. A ratio of 1V:2H for the inner and outer slope of the revetment was found to be safe within the assumptions made, but a slope of 1V:3H was chosen for the final design to cover for the variations in the local subsoil conditions. Recommendations for slope stability analyses are contained in the Guidelines and the Design Manual as well.

3.4.2 Revetment Design Formulas

The revetments were designed for flow velocities and wave conditions which, with all probability, could have been expected to occur within the pilot project period. The respective assumptions were derived from the data compiled in Section 2.4.

Slopes reaching down to about 11.3 m+PWD i.e. 2 m below SLW, were considered to be subjected to the effects of flow and wave loads, while for slopes below this level only flow attack was considered for dimensioning the protective layers.

At the initial start of the Test and Implementation Phase of the Project a comparison of different design formulas for revetments was carried out showing that the results are generally within a reasonable margin. For information the respective formulas are listed below, while the respective annotations are contained in Attachment 12 to this Design Report.

(a) Stability of Embankment Revetments under Current Attack

(1) **Pilarczyk-Formula** (1990)

$$D_n \geq 0.85\, D_{50} = \frac{0.035 \cdot u_b^{\,2}}{\Delta_m \cdot 2g} \cdot \frac{\phi \cdot K_r \cdot K_h}{K_S \cdot \Psi_{cr}}$$

(2) **PIANC-Formula** (1987a)
(for rip-rap)

$$D_{n50} \geq \frac{0.7 \cdot u_s^2}{\Delta_m \cdot g \cdot k}$$

(3) **Modified Isbash-Formula**
(for rip-rap)

$$D_{n50} \geq \frac{C \cdot u_b^2}{\Delta_m \cdot g \cdot k}$$

(4) **FAP 1-Formula**
(for concrete blocks)

$$D \geq 0.026 \cdot u^2 \cdot \frac{\pi}{6} \cdot \frac{\rho_s - 1}{\rho_c - 1}$$

(5) **BRTS-Formula** (5/1993, FAP 1)
(for concrete blocks)

$$D \geq \frac{0.7\ v^2}{2(S_s - 1)g} \cdot \frac{2}{\left[\log\left(6\frac{h}{D}\right)\right]^2} \cdot \frac{1}{\left[1 - \left(\frac{\sin\phi}{\sin\theta}\right)^2\right]^{1/2}}$$

(b) Stability of Embankment Revetments under Wave Attack

(1) **Pilarczyk-Formula** (1990)

$$D_n \geq 0.85\ D_{50} \geq \frac{H_s \cdot \xi_z^b}{\Delta_m \cdot \psi_u \cdot \phi \cdot \cos\alpha}$$

(2) **HUDSON-Formula**

$$W_{50} \geq \frac{\rho_c \cdot H_{des}^{\,3}}{K_D \cdot \left(\frac{\rho_s}{\rho_w} - 1\right) \cdot \cot\alpha}$$

The various formulas presented slightly different results, however, in a practical approach these are marginal and would be adjusted in the final designs for ease of construction works, by eliminating such theoretical margins.

Within the context of formula comparison the Pilarczyk-formulae were found to present a suitable method considering the various aspects of hydraulic loads and structure conditions. Therefore all formulae used are based on Pilarczyk (1990/94) with suitable modifications to cover differing boundary conditions.

For the chosen alternatives, design formulae for current and wave attack are presented and explained for each revetment type in the attachment listed in Table 3.4-1.

Type of Revetment	ATTACHMENT
• rip-rap (randomly placed)	1
• cc-blocks (cubical shape, randomly placed in multi-layer)	2
• non-interlocked cc-blocks (cc-blocks, cubical shape, hand-placed in single layer, chess pattern)	3
• interlocking concrete blocks (interlocked, tongue and groove, cable-connected)	4
• wire mesh mattresses	5
• geotextile mattresses	6

Table 3.4-1: Revetment design sheets

3.5 DESIGN OF PROTECTION APRONS

3.5.1 Definitions

"Launching Apron" consists of interconnected elements that are placed horizontally on the (excavated) floodplain and anchored at the toe of the embankment. The elements cannot develop freely once scouring occurs but launch down the slope;

"Falling Apron" consists of loose elements, mostly geo-bags and cc-blocks placed at the outer end of the structure. The elements develop independently once scouring reaches them and fall down the scouring slope to protect it

"Toe Protection" protection of the toe of an embankment revetment against erosion/scouring. Toe protections within the meaning of this report are dimensioned as falling aprons of suitable size and weight.

3.5.2 Falling Apron Design Formulae

At the time of project start only few theoretical approaches were available for the design of falling aprons. For comparison, known design formulas were analysed for Kamarjani Test Site, which showed that the results are generally within a reasonable margin. Annex 4 to the Final Project Evaluation Report (Consulting Consortium FAP 21/22, 2001 e) may be consulted in this regard.

Subsequently, the design methods have been further extended, for which the physical model tests in France (Consulting Consortium FAP 21/22, 1995 b) have produced useful inputs. The resultant design formula and recommendations are compiled and described in Attachment 7 to this Design Report and include

- design of falling aprons of blocks and stones/boulders, and
- design of falling aprons of geotextile sand containers

Both items present a step-by-step approach to determine

- single unit size for current attack;
- single unit size for wave attack, and
- dimensioning of the falling apron/scour protection blanket by
  - cross-section;
  - effective volume of the apron/blanket, and
  - width of falling apron

and include some additional design recommendations.

However, attention should be given to the Guidelines and Design Manual where extended design rules are being discussed and presented for future standard designs.

3.6 ORIGINAL DESIGN OF THE TEST STRUCTURE

3.6.1 Typical Design Cross Section

Three typical cross-sections were chosen in accordance with the findings presented in the Procurement and Construction Report (Consulting Consortium FAP 21/22, 1995 c). The toe level of the embankment slope has been maintained at 5 m and 9.5 m respectively below SLW in accordance with the Final Planning Study Report (Consulting Consortium FAP 21/22, 1993 a). The crest level of the test structure was defined at a level of 22.0 m+PWD (8.70 m+SLW), i.e. well above Design High Water Level at 21.1 m+PWD (7.80 m+SLW) to cope with unexpected high flood situations and wave run-up as estimated for the design recurrence intervals.

The typical cross-sections are presented in Fig. 3.6-1 to 3.6-3.

3.6.2 Revetment Designs

(a) Result of Design Computations

All design computations are summarised in Table 3.6-1.

Type of Revetment			Size Due to			Selected Size	Selected Layer Thickness
			wave load		current load		
			tolerable damage [cm]	No damage [cm]	[cm]	[cm]	[cm]
Rip-rap		D_{50}	17	30	31	30	60
cc-blocks, dumped randomly, multi-layer		D_n	21	32	27	30	60
cc-blocks, hand-laid, single layer		D_n	-	28	26	30	30
Interlocking cc-blocks		d	-	19	17	15/17	15/17
Wire mesh mattresses (stone fill) slope	1 : 3	d	-	24	26	23	23
	1 : 3.5	d	-	22	17	23	23
Wire mesh mattress (brick fill) slope	1 : 3	d	-	34	37	36	36
Sand filled tubular mattress (PROFIX)		D_{matt}	-	41	40	30/40	30/40
Collapsible block mattress (sand fill)		D_{matt}	-	41	40	35/45	35/45
Collapsible block mattress (sand-cement-grout fill)		D_{matt}	-	25	25	25	25

Table 3.6-1: Selected dimensions and layer thickness for different revetments

(b) Slope Protection above Berm Level

The different revetments were chosen for their reproducibility in Bangladesh and ease of installation in dry condition, e.g. for those areas located above water level. Some of the described systems appear identical, but block sizes were being dimensioned according to differing design criteria, such as turbulence factors, critical shear stress parameter, interaction upgrading factor, etc.

The alternatives are described in the following, all of which were planned for installation on different types of geotextile filter mats and granular filters respectively. The attached Drawings No R-G-004 and R-D-102 may be referred to in addition (Attachment 14).

- brick mattress (traditional system of two brick layers, the top one laid in fish bone pattern, between galvanised steel wire mesh); mattress thickness 15 cm and 20 cm;
- RENO©-mattress (imported), 36 cm thickness, filled with full-size bricks; the mattresses laid on a 25 cm thick intermediate rubble layer positioned on the geotextile filter mat;
- wire mesh mattress (local manufacture), 23 cm thickness, stone filled (D_{50} = 15 cm, Grading Range B), with a 25 cm thick intermediate rubble layer placed on the geotextile filter;
- rip-rap of hard rock (D_{50} = 25 cm, Grading Range D), with colloidal cement grouting (surface grouting at a rate of about 100 ltr. grout per 1 m^2 surface area, minimum cement content 550 kg for 1 m^3 of grout), weep holes are to be provided;
- cement concrete blocks size D_n = 30 cm using chipped bricks (khoa) as coarse aggregate, single layer, hand-laid in rows parallel to the berm, with staggered joints, and 10 mm joints between the blocks in a row;
- interlocking cement-concrete blocks, factory made (locally) tongue-and-groove type, thickness 15 cm;
- cement concrete blocks using chipped bricks (khoa) as coarse aggregate single layer, hand-laid in rows diagonal (at 30°), staggered joints; blocks are shaped to maintain a 10 mm gap between the

blocks in a row; to be laid on a two-layer granular filter, and for one part of a section, on a two-layer khoa filter;

- wire mesh mattress (local manufacture), 36 cm thickness, filled with full-size bricks, but without an intermediate rubble layer on the geotextile filter mat;
- interlocking cement-concrete blocks, factory made (locally), ship-lap-type, thickness 17 cm.
- rip-rap of hard rock (D_{50} = 20 cm, Grading Range C), with bitumen grout (full-depth pattern grouting), layer thickness 50 cm and 40 cm.

(c) Revetments below Berm

Placing of under-water slope protection materials require a considerably higher skill, equipment demand and standard of control than materials destined for the upper, i.e. dry part of the revetment.

All planned revetments were considered for installation under water, even though a part of it will always be above water level prevailing at the time of construction. This is particularly important for proper anchoring and securing of geotextile filter mats and mattress systems within the berm.

All granular cover materials used were designed to be laid on geotextile filter mats. Mattress systems with sand fill do not require additional filter layers, but function as a filter themselves. Where mattresses were designed to be filled with sand cement mix or cement grout, adequate permeability of the system must be ensured by filter openings and/or additional geotextile filter layers.

The designed alternatives are described in the following. Drawings No R-D-107 and R-D-111 are attached hereto for further reference.

- RENO©-mattress (imported), 23 cm thickness, stone filled (D_{50} = 15 cm, Grading Range B); the individual wire mesh cages connected to complete mattresses, with a 25 cm thick intermediate rubble layer placed on the geotextile filter;
- cement concrete blocks using chipped bricks (khoa) as coarse aggregate, randomly dumped at a slope coverage of theoretically two layers of the nominal block size D_n, only mono-size blocks D_n = 30 cm;
- cement concrete blocks using chipped bricks (khoa) as coarse aggregate, randomly dumped at a slope coverage of theoretically two layers of the nominal block size D_n, centre part mono-size blocks (D_n = 35 cm) up/downstream transitions with sizes D_n = 40 cm and 50 cm;
- rip-rap (hard rock, D_{50} = 30 cm, Grading Range E) randomly placed at a theoretical slope coverage of two layers of the nominal diameter D_{50} of a single unit of the protection layer;
- cement concrete blocks using chipped bricks (khoa) as coarse aggregate, different block sizes for toe area and centre part of the section, randomly placed to a coverage of three times the nominal block size D_n, , centre part D_n = 30 cm, along the toe of slope D_n = 40 cm. The centre part of the test structure was dimensioned below stability safety level, wherefore the layer thickness was chosen to be three times of D_n;
- mattress system of tubular tailored, woven fabrics (PROFIX-mattress©), the mattress system to be filled with specified Jamuna sand in dry condition and pulled down the slope step by step, using a special barge-mounted equipment. To avoid failure of the sand-filled mattress due to damage (e.g. by country boats etc.) the tubes in an area from berm level to about 1.5 to 2 m below SLW, were designed to be filled with sand cement mix or sand-asphalt. In any such case, the permeability of the mattress has to be ensured;
- collapsible block mattress of woven fabrics with filter points (INCOMAT-Sand Flex©). As filling material selected Jamuna sand was specified. The filling method was yet to be further developed to suit local adaptability and may be by pneumatic/hydraulic fill, by means of an air-compressor

of high delivery rate, sludge pumps and a sand hopper with feeder to transfer the sand into the mattress fabric, pre-installed on the under water slope;

- collapsible block mattress of woven fabrics (FORESHORE©). The filling material was chosen to be cement-sand grout. The installation and filling requires expert diver assistance. To achieve the desired flexibility the grouted mattress system provides two-dimensional pliability by cross-lines of concrete with a smaller cross-section between the main blocks of the mattress. These reduced sections are expected to act as predetermined breaking points in case of increasing deformations of the subgrade due to settlement, erosion, scouring, etc. Even though the cover textile could fail in such event, it is assumed that the integrity of the mattress would be maintained by reinforcing bands, spacing elements and synthetic ropes that are integrated in the mattress system. This system was also planned for application as falling apron.

Supplementary to the foregoing a further alternative was taken into consideration for implementation at the downstream end of the original test structure. For conditions where the prevalent river bed slopes was around at 1:4 to 1:5 to a water depth of more than 5 m below SLW it was considered attractive not to construct a revetment by dredging a slope of 1:3.5, providing a filter and placing protective layers plus a scour protection but only to provide a wide and thick falling apron on the existent river bed from below berm level (see Fig. 3.6-3). This solution would initially involve some more maintenance works as compared to fully developed and constructed revetments. However, these could be carried out by local means at reasonable cost and it was considered that such circumstance should not disqualify the solution. The alternative seems a suitable option for many situations in executional and economical aspect, in particular were severe hydraulic conditions prevent proper execution of slope protections by filters and cover layers. For this reason, the downstream termination of the original test structure was chosen for this alternative. A partial or local failure of this test area would not have led to consequent failure of adjacent test sections. For the most exposed part, the material were to be stones and boulders (D_{50} = 35 cm) ranging from D = 25 cm (40 kg) to D = 45 cm (230 kg), randomly placed to a coverage of two times the nominal D_{50} diameter of a single stone/boulder.

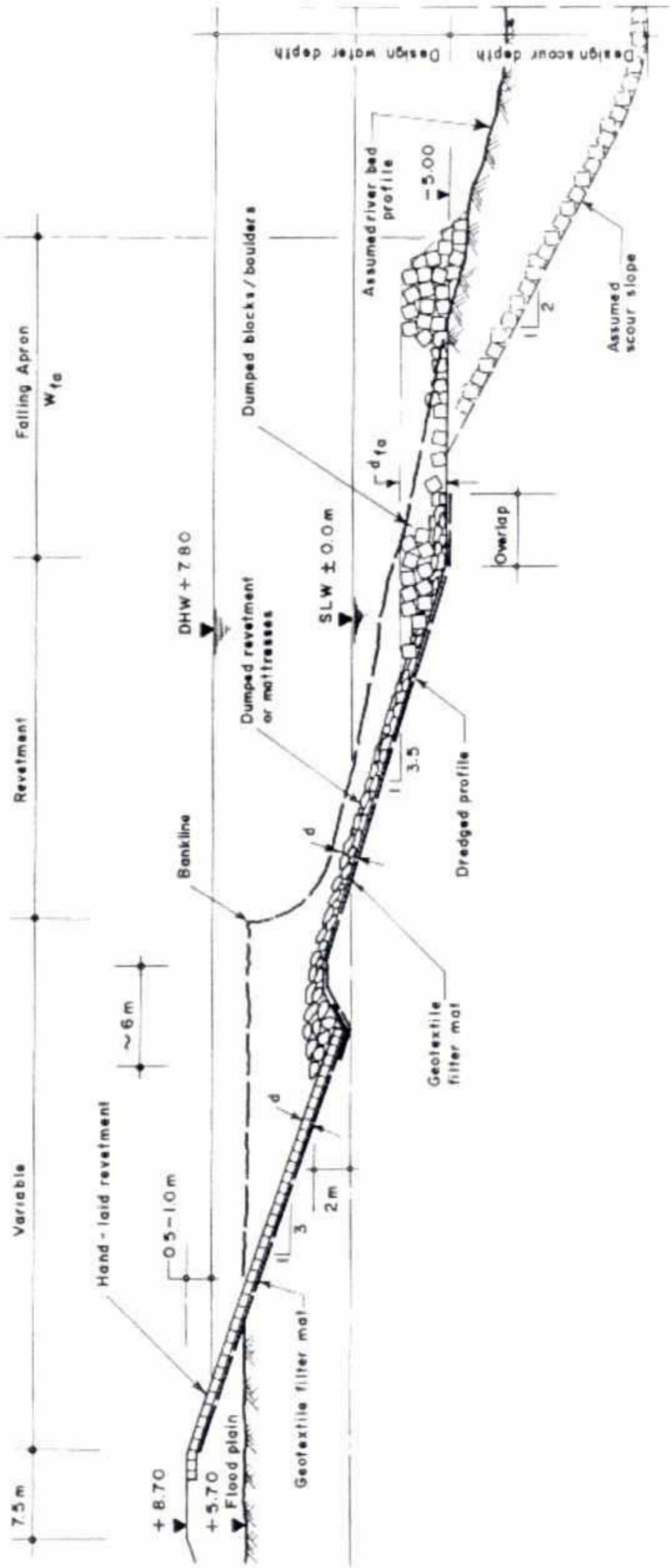

Fig. 3.6-1: Typical revetment section Type I (toe level at – 5.00 m+SLW)

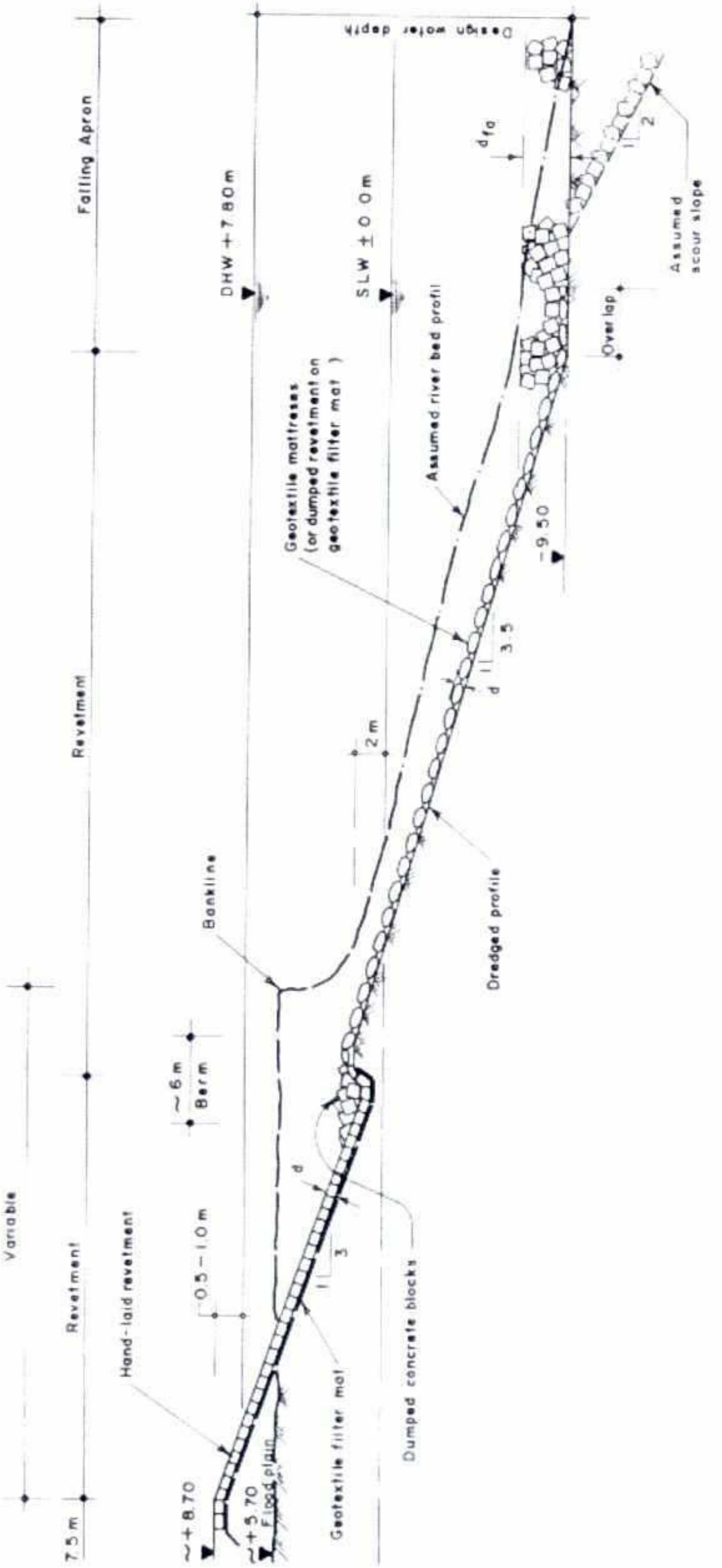

Fig. 3.6-2: Typical revetment section Type II (toe level at – 9.50 m+SLW)

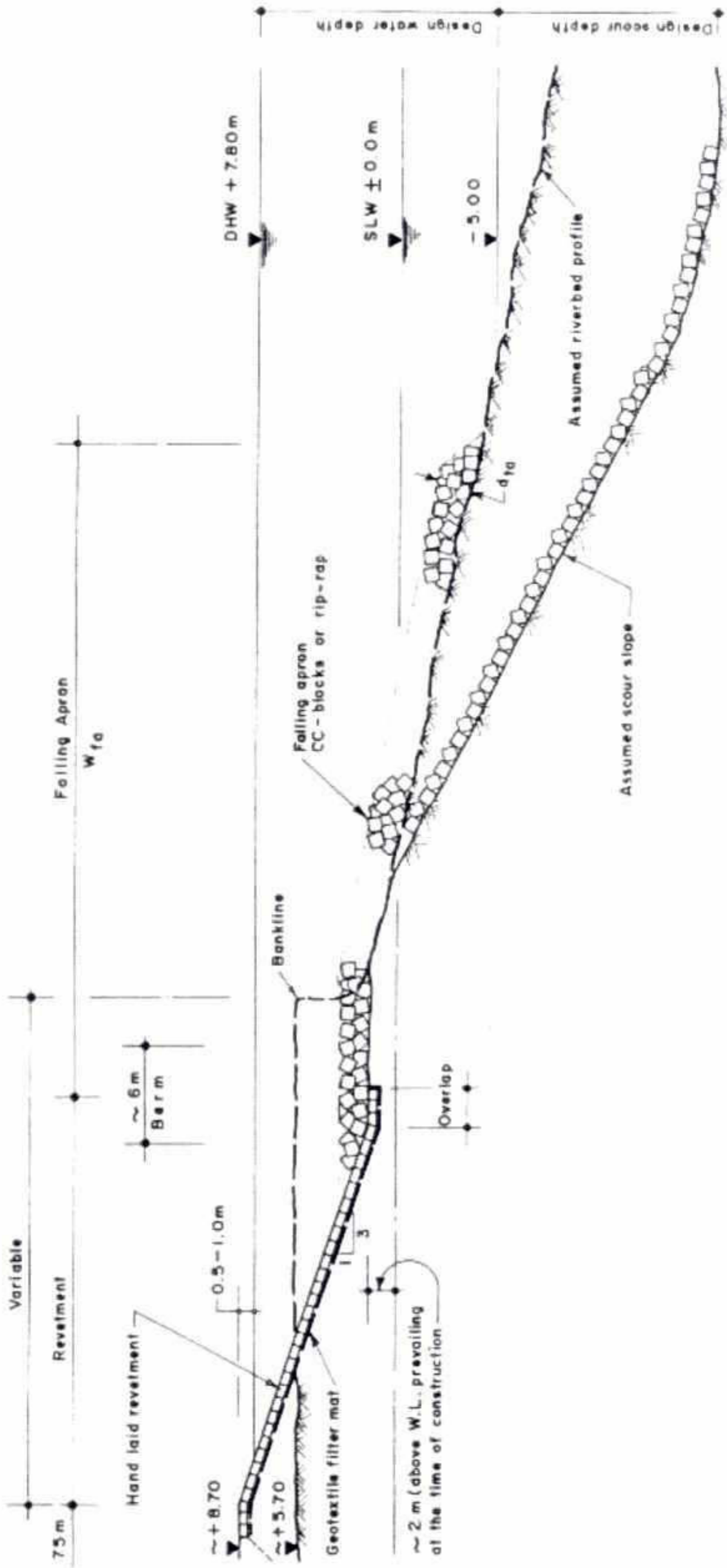

Fig. 3.6-3: Typical revetment section Type III (falling apron only below berm)

3.6.3 Falling Apron Design

(a) Result of Design Computations

The basic materials selected for scour protections were

- cement-concrete blocks of sizes ranging from D_n = 25 cm to D_n = 45 cm;
- stones and boulders, D_{50} = 30 cm and D_{50} = 35 cm respectively, with a range of D = 25 cm to 45 cm (W = 40 kg to 230 kg), dependent on the exposure of the respective apron;
- gabion sacks, filled with stones D_{50} = 15 cm, Grading Range B; fill volume about 0.65 m^3, weight about 1,300 kg/sack;
- geotextile sand containers of different fill volume, ranging from 180 kg/No to 900 kg/No, and
- scour protection mattress (FORESHORE© collapsible block mattress).

The design of falling aprons was carried out as per hydraulic loads and design assumptions presented in Sections 2.4 and 3.5 and in consideration of the methods presented in Attachment 8 hereto. The computation sheets for dimensioning the size of protection material and the geometrical shape of the falling apron are compiled in Attachment 12 to the Procurement and Construction Report (Consulting Consortium FAP 21/22, 1995 c), the results are summarised in Table 3.6-2. In case, graded block sizes are being used in falling aprons, the smallest block size D_n must be designed to withstand any displacement by currents and waves (if applicable).

Design Section	**Protection Material**	**Design Scour Depth**	**Block/Stone Size D_n**	**Geo-bag Weight**	**Calculated Falling Apron Dimensions**	
		[m]	[cm]	[kg]	Thickness [m]	total width [m]
A (end)	CC	-	25	-	0.85	5.60
A-a-1	CC	5.0	30	-	1.00	8.80
A-a-2	Rip-rap	8.0	25	-	1.00	15.0
A-b-1	Rip-rap	10.0	30	-	1.00	18.00
A-b-2	Rip-rap	12.0	30/35	-	1.00/1.20	26.30
B	GeCo	14.0	(45/50)	180/250	2 layers	31.50
C	GeCo	14.0	(40)	900	2 layers	25.20
D	CC	14.0	35	-	1.20	24.50
E-1	Gabion sacks	10.0	0.65 m^3/No		155 Nos per 100 m^2	17.50
E-2		8.0				14.80
F	CC	6.0	40	-	1.35	11.10
G	CC	6.0	35	-	1.20	10.50
H	CM	6.0	-	-	0.25	30.00
I-1	Rip-rap	10.0	35	-	1.20	17.50
I-2	CC	5.0	30	-	1.00	10.50

GeCo = Geotextile container with sand fill
CC = Cement concrete blocks
CM = Collapsible block mattress

Table 3.6-2: Selected dimensions of falling aprons

(b) CC-Blocks, Rip-Rap

For falling aprons of cc-blocks the quantity of material to be provided within the designed falling apron width W_{fa} was defined by the number of blocks to be placed within an area of 100 m^2. This will facilitate proper control of material placement. The respective information is compiled in Table 3.6-3, including the corresponding theoretical falling apron thickness d_{fa}.

CC-Block Size D_n [cm]	25		30		35		40		45	
	d_{fa} [m]	Nos [-]	d_{fa} [m]	Nos [-]	d_{fa} [m]	Nos [-]	d_{fa} [m]	Nos [-]	d_{fa} [m]	Nos [-]
Inner part (1/3 W_{fa})	0.40	2,100	0.45	1,300	0.55	1,000	0.60	720	0.70	600
Outer part (2/3 W_{fa})	0.85	4,100	1.00	2,800	1.20	2,100	1.35	1,600	1.50	1,250
Exposed edges	0.85	4,100	1.00	2,800	1.20	2,100	1.35	1,600	1.50	1,250

Table 3.6-3: Falling apron of cc-blocks; Nos of blocks per 100 m² area

(c) Geotextile Sand-Container

Contrary to blocks or boulders, where only the ground area is in contact with the river bed and the scour slope respectively, sand-filled geo-container cover a considerably larger area with identical unit weight, irrespective of their changing shape. Thus, they represent a relatively thin, but area-wise large protection element.

With the basic principles of Attachment 7 it is assumed that a theoretical coverage of the scour hole slope of at least two layers of flat-laying sand-containers should be adequate to stabilise the scour hole. Consequently, the number of geo-sand containers to be placed within 100 m² of falling apron area were designed as shown in Table 3.6-4.

Geo-Sand Container Type/Volume	B	C	D	E
	125 kg/No	180 kg/No	250 kg/No	900 kg/No
Equivalent CC-block D_n [cm]	40	45	50	-
Inner part (1/3 W_{fa})	420	320	260	120
Outer part (2/3 W_{fa})	690	520	430	200
Exposed edges	-	520	430	200

Table 3.6-4: Falling apron of geo-sand containers; Nos of containers per 100 m² area

(d) Mattress System

The behaviour of falling aprons was studied in physical model tests (Technical Report No. 4, Consulting Consortium FAP 21/22, 1995 b). The tests, however, dealt only with cc-block material of different sizes. Only little experience exists regarding the suitability of mattress systems to act as falling apron and to protect slopes of scour holes of about 6 m or even up to 14 m (as assumed to occur in front of the test structures).

Sand-filled mattress systems had not been considered suitable as launching apron at the initial design stage. A failure of the mattress fabric would lead to partial emptying of the mattress, possibly with consequent deficiencies in the protective system.

Therefore, a sand-cement grouted collapsible block mattress FORESHORE© was being designed as slope protection (falling apron) in the Original Design.

3.6.4 Selection of Geotextile Filters

The most important part in a revetment with regard to critical seepage forces is the area where wave attack and piping occurs. Seepage forces are at maximum during the falling stages of the river. They may also occur at the toe of the revetment and turbulent flow may induce particle migration around the block protection. Besides, some of the soils encountered may be susceptible to downslope migration. In general piping and a particle migration may be tolerable to some extent, as long as resultant deformations in the slope revetment do not lead to instability of the slope in itself.

Geotextile filter materials were selected on the basis of sample materials successfully tested in a series of filter stability investigations (Consulting Consortium FAP 21/22, 1995 a). Recalling that also under regular circumstances the final structure location is not known at the time of designing the filter and procurement of material, it is evident that the characteristics of geotextiles can not be optimised to match the conditions at the actual construction site, but must be universally suitable for almost any situation.

Geotextiles were categorised to the following application groups (see Subsection 3.2.3).

- Type GF-1: Preferably for use above SLW, but also up to a limited water depth;
- Type GF-2: For application below SLW;
- Type GF-3: (not utilised at Bahadurabad Test Site);
- Type GF-4: For heavy-duty applications below water;
- Type GF-5: Composite geotextile filter with an additional coarse fibre layer for soils susceptible to downslope migration, and
- Type GF-6: Composite geotextile filter with an additional thick coarse fibre layer, likewise for soils susceptible to downslope migration.

The selected geotextile filters are appropriately the general requirements in terms of preferred type of material Polyester (PES), or PES/PP (Polypropylene), mechanical properties and effective opening size. To match with the actually prevailing subsoil conditions it can possibly not be avoided to provide for additional granular filter sub-layers (e.g. within the areas above berm) or additional intermediate layers to be placed on the geotextile for particular types of revetment (e.g. stone filled mattresses).

For more information of the manufacturers and types of geotextile filter materials used within the Revetment Test Structure Annex 9 to the Final Project Evaluation Report (Consulting Consortium FAP 21/22, 2001 j) may be consulted.

3.7 EXECUTED DESIGN OF TEST SECTIONS

3.7.1 Preliminary Remarks

As said under Subsection 3.1 the Original Design concept could not be implemented. Among others it emerged that the locally available construction capabilities could not meet the requirements for construction of underwater slopes, while the engagement of expensive imported equipment capacity had to be disregarded. Therefore, in order to comply with the Project strategy, namely to plan and implement structures suitable for local construction capability, it was decided to modify the structure geometry allowing the construction in a dry construction pit just above SLW.

The modification of the structure design had to be carried out in consideration of the already procured construction materials, such as geotextile filter materials, geotextile mattresses, boulder sizes and concrete block sizes. Consequently, certain compromises had to be accepted for the modified design, which are commented in the following subsections.

3.7.2 Layout

For the Executed Design the original geometrical layout (plan view) of the embankment structure was retained, except minor alterations of upstream curvature and overall length. The structure was positioned at an angle of about 5° against the average bankline at the location. The final layout may be taken from Drawing No. R-A-302/1 attached to this Design Report.

3.7.3 Executed Design Cross Section

The idea of modifying the Original Design is based on the assumption that a suitably dimensioned falling apron can well protect an eroding slope. Thereby the width of the falling apron as well as the volume of protection material must be such that a slope to an emerging scour hole in front of the structure is well covered to stop the erosion progress. It was further considered that after such erosion processes the finally stabilised under water slope should meet approximately with the situation anticipated in the Original Design, i.e. the stability of the protection embankment must be ensured.

In line with this basic principle the Standard Design cross-section was developed as a combination of

- falling aprons (at the exposed river-side);
- launching aprons (in the transition between falling aprons and upper embankment);
- a berm as toe protection for the upper embankment, and
- the main embankment itself.

For definition of the terms "launching apron" and "falling apron" reference is made to Subsection 3.5.1 of this report. Fig. 3.7-1 presents the Original Design cross-section versus the modified cross-section, with the anticipated river bed morphology after the erosion process has stopped.

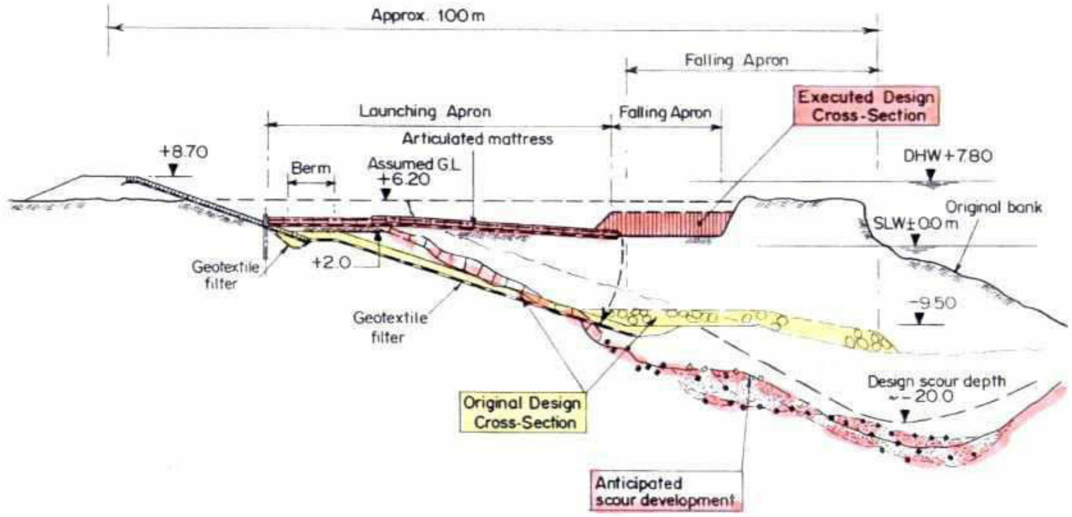

Fig. 3.7-1: Basic principle of executed design

Well in consideration of the already procured materials ten sections representing different protective layers were designed and implemented. Drawings No. R-A-303/1 and No. R-A-304/1 present an overview of the total arrangement and the materials utilised. Generally the descriptions outlined under Subsection 3.6 apply also to the Executed Design, however, two purpose made articulated mattress systems were newly introduced, which are described in more detail in Subsections 3.7.4 and 3.7.5.

3.7.4 Articulated CC-Block Mattress System

It is a basic consideration that an integrated mattress system may have an improved sustainability against the erosion processes. The utilised ready-made mattress systems INCOMAT-Sand Flex©, FORESHORE© and PROFIX-mattress© (refer to para c of Subsection 3.6.3) represent tailor-made solutions, but require a relatively high foreign currency investment furthermore the durability of the systems is questionable when the filing material is not of sufficient grain size (refer to Section 4.4).

With a view on the above, a concept of an articulated cc-block mattress was developed and finally implemented. The basic principle is as follows:

- a geotextile filter mat represents the base of the mattress. This filter mat must have a very high tensile strength and ductility elongation behaviour due to the anticipated system deformations once the erosion attack starts;
- concrete blocks are to be cast directly onto the geotextile filter mat, but must be connected to the mat by U-shaped steel needles;
- to ensure integrity of the system parallel and perpendicular steel wire cables are run through the in-situ cast blocks, and
- the anchor cables running perpendicular to the main embankment are to be anchored to deadmen installed within the berm at the toe of the main embankment.

For its dimensioning the design formula presented in Attachment 6 were applied.

For the Executed Design a compromise had to be accepted since the geotextile materials as procured for the Original Design were already available at site. It should be noted that for a standard solution a thicker, reinforced geotextile should be chosen. If the chosen geotextile is strong enough (e.g. a combined geotextile of heavy filter mat and a high strength woven synthetic mat) the steel wire link cables may be reduced in number.

Fig. 3.7-2 to 3.7-4 depict typical details of the articulated cc-block mattress, while Drawing No. R-A-309/3 presents the executed design cross-section.

Executional aspects are covered by the Procurement and Construction Report in Annex 9 to the Final Project Evaluation Report (Consulting Consortium FAP 21/22, 2001 j).

3.7.5 Articulated RENO-Mattress

RENO-Mattresses© are gabion-type wire-mesh boxes utilised for protection of riverbanks and river beds, e.g. against scouring by vessels screw race, etc.. They are extremely robust and long lasting due to heavy galvanising and supplementary PVC-coating. Under normal use, these mattress units are interlaced with strong steel wires to form an integrated system. For the use on the banks of the Jamuna river, however, it was considered to interconnect the individual mattress cages by steel wire cables, similar to the articulated cc-block mattress system described under Subsection 3.7.4.

The advantages of the system are the simplicity and speed of installation as well as the convenience of filling, for which bricks and suitably sized stones can be used. The mattress cages must, for the time being, be imported from specialised manufacturers, since locally hand-made cages would not provide the required strength and durability. However, for future standard designs it would be feasible to factory produce durable mattress cages in Bangladesh.

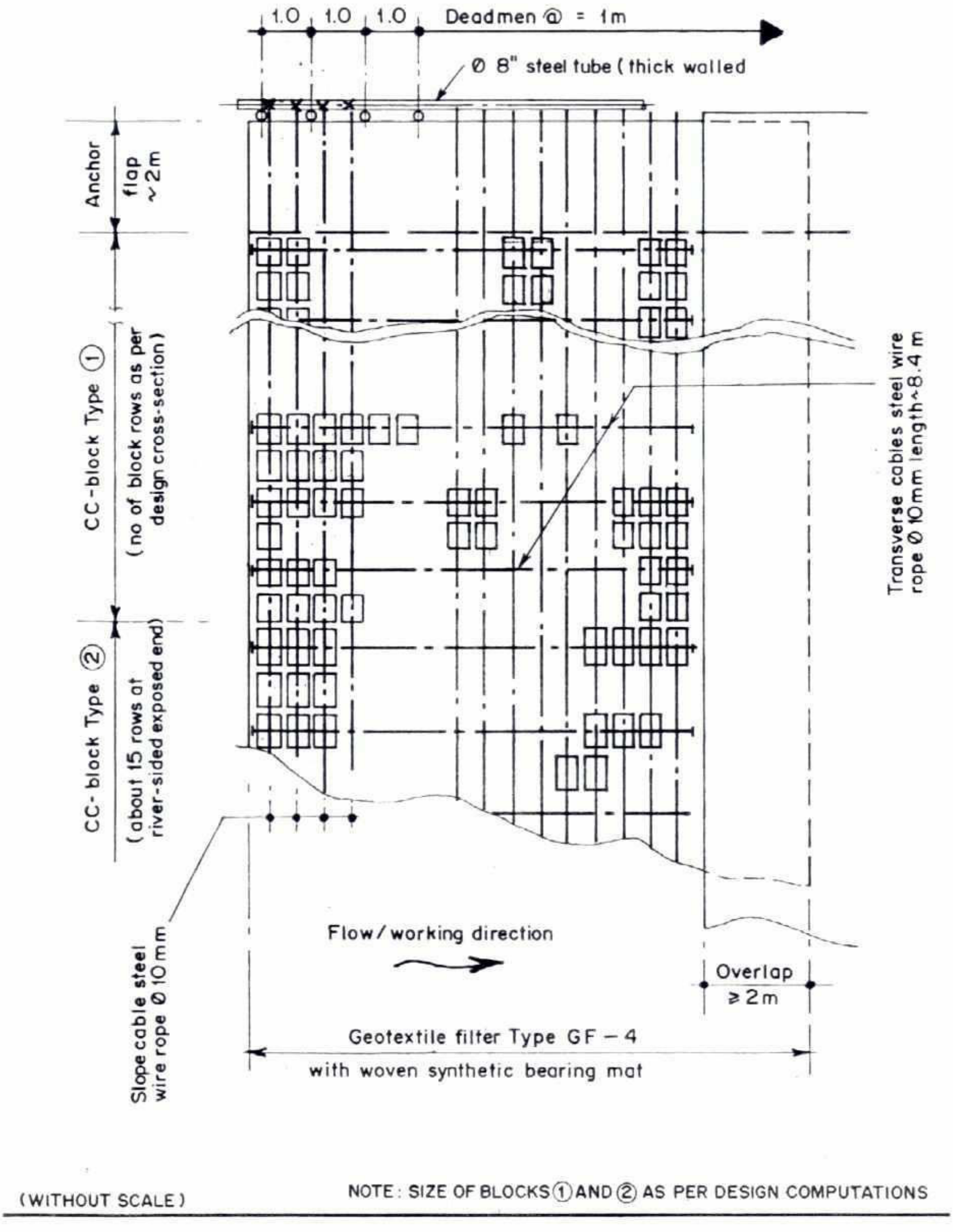

Fig. 3.7-2: Articulated cc-block mattress; typical layout (Plan View)

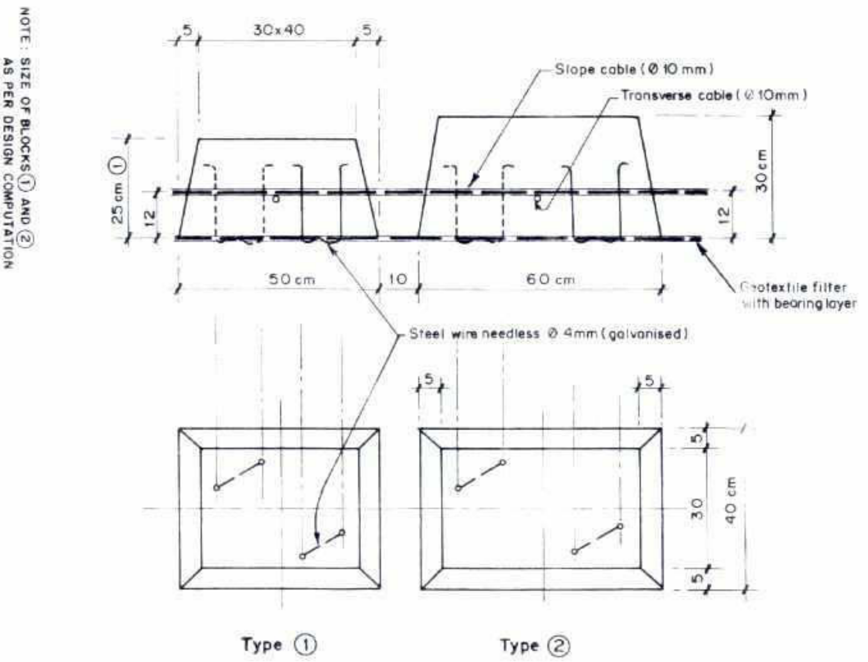

Fig. 3.7-3: Articulated cc-block mattress; typical cc-block dimensions

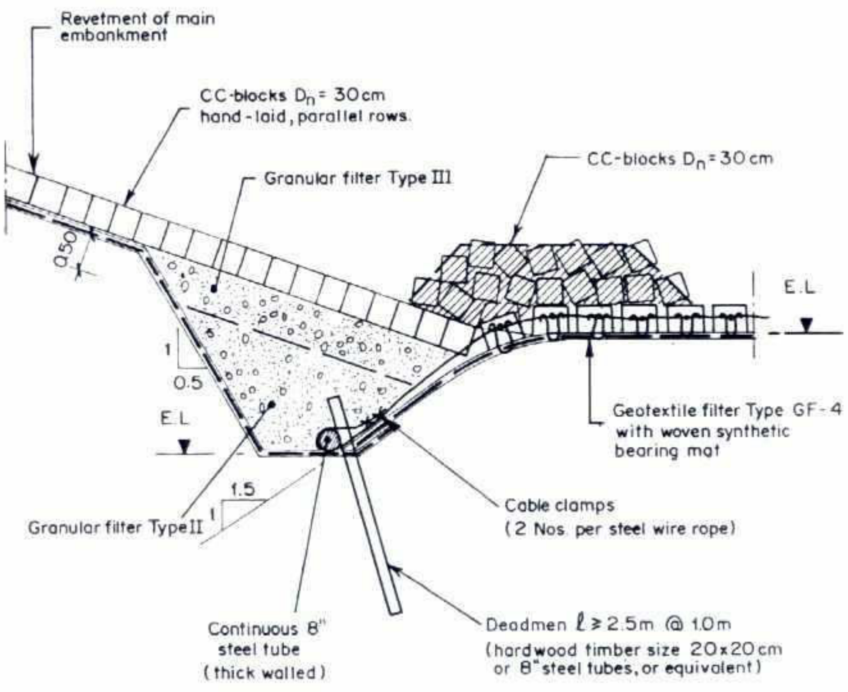

Fig. 3.7-4: Articulated cc-block mattress; typical anchoring of the mattress

4 LESSONS LEARNED

4.1 PRELIMINARY REMARKS

The construction works for the "Executed Design" could be carried out with ease, at comparatively low cost and the achieved progress rate suited the construction window. It is to be noted as a disadvantage that relatively large areas of land had to be acquired to construct this type of structure.

The response of the river in the vicinity of the test structure is compiled and commented in Chapters 5 and 8 of the Final Project Evaluation Report (Consulting Consortium FAP 21/22, 2001 l) as well as in Chapter 6 of Annex 1. In conclusion it can be summarized that the Executed Design withstood the occurring hydraulic loads and could stop the progressing bank erosion in the area, despite extreme scour holes of up to about 30 m below water level.

With the efficient behaviour of the falling aprons it is anticipated that the launching aprons in the transition between the falling apron and the berm of the main embankment can be somewhat optimised by reducing its width considerably. This would certainly enhance the feasibility of the measure by reducing the investment cost and the area of land to be acquired.

Two typical monitoring profiles are presented in Fig. 4.1-1 and 4.1-2, to support the effectiveness of the falling aprons and launching aprons.

4.2 FALLING APRONS

The falling aprons behaved as anticipated and protected the test structure. Some differences were observed between the individual test sections. CC-blocks have stabilised the scour slopes more effectively than geotextile sand containers, though the difference is marginal. Surprisingly, the scour slopes developed in front of the structure during the first season after construction remained practically stable during the subsequent seasons, despite rapidly changing situations of excessive scouring and depositing (refer to Fig. 4.1-1 and 4.1-2). This emphasises the suitability of falling aprons under the given situation at the Jamuna river.

At the downstream termination (test section H-1) local turbulence caused high attack on the falling apron (boulder material), but only during the first season following the construction. The falling apron was arranged on geotextile filter materials, which obviously prevented a free articulation of individual boulders and instead led to sliding of substantial volumes of protection material. Thus, parts of the area were exposed but without endangering the overall stability of the test section. After the first season the area was covered by additional quantities of boulder material.

As said before, it appears justified to reduce the width of the launching aprons considerably, but as a compensatory measure the volume of falling apron materials should then be enhanced reasonably.

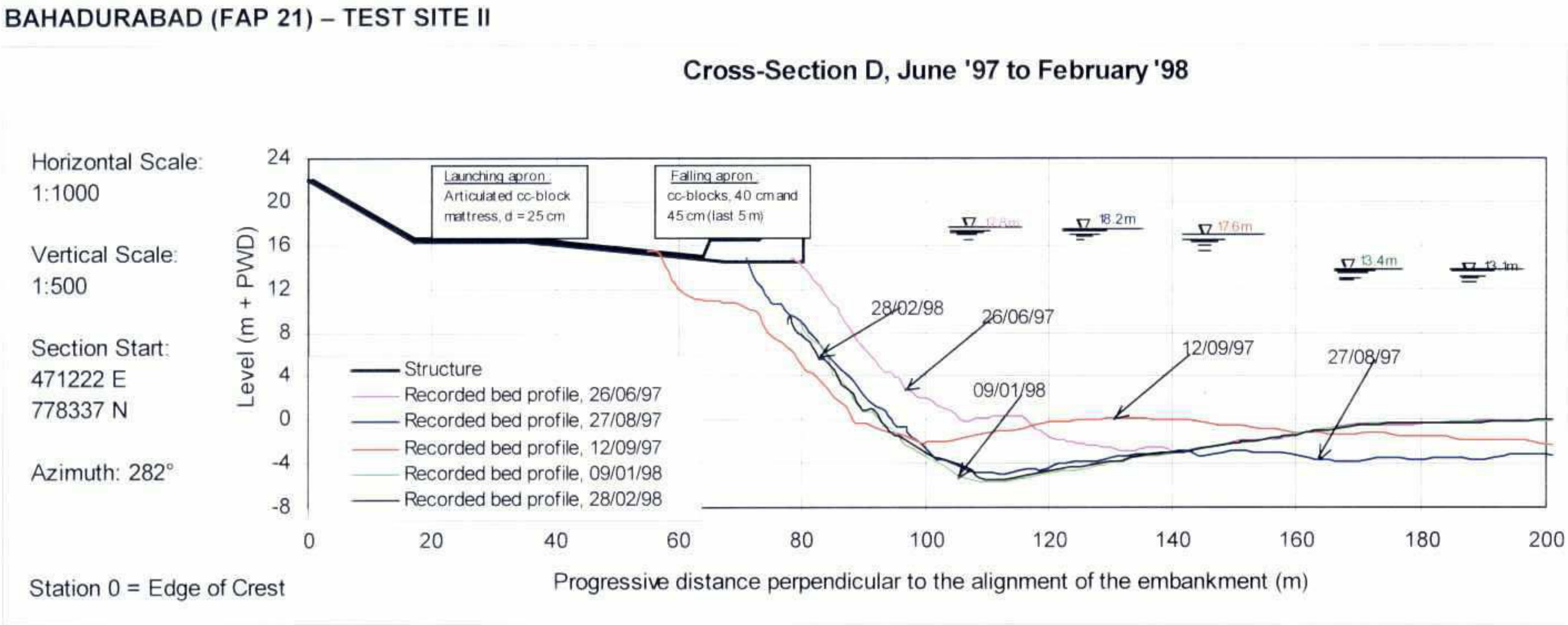

Fig. 4.1-1: Typical monitored bed level as proof of the effectiveness of falling aprons and launching aprons (1)

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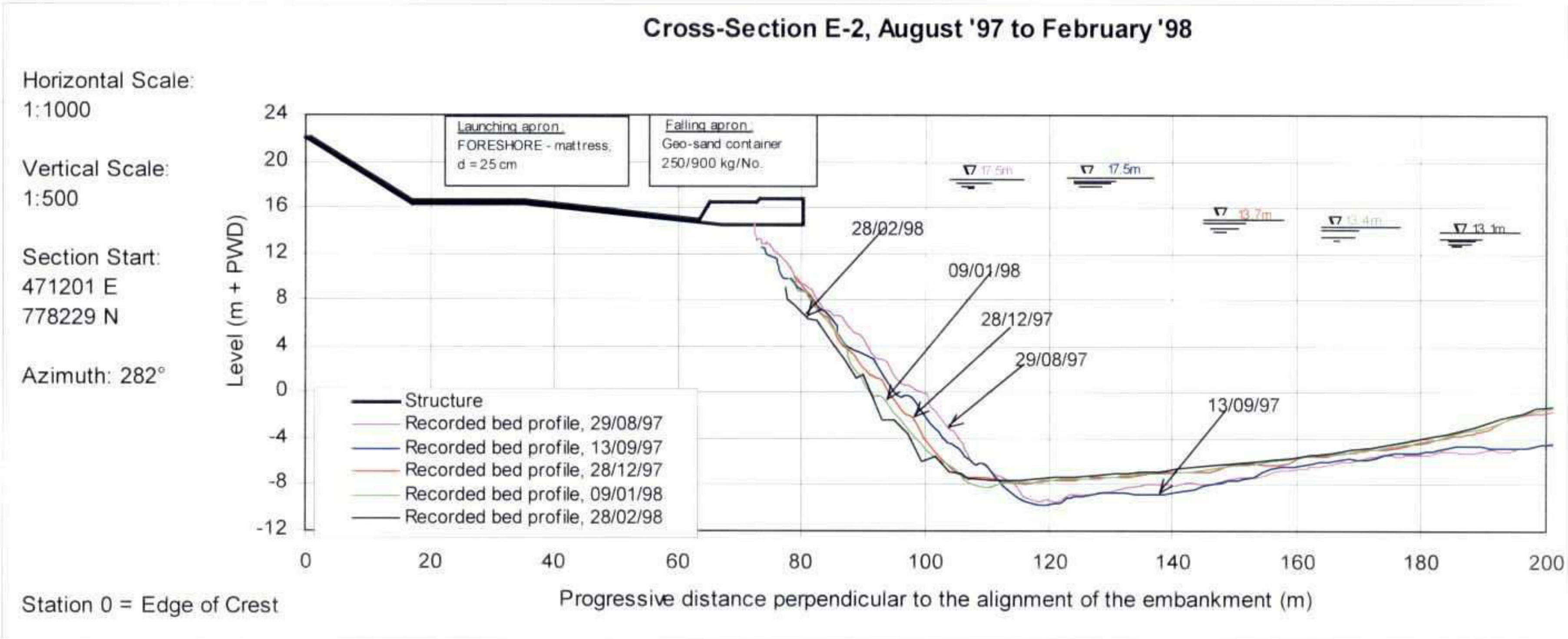

Fig. 4.1-2: Typical monitored bed level as proof of the effectiveness of falling aprons and launching aprons (2)

4.3 LAUNCHING APRONS

Until the flood season 1999/2000 the launching aprons of the test section hardly came under attack, which was mainly due to the efficiency of the falling aprons. An exception is the transition between test Sections B and C, were the articulated RENO-mattresses became exposed to river flow attack and bank erosion during the first seasons following its construction. The integrated mattress system articulated as expected and retained full integrity. The photograph presented in Fig. 4.3-1 clearly demonstrates the efficiency of such a system.

It has to be underscored in this regard that the success of such a system depends on the strength of the mattress units, the proper filling with ballast to ensure the required unit weight, the sound interconnection between the individual mattress cages and the reliability of the steel wire anchoring system.

Based on the experience in the flood season 1999/2000 this articulated mattress system is considered an economical and highly efficient system, which is easy to construct.

Fig. 4.3-1: Articulated RENO-mattress system after exposure to erosion attack

4.4 DESIGN DEFICIENCIES OF THE REVETMENT STRUCTURE

After three years studying the performance of the individually designed test sections no design deficiencies became apparent. Thus, it can be assessed that the individual elements of the systems, such as unit weights, volumes and area dimensions suited the hydraulic loads in all respect. Annex 11 to the Final Project Evaluation Report (Consulting Consortium FAP 21/22, 2001 I) presents an analysis of occurred hydraulic loads during the structure's monitoring period versus basic assumptions on which the test structure has been designed.

There are, however, two aspects to be mentioned, which should be given due consideration in any future design:

(1) direction of overlapping in sand-filled Geotextile Mattress Systems, and
(2) use of Ship-Lap Type Prefabricated CC-Slabs for Slope Protection.

To Item (1): To avoid migration of soil particles from joints, all overlaps, i.e. of geotextile filter materials as well as of geotextile mattress systems were designed and arranged against the direction of flow. In the second year and more excessively in the third year after construction, the overlaps of the sand-filled mattresses systems were turned-over by hydraulic forces. Obviously, this happened due to loss of sand fill from the mattresses, since the available material (Jamuna sand) is too fine to be fully retained by the geotextile used for the mattresses.

There are two conclusions to it: (a) Sand-filled mattress systems are cheap solutions, but a gradual loss of fines from the fill cannot be avoided. Therefore, for such systems the overlaps must be arranged in the direction of river flow. To avoid migration of underlying soil the width of overlaps must be increased considerably. (b) Sand-filled mattress system should not be utilised for permanent solutions since the gradual and continuous loss of Jamuna-sand fill may ultimately lead to a general weakness of the system. Improvement of the retention capability of geotextiles for mattresses is considered unfeasible by the manufacturers (at least, not within justifiable financial limits). Delivery of suitably grained sand from the northern part of the country would inflate the cost and make such alternative non-viable.

To Item (2): One test section within the main embankment was protected with ship-lap type factory-made cc-slabs of only 15 cm thickness. Due to its interlocking this light protection can withstand high hydraulic loads and as such appears to be a very economical solution, provided the manufacturing tolerances are maintained within very strict limits. Within the test section the subsoil migrated under the cover layer, though a special composite geotextile filter (Type GF-5, refer to Subsection 3.2.3) was utilised. One of the reasons is certainly the insufficient and non-uniform surface pressure on the geotextile filter due to the light-weight of the slabs as well as manufacturing tolerances. In this regard reference can be made to the Monitoring and Adaptation Report 1997 for Bahadurabad Test Site (Consulting Consortium FAP 21/22, 1999). Besides, the factory-made slabs suffered considerably from transportation damages, which could be avoided by improved transportation and handling methods (palletised transport). In conclusion the ship-lap type cover slabs may not be considered a viable solution under the prevalent conditions.

4.5 EXECUTIONAL CONSTRAINTS

The Construction and Procurement Report attached to the Final Project Evaluation Report as Annex 9 (Consulting Consortium FAP 21/22, 2001 j) contains detailed information on the work execution, experienced constraints, achieved production progress as well as equipment and manpower resources.

Main constraints were related to
- land acquisition
- organisation of earth works (peoples participation), and
- filling of geotextile mattress systems with sand.

4.6 EFFECT OF THE TEST STRUCTURE

Annexes 10 and 11 to the Final Project Evaluation Report (Consulting Consortium FAP 21/22, 2001 k and l) should be consulted for information about the river's response and the occurred hydraulic loads. Generally, it may be stated that the rivers' response was as anticipated, with some bank erosion further downstream from the structure in the first two years following the construction. In the subsequent seasons the river shifted away, causing excessive sedimentation in front of the structure and further downstream.

5 DESIGN OF ADAPTATION WORKS

There was no need for designing adaptation of the completed structure until season 1999/2000 since the test structure withstood all prevailing hydraulic conditions.

6 RECOMMENDATIONS FOR STANDARD REVETMENT DESIGNS

6.1 INTRODUCTION

The Guidelines and the Design Manual present the essential tools and recommendations for the planning and design of revetment structures. Therefore, the respective documents should be consulted for any future work.

Nevertheless, in the following subsections some simplified methods for dimensioning of revetments as well as of launching and falling aprons are given.

6.2 OUTLINE OF FUTURE STANDARD CROSS-SECTIONS

The geometry of two typical test sections based on the experience gained at Bahadurabad Test Site are presented in Fig. 6.2-1.

To consider specific site conditions the design rules presented in the above mentioned Guidelines and Design Manuals must be consulted in order to determine the basic design parameters, including projected scour depth, design flow velocity, direction of flow attack, wave height, etc.

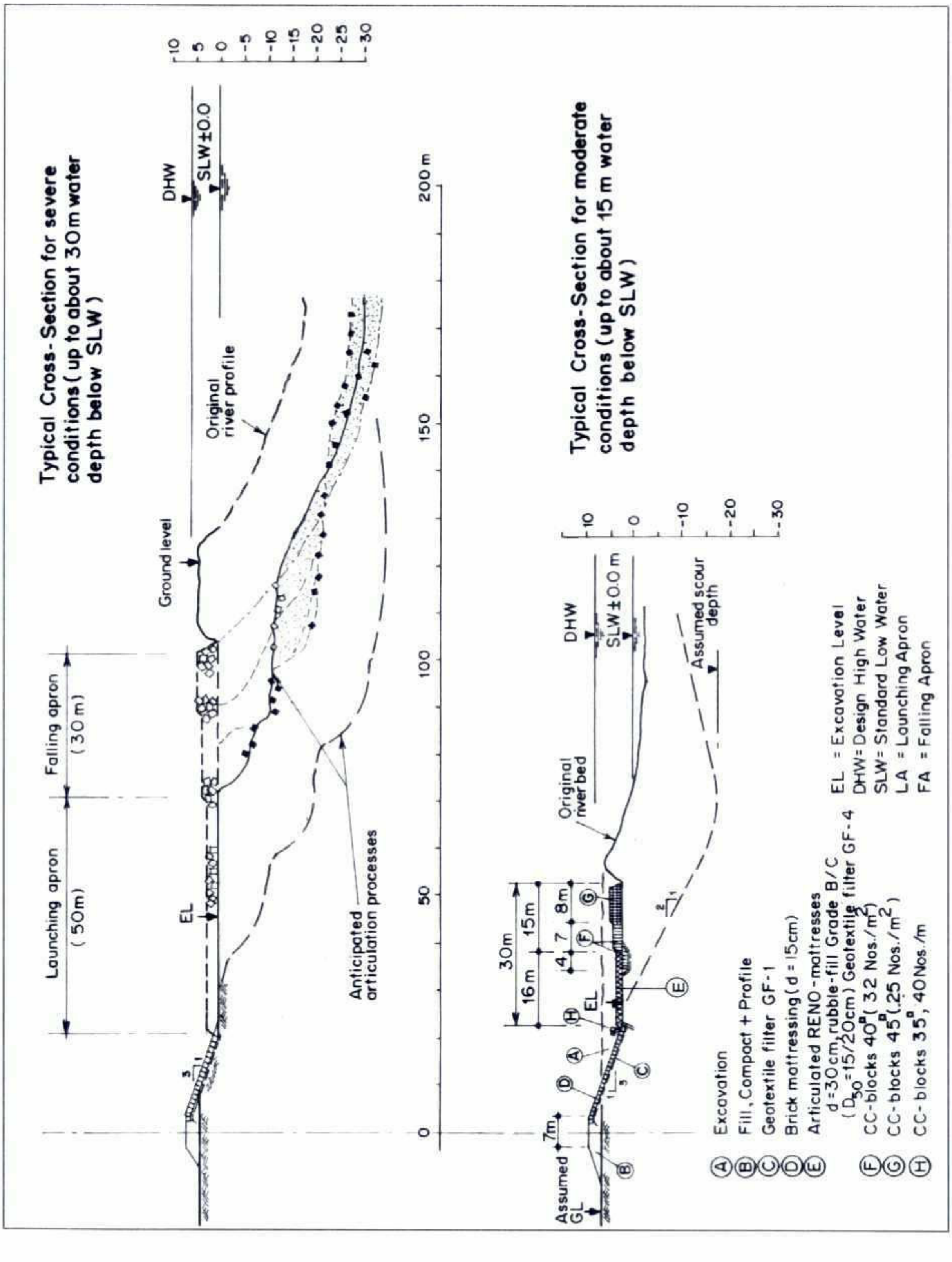

Fig. 6.2-1: Outline of future standard cross-sections (15 m and 30 m water depth below SLW)

6.3 A SIMPLIFIED APPROACH TO REVETMENT DESIGN

6.3.1 Preliminary Remarks

Within the Section 6.3 an attempt is being made to simplify the rather complicated design formulas for revetments towards presenting a handy design tool to the practising engineer. These initial considerations will have to be further refined and reviewed in the Design Manual.

6.3.2 Current Attack – Basic Formula

Most of the revetment types can be designed by the Pilarczyk formula:

$$D \geq \frac{0.035 \cdot u_b^2}{\Delta_m \cdot 2 \cdot g} \cdot \frac{\phi_{SC} \cdot K_t \cdot K_h}{K_S \cdot \Psi_{cr}} \qquad (6.3\text{-}1)$$

where

D	=	nominal thickness of the revetment cover layer	(m)
u_b	=	bottom flow velocity, assumed at 0.6 * $\bar{u}$	(m/s)
Δ_m	=	relative density of a system unit	
	=	$(\rho_s - \rho_w) / \rho_w$	(-)
g	=	acceleration due to gravity	
	=	9.81	(m/s²)
ϕ_{SC}	=	stability factor for current	(-)
ψ_{cr}	=	critical shear stress parameter	(-)
K_t	=	turbulence factor	(-)
K_h	=	depth factor	(-)
K_s	=	slope factor	
	=	$\cos\alpha \cdot \sqrt{1 - \frac{\tan^2\alpha}{\tan^2\varepsilon_s}}$	(-)
α	=	slope angle	(degree)
ε_s	=	angle of respose	(degree)

The design diagrams presented in Fig. 6.5-1 and 6.5-2 use the Pilarczyk – formula by means of practical simplification and summarisation of several coefficients:

$$D \geq \frac{0.035 \cdot u_b^2 \cdot K_h}{2 \cdot g} \cdot \frac{\phi_{SC}}{\Delta_m \cdot \Psi_{cr}} \cdot \frac{K_t}{K_S} = f_1 \cdot f_2 \cdot \frac{K_t}{K_S} \qquad (6.3\text{-}2)$$

For **gabions** and **articulated mattress systems** and their filling material the following formula applies:

$$D \geq \frac{u_b^2}{\Delta_m \cdot 2 \cdot g} \cdot \frac{0.03 \cdot K_h}{\Psi_{cr} \cdot K_s} \qquad (6.3\text{-}3)$$

This formula simplified to suit the development of design diagrams:

$$D \geq \frac{0.035 \cdot u_b^2 \cdot K_h}{2 \cdot g} \cdot \frac{0.03}{0.035 \cdot \Delta m \cdot \psi_{cr}} \cdot \frac{1}{K_s} = f_1 \cdot f_2 \cdot \frac{K_t}{K_s} \tag{6.3-4}$$

For **geotextile mattresses** the following formula can be used:

$$D_{eq} \geq \frac{\phi_s \cdot u_b^2 \cdot K_h}{\Delta m \cdot 2 \cdot g \cdot K_s} \tag{6.3-5}$$

This formula simplified to suit the development of design diagrams:

$$D \geq \frac{0.035 \cdot u_b^2 \cdot K_h}{2 \cdot g} \cdot \frac{\phi_s}{0.035 \cdot \Delta m} \cdot \frac{1}{K_s} = f_1 \cdot f_2 \cdot \frac{K_t}{K_s} \tag{6.3-6}$$

6.3.3 Wave Attack – Basic Formula

Most of the revetment design can be based on the general formula by Pilarczyk:

$$D \geq \frac{H_s \cdot \xi_z^b}{\Delta m \cdot \psi_u \cdot \phi_{SW} \cdot \cos\alpha} \tag{6.3-7}$$

where

D	=	nominal thickness of the revetment cover layer	(m)
H_s	=	significant wave height	(m)
T_m	=	mean wave period	(s)
Δ_m	=	relative density of a system unit	
	=	$(\rho_s - \rho_w) / \rho_w$	(-)
ϕ_{SW}	=	stability factor for wave loads	(-)
ψ_u	=	system determined stability upgrading factor	(-)
α	=	slope angle	(degree)
ξ_z	=	wave breaking parameter on a slope	(-)
	=	$\frac{1.25 \cdot T_m \cdot \tan\alpha}{\sqrt{H_s}}$	
b	=	interaction exponent	(-)

The design diagrams presented in Fig. 6.6-1 and 6.6-2 use the Pilarczyk – Formula by means of practical simplification and combination of several coefficients:

$$D \geq \xi_z^b \cdot \frac{H_s}{\cos\alpha} \cdot \frac{1}{\Delta m \cdot \psi_u \cdot \phi_{SW}} = f_1 \cdot f_2 \cdot \frac{1}{f_3} \tag{6.3-8}$$

In case of **geotextile mattresses** the formula is slightly different:

$$D_{eq} \geq \frac{H_s \cdot \xi_z^{-1}}{\Delta m \cdot \beta \cdot \cos\alpha} \tag{6.3-9}$$

where

D_{eq}	=	equivalent thickness of geotextile mattress	
	=	$0.75 \cdot D_{matt}$	(m)
Δ_m	=	relative density of a system unit	
	=	$(\rho_s - \rho_w) / \rho_w$	(-)
β	=	6, if $k_m / k_s > 1$	
k_m	=	permeability of the mattress	(m/s)
k_s	=	permeability of the subsoil	
	=	$3 * 10^{-5}$	(m/s)
α	=	slope angle	(degree)

The design diagrams presented in Fig. 6.6-1 and 6.6-2 use the Pilarczyk – Formula by means of practical simplification summarisation of several coefficients:

$$D_{eq} \geq \xi_z^{-1} \cdot \frac{H_s}{\cos\alpha} \cdot \frac{1}{\Delta m \cdot \beta} = f_1 \cdot f_2 \cdot \frac{1}{f_3} \tag{6.3-10}$$

6.4 ASSUMPTIONS AND PARAMETERS FOR THE REVETMENT DESIGN

6.4.1 Rip Rap

• slope	1:3 and 1:3.5 respectively
• density of protection material:	$\rho_s = 2600$ kg/m³
• density of water:	$\rho_w = 1000$ kg/m³

(a) Current Attack

K_t	=	1.5	(non-uniform flow with increased turbulence, mild outer bends)
ε_s	=	20°	angle of internal friction between cover layer and sublayer (angle of repose) for rip-rap on geotextile filter mat
ϕ_s	=	0.75	stability factor for continuous protection areas
ϕ_s	=	1.50	stability factor for exposed edges, transitions
ψ_{cr}	=	0.035	critical shear stress parameter for rip-rap (randomly placed material, movement of a few units allowed now and then)

(b) Wave Attack

ϕ_{sw}	=	2.25	stability factor for incipient motion
ϕ_{sw}	=	3.00	stability factor for maximum tolerable damage for a 2-layer system on granular filter
ψ_u	=	1.00	stability upgrading factor for rip-rap (2 layers)

ψ_u	=	1.33	stability upgrading factor for revetments with a tolerable damage to the rip-rap cover layer
b	=	0.5	interaction exponent (processes between waves and roughness/porosity of cover layer) for rough and permeable revetments

6.4.2 CC-Blocks (cubical shape, randomly placed in multi-layer)

• slope:	1:3 and 1:3.5 respectively
• density of protection material (concrete with Khoa aggregates):	ρ_c = 1980 kg/m³
• density of water:	ρ_w = 1000 kg/m³

(a) Current Attack

K_t	=	1.5	non-uniform flow with increased turbulence, mild outer bends
ε_s	=	30°	angle of internal friction between cover layer and sublayer (angle of repose) for CC-blocks on geotextile filter mat
ϕ_s	=	0.80	stability factor for continuous protection areas
ϕ_s	=	1.50	stability factor for exposed edges, transitions
ψ_{cr}	=	0.035	critical shear stress parameter for randomly placed material

(b) Wave Attack

ϕ_{sw}	=	2.25	stability factor for incipient motion
ϕ_{sw}	=	3.00	stability factor for maximum tolerable damage for a 2-layer system on granular filter
ψ_u	=	1.33	stability upgrading factor for dumped mono-size CC-blocks (2 layers)
ψ_u	=	1.50	stability upgrading factor for revetments with a tolerable damage to the CC-block dumped cover layer
b	=	0.667	interaction exponent (processes between waves and roughness/porosity of cover layer) for pitched blocks

6.4.3 Non-interlocked CC-blocks (cubical shape, hand placed in single-layer chess pattern)

• slope:	1:3and 1:3.5 respectively
• density of protection material (concrete with Khoa aggregates):	ρ_c = 1980 kg/m³
• density of water:	ρ_w = 1000 kg/m³

(a) Current Attack

K_t	=	1.5	non-uniform flow with increased turbulence, mild outer bends
ε_s	=	20°	angle of internal friction between cover layer and sublayer (angle of repose) for CC-blocks on geotextile filter mat
ϕ_s	=	0.65	stability factor for continuous protection areas
ϕ_s	=	1.25	stability factor for exposed edges, transitions
ψ_{cr}	=	0.050	critical shear stress parameter for paved CC-block cover layers

(b) Wave Attack

ϕ_{sw}	=	2.25	stability factor for incipient motion
ψ_u	=	1.50	stability upgrading factor for loose closely placed blocks on a geotextile filter mat laid on sand
b	=	0.667	interaction exponent (processes between waves and roughness/porosity of cover layer) for loose but closely placed blocks

6.4.4 Interlocked CC-blocks (tongue and groove)

• slope:	1:3 and 1:3.5 respectively
• density of protection material (concrete with Khoa aggregates):	ρ_c = 1980 kg/m³
• density of water:	ρ_w = 1000 kg/m³

(a) Current Attack

K_t	=	1.5	non-uniform flow with increased turbulence, mild outer bends
ε_s	=	20°	angle of internal friction between cover layer and sublayer (angle of repose) for CC-blocks on geotextile filter mat
ϕ_s	=	0.60	stability factor for continuous protection areas
ϕ_s	=	1.20	stability factor for exposed edges, transitions
ψ_{cr}	=	0.070	critical shear stress parameter for paved interlocked CC-block cover layers

(b) Wave Attack

ϕ_{sw}	=	2.25	stability factor for incipient motion
ψ_u	=	2.20	stability upgrading factor for interlocking blocks placed on a geotextile filter mat laid on granular sublayer
b	=	0.667	interaction exponent (processes between waves and roughness/porosity of cover layer) for loose but closely placed blocks

6.4.5 Cable Connected CC-blocks (articulating mattress)

• slope:	1:3 and 1:3.5 respectively
• density of protection material (concrete with Khoa aggregates):	ρ_c = 1980 kg/m³
• density of water:	ρ_w = 1000 kg/m³
• volume of voids (proportion of spaces in %):	n = 20 %

(a) Current Attack

K_t	=	1.5	non-uniform flow with increased turbulence, mild outer bends
ε_s	=	20°	angle of internal friction between cover layer and sublayer (angle of repose) for CC-blocks on geotextile filter mat
ϕ_s	=	0.50	stability factor for continuous protection areas
ϕ_s	=	1.10	stability factor for exposed edges, transitions
ψ_{cr}	=	0.060	critical shear stress parameter for cable connected blocks

(b) Wave Attack

ϕ_{sw}	=	2.25	stability factor for incipient motion
ψ_u	=	1.80	stability upgrading factor for cable connected blocks
b	=	0.667	interaction exponent (processes between waves and roughness/porosity of cover layer)

6.4.6 Wire Mesh Mattresses (articulating mattress)

• slope:	1:3 and 1:3.5 respectively
• density of protection material (rip-rap):	ρ_s = 2600 kg/m^3
• density of protection material (bricks):	ρ_s = 1800 kg/m^3
• density of water:	ρ_w = 1000 kg/m^3
• volume of voids (proportion of spaces) for rip-rap:	n = 40 %
• volume of voids (proportion of spaces) for bricks:	n = 15 %

(a) Current Attack

ε_s	=	20°	angle of internal friction between cover layer and sublayer (angle of repose) for wire mesh mattresses on geotextile filter mat
ϕ_{cr}	=	0.070	critical shear stress parameter for stone mattresses

(b) Wave Attack

ϕ_{sw}	=	2.25	stability factor for incipient motion
ψ_u	=	2.50	stability upgrading factor
b	=	0.667	interaction exponent (processes between waves and roughness/porosity of cover layer)

6.4.7 Sand Filled Tubular Mattresses

• slope:	1:3 and 1:3.5 respectively
• density of protection material (sand-cement grout):	ρ_s = 2300 kg/m^3
• density of protection material (Jamuna sand, dry filling method):	ρ_s = 1800 kg/m^3
• density of water:	ρ_w = 1000 kg/m^3

(a) Current Attack

ε_s	=	25°	angle of internal friction between cover layer and sublayer (angle of repose) for geotextile mattress on granular sublayer
ϕ_s	=	0.8	stability factor for continuous protection areas
ϕ_s	=	1.0	stability factor for exposed edges and transitions

(b) Wave Attack

β	=	4	stability coefficient, with uplift of mattress and deformation of subsoil as main failure mechanism
b	=	1.0	interaction exponent (processes between waves and roughness/porosity of cover layer)

6.4.8 Collapsable Mattresses (geotextile articulating matress)

• slope :	1:3 and 1:3.5 respectively
• density of protection material (sand-cement grout):	ρ_s = 2300 kg/m³
• density of protection material (Jamuna sand, hydraulic fill):	ρ_s = 1800 kg/m³
• density of water:	ρ_w = 1000 kg/m³

(a) Current Attack

ε_s	=	25°	angle of internal friction between cover layer and sublayer (angle of repose) for geotextile mattress on granular sublayer
ϕ_s	=	0.8	stability factor for continuous protection areas
ϕ_s	=	1.0	stability factor for exposed edges and transitions

(b) Wave Attack

β	=	4	stability coefficient, with uplift of mattress and deformation of subsoil as main failure mechanism
b	=	1.0	interaction exponent (processes between waves and roughness/porosity of cover layer)

6.5 STEP-BY-STEP DESIGN - CURRENT ATTACK

With the simplifications under Sections 6.3 and the parameters stipulated under Section 6.4 the size and thickness respectively of the revetment protection material can be determined by

Step 1: Select factor fc_1 for the design flow velocity from Fig. 6.5-1;

Step 2: Select factor fc_2 from Table 6.5-1 for the chosen type of revetment protection;

Step 3: Select angle of respose from Table 6.5-2 corresponding to the chosen built-up of the revetment and determine factor K_s from Fig. 6.5-2, and

Step 4: Select factor K_l from Table 6.5-3.

The respective factors can be introduced in the following formula and the nominal thickness of the protective material be computed:

$$D \geq fc_1 \cdot fc_2 \cdot \frac{K_l}{K_s} \qquad (6.5\text{-}1)$$

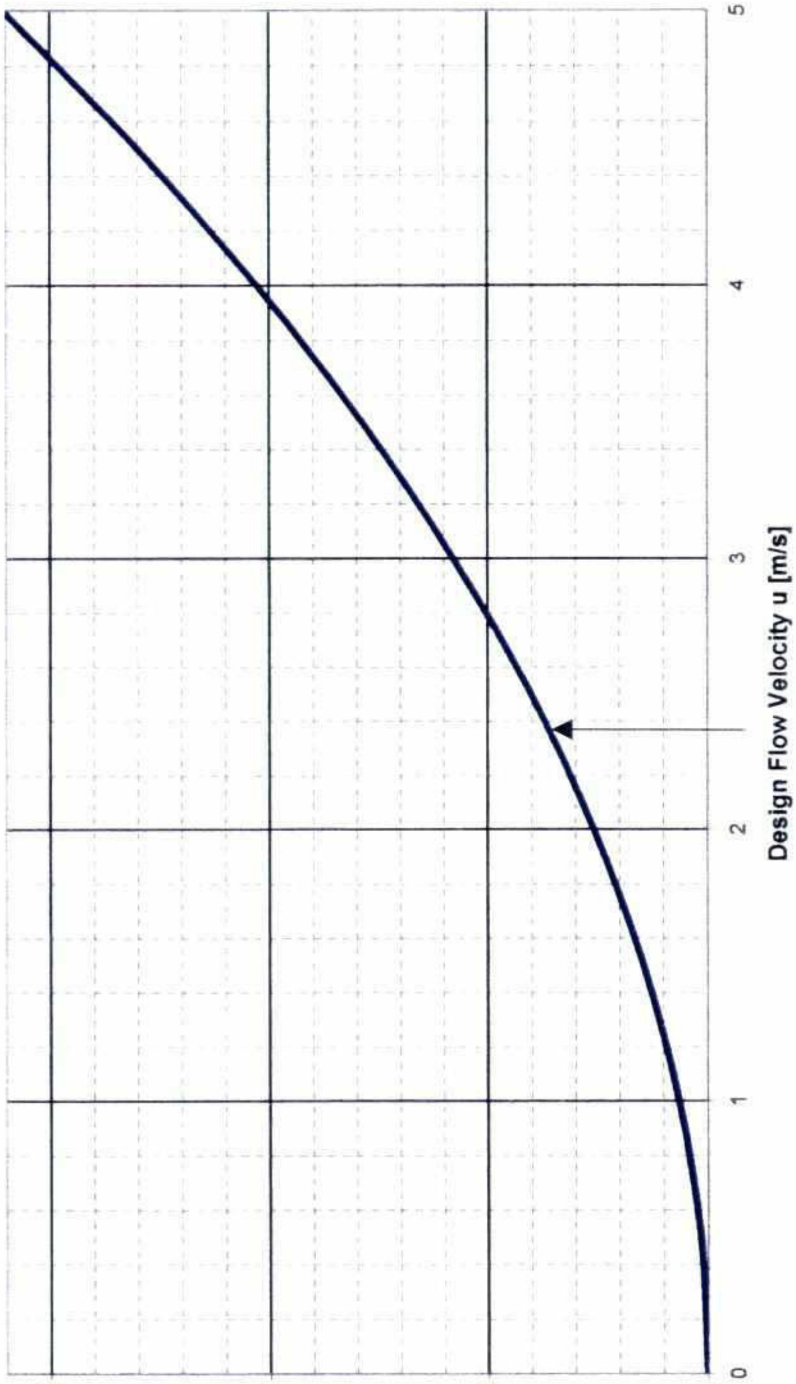

Fig. 6.5-1: Design Factor fc_1 (Current)

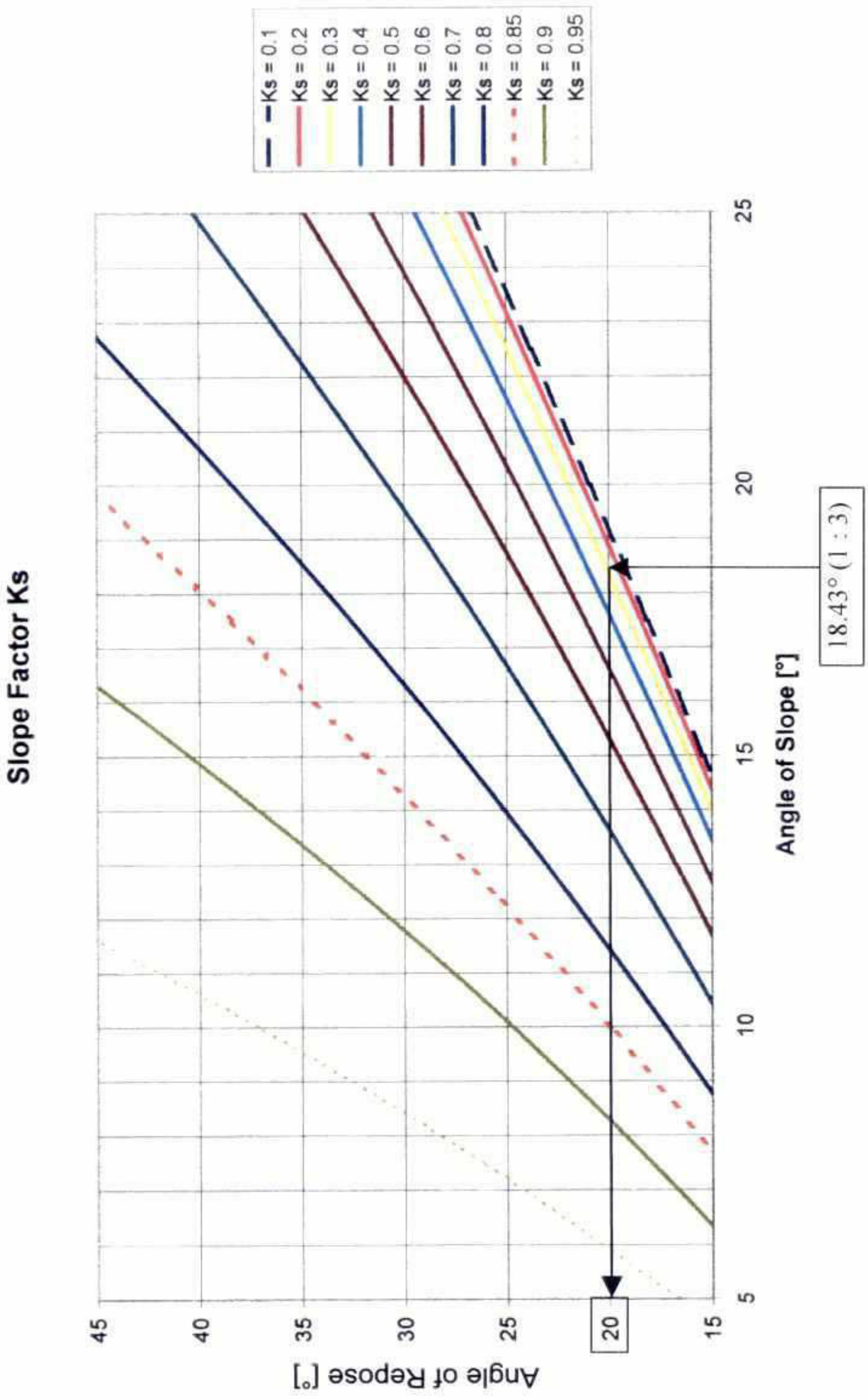

Fig. 6.5-2: Slope Factor K_s (Current)

Revetment Type	Continuous Protection Areas fc_2 [-]	Exposed Edges Transition Areas fc_2 [-]
Randomly placed, broken rip-rap and boulders	15.76	31.51
CC-blocks, cubical shape, randomly placed in multi-layer	22.86	42.86
CC-blocks, cubical shape, hand placed in single layer chess pattern	13.00	25.00
CC-blocks, interlocked and tongue and groove	8.57	17.14
CC-blocks, cable-connected (articulating mattresses)	10.42	22.92
Rip-rap fill in mattresses	7.00	7.00
Brick fill in mattresses	14.01	14.01
Mattresses filled with rock	12.76	12.76
Mattresses filled with full size bricks	18.01	18.01
Geotextile mattresses with sand-cement grout	17.58	21.98
Geotextile mattresses with Jamuna sand	28.57	35.71

Table 6.5-1: Design Factor fc_2 (Current)

Revetment Type		Angle of Repose ε_s
Cover Layer	Type of Filter	[°]
Randomly placed, broken rip-rap and boulders	Geotextile filter Granular filter	20 25
CC-blocks, cubical shape, randomly placed in multi-layer	Geotextile filter Granular filter	30 35
CC-blocks, cubical shape, hand placed in single layer chess pattern	Geotextile filter Granular filter	20 25
CC-blocks, interlocked and tongue and groove; cable connected	Geotextile filter Granular filter	20 25
Wiremesh mattresses; geotextile mattresses	Geotextile filter Granular filter	20 25
Gabion/mattress fillings by stones		45

Table 6.5-2: Angle of Repose ε_s for Various Revetment Structures

	K_t [-] Gabions, Mattresses	K_t [-] Others
Normal turbulence in rivers	1.0	1.0
Non-uniform flow with increased turbulence, mild outer bends	1.0	1.5
High turbulence, local disturbances, sharp outer bends	1.0	2.0

Table 6.5-3: Turbulence Factor K_t (Current)

6.6 STEP-BY-STEP DESIGN - WAVE ATTACK

With the simplifications under Sections 6.3 and the parameters stipulated under Section 6.4 the size and thickness respectively of the revetment protection material can be determined by

Step 1: Select factor fw_1 for the characteristic wave breaking parameter on a slope from Fig. 6.5-1, for the design wave parameters h_s and T_s and type of revetment protection chosen;

Step 2: Select wave factor fw_2 from Fig. 6.5-2 for the chosen slope of the revetment protection, and

Step 3: Select factor fw_3 from Table 6.5-1 corresponding to the chosen built-up of the revetment and the tolerable damage factor.

The respective factors can be introduced in the following formula and the nominal thickness of the protective material be computed:

$$D \geq \frac{fw_1 \cdot fw_2}{fw_3} \qquad (6.6\text{-}1)$$

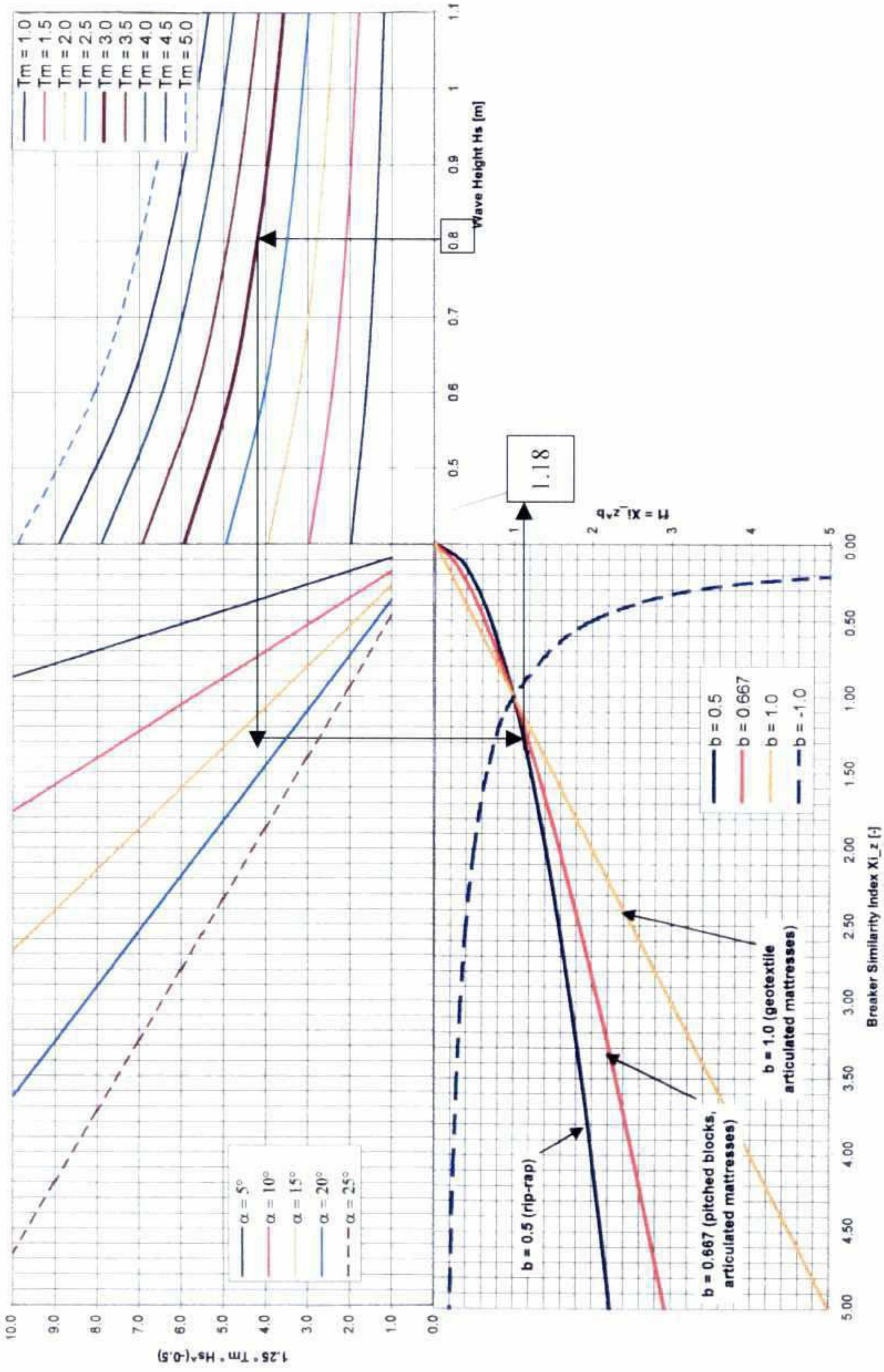

Fig. 6.6-1: Characteristic Wave Breaking Parameter fw_1

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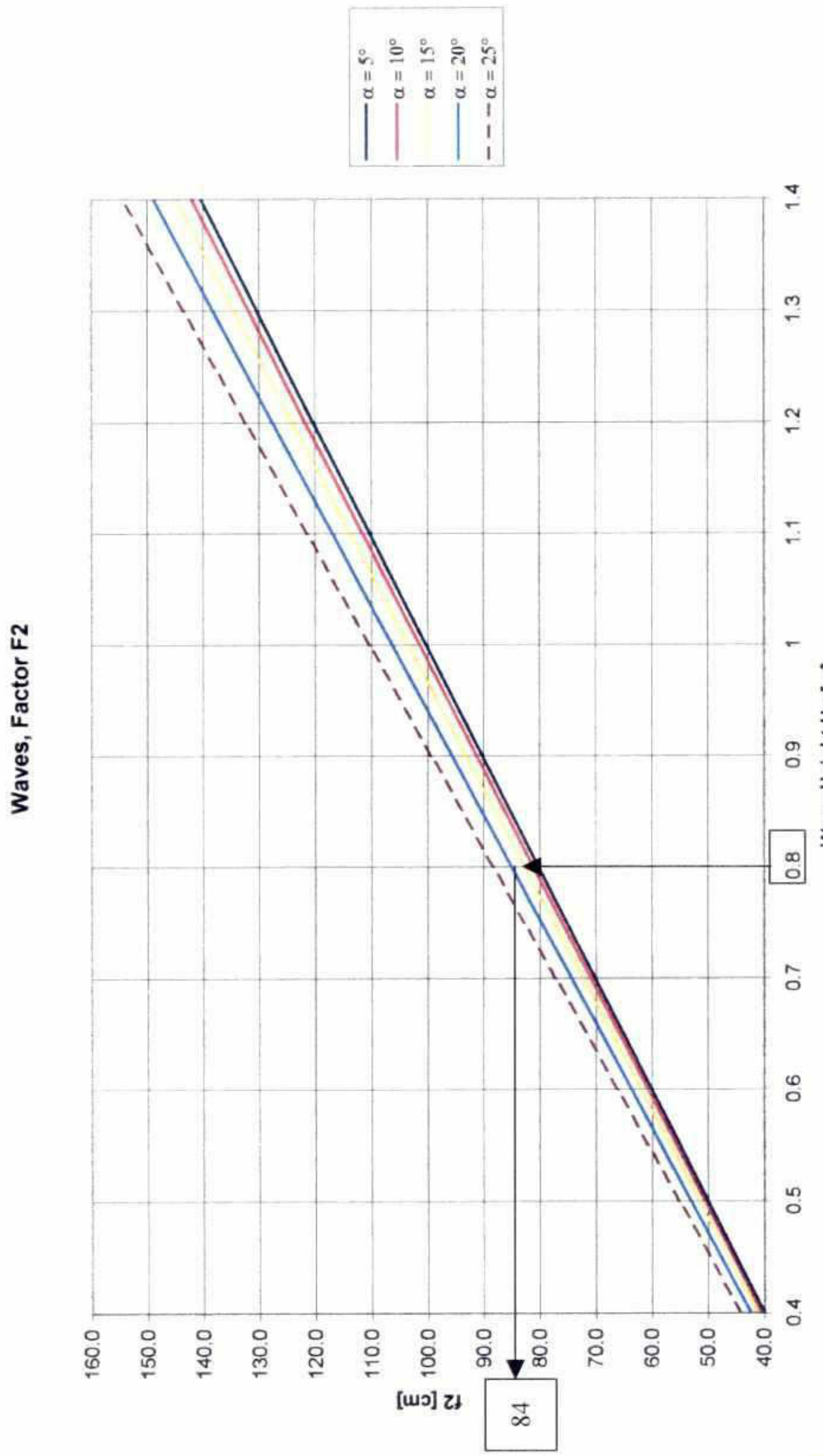


Fig. 6.6-2: Wave – Slope Relation Factor fw_2

Revetment Type	No Damage Accepted fw_3 [-]	Damage Tolerated fw_3 [-]
Rip-rap, Rock boulders	6.89	12.24
CC-blocks, cubical shape, randomly placed in multi-layer	2.99	4.5
CC-blocks, cubical shape, hand placed in single layer chess pattern	3.38	
CC-blocks, interlocked (groove-tongue type)	4.95	
CC-blocks, connected to geotextile (articulating mattress)	3.24	
Rip-rap/rock fill of gabion mattresses	7.65	
Brick fill of gabion mattresses	3.83	
Geotextile mattress with sand-cement grout fill	7.8	
Geotextile mattress with Jamuna sand fill	4.8	

Table 6.6-1: Tolerable Damage Factor fw_3

6.7 SAMPLE COMPUTATION

6.7.1 Design Assumptions

For a theoretical case the following is being assumed:

- Flow velocity u = 2.4 m/s
- Design slope 1 : 3, corresponding to 18.43°
- CC-blocks, randomly placed on geotextile filter
- Non-uniform flow with increased turbulence
- Waves H_s = 0.8 m; T_s = 3 sec.
- Damage to the revetment be tolerated.

6.7.2 Nominal Block Size – Current Load

$$D_n \geq fc_1 \cdot fc_2 \cdot \frac{K_t}{K_s} \qquad (6.7\text{-}1)$$

Select the parameters as follows:

Step 1: use Fig. 6.5-1, for u = 2.4 m/s → fc_1 = 0.38 cm

Step 2: use Table 6.5-1, for selected material → fc_2 = 15.76 [-]

Step 3: use Table 6.5-2 and Fig. 6.5-2, for ε_s = 20° and slope 1:3 → K_s = 0.3 [-]

Step 4: use Table 6.5-3, for assumed flow condition → K_t = 1.5 [-]

Therewith:

$$D_n = 0.38 \cdot 15.76 \cdot \frac{1.5}{0.3} = 30\,cm$$

6.7.3 Nominal Block Size – Wave Load

$$\boxed{D \geq \frac{fw_1 \cdot fw_2}{fw_3}} \qquad (6.7\text{-}2)$$

Select the parameters as follows:

Step 1: use Fig. 6.6-1 → $fw_1 = 1.18$ [-]

Step 2: use Fig. 6.6-2 → $fw_2 = 84$ [cm]

Step 3: use Table 6.6-1 → $fw_3 = 4.5$ [-] (damage tolerated)

→ $fw_3 = 2.99$ [-] (no damage accepted)

Therewith:

$$D_n = \frac{1.18 \cdot 84}{4.5} = 22\ cm \qquad \text{(damage tolerated)}$$

$$D_n = \frac{1.18 \cdot 84}{2.99} = 33\ cm \qquad \text{(no damage accepted)}$$

6.7.4 Selected Nominal Block Size

The larger of the two above cases (current / wave action) must be taken. Concluding for practical reasons

☑ D_n = 30 cm (damage due to excessive waves tolerated)

☑ D_n = 35 cm (no damage by waves accepted)

☑ Minimum layer thickness = $2 \cdot D_n$ = 60 cm respectively 70 cm.

ATTACHMENT 1

Dimensioning of Revetments
Rip-Rap

DIMENSIONING OF REVETMENTS
RIP-RAP
(Randomly placed broken rip-rap and boulders)

1 CURRENT ATTACK

1.1 GENERAL DESIGN FORMULA

The nominal size of rip-rap can be determined by the following formula, which is based on Pilarczyk (1990):

$$D_{50} \geq \frac{1}{0.85} \cdot \frac{0.035\, u_b^2}{\Delta_m\, 2g} \cdot \frac{\phi_s\, K_t\, K_h}{K_s\, \Psi_{cr}} \qquad (1\text{-}1)$$

Where:

D_{50} [m] = nominal diameter of a single unit of the protection layer:

(a) Broken rip-rap:

$$D_{50} = \frac{D_n}{0.85}$$

(b) Stones, boulders:

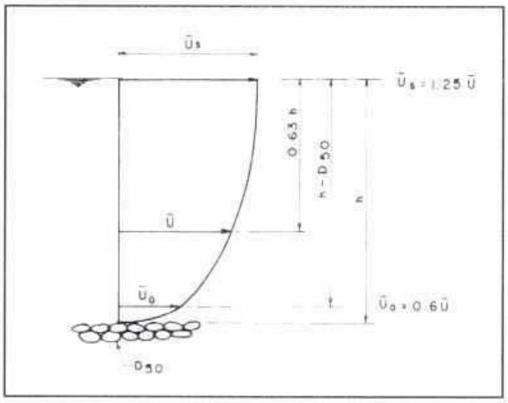
The formula (a) above, developed for broken rip-rap, may be used tentatively. The assumption should, however, be verified for stones/ boulders.

u_b [m/s] = bottom flow velocity, assumed at 0.6 $\bar{u}$

$\bar{u}$ [m/s] = depth averaged flow velocity

g [m/s²] = acceleration due to gravity

K_t [-] = turbulence factor;
apply:
K_t = 1.0 (normal turbulence in rivers)
K_t = 1.5 (non-uniform flow with increased turbulence, mild outer bends)
K_t = 2.0 (high turbulence, local disturbances, sharp outer bends)



Logorithmic Flow Velocity Profile

K_h [-] = depth factor
= 1.0 since bottom flow velocity u_b is being applied in the formula

The following factors express or are a function of the integrity of the revetment cover layer:

K_s [-] = slope factor

$$= \cos\alpha \sqrt{1 - \frac{\tan^2\alpha}{\tan^2\varepsilon_s}}$$

in which:
α = angle of slope
ε_s = angle of internal friction between cover layer and sublayer (angle of respose)

The slope factor K_s can be selected from the following table:

Embankment	Slope	1 : 2.5	1 : 3	1 : 3.5	1 : 4	1 : 5
	Angle	21.8°	18.4°	15.9°	14°	11.3°
Rip-rap on Geotextile Filter mat (ε_s = 20°)		—	0.385	0.599	0.707	0.820
Rip-rap on granular Filter (ε_s = 25°)		0.477	0.665	0.761	0.820	0.886

Δ_m [-] = relative density $(\rho_s - \rho_w)/\rho_w$

ρ_s [kg/m³] = density of protection material (boulders from India/Butan, which range from ρ_s = 2,400 to 2,800 kg/m³)

ρ_w [kg/m³] = density of water

for: ρ_s = 2,600 kg/m³
ρ_w = 1,000 kg/m³

therewith:
Δ_m = (2,600 - 1,000)/1,000 = 1.6

ϕ_s [-] = stability factor for current,
apply:
ϕ_s = 0.75 for continuous protection areas

ϕ_s = 1.25-1.50 for exposed edges, transitions;

ψ_{cr} [-] = critical shear stress parameter
= 0.035 for rip-rap (randomly placed material, movement of a few units allowed now and then).

1.2 PRELIMINARY DESIGN FORMULA (CURRENT)

The general formula (1-1) for dimensioning of rip-rap revetments can be simplified for preliminary dimensioning, while applying the following assumptions:

(ϕK_t) = ~ 0.85 (for continuous revetments at normal river conditions)
= ~ 2.5 (for critical/exposed areas)

for continuous revetments at normal river conditions and mild outer bends to:

$$D_{50} \geq \frac{u_b^2}{\Delta_m \cdot 2g \cdot K_s} \quad (1\text{-}2)$$

for critical/exposed revetment areas to:

$$D_{50} \geq \frac{2.5\, u_b^2}{\Delta_m \cdot 2g \cdot K_s \cdot 0.85} \quad (1\text{-}3)$$

2 WAVE ATTACK

2.1 GENERAL DESIGN FORMULA

The nominal size of rip-rap for embankment slopes of cot $\alpha > 2.0$ can be determined by the following empirical formula, which is based on Pilarczyk (1990):

$$D_{50} \geq \frac{1}{0.85} \cdot \frac{H_s\, \xi_z^b}{\Delta_m\, \psi_u\, \phi_{sw} \cos\alpha} \quad (1\text{-}4)$$

Where:

D_{50} [m] = nominal diameter of a single unit of the protection layer

Δ_m [-] = relative density $(\rho_s - \rho_w)/\rho_w$
ρ_s [kg/m^3] = density of protection material
(boulders from India/Butan, which range from ρ_s = 2,400 to 2,800 kg/m^3)
ρ_w [kg/m^3] = density of water

for: ρ_s = 2,600 kg/m^3
ρ_w = 1,000 kg/m^3

therewith:

$\Delta_m = (2{,}600 - 1{,}000)/1{,}000 = 1.6$

ϕ_{sw} [-] = stability factor for wave loads,
apply:
ϕ_{sw} = 2.25 for incipient motion
ϕ_{sw} = 3.0 for maximum tolerable damage for a 2-layer system on granular filter

ψ_u [-] = stability upgrading factor
= 1.0 for Rip-rap (2 layers)
= 1.33 for revetments with a tolerable damage to the Rip-rap cover layer

α [degree] = slope angle

Wave load related parameters:

H_s [m] = significant wave height ($H_s = H_{1/3}$ = average height of the one-third highest waves of a given wave spectrum).

L_o = deep water wave length [m]

$$= \frac{g\,T_m^2}{2\,\pi}$$

T_m = mean wave period [s]

ξ_z [-] = breaker similarity index

$$= \tan\alpha \left(\frac{H_s}{L_o}\right)^{-0.5}$$

$$= \frac{1.25\,T_m \tan\alpha}{\sqrt{H_s}}$$

b [-] = interaction exponent (processes between waves and roughness/porosity of cover layer)
= 0.5 for rough and permeable revetments

2.2 PRELIMINARY DESIGN FORMULA (WAVES)

The general formula (1-4) can be simplified while applying the following assumptions:

- **No damage tolerated**
  ψ_u = 1.0
  ϕ_{sw} = 2.25

$$D_{50} \geq 0.33\,.\,\frac{H_s\,\xi_z^{0.5}}{\cos\alpha} \qquad (1\text{-}5)$$

- **Some damage tolerated**

ψ_u = 1.33

ϕ_{sw} = 3.0

$$D_{50} \geq 0.18 . \frac{H_s \xi_z^{0.5}}{\cos\alpha} \qquad (1\text{-}6)$$

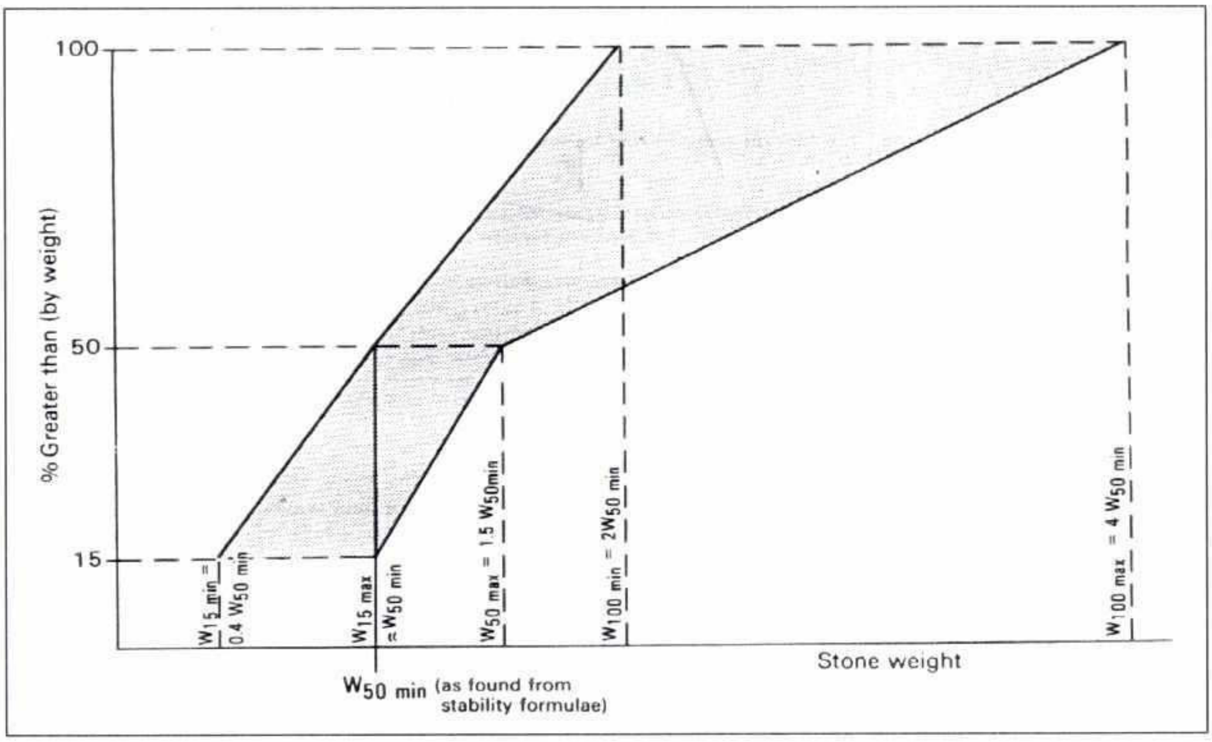
3 GRADING ENVELOP

With max. nominal D_{50} determined for current and wave attack by one of the above equations, select the grading envelop for rip-rap:

$W_{50_{min}}$ = weight of a single stone/boulder of nominal diameter D_{50};

$$W_{50_{min}} = D_n^3 \cdot \rho_s \quad [kg] = \left(\frac{D_{50}}{0.85}\right)^3 \cdot \rho_s \ [kg] \qquad (1\text{-}7)$$

Though there is no standard definition of the grading of rip-rap, many specifications for the material fall within the following upper and lower size limits, recommended by PIANC (1987a):

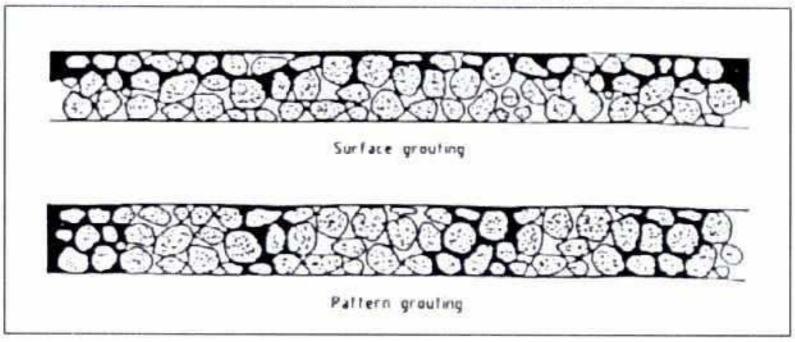


Grading Envelop for Rip-Rap
(Source: PIANC, 1987a)

4 GROUTED RIP-RAP

Current attack is normally not critical for grouted revetment cover layers. PIANC (1987) suggests for conditions of wave attack:

- surface grouted cover layers : $D_{50\,(grout)} = 0.9\ D_{50\,(rip\text{-}rap)}$
- pattern grouting : $D_{50\,(grout)} = 0.6\ D_{50\,(rip\text{-}rap)}$



Another approach is to adjust parameters as follows:

ϕ_s = 0.5/1.25 for continuous/exposed areas;

ψ_{cr} = 0.07 (continuous movement of blocks).

ATTACHMENT 2

Dimensioning of Revetments
Concrete Blocks

DIMENSIONING OF REVETMENTS
CONCRETE BLOCKS
(CC-blocks, cubical shape, randomly placed in multi-layer)

1 CURRENT ATTACK

1.1 GENERAL DESIGN FORMULA

The characteristic size of concrete blocks to be used for a pitched revetment cover layer can be determined by the following formula, which is based on Pilarczyk (1990):

$$D_n \geq \frac{0.035\, u_b^2}{\Delta_m\, 2g} \cdot \frac{\phi_s\, K_t\, K_h}{K_s\, \Psi_{cr}} \qquad (2\text{-}1)$$

Where:

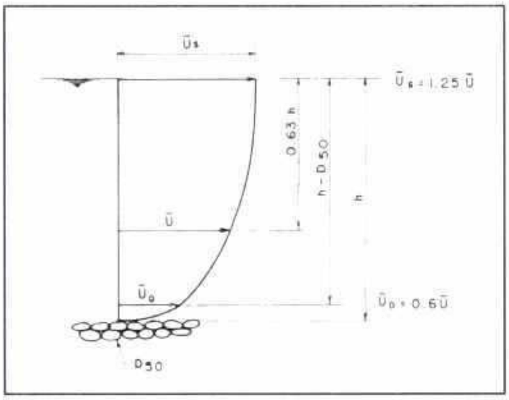
D_n [m] = characteristic size of a single block of the protection layer

u_b [m/s] = bottom flow velocity, assumed at 0.6 $\bar{u}$

$\bar{u}$ [m/s] = depth averaged flow velocity

g [m/s²] = acceleration due to gravity

K_t [-] = turbulence factor;
apply:
K_t = 1.0 (normal turbulence in rivers)
K_t = 1.5 (non-uniform flow with increased turbulence, mild outer bends)
K_t = 2.0 (high turbulence, local disturbances, sharp outer bends)



Logorithmic Flow Velocity Profile

K_h [-] = depth factor
= 1.0 since bottom flow velocity u_b is being applied in the formula

The following factors express or are a function of the integrity of the revetment cover layer:

K_s [-] = slope factor

$$= \cos\alpha \sqrt{1 - \frac{\tan^2\alpha}{\tan^2\varepsilon_S}}$$

in which:
α = angle of slope
ε_s = angle of internal friction between cover layer and sublayer (angle of repose)

The slope factor K_s can be selected from the following table:

Embankment	Slope	1 : 2.5	1 : 3	1 : 3.5	1 : 4	1 : 5
	Angle	21.8°	18.4°	15.9°	14°	11.3°
CC-blocks on Geotextile filter mat (ε_s = 30°)		0.670	0.776	0.837	0.875	0.920
CC-blocks on granular filter (ε_s = 35°)		0.762	0.835	0.879	0.907	0.940

Δ_m [-] = relative density $(\rho_c - \rho_w)/\rho_w$

ρ_c [kg/m^3] = density of protection material (concrete with a portion of coarse aggregate of khoa ranges $\rho_c \sim$ 1,980 to 2,000 kg/m^3)

ρ_w [kg/m^3] = density of water

for: ρ_c = 2,000 kg/m^3
ρ_w = 1,000 kg/m^3

therewith:

Δ_m = (2,000 - 1,000)/1,000 = 1.0

ϕ_s [-] = stability factor for current, apply:
ϕ_s = 0.80 for continuous protection areas
ϕ_s = 1.50 for exposed edges, transitions;

ψ_{cr} [-] = critical shear stress parameter
= 0.035 for randomly placed material.

1.2 PRELIMINARY DESIGN FORMULA

The general formula for dimensioning of pitched CC-block revetments can be simplified for preliminary dimensioning, while applying the following assumptions:

Δ_m = 1.0

$(\phi\, K_t)$ = ~ 0.85 (for continuous revetments at normal river conditions)
= ~ 2.5 (for critical/exposed areas)

for continuous revetments at normal river conditions and mild outer bends to:

$$D_n \geq \frac{0.85\ u_b^2}{2g \cdot K_s} = 0.04\ \frac{u_b^2}{K_s} \qquad (2\text{-}2)$$

for critical/exposed revetment areas to:

$$D_n \geq \frac{2.5\, u_b^2}{2g \cdot K_s} = 0.13\, \frac{u_b^2}{K_s} \qquad (2\text{-}3)$$

2 WAVE ATTACK

2.1 GENERAL DESIGN FORMULA

The characteristic size of concrete blocks to be used for a pitched revetment cover layer for embankment slopes of cot $\alpha > 2.0$ can be determined by the following empirical formula, which is based on Pilarczyk (1990):

$$D_n \geq \frac{H_s\, \xi_z^b}{\Delta_m\, \Psi_u\, \phi_{sw}\, \cos\alpha} \qquad (2\text{-}4)$$

Where:

D_n [m] = characteristic size of a single block of the protection layer

Δ_m [-] = relative density $(\rho_c - \rho_w)/\rho_w$
= 1.0 (see Item 1.1)

ϕ_{sw} [-] = stability factor for wave loads, apply:
ϕ_{sw} = 2.25 for incipient motion
ϕ_{sw} = 3.0 for maximum tolerable damage for a 2-layer system on granular filter

Ψ_u [-] = stability upgrading factor
= 1.33 for dumped mono-size CC-blocks (2 layers)
= 1.50 for revetments with a tolerable damage to the CC-block dumped cover layer

α [degree] = slope angle

Wave load related parameters:

H_s [m] = significant wave height ($H_s = H_{1/3}$ = average height of the one-third highest waves of a given group of waves). Alternatively a design wave height H [m] with associated wave period T [s] can be used.

L_o = wave length [m]
$= \frac{g\, T_m^2}{2\,\pi}$

T_m = mean wave period [s]

ξ_z [-] = breaker similarity index

$$= \tan\alpha \left(\frac{H_s}{L_o}\right)^{-0.5}$$

$$= \frac{1.25\, T_m \tan\alpha}{\sqrt{H_s}}$$

b [-] = interaction exponent (processes between waves and roughness/porosity of cover layer)
= 0.667 for pitched blocks

2.2 PRELIMINARY DESIGN FORMULA (WAVES)

The general formula (2-4) can be simplified while applying the following assumptions:

- **No damage tolerated**
  ψ_u = 1.33
  ϕ_{sw} = 2.25

$$D_n \geq 0.33 \cdot \frac{H_s \xi_z^{0.667}}{\cos\alpha} \qquad (2\text{-}5)$$

- **Some damage tolerated**
  ψ_u = 1.5
  ϕ_{sw} = 3.0

$$D_n \geq 0.22 \cdot \frac{H_s \xi_z^{0.667}}{\cos\alpha} \qquad (2\text{-}6)$$

3 SELECTION OF CHARACTERISTIC BLOCK SIZE

The maximum characteristic block size D_n as determined for current and wave attack by one of the above equations is to be selected.

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ATTACHMENT 3

Dimensioning of Revetments
Non-Interlocked Concrete Blocks

DIMENSIONING OF REVETMENTS
NON-INTERLOCKED CONCRETE BLOCKS
(CC-blocks, cubical shape, hand-placed in single layer chess pattern)

1 CURRENT ATTACK

1.1 GENERAL DESIGN FORMULA

The characteristic size of concrete blocks to be used for a paved revetment cover layer can be determined by the following formula, which is based on Pilarczyk (1990):

$$D_n \geq \frac{0.035\, u_b^2}{\Delta_m\, 2g} \cdot \frac{\phi_s\, K_t\, K_h}{K_s\, \Psi_{cr}} \qquad (3\text{-}1)$$

Where:

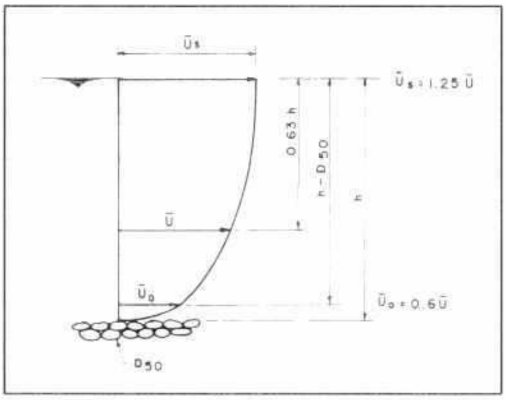
D_n [m] = characteristic size of a single block of the protection layer

u_b [m/s] = bottom flow velocity, assumed at 0.6 $\bar{u}$

$\bar{u}$ [m/s] = depth averaged flow velocity

g [m/s²] = acceleration due to gravity

K_t [-] = turbulence factor;
apply:
K_t = 1.0 (normal turbulence in rivers)
K_t = 1.5 (non-uniform flow with increased turbulence, mild outer bends)
K_t = 2.0 (high turbulence, local disturbances, sharp outer bends)



Logorithmic Flow Velocity Profile

K_h [-] = depth factor
= 1.0 since bottom flow velocity u_b is being applied in the formula

The following factors express or are a function of the integrity of the revetment cover layer:

K_s [-] = slope factor

$$= \cos\alpha \sqrt{1 - \frac{\tan^2\alpha}{\tan^2\varepsilon_S}}\ 1$$

in which:
α = angle of slope
ε_s = angle of internal friction between cover layer and sublayer (angle of respose)

The slope factor K_s can be selected from the following table:

Embankment	Slope	1 : 2.5	1 : 3	1 : 3.5	1 : 4	1 : 5
	Angle	21.8°	18.4°	15.9°	14°	11.3°
CC-blocks on Geotextile Filter mat (ε_s = 20°)		—	0.385	0.599	0.707	0.820
CC-blocks on granular Filter (ε_s = 25°)		0.477	0.665	0.761	0.820	0.886

Δ_m [-] = relative density $(\rho_c - \rho_w)/\rho_w$

ρ_c [kg/m^3] = density of protection material (concrete with a portion of coarse aggregate of khoa ranges $\rho_c \sim$ 1,980 to 2,000 kg/m^3)

ρ_w [kg/m^3] = density of water

for: ρ_c = 2,000 kg/m^3

ρ_w = 1,000 kg/m^3

therewith:

Δ_m = (2,000 - 1,000)/1,000 = 1.0

ϕ_s [-] = stability factor for current, apply:

ϕ_s = 0.65 for continuous protection areas

ϕ_s = 1.25 for exposed edges, transitions;

ψ_{cr} [-] = critical shear stress parameter

= 0.050 for paved CC-block cover layers

1.2 PRELIMINARY DESIGN FORMULA

The general formula for dimensioning of paved CC-block revetments can be simplified for preliminary dimensioning, while applying the following assumptions:

Δ_m = 1.0

$\frac{0.035\ \phi_s K_t}{\psi_{cr}}$ = ~ 0.6 (for continuous revetments at normal river conditions)

= ~ 1.75 (for critical/exposed areas)

for continuous revetments at normal river conditions and mild outer bends to:

$$D_n \geq \frac{0.6\ u_b^2}{2g \cdot K_s} = 0.03 \frac{u_b^2}{K_s} \qquad (3\text{-}2)$$

for critical/exposed revetment areas to:

$$D_n \geq \frac{1.75\, u_b^2}{2g \cdot K_s} = 0.09 \frac{u_b^2}{K_s} \qquad (3\text{-}3)$$

2 WAVE ATTACK

2.1 GENERAL DESIGN FORMULA

The characteristic size of concrete blocks to be used for a paved revetment for embankment slopes of cot $\alpha > 2.0$ can be determined by the following empirical formula, which is based on Pilarczyk (1990) (for $H_s < 1.5$ m):

$$D_n \geq \frac{H_s\, \xi_z^b}{\Delta_m\, \psi_u\, \phi_{sw} \cos\alpha} \qquad (3\text{-}4)$$

Where:

D_n [m] = characteristic size of a single block of the protection layer

Δ_m [-] = relative density $(\rho_c - \rho_w)/\rho_w$
= 1.0 (see Item 1.1)

ϕ_{sw} [-] = stability factor for wave loads, apply:
ϕ_{sw} = 2.25 for incipient motion

ψ_u [-] = stability upgrading factor
= 1.5 for loose closely placed blocks on a geotextile filter mat laid on sand

α [degree] = slope angle

Wave load related parameters:

H_s [m] = significant wave height ($H_s = H_{1/3}$ = average height of the one-third highest waves of a given group of waves). Alternatively a design wave height H [m] with associated wave period T [s] can be used.

L_o = wave length [m]
= $\frac{g\, T_m^2}{2\pi}$

T_m = mean wave period [s]

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ξ_z [-] = breaker similarity index

$$= \tan\alpha \left(\frac{H_s}{L_o} \right)^{-0.5}$$

$$= \frac{1.25\, T_m \tan\alpha}{\sqrt{H_s}}$$

b [-] = interaction exponent (processes between waves and roughness/porosity of cover layer)
= 0.667 for loose closed blocks

2.2 PRELIMINARY DESIGN FORMULA (WAVES)

The general formula (3-4) can be simplified:

$$D_n \geq 0.30 \cdot \frac{H_s \, \xi_z^{0.667}}{\cos\alpha} \qquad (3\text{-}5)$$

3 SELECTION OF CHARACTERISTIC BLOCK SIZE

The maximum characteristic block size D_n as determined for current and wave attack by one of the above equations is to be selected.

ATTACHMENT 4

Dimensioning of Revetments
Interlocking/Articulating Concrete Blocks

DIMENSIONING OF REVETMENTS
INTERLOCKING/ARTICULATING CONCRETE BLOCKS
(CC-blocks: interlocked; tongue and groove; cable-connected)

1 CURRENT ATTACK

1.1 GENERAL DESIGN FORMULA

The characteristic size of interlocking-type or cable-connected concrete blocks to be used for a paved revetment cover layer can be determined by the following formula, which is based on Pilarczyk (1990):

$$D \geq \frac{0.035\, u_b^2}{\Delta_m\, 2g} \cdot \frac{\phi_s\, K_t\, K_h}{K_s\, \Psi_{cr}} \qquad (4\text{-}1)$$

Where:

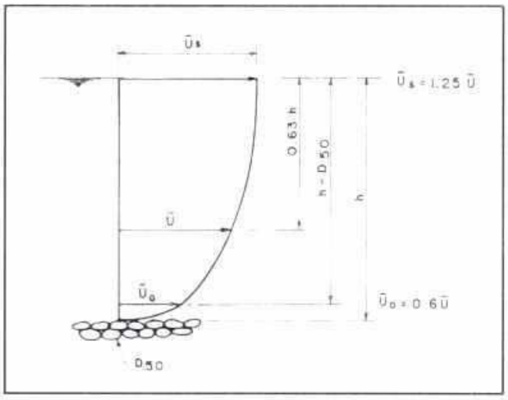
D [m] = nominal thickness of the revetment cover layer

u_b [m/s] = bottom flow velocity, assumed at 0.6 $\bar{u}$

$\bar{u}$ [m/s] = depth averaged flow velocity

g [m/s²] = acceleration due to gravity

K_t [-] = turbulence factor;
apply:
K_t = 1.0 (normal turbulence in rivers)
K_t = 1.5 (non-uniform flow with increased turbulence, mild outer bends)
K_t = 2.0 (high turbulence, local disturbances, sharp outer bends)



Logorithmic Flow Velocity Profile

K_h [-] = depth factor
= 1.0 since bottom flow velocity u_b is being applied in the formula

The following factors express or are a function of the integrity of the revetment cover layer:

K_s [-] = slope factor

$$= \cos\alpha \sqrt{1 - \frac{\tan^2\alpha}{\tan^2\varepsilon_s}}$$

in which:
α = angle of slope
ε_s = angle of internal friction between cover layer and sublayer (angle of respose)

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The slope factor K_s can be selected from the following table:

Embankment	Slope	1 : 2.5	1 : 3	1 : 3.5	1 : 4	1 : 5
	Angle	21.8°	18.4°	15.9°	14°	11.3°
CC-blocks on Geotextile filter mat ($\varepsilon_s = 20°$)		—	0.385	0.599	0.707	0.820
CC-blocks on granular filter ($\varepsilon_s = 25°$)		0.477	0.665	0.761	0.820	0.886

Δ_m [-] = relative density $(\rho_c - \rho_w)/\rho_w$

ρ_c [kg/m^3] = density of protection material
(concrete with a portion of coarse aggregate of khoa ranges
$\rho_c \sim 1{,}980$ to $2{,}000$ kg/m^3)

ρ_w [kg/m^3] = density of water

for: $\rho_c = 2{,}000$ kg/m^3
$\rho_w = 1{,}000$ kg/m^3

therewith:

for interlocking blocks:
$\Delta_m = (2{,}000 - 1{,}000)/1{,}000 = 1.0$

for cable connected blocks:
$\Delta_m = (1 - n)\Delta$
n = volume of voids (proportion of interspaces in %)
= 10% to 30%

therewith:
$\Delta_m = (1 - 0.2)\ 1.0$
$= 0.8$

ϕ_s [-] = stability factor for current,
apply:
ϕ_s = 0.60 for continuous protection areas with interlocking blocks
= 0.50 for continuous protection areas of cable connected blocks
ϕ_s = 1.20 for exposed edges and transitions of interlocking blocks
= 1.10 for exposed edges and transitions of cable connected blocks.

ψ_{cr} [-] = critical shear stress parameter
= 0.070 for paved interlocked CC-block cover layers
= 0.060 for cable connected blocks

1.2 PRELIMINARY DESIGN FORMULA (CURRENT)

The general formula (4-1) for dimensioning of paved interlocked CC-block revetments can be simplified for preliminary dimensioning, while applying the following assumptions:

Δ_m = 1.0 (for interlocking blocks)

Δ_m = 0.8 (for cable connected blocks)

$\frac{0.035\ \phi_s\ K_t}{\Psi_{cr}}$ = ~ 0.6 (for continuous revetments at normal river conditions)

= ~ 1.75 (for critical/exposed areas)

for continuous revetments at normal river conditions and mild outer bends to:

$$D \geq \frac{0.3\ u_b^2}{\Delta_m\ 2g\ K_s} = 0.02\ \frac{u_b^2}{\Delta_m\ K_s} \qquad (4\text{-}2)$$

for critical/exposed revetment areas to:

$$D \geq \frac{1.20\ u_b^2}{\Delta_m\ 2g\ K_s} = 0.06\ \frac{u_b^2}{\Delta_m\ K_s} \qquad (4\text{-}3)$$

2 WAVE ATTACK

2.1 GENERAL DESIGN FORMULA

The characteristic size of concrete blocks to be used for a paved revetment for embankment slopes of cot $\alpha > 2.0$ can be determined by the following empirical formula, which is based on Pilarczyk (1990) (for $H_s < 1.5$ m):

$$D \geq \frac{H_s\ \xi_z^b}{\Delta_m\ \Psi_u\ \phi_{sw}\ \cos\alpha} \qquad (4\text{-}4)$$

Where:

D [m] = nominal thickness of the revetment cover layer

Δ_m [-] = relative density $(\rho_c - \rho_w)/\rho_w$
= 1.0 for interlocking blocks (see Item 1.1)
= 0.8 for cable connected blocks (see Item 1.1)

2y

ϕ_{sw} [-] = stability factor for wave loads,
apply:
ϕ_{sw} = 2.25 for incipient motion

ψ_u [-] = stability upgrading factor
= 2.2 for interlocking blocks placed on a geotextile filter mat laid on granular sublayer
= 1.8 for cable connected blocks
= 1.5 for blocks only connected to a geotextile, laid on a granular sublayer

α [degree] = slope angle

Wave load related parameters:

H_s [m] = significant wave height ($H_s = H_{1/3}$ = average height of the one-third highest waves of a given group of waves). Alternatively a design wave height H [m] with associated wave period T [s] can be used.

L_o = wave length [m]

$$= \frac{g T_m^2}{2\pi}$$

T_m = mean wave period [s]

ξ_z [-] = breaker similarity index

$$= \tan\alpha \left(\frac{H_s}{L_o} \right)^{-0.5}$$

$$= \frac{1.25\, T_m \tan\alpha}{\sqrt{H_s}}$$

b [-] = interaction exponent (processes between waves and roughness/porosity of cover layer)
= 0.667

2.2 PRELIMINARY DESIGN FORMULA (WAVES)

The general formula (4-4) can be simplified while applying the following assumptions:

- **For interlocking blocks**
  ψ_u = 2.2
  ϕ_{sw} = 2.25

$$D \geq 0.20 \, . \frac{H_s \, \xi_z^{0.667}}{\Delta_m \cos\alpha} \qquad (4\text{-}5)$$

- **For cable connected blocks**

ψ_u = 1.8
ϕ_{sw} = 2.25

$$D \geq 0.25 \cdot \frac{H_s \xi_z^{0.667}}{\Delta_m \cos\alpha} \qquad (4\text{-}6)$$

- **For blocks only connected to a geotextile**

ψ_u = 1.5
ϕ_{sw} = 2.25

$$D \geq 0.30 \cdot \frac{H_s \xi_z^{0.667}}{\Delta_m \cos\alpha} \qquad (4\text{-}7)$$

3 SELECTION OF CHARACTERISTIC REVETMENT THICKNESS

The maximum nominal thickness D as determined for current and wave attack by one of the above equations is to be selected.

ATTACHMENT 5

Dimensioning of Revetments
Wire Mesh Mattresses

DIMENSIONING OF REVETMENTS
WIRE MESH MATTRESSES

1 CURRENT ATTACK

1.1 GENERAL DESIGN FORMULA FOR FILL MATERIAL

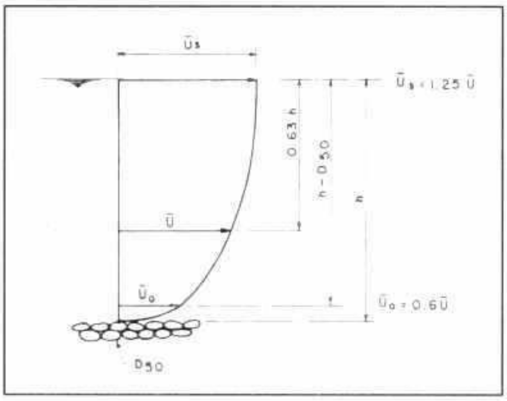
The nominal size of stones to be used for filling of wire mesh mattresses to be used as cover layer can be determined by the following formula, which is derived from Pilarczyk (1990):

$$D_{50} \geq \frac{1}{0.85} \cdot \frac{u_b^2}{\Delta_m 2g} \cdot \frac{0.03\, K_h}{\psi_{cr}\, K_s} \qquad (5\text{-}1)$$

Where:

D_{50} [m] = nominal diameter of a single stone to be used for gabion fill

$$D_{50} = \frac{D_n}{0.85}$$



Logorithmic Flow Velocity Profile

u_b [m/s] = bottom flow velocity, assumed at 0.6 $\bar{u}$

$\bar{u}$ [m/s] = depth averaged flow velocity

g [m/s²] = acceleration due to gravity

K_h [-] = depth factor
= 1.0 since bottom flow velocity u_b is being applied in the formula

The following factors express or are a function of the integrity of the fill:

K_s [-] = slope factor

$$= \cos\alpha \sqrt{1 - \frac{\tan^2\alpha}{\tan^2\varepsilon_s}}$$

in which:
α = angle of slope
ε_s = angle of internal friction between cover layer and sublayer (angle of respose)

The slope factor K_s can be selected from the following table:

Embankment	Slope	1 : 2.5	1 : 3	1 : 3.5	1 : 4	1 : 5
	Angle	21.8°	18.4°	15.9°	14°	11.3°
Stones in a gabion or Mattress (ε_s = 45°)		0.851	0.895	0.922	0.940	0.961

Δ_m [-] = relative density $(\rho_s - \rho_w)/\rho_w$

ρ_s [kg/m^3] = density of protection material

ρ_w [kg/m^3] = density of water = 1,000 kg/m^3

apply for rip-rap fill:

ρ_s = 2,600 kg/m^3

therewith:

$\Delta_{m\,fill}$ = (2,600 - 1,000)/1,000 = 1.6

apply for brick fill:

ρ_s = 1,800 kg/m^3

therewith:

$\Delta_{m\,fill}$ = 0.8

ψ_{cr} [-] = Shields parameter

= 0.09 for stone-fill in gabions/mattresses

1.2 GENERAL DESIGN FORMULA FOR WIRE MESH MATTRESSES

The nominal thickness of a mattress can be determined by the following formula which is derived from Pilarczyk (1990):

$$d \geq \frac{u_b^2}{\Delta_{mg}\, 2g} \cdot \frac{0.03\, K_h}{\phi_{cr}\, K_{s(m)}} \qquad (5\text{-}2)$$

Where:

d [m] = average thickness of mattress

Δ_{mg} [m] = relative density of the protection system

= $(1 - n)\,\Delta_m$

with: n = percentage of voids in the mattress fill (~ 0.4 for stones)

for rock filled mattress:

$\Delta_{mg} = (1 - 0.4)\ 1.6 = 0.96$

for mattresses stacked with full size bricks:

$\Delta_{mg} = (1 - 0.15)\ 0.8 = 0.68$

$K_{s(m)}$ [m] = slope factor (as defined above)

The slope factor $K_{s(m)}$ may be selected from the following table:

Embankment	Slope	1 : 2.5	1 : 3	1 : 3.5	1 : 4	1 : 5
	Angle	21.8°	18.4°	15.9°	14°	11.3°
Wire mesh mattresses on Geotextile filter mat (ε_s = 20°)		—	0.385	0.599	0.707	0.820
Wire mesh mattresses on granular filter mat (ε_s = 25°)		0.477	0.665	0.761	0.820	0.886

ϕ_{cr} = critical shear stress parameter
= 0.070 for stone mattresses

All other parameters as specified under Item 1.

1.3 PRELIMINARY DESIGN FORMULA

With the inputs specified under Items 1.1 and 1.2, mattresses and its fill can be roughly dimensioned by the following equations:

(a) Nominal Size of Fill Material

Stone Fill:

$$D_{50} \geq 0.013 \cdot \frac{u_b^2}{K_s} \qquad (5\text{-}3)$$

(b) Nominal Thickness of Mattress

With Stone Fill:

$$d \geq 0.023 \cdot \frac{u_b^2}{K_{s(m)}} \qquad (5\text{-}4)$$

Stacked with Full Size Bricks:

$$d \geq 0.043 \cdot \frac{u_b^2}{K_{s(m)}} \qquad (5\text{-}5)$$

1.4 SPECIAL REMARKS

When the flow velocity is likely to exceed 3 m/s or the wave height exceeds 1 m, then a granular sublayer of at least 0.2 m thickness should be provided between a geotextile filter mat and the wire mesh mattress.

2 WAVE ATTACK

2.1 GENERAL DESIGN FORMULA FOR FILL MATERIAL

The characteristic size of fill material to be used for wire mesh mattresses for embankment slopes of cot $\alpha > 2.0$ can be determined by the following empirical formula, which is based on Pilarczyk (1990) (for $H_s < 1.5$ m):

$$D_{50} \geq \frac{1}{0.85} \cdot \frac{H_s \xi_z^b}{\Delta_m \psi_u \phi_{sw} \cos\alpha} \qquad (5\text{-}6)$$

Where:

D_{50} [m] = nominal diameter of a stone to be used for gabion fill

Δ_m [-] = relative density $(\rho_c - \rho_w)/\rho_w$
= (see Item 1.1 for different fill materials)

ϕ_{sw} [-] = stability factor for wave loads, apply:
ϕ_{sw} = 2.25 for incipient motion

ψ_u [-] = stability upgrading factor
= range 2 to 3

α [degree] = slope angle

Wave load related parameters:

H_s [m] = significant wave height ($H_s = H_{1/3}$ = average height of the one-third highest waves of a given group of waves). Alternatively a design wave height H [m] with associated wave period T [s] can be used.

L_o = wave length [m]

$$= \frac{g T_m^2}{2\pi}$$

T_m = mean wave period [s]

ξ_z [-] = breaker similarity index

$$= \tan\alpha \left(\frac{H_s}{L_o} \right)^{-0.5}$$

$$= \frac{1.25\, T_m \tan\alpha}{\sqrt{H_s}}$$

b [-] = interaction exponent (processes between waves and roughness/porosity of cover layer)
= 0.5 for gabion fill (and mattresses)

2.2 GENERAL DESIGN FORMULA FOR WIRE MESH MATTRESS

The nominal thickness of a wire mesh mattress to be used for the revetment of embankment slopes of cot $\alpha > 2.0$ can be determined by the following empirical formula, which is based on Pilarczyk (1990):

$$d \geq \frac{H_s \xi_z^b}{\Delta_{mg} \psi_u \phi_{sw} \cos\alpha} \qquad (5\text{-}7)$$

Where:

d [m] = average thickness of the mattress

Δ_{mg} [-] = relative density of the mattress system
= $(1\text{-}n)\,\Delta_m$ (see Item 1.2 for different fill materials)

ϕ_{sw} [-] = stability factor for wave loads, apply:
ϕ_{sw} = 2.25 for incipient motion

b [-] = interaction exponent
= 0.5 to 0.667

ψ_u [-] = stability upgrading factor
= range 2 to 2.5

α [degree] = slope angle

Wave parameters as in Item 2.1.

2.3 PRELIMINARY DESIGN FORMULA (WAVES)

With the inputs specified under Items 2.1 and 2.2, mattresses and its fill can be roughly dimensioned by the following equations:

(a) Nominal Size of Fill Material

ψ_u = 2.5

Stone Fill:

$$D_{50} \geq 0.15 \, . \frac{H_s \xi_z^{0.5}}{\cos\alpha} \qquad (5\text{-}8)$$

Bricks:

$$D_{50} \geq 0.35 \, . \frac{H_s \xi_z^{0.5}}{\cos\alpha} \qquad (5\text{-}9)$$

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(b) Nominal Thickness of Mattress

ψ_u = 2.0

With Stone Fill:

$$d \geq 0.25 \,.\, \frac{H_s \xi_z^{0.5}}{\cos \alpha} \qquad (5\text{-}10)$$

Stacked with
Full Size Bricks:

$$d \geq 0.45 \,.\, \frac{H_s \xi_z^{0.5}}{\cos \alpha} \qquad (5\text{-}11)$$

3 MINIMUM THICKNESS OF WIRE MESH MATTRESS

The minimum thickness of a gabion mattress is

$$d_{min} = 1.8\, D_{50} \qquad (5\text{-}12)$$

with D_{50} determined to be the maximum value as per Item 1 or 2.

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ATTACHMENT 6

Dimensioning of Revetments
Geotextile Mattresses

DIMENSIONING OF REVETMENTS
GEOTEXTILE MATTRESSES

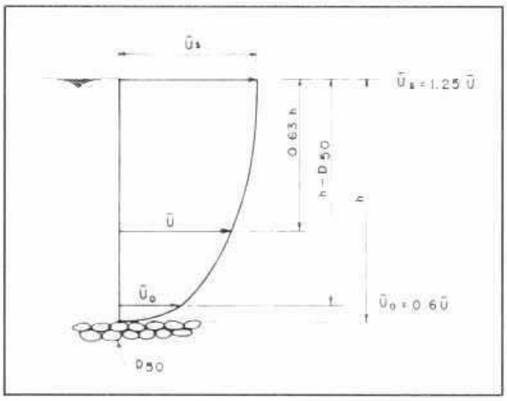
1 CURRENT ATTACK

1.1 GENERAL DESIGN FORMULA

The nominal thickness of a geotextile mattress can be determined by the following formula, which is based on Pilarczyk (1990):

$$D_{eq} \geq \frac{\phi_s \, u_b^2 \, K_h}{\Delta_m \, 2g \, K_s} \qquad (6\text{-}1)$$

Where:



Logorithmic Flow Velocity Profile

D_{eq} [m] = equivalent thickness of geotextile mattress
= 0.75 x D_{matt}

D_{matt} [m] = effective mattress thickness

u_b [m/s] = bottom flow velocity,
assumed at 0.6 $\overline{u}$

$\overline{u}$ [m/s] = depth averaged flow velocity

g [m/s²] = acceleration due to gravity

K_h [-] = depth factor
= 1.0 since bottom flow velocity u_b is being applied in the formula

The following factors express or are a function of the integrity of the revetment cover layer:

K_s [-] = slope factor

$$= \cos\alpha \sqrt{1 - \frac{\tan^2\alpha}{\tan^2\varepsilon_s}}$$

in which:

α = angle of slope

ε_s = angle of internal friction between cover layer and sublayer (angle of respose)

The slope factor K_s can be selected from the following table:

Embankment Slope	1 : 2.5	1 : 3	1 : 3.5	1 : 4	1 : 5
Angle	21.8°	18.4°	15.9°	14°	11.3°
Geotextile mattress on Geotextile filter mat (ε_s = 20°)	—	0.385	0.599	0.707	0.820
Geotextile mattress on granular sublayer (ε_s = 25°)	0.477	0.665	0.761	0.820	0.886

Δ_m [-] = relative density $(\rho_s - \rho_w)/\rho_w$
ρ_s = 2,300 kg/m^3 for sand-cement grout
ρ_s = 1,800 kg/m^3 for Jamuna sand

ϕ_s [-] = stability factor for current, apply:
ϕ_s = 0.8 for continuous protection areas,
ϕ_s = 1.0 for exposed edges and transitions.

1.2 PRELIMINARY DESIGN FORMULA (CURRENT LOADS)

The general formula for dimensioning of geotextile mattresses can be simplified for preliminary dimensioning for

Fabric Mattress with Sand Fill or Sand-Cement Grout Fill

- For normal areas (continues areas):

$$D_{eq} \geq 0.04 \cdot \frac{u_b^2}{\Delta_m K_s} \qquad (6\text{-}2)$$

- For exposed edges and transitions:

$$D_{eq} \geq 0.05 \cdot \frac{u_b^2}{\Delta_m K_s} \qquad (6\text{-}3)$$

DDH

2 WAVE ATTACK

2.1 GENERAL DESIGN FORMULA

The equivalent thickness of a fabric mattress to be used as slope revetment can be determined by the following empirical formula, which is based on Pilarczyk (1994) (for $H_s < 1.5$ m):

$$D_{eq} \geq \frac{H_s \xi_z^{-1}}{\Delta_m \beta \cos\alpha} \qquad (6\text{-}4)$$

Where:

D_{eq} [m] = equivalent thickness of geotextile mattress
= 0.75 x D_{matt}

Δ_m [-] = relative density (see Item 1.1)

β [-] = stability coefficient:

Select β = 4 (to max. 6) if k_m/k_s <1, with uplift of mattress and deformation of subsoil as main failure mechanism;
Select β = 6 (to max. 8) if k_m/k_s >1, with the deformation of subsoil as main failure mechanism.

where: k_m [m/s] = permeability of the mattress
k_s [m/s] = permeability of the subsoil

α [degree] = slope angle

Wave load related parameters:

H_s [m] = significant wave height ($H_s = H_{1/3}$ = average height of the one-third highest waves of a given group of waves). Alternatively a design wave height H [m] with associated wave period T [s] can be used.

L_o = wave length [m]

$$= \frac{g\ T_m^2}{2\ \pi}$$

T_m = mean wave period [s]

ξ_z [-] = breaker similarity index

$$= \tan\alpha \left(\frac{H_s}{L_o}\right)^{-0.5} = \frac{1.25\, T_m \tan\alpha}{\sqrt{H_s}}$$

b [-] = interaction exponent (processes between waves and roughness/porosity of cover layer)
= 0.667

3 SELECTION OF EQUIVALENT MATTRESS THICKNESS

The maximum equivalent thickness of geotextile mattress as determined for current and wave attack by one of the above equations is to be selected. Thereby:

$$D_{matt} = \frac{D_{eq}}{0.75} \qquad (6\text{-}5)$$

Note that for sand-filled mattress a factor of 1.2 should be applied if some washing out of fill from the mattress would be acceptable, respectively can not be avoided with certainly (refer to following Item 4).

4 SELECTION OF FABRIC FOR SAND-FILLED MATTRESS

For fabric mattresses to be filled with sand-cement grout, concrete or sand, woven geotextiles of Polypropylen (PP), Polyester (PES) and Polyamid (PA) or combinations thereof are common.

Fabric mattress systems have to fulfil various requirements, such as adequate permeability, strength, durability etc.. One important factor for sand-filled mattress systems is the capability to control adequately the erosion of the fill material respectively of the soil to be protected through the fabric.

An approximation can be made with the following criteria, to determine for a given sand-fill material the effective opening size (O_{90}, O_{98}) of a fabric or to select the appropriate grain size of a sand fill for a given fabric.

Conditions : For stationary hydraulic loads:

$\frac{O_{90}}{d_{b90}} < 1.0$ for woven geotextiles

For dynamic (cyclic) hydraulic loads:

$\frac{O_{98}}{d_{b15}} < 1.0$ if all grains shall be retained

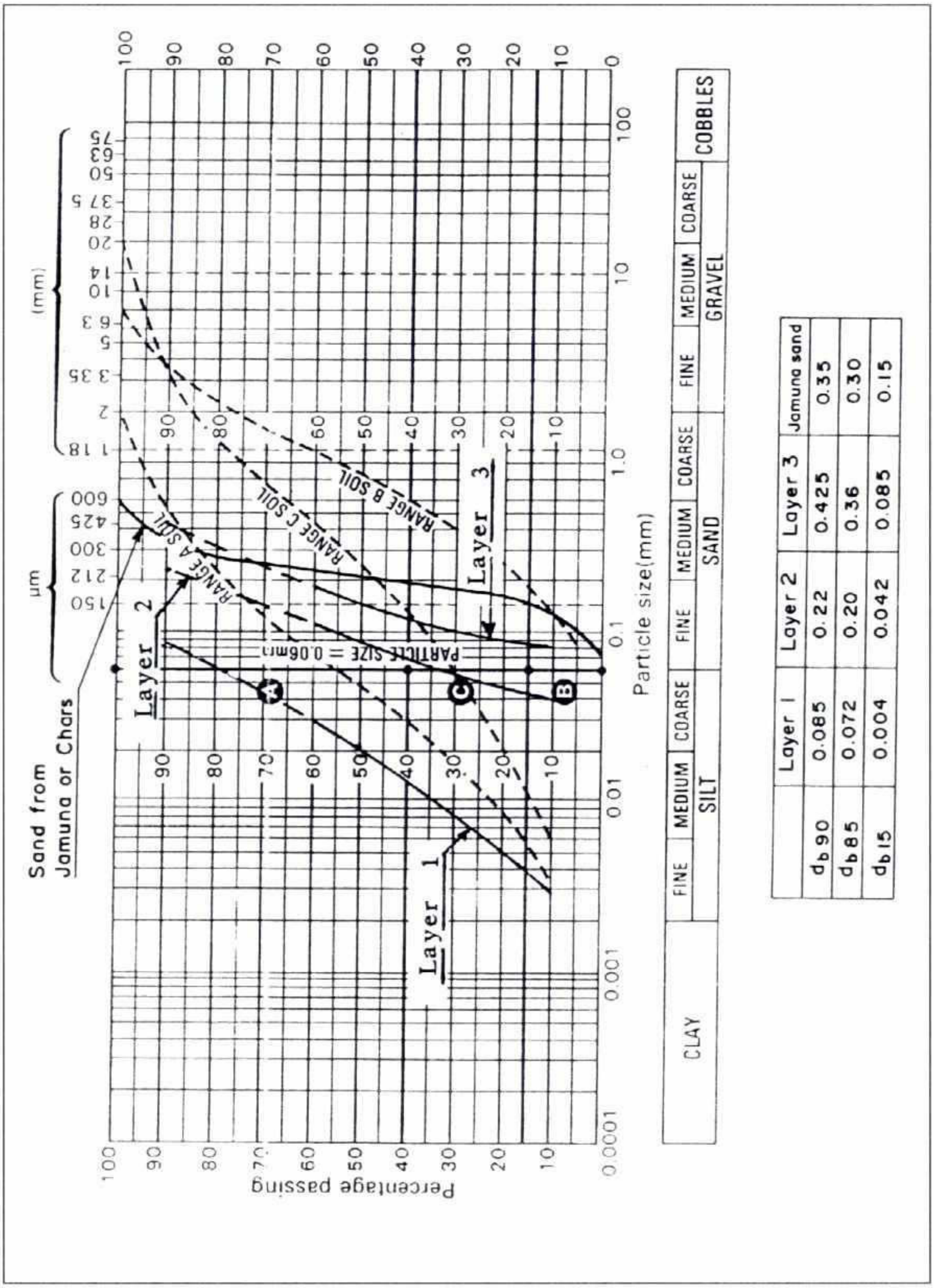
$\frac{O_{98}}{d_{b85}} < 1.0$ if some washing out is acceptable

The latter acceptance leads to a natural filter in the upper base layer. In general this criterion is sufficiently strict.

With the grain size distributions of soil to be protected (Layers 2 and 3, see Figure 6-1), and of commonly available material from Jamuna River (see Figure 6-1) the woven geotextile must meet the following requirements, if some washing out of fill material is considered acceptable:

Condition	Effective Opening Size	To Retain Fill Material	To Retain Soil Layer 2/3
For stationary hydraulic loads	O_{90}	≤ 0.35 mm	≤ 0.22 mm
For cyclic hydraulic loads, with some washing out permitted	O_{98}	≤ 0.30 mm	≤ 0.20 mm

Reference : PIANC, Supplement to Bulletins Nos. 78/79 (1992) Item 5.4.6



	Layer 1	Layer 2	Layer 3	Jamuna sand
d_{b90}	0.085	0.22	0.425	0.35
d_{b85}	0.072	0.20	0.36	0.30
d_{b15}	0.004	0.042	0.085	0.15

Fig. 6.1: Grain Size Ranges of Typical Soil and Fill Material

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ATTACHMENT 7

Dimensioning of Scour Protection Measures

DIMENSIONING OF SCOUR PROTECTION MEASURES

A. SCOUR PROTECTION BLANKETS OF BLOCKS OR STONES/BOULDERS

1 DIMENSIONING OF BLOCK SIZE

The following guidelines for dimensioning scour protection blankets are based on the assumption that

- a theoretical berm should be planned between the toe of embankment slope and the assumed edge of the scour hole;
- the slope of scour hole will develop to about 1V : 2H, and
- that a coverage of the scour slope by a theoretical block layer of 1.5 D_n should suffice to stabilise the scour hole.

Generally wave loads require heavy blocks and short scour blankets (4 to 6 $D_{n50} < W_{fa} <$ 3 to 4.5 H_s), while for current loads wider blankets (aprons) are required, but with comparably smaller block sizes.

1.1 CURRENT ATTACK

The design flow velocity $\bar{u}_{des}$ is to be determined according to the principles of ATTACHMENT 8.

For the present case, the following has been evaluated.

Depth averaged flow velocity $\bar{u}$ = 3.5 m/s

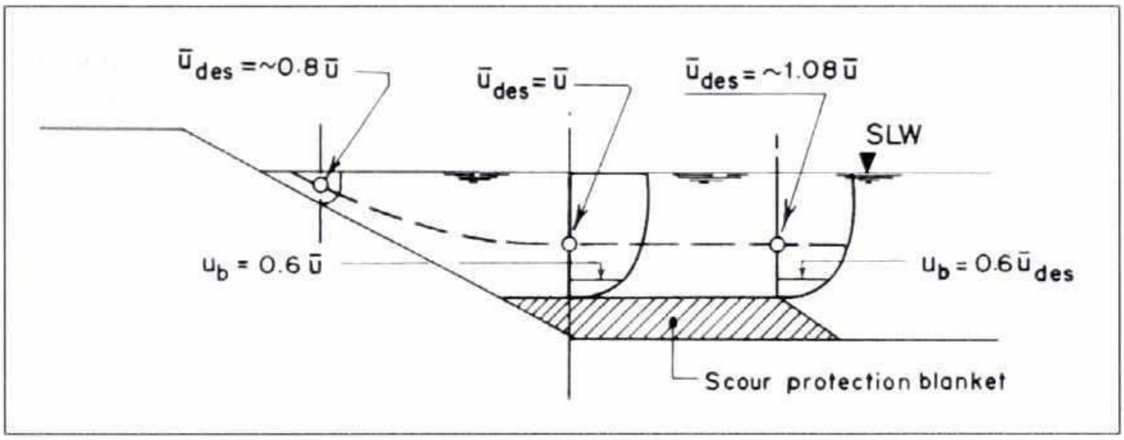

Fig. 7.1: Designation of Design Flow Velocities

$$D'_n \geq \frac{0.7\, u_b^2 \cdot K_t}{\Delta_m \cdot g \cdot K_s} \qquad (7\text{-}1)$$

The formula (7-1) is based on the Isbash - formula which has been modified by introduction of:

u_b [m/s] = 0.6 $\bar{u}_{des}$ (bottom flow velocity, assumed to occur at the part of scour blanket to be dimensioned)

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K_t [-] = turbulence factor
= 1.0 for normal flow conditions
= 1.1 to 1.25 for areas were turbulences are to be expected, e.g. exposed edges of scour blankets at upstream terminations or transitions.

The other parameters represent

K_s [-] = slope factor

$$= \cos\alpha \sqrt{1 - \left(\frac{\tan\alpha}{\tan\phi_O}\right)^2}$$

wherein: α = angle of slope of the toe scour blanket
ϕ_o = angle of respose of blanket material
= 40° - 45° for rock and blocks
= 30° - 35° for stones and boulders

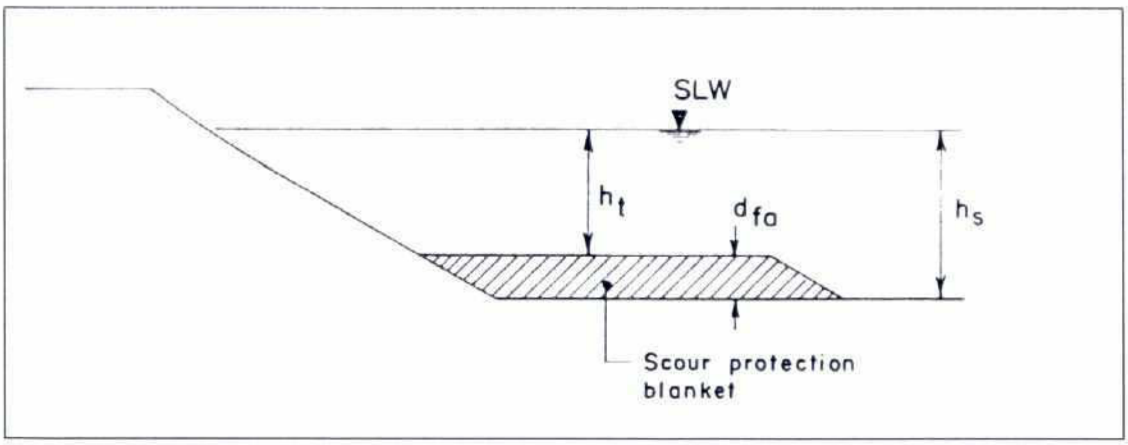
By the introduction of coefficients K_s and K_t and the definition of $\bar{u}_{des}$, negative factors such as decreasing shear forces near the bottom for larger depths are also covered.

1.2 WAVE ATTACK

Based on the analyses of wind generated waves (see ATTACHMENT 9) for various wind conditions and area aspects the following general wave data may be applied for the conditions at the Jamuna River.

Return Period [years]	Design Wave Height H [m]	Wave Period T [s]
5	0.8	3.0
10	0.9	3.3
25	1.0	3.5
50	1.2	3.8
100	1.3	4.0

The PIANC (1992) formula for scour protection blankets can be applied for the condition $0.4 < h_t / h_s < 0.8$:



- if $h_t / h_s < 0.4$: scour protections are to be dimensioned as per design formula for revetment protection
- if $h_t / h_s > 0.8$: wave loads are not decisive for scour protection design, but only current loads.

The following graphic permits a quick decision on the design method and formula to be applied.

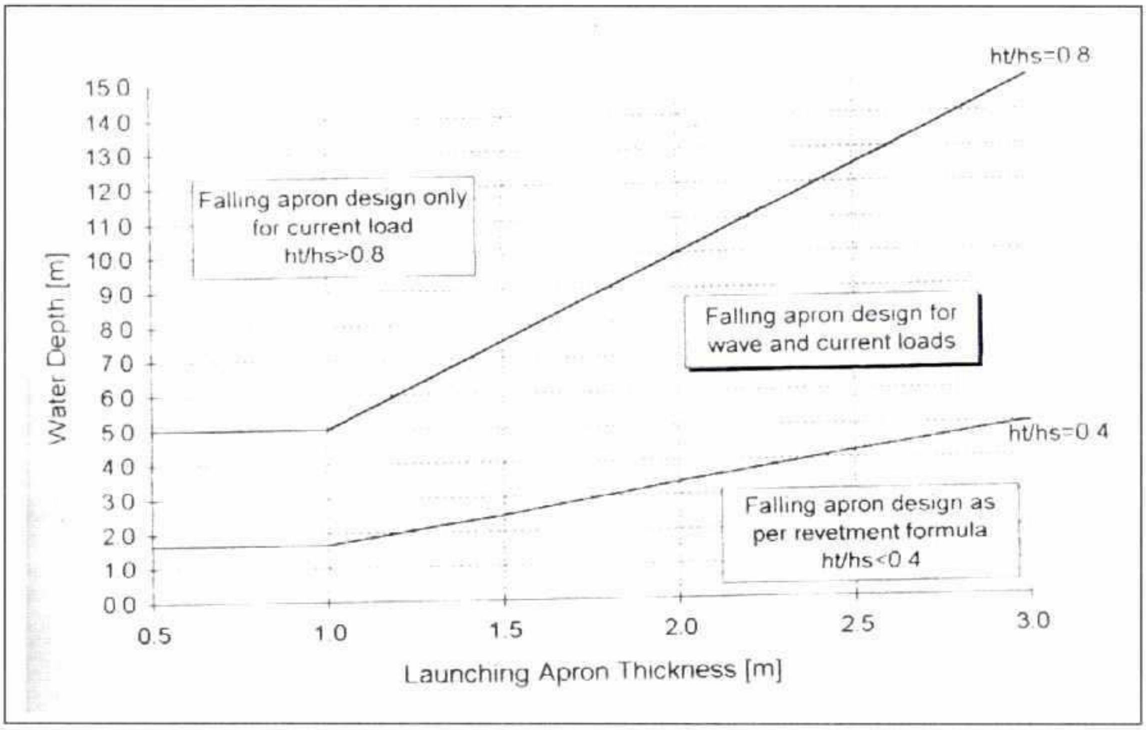


Fig. 7.2: Design of Scour Protection Measures - Range of Design Formula Application

The PIANC (1992) formula reads:

$$D'_n \geq \frac{H_s}{\Delta_m \left(1.14 + 0.03\frac{h_t}{h_s} + 8.38\left(\frac{h_t}{h_s}\right)^2\right)} \qquad (7\text{-}2)$$

Therein:

H_s [m] = significant wave height (alternatively the design wave height can be applied)

Δ_m [-] = relative density of protection material
= $(\rho_s - \rho_w)/\rho_w$

h_s [m] = water depth

h_t [m] = $(h_s - d_{fa})$ = water depth above scour blanket

d_{fa} [m] = thickness of scour blanket

1.3 SELECTION OF BLOCK SIZE D_n

Where wave and current loads occur together the larger size determined from wave and current formulae should be increased by a factor of at least $1.3^{0.33}$

$$D_n = 1.09\, D'_n \qquad (7\text{-}3)$$

2 DIMENSIONING OF SCOUR PROTECTION BLANKET (FALLING APRON)

2.1 TYPICAL CROSS-SECTION

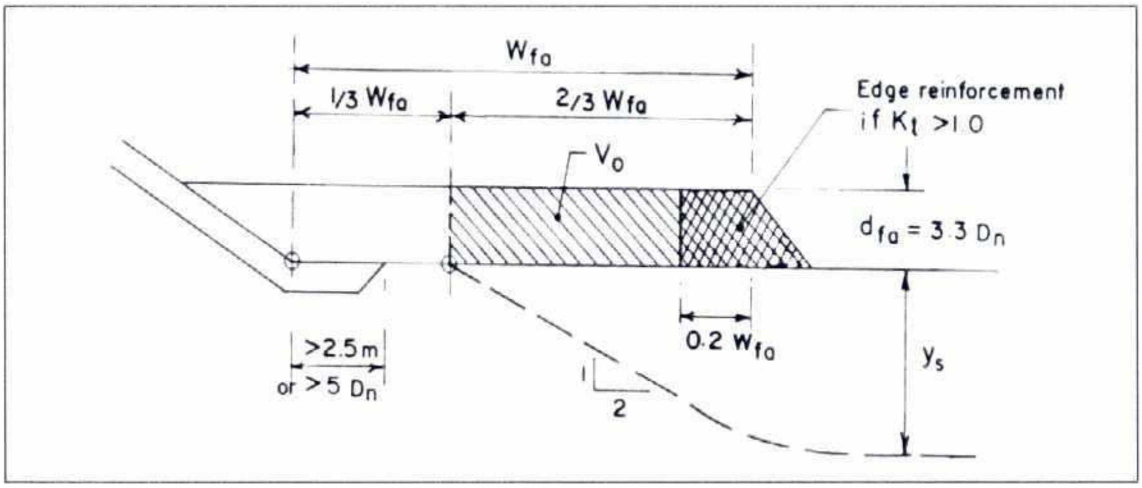


Fig. 7.3: Wave and Current Loads Occur Together or Flow Attack is Extremely Strong (flow attack coefficient $c_l = 5$)

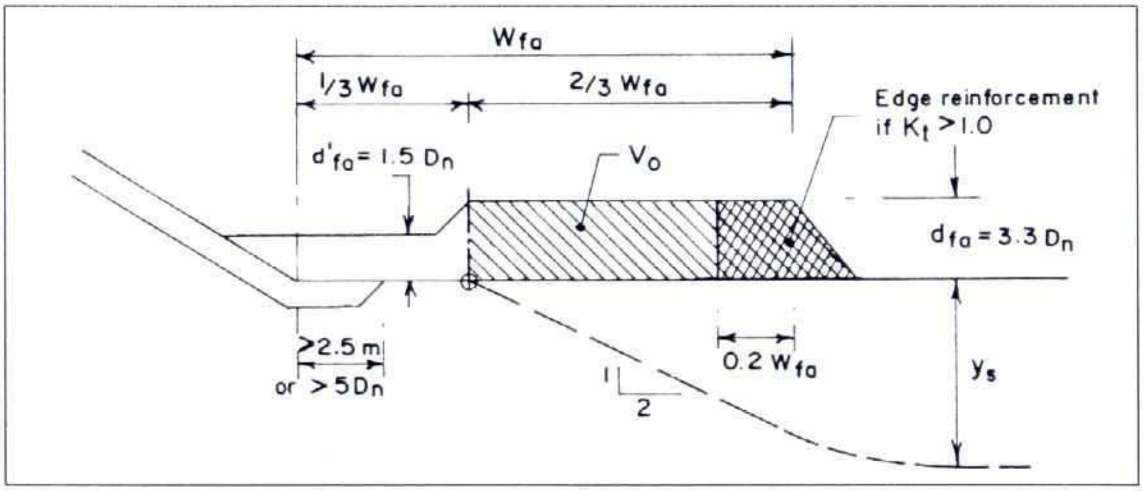


Fig. 7.4: Only Current Load Occur (flow attack coefficient $c_l = 4$)

2.2 EFFECTIVE VOLUME OF FALLING APRON

For locations with strong flow attack the volume V_o of a scour protection blanket per one meter can be estimated to

$$V_o = c_1 \cdot y_s \cdot D_n \qquad [m^3/m] \qquad (7\text{-}4)$$

in which:

V_o $[m^3/m]$ = Volume of falling apron per linear meter along the exposed length

c_1 [-] = flow attack coefficient
= 4.60 (moderate flow)
= 5.75 (strong flow attack)

D_n [m] = block size as determined by formula (7-3) above

y_s [m] = design scour depth

with the designations of Figures A.2.1-1 and A.2.1-2.

Attention must be given to the important note under Subitem A.2.3.

2.3 THICKNESS OF FALLING APRON

(a) The outer apron part, or the entire apron width in case of strongly attacked parts:

$$d_{fa} \geq 3.3\, D_n \qquad (7\text{-}5)$$

(b) The inner part of the apron, if moderate flow conditions prevail:

$$d'_{fa} \geq 1.5\, D_n \qquad (7\text{-}6)$$

Note that formula (7-5) and (7-6) apply only if minor damages are acceptable which can be repaired within regular maintenance works. In all other cases a factor of η = 1.5 to 2.0 should be applied for determination of d_{fa} and d'_{fa}.

2.4 WIDTH OF FALLING APRON

Measured from the toe of the embankment slope, as depicted in Figures A.2.1-1 and A.2.1-2:

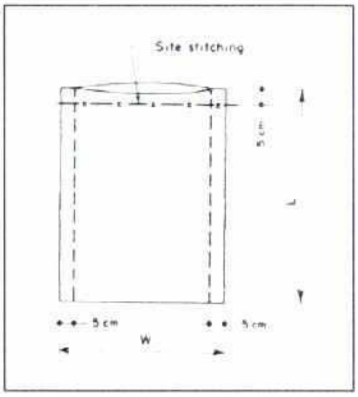
$$W_{fa} = \frac{1.5\, V_o}{d_{fa}} \qquad (7\text{-}7)$$

B. SCOUR PROTECTION BLANKETS OF GEOTEXTILE SAND CONTAINERS

1 DIMENSIONING OF UNIT SIZE

Giving consideration to the fact that a single protection unit shall practically not move under the hydraulic forces and wave loads, the equivalent weight of one protection unit can roughly be determined by Formulas (7-1) to (7-3).

For some typical block sizes, the equivalent size of sand-filled geotextile containers is given in Table B.1-1.



Concrete Block Size D_n [cm]	35	40	45	50	75
Geo-sand Container Type	A	B	C	D	E
- equivalent weight [kg]	90	125	180	250	900
- volume (~ 80% fill) [m^3]	0.05	0.07	0.10	0.14	0.50
- geotextile size of container L x W [m]	1.04 X 0.52	0.96 X 0.88	1.20 X 0.88	1.60 X 0.85	2.15 X 1.27
- theoretical area covered by 1 container [m^2] 1)	0.35	0.60	0.75	1.00	2.0
- theoretical thickness d_n [m]	0.14	0.12	0.13	0.14	0.25

1) net, excluding material loss for stitching (2 x 5 cm) and 15% shrink due to filling

Fig. 7.5: Equivalent Sand-Container Sizes

2 DIMENSIONING OF SCOUR PROTECTION BLANKET

2.1 TYPICAL CROSS-SECTION

Figures A.2.1-1 and A.2.1-2 are applicable, with the following altered values:

- outer part of falling apron: $d_{fa} = 4 \times d_n$
- inner part of falling apron: $d'_{fa} = 2 \times d_n$

with d_n = theoretical thickness of a protection unit (geo-sand container of the respective type).

The important note under Subitem A.2.3 must be given due consideration.

2.2 EFFECTIVE VOLUME OF FALLING APRON

For locations with strong flow attack the volume V_o of a scour protection blanket per one meter can be estimated to

$$V_o = c_l \cdot y \,.\, 1.5\, d_n \qquad (7\text{-}8)$$

in which:

V_o	$[m^3/m]$	=	Volume of falling apron per linear meter along the exposed length
c_l	[-]	=	flow attack coefficient
		=	4 (moderate flow)
		=	5 (strong flow attack)
d_n	[m]	=	theoretical thickness of protection unit
y_s	[m]	=	design scour depth

The important note under Subitem A.2.3 must be given due consideration.

2.3 THICKNESS OF FALLING APRON

(a) The outer apron part, or the entire apron width in case of strongly attacked parts:

$$d_{fa} \geq 5\, d_n \qquad (7\text{-}9)$$

(b) The inner part of the apron, if moderate flow conditions prevail:

$$d'_{fa} \geq 3\, d_n \qquad (7\text{-}10)$$

The important note under Subitem A.2.3 must be given due consideration.

2.4 WIDTH OF FALLING APRON

Formula (7-7) is to be applied.

C. ADDITIONAL DESIGN RECOMMENDATIONS

The toe of the revetment cover layer shall overlap with the scour protection blanket (falling apron) for at least 2.5 m or 5 D_n, whichever is larger. The thickness of overlap shall correspond with d_{fa} respectively d'_{fa}, for the conditions of formulae (7-5) and (7-6).

Outer edges of scour protection blankets which are exposed to severe flow attack (e.g. near upstream terminations) should be reinforced by providing heavier blocks (protection units); D_n should be determined by formula (7-1), applying K_t at 1.1 to 1.25. The width of reinforced edges should correspond to about 0.2 W_{fa}.

ATTACHMENT 8

Determination of
Flow Velocities Near a Revetment

Ra

DETERMINATION OF FLOW VELOCITIES NEAR A REVETMENT

1 INTRODUCTION

For the design of the toplayers of the revetment the distribution of the design flow velocities near the revetment should be known. In previous studies the design flow velocity was determined as the depth averaged flow velocity at the toe of the revetment. Given this design flow velocity, the distribution of the flow velocities over the falling apron and the slope of the revetment is determined in this note. This distribution has been determined on the basis of the results of a mathematical model.

2 APPROACH

In a vertical the flow velocity profile can be approximated by the logarithmic flow velocity profile if the boundary layer flow is well developed over the full depth. In a logarithmic flow velocity profile the depth averaged flow velocity is calculated at 0.37 h from the river bed. If the horizontal distribution of the depth averaged flow velocity is known than the whole flow field is determined.

It is assumed that the vertical accelerations in the flow near the revetments can be neglected and the bottom topography near the revetments changes gradually. The turbulence intensities in the flow are not described in this note.

Two situations are distinguished:

- An extreme flow attack by an unfavourable approach channel with a schematized cross-section, followed by some bank erosion at the upstream side (about 150 m) and a flood with a return period of 2, 10 and 100 years. The effect of local scour holes along the revetment on the distribution of the depth averaged flow velocities is neglected.
- The initial situation without bank erosion and the revetment just at the bank of the channel without fully developed local scour holes. This situation is expected just after completion of the construction of the revetment.

A revetment with a side slope 1:3 and a length of about 1 km has been assumed.

3 PRESENTATION OF THE RESULTS

The mathematical model simulations have been computed by the TRISULA model of Delft Hydraulics. The channel layout was schematized from several bathymetric surveys, see Annex 6 of the Final Report[1] of the Planning Study Phase of the project. The results of channel alignments A and C were analyzed especially in cross-sections 25 and 30 which are more than 200 m downstream of the upstream termination. The presented results are not valid for the upstream termination itself, where the flow field can be complicated by a flow separation point and an eddy.

Reference

[1] Bank Protection and River Training (AFPM) Pilot Project Final Report, Planning Study Phase, Annex 6 Mathematical Model Tests, June 1993

A dimensionless presentation has been selected for an easy application of the results to comparable channels at other locations where a similar type of revetment will be planned. The flow velocities in a cross-section are presented as a function of $B(x)/B_{toe}$, in which B(x) is the width measured from the intersection of the revetment with the water level and B_{toe} is the width between this intersection and the toe.

The flow velocities are made dimensionless by dividing them by the given depth average flow velocity at the toe: $u(x)/u_{toe}$. In the same graph the water depth is normalized with the water depth at the toe of the revetment. In the schematized profile the river bed is assumed to be horizontal.

The results presented in Figure 8.1 are estimated to be valid in the following range of the different parameters:

$10 <$ water depth $h < 25$ m,

$1.5 <$ flow velocity $u < 4$ m/s.

The river bed is assumed almost horizontal, downstream part of a revetment with 1:3 slope, bank erosion between 0 and 150 m. The range of $u(x)/u_{toe}$ indicated in Figure 8.1 gives also an idea on the accuracy of the determined flow velocity distribution.

The results show that the flow velocities near the revetment will increase as the upstream bank erosion increases and the approach channel has an unfavourable alignment. It is expected that local scour holes do not change this distribution of the flow velocities because the given depth averaged flow velocity at the toe includes the effect of the local scour holes.

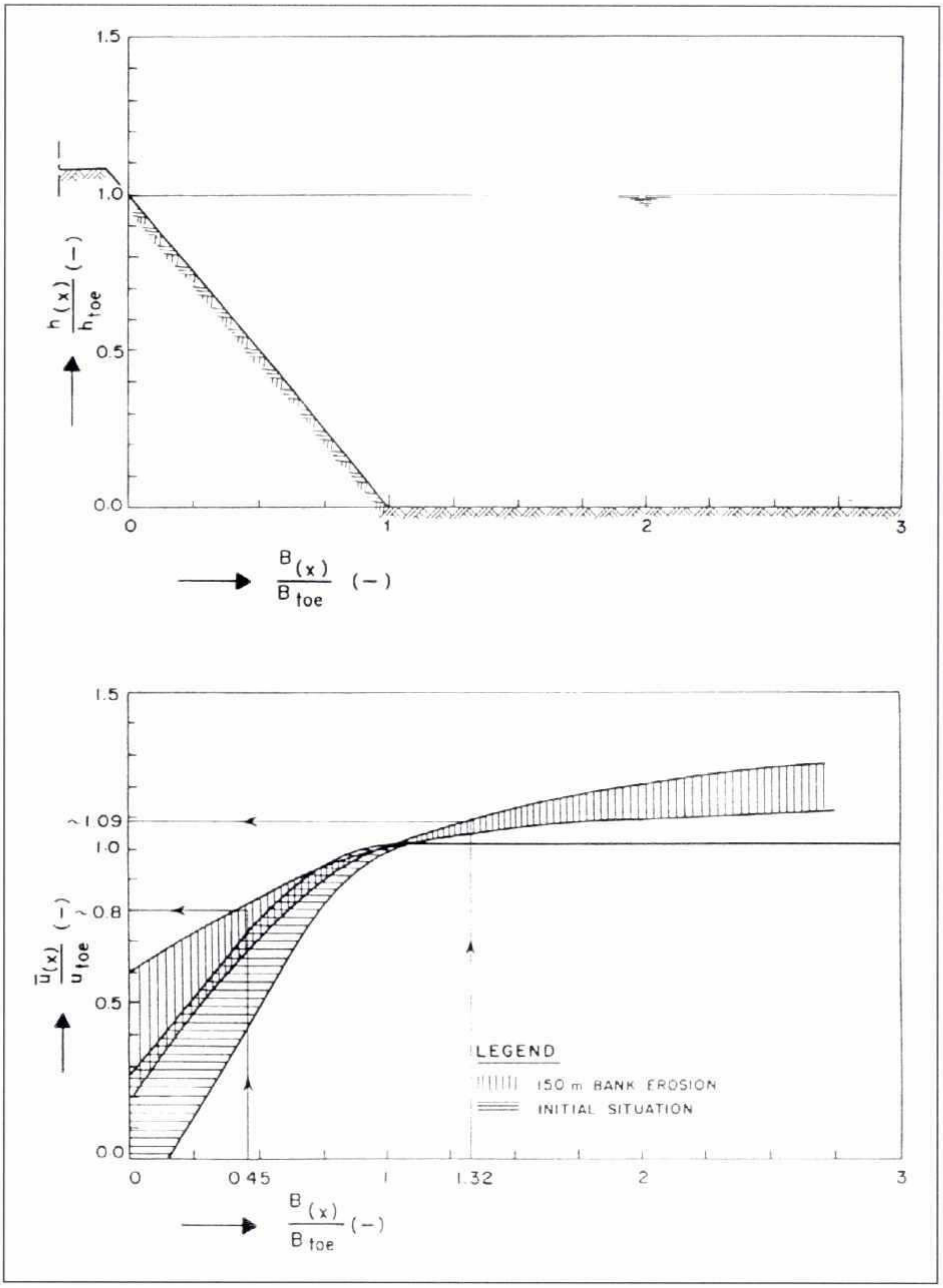
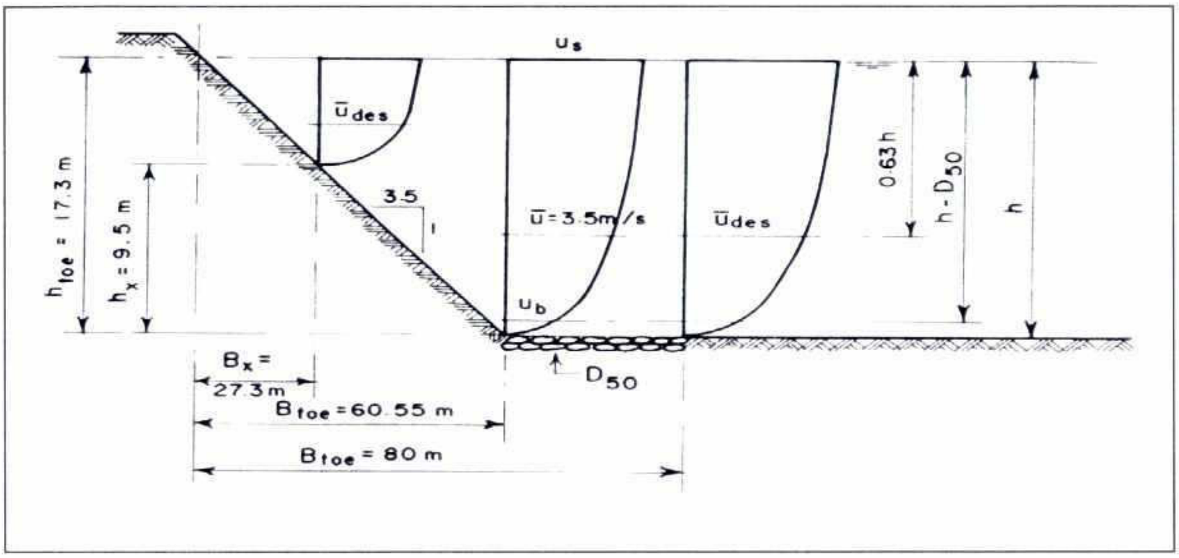


Fig. 8.1: Design Conditions, 0 and 150 m Bank Erosion

4 PRACTICAL EXAMPLE

Depth averaged flow velocity $\bar{u}$ = 3.5 m/s.



For location x along the slope :

$$\frac{B_x}{B_{toe}} = \frac{27.3}{60.55} = 0.45 \_ \text{ Fig. 8.1: } \frac{\bar{u}_x}{u_{toe}} = \sim 0.8$$

$$\bar{u}_{des} = \bar{u} \times 0.8 = 3.5 \times 0.8 = 2.8 \text{ m/s}$$

For the exposed edge of the falling apron :

$$\frac{B_x}{B_{toe}} = \frac{80}{60.55} = 1.32 \_ \text{ Fig. 8.1: } \frac{\bar{u}_x}{u_{toe}} = \sim 1.08$$

$$\bar{u}_{des} = \bar{u} \times 1.08 = 3.5 \times 1.08 = \sim 3.80 \text{ m/s}$$

ATTACHMENT 9

Analysis of Wind Generated Waves for the
Design of Bank Protection Structures
at the Jamuna River

ANALYSIS OF WIND GENERATED WAVES FOR THE DESIGN OF BANK PROTECTION STRUCTURES AT THE JAMUNA RIVER

1 PRELIMINARY REMARKS

Waves are generated on the Jamuna River by wind during the tropical Norwesters, by cyclones and by passing of ships. Since inland waterway transport does not yet play an important role for the reach of the Jamuna River in question, ship induced waves are infrequent and are therefore not given consideration in the present design assumptions. An approximate calculation of the wind induced waves can be done by theoretical methods. But, due to the very strong current component and the substantial fluctuations in water depth over the fetch length at the Jamuna river, a reliable theoretical prediction of wave parameters is rather complex. Nevertheless, a design wave height of H_{25} = 1.0 m is commonly used for the major rivers of Bangladesh and seems to provide a reasonable estimate. In the following only a brief analysis of the wave conditions is given, to verify this assumption and to investigate the band width of results.

2 WIND SITUATION AT THE JAMUNA

Important for the Jamuna situation are the squalls during pre-monsoon (Norwesters) and post monsoon situation, which generate considerable waves on the river. Squalls are local disturbances causing substantial wind speeds with thunderstorms, mainly occurring in the months of March to May, but also at other times of the year.

Cyclones, in the form of typhoons and hurricanes, which are associated with strong wind velocities are rare in the interior part of Bangladesh. According to studies done for the Jamuna Multipurpose Bridge Project severe cyclones with a gust speed of 33 m/s (64 knots) may be expected in this region once in 30 years only. Due to the rare recurrence, cyclonic storms are not being considered as a design criteria for erosion prevention structures of general nature.

3 DESIGN WIND VELOCITY

Wind data of the Bangladesh Meteorological Department, Dhaka were evaluated for the stations Faridpur, Sirajganj, Bogra, Rangpur and Mymensingh by FAP 1 [1]. These results are considered as representative for the FAP 21 - Pilot Project.

In addition reference is made to the Jamuna Bridge Report [2]. The distribution curves for the wind velocity as a function of the return period presented therein are applied for determination of the design wind velocity.

A period of 15 minutes has been chosen deliberately in [2] as an approximate time for the full growth of wind waves for the conditions of the Jamuna areas in question.

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[1] BRTS Master Plan Report (May 1993)
Technical Annexes, Annex 4, Appendix H

[2] JAMUNA BRIDGE PROJECT, Phase II Study
River Training Works (May 1990)

Using the distribution formula of [2]

$$V_{mean\ (15\,min)} = 15 + 2.25\ln(T) \qquad [m/s] \qquad (9\text{-}1)$$

where T = return period (years), the following data result:

Return Period [year]	2	5	10	25	50	100
$V_{mean\ (15\ min)}$ [m/s]	16.56	18.62	20.18	22.24	23.80	25.36

Table 9.1: Design Wind Velocity for Wave Generation $V_{mean\ (15\ min)}$

The above values are comparable with statistical values determined in [(1)], which resulted in a wind speed of 35 knots (~ 18 m/s) for a return period of about 5 years.

4 WIND DIRECTION

The wind directions from South-West to North-West (wind sector between 225° and 315°) are of major importance for the wind induced wave impact at the Bahadurabad Revetment.

5 FETCH LENGTH AND ASSOCIATED WATER DEPTH

An important parameter regarding wave generation is the fetch length. During monsoon, when the river flow is at its peak and many chars are inundated, the fetch length is at its maximum. The average water level elevations measured at Phulchari and Bahadurabad have been used as basis for the calculations (Table 9.2).

Location	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Phulchari	14.3	15.7	17.5	18.8	18.7	18.3	17.1	15.0	14.0	13.5	13.3	13.4
Bahadurabad	15.0	15.8	17.5	18.6	18.9	18.0	17.0	15.0	14.0	13.5	13.2	13.5

Table 9.2: Average High Water Levels [m PWD]

Considering the above compiled water level information and the typical cross-sections established for Bahadurabad in the study phase (Main Report FAP 21, ANNEX 7), an average water depth between 7 m and 10 m during high flood stage in the months of July, August and September, associated with the fetch area, was estimated. The fetch length was approximated from satellite images and is varying between 2 and 5 km.

6 WAVE PARAMETERS

Because of the continuous changes between sand bars, chars, tributories, etc. it is assumed that for the prediction of wind generated waves at the Jamuna River situation the "shallow water" conditions apply, even this is not following the general interpretation when analyzing the average values of relative water depth.

The significant design wave height H_s [m] and wave period T [s] can be computed by the following formulae (Shore Protection Manual, 1984):

$$H_s = 0.283 \tanh\left[0.530\left(\frac{g\,d}{U^2}\right)^{0.75}\right] \tanh\left\{\frac{0.0125\left(\frac{g\,F}{U^2}\right)^{0.42}}{\tanh\left[0.530\left(\frac{g\,d}{U^2}\right)^{0.75}\right]}\right\}\frac{U^2}{g} \qquad (9\text{-}2)$$

$$T = 1.20 \tanh\left[0.833\left(\frac{g\,d}{U^2}\right)^{0.375}\right] \tanh\left\{\frac{0.077\left(\frac{g\,F}{U^2}\right)^{0.25}}{\tanh\left[0.833\left(\frac{g\,d}{U^2}\right)^{0.375}\right]}\right\}\frac{2\pi U}{g} \qquad (9\text{-}3)$$

where:

U	[m/s]	=	$V_{mean\ (15)}$	=	15 + 2.25 ln (T)
F	[m]	=	fetch length		
d	[m]	=	average water depth within fetch		
g	[m/s^2]	=	gravitational acceleration		

The computed wave parameters for different recurrence intervals are presented in the Table 9.3.

Recurrence Interval T	**[year]**	**2**	**5**	**10**	**25**	**50**	**100**
$V_{mean(15)} = U$	[m/s]	16.56	18.62	20.18	22.24	23.80	25.36
Recurrence Interval T	**[year]**		**2**			**5**	
Fetch Length F	[m]	2,000	3,500	5,000	2,000	3,500	5,000
Water Depth d	[m]		7.00			7.00	
Wave Height H_s	[m]	0.56	0.69	0.78	0.64	0.78	0.88
Wave Period T	[s]	2.64	2.97	3.19	2.80	3.14	3.37
Recurrence Interval T	**[year]**		**10**			**25**	
Fetch Length F	[m]	2,000	3,500	5,000	2,000	3,500	5,000
Water Depth d	[m]		9.00			9.00	
Wave Height H_s	[m]	0.71	0.87	0.98	0.79	0.97	1.10
Wave Period T	[s]	2.92	3.29	3.53	3.08	3.47	3.73
Recurrence Interval T	**[year]**		**50**			**100**	
Fetch Length F	[m]	2,000	3,500	5,000	2,000	3,500	5,000
Water Depth d	[m]		10.00			10.00	
Wave Height H_s	[m]	0.86	1.06	1.20	0.93	1.15	1.30
Wave Period T	[s]	3.20	3.60	3.88	3.31	3.73	4.02

Table 9.3: Computed Wave Data for Various Recurrence Intervals

From these results a value of H_s = 1.0m is characterizing a lower estimate of the wave heights to be expected. On the other hand, the recurrence interval concerning the combination of extreme water levels and excessive wind speeds is much larger, hence, when designing for a 25 years return period, this will lead to a rather conservative layout. To prevent from over-dimensioning of the structure components and to allow for an investigation regarding the influence of predominant high flow velocities on the structure stability, a wave height of H_s = 1.0m seems to be practicable and was used as design basis for this project. For the estimation of wave induced loads at the revetment components, the design wave height H was defined at 1.0 H_s.

ATTACHMENT 10

Additional Hydraulic Loads at Ferry Ghat
Screw Race

ADDITIONAL HYDRAULIC LOADS AT FERRY GHATS
SCREW RACE

Revetments and bed protections around or near ferry ghats may be subjected to additional hydraulic loads caused by maneuvering ferry boats.

Ship propellers generate high jet velocities in the column water, called "screw race", which may impinge on the bed or bank of the waterway. Screw race is normally only a significant load at moorings or near ferry ghat where serious scour on the bank face can result from a vessel starting from stationary or whilst maneuvering near the bank. A bow-thruster with propulsion at the front of the ship can cause even more severe scours.

The analysis of screw race requires knowledge of the propulsion system and the size and duration of the applied load [1].

An indication of bottom velocities [1] due to the action of the propeller can be obtained with,

$$u_b = \alpha_2 u_o \frac{D_o}{z_b} \qquad (10\text{-}1)$$

Where:

u_b [m/s] = flow velocity at river bed

α_2 [-] = coefficient

u_o [m/s] = the axial efflux velocity

$$= 1.15\left(\frac{P_D}{D_o}\right)^{0.33} \qquad (10\text{-}2)$$

z_b [m] = vertical distance from propeller axis to bed of fairway.

and

D_o [m] = initial diameter of slipstream behind propeller
= D_p (for ships with a propeller in a nozzle)
= 0.7 D_p (for ships without a nozzle)

Where:

D_p [m] = diameter of the propeller, and

P_D [kW] = installed engine power.

[1] Verhey, H. J.
"The Stability of Bottom and Banks Subjected to the Velocities in the Propeller Jet Behind Ships"
Delft Publication No. 303 (April 1983)

The coefficient α_2 varies between 0.25 and 0.75 depending on the ship type and the rudder configuration. Commonly a value of α_2 = 0.3 is used as a first approximation.

Figure 10-1 illustrates the various parameters used in equation (10-1).

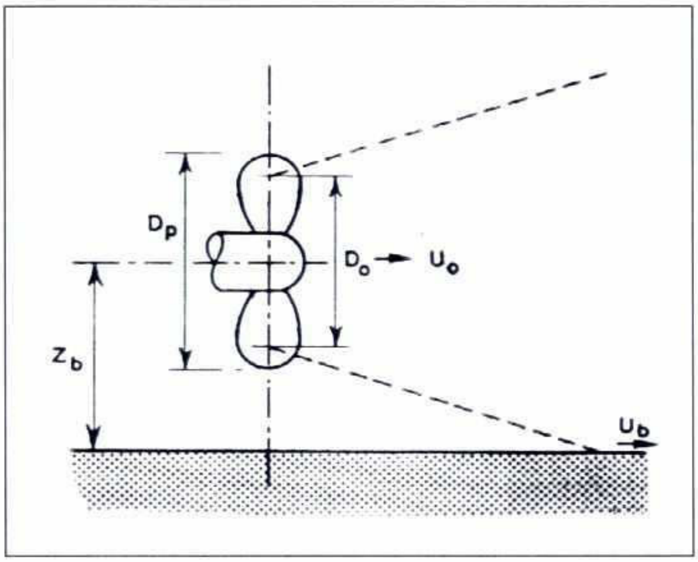


Fig. 10.1: Velocity Behind a Propeller

The formula for u_b is only valid for ships applying engine power from stationary.

For ships underway ($V_s \neq 0$) the velocities in the screw race are less important. The values in Table 10.1 give an indication of the bottom velocities.

V_s [m/s]	0	1	2
u_b [m/s]	2.5	2.0	1.5

Table 10.1: Screw Race Velocities for Inland Waterway Vessels

The level of damage is proportional to both the screw race velocity and the duration over which the screw race is attacking the area.

For taking appropriate consideration of screw race effects in the design of a revetment likely subjected to such effects, the following questionnaire may be used to obtain the desired data basis.

QUESTIONNAIRE

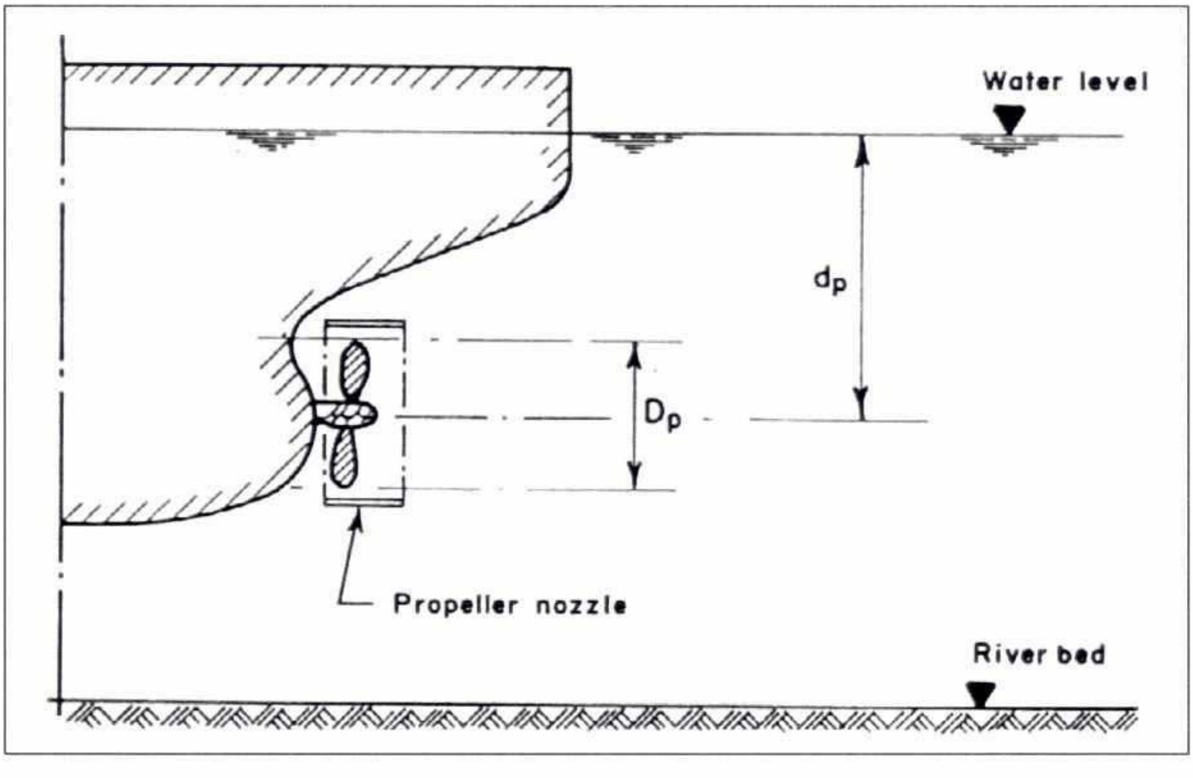
(to be addressed to Bangladesh Railways, BIWTA, BIWTC etc.)

"Ferry Ghat at ...."

To study the effects of vessels manoeuvering close to river banks (revetments), the following information is requested, either for the standard ferry boats, or, in case of major variations, for the range of typical ferries for railway waggons (tug boats / push boats) as well as passenger vessels operated by Bangladesh Railways, respectively of inland waterway vessels operated by others, e.g. fuel barges, etc.

- Diameter of propeller D_p : .... [m]
- Depth of propeller below water surface d_p : .... [m]
- Propeller installed in a nozzle : Yes / No
- Installed engine power P_D : .... [kW]
- No. of engines / propellers : .... [No.]
- Bow thruster installed : Yes / No

The following figure illustrates the meaning of some of the above designations :



ATTACHMENT 11

Design of Geotextile Filter

DESIGN OF GEOTEXTILE FILTER

With the FAP 21 project detailed subsoil investigations were carried out at several location on Jamuna right bank and left bank. The data generally be evaluated as presented in Table 11.1. The data may provide sufficient base for design of geotextile filter materials by the method described in PIANC (1987).

	Flood Plain Level to ± 0 m SLW	± 0.0 SLW to - 5.0 m SLW	Below - 5.0 m SLW
Soil classification	Sandy silt to silty Sand; clayey (CL - ML)	Fine to medium sand, silty, partly clayey (SM)	Sand
Grain size distribution (mm) d_{60} d_{50} d_{10}	0.03 to 0.09 0.02 to 0.07 0.003 to 0.03	0.11 to 0.20 0.09 to 0.22 0.04 to 0.07	0.20 to 0.26 0.15 to 0.22 0.06 to 0.08
Coefficient of uniformity $U = \frac{d_{60}}{d_{10}}$	3 to 10	3 to 4	3 to 4
Coefficient of permeability [m/s]	-	3×10^{-5}	
Angle of internal friction φ' [°]	25° to 27.5°	27.5° to 32.5°	
Cohesion c' [kN/m²]	7 to 20		0
Unit weight/submerged unit weight γ/γ' [kN/m³]	18/8		

Table 11.1: General Subsoil Data

1 GRAIN SIZE RANGE

In accordance with the diagram presented in Figure 11.1 the soil is categorised to the following ranges:

Layer	Depth	Grain Size [m]			Grain Size Range
		D_{10}	d_{50}	d_{60}	
1	Flood plain to ± 0 m SLW	0.003 to 0.03	0.02 to 0.07	0.03 to 0.09	A
2	± 0 m to - 5 m SLW	0.04 to 0.07	0.09 to 0.20	0.11 to 0.22	C
3	Below - 5 m SLW	0.06 to 0.08	0.15 to 0.22	0.20 to 0.26	B (C)

Table 11.2: Grain Size Range

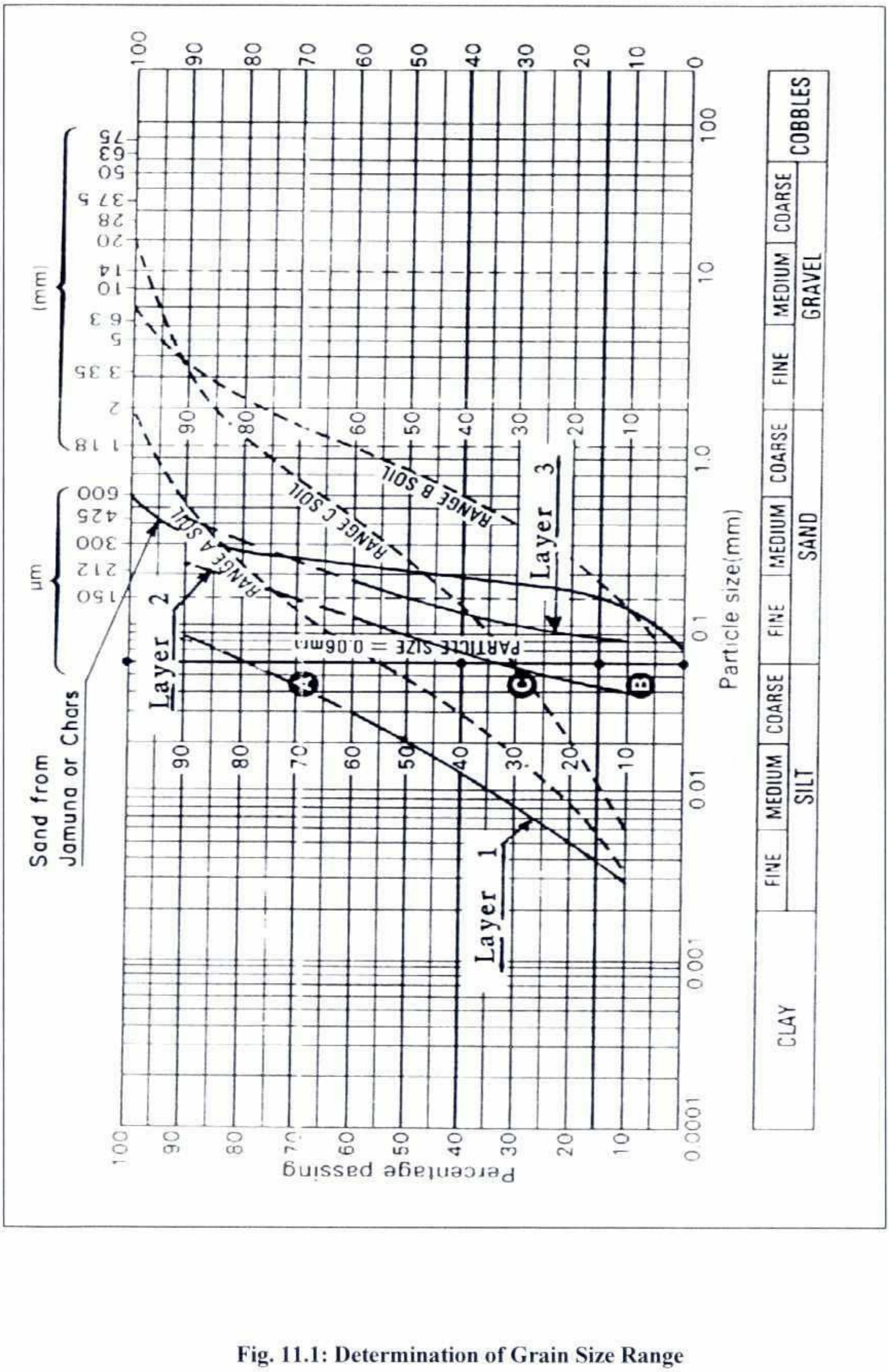


Fig. 11.1: Determination of Grain Size Range

2 EFFECTIVE OPENING SIZE OF GEOTEXTILE FILTER

2.1 SOIL ABOVE SLW - GRAIN SIZE RANGE A

For the condition $O_{90} < d_{90}$
$< 10\ d_{50}$
< 0.3 mm:

- $d_{90} \sim 0.08$ mm
- $10\ d_{50} = 10 \times 0.02 = 0.2$ mm
- $O_{90} < 0.08$ mm

2.2 SOIL BELOW SLW - GRAIN SIZE RANGE C

For the condition $O_{90} < 1.5\ d_{10} \sqrt{C_u}$
$< d_{50}$
< 0.5 mm :

$$C_u = \frac{d_{60}}{d_{10}}$$

- $1.5\ d_{10} = 1.5 \times 0.04 \times \sqrt{\frac{0.11}{0.04}} = 0.10$ mm
- $d_{50} = 0.09$ mm
- $O_{90} < 0.09$ mm

3 PERMEABILITY OF NON-WOVEN FILTER FABRIC

3.1 SOIL ABOVE SLW

The permeability criterion requires that

$$\eta\, k_g \geq k_s$$

where η = reduction factor

k_g = permeability of the geotextile

k_s = permeability of the soil

For non-woven fabrics thicker than 2 mm (measured at a normal stress of 2 kN/m^2) :

$$\eta = \frac{1}{50}$$

For woven fabrics PIANC (1987) presents diagrams for determination of η.

For the present soil with assumed $k_s = 3 \times 10^{-5}$ [m/s] :

The permeability of the fabric (non-woven) shall be :

$$k_g > 50\ k_s$$
$$> 50 \times 3 \times 10^{-5}$$
$$> 1.5 \times 10^{-3}\ m/s$$

3.2 SOIL BELOW SLW

The method of Item 3.1 applies. In the present case similar permeability of the subsoil is assumed.

4 IDENTIFICATION OF SUSCEPTIBILITY TO DOWNSLOPE MIGRATION

(a) A proportion of grain particles of smaller than 0.06 mm is available in soil layer 1 and 2.

(b) At least one of the following conditions must be fullfilled :

- The coefficient of uniformity $C_u < 15$ (see Table 11.2):

  Layer 1: $C_u = \frac{d_{60}}{d_{10}} = \frac{0.03}{0.003} = 10 < 15$

  Layer 2: $C_u = \frac{0.11}{0.04} = 2.75 < 15$

  Layer 3: $C_u = \frac{0.20}{0.06} = 3.33 < 15$

- More than 50% of grain particles be in the range of $0.02\ mm < d < 0.1\ mm$:

  Layer 1 : YES

  Layer 2+3: NO.

- The plasticity index

  $$\frac{\text{proportion of clay } (d < 0.002\ mm)}{\text{proportion of silt } (0.002 < d < 0.06\ mm)} < 0.5$$

  Layer 1: $\frac{10\,\%}{70\,\%} = 0.14 < 0.5$

(c) Conclusion

Item (a) and at least one condition of (b) is satisfied:

The soil is susceptible to downslope migration.

5 MEASURES OF PREVENTING DOWNSLOPE MIGRATION

(a) Generally geotextile filter mats should have a thickness of about 5 mm for such conditions.

(b) Soil Above SLW

- A granular sublayer of about 30 cm thickness is to be provided between the geotextile and the protective layer.

  The grading range of such sublayer does not need to fullfil filtering properties, but permeability has to be greater than that of the subsoil.

- Alternatively a thick layer of coarse fibres attached to the back of the geotextile can reduce downslope migration.

  Characteristic of coarse layer:

  O_{90} in the range of 0.3 mm to 1.5 mm;

  thickness t_{gg} in the range of 5 mm to 15 mm.

(c) Soils Below SLW

Stabilization of soil surface can be secured by a thick layer of coarse fibres attached to the back of the geotextile filter.

The coarse fibre layer will integrate with the soil surface, reducing downslope migration of soil particles within this layer.

Characteristic of coarse layer:

O_{90} in the range of 0.5 mm to 2.0 mm;

thickness t_{gg} in the range of 5 mm to 20 mm.

6 RECOMMENDED TYPES OF GEOTEXTILES

<table>
<tr><td>Type</td><td>GF-1</td><td colspan="2">GF-2</td><td>GF-4</td></tr>
<tr><td>Criteria</td><td>Soil A</td><td colspan="2">Soil A + C</td><td>Soil C</td></tr>
<tr><td>Location</td><td colspan="2">above SLW</td><td colspan="2">below SLW</td></tr>
<tr><td>O_{90}</td><td>< 0.07 mm</td><td colspan="2">< 0.07 mm</td><td>< 0.07 mm</td></tr>
<tr><td>Thickness</td><td>> 2 mm</td><td colspan="2">2 mm < d < 5 mm</td><td>> 5 mm</td></tr>
<tr><td>Permeability k_s</td><td>$> 1.5 \times 10^{-3}$</td><td colspan="2">$> 1.5 \times 10^{-3}$</td><td>$> 1.5 \times 10^{-3}$</td></tr>
<tr><td>Measures against downslope migration</td><td colspan="2">(a) granular sublayer on top of geotextile
(b) coarse fibre underlayer</td><td colspan="2">coarse fibre underlayer</td></tr>
</table>

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7 RECOMMENDED ALTERATIONS IN REVETMENT STRUCTURES

GF-1 : - with a granular sublayer (d = 25 cm) on top of the geotextile filter mat;

- with integrated coarse fibre underlayer (designated type GF-5), or

- minimum thickness of geotextile 5 mm, but no additional measures (i.e. to use GF-2 or GF-4).

GF-2 and
GF-4 : - with integrated coarse fibre underlayer to an about 5 mm thick geotextile filter (designated type GF-6), or

- minimum thickness of geotextile 6 mm.

For designations GF-1 to GF-6 refer to ANNEX 8, Subsection 3.2 of the Final Project Evaluation Report.

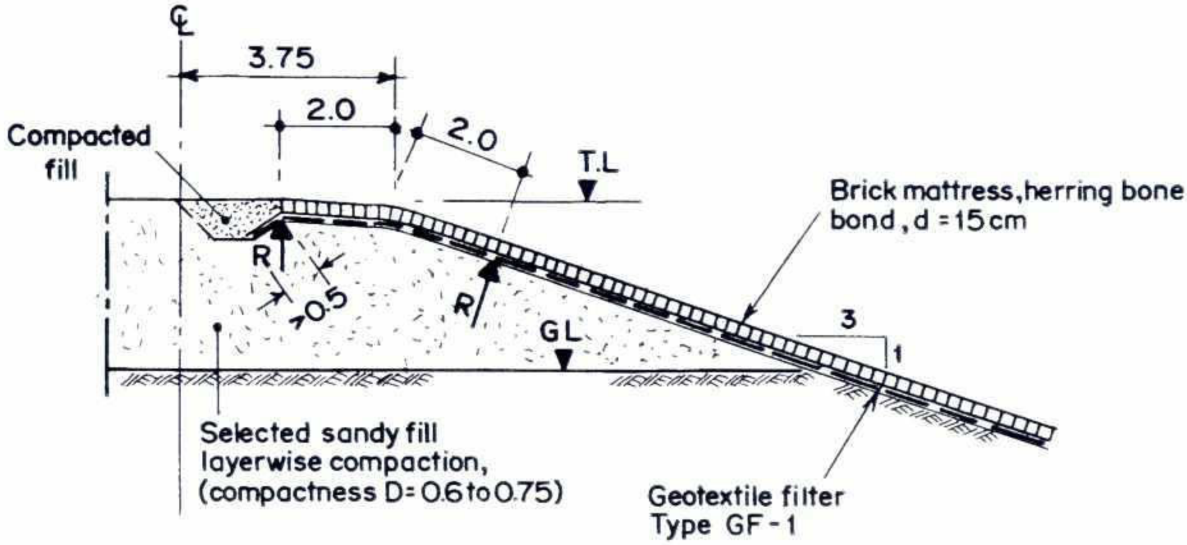
ATTACHMENT 12

Typical Design Details

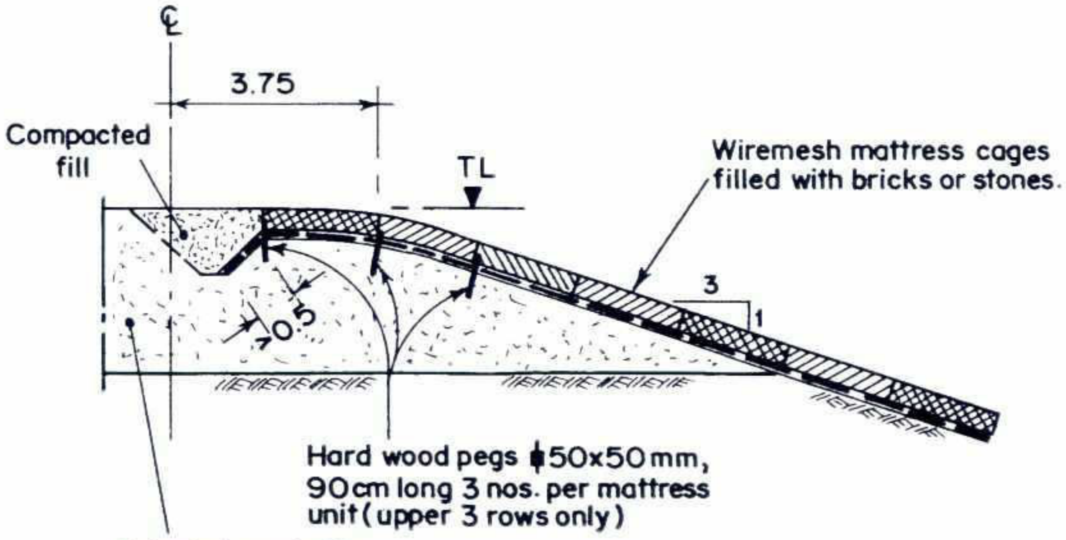
ATTACHMENT 12

List of Figures

Fig. A.12-1:	Typical anchorage of geotextile filters at top of main embankment
Fig. A.12-2:	Protection of main embankment above berm level; Typical brick mattressing (d = 15 cm)
Fig. A.12-3:	Protection of main embankment above berm level: Typical brick mattressing (d = 20 cm)
Fig. A.12-4:	General arrangement of wiremesh – mattresses on a slope
Fig. A.12-5:	Factory made interlocking cc-blocks (ship-lap type)
Fig. A.12-6:	Factory made interlocking cc-blocks (tongue and groove type)
Fig. A.12-7:	Articulating reno-mattresses; Typical layout plan of system
Fig. A.12-8:	Articulating Reno-mattresses typical shore sided anchorage
Fig. A.12-9:	Typical granular filter for sandy silt strata along Jamuna river
Fig. A.12-10:	Typical granular filter for sandy soils along Jamuna river
Fig. A.12-11:	Typical grading range of stones, boulders and hard rock for various applications
Fig. A.12-12:	Typical grading range of boulders and hard rock for revetments and falling aprons

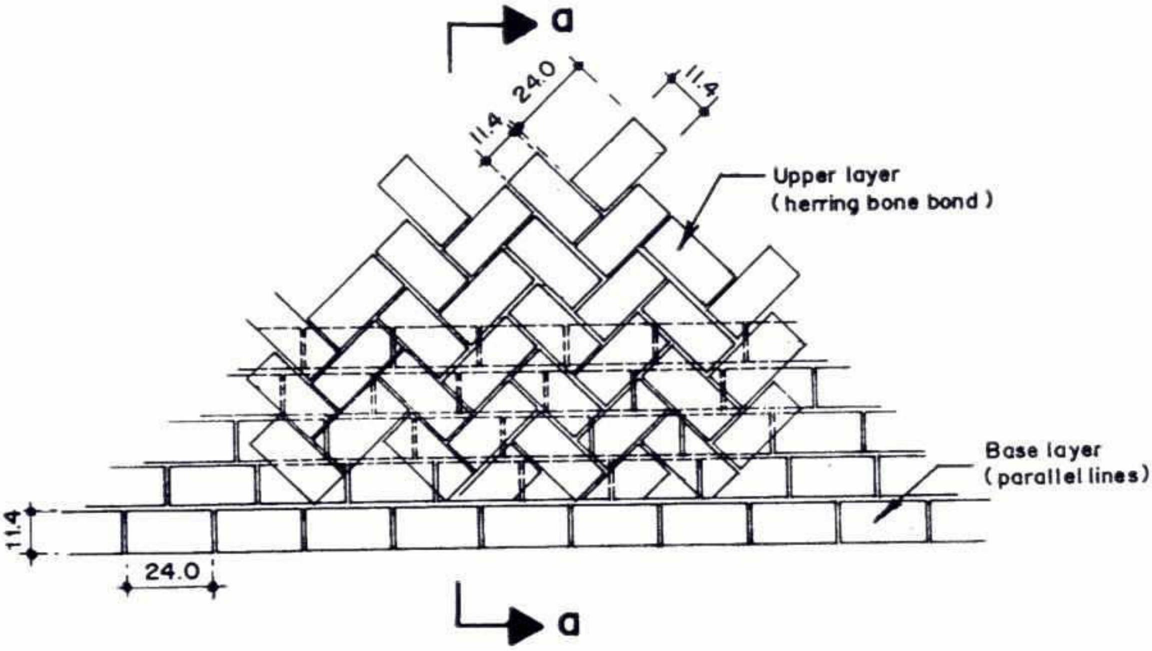


DETAIL (1)

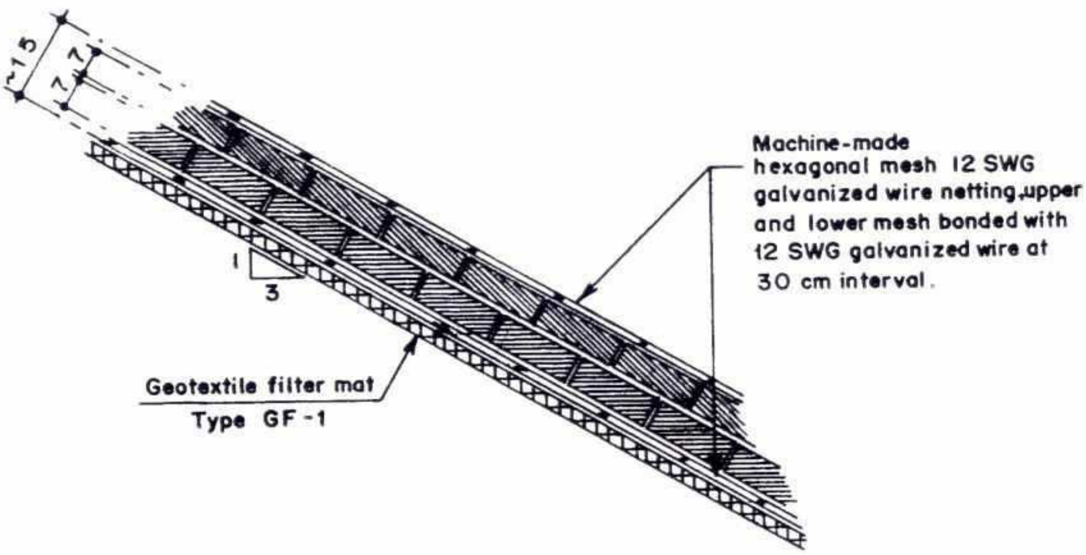


DETAIL (2)

Fig. A.12-1: Typical anchorage of geotextile filters at top of main embankment

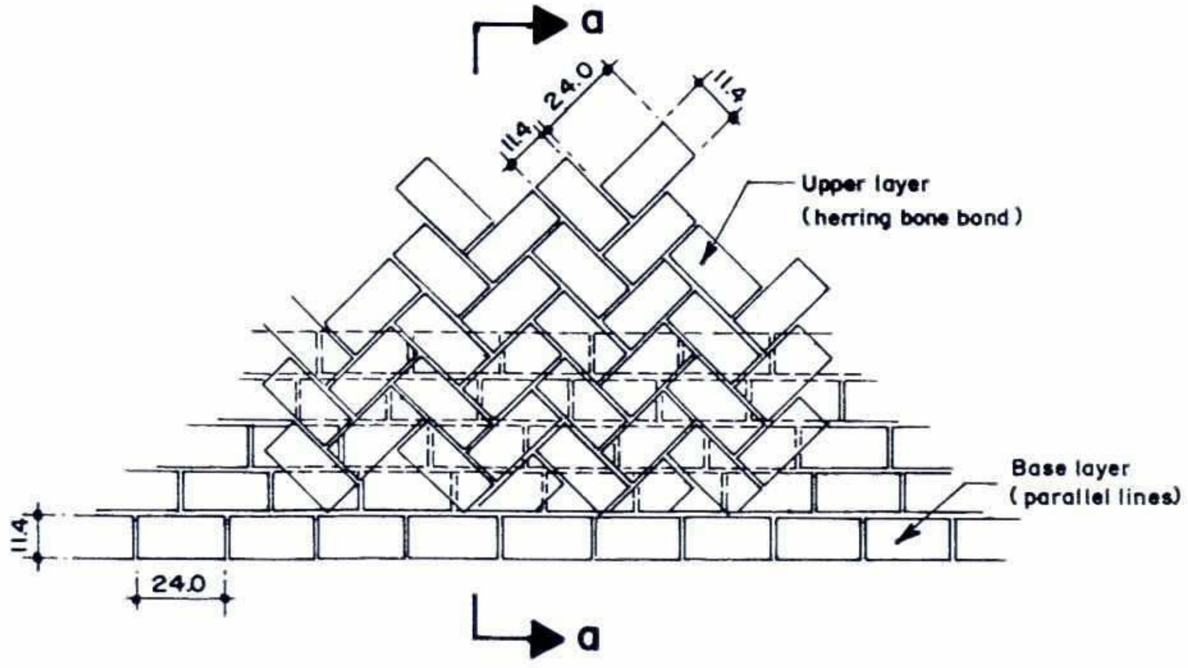


BRICK MATTRESS, d = 15 cm

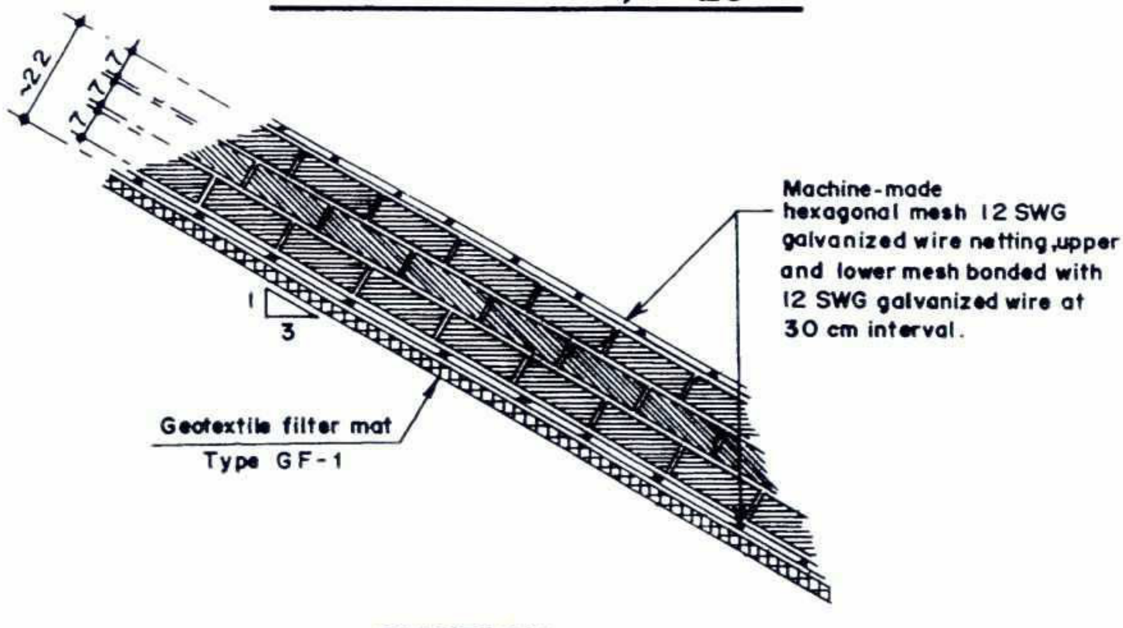


SECTION a-a

Fig. A.12-2: Protection of main embankment above berm level; Typical brick mattressing (d = 15 cm)



BRICK MATTRESS, d =20 cm



SECTION a-a

Fig. A.12-3: Protection of main embankment above berm level: Typical brick mattressing (d = 20 cm)

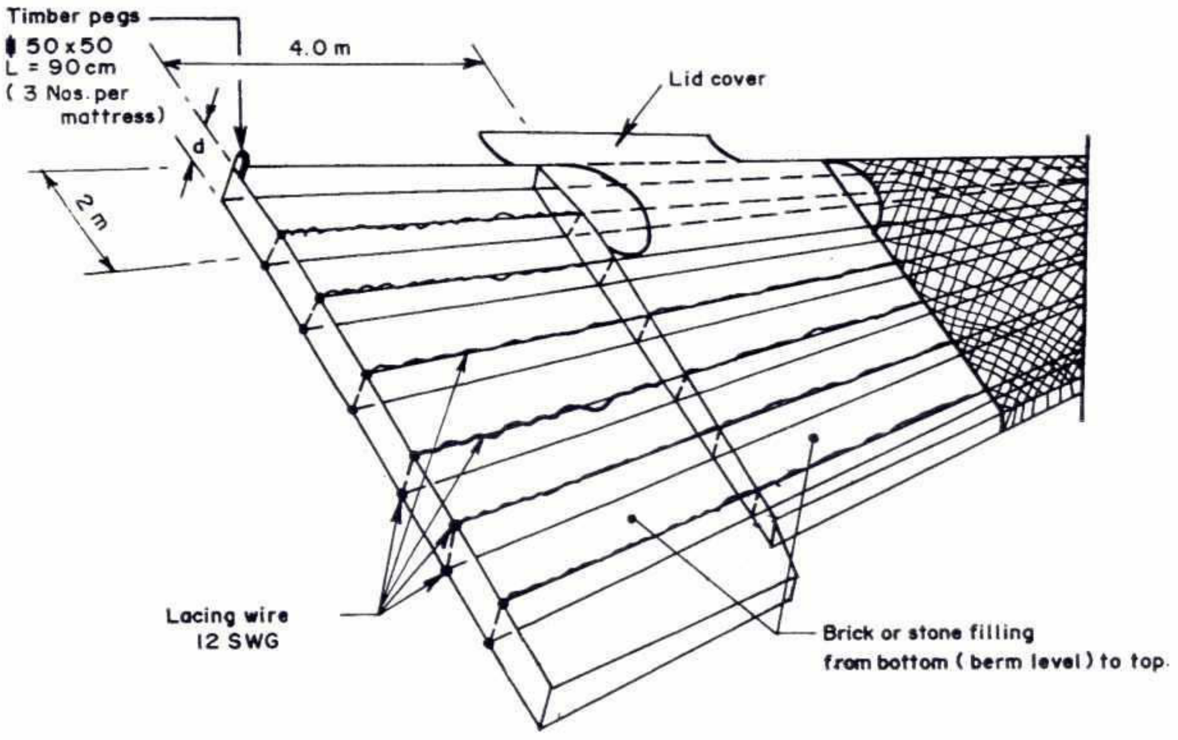
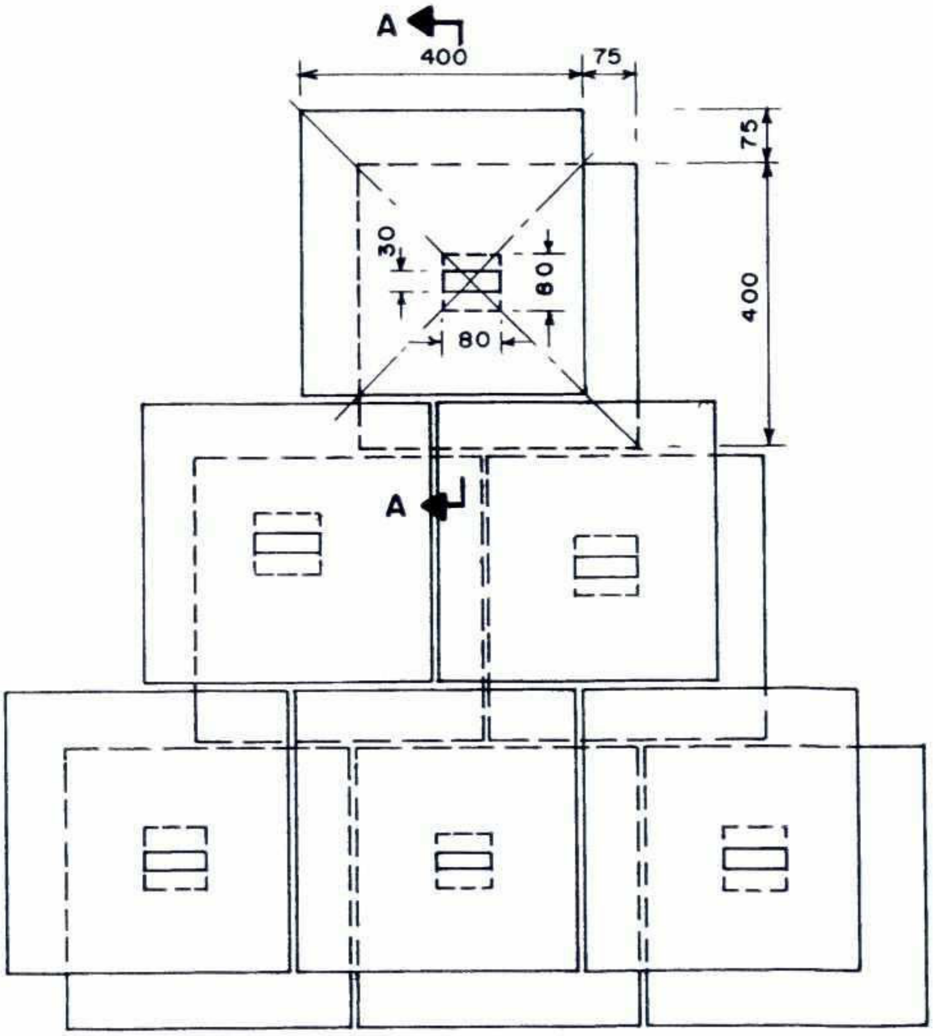


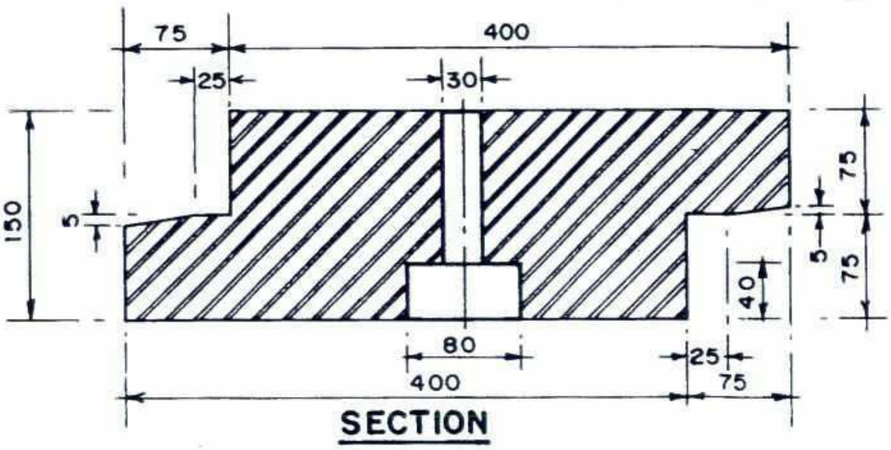
Fig. A.12-4: General arrangement of wiremesh – mattresses on a slope



PLAN

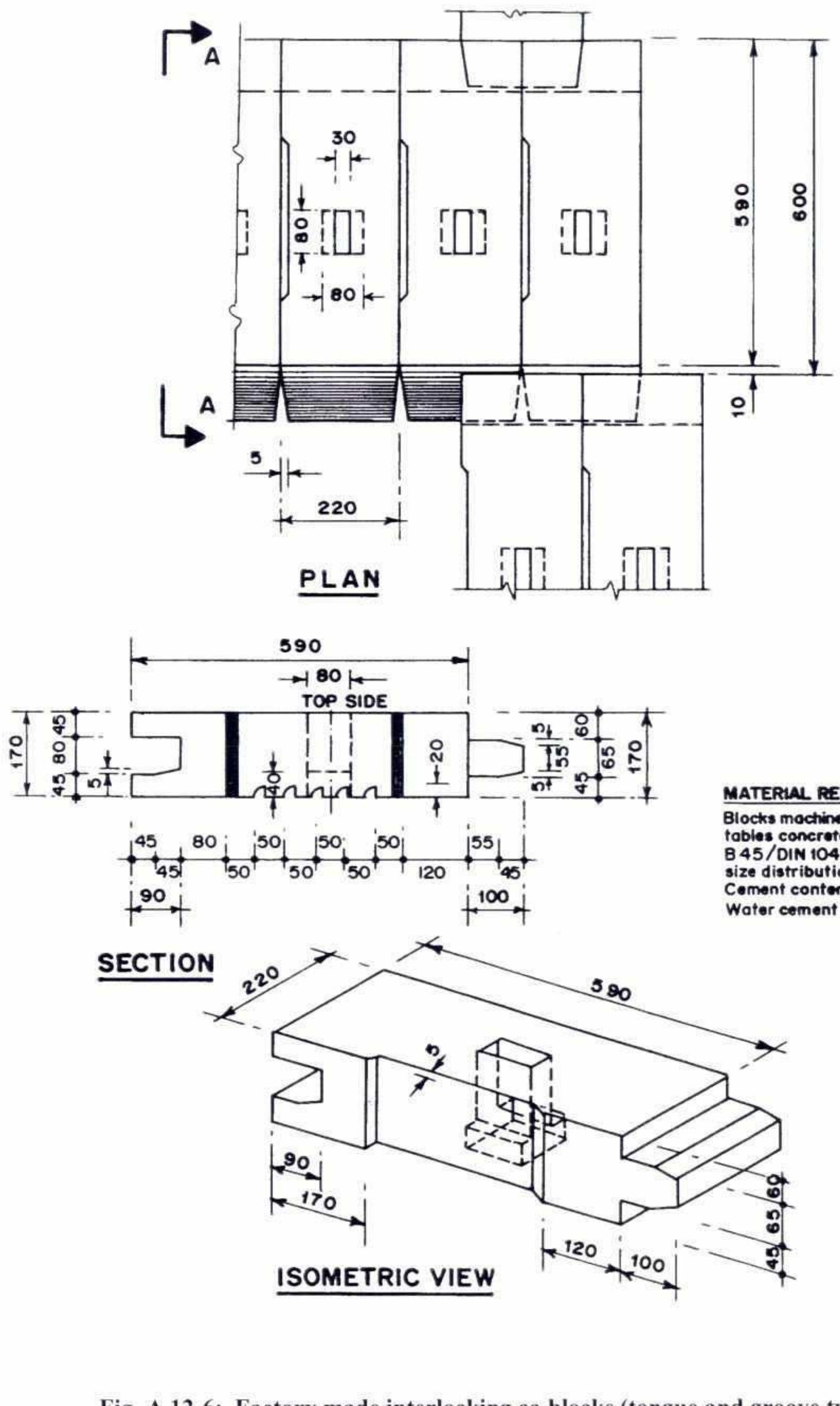
MATERIAL REQUIRMENTS

Blocks machine made on vibrator tables
Concrete class B45/DIN 1045
Aggregate grain size distribution 0-16 mm
Cement content ⩾ 350 kg/m³
Water cement ratio ⩽ 0.45



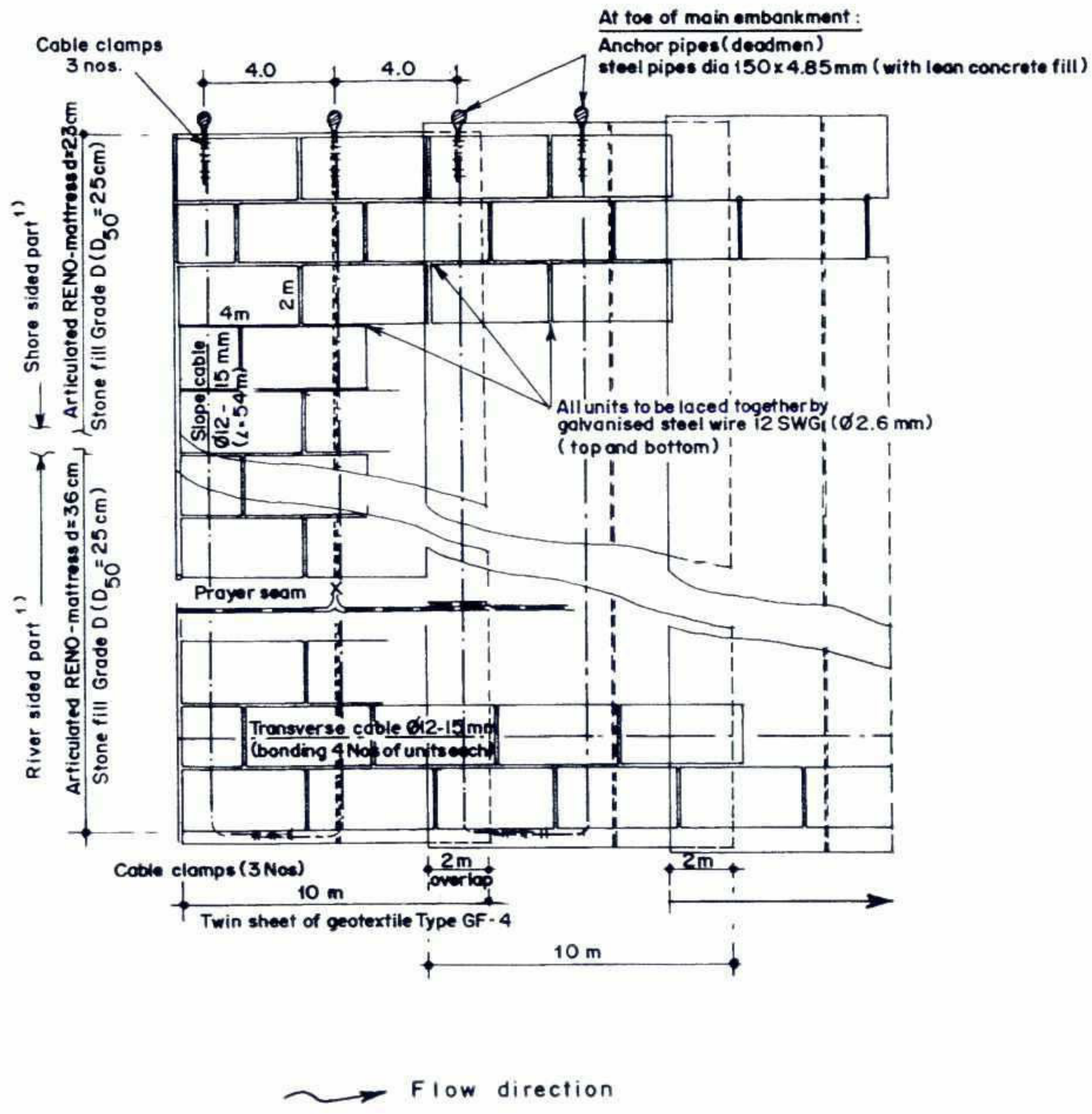
SECTION

Fig. A.12-5: Factory made interlocking cc-blocks (ship-lap type)



MATERIAL REQUIREMENTS
Blocks machine made on vibrator tables concrete class B 45/DIN 1045 aggregate grain size distribution 0-16 mm
Cement content ≥350 kg/m³
Water cement ratio ≤ 0.45

Fig. A.12-6: Factory made interlocking cc-blocks (tongue and groove type)



1) Number of mattress cages to be decided as per exposure and design scour hole

Fig. A.12-7: **Articulating Reno-mattresses; Typical layout plan of system**

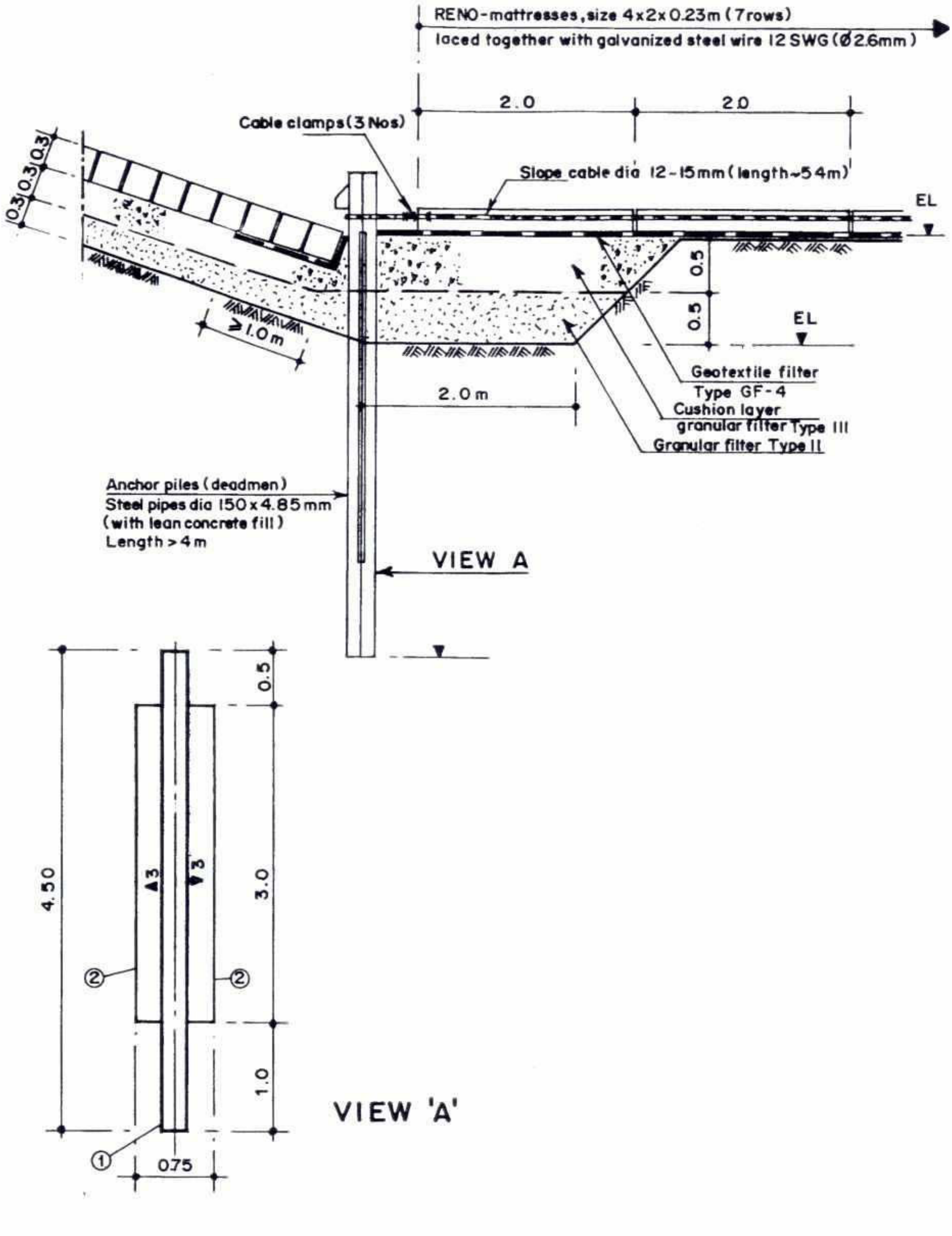


Fig. A.12-8: Articulating Reno-mattresses typical shore sided anchorage

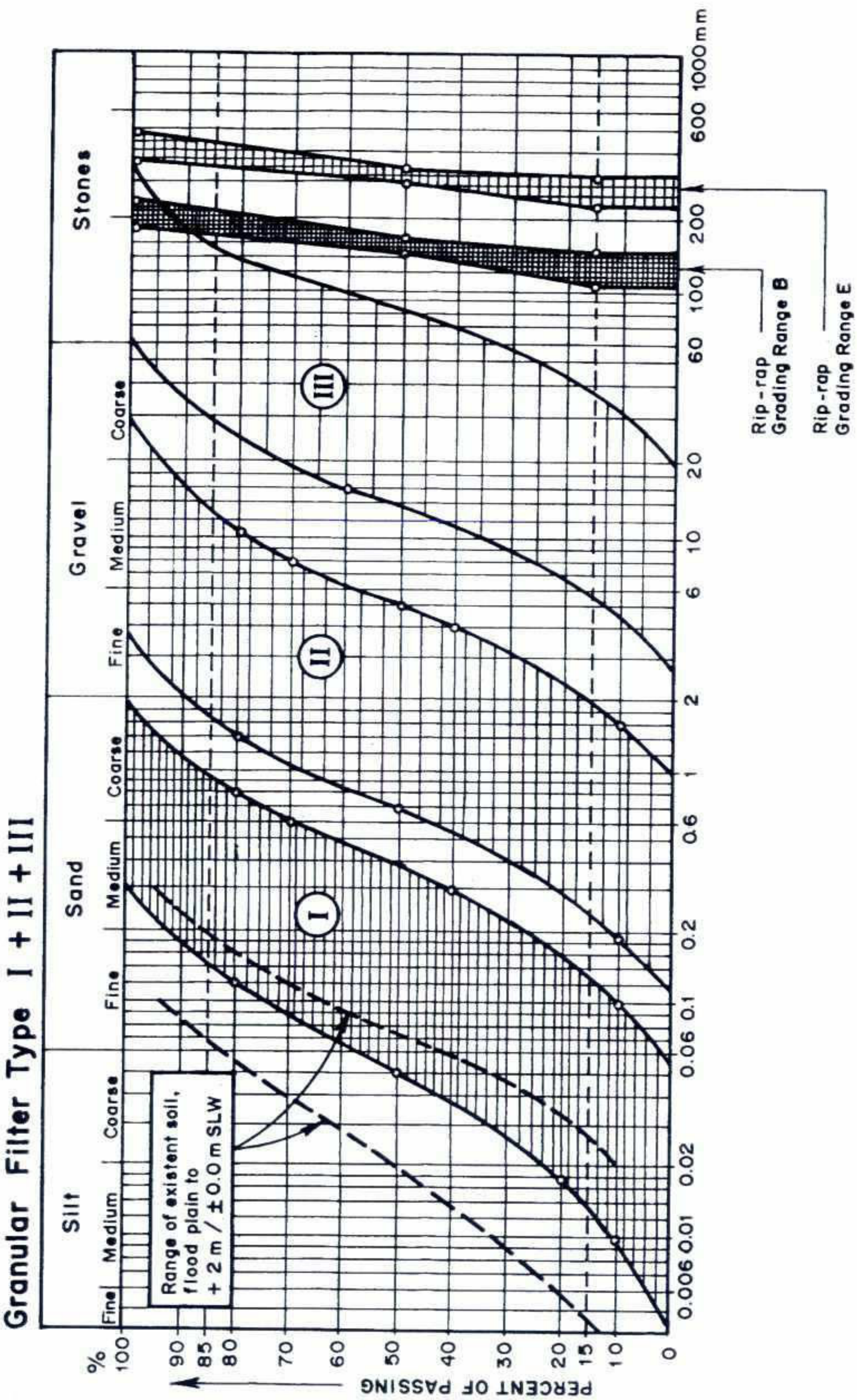


Fig. A.12-9: Typical granular filter for sandy silt strata along Jamuna river

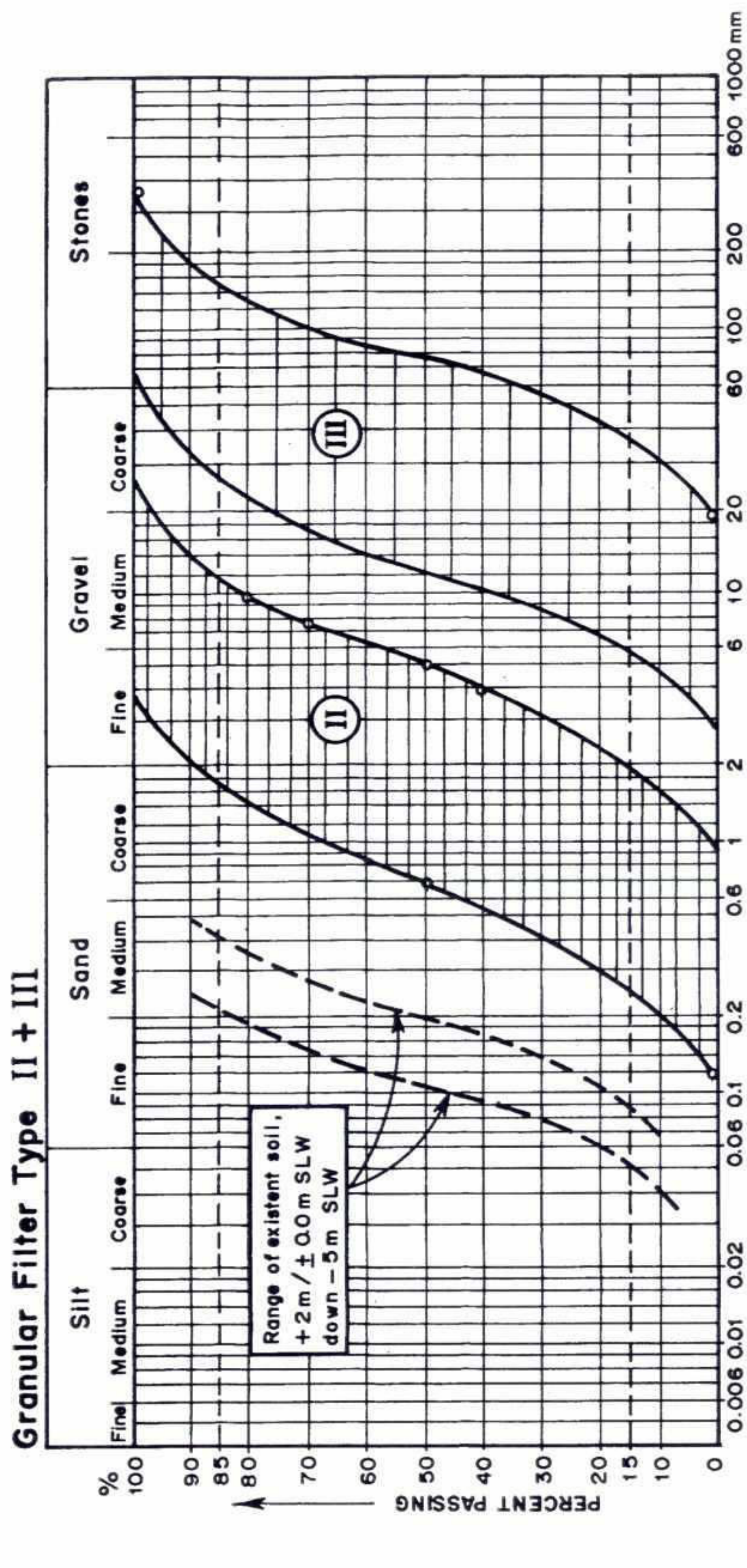
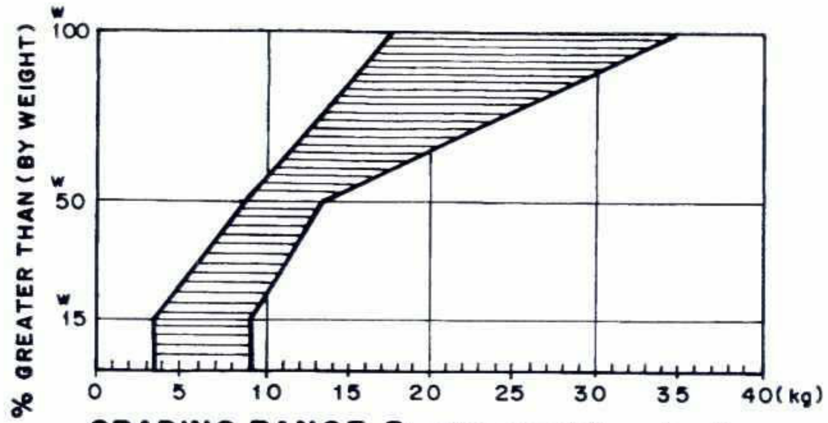
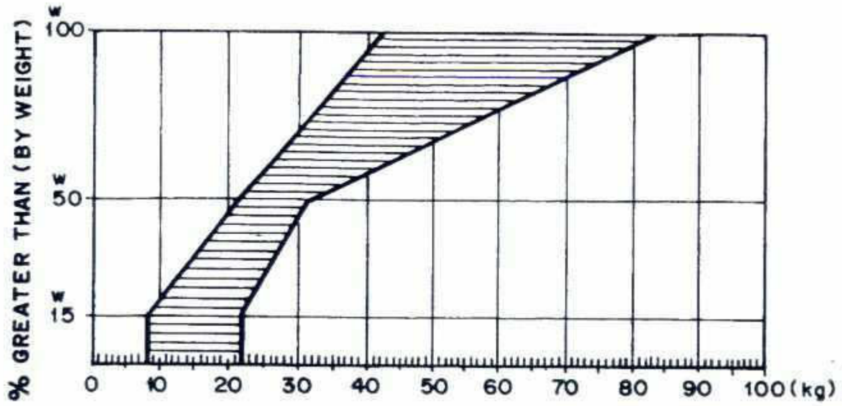


Fig. A.12-10: Typical granular filter for sandy soils along Jamuna river



GRADING RANGE B - Fill for Reno/Wire mesh mattresses

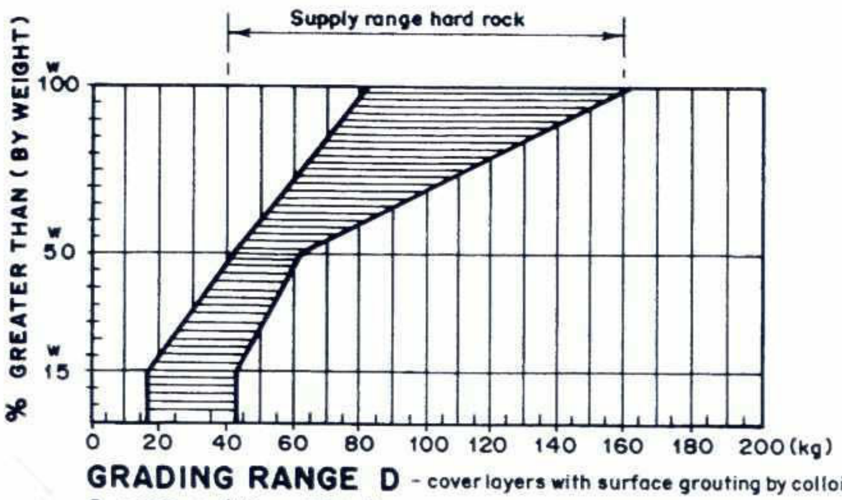
D_{50} = 15 cm



GRADING RANGE C - for cover layers with bitumen pattern grouting

D_{50} = 20 cm

Layer thickness = 40 cm/50cm



GRADING RANGE D - cover layers with surface grouting by colloidal cement grout.

D_{50}=25 cm (W_{50}=40 kg)

Layer thickness = 50 cm

Fig. A.12-11: Typical grading range of stones, boulders and hard rock for various applications

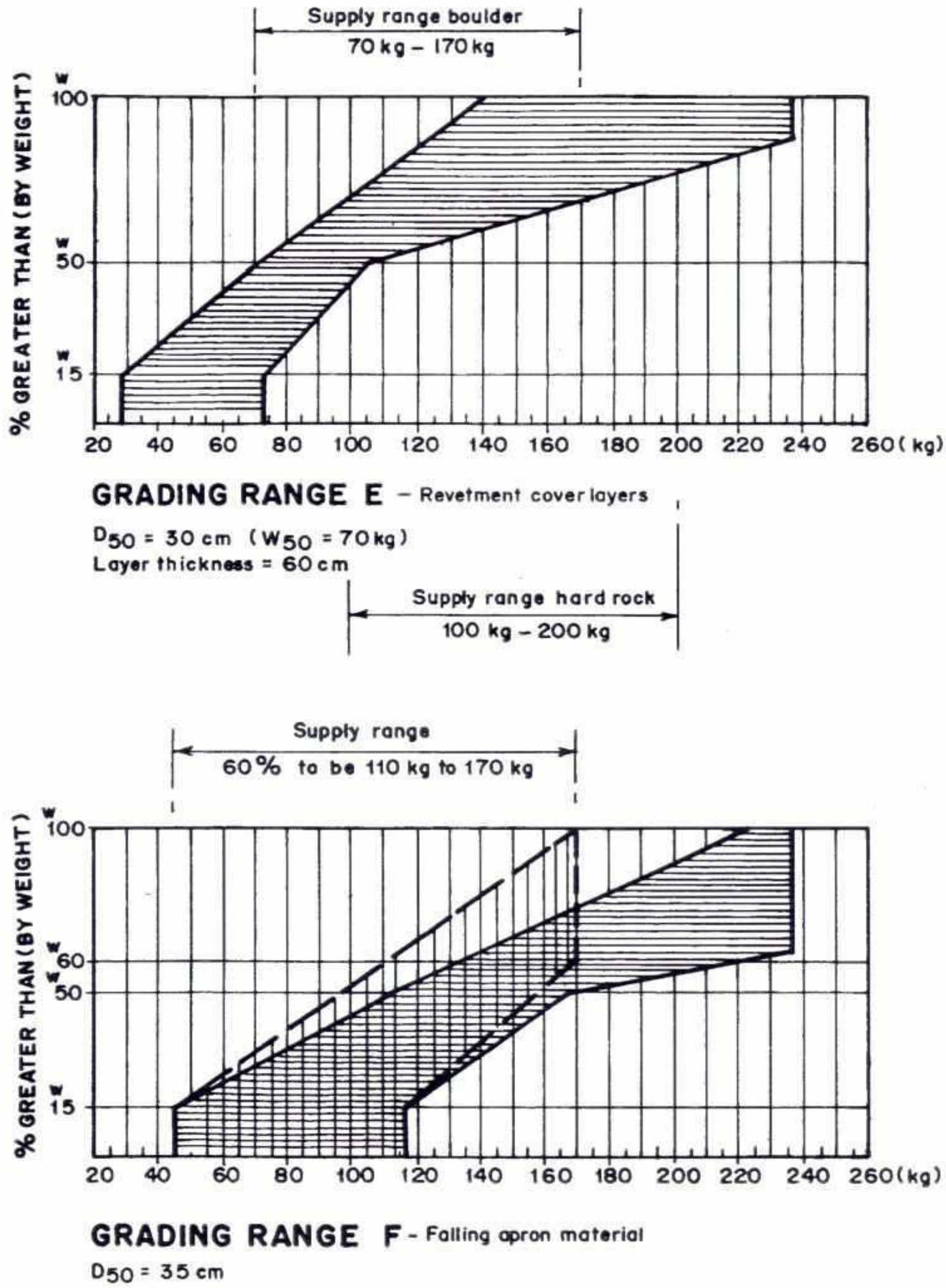


Fig. A.12-12: Typical grading range of boulders and hard rock for revetments and falling aprons

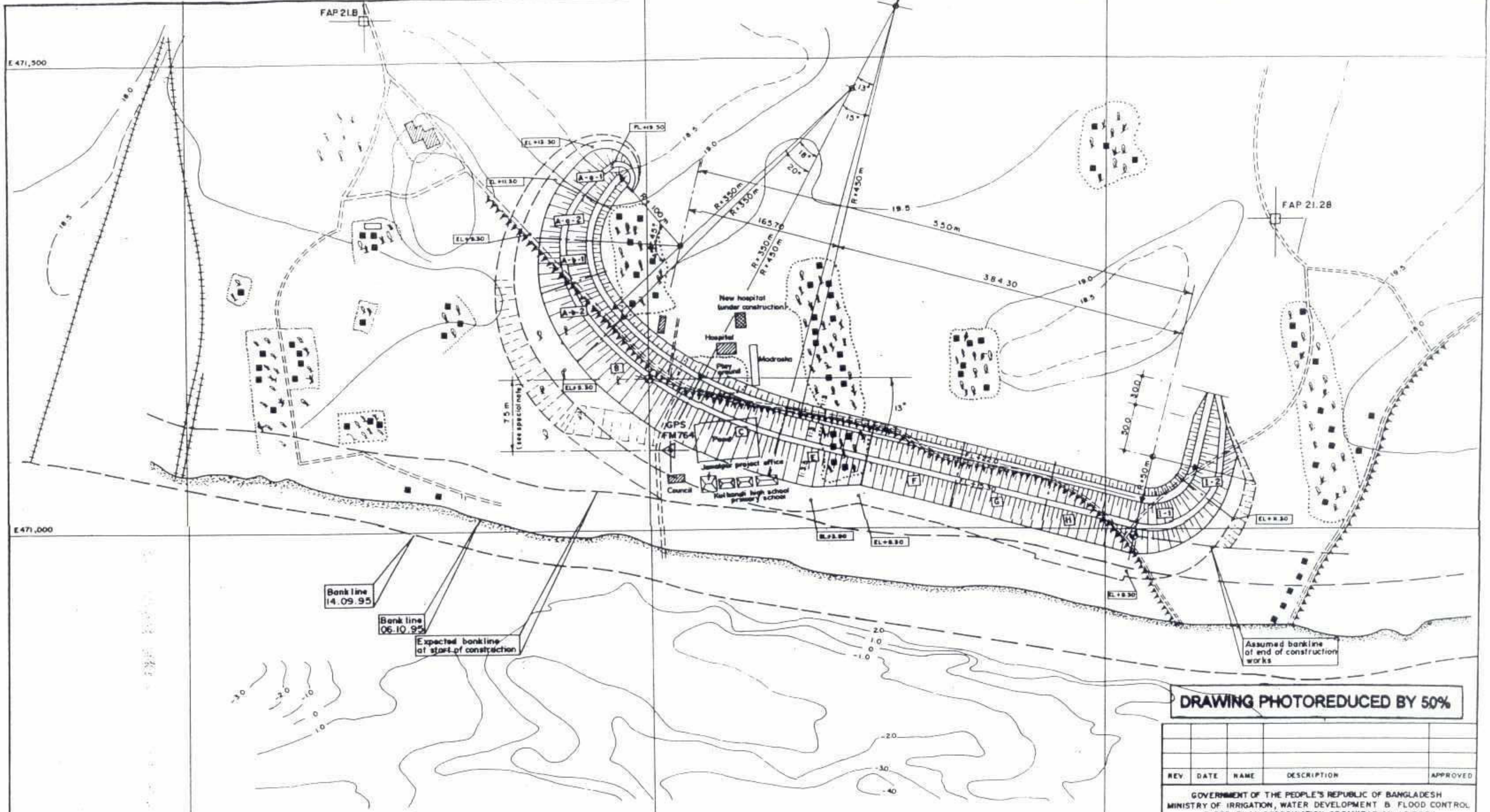
ATTACHMENT 13

Drawings; Original Design (October 1995)

ATTACHMENT 13

List of Drawings

Drawing R-G-003/1:	Detailed layout of Test Structure
Drawing R-G-004:	General layout of Test Structure; Designation of design sections and materials
Drawing R-D-102:	Geotextile filter materials; General arrangement
Drawing R-D-107:	Test Structure C; General plan and cross-section
Drawing R-D-111:	Test Structure E; General plan and cross-sections E-1/E-2



DRAWING PHOTOREDUCED BY 50%

SPECIAL NOTE

The location of the structure in East-West direction shall be optimized in accordance with actual progress of bank erosion till physical start of the construction works. The off-set against control point GPS-FM 764 towards East may have to be increased or reduced in consultation with the Employer.

SCALE 1 : 2000 (0, 50, 100, 200 m)

LEGEND

- Embankment
- Road Pucca, Kacha, Footpath
- High River Bank
- House Pucca, Kacha & Tinshed
- Traverse Station & Pillar
- Home stead
- Mosque

NOTES

1. The topography shown on this drawing is based on preliminary surveys combined with topographical maps of Survey of Bangladesh.
2. Levels refer to ± 0.00 m PWD
3. Depth contours of September 14, 1995
4. BTM-Coordinates of control points see Drawing No. R-G-002/1

REV.	DATE	NAME	DESCRIPTION	APPROVED

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION, WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN COORDINATION ORGANIZATION (FPCO)

BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

DETAILED LAYOUT OF TEST STRUCTURE

	NAME	DATE	SCALE 1 : 2,000	
DRAWN	ANOWAR	06-10-95		
CHECKED		10-10-95	DRAWING NO. R-G-003/1	REVISION 0
APPROVED				

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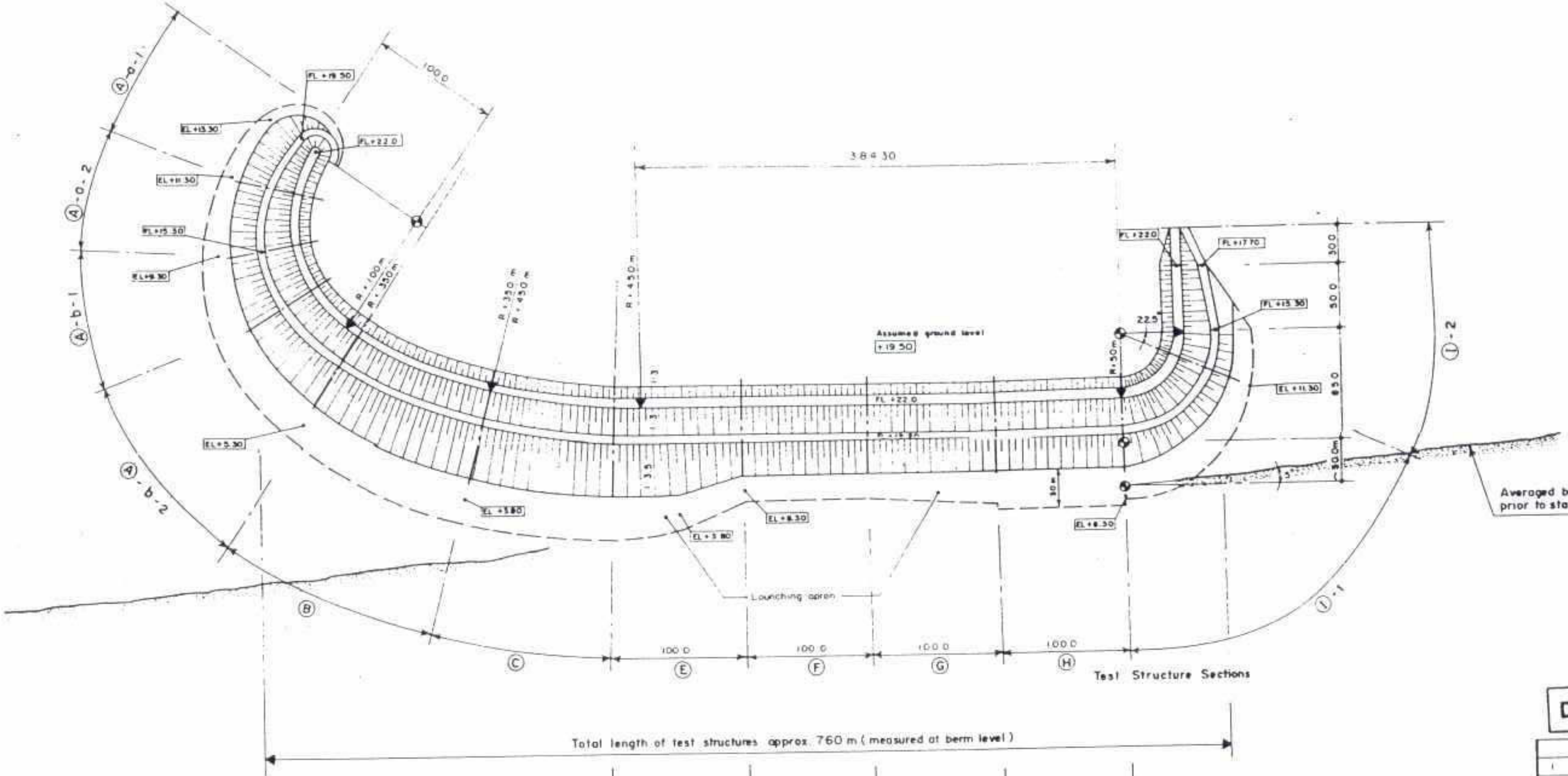

NOTES
1 Levels refer to ±0.00 m PWD
2 Measurements are shown in meter
3 F.L = Finished level
E.L = Excavation (dredging) level
4 Reference Drawings:
R-D-101 Detailed Layout of Test Structures at Jamuna Left Bank
R-D-102 Geotextile Filter Materials General Arrangement

0 50 100 200 m
SCALE 1:2000

DESIGN SECTION	A-a-1	A-a-2	A-b-1	A-b-2	B	C	E	F	G	H	I-1	I-2
Approx. length along berm	110 m		112 m		118 m	108 m	100 m	100 m	100 m	100 m	90 m	110 m
Revetment protection above berm level	Brick-mattress d = 15 cm	Brick-mattress d = 20 cm	Reno-mattresses d = 36 cm (brick fill) on intermediate rubble layer		Wiremesh-mattresses d = 23 cm (stone fill D_{50} = 15 cm) on intermediate rubble layer	Hard rock, D_{50} = 25 cm, Grading Range D, with surface bonding by cement grout	Inter locking CC-slabs, tongue and groove type	CC-blocks, D = 30 cm, single layer, hand-laid in parallel rows	Wire mesh-mattresses d = 36 cm (brick fill)	Inter locking CC-slabs ship-lap-type on intermediate rubble layer	Hard rock, D_{50} = 20 cm with bitumen pattern grouting, d = 50 cm	Hard-rock, D_{50} = 20 cm with bitumen pattern grouting d = 40 cm
Revetment protection below berm level	Reno-mattresses *) d = 23 cm, with stone fill D_{50} = 15 cm, on rubble layer		Dumped CC-blocks D_n = 30 cm		Dumped CC-blocks transition (us) D_n = 50 cm center part D_n = 35 cm transition (ds) D_n = 40 cm	Hard rock, D_{50} = 30 cm, Grading Range E	Dumped CC-blocks D_n = 35 cm Toe D_n = 40 cm	Tubular fabric mattress (PROFIX), sand-filled d = 30 cm d = 40 cm (transitions)	Collapsable block mattress (INCOMAT-Sand Flex) d = 35 cm d = 45 cm (transitions)	Collapsable block mattress (FORESHORE) d = 25 cm, with cement mortar grout fill, in the launching part with additional filter points in the mattress system	Rip-rap, D_{50} = 35 cm (stone/boulder size ranging d = 25 cm to d = 45 cm) (Range F)	Dumped CC-blocks, D_n = 30 cm and 35 cm
Launching apron (falling apron)	Dumped CC-blocks D_n = 40 cm (30 cm)	Rip-rap D_{50} = 25/30 cm	Rip-rap D_{50} = 30/35 cm	Rip-rap D_{50} = 30/35 cm	Geo-sand container Type C (180 kg/No) Type D (250 kg/No) for exposed edge	Geo-sand container, Type E (900 kg/No)	Gabion-sacks with stone fill (D_{50} = 15 cm), Volume ~ 0.65 m^3/No Weight ~ 1300 kg/No	Dumped CC-blocks, D_n = 45 cm	Dumped CC-blocks, D_n = 40 cm D_n = 45 cm for exposed edge	Exposed edge of apron Geo-sand container Type D (250 kg/No)		

*) to be supplemented by wiremesh mattresses of local manufacture

us = upstream
ds = downstream

DRAWING PHOTOREDUCED BY 50%

REV	DATED	NAME	DESCRIPTION	APPROVED
1	02.10.95	ANOWAR	Section D deleted, Reference level PWD	

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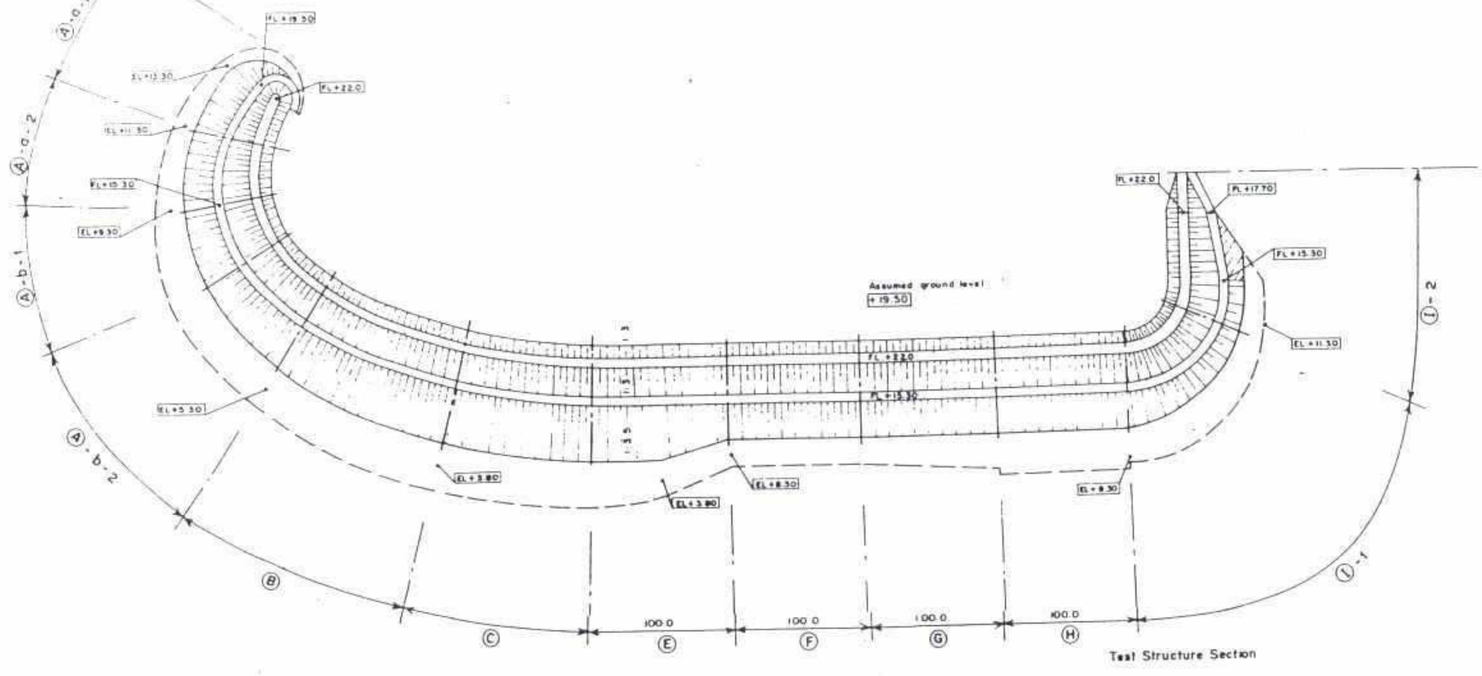
BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

GENERAL LAYOUT OF TEST STRUCTURES
DESIGNATION OF DESIGN SECTIONS AND MATERIALS

	NAME	DATE	
DRAWN	ANOWAR	14-03-95	SCALE 1:2,000
CHECKED		06-04-95	DRAWING NO. R-G-004 / REVISION 1
APPROVED			



DESIGN SECTION		A - a	A - b	B	C	E		F		G	H	I - 1	I - 2
Approx. length along berm		110 m	112 m	118 m	108 m	100 m		100 m		00 m	100 m	90 m	110 m
Geotextile filter mats above berm level	Spec. Type	GF-1	GF-2	GF-2	GF-6 (composition)	GF-1	GF-5	2-layer khoa-filter	2-layer granular filter	GF-1	GF-1	GF-4	GF-2
	Brand Name	BIDIM b7	BIDIM S 390	BIDIM S 550	Ho Te 0 22 14	DATEX AD1300	Ho Te J9014			BIDIM S 390	DATEX AD 1300	BIDIM S 700	Ho Te E 650
	Additional measures		—	Intermediate rubble layer	—	—		—		—	Intermediate rubble layer	—	—
Geotextile filter mats below berm level	Spec. Type	GF-1	GF-2	GF-4	GF-4	GF-2		Tubular fabric mattresses sand-filled (PROFIX)		Collapsable fabric block mattresses with sand fil (INCOMAT-Sand Fex) For 50 % of Secion G a geotextile filter of Type GF-1, GF-2, or GF-3 shall be provided (Material to be taken from surplus from other Sections)	Collapsable fabric block mattresses with cement-mortar grout fill (FORESHORE)	No geotextile filter mat	
	Brand Name	BIDIM b7	BIDIM S 550	BIDIM S 700	Ho Te K 251	DATEX AD 1600							
	Additional measures	Intermediate rubble layer	—	—	—	—							

0 50 100 200 m

SCALE 1:2000

NOTES

1. Levels refer to ± 0.00 m PWD.
2. Measurements are shown in meter.
3. F.L. = Finished level
   E.L. = Excavation (dredging) level
4. Geotextile filter materials and fabric mattresses will be supplied by the Employer in accordance with Specifications Subsections 220 and 230.
5. Reference Drawings
   R - D - 101 Detailed Layout of Test Structures of Jamuna Left Bank
   R - G - 004 General Layout of Test Structures Designation of Design Sections and Materials

DRAWING PHOTOREDUCED BY 50%

REV	DATE	NAME	DESCRIPTION	APPROVED
1	04.10.95	ANOWAR	Section D deleted, Reference level PWD	

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MINISTRY OF IRRIGATION, WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN COORDINATION ORGANIZATION (FPCO)

BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

GEOTEXTILE FILTER MATERIALS
GENERAL ARRANGEMENT

	NAME	DATE	SCALE 1:2,000	
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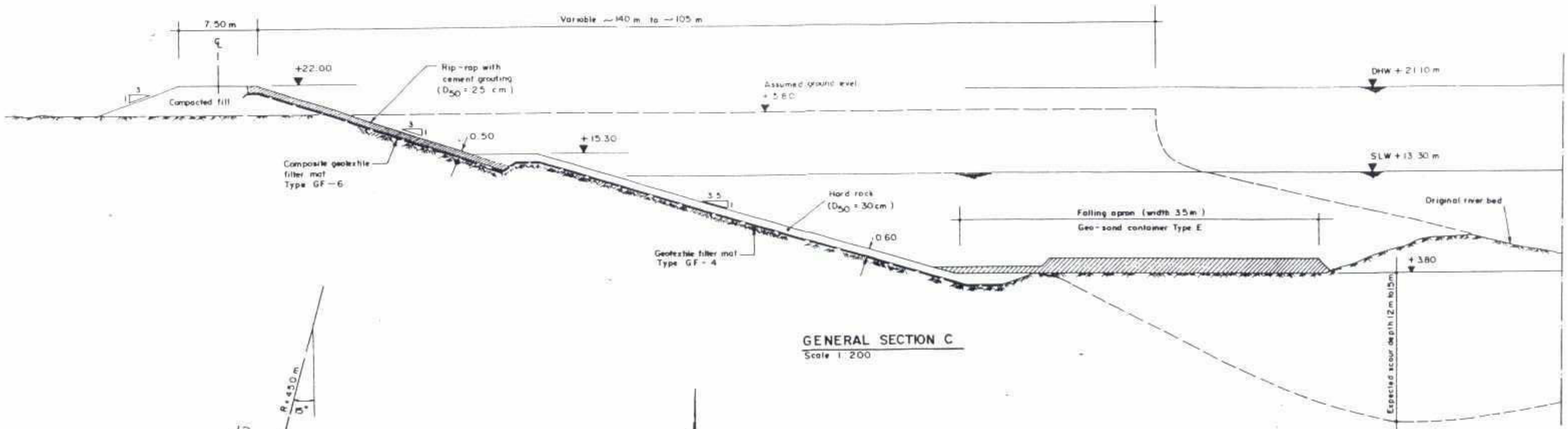
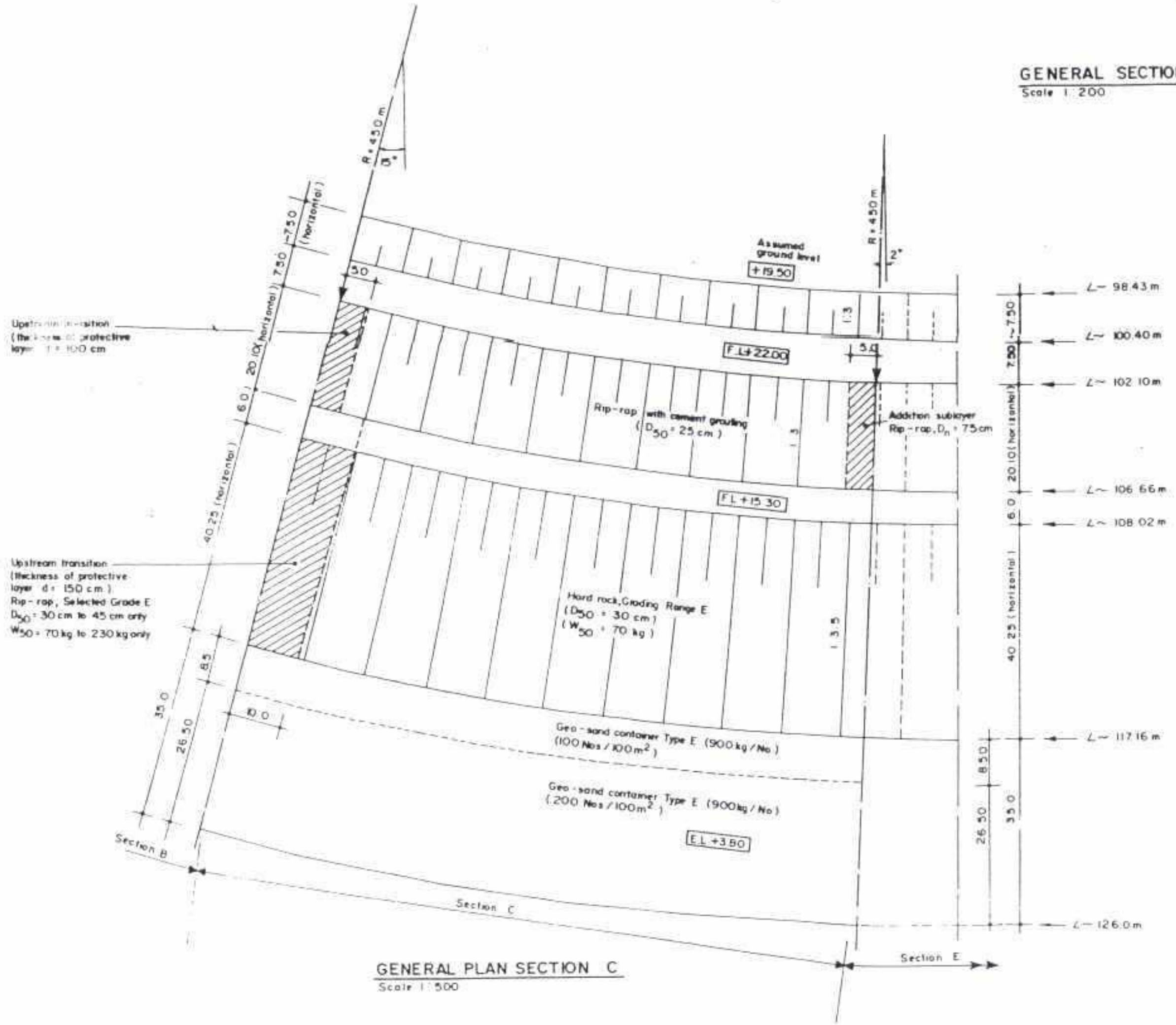
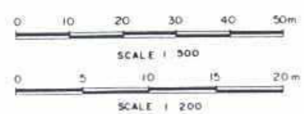
CHECKED		06-04-95	DRAWING NO. R - D - 102	REVISION 1
APPROVED				



GENERAL SECTION C
Scale 1:200



GENERAL PLAN SECTION C
Scale 1:500



Notes:

1. Levels refer to ±0.00 m PWD
2. Measurements are shown in meter, unless shown otherwise
3. F.L. = Finished level
   E.L. = Excavation (dredging) level
4. Reference Drawings:
   R-D-101 General Layout of Test Structures at Jamuna Left Bank
   R-D-102 Geotextile Filter Materials, General Arrangement
   R-D-108 Test Structure C, Detailed Sections, Details, Transitions.

DRAWING PHOTOREDUCED BY 50%

REV	DATE	NAME	DESCRIPTION	APPROVED
1	8-10-95	F Hossain	Reference level PWD; Section D deleted; Falling apron width	

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION, WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN COORDINATION ORGANIZATION (FPCO)

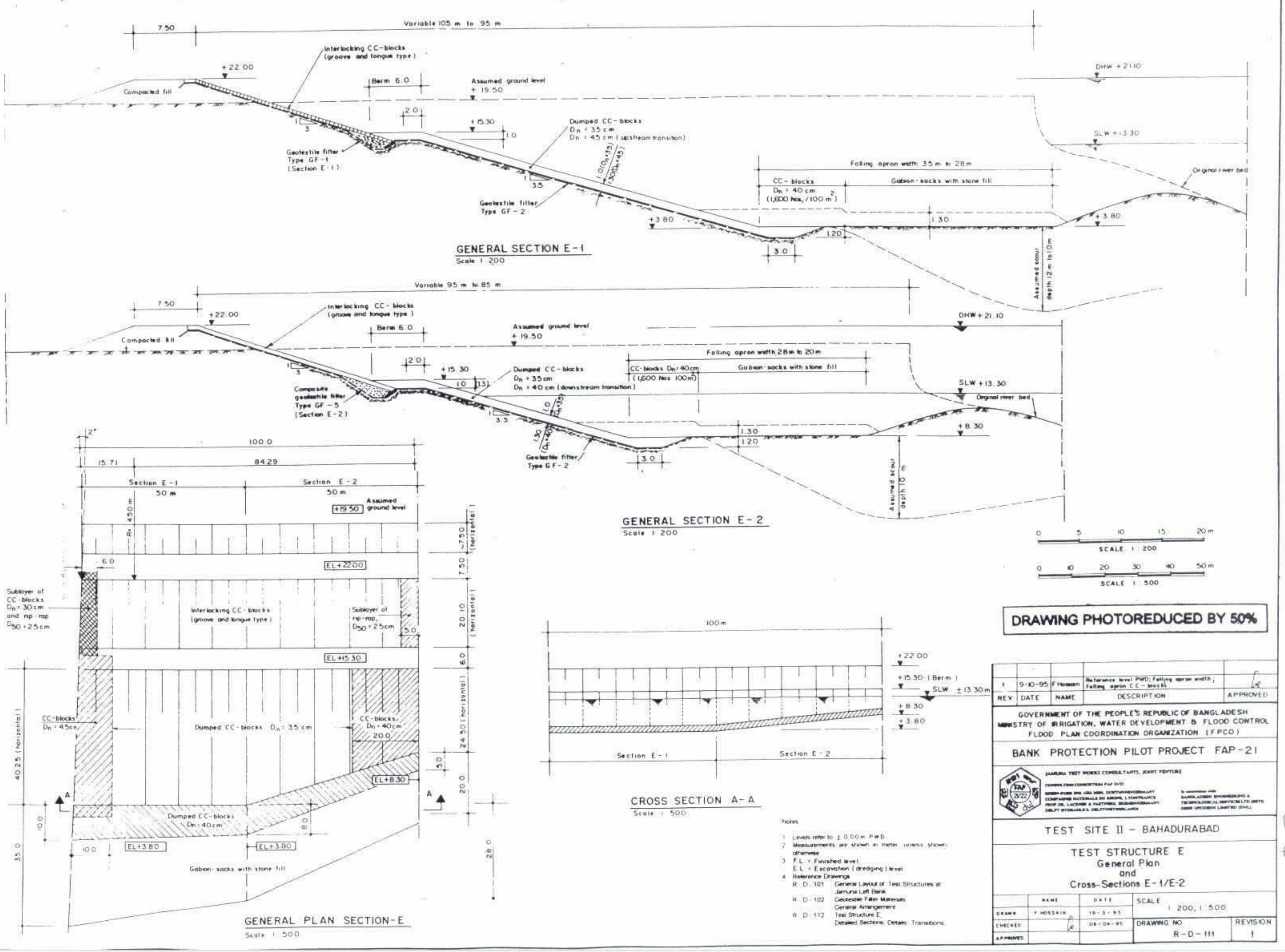
BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

TEST STRUCTURE C
General Plan
and
Cross Section

	NAME	DATE	
DRAWN	F. HOSSAIN	11-03-95	SCALE 1:200, 1:500
CHECKED		06-04-95	DRAWING NO. R-D-107
APPROVED			REVISION 1



DRAWING PHOTOREDUCED BY 50%

Notes

1. Levels refer to ± 0.00 m PWD.
2. Measurements are shown in meter unless shown otherwise.
3. F.L. = Finished level. E.L. = Excavation (dredging) level.
4. Reference Drawings
   - R-D-101 General Layout of Test Structures at Jamuna Left Bank
   - R-D-102 Geotextile Filter Materials General Arrangement
   - R-D-112 Test Structure E, Detailed Sections, Details, Transitions.

REV	DATE	NAME	DESCRIPTION	APPROVED
1	9-10-95	F. Hossain	Reference level PWD; Falling apron width; Falling apron CC-blocks	

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION, WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN COORDINATION ORGANIZATION (FPCO)

BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

TEST STRUCTURE E
General Plan
and
Cross-Sections E-1/E-2

	NAME	DATE
DRAWN	F. HOSSAIN	19-3-95
CHECKED		08-04-95
APPROVED		

SCALE 1:200, 1:500
DRAWING NO. R-D-111
REVISION 1

212

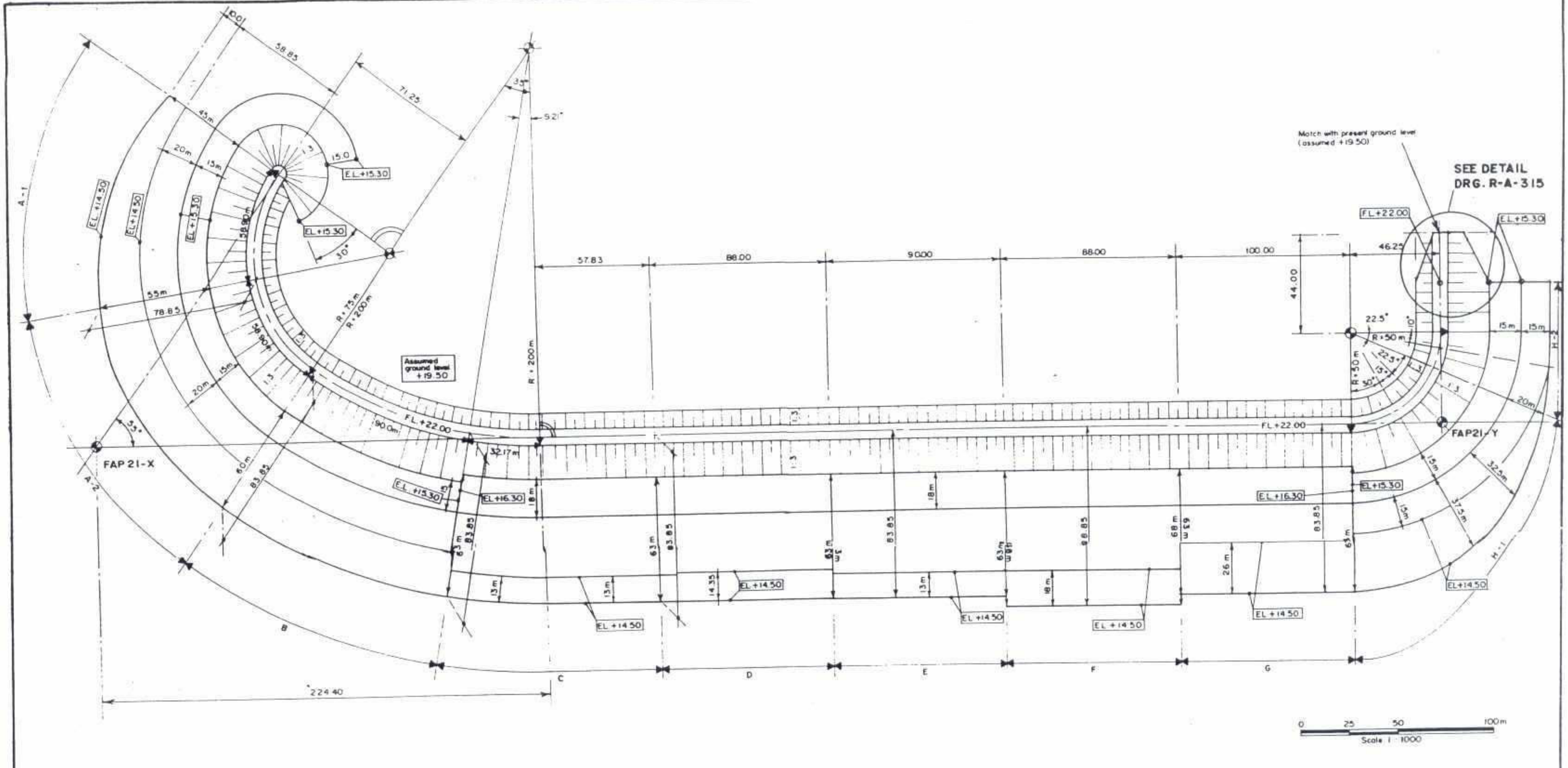
ATTACHMENT 14

Drawings; Executed Design (1996-1997)
As a Base for Future Standard Designs

ATTACHMENT 14

List of Drawings

Drawing R-A-302:	Detailed layout of Test Structure (1996/97)
Drawing R-A-303:	Designation of design sections and materials
Drawing R-A-304:	Geotextile filter mats; General arrangement
Drawing R-A-305:	Test Structure A; General plan and cross-sections
Drawing R-A-306:	Typical revetment details No. 1 to No. 8
Drawing R-A-307:	Test Structure B; General plan and cross-section, details
Drawing R-A-308:	Test Structure C; General plan and cross-section, details
Drawing R-A-309:	Test Structure D; General plan and cross-section, details
Drawing R-A-311:	Test Structure F; General plan and cross-section, details
Drawing R-A-312:	Test Structure G; General plan and cross-section, details
Drawing R-A-313:	Test Structure H; General plan section H-1, H-2 and cross-section, details
Drawing R-A-314:	Embankment top, details



CONTROL POINT SCHEDULE			
No. of Control Points	Co-ordinates BTM		Elevation (m PWD)
	Easting	Northing	
FAP 21-X	471,293.485	778,654.360	—
FAP21-Y	471,149.095	777,975.060	—

NOTES

1. Levels refer to ± 0.00m PWD
2. Measurements in meter
3. F.L : Finished level
   E.L : Excavation level
4. Reference Drawings
   - R-A-301 General Layout of Test Structure (1996/97)
   - R-A-305 Test Structure A General Plan and Cross-Sections
   - R-A-313 Test Structure H Cross-Sections H-1, H-2 Cross-Sections, Details

DRAWING PHOTOREDUCED BY 50%

REV	DATE	NAME	DESCRIPTION	APPROVED
1	21.4.97	Anowar	AS BUILT DRAWING	

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MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT FAP-21

TEST SITE II - BAHADURABAD

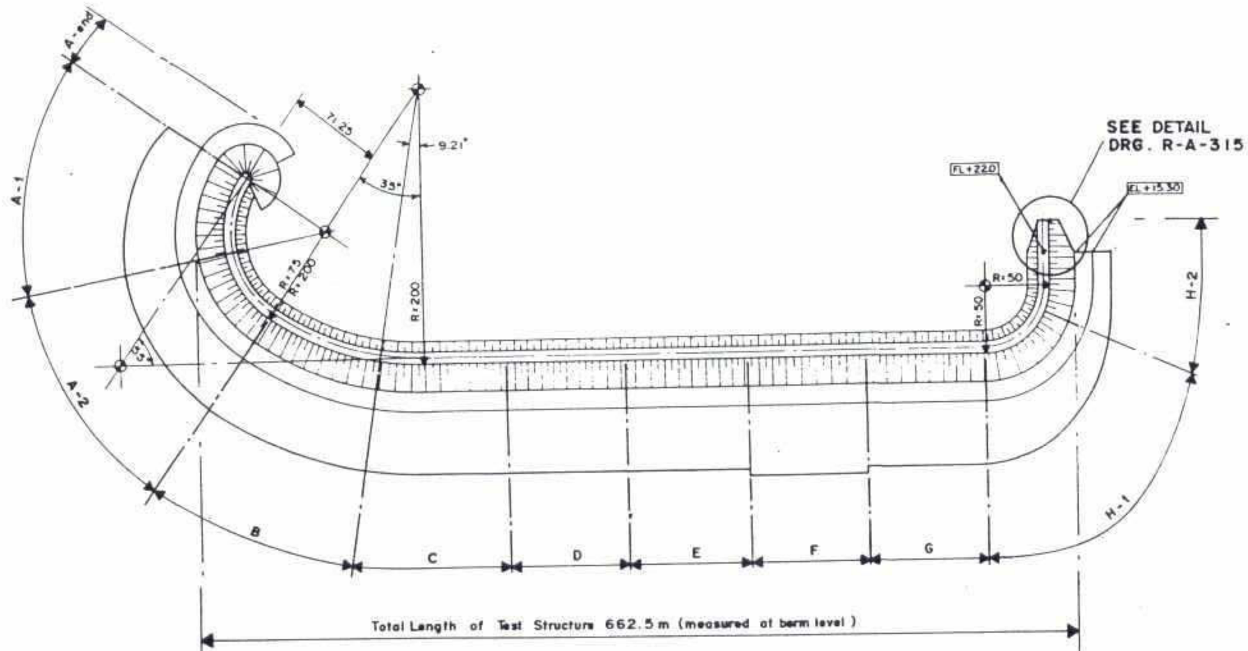
DETAILED LAYOUT OF TEST STRUCTURE (1996/97)

	NAME	DATE
DRAWN	ANOWAR	09-10-96
CHECKED		03-11-96
APPROVED		

SCALE: 1 : 1000

DRAWING NO. R-A-302

REVISION 1



0 50 100 200m

Scale 1:2000

NOTES

1. Levels refer to 0.00m PWD.
2. Measurements are shown in meter.
3. F.L. = Finished level
   E.L. = Excavation level
4. Reference Drawings:
   R-A-302 Detailed Layout of Test Structures
   R-A-304 Geotextile Filter Materials General Arrangement

Test Structure		A-end	A-1	A-2	B	C	D	E	F	G	H-1	H-2	H-2 (end)	
Land-sided slope		Brick mattress d=15cm	In all sections Durbo grass sods laid on Geo-jute soil sover						Detail on Top of Embankment Drg No.R-A-314				Village Road	
River side	Approximate length along toe of upper slope (at berm level)	~87.40	~74.70	~74.70	~99.10	~93.20	88.0	90.0	88.0	100.0	~82.75	~97.60	~20.0	~30.0
	Revetment above berm level (+15.3m to +22.0m PWD)	Brick mattress d=15cm	Brick mattress d=15 cm	Wiremesh mattress d=23/36 cm with stone fill Grade B (D_{50}=15 cm)	Wiremesh mattress d=23 cm with stone fill Grade B (D_{50}=15 cm) on intermediate rubble layer (d=25cm)	CC-blocks D_n=30 cm hand-laid in single, diagonal lines	CC-blocks D_n=30cm hand-laid in single, parallel lines	Inter locking CC-slabs (ship-lap type)	Wiremesh mattress d=36 cm with brick fill	Interlocking CC-slabs (tongue-groove type) on intermediate layer	Rip-rap Grade C (D_{50}=20cm) Top 20 cm with stone pitching (d=50cm)	Rip-rap Grade C (D_{50}=20cm) Top 20 cm with stone pitching (d=40 cm)	As H-2	Rip rap E+F 80 cm on 20 cm
	Launching Apron at and below berm level (+14.5m to +15.3m PWD)		Dumped CC-blocks D_n=30 cm	Dumped CC-blocks D_n=35cm	Dumped CC-blocks Edge us: D_n=50 cm Center: D_n=35 cm Edge ds: D_n=40 cm	Articulated Reno-mattress d=23/36 cm; stone fill grade B, C, D (D_{50}=25 cm) with inter-connecting steel wire ropes and anchor pipes at berm level	Articulated CC-block mattress with inter-connecting steel wire ropes and anchor pipes at berm level	FORESHORE-mattress (collapsible block mattress with cement grout fill)	PROFIX-mattress (tubular fabric mattress with sand and sand-bitumen fill)	INCOMAT-sandflex mattress (collapsible block mattress with sand fill)	Rip-rap Grade F (D_n=25-35-45cm)	CC-blocks D_n=30 cm D_n=35 cm (mixed)		
	Transition between launching apron and falling apron		CC-blocks D_n=30cm	CC-blocks D_n=30 cm	CC-blocks D_n=35 cm				Rip-rap Grade E CC-blocks, D_n=30cm #1	CC-blocks D_n=35 cm #2				
	Falling Apron (level +14.5 m PWD)	Dumped CC-blocks D_n=30cm	Dumped CC-blocks D_n=35 cm D_n=40 cm (mixed)	Rip-rap, Grade E (D_{50}=30 cm)	Geo-sand-container Type C (180kg/No.)	Geo-sand-container Type E (900kg/No.)	CC-blocks D_n=40 cm	CC-blocks D_n=40 cm / Geo-sand container D	CC-blocks D_n=40/45 cm (mixed)	CC-blocks D_n=35/40 cm (mixed)				
	Exposed edge of falling apron			Rip-rap, Grade F (D_n=25/35/45 cm)	Geo-sand-container Type D (250kg/No.)		CC-blocks D_n=45 cm	CC-blocks D_n=45 cm / Geo-sand container E	Gabion sacks with stone fill Grade B (D_{50}=15cm) (1300kg/No.)	CC-blocks D_n=40 cm	Selected boulders D_n=35-45 cm			

us = upstream
ds = downstream

#1 MIXED CC-BLOCKS 30cm + BOULDERS GRADE E IN EVELOPE OF DOUBLE LAYER CHAIN LINK FENCE

#2 MIXED CC-BLOCKS 35 cm + BOULDERS GRADE F IN EVELOPE OF DOUBLE LAYER CHAIN LINK FENCE

1a. FEATURES INTERCHANGED C, D CORRECTION AND ADDITION E TO H-2

REV	DATE	NAME	DESCRIPTION	APPROVED
1	1.6.97	Anowar	AS BUILT DRAWING	

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WATER RESOURCES PLANNING ORGANISATION (WARPO)

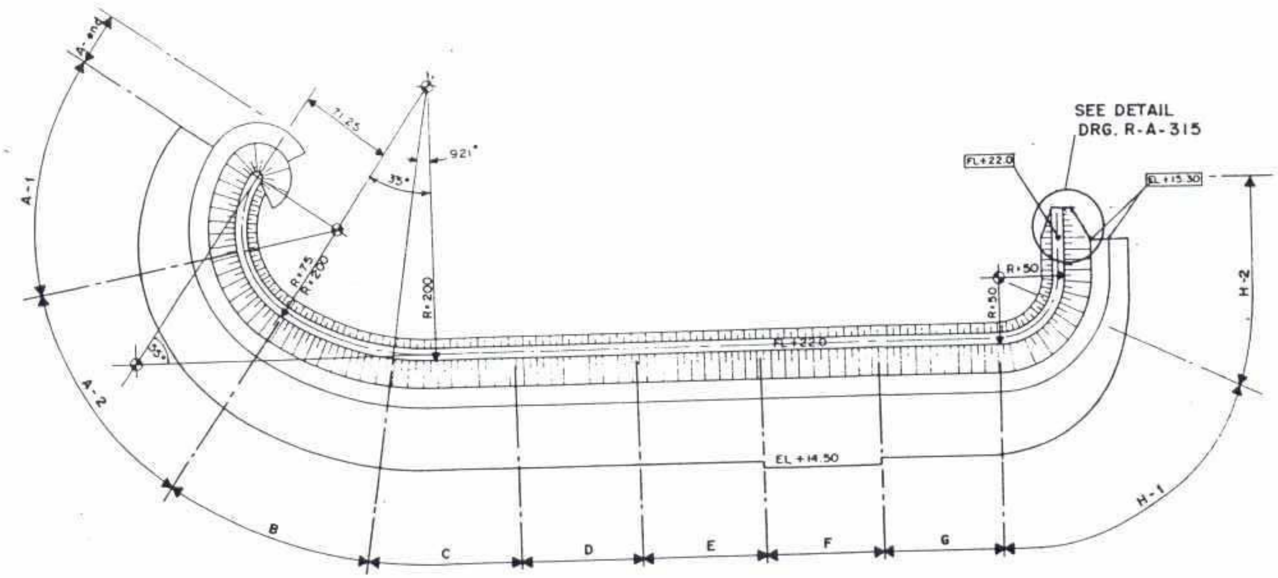
BANK PROTECTION PILOT PROJECT FAP-21

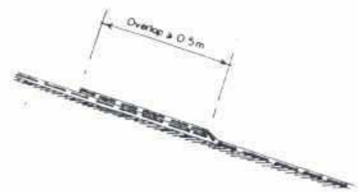
TEST SITE II - BAHADURABAD

DESIGNATION OF DESIGN SECTIONS AND MATERIALS

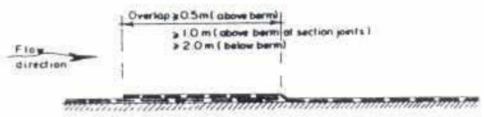
	NAME	DATE	
DRAWN	ANOWAR	15-10-96	SCALE 1:2000
CHECKED		18-10-96	DRAWING NO. R-A-303
APPROVED			REVISION 1

DRAWING PHOTOREDUCED BY 50%





POSITION OF OVERLAPS DOWN-THE-SLOPE



POSITION OF OVERLAPS IN DIRECTION OF FLOW

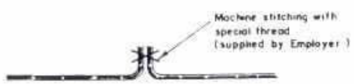
NOTES

1. Levels refer to ±0.00 m PWD.
2. Measurements are shown in meter.
3. F.L = Finished level
   E.L = Excavation level
4. Geotextile filter materials and fabric mattresses will be supplied by the Employer in accordance with Specifications, Sub sections 220 and 230
5. Reference Drawings
   R-A-302 Detailed Layout of Test Structures
   R-A-303 Designation of Design Sections and Materials

0 50 100 200m
SCALE 1:2000

Test Structure			A-end	A-1	A-2	B	C		D	E		F	G	H-1	H-2	H-2 (end)	
Land-sided slope			GF-1	In all sections Geo-jute Soil Saver								Detail on Top of Embankment Drg. No. R-A-314				Village Road	
River Side	Approximate length along toe of upper slope (at berm level)		~8740	~7470	~7470	~9910	~93.20		88.0	90.0		88.0	100.0	~8275	~9760	+20.0-0	~30.0
	Geotextile filter mats above berm level	Spec. Type	GF-1/-5	GF-1	GF-5	GF-2	Filter III on filter II	Khoa on filter II	GF-2	GF-1	GF-5	GF-1	GF-1	GF-4	GF-4/-2	As	GF-2
		Brand Name	BIDIM b7 HoTe O2214	BIDIM b7	HoTe O 2214	BIDIM S 550			BIDIM S 550	DATEX AD1300	Hote 39014	BIDIM S 390	DATEX AD 1300	BIDIM S 700	HoTe E650/K251	H-2	HoteE650
	Geotextile filter mats at and below berm level	Spec. Type	GF-1/-5	GF-2	GF-2	GF-4	GF-2		GF-4	FORESHORE-mattress (collapsible fabric block mattress with cement grout fill)		PROFIX-mattress (tubular fabric mattress with sand and sand-bitumen fill)	GF-1 (sub-layer to INCOMAT-sand flex mattress)	GF-1	GF-1	—	—
		Brand Name	BIDIM b7 HoTe O2214	BIDIM S 550	BIDIM S 550	HoTe K 251	DATEX AD 1600		BIDIM S 700				BIDIM b 7	BIDIM S 390	BIDIM S 390	—	—

NOTE : In Section A and H-1 all geotextile filter mats are to be placed as single sheets. In all other sections two sheets each are to be joined by stitching (prayer seam) to "twin sheets".



PRAYER SEAM
(without scale)

Le. FEATURES INTERCHANGED C,D

REV	DATE	NAME	DESCRIPTION	APPROVED
1	1.6.97	Anowar	AS BUILT DRAWING	

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MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT FAP-21

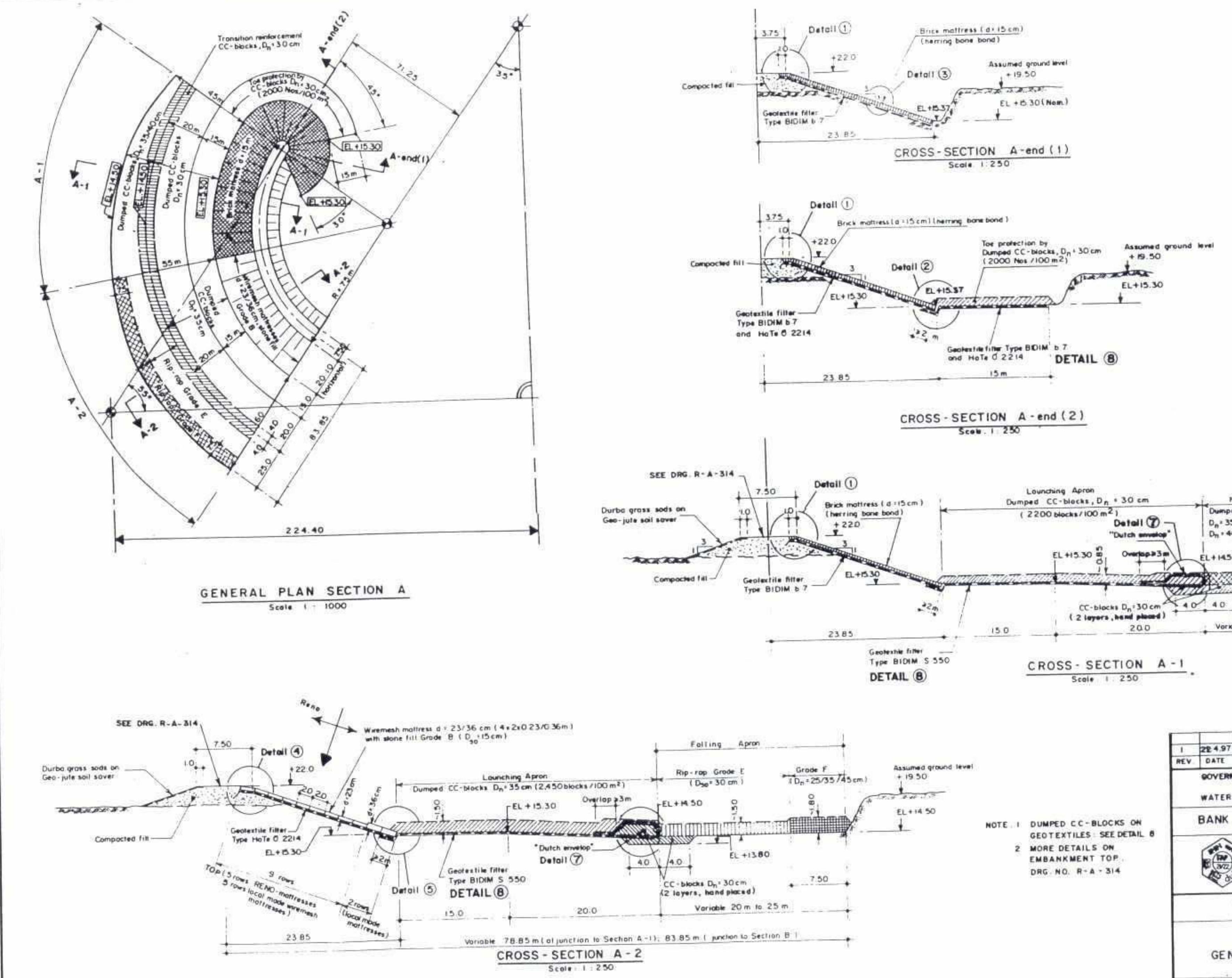
JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE

TEST SITE II - BAHADURABAD

GEOTEXTILE FILTER MATS
GENERAL ARRANGEMENT

	NAME	DATE	SCALE 1:2000	
DRAWN	ANOWAR	17-10-96		
CHECKED		19-10-96	DRAWING NO. R-A-304	REVISION 1
APPROVED				

DRAWING PHOTOREDUCED BY 50%



NOTES

1. Levels refer to +0.00m PWD.
2. Measurements are shown in meter, unless shown otherwise.
3. Dredging, excavation, filling and compaction to comply with Specifications, Sections 800 and 900.
4. Geotextile filter materials as per Specifications, Sections 200 and 1000.
5. Revetment materials as per Specifications, Sections 200 and 1000.
6. Falling apron materials as per Specifications, Sections 200 and 1000.
7. Reference Drawings :
   - R-A-302 Detailed Layout of Test Structures
   - R-A-304 Geotextile Filter Materials General Arrangement
   - R-A-306 Typical Revetment Details
   - R-G-014 Rip-rap Gradations

REV	DATE	NAME	DESCRIPTION	APPROVED
1	22.4.97	Anowar	AS BUILT DRAWING	

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BANK PROTECTION PILOT PROJECT FAP-21

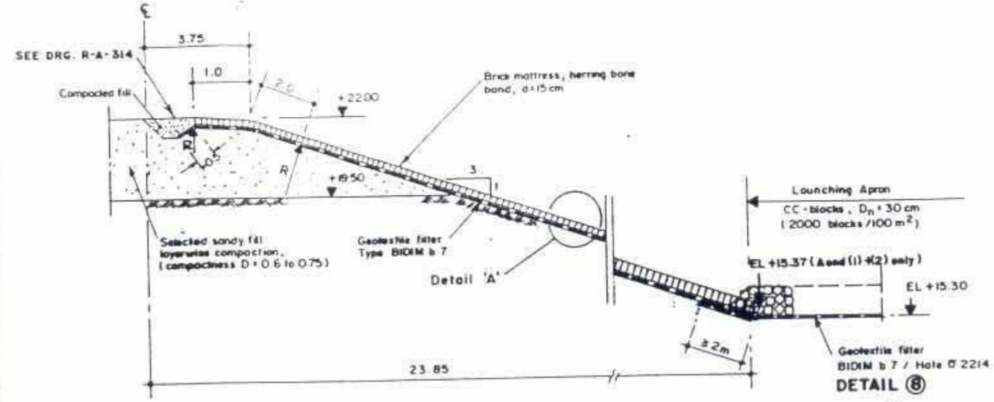
TEST SITE II - BAHADURABAD

TEST STRUCTURE A
GENERAL PLAN AND CROSS-SECTIONS

	NAME	DATE
DRAWN	ANOWAR	18-10-96
CHECKED		24-10-96
APPROVED		

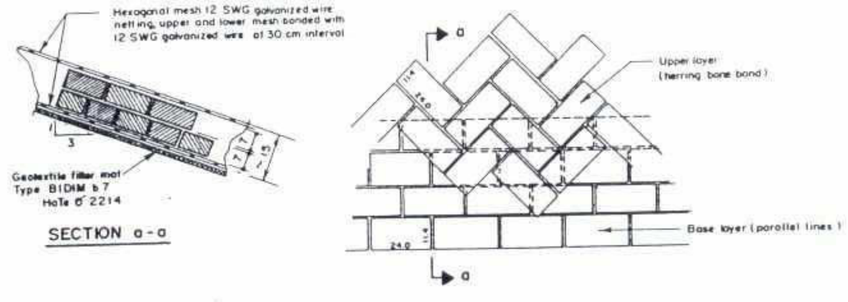
SCALE: 1 : 1000, 1 : 250
DRAWING NO. R-A-305
REVISION 1

DRAWING PHOTOREDUCED BY 50%

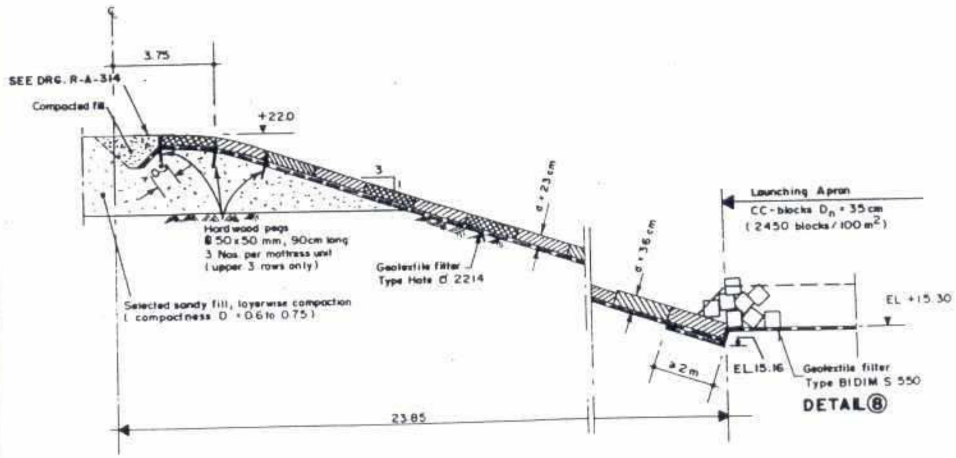


DETAIL ①
Scale 1:100

DETAIL ②
Scale 1:100

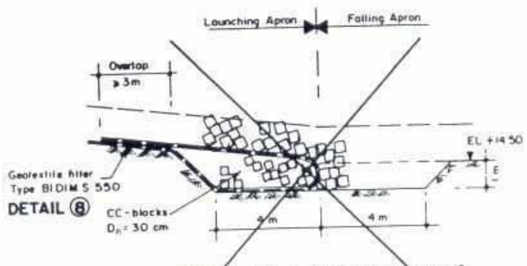


DETAIL ③ : BRICK MATTRESS, d = 15 cm (measurements in cm)

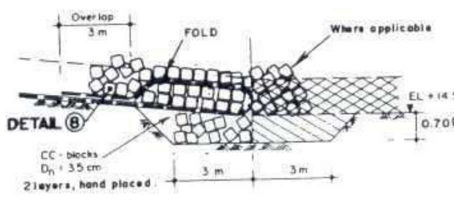


DETAIL ④
Scale 1:100

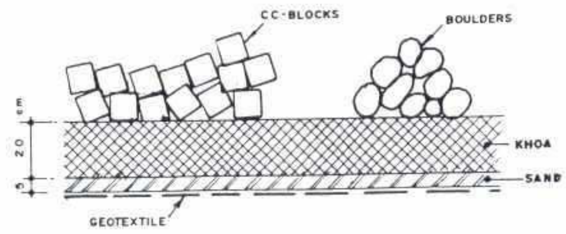
DETAIL ⑤
Scale 1:100



DETAIL ⑥ " DUTCH ENVELOP"
Scale 1:100
(NOT USED)



DETAIL ⑦ "DUTCH ENVELOPE (Alternative)"
Scale 1:100



DETAIL ⑧ PROTECTION LAYER
NOT TO SCALE

ENVELOPE: 2 LAYERS PLACED INSIDE } A-1, B
1 LAYER PLACED ON TOP } 80%, A-2
VICE VERSA: A-2 (20%)

NOTES

1. Level refer to ± 0.00 m PWD
2. Measurements are shown in meter, unless shown otherwise.
3. Dredging, excavation, filling and compaction to comply with Specifications Sections 800 and 900.
4. Geotextile filter materials as per Specifications Sections 200 and 1000.
5. Revetment materials as per Specifications, Sections 200 and 1000.
6. Falling apron materials as per Specifications, Sections 200 and 1000.
7. Reference Drawings:
   - R-A-302 Detailed Layout of Test Structures
   - R-A-304 Geotextile Filter Materials, General Arrangement
   - R-A-305 Test Structure A General Plan and Cross-Sections

0 25 50 100 m
Scale 1:100

247

REV	DATE	NAME	DESCRIPTION	APPROVED
1	25.4.97	Anowar	AS BUILT DRAWING	

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BANK PROTECTION PILOT PROJECT FAP-21

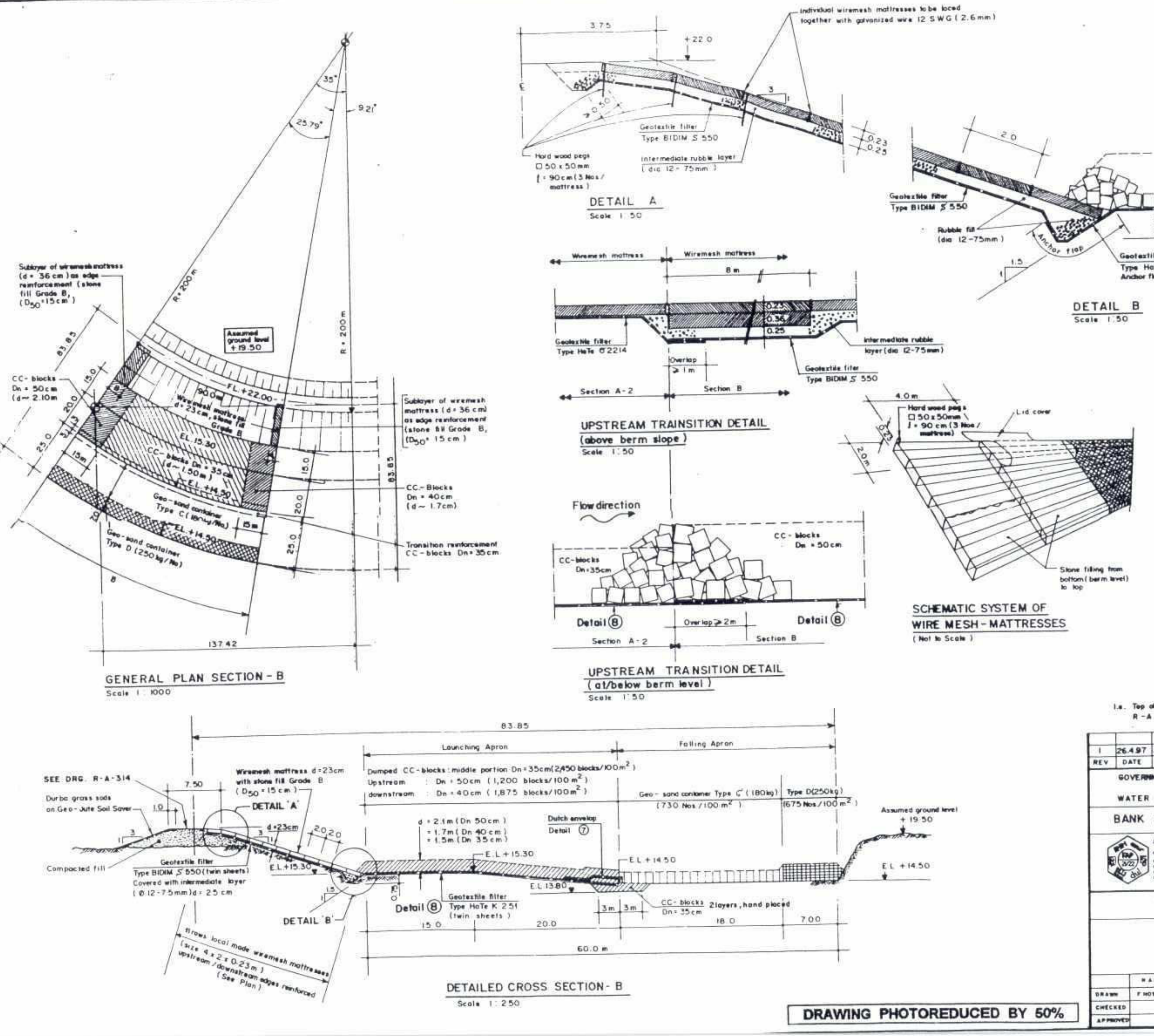
JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

TYPICAL REVETMENT DETAILS
NO. ① TO NO. ⑧

	NAME	DATE	
DRAWN	ANOWAR	23-10-96	SCALE: 1:100
CHECKED		24-10-96	DRAWING NO. R-A-306 / REVISION 1
APPROVED			

DRAWING PHOTOREDUCED BY 50%



NOTES :

1. Levels refer to + 0.00m PWD
2. Measurements are shown in meter, unless shown otherwise
3. Dredging, excavation, filling and compaction to comply with Specification, Sections 800 and 900
4. Geotextile filter materials as per Specifications, Sections 200 and 1000.
5. Revetment materials as per Specifications, Sections 200 and 1000
6. Falling apron materials as per Specification, Sections 200 and 1000.
7. Reference Drawings :
   - R - A - 302 Detailed Layout of Test Structures
   - R - A - 304 Geotextile Filter Materials
   - R - A - 306 Typical Revetment Detail (4) to (7)
   - R - G - 014 Rip - Rap Gradations

0 20 40 60 80 100 m
SCALE 1:1000

0 5 10 15 20 25 m
SCALE 1:250

0 3 6 9 12 15 m
SCALE 1:150

i.e. Top of embankment shown DRG. R-A-314

REV	DATE	NAME	DESCRIPTION	APPROVED
1	26.4.97	Anowar	AS BUILT DRAWING	

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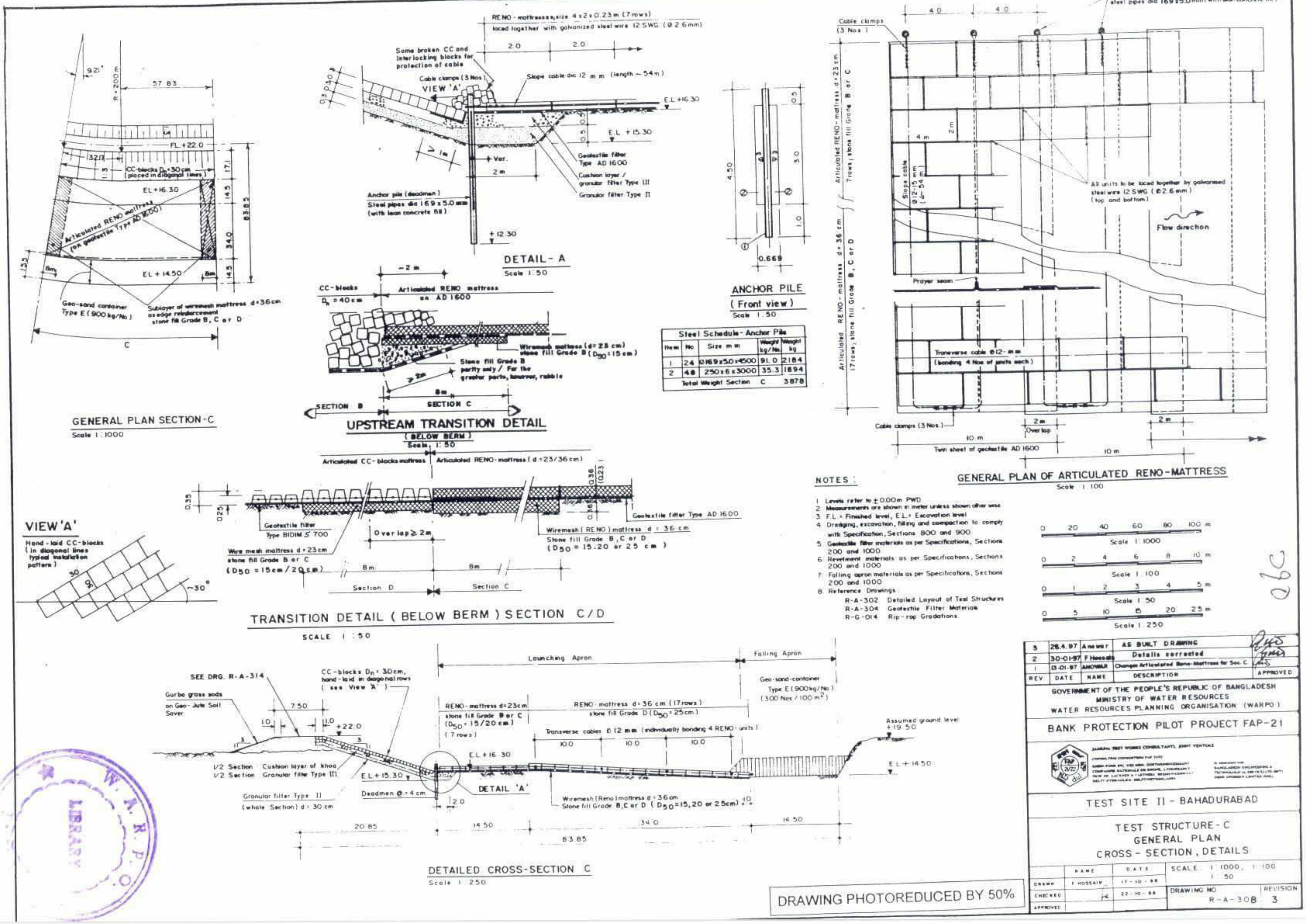
JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

TEST STRUCTURE - B
GENERAL PLAN
CROSS - SECTION, DETAILS

	NAME	DATE	SCALE 1:1000, 1:250, 1:150	
DRAWN	F HOSSAIN	18-10-96	DRAWING NO. R-A-307	REVISION 1
CHECKED		18-10-96		
APPROVED				

DRAWING PHOTOREDUCED BY 50%



Steel Schedule - Anchor Pile

Item	No	Size mm	Weight kg/No	Weight kg
1	24	Ø169×5.0×4500	91.0	2184
2	48	250×6×3000	35.3	1694
Total Weight Section C				3878

NOTES:

1. Levels refer to ±0.00m PWD
2. Measurements are shown in meter unless shown other wise
3. F.L. = Finished level, E.L. = Excavation level
4. Dredging, excavation, filling and compaction to comply with Specification, Sections 800 and 900
5. Geotextile filter materials as per Specifications, Sections 200 and 1000
6. Revetment materials as per Specifications, Sections 200 and 1000
7. Falling apron materials as per Specifications, Sections 200 and 1000
8. Reference Drawings:
   - R-A-302 Detailed Layout of Test Structures
   - R-A-304 Geotextile Filter Materials
   - R-G-014 Rip-rap Gradations

REV	DATE	NAME	DESCRIPTION	APPROVED
3	28.4.97	Anwar	AS BUILT DRAWING	
2	30-01-97	F Hossain	Details corrected	
1	13-01-97	ANOWAR	Changes Articulated Reno-Mattress for Sec. C	

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WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

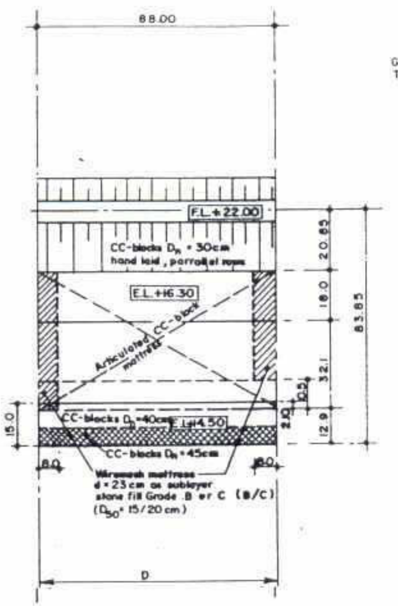
TEST SITE II - BAHADURABAD

TEST STRUCTURE-C
GENERAL PLAN
CROSS-SECTION, DETAILS

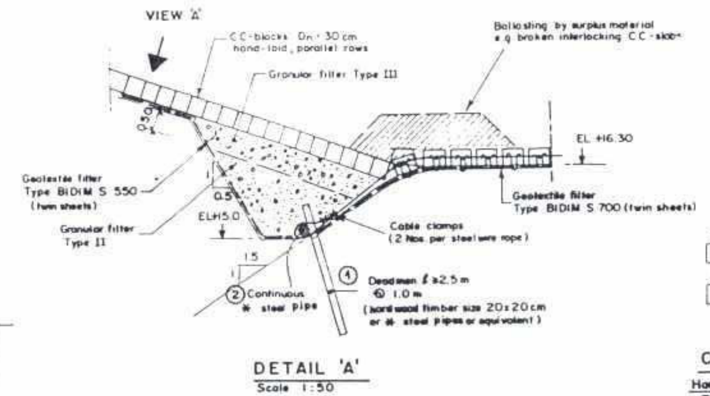
	NAME	DATE
DRAWN	F HOSSAIN	17-10-96
CHECKED		22-10-96
APPROVED		

SCALE 1:1000, 1:100, 1:50
DRAWING NO R-A-308
REVISION 3

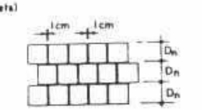
DRAWING PHOTOREDUCED BY 50%



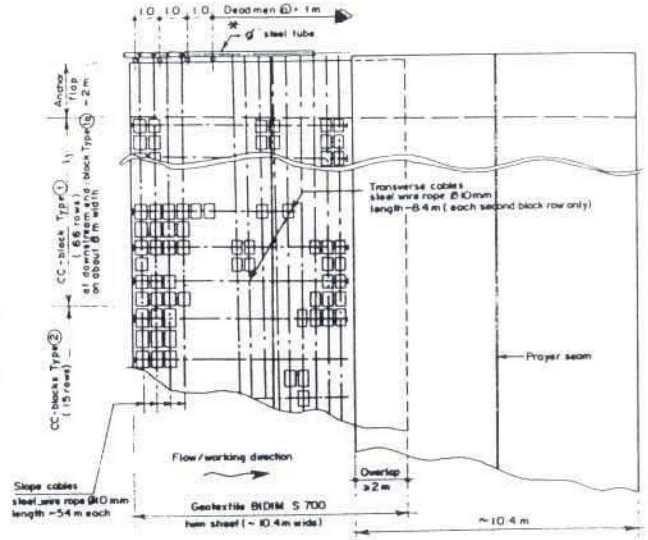
GENERAL PLAN SECTION D
Scale 1 : 1000



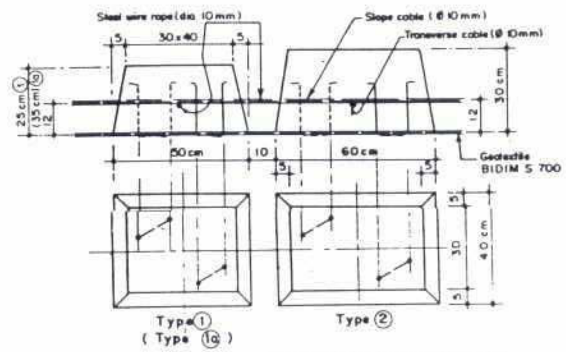
DETAIL 'A'
Scale 1 : 50



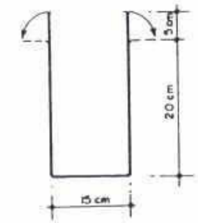
VIEW 'A'
CC-BLOCKS, D_n = 30 cm
Hand Laid in Parallel Rows
Typical Installation Pattern



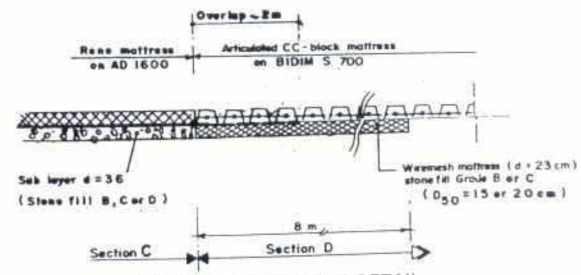
GENERAL PLAN OF ARTICULATED BLOCK MATTRESS
Scale : 1 : 100



CC- BLOCK DIMENSIONS FOR THE ARTICULATED MATTRESS (Cast in-situ) (Measurements in centimeters)
Scale 1 : 10



STEEL WIRE NEEDLE Ø 4 mm (8 SWG)
Scale 1 : 5 (galvanized)
(Punch needles through geotextile shape and hooks only thereafter)



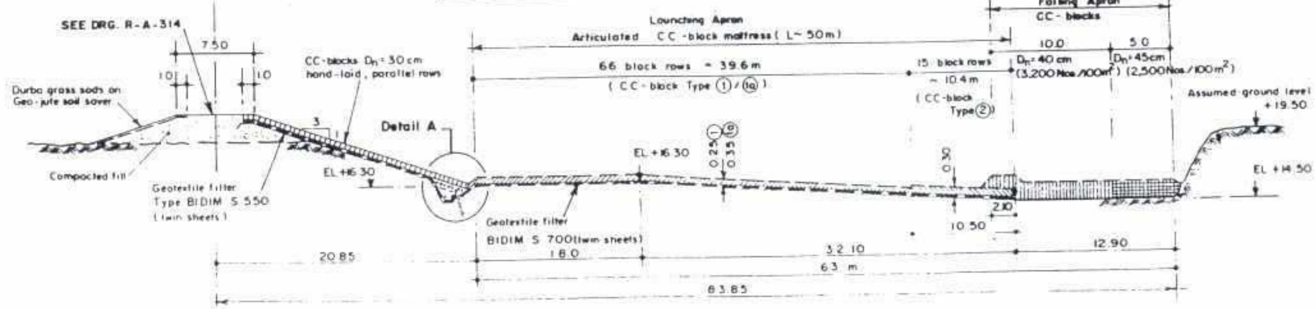
UPSTREAM TRANSITION DETAIL
(below berm)
Scale 1 : 50

Concrete quality for cast in-situ blocks of mattress: Concrete Class B25
Cement content ≥350 kg/m³ concrete
W/C ratio 0.6
Coarse aggregates size 0-20mm
(crushed aggregates)

* STEEL PIPE 169 x 5mm
(To be Grout / Concrete filled after installation)

STEEL SCHEDULE ANCHORING

ITEM	QTY	UNIT	SIZE (mm)	WEIGHT/UNIT (kg)	WEIGHT (kg)
(1)	89	Nos	ø169x5.0x2500	50.6	4,500
(2)	88	ml	ø169x5.0	20.2	1,780
Total weight section D					6,280



CROSS - SECTION D
Scale 1 : 250

NOTES
1. Levels refer to ±0.00 PWD
2. Measurements are shown in meter unless shown otherwise
3. F.L. : Finished Level
E.L. : Excavation Level
4. Reference Drawings
R-A-302 Detailed Layout of Test Structures
R-A-304 Geotextile Filter Materials General Arrangement
R-G-014 Rip-rap Gradations

SCALE 1 : 1000 (0 – 25 – 50 – 100 m)
SCALE 1 : 250 (0 – 50 – 100 – 150 – 200 – 250 m)
SCALE 1 : 100 (0 – 2.5 – 5 – 10 m)
SCALE 1 : 50 (0 – 1.0 – 2.5 – 5.0 m)
SCALE 1 : 10 (0 – 0.25 – 0.5 – 1.0 m)
SCALE 1 : 5 (0 – 0.1 – 0.2 – 0.3 – 0.4 – 0.5 m)

DRAWING PHOTOREDUCED BY 50%

REV.	DATE	NAME	DESCRIPTION	APPROVED
3	26.4.97	Anowar	AS BUILT DRAWING	
2	30.01.97	F.Hossain	Details corrected	
1	14.01.97	ANOWAR	Change Articulated Block Mattress in Sec. D	

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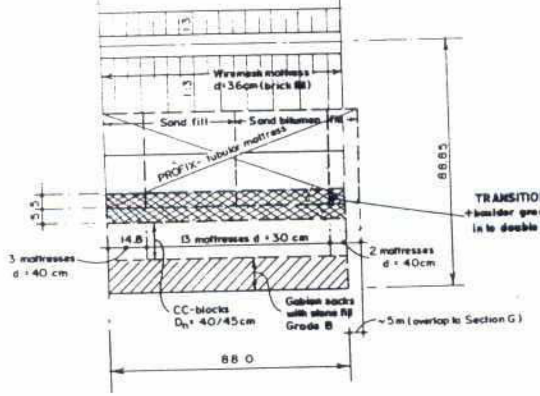
BANK PROTECTION PILOT PROJECT FAP-21

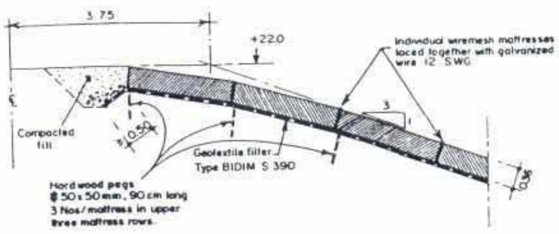
TEST SITE II - BAHADURABAD

TEST STRUCTURE D
GENERAL PLAN
CROSS - SECTION, DETAILS

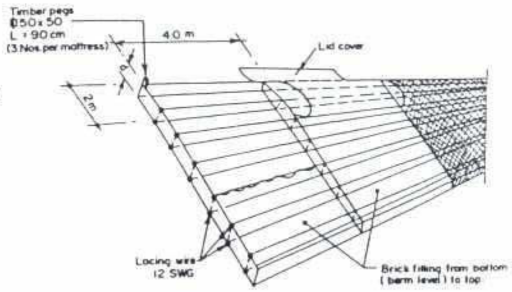
	NAME	DATE	
DRAWN	ANOWAR	17-10-96	SCALE 1:1000, 1:250, 1:100, 1:50, 1:10, 1:5
CHECKED		20-10-96	DRAWING NO. R-A-309 REVISION 3
APPROVED			



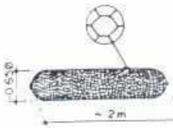
GENERAL PLAN SECTION F
Scale 1:1000



DETAIL A
Scale 1:50

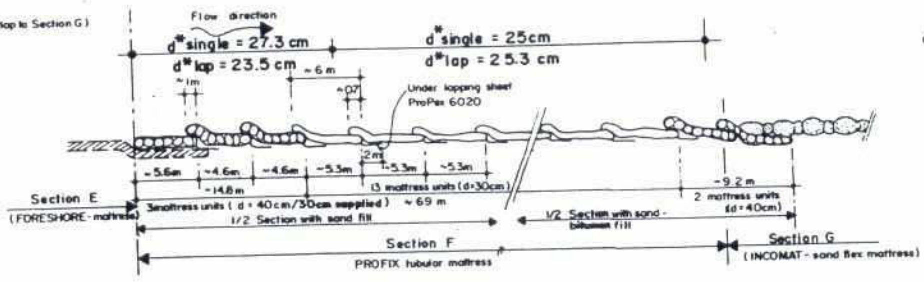


SCHEMATIC SYSTEM OF WIRE MESH - MATTRESSES
(Not to Scale)

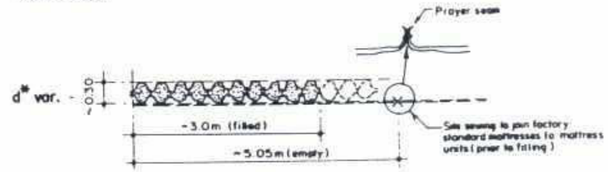


TYPICAL GABION - SACK
($0.65 m^3$/ No.)

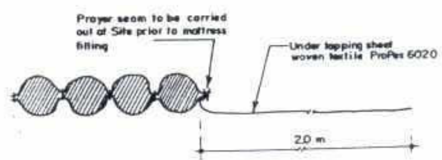
1. To be Site assembled from plain mesh wire sheets, size 2m x 2m, wire Ø 2.7mm, PVC-coated, mesh width 80mm (supplied by Employer)
2. To be filled with stone, Grading Range B, (D_{50} = 15 cm, W_{50} = 9 kg) and closed with end draw wires tightly



GENERAL CROSS-SECTION OF PROFIX - MATTRESSES
(measurements refer to covered area in filled condition of mattress units)
(With out Scale)

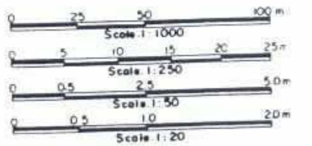


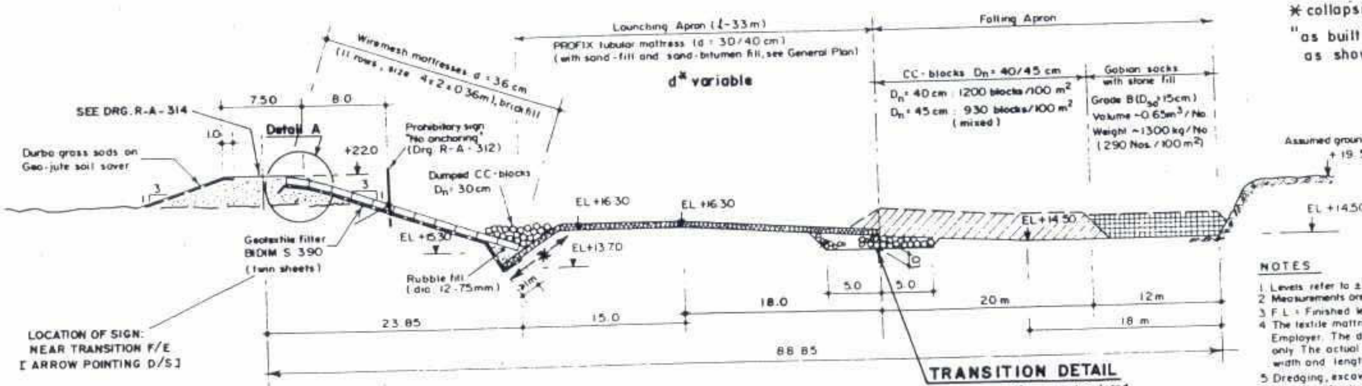
TYPICAL SECTION OF A FACTORY STANDARD MATTRESS
Scale 1:50



OVERLAP (Under lapping sheet) OF PROFIX-MATTRESS
Scale 1:20

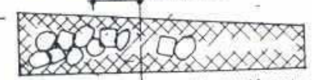
NOTE:
* collapsible block mattress
"as built" d^* = variable
as shown





DETAILED CROSS-SECTION F
Scale 1:250

TRANSITION DETAIL



DOUBLE LAYER CHAIN LINK (galv'd) (overlap in FLOW DIRECTION ≥ 1.0 m)
FILL: Packed Boulders Grade E and CC-blocks, D_n = 30 cm with sandy soil

* NOTE:
ANCHOR LENGTH OF PROFIX MATTRESS:
"IN FILLED CONDITION" VARIABLE FROM 0-3m
AS SUPPLIED MATERIAL DID NOT CONFORM
TO ORDER (ℓ = 36 m ; FILLED LENGTHS AT TIMES
ℓ ± 30m) ONLY) BUT UNDERLAYING SHEET
ALWAYS ℓ = 36 m

DRAWING PHOTOREDUCED BY 50%

NOTES
1. Levels refer to ±0.00m PWD
2. Measurements are shown in meter unless shown otherwise
3. F.L = Finished level, E.L = Excavation level
4. The textile mattress type PROFIX will be supplied by the Employer. The dimensions shown on the drawing are indicative only. The actual material supply may differ slightly by width and length of individual mattress units
5. Dredging, excavation, filling and compaction to comply with Specification, Sections 800 and 900
6. Geotextile filter materials as per Specifications, Sections 200 and 1000
7. Revetment materials as per Specifications, Sections 200 and 1000
8. Falling apron materials as per Specification, Sections 200 and 1000
9. Reference Drawings:
   - R-A-302 Detailed Layout of Test Structures
   - R-A-304 Geotextile Filter Materials
   - R-A-312 Test Structure G
   - R-G-014 Rip-rap Gradations

REV	DATE	NAME	DESCRIPTION	APPROVED
1	20.5.97	Anowar	AS BUILT DRAWING	

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BANK PROTECTION PILOT PROJECT FAP-21

TEST SITE II - BAHADURABAD

TEST STRUCTURE F
GENERAL PLAN
CROSS-SECTION, DETAILS

	NAME	DATE	
DRAWN	ANOWAR	21-10-96	SCALE: 1:1000, 1:250, 1:50, 1:20
CHECKED		22-10-96	DRAWING NO. R-A-311 — REVISION 1
APPROVED			

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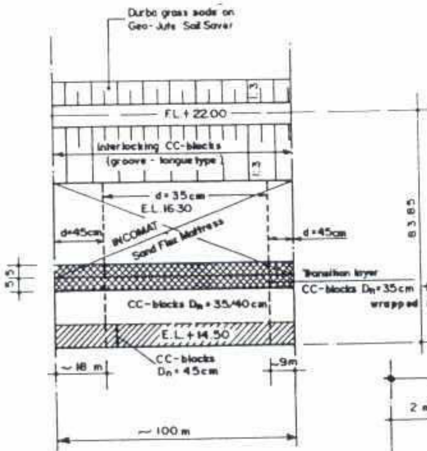
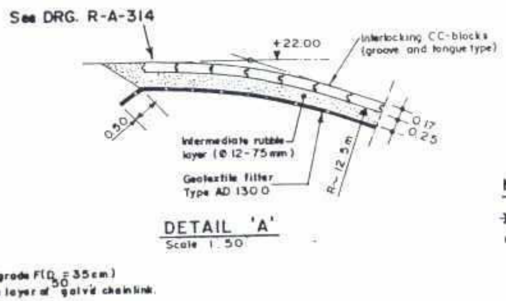
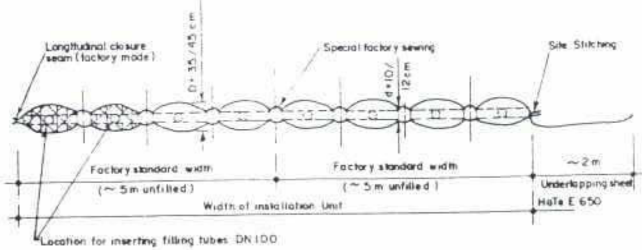


GENERAL PLAN SECTION-G
Scale 1:1000

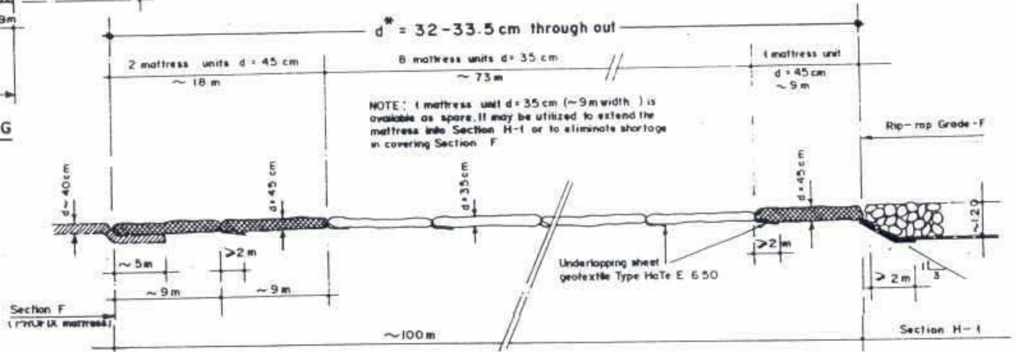


DETAIL 'A'
Scale 1:50

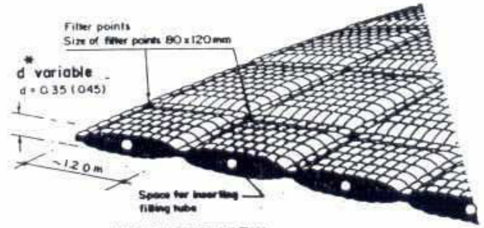
NOTE :
* collapsible block mattress "as built" d* = variable as shown



GENERAL SECTION OF ONE MATTRESS UNIT
(Not to Scale)

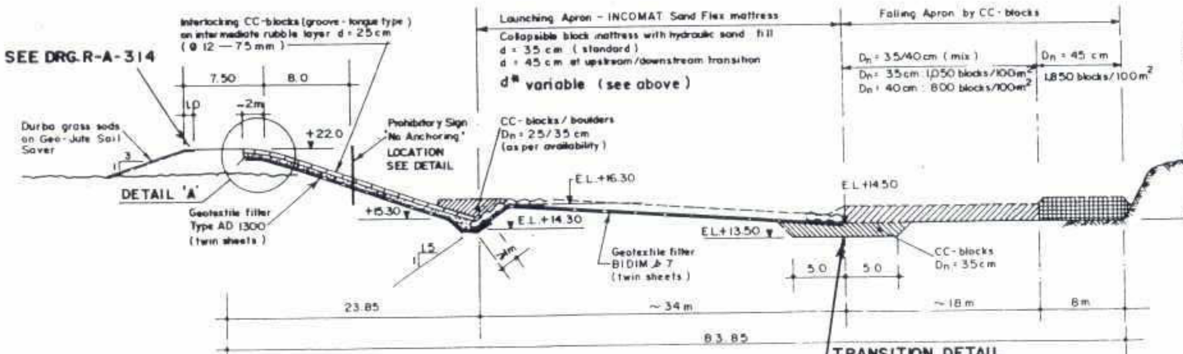


GENERAL CROSS-SECTION OF INCOMAT SAND FLEX MATTRESSES
(measurements refer to covered area in filled condition)
(without scale)



ISOMETRIC VIEW
COLLAPSABLE BLOCK MATTRESS
INCOMAT - Sand Flex

NOTES
1. Levels refer to +0.00 m PWD
2. Measurements are shown in meter, unless shown otherwise
3. F.L = Finished level
E.L = Excavation level
4. The textile mattress type INCOMAT-Sand Flex will be supplied by the Employer. The dimensions shown on the drawing are indicative only. The actual material supply may differ slightly for block size and mattress width.
5. Dredging, excavation, filling and compaction to comply with Specifications, Sections 800 and 900
6. Geotextile filter materials as Specifications, Sections 200 and 1000.
7. Revetment materials as per Specifications, Sections 200 and 1000
8. Falling apron materials as per Specifications, Sections 200 and 1000
9. Reference Drawings
R-A-302 Detailed Layout of Test Structure
R-A-304 Geotextile Filter Materials General Arrangement

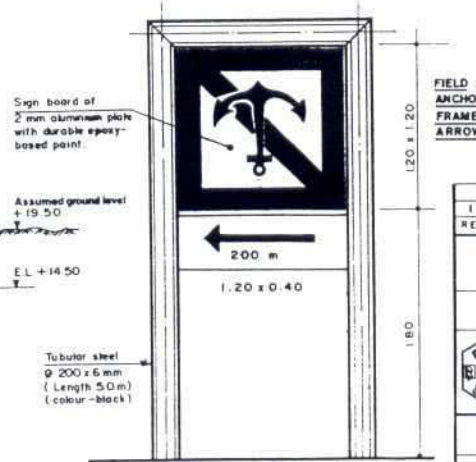


DETAILED CROSS-SECTION - G
Scale 1:250

TRANSITION DETAIL

Double layer chain link (galv'd) (overlap in Flow direction ≥1.0m)
FILL: Packed CC-blocks D_n = 35 cm and boulders grade F (D_n = 35 cm) with sandy soil.

LOCATION: SIGN PLACED NEAR TRANSITION G/H - I
ARROW POINTING U/S



FIELD : WHITE
ANCHOR : BLACK
FRAME+BAR : RED
ARROW : RED ON WHITE

(all coatings by epoxy-based paints)

PROHIBITORY SIGN
'NO ANCHORING'
Scale 1:200

0	20	40	60	80	100m
Scale 1:1000					
0	5	10	15	20	25m
Scale 1:250					
0	4	8	12	16	20 m
Scale 1:200					
0	1	2	3	4	5 m
Scale 1:50					

REV	DATE	NAME	DESCRIPTION	APPROVED
1	20.5.97	Anwar	AS BUILT DRAWING	

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BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT-VENTURE

TEST SITE II - BAHADURABAD

TEST STRUCTURE - G
GENERAL PLAN
CROSS - SECTION, DETAILS

	NAME	DATE	SCALE 1:1000, 1:250, 1:200	
DRAWN	F HOSSAIN	21-10-96		
CHECKED		23-10-96	DRAWING NO. R-A-312	REVISION 1
APPROVED				

DRAWING PHOTOREDUCED BY 50%

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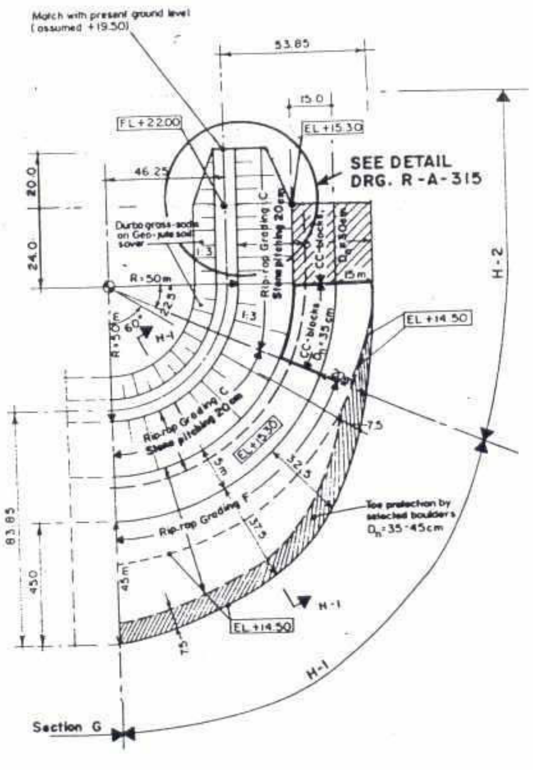
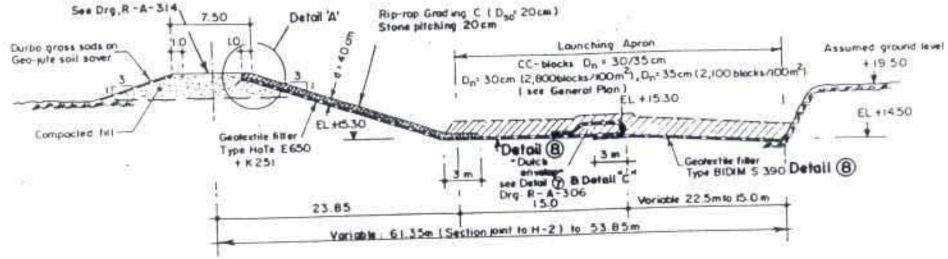


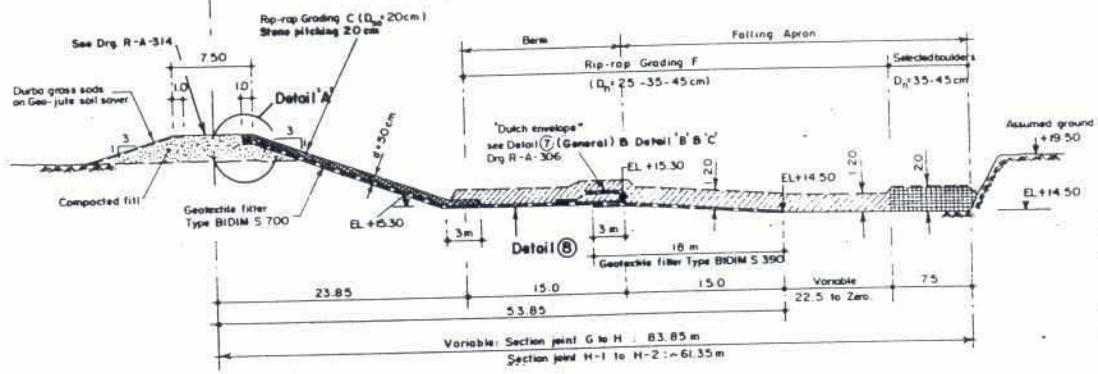
GENERAL PLAN SECTIONS H-1, H-2

Scale 1 : 1000



DETAILED CROSS-SECTION H-2

Scale 1 : 250



DETAILED CROSS-SECTION H-1

Scale 1 : 250

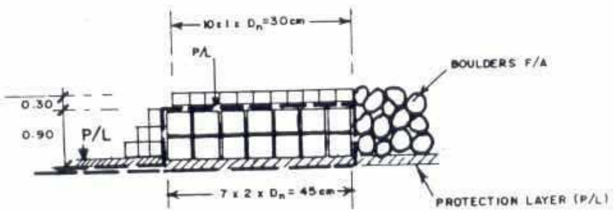
NOTES

1. Level refer to ± 0.00m PWD.
2. Measurements are shown in meter, unless shown otherwise.
3. Dredging, excavation, filling and compaction to comply with Specifications Sections 800 and 900.
4. Geotextile filter materials as per Specifications Sections 200 and 1000.
5. Revetment materials as per Specifications, Sections 200 and 1000.
6. Falling apron materials as per Specifications, Sections 200 and 1000.
7. Reference Drawings:
   - R-A-302 Detailed Layout of Test Structures
   - R-A-304 Geotextile Filter Materials General Arrangement
   - R-A-306 Typical Revetment Details No. ① to No ⑦

0 25 50 100m — Scale 1 : 1000

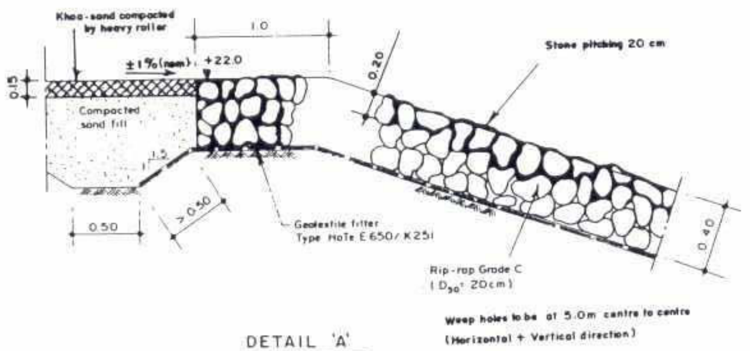
0 5 10 15 20 25 m — Scale 1 : 250

0 0.5 1.0 1.5 2.0m — Scale 1 : 20



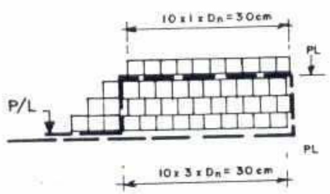
DETAIL 'B'

Scale 1 : 100



DETAIL 'A'

Scale 1 : 20



DETAIL 'C'

Scale 1 : 100

DRAWING PHOTOREDUCED BY 50%

REV	DATE	NAME	DESCRIPTION	APPROVED
1	20.5.97	Anowar	AS BUILT DRAWING	

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JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

TEST STRUCTURE H
GENERAL PLAN SECTIONS H-1, H-2
CROSS-SECTIONS, DETAILS

	NAME	DATE	
DRAWN	ANOWAR	22-10-96	SCALE: 1:1000, 1:250, 1:20
CHECKED		23-10-96	DRAWING NO. R-A-313 — REVISION 1
APPROVED			

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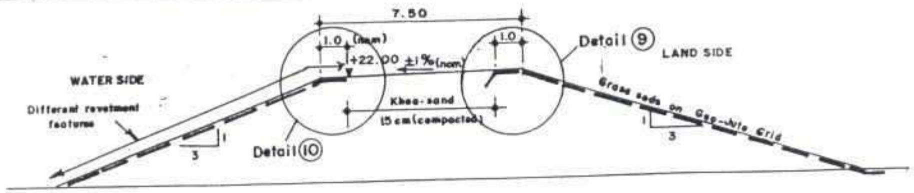
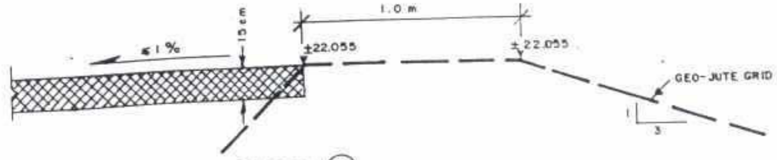
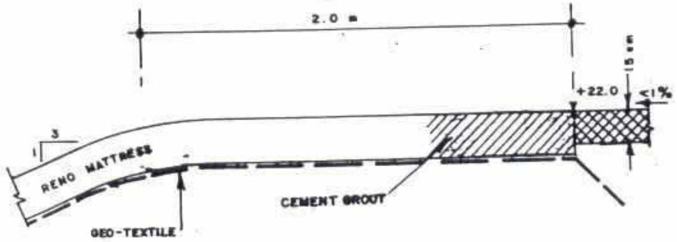


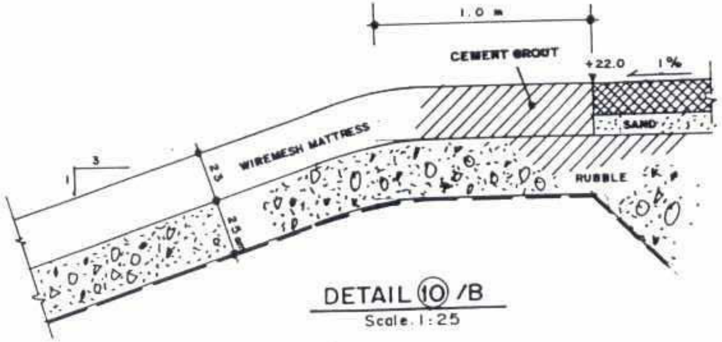
EMBANKMENT TOP
General Cross-Section
Scale. 1:200



DETAIL 9
Scale. 1:25



DETAIL 10 / "A-2"
Scale. 1 : 25



DETAIL 10 /B
Scale. 1:25

LEGEND

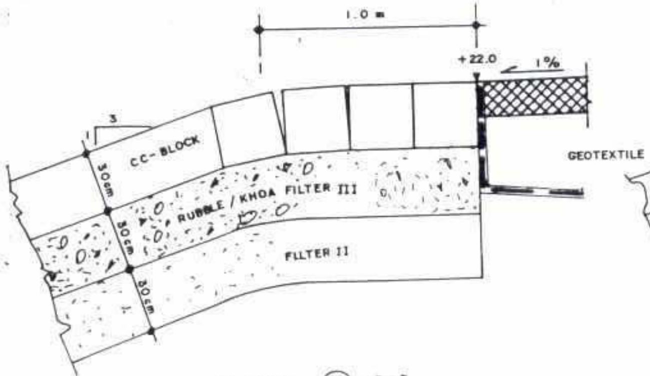
KHOA-SAND 15 cm (Compacted)

CEMENT GROUT

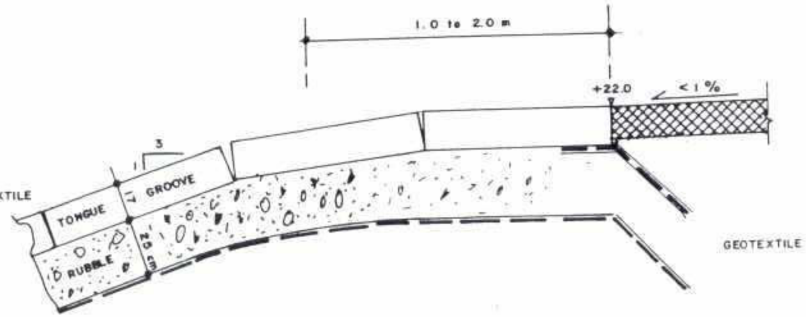
NOTE: AREAS OF CEMENT GROUTING SHOWN INDICATIVELY ONLY.

0 — 2.5 — 5.0 — 10.0 m
SCALE. 1:200

0 — 0.25 — 0.50 — 0.75 — 1.0 — 1.25 m
SCALE. 1:25



DETAIL 10 / "C"
Scale. 1 : 25



DETAIL 10 / "G"
Scale. 1 : 25

REV.	DATE	NAME	DESCRIPTION	APPROVED
1	1.6.97	Anowar	AS BUILT DRAWING	

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BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE II - BAHADURABAD

EMBANKMENT TOP
DETAILS

	NAME	DATE
DRAWN	ANOWAR	20.04.97
CHECKED		
APPROVED		05/05/97

SCALE: 1:25, 1:200

DRAWING NO. R-A- 314

REVISION 1

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BANK PROTECTION PILOT PROJECT

FAP 21

FINAL PROJECT EVALUATION REPORT

ANNEX 9: PART A - TEST SITE II AT BAHADURABAD

THE REVETMENT TEST STRUCTURE; PROCUREMENT AND CONSTRUCTION REPORT

MAY 2001

FAP 21 - BANK PROTECTION PILOT PROJECT

FINAL PROJECT EVALUATION REPORT

ANNEX 9: PART A – TEST SITE II AT BAHADURABAD

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LIST OF ACRONYMS

AFPM	-	Active Flood Plain Management
ASTM	-	American Society for Testing and Materials
BWDB	-	Bangladesh Water Development Board
CC	-	Cement Concrete
CNR	-	Compagnie Nationale du Rhone
DHW	-	Design High Water
FAP	-	FLOOD ACTION PLAN
FPCO	-	Flood Plan Co-ordination Organisation
FPM	-	Final Programme of Measures
HFW	-	High Flood Water Level
IALA	-	International Association of Lighthouse Authorities
JTWC	-	Jamuna Test Works Consultants
PIANC	-	Permanent International Association of Navigation Congress
PWD	-	Public Works Datum
RRI	-	River Research Institute, Faridpur
SHW	-	Standard High Water
SIGNI	-	Signs and Signals on Inland Waterways
SIPPS	-	Strategy for Identification and Implementation of Priority Protection Sites
SLW	-	Standard Low Water
SMP	-	Strategic Master Plan
SPT	-	STANDARD PENETRATION TEST
TPM	-	Tentative Programme of Measures
WARPO	-	Water Resources Planning Organisation (ex. FPCO)

SUMMARY

This Annex describes the implementation of the Revetments Test Structures at Bahadurabad (Part A) and Ghutail (Part B).

Before starting of construction works, the necessary land had to be acquired from the local population. This revealed as a main constraint. Land acquisition procedures are described in Annex 2.

Availability of construction materials was studied well in advance to the implementation. With the exception of geotextile fabrics all materials needed for the construction of the revetment structures could be obtained within Bangladesh. The works could be executed completely with local construction capacities and equipment.

After an open tender procedure, in August 1995 the contract for the civil works for the Bahadurabad Test Structure was awarded to the Consortium "EC-MB Joint Venture", consisting of 4 local and international firms respectively.

Works started in December 1995 but were delayed in the beginning, so that completion before the next monsoon season became unlikely. It was therefore decided, to suspend the works and to restart again during the following dry season. In consequence, most of the implementation area together with the already executed earth works was lost during the monsoon flood. The works were restarted in June 1996 and substantially completed until end of May 1997.

To allow for a fast progress and completion of the works before the next monsoon season, the earthworks were carried out with mechanical equipment. The embankment was built for the most part using the soil excavated from the flood plain for installation of the aprons.

Installation of revetments was done by labourers. Most works could be carried out without problems. As far as possible, the elements were pre-cast. Articulating systems, such as concrete-block mattresses, gabions or collapsible geotextile mattresses were cast in situ.

1 INTRODUCTION

1.1 AIM OF THE PROCUREMENT AND CONSTRUCTION REPORT

The objectives of the Bank Protection Pilot Project (FAP 21) are to find improved solutions for bank protection works against erosion, by designing, specifying and constructing different types of groynes and revetments using different materials and protective layers and investigating at the same time the suitability of local materials and construction methods. After construction of the test structures at different locations on the Jamuna, their behaviour was to be monitored for a period of several years. Finally suitable design criteria, cost-effective construction methods and maintenance strategies shall be developed and optimised which may serve as future standard solutions, most appropriate for the prevailing conditions at the Jamuna and other main rivers of Bangladesh.

One of the focal points of the study was the selection of sites where the test structures could be built with a high probability of exposure to the river attack during the entire Test and Monitoring Phase of the project. The first one on Jamuna right bank at the pre-selected location near Kamarjani as a permeable groyne structure, a second one at the Jamuna left bank at the pre-selected location near Bahadurabad Ghat a third one at the pre-selected location of Ghutail as a revetment structures.

The present Procurement and Construction Report deals with the groyne test structures at the so-called Test Site II – Bahadurabad. Attached to this annex is the description of test site III Ghutail as well. As the structures are basically the same, all details were not repeated for Ghutail description. Summarising and supplementing earlier reports [1] and [3] it shall highlight the

- Initial determination of construction methods and equipment;
- Procedures for procurement of construction materials and equipment;
- Pre-qualification of contractors, tender process and contract award;
- Applied construction methods and experience gained;
- Utilised construction equipment and experience gained;
- Rate of progress achieved;
- Compilation of material and construction cost, and
- Constraints experienced during implementation.
- Comparison of different alternatives with the goal to define the most feasible solution in terms of response to loads, sustainability and cost.

The following Annexes to the Final Project Evaluation Report [1] are supplementing this Procurement and Construction Report and may be consulted for reference:

- Socio-Economic Investigations [Annex 2];
- The Revetment Test Structure – Design Report [Annex 8];
- Evaluation of Hydraulic Loads and River Response [Annex 7], and
- Financial and Economic Evaluation [Annex 12].

The project Test and Implementation Phase started on 15 May 1993, after receiving the formal go-ahead from the Donors and FPCO. According to the agreed work program the works at Test Site II were scheduled to commence by 01 October 1995 and had to be completed within the construction window of the dry season 1995-96.

Unfortunately this schedule could not be maintained. Due to various - mainly political - reasons the works had to be stopped in January 1996. Works with a modified design restarted in November 1996 but the location had to be shifted about 100 m land inwards since the river bank was eroded during

1996 flood by approximately this figure. So finally the second test site was constructed during the dry season 1996-97 (for details refer to "Revetment Test Structures At Bahadurabad, Proposal for Final Implementation During Dry Season 1996/1997", April 1996).

1.2 PREPARATORY ISSUES RELATED TO THE IMPLEMENTATION OF THE PROJECT

1.2.1 Preliminary Remarks

Before starting the implementation of the works at Test Site II, as it was done for the first construction site, two essential preparatory tasks had to be fulfilled besides the technical planning and procurement, namely the "Peoples Participation" and the "Land-Acquisition".

1.2.2 Peoples Participation

Already at the time of preparation for the first test site information on the intended structures on the left side of the river were presented to the people of the area of Belgacha, the than pre-selected second test site. Belgacha is situated between Bahadurabad and Ghutail.

Prior to and during the land acquisition procedures for the Bahadurabad test site the local people have been informed about and discussions were held on the planned structure and its location.
Refer also to Annex 5

ANNEX 2 provides full disclosure of actions initiated within the FAP 21-project, as well as of positive but also negative response experienced.

1.2.3 Land Acquisition

1.2.3.1 <u>Introduction</u>
The same procedure as described in Annex 5 was followed for the acquisition of land for the Bahadurabad test site.

1.2.3.2 <u>Selection of the Test Site Area</u>
Like Kamarjani as first test site the Bahadurabad area was pre-selected for the second test site already during the Study Phase.

As said before, one of the focal points during the study phase of the project was the selection of sites where the test structures could be built with a high probability of exposure to the river attack during the entire Test and Monitoring Phase of the project. Thereby, through an analysis of the plan-form data and bank erosion rates presented by a satellite image of 8 March 1992 and images over the past 20 years period, the pre-selected test site area at Kamarjani was reconfirmed, also taking due account of environmental and socio-economic aspects. After the flood season of 1992, the Consultants continued to monitor the bank erosion around the Kamarjani area. The observations were compared with the earlier predictions and although some deviations could be noticed the general trend appeared to be in line with the predictions.

During the construction of the first test site the Consultants continued to monitor the development within the pre-selected test site area of Bahadurabad through analysis of recent satellite images and detailed survey. The evaluation of satellite images of 1994 and the comparison with the previous investigations confirmed the earlier predictions. The morphological changes were analysed and future predictions for the area of the proposed Test Site II "Bahadurabad" supported in a separate report [4].

Based on the results it was finally concluded in November 1994 between the Donors, FPCO and the Consultants that Test II with a revetment structure shall be constructed in front of the village "Kulkandi" near Bahadurabad Ghat.

The test site Bahadurabad is situated on the left bank of the Jamuna River at an approximate Latitude of 25°20'N (BTM 777 800 to 778 600 North and 470 900 to471 400 East).

The location and general layout of the test structure as per initial layout and design is shown in Fig. 1.2-1.

1.2.3.3 Land Acquisition Procedures
Refer to Annex 2 and 5

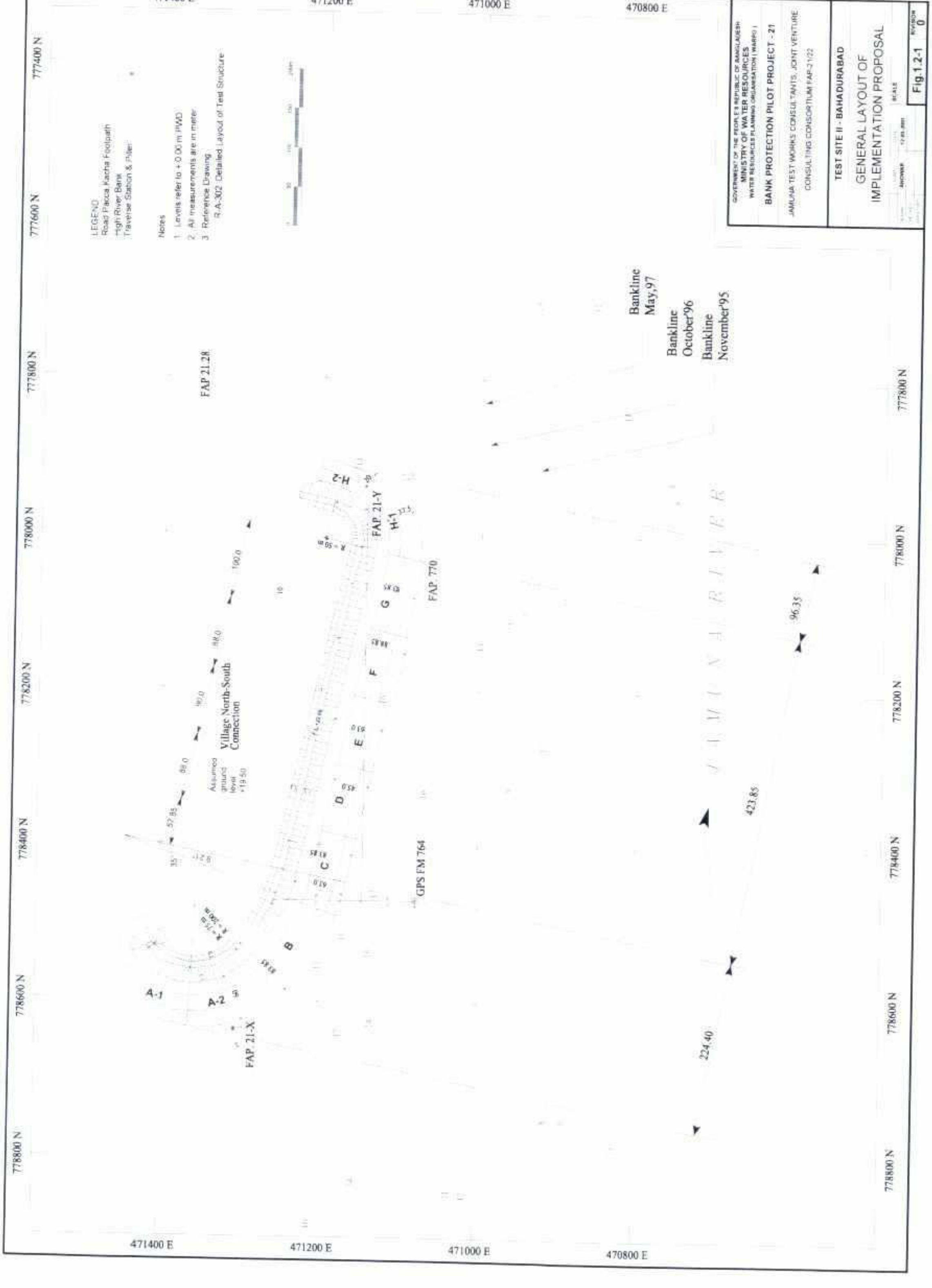

Fig. 1.2-1: General Layout of Implementation Proposal – Test Site II

2 DESIGN OF THE TEST STRUCTURE

For the design of the test structures Annex 8 may be consulted, which contains all original design data and principles related to the revetment structures and associated works.

For the purpose of this Construction and Procurement Report a selection of design and construction drawings is included under Attachment 1.

3 PRE-DETERMINATION OF CONSTRUCTION METHODS AND EQUIPMENT

Refer to Annex 5, Chapter 3, Section 3.1.

4 SOURCES OF CONSTRUCTION MATERIALS

Refer to Annex 5, Chapter 4.

5 PROCUREMENT OF MATERIALS AND EQUIPMENT

5.1 GENERAL INFORMATION

Most construction works of bank protection projects have to be executed during a construction window defined by the low water period between the monsoon seasons. Procurement and construction contracts can normally be awarded only after the final decision regarding location and design of the respective structure is sanctioned. This is possible at the end of (say October) but more likely only much after the end of monsoon season (say by end November / early December). With a construction window about expected to last from mid October to mid April it is too late to start the procurement of materials and equipment at this stage. Consequently, advance procurement under separate contracts or by the implementing authority have to be made, if the start of construction works shall not be delayed for lack of materials and equipment. In case of procurements from outside Bangladesh sufficient time for shipping, custom clearance and payment of duties by the Client (or GoB) must be allowed.

Foreign firms do not have a general import license and have to apply for an import permit for every single supply contract through the implementing authority and other authorities, which can be a time consuming process.

Delay in cargo handling, customs clearance and duty payment often causes demurrage where nobody takes responsibility. So finally the project has to pay the involved costs to get the cargo cleared and the works started.

In anticipation of the foregoing the Consultants in their function as Main Contractor initiated material as well as equipment procurement inside and outside of Bangladesh well in advance through individual supply contracts. The items were procured in the name of the Consultants and the GoB through FPCO arranged for the payment of import duties and taxes. It was for this strategy that materials and essential construction equipment could be made available to the Sub-contractor for the execution of the works in due time.

For procurement of bricks for concrete, mattressing or other purpose it must be considered that burning of bricks is being carried out only during the dry season wherefore new supplies are usually only available early December. Commonly only minor quantities of bricks are available in the market from previous productions at the end of the monsoon season. Therefore it was also important to procure even bricks much in advance of the start of construction works.

All procurement and material supplies followed the technical specifications specially elaborated for the purpose of the project and as also included in the Tender Documents for the construction works for information of the contractor.

5.2 CONSTRUCTION MATERIAL PROCUREMENT

Remarks:
The procurement of material and equipment was according to the design of the structures scheduled for implementation during the dry season of 1995-1996.

Due to the one-year delay, the modified design and modified procurement orders the finally implemented materials and the quantities as well as the used equipment are different from the initial procurement.

This advance procurement, nevertheless allowed an accelerated installation procedure as mentioned above and thus is recommended for future works.

5.2.1 Local Material Procurement

In the following only the main material supplies from within Bangladesh are compiled, more details are presented in Table (P1).

Boulders for filling of RENO-mattress and for rip-rap (in various gradation ranges)

Supplied quantity:	21,353 m^3
Procurement cost	Taka: 26,820,900 (without VAT)
Equivalent to	DM: 1,017,266

Geo-textile filter materials and sand bags/containers

Supplied quantity:	35,000 Nos. (sand bags)
Procurement cost	Taka: 2,124,954 (without VAT)
Equivalent to	DM: 77,905

Interlocking CC-Blocks

Supplied quantity:	37,600 Nos.
Procurement cost	Taka: 7,445,490 (without VAT)
Equivalent to	DM: 267,241

5.2.2 Imported Materials

In the following only the main material imports into Bangladesh are compiled, more details are presented in Table (P2).

__Country of Origin Australia:__

Geo-Textile-Mattress "System-FORESHORE"

Supplied quantity:	9,500 m^2
Procurement cost (CIF Chittagong)	A$ 150,202 (without VAT)
Equivalent to	Taka 3,937,727 (without VAT)

__Country of Origin Germany:__

Geo-Textile-Mattress "System-INCOMAT"

Supplied quantity:	5,040 m^2 (mattress) 1,500. m^2 (filter mat)
Procurement cost (cif Chittagong)	DM: 149,444 (without VAT)
Equivalent to	Taka: 3,885,544 (without VAT)

Geo-Textile-Filter Material

Supplied quantity:	18,000 m^2 (filter mat) Inclusive thread
Procurement cost (cif Chittagong)	DM: 125,923 (without VAT)
Equivalent to	Taka: 3,273,998 (without VAT)

Country of Origin Netherlands:

Geo-Textile-Mattress "System-PROFIX"

Supplied quantity:	38 sheets (mattress) 1,995. m² (filter mat)
Procurement cost (cif Chittagong)	DM: 95,487 (without VAT)
Equivalent to	Taka: 2,482,666 (without VAT)

Country of Origin France:

Geotextile filter materials and sand bags/containers

Supplied quantity:	157,971 m² (filter mats) Inclusive thread
Procurement cost (cif Chittagong)	DM: 529,360 (without VAT)
Equivalent to	Taka: 14,763,372 (without VAT)

Gabions "System-RENO-Mattress"

Supplied quantity:	630 Nos. (wire mash mattress) 3,100 Nos. (wire mash bags)
Procurement cost (cif Chittagong)	DM: 126,555 (without VAT)
Equivalent to	Taka: 3,290,432 (without VAT)

5.3 COST OF CONSTRUCTION EQUIPMENT

5.3.1 Local Equipment Procurement

Local equipment procurement was limited to purchase of a second survey boat with outboard engines, one side scan sonar, additional wireless communication equipment and parts of a pulling beam. Details are compiled in Table P3.

5.3.2 Other Local Procurement

In addition local cost incurred in connection with equipment rentals, car-insurance and port charges, forwarding and demurrage in connection with imports for the project, all of which are compiled in Table P4.

5.3.3 Import of Construction and Ancillary Equipment

No procurement of important equipment was required for the execution of the Bahadurabad test site

More details may be taken from Table P5 (Procurement of Equipment Outside Bangladesh) and Table P6 (Other Procurement Outside Bangladesh).

Procurement

Test Site II - Bahadurabad, 1995/1997

Serial No.	Description	Supplier	Delivery Period	Quantity	Unit	Total per Unit Taka	TOTAL Taka	TOTAL DM	Remarks
1	2	3	4	5	6	7	8	9	10
1	**Stones for Revetments, Scour Protection and Wire Mesh-Mattresses**								
	Delivered at Burimari	Exchange International	Okt 95	12.713	m^3	900	11.441.700	433.962	
	Delivered at Bahadurabad	Dhaka	to	8.640	m^3	1.780	15.379.200	583.304	
	Shifting of boulders from Kamarjani to Bahadurabad		Mrz 97	5.603	m^3	570	3.193.511	121.124	
				26.956	m^3		**30.014.411**	**1.138.390**	
2	**Hard Rock for Revetments / Bed Protections**								
		M/S Sapphire Dhaka	Okt 95	8.200	m^3	1.335 to 1.695	**3.957.900**	**141.263**	*Sapphire failed to deliver court case still pending* **occurred loss**
3	**Interlocking CC-Blocks (Factory-made)**								
	Tongue and grove CC-slabs	MIMPEX International	Okt 95	20.600	nos	155	3.193.000	114.606	
	Ship-lap-type CC-slabs		to	17.000	nos	160	2.720.000	97.629	
	Moulds and Transport	Dhaka	Apr 97		ls		1.532.490	55.006	
							7.445.490	**267.241**	
4	**Geo-Textile Bags (Container), tailoring (material supplied by the project and by DIRD)**								
	Cutting the supplied Geotextile material and sewing to different sizes (Types C,D,E)	DIRD Private Ltd Dhaka	Feb 96 to Mrz 97	35.000	nos	40 to 60	1.932.454	70.774	
	Supply of thread			1.750	cone	110	192.500	7.132	
							2.124.954	**77.905**	
	TOTAL MATERIAL PROCUREMENT IN BANGLADESH						**43.542.755**	**1.624.799**	

Table 5.2-P1: Procurement of construction material in Bangladesh

Procurement

Test Site II - Bahadurabad, 1995/1997

page 1 of 2

Serial No	Description	Supplier	Delivery Period	Quantity	Unit	Total per Unit Taka	Total per Unit DM	TOTAL Taka	TOTAL DM
1	2	3	4	5	6	7	8	9	10
1	**Geo-Textile Filter Materials:**								
1,1	**BIDIM:**	BIDIM	Jun 95						
1 1a	BIDIM b 7	France		8 480	m²	57	2,18	480 597	18 484
1 1b	BIDIM S 390			8 480	m²	70	2,67	589 532	22 674
1 1c	BIDIM S 550			26 235	m²	94	3,63	2 478 077	95 311
1 1d	BIDIM S 700			14 310	m²	120	4,62	1 719 335	66 128
1 1e	Thread, Type 8/3, PES, white, 38400 m			6	box	4 534	174,38	27 204	1 046
1 1f	Thread, Type 8/3, PES, black, 25600 m			4	box	6 423	247,04	25 692	988
								5.320.435	**204.632**
1,2	**Thermolite:**	Thermolite	Aug 95						
1 2a	AD 1300	France		6 120	m²	60	2,31	367 445	14 133
1 2b	AD 1600			7.650	m²	97	3,72	739 149	28 429
1 2c	Thread, PES, black			2	kg	636	24,47	1 272	49
1 2d	Thread, PES, white			2	kg	636	24,47	1 272	49
								1.109.139	**42.659**
1,3	**Huesker:**	Huesker	Aug 95						
1 3a	HaTe E 650	Germany		3 000	m²	102	3,91	304 980	11 730
1 3b	HaTe K 251			9 000	m²	109	4,19	980 460	37 710
1 3c	HaTe J 9014			2 000	m²	244	9,37	487 240	18 740
1 3d	HaTe O 2214			4 000	m²	262	10,09	1.049 360	40 360
1 3e	Thread, PES, white			20	pc	728	28,00	14 560	560
1 3f	Thread, PES, black			20	pc	832	32,00	16 640	640
1 3g	Transport			1	ls	563 420	21 670,00	563 420	21 670
1 3h	Special rebate			5	%	- 142 662	- 5 487,00	-142 662	-5 487
								3.273.998	**125.923**
				Sub-Total Geo-Textile Filtermaterial				**9.703.572**	**373.214**
2	**Material for Geo-Textile Sand Containers**								
2,1	**BIDIM:**								
2 1a	BIDIM b 777	BIDIM	Jun 95	36 000	m²	60	2,33	2 176 287	83 703
2 1b	Thread, Type12/3, PES, blue, 192000 m	France		20	box	6 423	247,04	128 461	4 941
2 1c	Thread, Type 12/3, PES, black, 38400 m			4	box	6 423	247,04	25 692	988
2 1d	Thread, Type 12/3, PES, white, 19200 m			2	box	6 423	247,04	12 846	494
								2.343.287	**90.126**
2,2	**Thermolite:**	Thermolite	Aug 95						
2 2a	AD 1600	France		50 696	m²	97	3,72	4 898 264	188 395
2 2b	Thread, PES, blue			125	kg	636	24,47	79 523	3 059
2 2c	Thread, PES, black			10	kg	636	24,47	6 362	245
2 2d	Thread, PES, white			10	kg	636	24,47	6 362	245
2 2d								**4.990.511**	**191.943**
				Sub-Total Geo-Textile Sand Containers				**7.333.797**	**282.069**
						to be carried forward:		**17.037.370**	**655.283**

Table 5.2-P2: Procurement of construction material outside Bangladesh

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Procurement
Test Site II - Bahadurabad, 1995/1997

Serial No.	Description	Supplier	Delivery Period	Quantity	Unit	Total per Unit Taka	Total per Unit DM	TOTAL Taka	TOTAL DM
1	2	3	4	5	6	7	8	9	10
							carried forward	**17.037.370**	**655.283**
3	**Material for Geo-Textile Mattresses:**								
3,1	**Foreshore :**	Foreshore Protection	Okt 95						
3.1a	Block Mattress (cement grouted)	Australia		9.500.000	m^2	343	13,19	3.257.814	125.301
3.1.b	Rent & purchase of colcrete pump				ls			679.913	24.901
								3.937.727	**150.202**
3,2	**Huesker:**	Huesker	Aug 95						
3.2a	Incomat-Sand-Flex-Mattress type 20.152	Germay	to	1.260	m^2	793	30,50	999.180	38.430
3.2b	Incomat-Sand-Flex-Mattress type 20.140		Mai 96	3.780	m^2	715	27,50	2.702.700	103.950
3.2c	Geo-Textile FilterHaTeE 650			1.500	m^2	119	4,56	177.840	6.840
3.2d	Thread			8	pc	728	28,00	5.824	224
								3.885.544	**149.444**
3,3	**PROFIX:**	Boskalis Zincon bv	Aug 95						
3.3a	Tubular Mattress	Netherlands		38	sheet	52.234	2.009,00	1.984.889	76.342
3.3b	Underlapping sheets			1.995	m^2	59	2,25	116.708	4.489
3.3c	Transport			1	ls	381.069	14.656,52	381.069	14.657
								2.482.666	**95.487**
				Sub-Total Material for Geo-Textile Mattress:				**10.305.937**	**395.133**
4	**Material for Gabions:**								
4,1	**Reno-Mattress**	France Gabions							
4.1a	Wire mesh mattress 4x2x0.23 m	France		240	nos	1.849	71,11	443.725	17.066
4.1b	Wire mesh mattress 4x2x0.36 m			390		2.090	80,40	815.231	31.355
4.1c	Gabion sacks			3.100		566	21,77	1.754.525	67.482
4.1d	Lacing wire			4.000	kg	64	2,47	256.576	9.868
4.1e	Tools			3	set	6.792	261,22	20.375	784
								3.290.432	**126.555**
	TOTAL MATERIAL PROCUREMENT OUTSIDE BANGLADESH							**30.633.739**	**1.176.972**

Table 5.2-P2 (continued): Procurement of construction material outside Bangladesh

Procurement

Test Site II - Bahadurabad, 1995/1997

Serial No.	Description	Supplier	Delivery Period	Quantity	Unit	Total per Unit Taka	TOTAL Taka	TOTAL DM
1	2	3	4	5	6	7	8	9
1	**Survey Boat**							
1a	Unsinkable boat	B.F. Enterprise Dhaka	Mai 95	1	No.		1.229.700	43.634
2	**Survey Equipment for Monitoring**							
2a	Side Scan Sonar	River Survey Project FAP 24 Dhaka	Jun 94	1	No.		1.580.000	57.987
3	**Communication Equipment**							
3a	Transceiver VHF, FTL 2011C with Accessories & Divers	Logistic & Services Dhaka Yeasu Musen, Japan	Aug 95 Jan 97	1 div	No.		155.485 56.363	5.590 2.162
3b	License fees	T&T Board, Dhaka	95-97				261.180	9.620
						Total	473.028	17.372
4	**Construction Equipment**							
4a	Pulling Beam	Highspeed Ship Building Bangladesh	Aug 95				550.000	19.822
	TOTAL EQUIPMENT PROCUREMENT IN BANGLADESH						**3.832.728**	**138.814**

Table 5.2-P3: Procurement of equipment in Bangladesh

Procurement

Test Site II - Bahadurabad, 1995/1997

Serial No.	Description	Supplier	Delivery Period	Quantity	Unit	Total per Unit Taka	TOTAL Taka	TOTAL DM
1	2	3	4	5	6	7	8	9
1	**Import, Port & Demurrage**							
1a	Charges	Forwarding Agents Chittagong, Dhaka	Nov 95 Feb 96				3.933.809	139.982
2	**Insurance**							
2a	CAR, Hull, CPM, Marine insurance	Sadharan Bima Co Dhaka	Aug 95 Nov 95				4.466.514	157.346
3	**Hire of Equipment**							
3a	Hire of crawler crane and barge	Multiple Equipment Dhaka	Aug 95 Feb 97				10.412.000	374.589
4	**Construction Works**							
4a	Construction Contract	EC-MB Joint Venture	Sep 95 Mai 98				283.120.435	10.621.822
5	**Other Procurements** for maintenance and repair and miscelaneous items		95-97				1.220.873	43.581
	TOTAL OTHER PROCUREMENT IN BANGLADESH						**303.153.631**	**11.337.321**

Table 5.2-P4: Other procuremnent in Bangladesh

Procurement

Test Site II - Bahadurabad, 1995/1997

page 1 of 2

Serial No.	Description	Supplier	Delivery Period	Quantity	Unit	Total per Unit Taka	Total per Unit DM	TOTAL Taka	TOTAL DM
1	2	3	4	5	6	7	8	9	10
1	**Monitoring Equipment**								
1,1	OSAE:	OSAE	Nov 95						
1.1a	PC, software, echosounder	Bremen, Germany	to					3.395.315	130.589
1.1b	Repair		Mrz 97					90.221	3.470
1.1c	Training							578.532	22.251
								4.064.068	156.310
1,2	VALEPORT	VALEPORT	Okt 95					1.102.674	42.411
1.2a	Current Meter (2 nos.)	Devon, England	to					28.602	1.100
1.2b	Transport		Sep 96					1.131.276	43.511
1,3	Instrument Technology	Instrument Technology	Jun 96						
1.3a	div repair	Bremen, Germany	Jun 97					142.168	5.468
1,4	STN Atlas Electronic	STN Atlas Electronic	Okt 96						
1.4a	Repair and spare parts echosounder	Bremen, Germany	Sep 97					451.438	17.363
1,5	Roda Computer	Roda Computer	Apr 97						
1.5a	Monitoring Computer	Lichtenau, Germany						143.776	5.530
1,6	Ashtech	Ashtech	Jan 00						
1.6a	Repair GPS	Long Hanborough, England						64.511	2.481
1,7	MARIMATECH	MARIMATECH	Sep 97						
1.7a	Paper rolls	Aarhus, Denmark						71.682	2.757
1,8	EIVA	EIVA	Mrz 97						
1.8a	Marine Antenna	Aarhus, Denmark						37.076	1.426
							to be carried forward:	**6.105.994**	**234.846**

Table 5.2-P5: Procurement of equipment outside Bangladesh

Procurement

Test Site II - Bahadurabad, 1995/1997

page 2of2

Serial No	Description	Supplier	Delivery Period	Quantity	Unit	Total per Unit Taka	Total per Unit DM	TOTAL Taka	TOTAL DM
1	2	3	4	5	6	7	8	9	10
						carried forward:		**6.105.994**	**234.846**
1,9	Lambrecht	Lambrecht	Feb 96						
1.9a	Spare parts	Goettingen, Germany	Sep 97					11.006	423
1.10	Boss	Boss	Sep 97						
1.10a	Battery charger	Dortmund, Germany						4.171	160
1,11	Hewlett Packard	Hewlett Packard	Feb 96						
1.11a	spare part	Boeblingen, Germany						8.149	313
1,11	Transport								
1.11a	Kuehne und Nagel	Germany	Mrz 97					10.556	406
1.11b	Schenker	Germany	Sep 97					16.712	643
								27.268	1.049
2	**Geo-Textile Acessories**								
2,1	Spare parts sewing machines	Union Special Germany	Nov 95					109.847	4.225
3	**Construction Equipment**								
3,1	Winches, shackles,	Atlantic Dragage	Nov 95					6.262.755	240.875
3,2	pulling beam accessories	Nanterre France	to					1.270.522	48.866
3,3	anchors		Aug 97					3.614.610	139.023
3,4	satellite phone							243.509	9.366
								11.391.396	438.131
								17.657.830	**679.147**

Table 5.2-P5 (continued): Procurement of equipment outside Bangladesh

Procurement

Test Site II - Bahadurabad, 1995/1997

Serial No.	Description	Supplier	Delivery Period	Quantity	Unit	Total per Unit Taka	Total per Unit DM	TOTAL Taka	TOTAL DM
1	2	3	4	5	6	7	8	9	10
1	**Management Support**								
1a	Site Supervision Management Support	Atlantic Dragage France	Jan 95 Okt 95					2.909.693	111.911
	TOTAL OTHER PROCUREMENT OUTSIDE BANGLADESH							2.909.693	111.911

Table 5.2-P6: Other procuremnent outside Bangladesh

6 TENDER PROCEDURES – CIVIL ENGINEERING WORKS

6.1 PRE-QUALIFICATION PROCEDURES

In accordance with the terms of reference related to the Consulting Agreement the Consultants are required to carry out the construction works for the test structures as a General Contractor with the help of local subcontractors.

Different to the procedure for the first test site (Enlistment of so-called "A"-class contractors, replacing a pre-qualification), this time contractors were invited to submit pre-qualification documents by publication. The invitation for pre-qualification was published in two local newspapers:

- The Bangladesh Observer on February 21, 1995, and
- The Daily Ittefaq on February 23, 1995

At the last date for receiving applications (15/03/95) a total of 22 individual firms or joint ventures submitted their pre qualification documents. Among these were three single foreign firms and 9 joint ventures of foreign/local firms. All of these 12 applicants (foreign firms and joint ventures with foreign partners) were subsequently informed that eligible tenders are to be from the People's Republic of Bangladesh, or, in case of joint ventures one foreign partner would be permitted with the partner-in-charge from Bangladesh. Only four of them responded positively.

Evaluation of PQ-documents was carried out as per following criteria:

(a) Technical Evaluation

- Experience with similar works during past 10 years
    - Dredging, excavation;
    - Revetment works;
    - Geo textile filter installation.
- Assigned Sub-Contractors
- Equipment (owned/leased)
    - Floating equipment;
    - Earth cutting, moving, compaction;
    - General equipment.
- Technical Personnel
    - Organisational set-up;
    - Leading staff qualification;
    - Key personnel qualification.

(b) Financial Evaluation

- Value of single contracts handled;
- Value of work in hand;
- Bank solvency certificate.

With the set scoring criteria of minimum 50% in each category, but a minimum of 60 % in the overall evaluation, seven firms/joint ventures were finally pre-selected for participation in the tendering. These are:

1. Soiltech International Ltd.
   House # 98 (new), Road # 9/A (new)
   Dhanmondi Residential Area
   Dhaka

20৬

2. Consortium The Engineers Ltd. &
Corolla Corporation (BD) Ltd.
19/1 Kakrial, Dhaka-1000

3. Consortium Bengal Development
Corporation Ltd. &
China Harbour Engineering Co.
125/A, Motijheel Commercial Area (5th floor)
Dhaka-1000

4. DIRD - AML Joint Venture
Plot # 1/B, Road # 126
Gulshan, Dhaka

5. Neptune Commercial Ltd.
73, Siddheswari Road
Dhaka-1217

6. Monico Ltd. and Boskalis International
9/A, North Dhanmondi
Kalabagan
Dhaka-1205

7. Association of Bengal Electric Ltd. &
China International Water and
Electric Corporation (CWEC)
11 Green Road
Dhaka-1205

The above listed firms and joint ventures were informed of their successful pre-selection in writing on April 08, 1995 and the date for the collection of tender document was set at April 16, 1995.

6.2 TENDERING PROCEDURES

6.2.1 Tender Documents

The tender documents were drafted as per international standards and comprised of the following:

☑	Volume I:	Form of Tender, Appendix to Tender, Form of Tender Security
		Instructions to Tenders
		Sample Form of Agreement
		Forms of Performance Security, Bank Guarantee for Advance Mobilisation Payment
		Bill of Quantities
		Schedules
☑	Volume II	General Conditions of Contract
		Conditions of Particular Application
☑	Volume III	Technical Specifications
☑	Volume IV	Tender Drawings

Particular emphasises was given to the Technical Specification, outlining and describing the individual construction works and methods in much detail. Thus all bidders were given the opportunity to clearly understand the scope of works, to elaborate their technical proposal and to select the respective construction equipment.

The General Conditions of Contract as well as the Instructions to Bidders were drafted on the principles of FIDIC, suitably adopted to take consideration of the General Contractor – Sub-contractor relationship.

6.2.2 Tender Period

Issue of Tender Documents
Following the earlier announcement all seven pre-selected firms and joint ventures collected the Tender Documents at the JTWC-office in Dhaka on April 16,1995. The dead line of submission of bids was set at June 04, 1995.

Pre-bid Meeting
A pre-bid meeting was held at the JTWC - Dhaka office on May 15, 1995. Representatives of six tenders attended the meeting. The questions and answers raised during the meeting are recorded in the Minutes of Pre-bid Meeting, which was subsequently circulated to all tenders.

On the request of some of the bidders, the dead line for submission of tenders was extended to Sunday, June 11, 1995.

Circulars and Addenda to the Tender
Three circulars letters were issued to all tenders, namely:

- Minutes of Pre-bid Meeting, dated 15.05.95, containing questions and answers Nos. 1 to 20;
- Circular letter dated May 22, 1995, containing question and answer No. 21, and
- Circular letter dated May 31, 1995, containing questions and answers Nos. 22 to 24, as well as a supplementary bill of quantities to Bill 04 (Employer's Facilities).

No formal Addendum to the Tender Documents was issued.

Tender Submission
On the day of tender opening (June 11, 1995) six bids were submitted.

The announcement of the tenders names, the tender prices, offered discounts, tender modifications and the presence or absence of tender security were made in the presence of all tenders and recorded.

The attendance list of the tender opening is presented in Table 6.2-1 and the result of tender opening is compiled in Table 6.2-2.

FAP 21 REVETMENT TEST STRUCTURE

TENDER OPENING ON JUNE 11, 1995

At 10.00 hrs. at the Office of

JANUMA TEST WORKS CONSULTANTS

LIST OF TENDERERS PRESENT

Name of Tenderer	Represented by	Signature	Tendered Yes / No
Soiltech International Ltd. and HAM-Vanoord JV	Engr. Md. Mohsin	[illegible] 11/6/95	Yes
Consortium: The Engineers & Corolla Corporation (BD) Ltd.	Engr. A.S. MASSOOD	[illegible] 11/6/95	Yes
Consortium: Bengal Development Corp. Ltd. and China Harbour Engineering Co.	—	—	—
DIRD - AML Joint Venture	Engr. A R Chowdhury	[illegible]	Yes
Neptune Commercial Ltd.	A.K.M. Saiful Alam	[illegible]	YES
Monico Ltd. and Boskalis International	B. Doza	[illegible] 11/6/95	Yes
Association of Bengal Electric Ltd. and China International Water and Electric Corporation (CWC)	Anwarul Haque	[illegible] 11-6-95	Yes

Table 6.2-1 : Attendance List during Tender Opening

Sl. No.	Name of Tenderer	Tender Security	Tender Prices (Taka)			Total Net Tender Price (Taka)	Discount	
			Total of Bills	Total of Daywork	10 % Contingen.		Present	Condition
1.	Soiltech International Ltd. & HAM – Van Oord JV	5,000,000	248,749,053	8,746,548	24,874,905.30	282,370,506.30	Nil.	-
2.	Consortium: The Engineers & Corolla Corporation (BD) Ltd.	5,000,000	254,307,775	7,646,565	25,430,777.00	287,385,117.00	1 %	On all
3.	Consortium: Bengal Development Corp. Ltd. China Harbour Engineering Co.	-	-	-	-	-	-	-
4.	DIRD – AML Joint Venture	5,000,000	325,848,845	5,860,625	32,584,885.00	364,294,355.00	12 %	On all Except Daywork
5.	Neptune Commercial Ltd.	5,000,000	268,075,900	8,025,495	26,807,590.00	302,908,985.00	7.25 %	On all
6.	Monico Ltd. and Boskalis International	5,000,000	261,678,975	7,048,740	26,167,897.00	294,895,612.00	4.75 %	On all Except Provisional Sums
7.	Association of Bengal Electric Ltd. and China International Water and Electric Corporation (CWEC)	5,000,000	240,254,250	7,478,412	24,773,266.20	272,504,928.20	Nil.	-

Table 6.2-2 : Test Site II - Revetment Test Structure
Result of Tender Opening on June 11, 1995, at 10.00 hrs.
at the Office of JAMUNA TEST WORKS CONSULTANTS

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6.2.3 Technical Assessment of Bids

The assessment of the bids was carried out by Consultants team in Dhaka. The result of the technical assessment of bidder's technical proposals for carrying out the works is compiled in Table 6.2-3.

Sl. No.	Description	Maximum Score	Soiltech Intern. Ltd. HAM Van Oord J.V.	The Engineers Ltd. Corolla Corp. Ltd.	DIRD AML – Joint Venture	Neptune Commercial Ltd.	Monico Ltd. Boskalis International	Bengal Electric Ltd. C.I.W.E. Co.
1	2	3	4	5	6	7	8	9
1	Adequacy of Main Construction Equipment	30	27	27	27	18	25	21
2	Qualification of Leading Site Personnel	15	12	10	10	8	12	6
3	Planning of the Works	15	15	12	15	6	4	9
	- General Construction Time Schedule	8	8	7	8	4	5	4
	- Equipment Employment Schedule	4	4	3	4	1	2	1
	- Procurement Schedule	3	3	2	3	1	2	2
4	Work Method Statements	40	25	31	30	11	37	10
	- Surveying Method and Equipment	5	2	3	3	1	4	0
	- Dredging Method and Equipment	8	6	6	6	2	8	2
	- Common Excavation	3	2	2	2	1	3	1
	- Filling and Compaction Works	3	3	3	3	2	3	1
	- Geotextile Filter Installation	8	6	6	6	2	7	2
	- Revetment Installation	2	1	2	2	1	2	1
	- Fabric Mattress Installation	8	4	6	5	1	7	2
	- Scour Protection Installation	3	1	3	3	1	3	1
	TOTAL SCORE (Technical)	100	79	80	82	43	83	43

Required overall minimum score of a successful technical proposal: 60 %

Table 6.2-3: Summary of Technical Evaluation

Two bidders did not submit a proposal which would serve a `promising base for the successful implementation of the works. These are Neptune Commercial Ltd. and the Association Bengal Electric Ltd./China International Water and Electric Corporation. The remaining technical proposals can be ranked as follows:

1. J.V. Monico Ltd./Boskalis International BV;
2. J.V. DIRD-AML;
3. Consortium The Engineers Ltd./Corolla Corporation Ltd., and
4. J.V. Soiltech International/HAM Van Oord.

6.2.4 Financial Assessment of Bids

Based on the bill of quantities the Consultants carried out a confidential detailed cost estimate prior to the tendering of works, arriving at an Estimated Total Net Tender Price of **288,102,428 Taka**.

The Total Net Tender Price being defined as total of all bills, plus 5 % for day-work (Provisional Sum) and 10% contingencies for unforeseen works (Provisional Sum), but excluding VAT.

Generally, the offered unit rates and lump sum prices are well in line with the Consultants' cost estimate (PCR 4/95). In order to make the bids comparable some clarification were requested from the bidders and the bids corrected accordingly.

The bids, after correction, were adjusted for the purpose of direct comparison as follows:

1. Provisional Sums (P 1.10, P 1.15) were omitted initially for computing offered discounts, but added finally to the total amounts again;

2. Bill No. 05 (Monitoring Field Station) has been deleted, since Employer's camp will be retained partly after completion of the works;

3. Supply of stones/boulders from Burimari to the Site are being considered by application of the respective alternative unit rates;

4. Providing of additional container accommodation/office for Employers' camp has been replaced by providing semi-permanent brick buildings;

5. Some bidders have chosen not to make use of special equipment optionally offered by the Employer (reference Specifications, Subsection 310(2)), but to make use of their own resources. Consequently, those bids which require Employer's equipment were added by the estimated cost to be spend by the Employer for providing such special equipment, and

6. The Jamuna Test Works Consultants deems it necessary to support the selected sub-contractor by providing expatriate construction experts for specialised works, such as dredging/profiling of slopes, and installation of geo textile filter mats respectively mattresses under water. Not only to ensure proper implementation of the works, but to provide proper training and transfer of know-how to the local contractor. Some bidders have already offered such expert support in their bids. In this case, JTWC could limit their engagement of additional expatriates. Those bids, which do not provide for expatriate construction experts during the construction period, have been added with the estimated cost, which would incur to JTWC for such experts.

Table 6.2-4 compiles the details of computing the adjusted as well as the comparable Tender Prices. Thereby, the Adjusted Tender Price is the total of all bills (after correction of errors) plus the affects of sub-items 1 to 4 above. For the Comparable Tender Prices the above sub-items 5 and 6 were considered in addition. Written clarification of bidders in response to JTWC's enquiries were given consideration in the evaluation of the Comparable Tender Prices.

Table 6.2-5 compiles the ranking as per Comparable Tender Prices.

Bill / Item No.	Description	Unit	Quantity	Soiltech Inter. Ltd. & HAM Van Oord J.V Rate [Taka]	Soiltech Inter. Ltd. & HAM Van Oord J.V Amount [Taka]	The Engineers Ltd. Corolla Cor. (BD) Ltd Rate [Taka]	The Engineers Ltd. Corolla Cor. (BD) Ltd Amount [Taka]	DIRD - AML Joint Venture Rate [Taka]	DIRD - AML Joint Venture Amount [Taka]	Neptune Commercial Ltd. Rate [Taka]	Neptune Commercial Ltd. Amount [Taka]	Monico Ltd. Boskalis International Rate [Taka]	Monico Ltd. Boskalis International Amount [Taka]	Bengal Electric Ltd China Int. Water&Elec. Cor Rate [Taka]	Bengal Electric Ltd China Int. Water&Elec. Cor Amount [Taka]
	TOTAL OF BILLS (1) (after correction of errors)				257 064 945		253 545 275		325 848 845		268 075 900		261 678 975		240 254 250
	Deduction of Provisional Sums														
P 1.10	Supply of hydrographic survey equipment	Sum	—	—	-6 750 000	—	-6 750 000	—	-6 750 000	—	-6 750 000	—	-6 750 000	—	-6 750 000
P 1.15	Provisional Sum for contingency measures	Sum	—	—	-10 000 000	—	-10 000 000	—	-10 000 000	—	-10 000 000	—	-10 000 000	—	-10 000 000
Bill 05	Monitoring Field Station	Total of Bill		—	-828 000	—	-1 175 000	—	-397 500	—	-1 471 000	—	-1 555 000	—	-655 000
	Sub-Total (2) - Deductions				-17 578 000		-17 925 000		-17 147 500		-18 221 000		-18 305 000		-17 405 000
	Alteration of Scope of Works														
Bill 03	Delete following Items:														
3.40	Graded stones, Grade B, transport Chilmari to Site	m^3	3 800	350	-1 330 000	750	-2 850 000	375	-1 425 000	250	-950 000	410	-1 558 000	300	-1 140 000
3.41	Graded stones, Grade C, transport Chilmari to Site	m^3	2 100	350	-735 000	750	-1 575 000	375	-787 500	255	-535 500	410	-861 000	300	-630 000
3.42	Graded stones, Grade D, transport Chilmari to Site	m^3	2 500	350	-875 000	750	-1 875 000	375	-937 500	265	-662 500	410	-1 025 000	300	-750 000
3.43	Graded stones, Grade E, transport Chilmari to Site	m^3	8 200	350	-2 870 000	750	-6 150 000	375	-3 075 000	270	-2 214 000	410	-3 362 000	300	-2 460 000
3.44	Graded stones, Grade F, transport Chilmari to Site	m^3	4 500	350	-1 575 000	750	-3 375 000	375	-1 687 500	275	-1 237 500	410	-1 845 000	300	-1 350 000
	Replace by following Item:														
3.45	Graded stones, Grades B to F, transport from Burirnari to Bahadurabad	m^3	21 100	825	17 407 500	900	18 990 000	375	7 912 500	275	5 802 500	760	16 036 000	1 600	33 760 000
	Sub-Total (3) - Variations Bill No. 03				10 022 500		3 165 000		0		203 000		7 385 000		27 430 000
Bill 04	Delete following Items:														
P 4.06	Provide Employer's accommodation 2x20ft, 2x40ft container, complete	Sum	—		-250 000		-1 210 000		-250 000		-700 000		-1 000 000		-500 000
P 4.07	Transportation of containers of Item P 4.06 to Site	Sum	—		-350 000		-250 000		-62 500		-200 000		-100 000		-100 000
	Replace by following Item:														
A 4.14	Construction of semi-permanent offices	m^2	75	5 000	375 000	8 000	600 000	3 500	262 500	*5 000*	*375 000*	8 070	605 250	3 500	262 500
A 4.15	Construction of semi-permanent accommodation	m^2	93	5 500	511 500	8 000	744 000	3 500	325 500	*5 000*	*465 000*	8 070	750 510	4 000	372 000
A 4.16	Supply of air conditioners and furniture	Total of Item			1 429 100		1 842 700		1 069 000		*1 500 000*		1 801 760		1 167 200
	Sub-Total (4) - Variations Bill No. 04				1 715 600		1 726 700		1 344 500		*1 440 000*		2 057 520		1 201 700
A	Total of Bills and Variations (1) to (6)				251 225 045		240 511 975		310 045 845		251 497 900		252 816 495		251 480 950
B	Discount (if any)			(non)		1.00%	-2 405 120	12.00%	#VALUE!	7.25%	#VALUE!	4.75%	-12 008 784	(non)	
C	Total of Bills and Variations after Discount				251 225 045		238 106 855		#VALUE!		#VALUE!		240 807 711		251 480 950
D	Total of Daywork (Provisional Sum)				8 746 548		7 646 565		5 860 625		8 025 495		7 048 740		7 478 412
E	Discount (if any) on Daywork			(non)		1.00%	-76 466	(non)		7.25%	#VALUE!	4.75%	-334 815	(non)	
F	Total of Daywork after Discount				8 746 548		7 570 099		5 860 625		#VALUE!		6 713 925		7 478 412
G	Add 10% of Total C for Contingencies (Provisional Sum)			10%	25 122 505	10%	23 810 686	10%	#VALUE!	10%	#VALUE!	10%	24 080 771	10%	25 148 095
P 1.10	Supply of hydrographic survey equipment	Sum	—		6 750 000		6 750 000		6 750 000		6 750 000		6 750 000		6 750 000
P 1.15	Provisional Sum for Contingency Measures	Sum	—		10 000 000		10 000 000		10 000 000		10 000 000		10 000 000		10 000 000
H	**Sub-Total of Adjusted Tender Price**				**301.844.098**		**286.237.640**		**#VALUE!**		**#VALUE!**		**288.352.407**		**300.857.457**
Spec Subsec	Valuation of Differences in Construction Equipment														
	400-t-flat top barge		Estimate	(included)		(included)		(included)		(included)		(included)			1 200 000
350	15-t-mooring winches (single drum 6 Nos.)		Estimate		*7 200 000*	(included)		(included)			*7 200 000*		*7 200 000*		7 200 000
360	20-t-main pulling winch		Estimate		*3 000 000*	(included)			*3 000 000*		*5 000 000*		*3 000 000*		5 000 000
370	Colloidal grout plant		Estimate		*1 000 000*	(included)			*1 000 000*		*1 000 000*		*3 000 000*		3 000 000
380	Mobile concrete pump		Estimate	(included)		(included)			*4 800 000*		*4 800 000*		*4 800 000*	(included)	
	Sub-Total (5) - Valuation Construct. Equipm.				*15 200 000*				*12 800 000*		*20 000 000*		*20 000 000*		*16 400 000*
	Valuation of Providing Expatriate Construction Experts														
	2 Construction specialists / experts for working 8 months each in Bangladesh	MM	16	Included in Bid		*1 000 000*	*16 000 000*	*1 000 000*	*16 000 000*	*1 000 000*	*16 000 000*	Included in Bid		*(OFFERED AFTER BID SUBMISSION)*	
	Sub-Total (6) - Valuation of Expat. Services				0		*16 000 000*		*16 000 000*		*16 000 000*		0		
	COMPARABLE TENDER PRICE				**317.044.098**		**302.237.640**		**#VALUE!**		**#VALUE!**		**308.352.407**		**317.257.457**

Table 6.2-4 : Computation of Comparable Tender Prices

Rank	Bidders	Comparable Tender Price (Taka)
1.	Consortium The Engineers Ltd./ Corolla Corporation (BD) Ltd.	302,237,640
2.	Monico Ltd./Boskalis International BV, J.V.	308,352,407
3.	Neptune Commercial ltd. (*)	316,784,379
4.	Soiltech International Ltd./HAM Van Oord J.V.	317,044,098
5.	Association Bengal Electric Ltd./ China International Water & Electric Corp (*)	317,257,457
6	DIRD - AML Joint Venture	351,535,003

(*) Technically disqualified

Table 6.2-5 : Rankings as per Comparable Tender Prices

6.2.5 Summary and Conclusion

According to the assessment under Subsection 6.2.3 of this Report, the technical proposals of two bidders are assessed to be inadequate. Therefore, these two bids have not been considered in the final evaluation.

The assessment of the remaining four bids is summarised in the Table 6.2-6.

Bidders	Financial Assessment (Item 4.5.4)				Technical Assessment
	Comparable		Adjusted		
	Tender %	Rank	Tender %	Rank	(Item 4.4.7)
Consortium The Engineers Ltd./ Corolla Corporation (BD) Ltd.	100.00	1	100.00	1	3
Monico Ltd./Boskalis International BV, J.V.	102.02	2	100.74	2	1
Soiltech International Ltd./ HAM Van Oord J.V.	104.90	3	105.45	3	4
DIRD - AML Joint Venture	116.31	4	112.75	4	2

Table 6.2-6: Summary of Bid Assessment

It can be seen that the Consortium The Engineers Ltd./Corolla Corporation (BD) Ltd. has submitted the most competitive financial bids among the technically acceptable tenders, with the bid of Joint Venture Monico Ltd./Boskalis International BV only at a marginal difference in their evaluated tender prices. Thereby, J.V. Monico/Boskalis have submitted the most promising technical proposal for the executions of the works, despite some weakness in equipment resources.

Bill / Item No.	Description	Unit	Quantity	The Engineers Ltd. Corolla Cor. (BD) Ltd. Rate [Taka]	The Engineers Ltd. Corolla Cor. (BD) Ltd. Amount [Taka]	Monico Ltd. & Boskalis International Rate [Taka]	Monico Ltd. & Boskalis International Amount [Taka]
	TOTAL OF BILLS (1) (after correction of errors)				253,545,275		261,678,975
	Deduction of Provisional Sums						
P 1.10	Supply of hydrographic survey equipment	Sum	---	---	-6,750,000	---	-6,750,000
P 1.15	Provisional Sum for Contingency measures	Sum	---	---	-10,000,000	---	-10,000,000
Bill 05	Monitoring Field Station	Total of Bill		---	-1,175,000	---	-1,555,000
	Sub-Total (2) – Deductions				-17,925,000		-18,305,000
	Alteration of Scope of Works						
Bill 03	**Delete** following Items:						
3.40	Graded stones, Grade B, transport Chilmari to Site	m^3	3,800	750	-2,850,000	410	-1,558,000
3.41	Graded stones, Grade C, transport Chilmari to Site	m^3	2,100	750	-1,575,000	410	-861,000
3.42	Graded stones, Grade D, transport Chilmari to Site	m^3	2,500	750	-1,875,000	410	-1,025,000
3.43	Graded stones, Grade E, transport Chilmari to Site	m^3	8,200	750	-6,150,000	410	-3,362,000
3.44	Graded stones, Grade F, transport Chilmari to Site	m^3	4,500	750	-3,375,000	410	-1,845,000
	Replace by following Item:						
3.45	Graded stones, Grades B to F, transport from Burimari to Bahadurabad	m^3	21,100	900	18,990,000	760	16,036,000
	Sub-Total (3) – Variations Bill No. 03				3,165,000		7,385,000
Bill 04	**Delete** following Items:						
P 4.06	Provide Employer's accommodation 2x20ft, 2x40ft container, complete.	Sum	---		-1,210,000		-1,000,000
P 4.07	Transportation of containers of Item P 4.06 to Site.	Sum	---		-250,000		-100,000
	Replace by following Item:						
A 4.14	Construction of semi-permanent offices	m^2	75	8,000	600,000	8,070	605,250
A 4.15	Construction of semi-permanent accommodation	m^2	93	8,000	744,000	8,070	750,510
A 4.16	Supply of air conditioner and furniture	Total of Item			1,842,700		1,801,760
	Sub-Total (4) – Variations Bill No. 04				1,726,700		2,057,520
A	Total of Bills and Variations (1) to (4)				240,511,975		252,816,495
B	Discount (if any)			1.00%	-2,405,120	4.75%	-12,008,784
C	Total of Bills and Variations after Discount				238,106,855		240,807,711
D	Total of Daywork (Provisional Sum)				7,646,565		7,048,740
E	Discount (if any) on Daywork			1.00%	-76,466	4.75%	-334,815
F	Total of Daywork after Discount				7,570,099		6,713,925
G	Add 15% of Total C for Contingencies (Provisional Sum)			15%	35,716,028	15%	36,121,157
P 1.10	Supply of hydrographic survey equipment	Sum	---		6,750,000		6,750,000
P1.15	Provisional Sum for Contingency Measures	Sum	---		10,000,000		10,000,000
H	**Sub-Total of Adjusted Tender Price**				**298,142,982**		**300,392,793**

Table 6.2-7: Computation of Tentative Price of Contract of:
- JV The Engineers Ltd.-Corolla Corp.
- JV Monico Ltd.-Boskalis International

6.2.6 Contract Award

Prior to the contract award discussions were held with both joint venture groups. In order to make the advantages of both groups available to the project JTWC proposed a merger of the two groups in to one single Joint Venture with full responsibility of all partners in all fields.

The bidders and the Client and the Donors finally accepted this proposal.

A new Joint Venture was formed and named

- **EC-MB Joint Venture**

with The Engineers Ltd. as the lead firm.

The offers of both groups were "harmonised" following principally the Offer and BoQ of the group The Engineers Ltd. & Corolla Corp.

The contract was awarded to the EC-MB JV at a basic contract price of:

Taka 243,318,395 (excluding VAT).

The letter of acceptance of the merged bids was issued on August 7, 1995. On August 31, 1995 the Sub-contractor received instruction from the Consultants to proceed with the works. Latest Commencement of works at site was fixed for October 15, 1995.
The Contract was signed on September 30, 1995.

On October 1995 Variation Order No. 1 for additional provisional sums was issued with a new basic contract price of

Taka 260,210,097 (excluding VAT).

Although the start of works was scheduled for mid October 1995 until end of November 1995 no activities except contractors site installation and the construction of the Consultants camp facilities took place. As reason the Contractor claimed non-availability of land and hartals (political general strikes), the Consultants held against the non-availability of appropriate and sufficient equipment by the Contractor. End of November 1995 it emerged that the Contractor can not mobilise the main construction equipment for dredging and under water works on time.

In order the to save the possibility to execute the second test site within the dry season of 1995/1996 the Consultants modified the initial design so that under water works and dredging were eliminated. The Contractor confirmed to be capable of completing the test structures within the remaining period of time, as per alternative design proposed by the JTWC

Due to the change of design and due to the postponement of the works in February 1996 (refer to Section 7.1) Variation Order No. 2 was issued on December 01, 1996 with a new basic contract price of:

Taka 228,246,236 (excluding VAT).

7 EXECUTION OF WORKS

7.1 PRELIMINARY REMARKS

Works under the alternative design started finally on December 08, 1995. End of January 1996 only marginal parts of works had been completed and the risk of non timely completion before the monsoon season of 1996 became very likely. The main reasons for the delay have been stated as follows:

- frequent work interruption by workers who have be influenced by the former land owners seeking sub-contracts;
- interruptions of works and delay in supply due to frequent political unrest, and
- failure of the Contractor to comply with its general contractual obligations and responsibilities.

As consequence and in view of a very high likelihood of frequent unrest due to the prevailing political situation in Bangladesh the Consultants with the consent of the Client and Donors decided on February 1, 1996 to suspend the construction works with the intention to restart again during the dry season of 1996/1997.

The suspension of works was related only to the execution of the structure itself. All supply of material and the prefabrication of cc-blocks went ahead as per schedule as far as possible. In March 1996 activities in Bangladesh came practically to a standstill due the political situation which justified the decision of suspension of the works. At the time of suspension at the structures only earth works had been executed.

During the flood of 1996 most of the area of the implementation the test site had been eroded and the already executed earth works were lost. For the restart the location of the structure had to be shifted by approximately 100 m backwards. After the review mission of the Donors in July 1996 it was decided to re-start the works and the instruction to the Contractor to continue was issued on July 07, 1996. The following chapters will only deal with structures realised during the dry season 1996/1997.

7.2 REVETMENT STRUCTURE

7.2.1 General

The test structure of test site number two comprises of a revetment structure with embankment, launching apron and falling apron. The structure is divided in 8 Sections A to H with two subdivisions each in the two end Sections A and H.

The design per section is as follows (refer also to drawings of Attachment 1):

For the three main protective elements a specific nomenclature has been used utilising terms widely used in Bangladesh but others in a more specific sense:

- slope protection: standard term used in BWDB for the protection of embankment slopes; reaches up to the toe of the embankment;
- launching apron consists of interconnected elements that are placed horizontally on the (excavated) floodplain and anchored at the toe of the embankment. The elements can not develop freely once scouring occurs but launch down the slope;

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- falling apron — consists of loose elements, mostly geo-bags and cc-blocks placed at the outer end of the structure. The elements develop independently once scouring reaches them and fall down the scouring slope to protect it.

Water Board distinguishes the functional difference between slope protection, which is aimed at erosion prevention from wave attack and bank protection with major goal to protect from current attack. The terms launching or falling apron are used indiscriminately within BWDB and mainly refer to loose elements that are dumped into the river e.g. as toe protection for revetments (bank protection).

All sections subsequently described consist at the shoreline of a 1:3 embankment slope covered by different materials followed by a launching apron of 35 to 50 m length. Thereafter a falling apron of variable length is placed to come to a protected length from the centreline of the embankment up to the outer edge of the falling apron of approximately 84 m.

Each main section in the straight part of the structure is between 80 and 100 meter long.
Construction started at the northern termination point. After excavation the first activities concentrated on installation of the launching apron. Then falling apron and slope protection followed. Finally the crest road and the land sided slope were completed.

Based on the bad experience with labour intensive excavation (head basket method), the contractor employed more equipment and reduced the manual works. One dragline and three excavators (0.6 m^3) were employed with a number of small dump trucks of 6 ton capacity. Placing was done manually or by the help of front-loaders. The machinery in general was old and slow.

7.2.2 Section A

Section A is the northern termination point consisting of a 90° angle with 71.25 m radius to the centreline of the embankment. At the landside a curved termination which slope is covered with brick mattressing and a cc-block apron was executed.

Slope:
The slope protection in Section A-1 consists of brick mattressing placed on geotextile (bidim b7). After levelling of the compacted fill and existing ground down to the apron level the geotextile was placed and the brick laid. Two layers are executed, starting with a flat placed runner in longitudinal direction followed by a flat placed herring bone bond. The total is contained with locally made wiremesh, that is hold together by vertical wire of 30 cm spacing.

In Section A-2 a 23/36 cm thick wiremesh mattress with stone fill of D_{50}=15 cm was built. The geotextile filter is HaTe O 2214. Specific supervision must be made for the wire lacing of the Reno boxes as it ensures the integrity of the whole works.

Launching Apron:
The launching apron consists of concrete blocks 30 cm for the end part and a mixture of 35 and 40 cm thereafter. Placing on the geotextile could only be executed in adding a protective layer on top of the bidim S550. This layer consists of 5 cm of sand followed by 20 cm of khoa and allowed to approach the dumping site with all kinds of vehicles.

The dumping process started chaotically due to the employment of a number of subcontractors for carrying the cc-blocks from the casting yard that was several kilometres away. As mainly power trailers were employed and the subcontractors did not follow a systematic approach but dumped wherever there engines stopped, it took several days to come to a final system that consisted of dumping of blocks in front of the finally placed area, followed by stacking procedure with the help of front-loaders. One access to the site and one departure ramp were built to work in a sequential way and preventing from chaos.

At the transition zone to the falling apron a Dutch envelope was specified, i.e. the geotextile was turned back over the last 3 meters of cc-blocks and finally its end was covered by cc-blocks. This can only reasonably be done, when the cc-blocks are stacked as otherwise the geotextile ruptures.

Falling Apron:
The falling apron consists of different type of rip-rap. The outer part is made of bigger diameter (25 to 45 cm) the inner part of 30 cm boulders. The boulders were stacked to required height. Working was difficult, as boulders of this dimension weight more than 40 kg.

Photo 7.2-1: Section A-1 end
Slope: Brick Mattress
Launching Apron: CC-Blocks

Photo 7.2-2: **Section A-1**
Slope: Brick Mattress
Launching Apron: CC-Blocks

Photo 7.2-3: **Section A-1 end**
Slope: Brick Mattress
Trench for Foot Stabilisation
Launching Apron: CC-Blocks

Photo 7.2-4: **Section A-2**
Slope: Geo-Textile Filter Mat
Foot Stabilisation, CC-Blocks
Launching Apron: CC-Blocks
Falling Apron: Rip-Rap

Photo 7.2-5: **Section A-2**
Slope: Geo-Textile Filter Mat
Wiremesh Mattress (Reno), Boulder Fill
Foot Stabilisation, CC-Blocks
Launching Apron: CC-Blocks

Photo 7.2-6: Section A-2
Slope: Wiremesh Mattress (Reno), Boulder Fill
Launching Apron: CC-Blocks Transition, CC-Blocks
Falling Apron: Rip-Rap

7.2.3 Section B

Following Section A, a transition radius of 200 m with in total 35° angle follows before the structure is straight. The first 25.79° (as designed) are Section B. The rest plus an initial straight part is Section C.

Slope:
The slope protection is the same as in A-2.

Launching Apron:
The falling apron consists of cc-blocks 35 cm. A 15 m wide transition with Section A was made with cc-blocks of 50 cm and of 40 cm respectively to Section C. The total width of the launching apron is 35 m. Here the same methodology as for A was applied.

Falling Apron:
Geo-bags of 180 kg weight were placed here. The bags were made of geotextile 1*1.05 m, folded and sewn together at the sides. Following the inner part was turned outside, so that the seem was in the bag. The bags were filled with local sand from the excavation. This is problematic, as the amount of fines must be controlled to reduce the loss. The O_{90} of type C geotextile used here is 0.09 mm. When filling soil type 4 with d_{60} 0.012 to 0.06 mm into these bags, which is realistic as the top soil tends to be the finest, a direct loss of more that 50 % can be expected. Considering the shape and the turbulent shear layer at the bankline a drastic reduction in lifetime is expected.

The outer 7 meter of the falling apron consist of rip-rap.

Photo 7.2-7: **Section B**
Slope: Wiremesh Mattress (Reno), Boulder Fill
Foot Stabilisation, CC-Blocks
Launching Apron: CC-Blocks

Photo 7.2-8: **Section B**
Slope: Wiremesh Mattress (Reno), Boulder Fill
Foot Stabilisation, CC-Blocks
Launching Apron: CC-Blocks

Photo 7.2-9: **Section B**
Falling Apron:Geo-Textile Sand Containers

Photo 7.2-10: **Section B**
Slope: Wiremesh Mattress (Reno), Boulder Fill
Launching Apron: CC-Blocks
Falling Apron:Geo-Textile Sand Containers
(covered by earth fill)

7.2.4 Section C

Starting in Section C interconnected materials were used for the launching apron.

Slope:
Protection consists of 30 cm concrete blocks, placed diagonally (30° inclined to the horizontal) on the slope. This placing is not recommendable as due to tolerances of the blocks significant gaps occur.

Launching Apron:
Reno mattresses used here consisted of 4 x 2 m boxes separated into four units by diaphragm walls. The boxes are 36 cm high. Under the boxes geotextile sheets were placed: two sheets joint together with 2 m overlap to the next twin sheet.

The Reno mattress is laced together at all edges and corners resulting in a continuous mat. Stone fill with D_{50} of about 20 cm was packed into the boxes. Slope cables, i.e. 12 to 15 mm wire rope were lead through the centre of the box from an anchor pile (dead men) at the toe of the embankment to the outer edge and after 4 m back to the next anchor pile. Thus every 4 m boxes are tightly hold together and additionally anchored at 3 m long piles with 4 m spacing. In transverse direction 3 12 mm cables with 10 m spacing hold together 4 units each. The ends of the wire rope were fixed to a reinforcement bar placed horizontally in the centre of the box. On the transition additional blocks were dumped as supplementary reinforcement to prevent from separation of the two protective layers.

Falling Apron:
Three geo-bags per square meter of 900 kg weight were placed. The bags were filled directly with the excavated soil to prevent from double handling. Once filled a bag could not be moved again. The total width of the apron is 14.5 m.

Photo 7.2-11: Section C
Slope: CC-Blocks (diagonal lines)

Photo 7.2-12: Section C
Slope: CC-Blocks (diagonal lines)
Launching Apron: Wiremesh Mattress (Reno), Boulder Filled
Falling Apron: Geo-Textile Sand Containers
(partly covered by earth fill)

Photo 7.2-13: Section C
Slope: Granular Filter, Khoa
Launching Apron: Wiremesh Mattress
(Reno), Anchor+Anchor Cable

Photo 7.2-14: Section C
Slope: Granular Filter, Khoa
Launching Apron: Wiremesh Mattress (Reno), Anchor+Anchor Cable

7.2.5 Section D

Slope:
The same protection as in Section C was chosen, only that the blocks are placed parallel to the toe.

Launching Apron:
Articulated concrete mattresses, consisting of 25 cm high conical shaped concrete blocks, made with concrete class B25 (stone aggregates) cast in situ were built. After placing of the geotextile, holes for the needles to connect the block with the geotextile were punctured. The needles were bent into a U-shape and the ends turned outwards after positioning. The next step was the arrangement of the shutter and the placing of the slope cables. In the sides of the shutter holes were kept open to allow the slope cables to pass. Concreting was done manually by carrying the concrete with head baskets to the individual shutter. There the concrete was compacted.

At the toe of the embankment 2.5 m long wooden piles were driven in an anchor trench. The slope cables are fixed at a horizontal steel pipe placed behind the wooden piles. The trench was filled with rubble and sand prior to placing of the slope protection.

After some learning time progress was satisfactory.

Falling Apron:
The falling apron consisted of concrete blocks. At the inner part 32 nos. of 40 cm blocks were dumped per square meter on a length of 10 m. Thereafter for on a 5 m wide strip 25 nos. blocks of 30 cm size per square meter followed.

Photo 7.2-15: Section D
Slope: CC-Blocks (parallel lines)
Foot Stabilisation, CC-Blocks
Launching Apron: Articulated CC-Block Mattress

Photo 7.2-16: Section D
Launching Apron: Articulated CC-Block Mattress
Anchor Cables
Falling Apron: CC-Blocks

Photo 7.2-17: **Section D**
Launching Apron: Articulated CC-Block Mattress
Falling Apron:CC-Blocks

Photo 7.2-18: **Section D**
Slope: CC-Blocks (parallel lines)
Launching Apron: Articulated CC-Block Mattress
Falling Apron:CC-Blocks

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Photo 7.2-19: Section D
Slope: Geo-Textile Filter Mat Anchor Trench
Launching Apron: Articulated CC-Block Mattress
Anchor, Cables

Photo 7.2-20: Section D
Launching Apron: Articulated CC-Block Mattress
Anchoring System

7.2.6 Section E

Section E is the first of three sections with cellular geotextile mattresses.

Slope:
On the slope double interlocking concrete slabs were placed.

Photo 7.2-21: Section E
Double Interlocking CC-Slab (Ship-Lap Type)

Launching Apron:
The launching apron consists of a Foreshore cellular geotextile mattress. Prior to filling slope cables (Nylon) have to be attached to increase the bond between adjacent elements. Starting from the falling apron the mats were filled with concrete grout (sand-cement). Into every third cushion a filling hole was cut for the filling process. During pouring of concrete by help of colcrete concrete pressure pump, labour compacted and kneaded the cushions with their feet to obtain a sufficient compaction and degree of filling. Adjacent mats were 3 m overlapped against the flow following suppliers specification. The total width of the mats is 10.2 m thus 30 % additional material are used for placing.

At the toe of the embankment a trench was dug, where the end is dug in. The fill consists of rubble on which the slope protection was placed. Additional reinforcement is done by packing cc blocks on the transition zone to assure a permanent good surface protection also during working of the apron.

Falling Apron:
The falling apron consists of two parts, one 30 m long upstream and one 60 m long downstream part. The upstream part is made of cc blocks of 40 cm at the inner 8 m width (32 Nos/m^2) and of 45 cm at the outer 7 m (25 Nos./m^2). The second alternative consists of 250 kg geo-bags at the inner part (8.4 Nos./m^2)and 900 kg geo-bags at the outer part (6.4 Nos/m^2).

Photo 7.2-22: Section E
Slope: Double Interlocking CC-Slabs (Ship-Lap Type)
Foot Stabilisation, CC-Blocks

Photo 7.2-23: Section E
Launching Apron: Foreshore Cellular Geo-Textile
Mattress Filling with Concrete Grout

Photo 7.2-24: **Section E**
Launching Apron: Filled Foreshore Cellular Geo-Textile Mattress Overlapping

Photo 7.2-25: **Section E**
Launching Apron: Foreshore Cellular Geo-Textile Mattress (Foreground: Slope of Section D)

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7.2.7 Section F

Slope:

The slope is covered by locally made wiremesh mattresses filled with bricks. The mats are directly placed on a geotextile filter. All wiremesh cages are laced together to obtain an interconnected layer. Local wiremesh was used.

Launching Apron:

The launching apron consists of Profix cellular geotextile mats. The mats are filled with sand bitumen fill in the upstream half and only sand in the downstream part. The sand was filled in through funnels with manual pistons, i.e. a long rod with a round plate at the end.

Overlapping of the 6 m wide mats is 2 m against flow onto the 2 m wide woven geotextile sewn to the downstream side of each strip. Thus 33 % more quantities are needed for a reasonably reliable covering of the slope.

Falling Apron:

The falling apron consists of cc blocks 40/45 cm of 20 m width followed by a 12 m wide strip of gabion sacks with stone fill. The gabion sacks were made of wiremesh closed at one side and then filled. After closing the other end they were stacked.

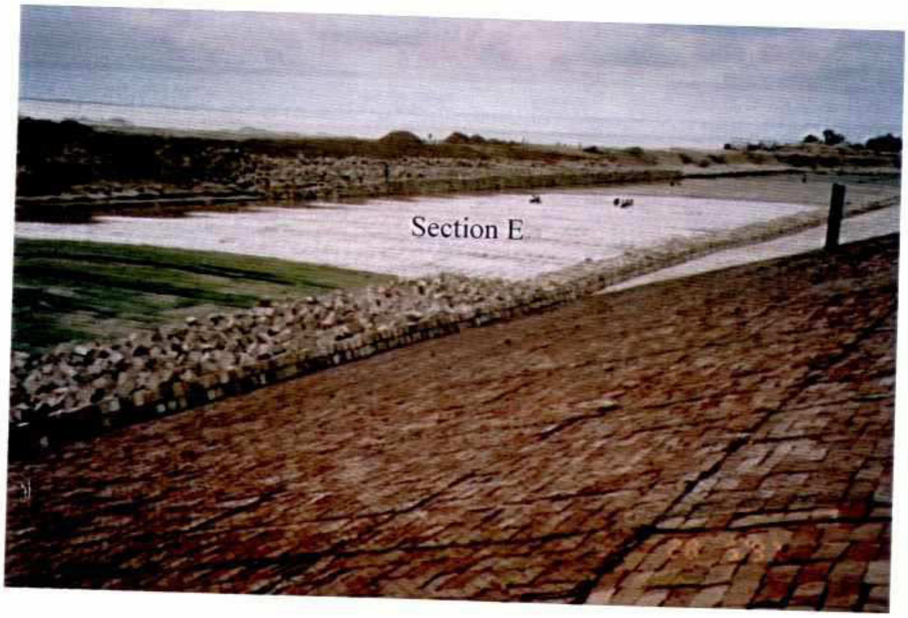

Photo 7.2-25: Section F
Slope: Wiremesh Mattress, Brick Filled
Foot Stabilisation CC-Blocks
Launching Apron:Profix Cellular Geo-Textile Mat
(Background: Section E)

Photo 7.2-26: **Section F**
Launching Apron: Foreshore Cellular Geo-Textile Mattress

Photo 7.2-27: **Section F**
Slope: Wiremesh Mattress, Brick Filled
Foot Stabilisation CC-Blocks
Launching Apron: Profix Cellular Geo-Textile Mattress
Falling Apron:CC-Blocks

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Photo 7.2-28: Section F
Falling Apron:CC-Blocks, Gabion Sacks

7.2.8 Section G

Slope:

A tongue grove type slab made of high quality concrete was used here. The slabs were placed vertically to the slope. Significant difficulties arose from the transport of the slabs as the grove was too sensitive to breakage and a high amount of waste occurred.

Photo 7.2-29: Section G
Slope: Interlocking CC-Slabs (Tongue +Grove Type)

Launching Apron:
Collapsible block mats of type Incomat were placed. The mats are filled with fine sand, dried prior to filling.

Starting from the falling apron the first six meters of the mats was filled. The rest, reaching up to the embankment was gathered up. Filling was done by 6 silos with compressed air intake to blow the sand through the six meter long filling pipes. As the filled mats could not be moved the filling machines retreated towards the embankment and subsequently the protection developed.

Falling Apron:
Concrete blocks of 35 and 40 cm in total 18 Nos/m^2 were placed on a 18 m wide strip followed by an 8 m wide strip of 45 cm cc blocks (18.5 Nos/m^2).

Photo 7.2-30: Section G
Slope: Interlocking CC-Slabs (Tongue + Grove Type)

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Photo 7.2-31: Section G
Launching Apron: Incomat Collapsible Sandflex Mattress
Falling Apron:CC-Blocks

Photo 7.2-32: Section G
Launching Apron: Incomat Collapsible Sandflex Mattress, Sand Filled

Photo 7.2-33: Section G
Launching Apron: Incomat Sandflex Mattress
Falling Apron: CC-Blocks
(Foreground Section H, F.-A.: Selected Boulders)

7.2.9 Section H

Section H is the curved end section consisting of a 90° angle with 50 m radius. Similar to Section A it is divided into two subsections H1 and H2. the total width of protection, measured from the centreline of the embankment is 54 m.

Slope:
The slope is protected by grouted rip rap with D_{50} = 20 cm. As the contractor could not produce collodial cement grout, due to the non-availability of the high speed mixing machines, normal cement grout was chosen. Only the surface is grouted to provide for sufficient bond between the smaller sized stones. Additionally weep holes have been incorporated, as the standard cement grout is practically impermeable.

Launching Apron:
a standard lunching apron of boulder rip rap was placed of 15 m width. The geotextile forms at the end - same as in Section A - a Dutch envelop.

Falling Apron:
The falling apron of average 10 m width consists of the same boulder rip-rap, only at the outer end an additional 7.5 m wide strip of selected bigger sized boulders (35 to 45 cm) is placed.

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Photo 7.2-34: Section H-1, H-2
Slope: Rip-Rap with Stone Pitching (Cement Grouting)

Photo 7.2-35: Section H-2, H-2 end
Slope: Rip-Rap with Stone Pitching (Cement Grouting)
Launching Apron: CC-blocks

Photo 7.2-36: **Section H-1**
Falling Apron:Rip-Rap on Granular Filter

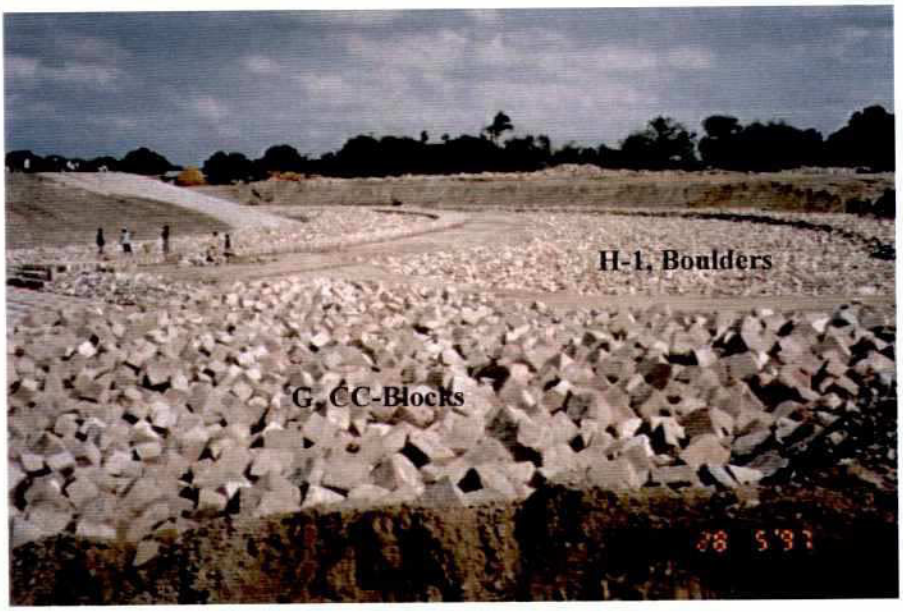

Photo 7.2-37: **Section H-1**
Slope: Rip-Rap with Stone Pitching (Cement Grouting)
Launching Apron: Rip-Rap
Falling Apron: Selected Boulders

7.3 IMPLEMENTATION PLAN

After approval of the final design and test site location the physical works at Test Site II, named after the nearby railway-ferry ghat "Bahadurabad", re-started on 26 of November 1996 with the update of the site installation and execution of earth works. At that time nearly all quantities of cc-blocks had been prefabricate and nearly all supplies had reached the site.
The key data are:

03.07.1996	Decision by Client and Donors to restart the construction works of test site II
07.07.1996	Instruction to the Sub-Contractor to re-mobilize
26.11.1996	Re-start of the works with excavation at Section B and D
31.05.1997	Substantial completion of works
21.07.1997	Hand over of Substantial Completion Certificate to the Sub-Contractor

From Figure 7.3.1 it can be seen that due to the short construction time (dry season window) from November/December to April/May all different works in all section were executed in parallel.

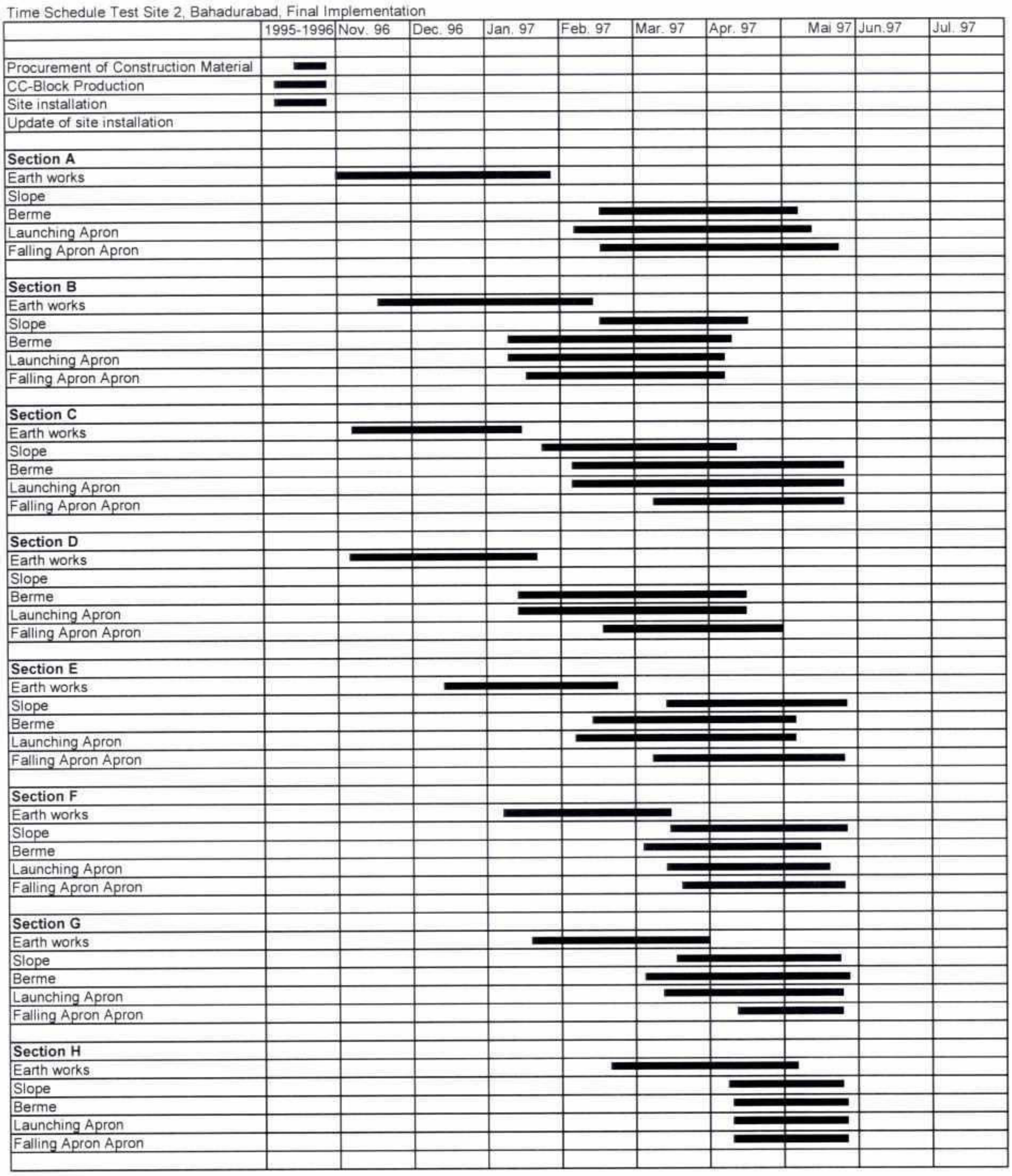

Fig. 7.3-1: Final Implementation Time Schedule

7.4 HIRE OF MAIN EQUIPMENT

In May 1994 the Consultants under their procurement program for test site one concluded a contract for hiring of a 400 ton flat top barge, a 150-ton MANITOWOK crawler crane and mooring winches and a 100 KVA generator installed on the barge. This equipment pack was initially scheduled to continue to work for test site two but was forced to remain mainly at test site no. one for the adaptation works in the dry season of 1995/1996 and 1996/1997. Therefore, all equipment for the execution of test site two was supplied and or hired by the Contractor under his contract.

7.5 SITE INSTALLATION

The site installation layout plans are shown in Figures 7.5-1 to 7.5-3 presenting layouts of general site arrangements as well as the cc-block production yard and Sub-Contractors camp.

The concrete yard for the prefabrication of cc-blocks was located on the flood plain about 300 m downstream of Section H, covering an overall production area of over 35.000.m^2. This included area for brick storage and chipping, washing of aggregates, concrete production as well as storage of produced cc-blocks.

The sub-contractor's general site installations comprised of offices, material testing laboratory, workshops, storerooms, living quarters, which were arranged about 100 meters land-sided behind the construction site area of Section A

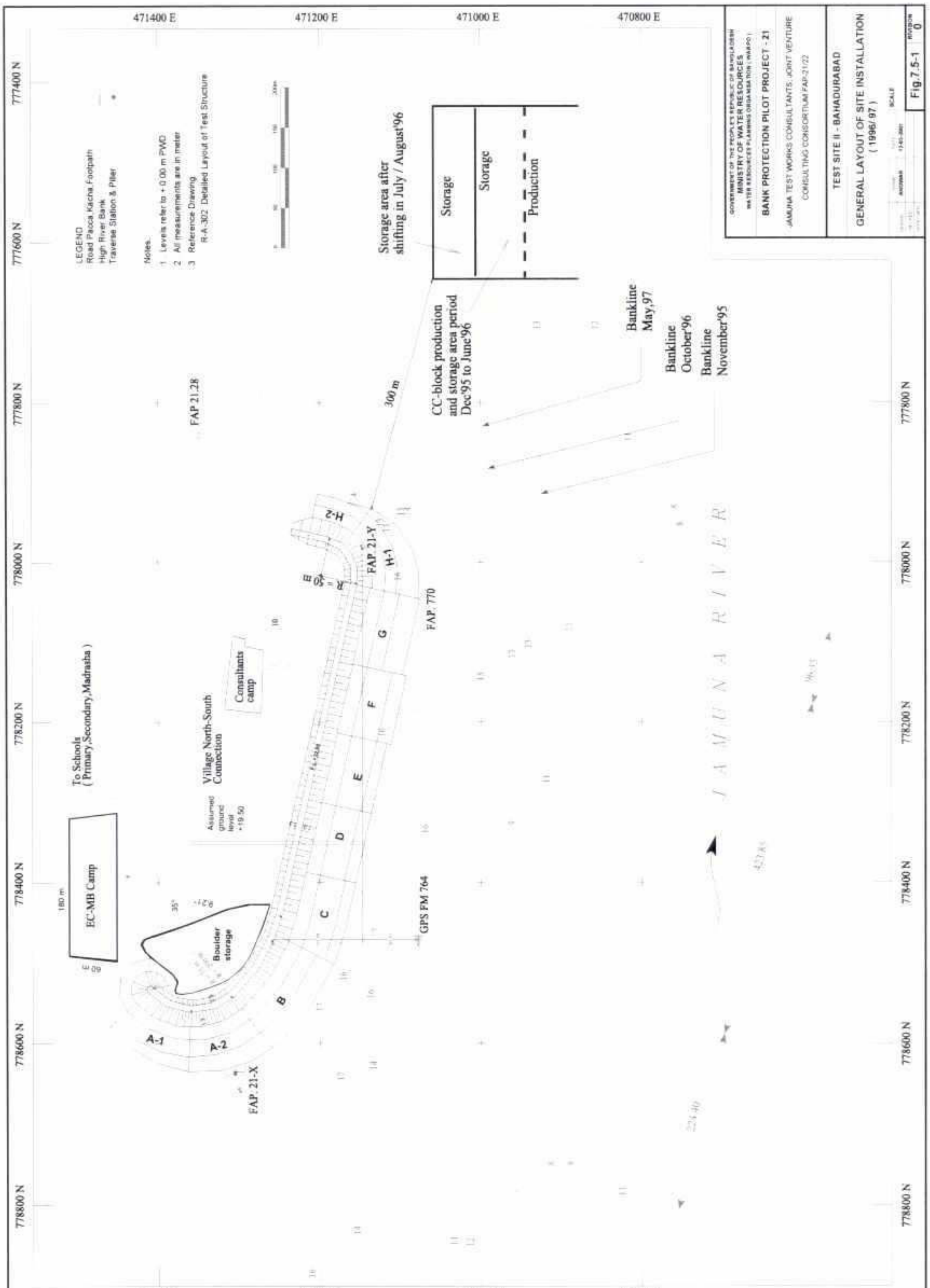

Fig. 7.5-1: General Layout of Site Installation at Bahadurabad

Fig. 7.5-2: General Layout of the CC Block Production Yard

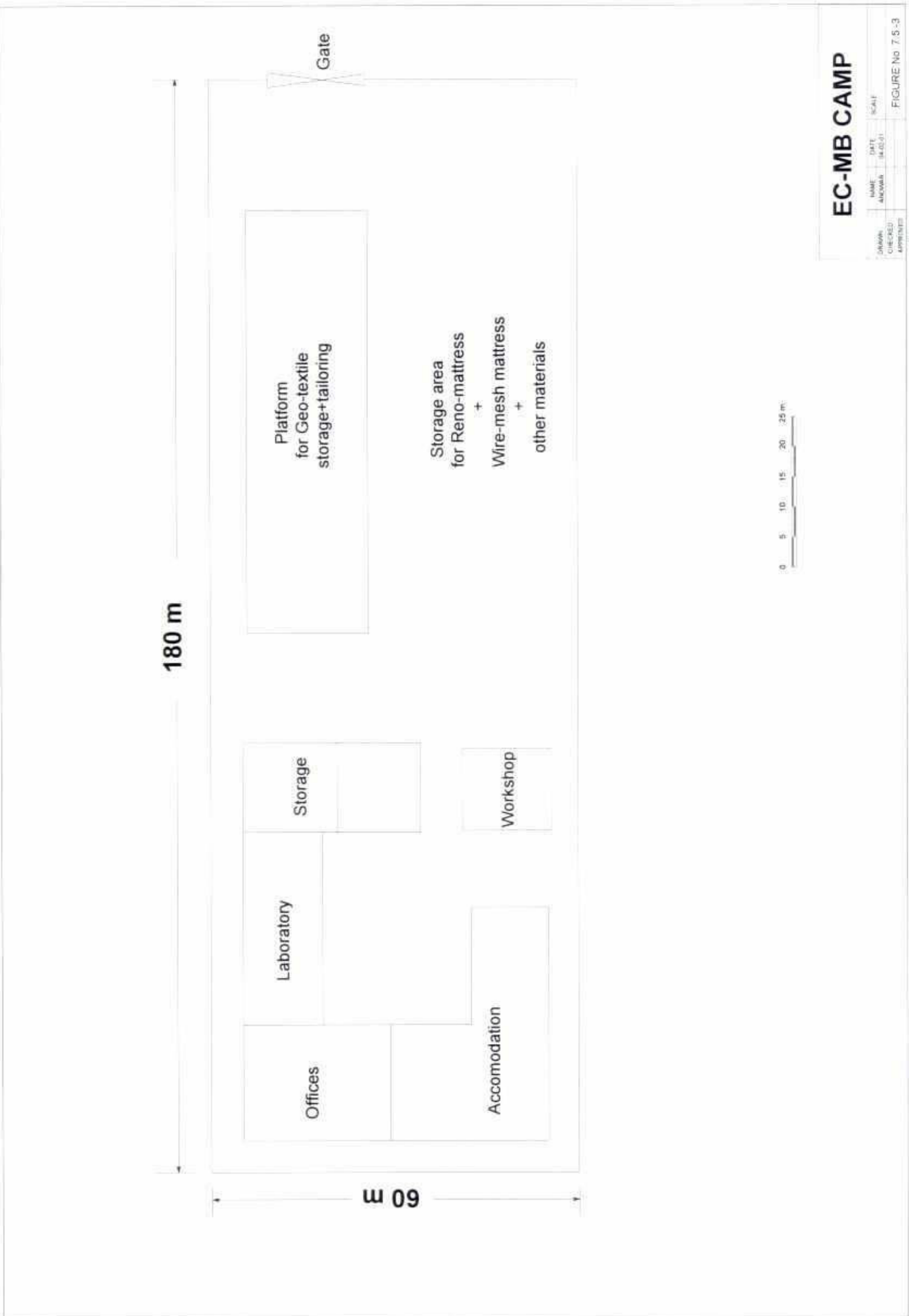

Fig. 7.5-3: General Layout of Sub-Contractors Camp

7.6 EARTH WORKS

7.6.1 General

Due to the bad experience with the labour forces at the first implementation period end of 1995 the Contractor decided to apply mainly for mechanical earth works by bulldozers, excavators, pay-loaders and trucks.

Photo 7.6-1: Manual Earth Works during First Implementation Period 1995/1996

Photo 7.6-2: Manual Earth Works during First Implementation Period 1995/1996

Photo 7.6-3: Mechanical Earth Works during Second Implementation Period 1996/1997 Excavation by Excavator (Backhoe)

Photo 7.6-4: Mechanical Earth Works during Second Implementation Period 1996/1997 Excavation by Excavator (Dragline)

7.6.2 Site Clearance

The site was cleared of all obstacles and remaining from crops by bulldozer.

7.6.3 Construction of Earth Dam

The Embankment was constructed from parts of soil excavated for profiling the aprons. The soil was pushed by bulldozer into profile, later at the upper part with filling by trucks and compacted to design density by passes of bulldozers and loaded trucks. The crest of the embankment was finished with a compacted layer of a khoa-sand mixture. The land sided slope was covered with grass sods on geo-jute soil saver.

Photo 7.6-5: Embankment; Grass Sods on Geo-Jute Soil Saver Mat

**Photo 7.6-6: Embankment;
Crest Finishing with compacted Khoa-Sand Mix**

7.6.4 Construction of Slopes for Launching and Falling Apron

The soil to be excavated for the profiling of the slope for the launching and falling aprons was partly pushed directly by bulldozer into the river and partly excavated by excavators, loaded to trucks and dumped for filling purpose or deposit. The final profile to the sections was made hand. In some areas the existing soil was of very bad quality (water keeping clay lenses) that these parts had to be exchanged with soil of good quality.

7.7 CC-BLOCK PRODUCTION

The total cc-block production was 29,000 m^3.

9,000 m^3 in block size 30x30x30 cm	=	333,300 nos.
8,200 m^3 in block size 35x35x35 cm	=	191,150 nos.
7,000 m^3 in block size 40x40x40 cm	=	109,375 nos.
4,000 m^3 in block size 45x45x45 cm	=	43,900 nos.
800 m^3 in block size 50x50x50 cm	=	6,400 nos.

Placed or dumped at the different sections were in total 597.975 cc-blocks:

6,892 m^3 of 30x30x30 cm block size	=	255,260 nos.
8,081 m^3 of 35x35x35 cm block size	=	188,370 nos.
6,775 m^3 of 40x40x40 cm block size	=	105,860 nos.
3,843 m^3 of 45x45x45 cm block size	=	42,185 nos.
788 m^3 of 50x50x50 cm block size	=	6,300 nos.

The difference of quantities between production and placing/dumping was produced for maintenance and used in 1997/1998 dry season for adaptation works at Section H

The blocks were manufactured in a so-called concreting-bed with steel framework using 2 medium size concrete mixers of 500 litre capacity with winch driven charge bucket. Daily production rate was up to 450 m3. The ready cc-blocks were stored in stock-piles.

Photo 7.7-1: Brick Cutting for Aggregates and Filter Material

Photo 7.7-2: Semi-Automatic Concrete Mixer

Photo 7.7-3: CC-Block Casting

Photo 7.7-4: CC-Block "Transport"

7.8 INSTALLATION OF REVETMENT PROTECTION

Geo textile filter placing was planned that after unrolling (and cutting the sheets to size if necessary) to sew the sheets together by special hand held sewing machines but due to the time pressure, lack of skilled "tailors" and frequent brake down of the sewing machines overlapping was more or less applied. Other wise filter placing whether geo-textile or granular filter was not a problems.

Brick and brick mattress laying is a very common construction method in Bangladesh. However availability of bricks of high quality can create difficulties.

The wire for site made wire mesh mattress was found not very durable due to bad and uneven galvanization.

Photo 7.8-1: Laying Out of Geo-Textile Filter Mat

Photo 7.8-2: Granular Filter Layers (Granular Filter II and III)

Photo 7.8-3: Granular Filter Layer (Khoa)

Photo 7.8-4: Trench between Slope and L.-A. filled with Gravel (here Section G)

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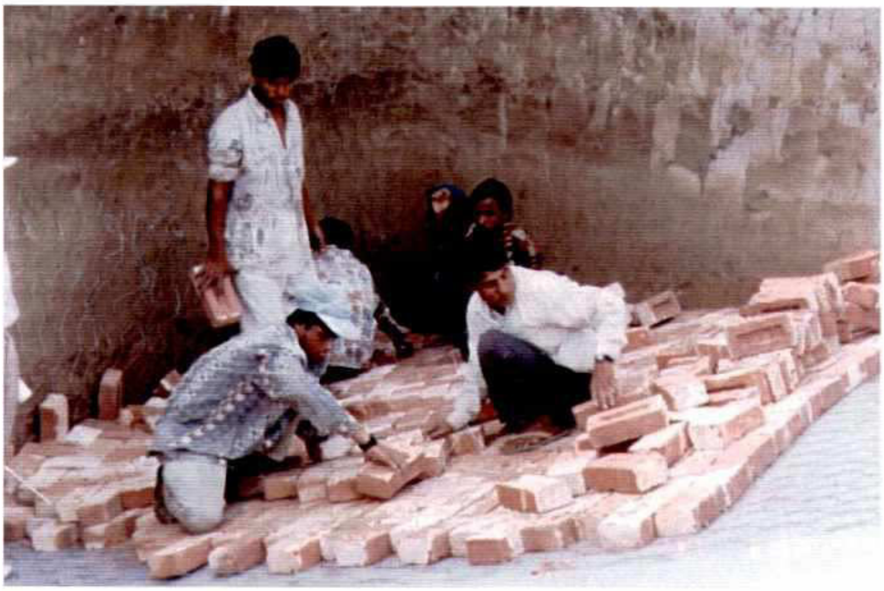

Photo 7.8-5: Brick Mattressing

Photo 7.8-6: Brick Mattressing

Photo 7.8-7: Wiremesh Mattress, Brick Filling

Photo 7.8-8: Wiremesh Mattress, Brick Filling

7.9 INSTALLATION OF BED PROTECTIONS / FALLING APRONS

7.9.1 General

Installation of bed protection generally has not been a problem but due to the huge quantities of material to be installed or placed these parts of the structures were always on the critical path to be finalised before water in the river starts raising.

7.9.2 Reno Mattress, Wire Mesh Mattress (Section A-2 and C)

Attention has to be given to the maximum filling grade and the proper closure of the mattresses as well as to the good tightening of the cables of the anchor system, eventually by minor pre-stressing. Placing of gravel filter and Reno mattress as well as the filling of the gabions was done by hand. The closure of the gabions was done by hand too but with special lacing wire and tools supplied by the manufacturer of the Reno mattress.

Photo 7.9-1: Wiremesh (Reno) Mattress, Boulder Filling

Photo 7.9-2: Wiremesh (Reno) Mattress, Boulder Filling

Photo 7.9-3: Wiremesh (Reno) Mattress, Boulder Filled

Photo 7.9-4: Closing of Wiremesh Mattress

7.9.3 Articulated CC-Block Mattress (Section D)

The placed geo-textile filter mat was punched with steel needles in U-form. The needles were shaped at the open end prior to installation of the concrete forms and the anchor cables. The function of the needles is the good connection of the filter mat with the articulated cc-blocks.

The B25 (DIN 1045) was mixed in a 750 l concrete mixer on a remaining berm at the end of Section C and pumped to the concreting location with a concrete pump.

The installation of the articulated cc-block mattress was time consuming but caused no specific problems.

Photo 7.9-5: **Articulated CC-Block Mattress**
Geo-Textile Filter Mat Needle Punched

Photo 7.9-6: **Articulated CC-Block Mattress**
Casting Form, Trapezoid CC-Blocks, Anchor Cable

Photo 7.9-7: Articulated CC-Block Mattress

Photo 7.9-8: Articulated CC-Block Mattress

7.9.4 Foreshore Collapsible Block Mattress (Section E)

Placing of the Foreshore collapsible block mattress and inserting the slope cables was done by hand without problems.

Filling the mattress with concrete (grouting) with a special colcrete mixer pump caused problems achieving the design filling rate (d=25 cm). Additional filling holes to reduce the filling length and additional pressure by "foot stamping" remedied the matter.

Overlapping against the river flow of the 10.2 m wide mattress was .3 m.

Photo 7.9-9: Foreshore Collapsible Mattress

Photo 7.9-10: Foreshore Collapsible Mattress Filling with Cement Grout (Colcrete)

Photo 7.9-11: Foreshore Collapsible Mattress Filling by "Footstamping"

Photo 7.9-12: Foreshore Collapsible Mattress Cement Grout Filled Cushions

7.9.5 Profix Tubular Mattress (Section F)

One section of the Profix tubular mattress was filled with coarse sand a second part with sand bitumen.

In distances of 6 m a filling steel pipe was inserted through a hole into the tube of the mattress. The filling pipe was fixed with an open and at the bottom to the filling pipe radius shaped steel bucket. With a 6 m long pusher rod with a round steel plate on the top dried coarse sand respectively hot mixed sand bitumen filled into the bucket was pushed into the mattress.

Overlapping against the river flow of the 6 m wide mattress was .0.70 m on a 2 m wide underlapping geo-textile filter mat.

The installation of Profix tubular mattress cause no problems.

Photo 7.9-13: Profix Tubular Mattress

Photo 7.9-14: Drying of Coarse Sand and Mixing of Sand-Bitumen for Filling of Profix Mat

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Photo 7.9-15: Filling of Tube of Profix Mat with Sand-Bitumen

Photo 7.9-16: Filling of Tube of Profix Mat with Coarse Sand

7.9.6 INCOMAT Sand-Flex Mattress (Section G)

The Incomat sand-flex mattress is a mattress of 80 by 120 cm sized articulated cushions. Each 5m wide mattress has 8 cushion tubes connected crosswise with small filter cushions with a drainage hole. It was scheduled to fill the mattress with hydraulic sand fill. But filling test prior to the construction period developed that hydraulic fill is to difficult. New method were developed and tested. The best and applied method was to fill the mattress by high air pressure. The total length of the mattress was ribbed over 6 filling pipes. Each of these filling pipes of 2-inch diameter was connected to a large funnel at its outlet. The funnel was filled with dried coarse sand and the sand was blown into the mattress by high air pressure produced with powerful air compressors (air jetting). Following the filling degree the 8 funnels with their filling pipes were retracted in a row to free the next cushions to be filled. The drainage holes designed for hydraulic fill had been closed by hand with patches of the same material.

With the new method the mattress could be successfully filled in relatively short time.

Photo 7.9-17: Filling of Incomat Collapsible Sandflex Mattress with Dry Coarse Sand By "Air Stream Blasting"

Photo 7.9-18: Filling of Incomat Collapsible Sandflex Mattress with dry Coarse Sand by "Air Stream Blasting"

Photo 7.9-19: Sand Filled Cushion of Incomat Mattress

Photo 7.9-20: Sand Filled Cushion Of Incomat Mattress

7.9.7 Geo-Textile Sand Container (Section B, C, E)

Geo-sand containers have been partly supplied ready-made and partly made from mat material by cutting sewing to size with sewing machines. The containers were filled with sand/earth close to the build-in area. Dumping of the containers was by hand (smaller sizes) and by front-loader. In some parts the large 900 kg containers were filled 'in situ'. The containers were closed after filling by hand made seam.

Photo 7.9-21: Geo-Textile Sand Container (Type E, 900 kg)

Photo 7.9-22: In Situ Filling of Sand Containers

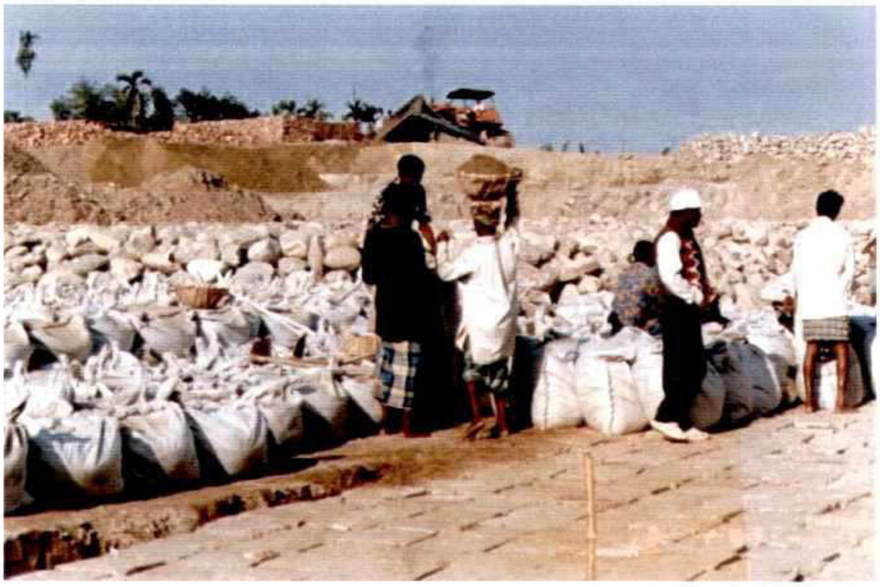

Photo 7.9-23: In Situ Filling of Sand Containers

Photo 7.9-24: In Situ Filling of Sand Containers

7.9.8 Gabion Sacks (Section F)

The ready-made supplied gabion sacks (wire-mash sacks) were filled with stones/boulders grade D50= 15 cm to a size of approximately 0.65 m3 or 1300 kg and dumped at the build-in location by front-loader.

7.9.9 Concrete Blocks (All Sections)

Concrete blocks of all sizes 30 to 50 cm were transported from the far away storage area to the construction site by rickshaw-van, push car, bullock car, tractor with trailer and truck. Depending on the design they were dumped randomly by hand or by front-loader, excavator (bucket) or truck (most falling aprons) or set by hand to the given form (slope protection, launching apron)

7.9.10 Transition Zones

All sections received transition or overlapping zones in longitudinal direction between slope and berm/launching apron, and between launching apron and falling apron, and traverse direction along the edges of the sections always against the river flow.

For details refer to drawings of Attachment 1.

Photo 7.9-25: Transition/Overlapping

Photo 7.9-26: Overlapping (Section E, Foreshore Mattress)

7.10 LABOUR & WORKMANSHIP

During the first construction period the subcontractor faced many problems with the local labours and their leaders. Therefore, they tried as much as possible to use mechanised work, mainly for earth works and dumping of cc-blocks, boulders and geo-textile sand containers. Placing of geo textile filter mats bricks and filling of the geo-textile mattress systems was still done by hand.

An average of 900 workers was employed during the main construction period of February to May 1997.

It is major problem in Bangladesh to employ skilled labour gangs from outside the construction area. The local population, normally jobless except harvest periods, insists strongly or even fight for being employed. Influential local leaders mostly guide them.

8 CONSULTANTS MANAGEMENT AND CONTROL OF THE WORK IMPLEMENTATION

8.1 CONSULTANT AS MAIN CONTRACTOR

The classical role of a Consultant is the planning, design and supervision of structures and construction sites. He is the representative of the employer.

In view of the originality and the character of this project and the fact that bank protection structures of this scale have not been executed in Bangladesh before the Donors created a new concept. In this concept the Consultant is not only the "Employers Representative" but at the same time the "General Contractor" for the works and the test structures.

As General Contractor the Consultant has awarded contracts and subcontracts for procurement and works to local and international suppliers and contractors.

8.2 SPECIALIST SUPPORT

The Consultants arranged specialists to guide and assist the local personnel as well as the management of the local sub-contractors in the under water construction part of the revetments of launching and falling aprons.
Due to the change of the design and the elimination of under water works for the final implementation in 1996/97 the specialist support was abandoned when works were stopped in January 1996.

8.3 CONSULTANTS SITE CAMP

The Consultants/Employer's semi-permanent camp with site office and accommodation was constructed on an area of 3750 m² 70m behind of section F of the structure consists of 2 lounges, 14 accommodation rooms, offices, kitchen and staff facilities.

Total construction and installation costs of the camp was TK 10,841,150

Power supply was by diesel engine generators under the contract for maintenance.

In early 2000 the Rural Power Board of GoB installed a 50 KVA power line up to the village of Kulkandi. Under the project the power line was continued up to the camp in October 2000 with the effect that the contractor could be released from the maintenance contract.

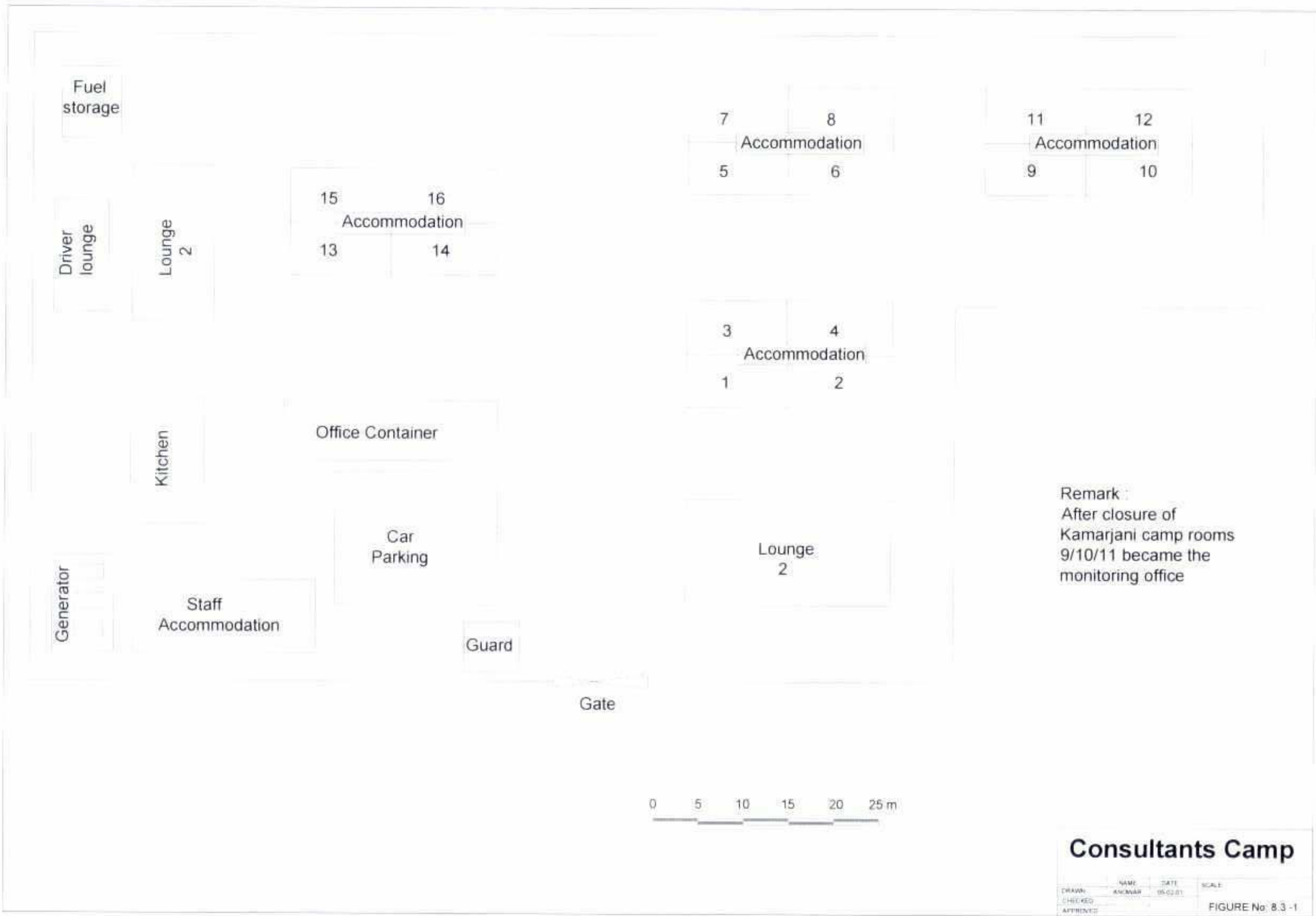

Fig. 8.3-1: General Layout Consultant/Employer's Camp – Test Site II

8.4 COMMUNICATION SYSTEM

Due to the non-availability of telephone connection in the area of test site 2 the same HF and VHF radio link system as described in Annex 5 was continued to use.

In summer 2000 the Company GRAMEEN PHONE established a mobile phone (mobile to mobile only) in a belt ring passing north of the test site area. With a special high mounted antenna the site could access the network and with a second mobile phone in the Dhaka office the phone link was established. This allowed to abandon the HF radio system. The VHF system remained for monitoring purpose.

9 FINANCIAL SUMMARY

9.1 SUMMARY OF OVERALL COST

Details are shown in Table 9.1-1 Costs-Test Site Bahadurabad

9.1.1	Total cost of imported materials:	DM	1,176,972	equivalent to	TK	30,633,739
9.1.2	Total cost of local materials:	TK	52,530,785	equivalent to	DM	1,964,050
9.1.3	Total cost of imported (purchased) equipment: including repair costs	DM	678,947	equivalent to	TK	17,652,633
9.1.4	Total cost of local equipment hire:	TK	10,412,000	equivalent to	DM	374,589
9.1.5	Total cost of construction works, cost of additional works, camp, claims, etc.: (For details ref. to table 9.1-2)	TK	283,120.435	equivalent to	DM	10,621,822
9.1.6	Total cost of specialists:	DM	111,911	equivalent to	TK	2,909,692
9.1.7	Total cost for VAT and Taxes born by G.O.B.:					
	a) VAT and Taxes on imported materials:	TK	84,270,468	equivalent to	DM	3,241,172
	b) VAT and Taxes on imported equipment:	TK	35,400,811	equivalent to	DM	1,361,570
	c) VAT on works (4.5% of contract value):	TK	12,740,420	equivalent to	DM	490,016

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FAP 21 TEST STRUCTURES BAHADURABAD

Total Construction Costs of Test Structure

Description	Amount D.M.	Amount TK.
A. WORKS (Subcontract)		
Construction contract (for details refer to table 9.1.5)	10,621,822	283,120,435
B. Local Procurement & Supply :		
Supply of stones and boulders	1,279,653	33,972,311
Supply of precast concrete slabs	267,241	7,445,490
Supply and stitching of geo-textile bags	77,905	2,124,954
Hiring of equipment	374,589	10,412,000
Port Charges & Demurrage	156,231	4,400,000
Other	183,070	4,588,030
Insurance premium	157,346	4,466,514
Subtotal local	2,496,035	67,409,299
C. Non Local Procurement & Supply :		
Supply of Geo-Textile Filter Material	373,214	9,703,572
Supply of Geo-Textile Sand Containers	282,069	7,333,797
Supply of Geo-Textile Mattresses	395,133	10,305,937
Supply of Material for Gabions	126,555	3,290,432
Supply of Equipment	437,931	11,386,196
Monitoring Equipment and Repair	241,017	6,266,437
Management/Specialist Support	111,911	2,909,692
Subtotal non local	1,967,830	51,196,063
Total	**15,085,687**	**401,725,797**

Table 9.1-1: Summary of Overall Construction Costs , Test Structure Bahadurabad

Test Structures Bahadurabad
Construction Contract Works

1. Costs Construction Contract					
1.1 Costs 1st phase 1995/1996		as per Certificate No 10 September 1996			
1.2 Costs 2nd phase 1996/1997		as per Certificate No 18 June 1997			
		1.1 Costs 1st phase 1995/1996		1.2 Costs 2nd phase 1996/1997	
		costs	loss *	costs	effective costs
		TK	TK	TK	TK
General:					
Clearing		460,605	460,605	349,360	349,360
Mobilization		3,500,000	947,000	947,000	3,500,000
Mob Equipment		15,800,000	1,200,000	1,200,000	15,800,000
Site Laboratory		1,170,000	1,170,000	1,155,000	1,155,000
De-mob				1,080,000	1,080,000
General		225,000		140,000	365,000
	sub total A	21,155,605	3,777,605	4,871,360	22,249,360
Employers Camp					
Construction		9,221,150			
Maintenance		1,260,000	1,260,000	1,620,000	1,620,000
	sub total B	10,481,150	1,260,000	1,620,000	10,841,150
Take over of Material					
Geo-textile		553,325			
Bricks		- 994,600			
Boulders				1,985,400	1,985,400
Other		30,000		60,000	90,000
	sub total C	- 411,275	-	2,045,400	1,634,125
Works:					
Earth Works		18,491,034	18,491,034	25,240,754	25,240,754
CC blocks production		90,763,000			90,763,000
Revetment works				58,154,584	58,154,584
Maintenance					-
	sub total D	109,254,034	18,491,034	83,395,338	174,158,338
	Total-1	140,479,514	23,528,639	91,932,098	208,882,973
Rebate	1%	- 1,404,795	- 235,286	- 919,321	- 2,088,830
	Total-2	139,074,719	23,293,353	91,012,777	206,794,143
Variation orders		6,426,697		22,030,899	28,457,596
Dayworks		107,923		107,923	215,846
	Total-3	145,609,339	23,293,353	113,151,599	235,467,585
Claims		-	0	8,000,000	8,000,000
	Total-4	145,609,339	23,293,353	121,151,599	243,467,585
Maintenance+Monitoring 6/97 to 6/98				16,359,497	16,359,497
	Total-5	145,609,339	23,293,353	137,511,096	122,316,032

	costs phase I and II	**loss ***	**effective costs #**
Grand Total-1	232,411,612	23,528,639	208,882,973
Grand Total-2	230,087,496	23,293,353	206,794,143
Grand Total-3	258,760,938	23,293,353	235,467,585
Grand Total-4	266,760,938	23,293,353	243,467,585
Grand Total-5	**283,120,435**	**23,293,353**	**259,827,082**

* non recoverable loss due to one year interruption and shifting of implementation area

\# does not reflect the "net as built costs" due to change in design and non-use of procured material and equipment

Table 9.1-2: Cost analysis for the Construction Contract

9.2 ANALYSES OF PROJECT COST

In the following tables a breakdown of costs is given for the revetment test structure. The tables show the net construction costs for the "as built" situation including the supply of material by the employer. General costs like site installation, employer's camp and equipment supplied by the employer are added (approximately pro rata of total area of construction surface per section) at the end of each table.

General costs are TK 22,249,360, camp costs are TK 10,841,150, total = TK 33,090,510.
Total surface of the structure is approximately 73,000 m^2, that means that the general costs are 453.29 TK/m^2.

The costs for the first construction period, surplus material and equipment are not included.

Tables 9.2-1 to 9.2-15 show the effective construction costs for each section A-1 end 1 up to H-2 end.

Table 9.2-16 shows the summary of the construction costs

Total Cost Assessment Section A-1 end 1					Page 1
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure A-1 end 1 **Upstream Termination l = 31.30 m**				
	(A) Earth works				
1	(a) Top soil removal	m^2	375	6	2,250
	(b) Excavation, direct placing and compaction	m^3	-	95	-
	(c) Excavation and disposal	m^3	2,000	60	120,000
	(d) Filling for embankment	m^3	1,080	100	108,000
	Sub-total (A)				**230,250**
	(B) Above Berm Level				
2	Geotextile filter mat BIDIM b7 (GF-1)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	535	57	30,481
	(b) Transport to Site	t	0.18	3,000	540
	(c) Placing of BIDIM b7	m^2	465	12	5,580
	Sub-total (2)				36,601
3	Brick mattress, height 15 cm, double layer, tying, complete	m^2	372	550	204,600
	Sub-total (3)				
	Sub-total (B)				**241,201**
	Total Cost Section A-1 end 1				***471,451***
	General costs pro rata of surface of section	m^2	370	453.29	167,719
	Grand Total Section A-1 end 1				**639,170**

Table 9.2-1: Total Cost Assessment Section A-1 end 1

Total Cost Assessment Section A-1 end 2					Page 1
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure A-1 end 2 **Upstream Termination l = 56.35 m**				
1	**(A) Earth works**				
	(a) Top soil removal	m²	2,500	6	15,000
	(b) Excavation, direct placing and compaction	m³	1,780	95	169,100
	(c) Excavation and disposal	m³	4,100	60	246,000
	(d) Filling for embankment	m³	1,940	100	194,000
	(e) Re-filling over aprons	m³	11,925	85	1,013,625
	Sub-total (A)				**1,637,725**
	(B) Above Berm Level				
2	Geotextile filter mat a) BIDIM b7 b) HaTe 02214				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m²	963	57	54,865
	(b) Supply c&f Chittagong (incl. 15% wastage)	m²	963	262	252,188
	(c) Transport to Site	t	1.20	3,000	3,600
	(d) Placing of BIDIM b7	m²	837	12	10,044
	(e) Placing of HaTe 02215	m²	837	25	20,925
	Sub-total (2)				341,622
3	Brick mattress, height 15 cm, double layer, tying, complete	m²	668	550	367,400
	Sub-total (3)				367,400
	Sub-total (B)				**709,022**
	(C) Berm, Launching Apron				
4	Geotextile filter mat a) BIDIM b7 b) HaTe 02214				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m²	2,974	57	169,512
	(b) Supply c&f Chittagong (incl. 15% wastage)	m²	2,974	293	871,353
	(c) Transport to Site	t	3.68	3,000	11,025
	(d) Placing of BIDIM b7	m²	2,586	12	31,032
	(e) Placing of HaTe 02214	m²	2,586	25	64,650
	Sub-total (4)				1,147,572
5	Concrete blocks, size 30*30*30 cm.				
	(a) Production	m³	960	3,400	3,264,000
	(b) Dumping	m²	960	370	355,200
	Sub-total (5)				3,619,200
	Sub-total (C)				**4,766,772**
	Total Cost Section A-1 end 2				**7,113,519**
	General costs pro rata of surface of section	m²	2,400	453.29	1,087,907
	Grand Total Section A-1 end 2				**8,201,427**

Table 9.2-2: Total Cost Assessment Section A 1 end 2

Total Cost Assessment Section A-1					Page 1 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure A-1 **Upstream Termination l = 74.90 m**				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	3,150	6	18,900
	(b) Excavation, direct placing and compaction	m^3	2,370	95	225,150
	(c) Excavation and disposal	m^3	29,643	60	1,778,580
	(d) Filling for embankment	m^3	2,590	100	259,000
	(e) Re-filling over aprons	m^3	16,250	85	1,381,250
	Sub-total (A)				**3,662,880**
	(B) Above Berm Level				
2	Geotextile filter mat BIDIM b7 (GF-1)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	1,932	57	110,124
	(b) Transport to Site	t	0.65	3,000	1,941
	(c) Placing of BIDIM b7	m^2	1,680	12	20,160
	Sub-total (2)				132,225
3	Brick mattress, height 15 cm, double layer, tying, complete	m^2	1,461	550	803,550
	Sub-total (B)				**935,775**
	(C) Berm, Launching Apron				
4	Geo-textile filter mat BIDIM S 550 (GF-2)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	5,175	94	486,450
	(b) Transport to Site	t	2.85	3,000	8,538
	(c) Placing of BIDIM S 550	m^2	4,500	12	54,000
	Sub-total (5)				548,988
5	Concrete blocks, size 30*30*30 cm.				
	(a) Production	m^3	1,965	3,400	6,681,000
	(b) Dumping	m^3	1,965	370	727,050
	Sub-total (6)				7,408,050
	Sub-total (C)				**7,957,038**

Table 9.2-3: Total Cost Assessment Section A 1

Total Cost Assessment Section A-1					Page 2 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	(D) Transition LA-FA				
6	Concrete blocks, size 30*30*30 cm,				
	(a) Production	m^3	300	3,400	1,020,000
	(b) Dumping	m^2	300	370	111,000
	Sub-total (D)				**1,131,000**
	(E) Falling Apron				
7	Concrete blocks, size 35*35*35 cm,				
	(a) Production **)	m^3	860	3,400	2,924,000
	(b) Dumping	m^3	860	420	361,200
	Sub-total (8)				3,285,200
8	Concrete blocks, size 40*40*40 cm,				
	(a) Production	m^3	617	3,400	2,097,800
	(b) Dumping	m^3	617	425	262,225
	Sub-total (9)				2,360,025
	Sub-total (E)				**5,645,225**
	Total Cost Section A-1				**19,331,918**
	General costs pro rata of surface of section	m^2	6,040	453.29	2,737,900
	Grand Total Section A-1				**22,069,818**

Table 9.2-3 (continued): Total Cost Assessment Section A 1

Total Cost Assessment Section A-2					Page 1 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure A-2 **Upstream Termination l = 74.90 m**				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	3,150	6	18,900
	(b) Excavation, direct placing and compaction	m^3	2,370	95	225,150
	(c) Excavation and disposal	m^3	23,581	60	1,414,860
	(d) Filling for embankment	m^3	2,590	100	259,000
	Sub-total (A)				**1,917,910**
	(B) Above Berm Level				
2	Geotextile filter mat Hate O 2214 (GF-5)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	2,760.00	262	723,120
	(b) Transport to Site	t	2.48	3,000	7,452
	(c) Placing of Hate O 2214	m^2	2,400	25	60,000
	Sub-total (2)				790,572
3	Reno-mattress, height 23 cm				
	(a) Supply c&f Chittagong	Nos.	78	1,849	144,222
	(b) Transport to Site	t	2.46	3,000	7,380
	(c) Placing	m^2	624	30	18,720
	Sub-total (3)				170,322
4	Wire-mesh mattress, height 23 cm and 36 cm, to be supplied, assembled, positioned and secured in place	m^2	976	300	292,800
5	Stones, Grading range B, D_{50} = 15cm				
	(a) Supply and stockpiled at Burimari	m^3	406	900	365,400
	(b) Transport to Site	m^3	406	900	365,400
	(c) Filling into prepared wire-mesh mattress	m^3	406	450	182,700
	Sub-total (5)				1,206,300
	Sub-total (B)				**2,167,194**

Table 9.2-4: Total Cost Assessment Section A 2

Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Total Cost Assessment Section A-2				Page 2 of 2
	(C) Berm, Launching Apron				
6	Geo-textile filter mat BIDIM S 550 (GF-2)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	5,175.00	94	486,450
	(b) Transport to Site	m^3	2.85	3,000	8,538
	(c) Placing of BIDIM S 550	m^2	4,500	12	54,000
	Sub-total (7)				548,988
7	Concrete blocks, size 35*35*35 cm.				
	(a) Production	m^3	3,392	3,400	11,532,800
	(b) Dumping	m^3	3,392	370	1,255,040
	Sub-total (8)				12,787,840
	Sub-total (C)				**13,336,828**
	(D) Transition LA-FA				
8	Concrete blocks, size 30*30*30 cm.				
	(a) Production	m^3	300	3,400	1,020,000
	(b) Dumping	m^3	300	370	111,000
	Sub-total (9)				1,131,000
	Sub-total (D)				**1,131,000**
	(E) Falling Apron				
9	Rip-rap, Grading Range E, D_{50} = 30 cm				
	(a) Supply and stockpiled at Burimari	m^3	2,602	900	2,341,800
	(b) Transport to Site	m^3	2,602	900	2,341,800
	(c) Placing	m^3	2,602	370	962,740
	Sub-total (10)				5,646,340
10	Rip-rap, Grading Range F, D_{50} = 35 cm				
	(a) Supply and stockpiled at Burimari	m^3	1,582	900	1,423,800
	(b) Transport to Site	m^3	1,582	900	1,423,800
	(c) Filling into prepared wire-mesh mattress	m^3	1,582	370	585,340
	Sub-total (11)				3,432,940
	Sub-total (E)				**9,079,280**
	Total Cost Section A-2				**27,632,212**
	General costs pro rata of surface of section	m^2	6,900	453.29	3,127,733
	Grand Total Section A-2				**30,759,945**

Table 9.2-4 (continued): Total Cost Assessment Section A 2

Total Cost Assessment Section B					Page 1 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure B **Upstream Termination l = 99.40 m**				
1	**(A) Earth works**				
	(a) Top soil removal	m^3	4,175	6	25,050
	(b) Excavation, direct placing and compaction	m^3	3,140	95	298,300
	(c) Excavation and disposal	m^3	45,437	60	2,726,220
	(d) Filling for embankment	m^3	3,425	100	342,500
	(e) Soil filling for slope, anchor, others	m^3	2,585	85	219,725
	Sub-total (A)				**3,611,795**
	(B) Above Berm Level				
2	Geotextile filter mat BIDIM S 550				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	3,072	94	288,735
	(b) Transport Chittagong to Site	t	1.69	3,000	5,067
	(c) Placing of BIDIM S 550	m^2	2,671	12	32,052
	Sub-total (2)				325,854
3	Rubble, Grading range 12 mm to 75 mm, to Be supplied and placed	m^3	803	1,800	1,445,400
4	Wire-mesh mattress, height 23+36 cm, To be supplied, assembled, positioned and secured in place	m^2	2,344	300	703,200
5	Stone, Grading Range B, D_{50} = 15 cm				
	(a) Supply and stockpiled at Burimari	m^3	582	900	523,800
	(b) Transport to Site	m^3	582	900	523,800
	(c) Filling into prepared wire-mesh mattress	m^3	582	450	261,900
	Sub-total (5)				1,309,500
	Sub-total (B)				**3,783,954**
	(C) Berm, Launching Apron				
6	Geo-textile filter mat Hate K 251 (GF-4)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	7,504	105	786,018
	(b) Transport Chittagong to Site	t	5.63	3,000	16,884
	(c) Placing of Hate K 251	m^2	6,525	12	78,300
	Sub-total (6)				881,202

Table 9.2-5: Total Cost Assessment Section B

Total Cost Assessment Section B					Page 2 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
7	Launching apron by dumped concrete blocks size 35*35*35 cm				
	(a) Production	m^3	2,850	3,400	9,690,000
	(b) Dumping	m^3	2,850	420	1,197,000
	Sub-total (7)				10,887,000
8	Launching apron by dumped concrete blocks size 40*40*40 cm				
	(a) Production	m^3	630	3,400	2,142,000
	(b) Dumping	m^3	630	420	264,600
	Sub-total (8)				2,406,600
9	Launching apron by dumped concrete blocks size 50*50*50 cm				
	(a) Production	m^3	788	3,400	2,679,200
	(b) Dumping	m^3	788	425	334,900
	Sub-total (9)				3,014,100
	Sub-total (C)				**17,188,902**
	(D) Transition LA-FA				
10	Concrete blocks, size 35*35*35 cm				
	(a) Production	m^3	737	3,400	2,505,800
	(b) Dumping	m^3	737	425	313,225
	Sub-total (D)				**2,819,025**
	(E) Falling Apron				
11	Geo-textile containers Type C (180kg), BIDIM b777				
	(a) Supply c&f Chittagong				
	(incl. thread and 15% wastage)	m^2	36,000	60	2,160,000
	(b) Transport Chittagong to Site	t	11.20	3,000	33,600
	(c) Cutting and sewing at Site	Nos.	15,603	40	624,120
	(d) Filling and sealing	Nos.	15,603	12	187,236
	Sub-total (11)				3,004,956
12	Geo-textile containers Type D (250kg), AD 1600				
	(a) Supply c&f Chittagong				
	(incl. thread and 15% wastage)	m^2	19,250	97	1,867,250
	(b) Transport Chittagong to Site	t	10.50	3,000	31,500
	(c) Cutting and sewing at Site	Nos.	5,850	40	234,000
	(d) Filling and sealing	Nos.	5,850	20	117,000
	Sub-total (12)				2,249,750

Table 9.2-5 (continued): Total Cost Assessment Section B

Total Cost Assessment Section B					Page 3 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
13	Falling apron of sand containers Type C, placing, dumping	Nos.	15,603	16	249,648
14	Falling apron of sand containers Type D, placing, dumping	Nos.	5,850	25	146,250
	Sub-total (E)				**5,650,604**
	Total Cost Section B				**33,054,280**
	General costs pro rata of surface of section	m^2	8,600	453.29	3,898,334
	Grand Total Section B				**36,952,614**

Table 9.2-5 (continued): Total Cost Assessment Section B

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Total Cost Assessment Section C-1					Page 1 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure C-1, l = 46.60(34.95+11.65)				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	1,960	6	11,760
	(b) Excavation and direct placing, compaction	m^3	1,475	95	140,125
	(c) Excavation and disposal	m^3	17,950	60	1,077,000
	(d) Filling for embankment	m^3	1,600	100	160,000
	(e) Soil filling for slope, anchor, others	m^3	1,200	85	102,000
	Sub-total (A)				**1,490,885**
	(B) Above Berm Level				
2	Granular filter grading range Type II, to be provided, complete	m^3	365	1,375	501,875
3	Granular **gravel/stone** filter, grading range Type III, to be provided, complete	m^3	391	2,200	860,200
4	Concrete blocks, size 30*30*30 cm,				
	(a) Production	m^3	252	3,400	856,800
	(b) Placing in diagonal lines	m^3	252	350	88,200
	Sub-total (5)				945,000
	Sub-total (B)				**2,307,075**
	C) Berm, Launching Apron				
5	Granular filter grading range Type II, to be provided, complete (joint reinforcement)	m^3	113	1,375	155,375
6	Granular gravel/stone filter, grading range Type III, to be provided, complete (joint reinforcement)	m^3	138	2,200	303,600
7	Geo-textile filter mat DATEX AD 1600 (GF-2)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	3,486.80	89	309,454
	(b) Transport Chittagong to Site	t	2.09	3,000	6,276
	(c) Placing of DATEX AD 1600	m^2	3,032	12	36,384
	Sub-total (9)				352,114

Table 9.2-6: Total Cost Assessment Section C-1

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Total Cost Assessment Section C-1					Page 2 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
8	Reno-mattress, height 23 cm				
	(a) Supply c&f Chittagong	Nos.	80	1,849	147,920
	(b) Transport Chittagong to Site	t	2.52	3,000	7,560
	(c) Placing	m²	622	30	18,660
	Sub-total (10)				174,140
9	Reno-mattress, height 36 cm				
	(a) Supply c&f Chittagong	Nos.	196	2,090	409,640
	(b) Transport Chittagong to Site	t	7.39	3,000	22,170
	(c) Placing	m²	1,694	30	50,820
	Sub-total (11)				482,630
10	Wire-mesh mattresses, height 23 cm, supplied, assembled, positioned, secured	m²	528	300	158,400
11	Anchorage of mattress, incl. deadmen, cable clamps, fittings, complete	Set	12	21,600	259,200
	Sub-total (C)				**1,885,459**
	(D) Transition and overlapping				
12	Wire-mesh mattresses, height 23 cm, supplied, assembled, positioned, secured	m²	416	300	124,800
13	Stone, Grading Range B, D_{50} = 15 cm				
	(a) Supply and stockpiled at Burimari	m³	150	900	135,000
	(b) Transport to Site	m³	150	900	135,000
	(c) Filling into prepared wire-mesh mattress	m³	150	450	67,500
	Sub-total (15)				462,300
	Sub-total (D)				**587,100**

Table 9.2-6 (continued): Total Cost Assessment Section C-1

Total Cost Assessment Section C-1					Page 3 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	(E) Falling Apron				
14	Geo-textile containers Type E (900kg), AD 1600				
	(a) Supply c&f Chittagong				
	(incl. thread and 15% wastage)	m^2	13,400	91	1,216,050
	(b) Transport Chittagong to Site	t	14	3,000	42,000
	(c) Cutting and sewing at Site	Nos.	2,280	45	102,600
	(d) Filling and sealing	Nos.	2,280	195	444,600
	Sub-total (17)				1,805,250
15	Falling apron of sand containers Type E, placing, dumping	Nos.	2,280	60	136,800
	Sub-total (E)				**1,942,050**
	Total Cost Section C-1				**8,212,569**
	General costs pro rata of surface of section	m^2	4,050	453.29	1,835,844
	Grand Total Section C-1				**10,048,412**

Table 9.2-6 (continued): Total Cost Assessment Section C-1

Total Cost Assessment Section C-2					Page 1 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure C-2, l = 46.60 (57.85-11.65)				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	1,960	6	11,760
	(b) Excavation and direct placing, compaction	m^3	1,475	95	140,125
	(c) Excavation and disposal	m^3	17,950	60	1,077,000
	(d) Filling for embankment	m^3	1,600	100	160,000
	(e) Soil filling for slope, anchor, others	m^3	1,200	85	102,000
	Sub-total (A)				**1,490,885**
	(B) Above Berm Level				
2	Granular **stone** filter grading range Type II, to be provided, complete	m^3	478	1,375	657,250
3	Granular **Khoa** filter, grading range Type II, to be provided, complete	m^3	334	1,000	334,000
4	Concrete blocks, size 30*30*30 cm,				
	(a) Production	m^3	252	3,400	856,800
	(b) Placing in diagonal lines	m^3	252	350	88,200
	Sub-total (5)				945,000
5	Toe protection by cc-blocks 30*30*30 cm				
	(a) Production	m^3	135	3,400	459,000
	(b) Placing	m^3	135	370	49,950
	Sub-total (6)				508,950
	Sub-total (B)				**2,445,200**
	C) Berm, Launching Apron				
6	Granular filter grading range Type II, to be provided, complete (joint reinforcement)	m^3	113	1,375	155,375
7	Granular gravel/stone filter, grading range Type III, to be provided, complete (joint reinforcement)	m^3	138	2,200	303,600
8	Geo-textile filter mat DATEX AD 1600				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	3,168.25	89	281,182
	(b) Transport Chittagong to Site	t	1.90	3,000	5,700
	(c) Placing of DATEX AD 1600	m^2	2,755	12	33,060
	Sub-total (9)				319,942

Table 9.2-7: Total Cost Assessment Section C-2

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Total Cost Assessment Section C-2					Page 2 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
9	Reno-mattress, height 23 cm				
	(a) Supply c&f Chittagong	Nos.	80	1,849	147,920
	(b) Transport Chittagong to Site	t	2.52	3,000	7,560
	(c) Placing	m^2	760	30	22,800
	Sub-total (10)				178,280
10	Reno-mattress, height 36 cm				
	(a) Supply c&f Chittagong	Nos.	196	2,090	409,640
	(b) Transport Chittagong to Site	t	7.39	3,000	22,170
	(c) Placing	m^2	1,348	30	40,440
	Sub-total (11)				472,250
11	Wire-mesh mattresses, height 23 / 36 cm, supplied, assembled, positioned, secured	m^2	528	300	158,400
12	Anchorage of mattress, incl. deadmen, cable clamps, fittings, complete	Set	12	21,600	259,200
13	Stone, Grading Range B, D_{50} = 25 cm				
	(a) Supply and stockpiled at Burimari	m^3	901	900	810,900
	(b) Transport to Site	m^3	901	900	810,900
	(c) Filling into prepared wire-mesh mattress	m^3	901	450	405,450
	Sub-total (14)				2,027,250
	Sub-total (C)				**3,874,297**
	(D) Transition and overlapping				
14	Wire-mesh mattresses, height 23 cm, supplied, assembled, positioned, secured	m^2	416	300	124,800
15	Stone, Grading Range B, D_{50} = 15 cm				
	(a) Supply and stockpiled at Burimari	m^3	150	900	135,000
	(b) Transport to Site	m^3	150	900	135,000
	(c) Filling into prepared wire-mesh mattress	m^3	150	450	67,500
	Sub-total (16)				337,500
	Sub-total (D)				**462,300**

Table 9.2-7 (continued): Total Cost Assessment Section C-2

Total Cost Assessment Section C-2					Page 3 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	(E) Falling Apron				
16	Geo-textile containers Type E (900kg), AD 1600				
	(a) Supply c&f Chittagong				
	(incl. thread and 15% wastage)	m^2	13,400	91	1,216,050
	(b) Transport Chittagong to Site	t	14	3,000	42,000
	(c) Cutting and sewing at Site	Nos.	2,187	45	98,415
	(d) Filling and sealing	Nos.	2,187	195	426,465
	Sub-total (17)				1,782,930
17	Falling apron of sand containers Type E, placing, dumping	Nos.	2,187	60	131,220
	Sub-total (E)				**1,914,150**
	Total Cost Section C-2				**10,186,832**
	General costs pro rata of surface of section	m^2	3,960	453.29	1,795,047
	Grand Total Section C-2				**11,981,879**

Table 9.2-7 (continued): Total Cost Assessment Section C-2

Total Cost Assessment Section D					Page 1 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure D, l = 88 m				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	3,700	6	22,200
	(b) Excavation and direct placing, compaction	m^3	2,780	95	264,100
	(c) Excavation and disposal	m^3	29,088	60	1,745,280
	(d) Filling for embankment	m^3	3,030	100	303,000
	(e) Soil filling for slope, anchor, others	m^3	2,300	85	195,500
	Sub-total (A)				**2,530,080**
	(B) Above Berm Level				
2	Geotextile filter mat BIDIM S 550 (GF-2)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	3,466.10	91	316,282
	(b) Transport Chittagong to Site	t	2	3,000	6,000
	(c) Placing of BIDIM S 550	m^2	3,014	12	36,168
	Sub-total (2)				358,450
3	Concrete blocks, size 30*30*30 cm,				
	(a) Production	m^3	531	3,400	1,805,400
	(b) Placing in single parallel lines	m^3	531	350	185,850
	Sub-total (3)				1,991,250
4	Granular filter grading range Type II, To be provided, complete (Anchor trench)	m^3	145	1,375	199,375
5	Granular filter grading range Type III, To be provided, complete (Anchor trench)	m^3	132	2,200	290,400
6	Toe protection by cc-blocks 30*30*30 cm				
	(a) Production	m^3	269	3,400	914,600
	(b) Placing	m^3	269	350	94,150
	Sub-total (6)				1,008,750
	Sub-total (B)				**3,848,225**
	(C) Berm, Launching Apron				
7	Geo-textile filter mat BIDIM S 700 (GF-4)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	7,331.25	116	850,938
	(b) Transport Chittagong to Site	t	5.13	3,000	15,396
	(c) Placing of BIDIM S 700	m^2	6,375	12	76,500
	Sub-total (5)				942,834
8	Concrete Class B 25, for articulated cc-block mattress, incl. In situ casting of cc-blocks	m^3	627	7,000	4,389,000

Table 9.2-8: Total Cost Assessment Section D

Total Cost Assessment Section D					Page 2 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
9	Anchorage of mattress, incl. deadmen, cable clamps, fittings, complete	Nos.	4,673	320	1,495,360
	Sub-total (C)				**6,827,194**
	(E) Falling Apron				
10	Concrete blocks, size 40*40*40 cm,				
	(a) Production	m^3	1,820	3,400	6,188,000
	(b) Dumping	m^3	1,820	425	773,500
	Sub-total (10)				6,961,500
11	Concrete blocks, size 45*45*45 cm,				
	(a) Production	m^3	1,002	3,400	3,406,800
	(b) Dumping	m^3	1,002	425	425,850
	Sub-total (11)				3,832,650
	Sub-total (E)				**10,794,150**
	Total Cost Section D				**23,999,649**
	General costs pro rata of surface of section	m^2	7,750	453.29	3,513,034
	Grand Total Section D				**27,512,683**

Table 9.2-8 (continued): Total Cost Assessment Section D

Total Cost Assessment Section E-1					Page 1 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure E-1, l = 30 m				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	1,260	6	7,560
	(b) Excavation and direct placing, compaction	m^3	950	95	90,250
	(c) Excavation and disposal	m^3	9,480	60	568,800
	(d) Filling for embankment	m^3	1,030	100	103,000
	(e) Soil filling for slope, anchor, others	m^3	780	85	66,300
	Sub-total (A)				**835,910**
	(B) Above Berm Level				
2	Geotextile filter mat Datex AD 1300 (GF-1)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	821	231	189,674
	(b) Transport Chittagong to Site	t	0	3,000	738
	(c) Placing of Datex AD 1300	m^2	714	12	8,568
	Sub-total (2)				198,980
3	Interlocking cc-slabs, ship-lap type				
	(a) Production	Nos.	3,581	160	572,960
	(b) Transportation to Site	t	189	800	151,200
	(c) Laying, complete	m^2	573	200	114,600
	Sub-total (3)				838,760
4	Rubble, Grading range 12 mm to 75 mm, to To be provided, complete (Anchor trench)	m^3	125	1,800	225,000
5	Toe protection by cc-blocks 30*30*30 cm				
	(a) Production	m^3	45	3,400	153,000
	(b) Placing	m^3	45	350	15,750
	Sub-total (5)				168,750
	Sub-total (B)				**1,431,490**
	(C) Berm, Launching Apron				
6	FORESHORE collapsible block mattress				
	(a) Supply c&f Chittagong	m^2	3,176	343	1,089,368
	(b) Transport Chittagong to Site	t	0.95	3,000	2,859
	(c) Installing of FORESHORE mattress	m^2	2,178	100	217,800
	(d) Portland cement	t	198	5,000	990,000
	(e) Selected Jamuna sand	m^3	351	400	140,400
	(f) Sand-cement grout mix, produced and pumped into mattress	m^3	430	350	150,500
	Sub-total (6)				2,590,927
	Sub-total (C)				**2,590,927**

Table 9.2-9: Total Cost Assessment Section E-1

Total Cost Assessment Section E-1					Page 2 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	(E) Falling Apron				
7	Concrete blocks, size 40*40*40 cm,				
	(a) Production	m^3	492	3,400	1,672,800
	(b) Dumping	m^2	492	425	209,100
	Sub-total (7)				1,881,900
8	Concrete blocks, size 45*45*45 cm,				
	(a) Production	m^3	478	3,400	1,625,200
	(b) Dumping	m^2	478	425	203,150
	Sub-total (8)				1,828,350
	Sub-total (E)				**3,710,250**
	Total Cost Section E-1				**8,568,577**
	General costs pro rata of surface of section	m^2	2,490	453.29	1,128,704
	Grand Total Section E-1				**9,697,281**

Table 9.2-9 (continued): Total Cost Assessment Section E-1

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Total Cost Assessment Section E-2					Page 1 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure E-2, l = 60 m				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	2,520	6	15,120
	(b) Excavation and direct placing, compaction	m^3	1,900	95	180,500
	(c) Excavation and disposal	m^3	18,950	60	1,137,000
	(d) Filling for embankment	m^3	2,070	100	207,000
	(e) Soil filling for slope, anchor, others	m^3	1,560	85	132,600
	Sub-total (A)				**1,672,220**
	(B) Above Berm Level				
2	Geotextile filter mat Hate J 9014 (GF-5)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	1,840	244	448,960
	(b) Transport Chittagong to Site	t	0.83	3,000	2,484
	(c) Placing of Hate J 9014	m^2	1,600	25	40,000
	Sub-total (2)				491,444
3	Interlocking cc-slabs, ship-lap type				
	(a) Production	Nos.	7,163	160	1,146,080
	(b) Transportation to Site	t	378	800	302,400
	(c) Laying, complete	m^2	1,146	200	229,200
	Sub-total (3)				1,677,680
4	Rubble, Grading range 12 mm to 75 mm, to To be provided, complete (Anchor trench)	m^3	225	1,800	405,000
5	Toe protection by cc-blocks 30*30*30 cm				
	(a) Production	m^3	90	3,400	306,000
	(b) Placing	m^3	90	350	31,500
	Sub-total (5)				337,500
	Sub-total (B)				**2,911,624**
	(C) Berm, Launching Apron				
6	FORESHORE collapsible block mattress				
	(a) Supply c&f Chittagong	m^2	6,333	311	1,971,146
	(b) Transport Chittagong to Site	t	1.90	3,000	5,700
	(c) Installing of FORESHORE mattress	m^2	4,356	100	435,600
	(d) Portland cement	t	395	5,000	1,975,000
	(e) Selected Jamuna sand	m^3	703	400	281,200
	(f) Sand-cement grout mix, produced and pumped into mattress	m^3	860	350	301,000
	Sub-total (6)				4,969,646
	Sub-total (C)				**4,969,646**

Table 9.2-10: Total Cost Assessment Section E-2

Total Cost Assessment Section E-2					Page 2 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	(E) Falling Apron				
7	Geo-textile containers Type D (250kg), AD 1600				
	(a) Supply c&f Chittagong				
	(incl. thread and 15% wastage)	m^2	13.250	97	1.285.250
	(b) Transport Chittagong to Site	t		3,000	
	(c) Cutting and sewing at Site	Nos.	4,032	35	141,120
	(d) Filling and sealing (250 kg)	Nos.	4,032	30	120,960
	Sub-total (7)				1,547,330
8	Geo-textile containers Type E (900kg), AD 1600				
	(a) Supply c&f Chittagong (incl. thread)				
	(incl. thread and 15% wastage)	m^2	16,675	97	1,617,475
	(b) Transport Chittagong to Site	t		3,000	-
	(c) Cutting and sewing at Site	Nos.	2,520	35	88,200
	(d) Filling and sealing (900 kg)	Nos.	2,520	195	491,400
	Sub-total (8)				2,197,075
9	Falling apron of sand containers Type D, Placing, dumping	Nos.	4,032	20	80,640
10	Falling apron of sand containers Type E, Placing, dumping	Nos.	2,520	60	151,200
	Sub-total (E)				**3,976,245**
	Total Cost Section E-2		90		**13,529,735**
	General costs pro rata of surface of section	m^2	4,780	453.29	2,166,749
	Grand Total Section E-2				**15,696,484**

*) Additional cost since production yard (1st period) was far away from final place of dumping (2nd period)

Table 9.2-10 (continued): Total Cost Assessment Section E-2

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Total Cost Assessment Section F					Page 1 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure F, l = 88 m				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	3,700	6	22,200
	(b) Excavation and direct placing, compaction	m^3	2,780	95	264,100
	(c) Excavation and disposal	m^3	30,776	60	1,846,560
	(d) Filling for embankment	m^3	3,030	100	303,000
	(e) Soil filling for slope, anchor, others	m^3	2,300	85	195,500
	Sub-total (A)				**2,631,360**
	(B) Above Berm Level				
2	Geotextile filter mat BIDIM S 390 (GF-1)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	2,782	67	186,829
	(b) Transport Chittagong to Site	t	1.09	3,000	3,255
	(c) Placing of BIDIM S 390	m^2	2,419	12	29,028
	Sub-total (2)				219,112
3	Wire-mesh mattress, height 36 cm, to be supplied, assembled, positioned and secured in place	m^2	1,960	350	686,000
4	Bricks, first class quality, supplied and filled densely into wire-mesh mattress	m^3	706	1,032	728,592
5	Rubble, Grading range 12 mm to 75 mm, to to be provided, complete (Anchor trench)	m^3	88	1,800	158,400
6	Toe protection by cc-blocks 30*30*30 cm				
	(a) Production	m^3	142	3,400	482,800
	(b) Placing	m^3	142	350	49,700
	Sub-total (6)				532,500
	Sub-total (B)				**2,324,604**

Table 9.2-11: Total Cost Assessment Section F

Total Cost Assessment Section F					Page 2 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	(C) Berm, Launching Apron				
7	PROFIX-tubular fabric mattress				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	3,235	410	1,326,350
	(b) Underlapping sheet	m^2	1,000	59	59,000
	(c) Transport Chittagong to Site	t	2	3,000	6,000
	(d) Placing of PROFIX-mattress and filling with selected Jamuna **sand**	m^2	1,822	350	637,700
	Sub-total (7)				2,029,050
8	PROFIX-tubular fabric mattress				
	(a) Supply c&f Chittagong	m^2	2,905	410	1,191,050
	(b) Underlapping sheet	m^2	995	59	58,705
	(c) Transport Chittagong to Site	t	46	3,000	138,000
	(d) Placing of PROFIX-mattress and filling with **sand bitumen**	m^2	1,636	1,450	2,372,200
	Sub-total (8)				3,759,955
	Sub-total (C)				**5,789,005**
	(D) Transition LA-FA, (Joint reinforcement)				
9	Rip-rap, Grading Range E, d_{50} = 30 cm,				
	(a) Supply and stockpiled at Burimari	m^3	400	900	360,000
	(b) Transport to Site	m^3	400	900	360,000
	(c) To be placed at defined areas (transition)	m^3	400	350	140,000
	Sub-total (9)				860,000
10	Concrete blocks, size 30*30*30 cm				
	(a) Production	m^3	258	3,400	877,200
	(b) Dumping	m^3	258	425	109,650
	Sub-total (10)				986,850
	Sub-total (D)				**1,846,850**
	(E) Falling Apron				
11	Concrete blocks, size 40*40*40 cm,				
	(a) Production	m^3	1,352	3,400	4,596,800
	(b) Placing	m^3	1,352	425	574,600
	Sub-total (11)				5,171,400
12	Concrete blocks, size 45*45*45 cm,				
	(a) Production	m^3	1,492	3,400	5,072,800
	(b) Placing	m^3	1,492	425	634,100
	Sub-total (12)				5,706,900

Table 9.2-11 (continued): Total Cost Assessment Section F

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Total Cost Assessment Section F					Page 3 of 3
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
13	Rip-rap, Grading range B, D_{50} = 15 cm				
	(a) Supply and stockpiled at Burimari	m^3	1,986	900	1,787,400
	(b) Transport to Site	m^3	1,986	900	1,787,400
	Sub-total (13)				3,574,800
14	Gabion-sacks				
	(a) Supply c&f Chittagong	Nos.	3,103	566	1,756,298
	(b) Transport Chittagong to Site	t	28.61	3,000	85,830
	(c) Assembled and filled with rip-rap, Grading range B, D_{50} = 15 cm	Nos.	3,103	230	713,690
	(d) Placing, complete	Nos.	3,103	50	155,150
	Sub-total (14)				2,710,968
	Sub-total (E)				**17,164,068**
	Total Cost Section F				**29,755,887**
	General costs pro rata of surface of section	m^2	7,300	453.29	3,309,051
	Grand Total Section F				**33,064,938**

Table 9.2-11 (continued): Total Cost Assessment Section F

Total Cost Assessment Section G					Page 1 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure G, l = 100 m				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	4,200	6	25,200
	(b) Excavation and direct placing, compaction	m^3	3,160	95	300,200
	(c) Excavation and disposal	m^3	34,854	60	2,091,240
	(d) Filling for embankment	m^3	3,450	100	345,000
	(e) Soil filling for slope, anchor, others	m^3	2,600	85	221,000
	Sub-total (A)				**2,982,640**
	(B) Above Berm Level				
2	Geotextile filter mat DATEX AD 1300 (GF-1)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	3,355	55	184,903
	(b) Transport Chittagong to Site	t	1.01	3,000	3,018
	(c) Placing of DATEX AD 1300	m^2	2,917	12	35,004
	Sub-total (2)				222,925
3	Rubble, Grading range 12 mm to 75 mm, to be supplied and placed as intermediate layer	m^3	802	1,800	1,443,600
4	Interlocking cc-slabs, groove-tongue type				
	(a) Fabrication of moulds	Nos.	100	3,000	300,000
	(b) Production	Nos.	20,600	155	3,193,000
	(c) Transportation to Site	t	1,096	800	876,800
	(d) Laying, complete	m^2	2,250	300	675,000
	Sub-total (4)				5,044,800
5	Toe protection by cc-blocks 30*30*30 cm				
	(a) Production	m^3	174	3,400	591,600
	(b) Placing	m^3	174	370	64,380
	Sub-total (5)				655,980
	Sub-total (B)				**7,367,305**
	(C) Berm, Launching Apron				
6	Geo-textile filter mat BIDIM b7 (GF-1)				
	(a) Supply c&f Chittagong	m^2	5,120	55	280,309
	(b) Transport Chittagong to Site	t	1.72	3,000	5,145
	(c) Placing of BIDIM b7	m^2	4,452	12	53,424
	Sub-total (6)				338,878

Table 9.2-12: Total Cost Assessment Section G

Total Cost Assessment Section G					Page 2 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
7	INCOMAT Sand-Felx				
	(a) Supply c&f Chittagong type 20.152	m^2	1,260	793	999,180
	Supply c&f Chittagong type 20140	m^2	3,780	715	2,702,700
	(b) Transport Chittagong to Site	t	3	3,000	10,200
	(c) Installing on slopes	m^2	3,550	200	710,000
	(d) Hydraulic sand fill,				
	supplied and pumped into mattress	m^3	1,190	500	595,000
	Sub-total (7)				5,017,080
	Sub-total (C)				**5,355,958**
	(D) Transition LA-FA, (Joint reinforcement)				
8	Rip-rap, Grading Range F, d_{50} = 30 cm,				
	(a) Supply and stockpiled at Burimari	m^3	400	900	360,000
	(b) Transport to Site	m^3	400	900	360,000
	(c) To be placed at defined areas (transition)	m^3	400	350	140,000
	Sub-total (9)				860,000
9	Concrete blocks, size 30*30*30 cm				
	(a) Production	m^3	400	3,400	1,360,000
	(b) Dumping	m^3	400	425	170,000
	Sub-total (10)				1,530,000
	Sub-total (D)				**2,390,000**
	(E) Falling Apron				
10	CC-blocks, size 35*35*35 cm				
	(a) Production	m^3	810	3,400	2,754,000
	(b) Placing	m^3	810	420	340,200
	Sub-total (9)				3,094,200
11	CC-blocks, size 40*40*40 cm				
	(a) Production	m^3	922	3,400	3,134,800
	(b) Placing	m^3	922	425	391,850
	Sub-total (10)				3,526,650
12	CC-blocks, size 45*45*45 cm				
	(a) Production	m^3	1,349	3,400	4,586,600
	(b) Placing	m^3	1,349	425	573,325
	Sub-total (11)				5,159,925
	Sub-total (E)				**11,780,775**
	Total Cost Section G				***29,876,678***
	General costs pro rata of surface of section	m^2	7,800	453.29	3,535,699
	Grand Total Section G				**33,412,377**

Table 9.2-12 (continued): Total Cost Assessment Section G

Total Cost Assessment Section H-1					Page 1 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure H-1 **Downstream Termination l = 82.75**				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	3,475	6	20,850
	(b) Excavation and direct placing, compaction	m^3	2,600	95	247,000
	(c) Excavation and disposal	m^3	30,687	60	3,068,700
	(d) Filling for embankment	m^3	2,850	100	285,000
	Sub-total (A)				**3,621,550**
	(B) Above Berm Level				
2	Geotextile filter mat BIDIM S 700 (GF-2)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	3,540	120.00	424,764
	(b) Transport Chittagong to Site	t	2.45	3,000.00	7,344
	(c) Placing of BIDIM S 700	m^2	3,078	12.00	36,936
	Sub-total (2)				469,044
3	Rip-rap, Grading Range C, D_{50} = 20 cm				
	(a) Supplied and stockpiled at Site	m^3	985	1,335.00	1,314,975
	(b) Placing on slope, complete	m^3	985	425.00	418,625
	Sub-total (3)				1,733,600
4	Surface grouting for rip-rap	m^2	2,541	300.00	762,300
	Sub-total (B)				**2,964,944**
	(C) Berm, Launching Apron				
5	Geotextile filter mat BIDIM S 700 (GF-2)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	4,750	120.00	569,940
	(b) Transport Chittagong to Site	t	3.33	3,000.00	9,975
	(c) Placing of BIDIM S 700	m^2	4,130	12.00	49,560
	Sub-total (2)				629,475
6	Berm by rip-rap, Grading range F, D_{50}=35 cm				
	(a) Supply and stockpiled at Burimari	m^3	1,800	900.00	1,620,000
	(b) Transport to Site	m^3	1,800	900.00	1,620,000
	(c) Placing on geotextile of Item No. 18.02	m^3	1,800	450.00	810,000
	Sub-total (5)				4,050,000
7	Concrete blocks, size 30*30*30 cm.				
	(a) Production	m^3	106	3,400	360,400
	(b) Placing	m^3	106	420	44,520
	Sub-total (7)				404,920

Table 9.2-13 : Total Cost Assessment Section H-1

Total Cost Assessment Section H-1					Page 2 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
8	Concrete blocks, size 45*45*45 cm				
	(a) Production	m^3	350	3,400	1,190,000
	(b) Placing	m^3	350	420	147,000
	Sub-total (8)				1,337,000
	Sub-total (C)				**6,421,395**
	(E) Falling Apron				
9	Geo-textile filter mat BIDIM S 390				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	2,263	70.00	158,424
	(b) Transport Chittagong to Site	t	0.88	3,000.00	2,649
	(c) Placing of BIDIM S390	m^2	1,968	12.00	23,616
	Sub-total (6)				184,689
10	Rip-rap, Grading range F, D_{50} = 35 cm				
	(a) Supply and stockpiled at Burimari	m^3	3,911	900.00	3,519,900
	(b) Transport to Site	m^3	3,911	900.00	3,519,900
	(c) Placing	m^3	3,911	450.00	1,759,950
	Sub-total (7)				8,799,750
11	Selected boulders, D_n = 35 cm to 45 cm				
	(a) Supply and stockpiled at Burimari	m^3	2,320	900.00	2,088,000
	(b) Transport to Site	m^3	2,320	900.00	2,088,000
	(c) Placing	m^3	2,320	450.00	1,044,000
	Sub-total (8)				5,220,000
	Sub-total (E)				**14,204,439**
	Total Cost Section H-1				**27,212,328**
	General costs pro rata of surface of section	m^2	6,900	453.29	3,127,733
	Grand Total Section H-1				**30,340,061**

Table 9.2-13 (continued): Total Cost Assessment Section H-1

Total Cost Assessment Section H-2					Page 1 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure H-2 l = 51.6 **Downstream Termination**				
1	**(A) Earth works**				
	(a) Top soil removal	m^2	2,170	6	13,020
	(b) Excavation and direct placing, compaction	m^3	1,630	95	154,850
	(c) Excavation and disposal	m^3	15,568	60	934,080
	(d) Filling for embankment	m^3	1,780	100	178,000
	Sub-total (A)				**1,279,950**
	(B) Above Berm Level				
2	Geotextile filter mat Hate K251 (GF-4)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	4,500	109.00	490,500
	(b) Transport Chittagong to Site	t	3.38	3,000.00	10,125
	(c) Placing of Hate K251	m^2	3,614	12.00	43,368
	Sub-total (2)				543,993
3	Geotextile filter mat BIDIM S 700 (GF-2)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	4,500	120.00	540,000
	(b) Transport Chittagong to Site	t	3.15	3,000.00	9,450
	(c) Placing of BIDIM S 700	m^2	1,536	12.00	18,432
	Sub-total (3)				567,882
4	Rip-rap, Grading Range C, D_{50} = 20 cm				
	(a) Supplied and stockpiled at Site	m^3	1,026	1,335.00	1,369,710
	(b) Placing on slope, complete	m^3	1,026	425.00	436,050
	Sub-total (4)				1,805,760
5	Surface grouting for rip-rap	m^2	2,645	300.00	793,500
	Sub-total (B)				**3,711,135**
	(C) Berm, Launching Apron				
6	Geo-textile filter mat BIDIM S 390 (GF-1)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m^2	2,790	67.16	187,370
	(b) Transport Chittagong to Site	t	1.09	3,000.00	3,264
	(c) Placing of BIDIM S390	m^2	2,426	12.00	29,112
	Sub-total (6)				219,746

Table 9.2-14: Total Cost Assessment Section H-2

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Total Cost Assessment Section H-2					Page 2 of 2
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
7	Concrete blocks, size 30*30*30 cm,				
	(a) Production	m^3	635	3,400	2,159,000
	(b) Placing	m^3	635	420	266,700
	Sub-total (7)				2,425,700
8	Concrete blocks, size 35*35*35 cm,				
	(a) Production	m^3	956	3,400	3,250,400
	(b) Placing	m^3	956	420	401,520
	Sub-total (8)				3,651,920
	Sub-total (C)				**6,297,366**
	Total Cost Section H-2				**11,288,451**
	General costs pro rata of surface of section	m^2	2,660	453.29	1,205,764
	Grand Total Section H-2				**12,494,215**

Table 9.2-14 (continued): Total Cost Assessment Section H-2

Total Cost Assessment Section H-2 end + road					Page 1 of 1
Item. No.	Description	Unit	Quantity	Unit Rate (Taka)	Total Amount (Taka)
	Test Structure H-2 end + road Downstream Termination l =20 + 30 m				
1	**(A) Earth works**				
	(a) Top soil removal	m²	800	6	4,800
	(b) Excavation and direct placing, compaction	m³	750	95	71,250
	(c) Excavation and disposal	m³	450	60	27,000
	(d) Filling for embankment	m³	450	100	45,000
	Sub-total (A)				**148,050**
	(B) Above Berm Level				
2	Geotextile filter mat BIDIM S 700 (GF-2)				
	(a) Supply c&f Chittagong (incl. 15% wastage)	m²	2,070	116.07	240,265
	(b) Transport Chittagong to Site	t	1.45	3,000.00	4,350
	(c) Placing of BIDIM S 700	m²	1,800	12.00	21,600
	Sub-total (2)				266,215
3	Rip-rap, Grading Range C, D_{50} = 20 cm				
	(a) Supplied and stockpiled at Site	m³	320	1,335.00	427,200
	(b) Placing on slope, complete	m³	320	425.00	136,000
	Sub-total (3)				563,200
4	Surface grouting for rip-rap	m²	800	300.00	240,000
	Sub-total (B)				**1,069,415**
	Total Cost Section H-2 end + road				**1,217,465**
	General costs pro rata of surface of section	m²	800	453.29	362,636
	Grand Total Section H-2 end + road				**1,580,101**

Table 9.2-15: Total Cost Assessment Section H-2 end

	(A)Earth Works	(B) Above Berm Level	(C) Berm / Launching Apron	(D)Transition	(E) Falling Apron	Total Cost	General Costs	Grand Total Costs
Section A-1 end 1	230,250	241,201				471,451	167,719	**639,170**
Section A-1 end 2	1,637,725	709,022	4,766,772			7,113,519	1,087,907	**8,201,427**
Section A-1	3,662,880	935,775	7,957,038	1,131,000	5,645,225	19,331,918	2,737,900	**22,069,818**
Section A-2	1,917,910	2,167,194	13,336,828	1,131,000	9,079,280	27,632,212	3,127,733	**30,759,945**
Total Section A	**7,448,765**	**4,053,192**	**26,060,638**	**2,262,000**	**14,724,505**	**54,549,100**	**7,121,260**	**61,670,360**
Section B	**3,611,795**	**3,783,954**	**17,188,902**	**2,819,025**	**5,650,604**	**33,054,280**	**3,898,334**	**36,952,614**
Section C-1	1,490,885	2,307,075	1,885,459	462,300	1,942,050	8,087,769	1,835,844	**9,923,612**
Section C-2	1,490,885	2,445,200	3,874,297	337,500	1,914,150	10,062,032	1,795,047	**11,857,079**
Total Section C	**2,981,770**	**4,752,275**	**5,759,756**	**799,800**	**3,856,200**	**18,149,801**	**3,630,891**	**21,780,691**
Section D	**2,530,080**	**3,848,225**	**6,827,194**		**10,794,150**	**23,999,649**	**3,513,034**	**27,512,683**
Section E-1	835,910	1,431,490	2,590,927		3,710,250	8,568,577	1,128,704	**9,697,281**
Section E-2	1,672,220	2,911,624	4,969,646		3,976,245	13,529,735	2,166,749	**15,696,484**
Total Section E	**2,508,130**	**4,343,114**	**7,560,573**		**7,686,495**	**22,098,312**	**3,295,452**	**25,393,765**
Section F	**2,631,360**	**2,324,604**	**5,789,005**	**1,846,850**	**17,164,068**	**29,755,887**	**3,309,051**	**33,064,938**
Section G	**2,982,640**	**7,367,305**	**5,355,958**	**2,390,000**	**11,780,775**	**29,876,678**	**3,535,699**	**33,412,377**
Section H-1	3,621,550	2,964,944	6,421,395		14,204,439	27,212,328	3,127,733	**30,340,061**
Section H-2	1,279,950	3,711,135	6,297,366			11,288,451	1,205,764	**12,494,215**
Section H-end	148,050	1,069,415				1,217,465	362,636	**1,580,101**
Total H	**5,049,550**	**7,745,494**	**12,718,761**		**14,204,439**	**39,718,244**	**4,696,133**	**44,414,377**
	29,744,090	**38,218,163**	**87,260,787**	**10,117,675**	**85,861,236**	**251,201,950**	**32,999,854**	**284,201,805**
							DM	11,368,072.18

Table 9.2-16: Summary of all Sections

10 REPAIR WORKS, MAINTENANCE AND MONITORING OF BAHADURABAD TEST SITE; PERIOD September 1998 To September 1999

10.1 PRELIMINARY REMARKS

During the flood season of 1997 minor damage occurred to Section H-1 and H-2 due to erosion by return currents. Parts of the falling apron was washed away and the geo-textile filter layer was cut because it could not bear the load of the boulders and cc-blocks on a steep slope which developed under the erosion. For details refer to "Report on Monitoring and Adaptation at Bahadurabad Test Site, Monsoon 1997", March 1999.

At Section E some settlement of the embankment slope protection occurred due to rainwater cuts underneath the filter layer. Rain water could pass through the geo-textile filter layer too fast and caused the cuts because the contact of the inter-locking cc-slabs with the filter was not close enough.

10.2 DESIGN OF THE TEST STRUCTURE

For the adaptation design of the test structures Annex 8 may be consulted, which contains all design data and principles related to the revetment structures and associated works. For the purpose of this Construction and Procurement Report the construction drawings for repair are included under Attachment 2

10.3 FINANCIAL SUMMARY OF REPAIR WORKS, MAINTENANCE AND MONITORING

10.3.1 Repair Works

For the repair works at Section H remaining surplus material of the construction phase was used. No additional material was procured. The damaged parts were rehabilitated and reinforced by slope filling with cc-blocks and boulders.

At Section E the cc-slabs and the geo-textile filter layer were taken out in order to repair the rain cuts. After the filter was laid back with an additional layer of gravel filter to guarantee a better contact between the filter layer and the cc-slabs.

The work contract for repair and maintenance was given in form of variation order no. 3 to the Joint Venture of the construction phase. Smaller repairs have been ordered to local contractors of the area under day work rules.

The total amount of the contract (variation order no. 3) is	TK	9,037,614
This amount includes for:		
• Re-mobilisation	TK	350,000
• Repair works at Section H	TK	2,661,382
• Repair works at Section E	TK	628,642
• Maintenance of the camp (12 month)	TK	2,471,040
• Supply of fuel for survey boats, maintenance of the provisional hospital, day work and other	TK	2,926,550
Total	TK	9,073,614
equivalent to	DM	348,914

**Photo 10.3-1: Section E;
Repair of Slope Protection**

**Photo 10.3-2: Section H
Repair of Falling Apron**

GOV

10.3.2 Monitoring and Other

A) Expenses Outside Bangladesh:

1)	Purchase of additional monitoring equipment, repair of existing equipment	TK	1,432,089
2)	Current measurement (sub-contract Labor füer Wasserbau, Hochschule Bremen)	TK	2,499,281
3)	Side sonar and bottom profiler scanning (sub-contract OSAE, Bremen	TK	1,077,505
	Total	TK	5,008,876
	equivalent to	DM	192,649

B) Expenses in Bangladesh:

1)	Monitoring (for boats, engines, survey equipment	TK	2,459.029
2)	Radio licence fees	TK	274,250
3)	Repair by local contractors	TK	1,157,664
4)	Camp electrification (rural power board)	TK	111,338
5)	Land purchase for camp	TK	350,000
6)	Compensation for Hospital	TK	1,500,000
	Total	TK	5,852,281
	equivalent to	DM	229,633

Grand Total Repair Works, Maintenance and Monitoring Period September 1998 to September 1999

	TK	*19,988,771*
equivalent to	**DM**	**771,196**

REFERENCES

FAP 21 Final Report Planning Study (June 1993)

FAP 21 Procurement and Construction Report Test Site II – Bahadurabad (April, 1995)

FAP 21 Final Project Evaluation Report (2001)

FAP 21 Morphological Predictions for Test Areas - November 1993

FAP 21 Contract of Revetment Structure, Report on the Evaluation and Assessment of Tenders (July 1995)

FAP 21 Revetment Test Structures at Bahadurabad, Proposal for Final Implementation During Dry Season 1996/97

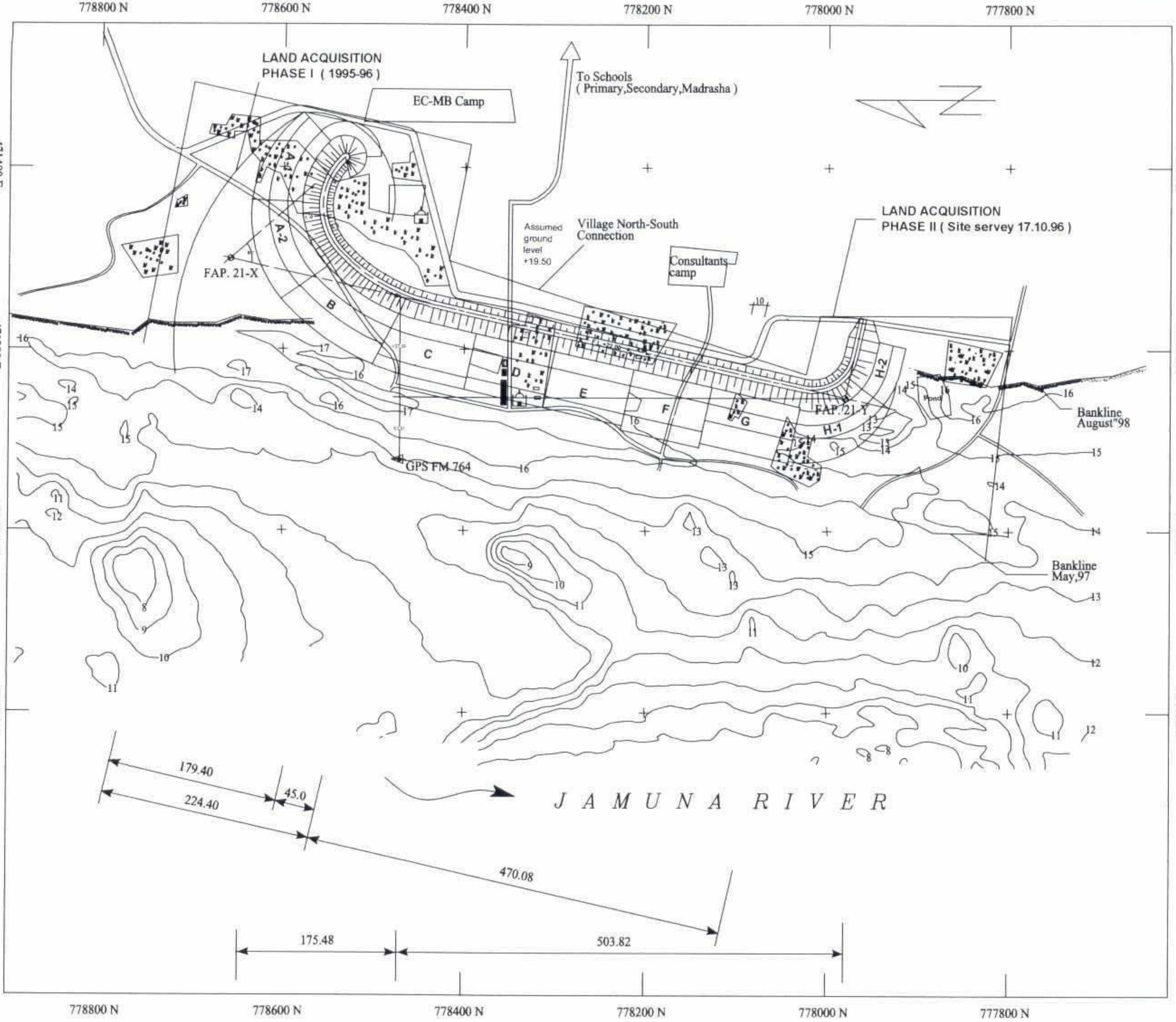
Attachment 1

Selection of Design and Construction Drawings, Bahadurabad

ATTACHMENT 1

List of Drawings

Drawing R-A-301:	Detailed layout of Test Structure
Drawing R-A-302:	Detailed layout of Test Structure (1996/97)
Drawing R-A-303:	Designation of design sections and materials
Drawing R-A-304:	Geotextile filter mats; General arrangement
Drawing R-A-305:	Test Structure A; General plan and cross-sections
Drawing R-A-306:	Typical revetment details No. 1 to No. 8
Drawing R-A-307:	Test Structure B; General plan and cross-section, details
Drawing R-A-308:	Test Structure C; General plan and cross-section, details
Drawing R-A-309:	Test Structure D; General plan and cross-section, details
Drawing R-A-310:	Test Structure E; General plan and cross-section, details
Drawing R-A-311:	Test Structure F; General plan and cross-section, details
Drawing R-A-312:	Test Structure G; General plan and cross-section, details
Drawing R-A-313:	Test Structure H; General plan section H-1, H-2 and cross-section, details
Drawing R-AD-01:	Layout plan of section H (1996/97)
Drawing R-AD-02:	Details, section H
Drawing R-AD-03:	Details, section H-1
Drawing R-AD-04:	Details, section H-1/x



CONTROL POINT SCHEDULE

No. of Control Point	Co-ordinates BTM Easting	Co-ordinates BTM Northing	Elevation (m PWD)
FAP 21-X	471,293.485	778,654.360	——
FAP 21-Y	471,149.095	777,975.060	——
GPS FM764	471,086.185	778,478.880	——

LEGEND
- Road Pacca,Kacha,Footpath
- High River Bank
- House Pacca,Kacha & Tinshed
- Traverse Station & Piller
- Home Stead
- Mosque

Notes:
1 . The topography shown on this drawing is based on JTWC's survey of Oct'96 combined with topographical maps of Survey of Bangladesh
2 . Levels refer to ± 0.00 m PWD
3 . Bankline and bathymetic survey as on 09/10/96
4 . Reference Drawing R-A-302 Detailed Layout of Test Structure

026

0 50 100 150 200m

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BANK PROTECTION PILOT PROJECT - 21

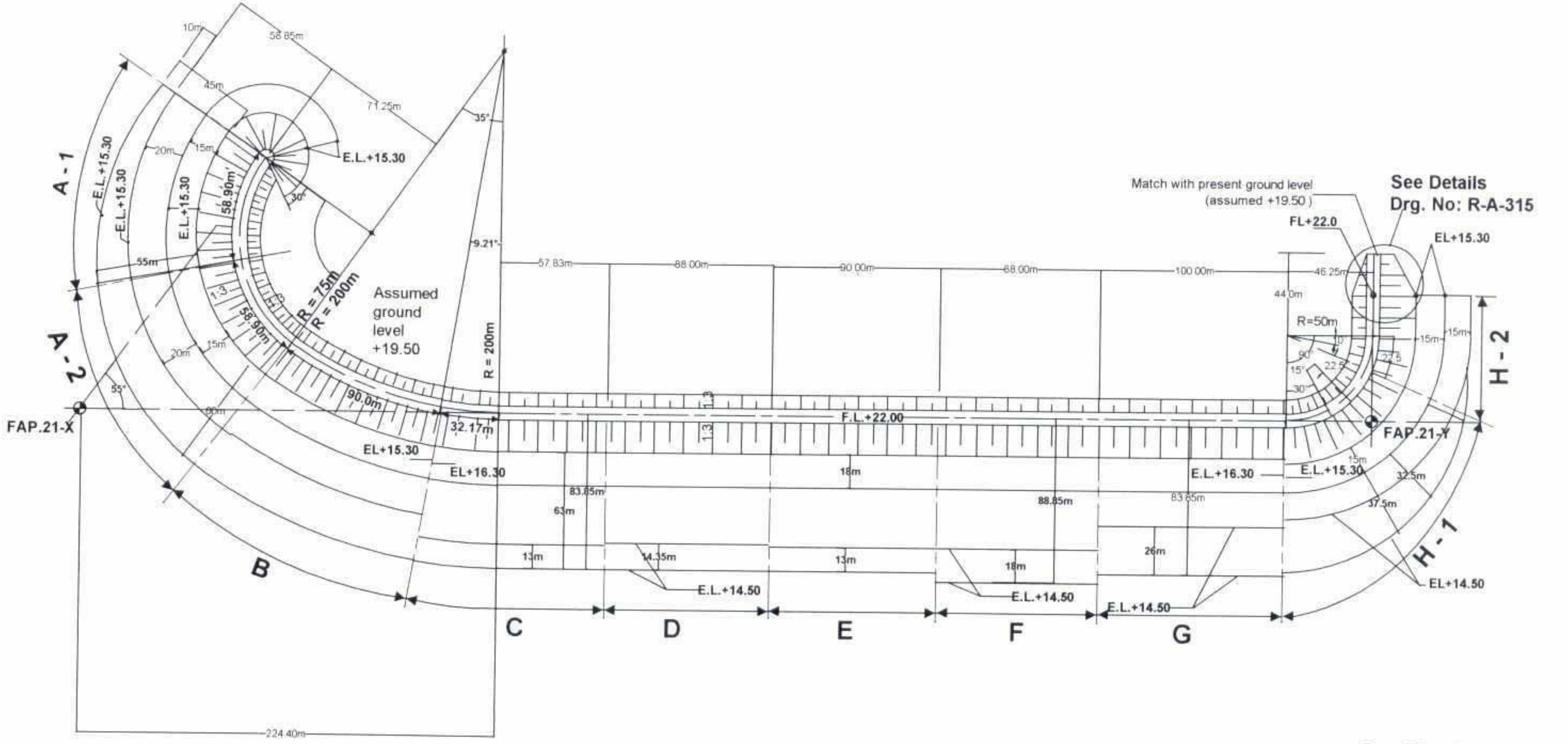
JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II - BAHADURABAD

DETAILED LAYOUT OF TEST STRUCTURE

	NAME	DATE	SCALE
DRAWN	ANOWAR	26-02-2001	
CHECKED			
APPROVED			

DRAWING No. R -A -301 · RIVISION 0



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CONTROL POINT SCHEDULE			
No. of Control Points	Co-ordinate's BTM		Elevation (m PWD)
	Easting	Northing	
FAP 21 - X	471,293.485	778,654.360	——
FAP 21 - Y	471,149.095	777,975.060	——

Notes:

1. Levels refer to ±0.00 m PWD
2. Measurements in meter
3. F.L = Finished Level
   E.L = Excavation Level
4. Reference Drawing
   R-A-301 General Layout of Test Structure(1996/97)
   R-A-305 Test Structure h
   Cross-Section H-1,H-2
   Cross-Section ,Details

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TEST SITE II - BAHADURABAD

DETAILED LAYOUT OF TEST STRUCTURE
(1996/97)

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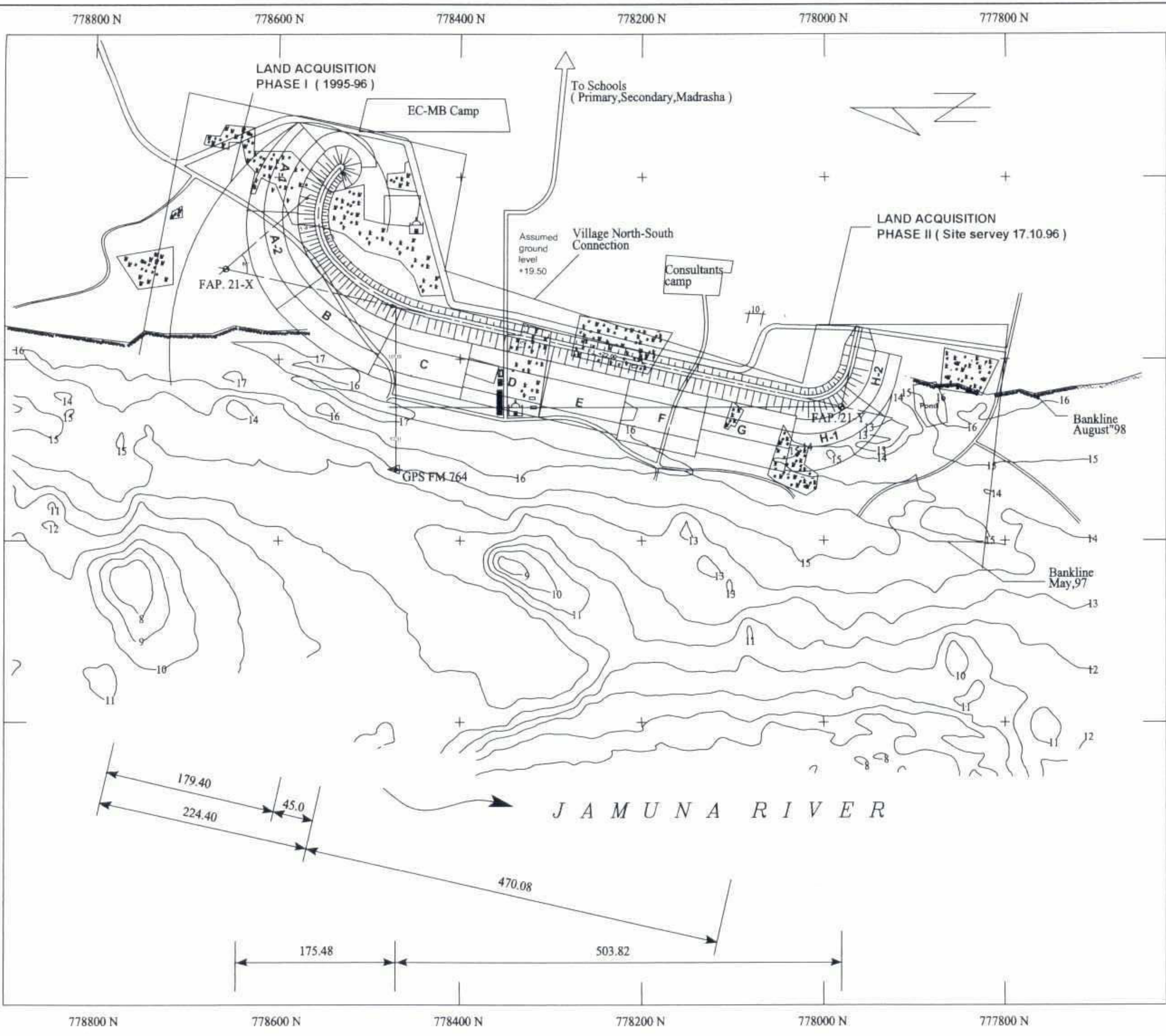
CHECKED				
APPROVED				



CONTROL POINT SCHEDULE

No. of Control Point	Co-ordinates BTM Easting	Co-ordinates BTM Northing	Elevation (m PWD)
FAP 21-X	471,293.485	778,654.360	——
FAP 21-Y	471,149.095	777.975.060	——
GPS FM764	471,086.185	778,478.880	——

LEGEND
- Road Pacca,Kacha,Footpath
- High River Bank
- House Pacca,Kacha & Tinshed
- Traverse Station & Piller
- Home Stead
- Mosque

Notes:
1. The topography shown on this drawing is based on JTWC's survey of Oct'96 combined with topographical maps of Survey of Bangladesh
2. Levels refer to ± 0.00 m PWD
3. Bankline and bathymetic survey as on 09/10/96
4. Reference Drawing
   R-A-302 Detailed Layout of Test Structure

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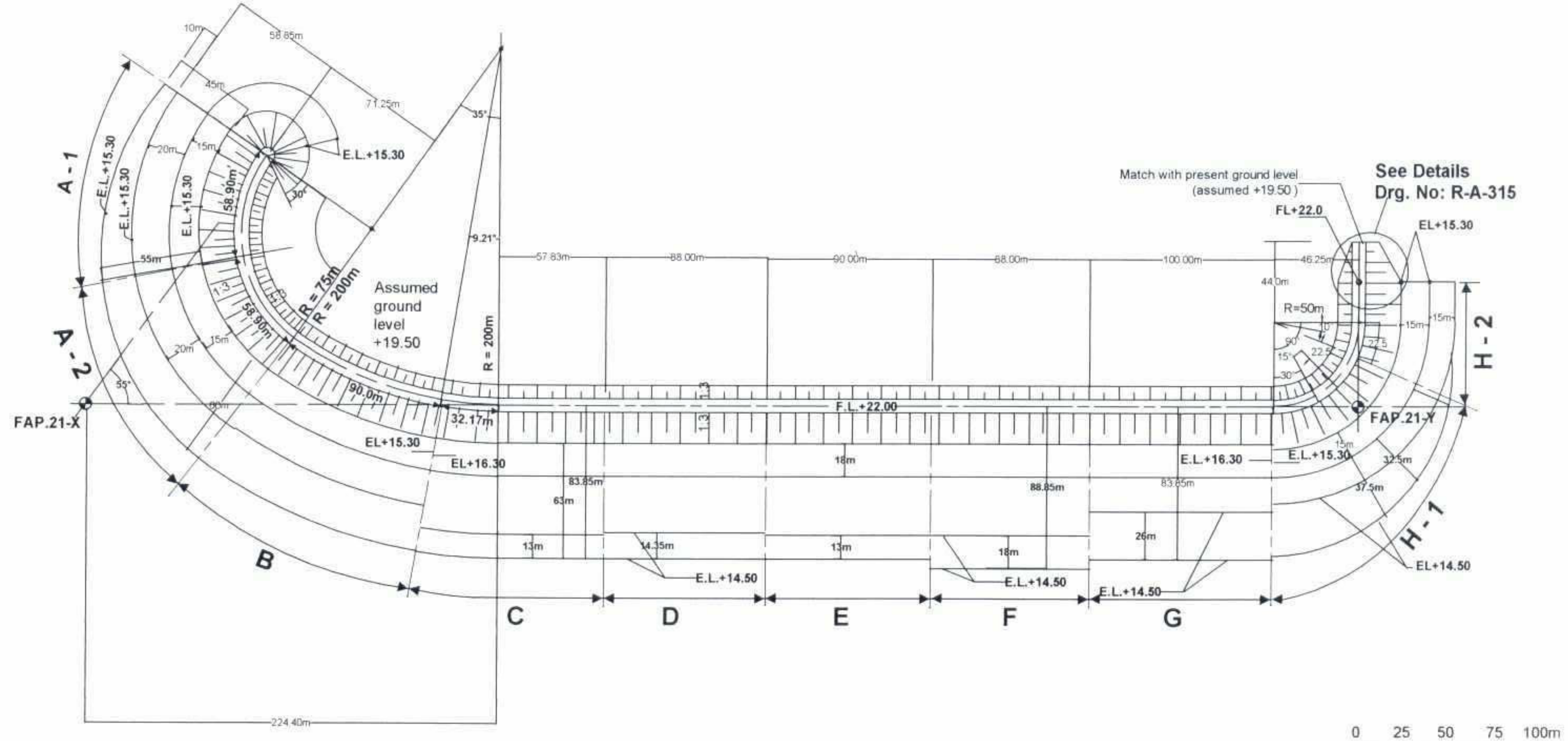
JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II - BAHADURABAD

DETAILED LAYOUT OF TEST STRUCTURE

	NAME	DATE	SCALE
DRAWN	ANOWAR	26-02-2001	
CHECKED			DRAWING No. R -A -301
APPROVED			RIVISION 0

008



CONTROL POINT SCHEDULE			
No. of Control Points	Co-ordinate's BTM		Elevation (m PWD)
	Easting	Northing	
FAP 21 - X	471,293.485	778,654.360	——
FAP 21 - Y	471,149.095	777,975.060	——

Notes:
1. Levels refer to ±0.00 m PWD
2. Measurements in meter
3. F.L = Finished Level
   E.L = Excavation Level
4. Reference Drawing
   R-A-301 General Layout of Test Structure(1996/97)
   R-A-305 Test Structure h
   Cross-Section H-1,H-2
   Cross-Section ,Details

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JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
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TEST SITE II - BAHADURABAD

DETAILED LAYOUT OF TEST STRUCTURE (1996/97)

	NAME	DATE	SCALE 1 : 2500	
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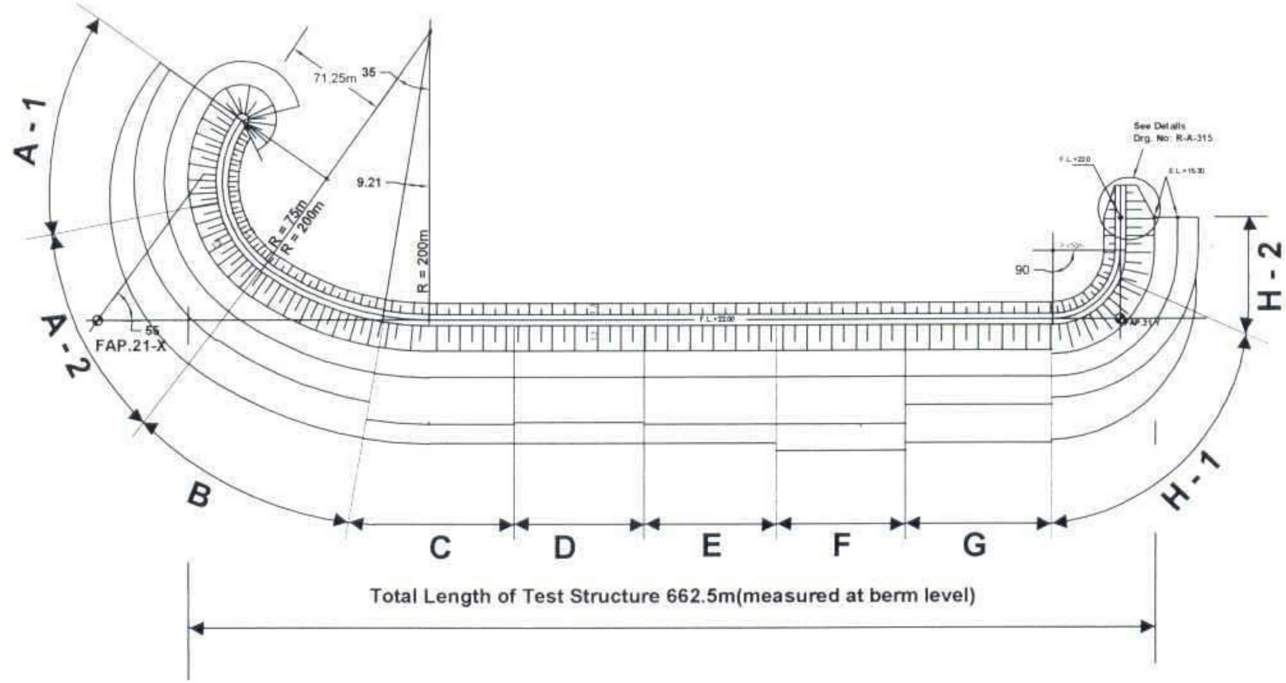
CHECKED				
APPROVED				



	Test Structure	A - end	A - 1	A - 2	B	C	D	E	E	F	G	H-1	H-2	H-2(end)	H-2(end)
	Land - sided slope	Brick mattress d = 15cm	In all sections durba grass sods laid on Geo-jute soil saver								Detail on top of Embankment Drg. No. R-A-314				
River side	Approximate length along toe of upper slope (at berm level)	87.40	74.70	74.70	99.10	93.20	88.0	90		88.0	100.0	82.75	97.60	20.0	30.0
River side	Revetment above berm level (+15.3m to +22.0m PWD)	Brick mattress d = 15cm	Brick mattress d = 15cm	Wiremesh mattress d = 23/36cm with stone fill Grade B (D_{50} = 15 cm)	Wiremesh mattress d = 23cm with stone fill Grade B (D_{50}= 15cm) on intermediate rubble layer (d = 25cm)	CC-blocks D_n = 35cm hand-laid in single, diagonal lines	CC-blocks D_n = 35cm hand-laid in single, parallel lines	Inter Locking CC-slabs (ship-lap TYPE)		wiremesh mattress d=36m with brick fill	Interlocking CC-slabs (tongue-groove type) on intermediate layer	Rip-rap Grade C (D_{50}= 20cm) Top 20cm with stone pitching(d =50cm)	Rip-rap Grade C (D_{50}= 20cm) Top 20cm with stone pitching(d =40cm)	As H-2	Rip-rap E+F 80cm on 20cm
River side	Launching Apron at and below berm level (+14.5m to +22.0m PWD)		Dumped CC-blocks D_n= 30cm	Dumped CC-blocks D_n = 35cm	Dumped CC-blocks Edge us:D_n = 50cm Center :D_n = 35cm Edge ds:D_n = 40cm	Articulated RENO-mattress d = 23/36cm;stone fill Grade B,C,D (D =25cm) with inter-connecting steel wires ropes and anchor pipes at berm level	Articulated CC-blocks mattress with inter-connecting steel wire ropes and anchor pipes at berm level	FORESHORE-mattress (Collapsible block mattress with cement grout fill)		PROFIX-mattress (tubular fabric mattress with sand and sand-bitumen fill)	INCOMAT-sandflex mattress (collapsible block mattress with sand fill)	Rip-rap Grade F (D_n=25-35-45cm)	CC-blocks, D_n=30cm D_n=35cm (mixed)		
River side	Transition between launching Apron and falling Apron		CC-blocks D_n= 30cm		CC-blocks D_n = 35cm					Rip-rap,Grade E CC-blocks,(D_n=30cm) *1	CC-blocks, D_n=35cm *2				
River side	Falling Apron (Level +14.5m PWD)	Dumped CC-blocks D_n = 30cm	Dumped CC-blocks D_n= 35cm D_n= 40cm (mixed)	Rip-rap,Grade E (D_{50} = 30 cm)	Geo-sand-container Type C (180Kg/No.)	Geo-sand-container Type E (900Kg/No.)	CC-blocks D_n= 40cm		Geo-sand -container D	CC-blocks D_n=40/45cm (mixed)	CC-blocks D_n=35/40cm (mixed)				
River side	Transition between launching Apron and falling Apron			Rip-rap, Grade F (D_n = 25/35/45cm)	Geo-sand-container Type C(250Kg/No.)		CC-blocks D_n= 45cm	CC-blocks D_n=40cm	Geo-sand -container E	Gabion sacks with stone fill Grade B (D_{50}=15cm)(1300kg/No)	CC-blocks D_n =40cm	Selected boulders D_n= 35 - 45cm			

0 50 100 150m

us = Upstream
ds = Downstream

*1 Mixed CC-blocks 30cm + boulder Grade E in evelope of double layer chain link fence

*2 Mixed CC-blocks 35cm + boulder Grade F in evelope of double layer chain link fence

Notes:

1. Levels refer to ±0.00m PWD.
2. Measurements in meter.
3. F.L = Finished level
   E.L = Excavation level
4. Reference Drawings:
   R-A-302 Detailed layout of Test Structures
   R-A-304 Geotextile Filter Materials General Arrangement

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
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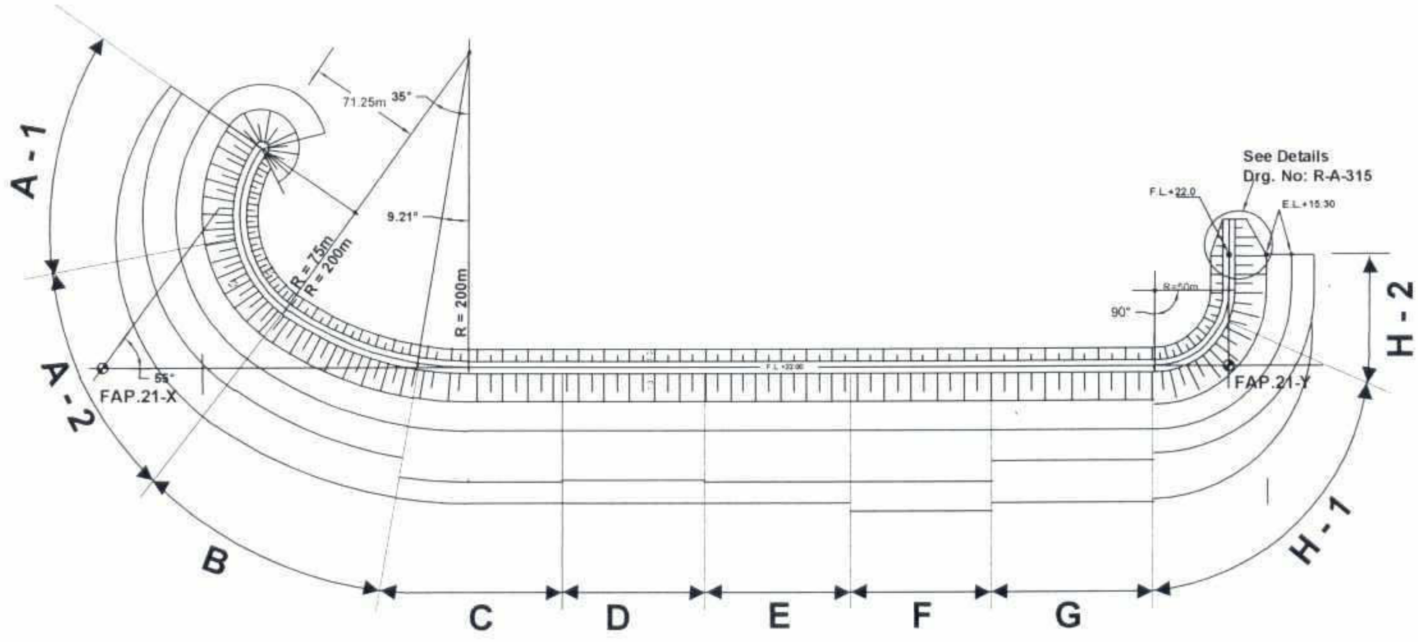
BANK PROTECTION PILOT PROJECT - 21

JAMUNA TEST WORKS CONSULTANTS,JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II-BAHADURABAD

DESIGNATION OF DESIGN SECTIONS AND MATERIALS

DRAWN: ANOWAR 13-04-2000 | SCALE | DRAWING No. R -A -303 | REVISION 0

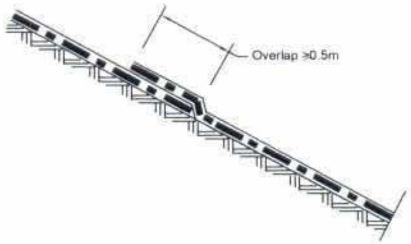


Notes:

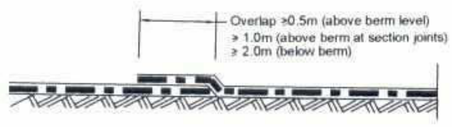
1. Levels refer to ±0.00m PWD.
2. Measurements are shown in meter.
3. F.L = Finished level
   E.L = Excavation level
4. Geotextile filter materials and fabric mattresses will be supplied by the Employer in accordance with Specifications 220 and 230.
5. Reference Drawings:
   R-A-302 Detailed layout of Test Structures
   R-A-303 Designation of Design Sections and Materials

NOTE:
In section A and H-1 all geotextile filter mats are to be placed as single sheets. In all other sections two sheets each are to be joined by stitching (prayer seam) to " twin sheets".

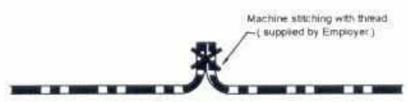
Test Structure			A - end	A - 1	A - 2	B	C	D	E	F	G	H-1	H-2	H-2(end)
Land - sided slope			GF - 1	In all sections geo-jute Soil saver							Detail on top of Embankment Drg. No. R- A -314			Village Road
River side	Approximate length along toe of upper slope (at berm level)		87.40	74.70	74.70	99.10	93.20	88.0	90	88.0	100.0	82.75	97.60	20.0 / 30.0
	Geotextile filter mats above berm level	Spec. type	GF-1/-5	GF - 1	GF - 5	GF - 2	Filter III on Filter II / Khoa on Filter II	GF - 2	GF - 1 / GF - 5	GF - 1	GF - 1	GF - 4	GF - 4	As / GF - 2
		Brand Name	BIDIM HaTe O 2214	BIDIM b 7	HaTe O 2214	BIDIM S 550		BIDIM S 550	DATEX AD 1300 / HaTe J 9014	BIDIM S 390	DATEX AD 1300	BIDIM S 700	HaTe E 650 /K 251	H-2 / HaTe E 650
	Geotextile filter mats at and below berm level	Spec. type	GF-1/-5	GF - 2	GF - 2	GF - 4	GF - 2	GF - 4	FORESHORE-mattress (collapsible fabric black mattress with cement grout fill)	PROFIX-mattress (tubular fabric mattress with cement grout fill)	GF -1 (sub-layer to INCOMAT-sand flex mattress)	GF - 1	GF - 1	— / —
		Brand Name	BIDIM HaTe O 2214	BIDIM S 550	BIDIM S 550	HaTe K 251	DATEX AD 1600	BIDIM S 700			BIDIM b 700	BIDIM S 390	BIDIM S 390	— / —



POSITION OF OVERLAPS
DOWN-THE-SLOPE



POSITION OF OVERLAPS
IN DIRECTION OF FLOW



PRAYER SEAM

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JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE CONSULTING CONSORTIUM FAP-21/22
TEST SITE II-BAHADURABAD
GEOTEXTILE FILTER MATS GENERAL ARRANGEMENT

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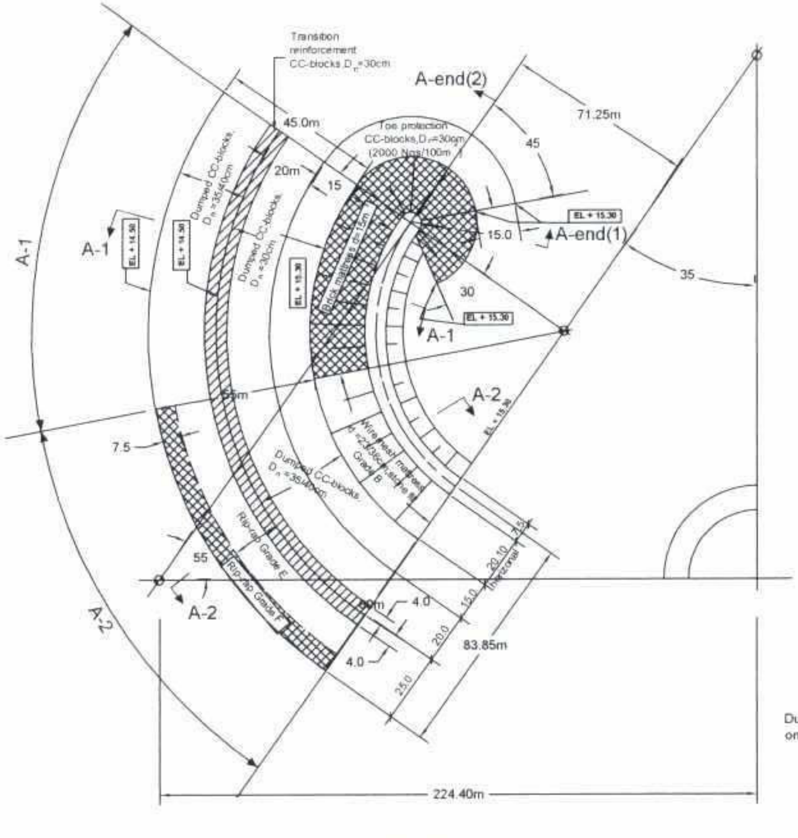
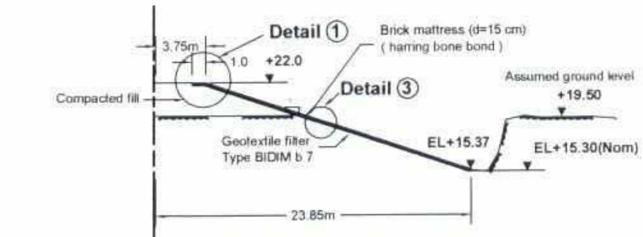
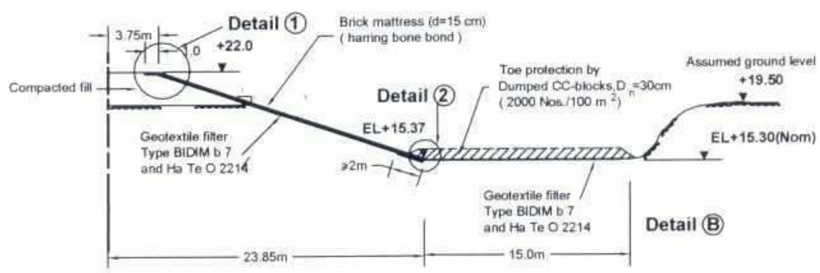
CHECKED			DRAWING No. R -A -304
APPROVED			REVISION 0



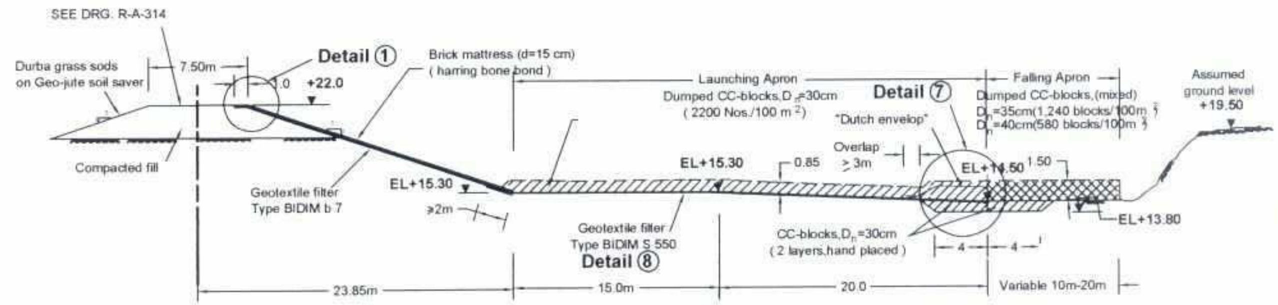
GENERAL PLAN SECTION A



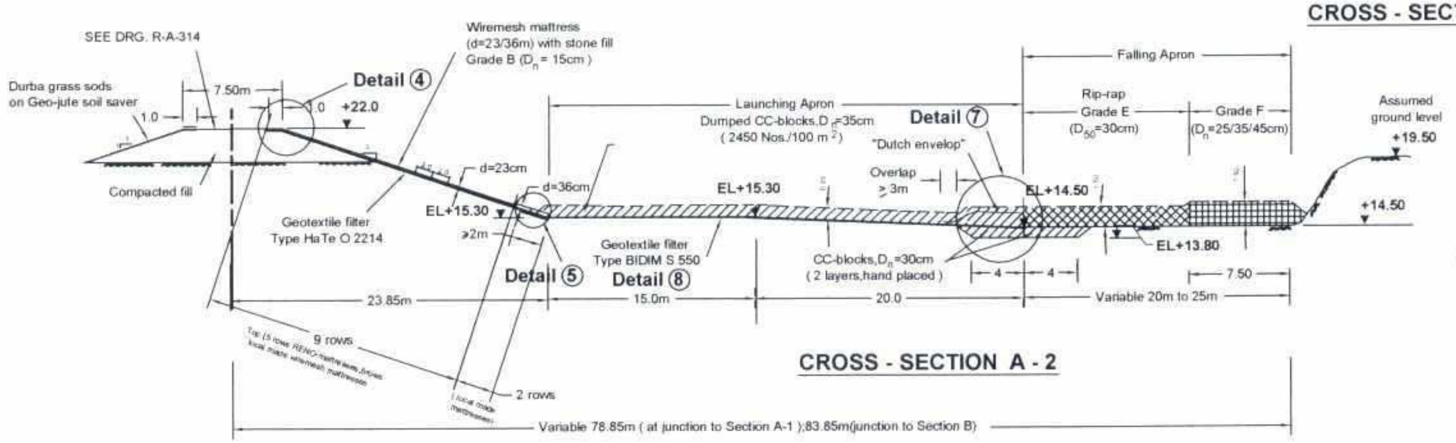
CROSS- SECTION A - end (1)



CROSS - SECTION A - end (2)



CROSS - SECTION A - 1



CROSS - SECTION A - 2

Notes :

1. Levels refer to +0.0 m PWD.
2. Measurements are shown in meter unless shown otherwise
3. Dredging, excavation, filling and compaction to comply with Specifications,Sections 800 and 900
4. Geotextile filter materials as per Specifications, Sections 200 and 1000
5. Revetment materials as per Specifications, Sections 200 and 1000
6. Falling Apron materials as per Specifications, Sections 200 and 1000
7. Reference Drawings
   - R -A - 302 Detailed layout of Test Structures
   - R -A - 304 Geotextile Filter Materials General Arrangement
   - R -A - 306 Typical Revetment Details
   - R -G - 014 Rip-rap Gradations

Notes :

1. Dumped CC- Blocks on Geotextiles See Detail 8
2. More Details on Embankment top R -A - 314

0 25 50 75 100m

0 5 10 15 20m

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT - 21

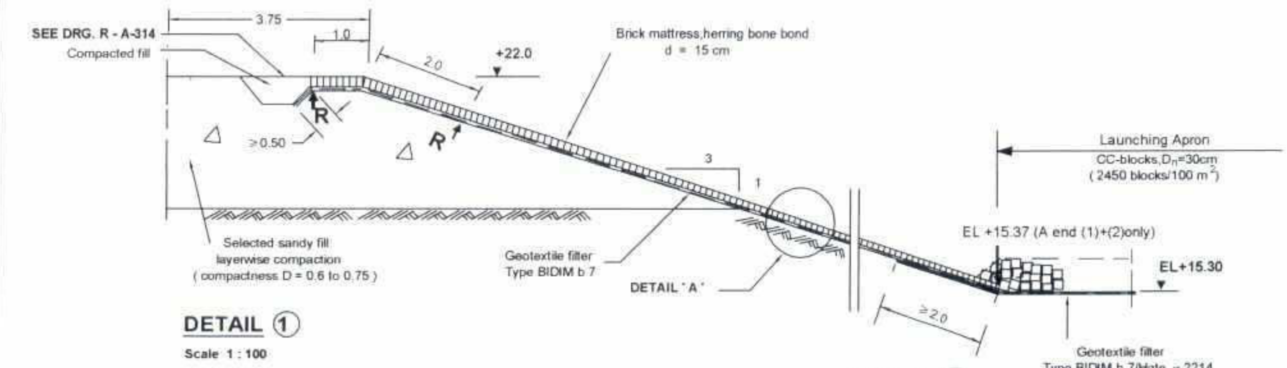
JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II-BAHADURABAD

TEST STRUCTURE A

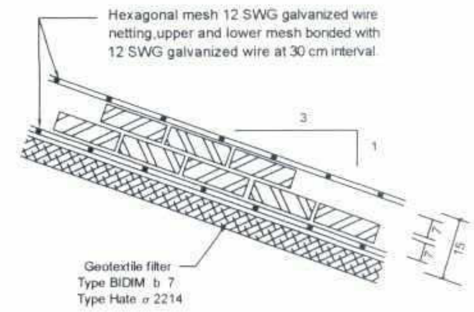
GENERAL PLAN AND CROSS-SECTION

	NAME	DATE	SCALE	
DRAWN	ANOWAR	26-04-2000		
CHECKED			DRAWING No. R -A -305	RIVISION 0
APPROVED				

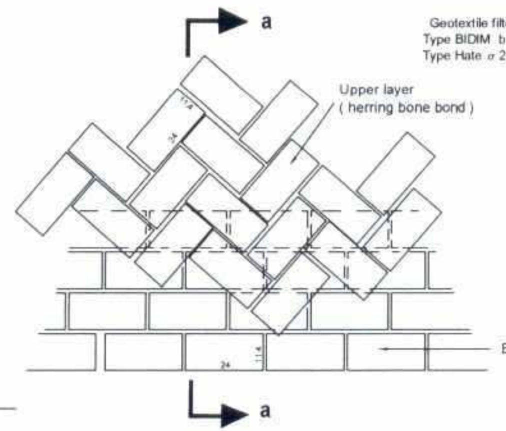


DETAIL ①
Scale 1 : 100

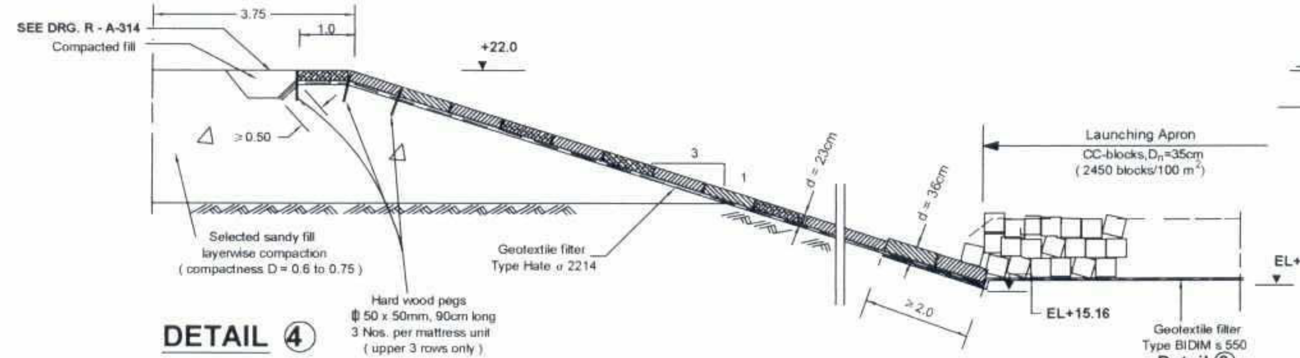
DETAIL ②
Scale 1 : 100



SECTION a - a



Detail ③: Brick Mattress, d = 15cm
(measurements in cm)



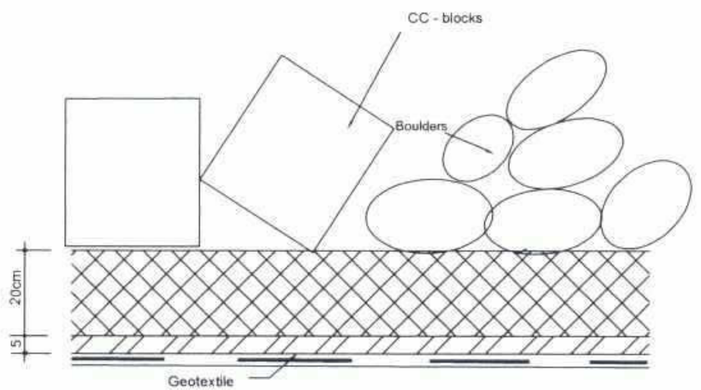
DETAIL ④

DETAIL ⑤

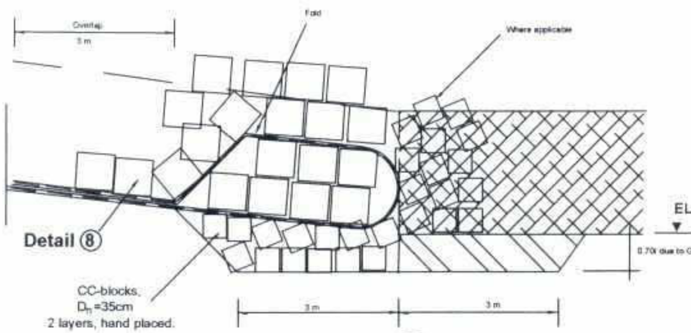
0 1 2 3 4 5m

Notes :

1. Levels refer to +0.0 m PWD.
2. Measurements are shown in meter,unless shown otherwise.
3. Dredging, excavation, filling and compaction to comply with Specifications Sections 800 and 900.
4. Geotextile filter materials as per Specifications Sections 200 and 1000.
5. Revetment materials as per Specifications Sections 200 and 1000.
6. Falling apron materials as per Specification Sections 200 and 1000.
7. Reference Drawings
   - R -A - 302 Detailed layout of Test Structures
   - R -A - 304 Geotextile Filter Materials General Arrangement
   - R -A - 305 Test structure A General Plan And Cross- Section



Detail ⑧ Protection Layer



Detail ⑦ "DUTCH ENVELOPE(Alternative)"

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BANK PROTECTION PILOT PROJECT - 21

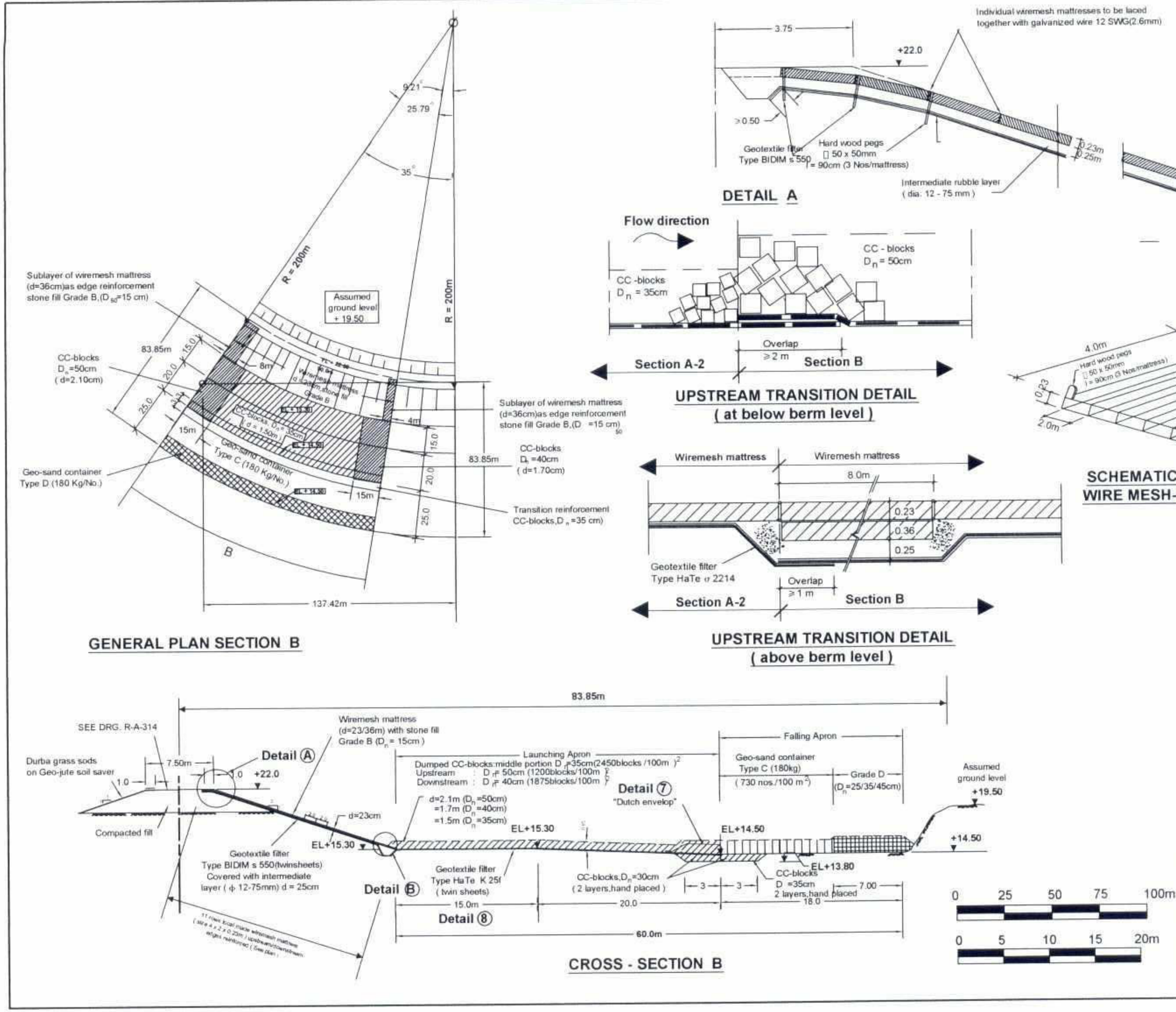
JAMUNA TEST WORKS CONSULTANTS,JOINT VENTURE
CONSULTING CONSORTIUM FAP 21/22

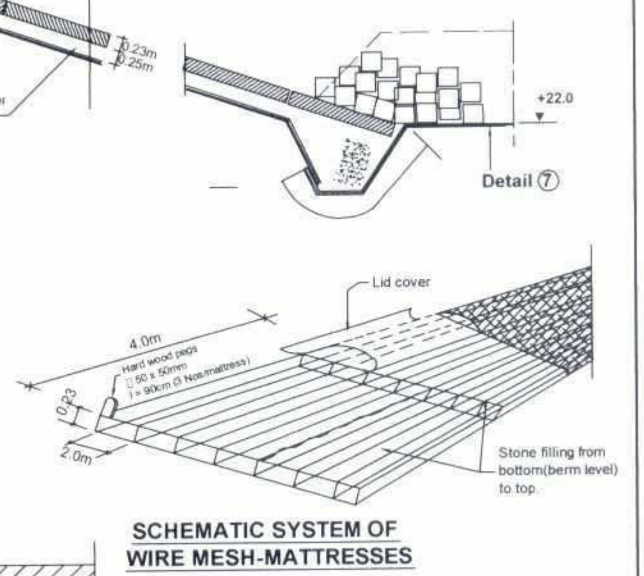
TEST SITE II-BAHADURABAD

TYPICAL REVETMENT DETAILS
No. ① To No. ⑧

	NAME	DATE	SCALE
DRAWN	ANOWAR	08-10-2000	
CHECKED			DRAWING No. R -A -306
APPROVED			REVISION 1

620





Notes :

1. Levels refer to ± 0.0 m PWD
2. Measurements are shown in meter,unless shown otherwise
3. Dredging, excavation, filling and compaction to comply with Specifications,Sections 800 and 900
4. Geotextile filter materials as per Specifications, Sections 200 and 1000
5. Revetment materials as per Specifications, Sections 200 and 1000
6. Falling apron materials as per Specification, Sections 200 and 1000
7. Reference Drawings
   - R -A - 302 Detailed layout of Test Structures
   - R -A - 304 Geotextile Filter Materials General Arrangement
   - R -A - 306 Typical Revetment Details 1 to 7
   - R -G - 014 Rip-rap Gradations

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

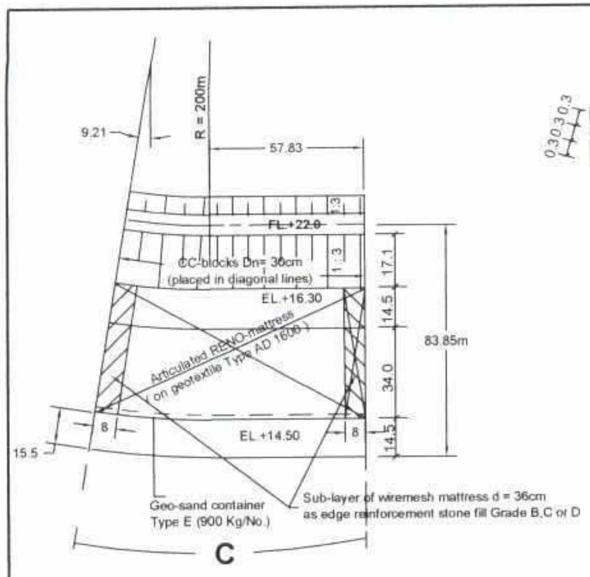
BANK PROTECTION PILOT PROJECT - 21

JAMUNA TEST WORKS CONSULTANTS,JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

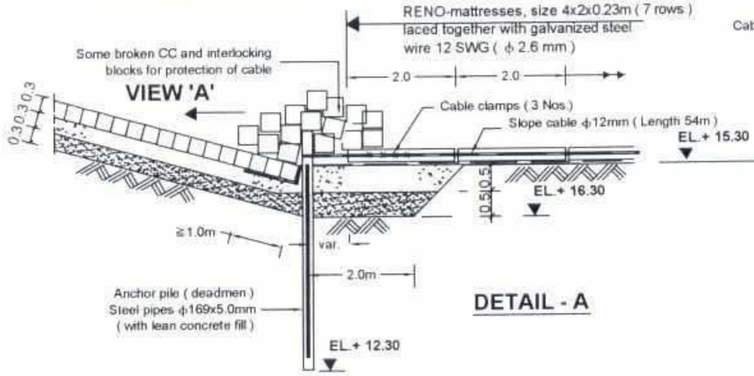
TEST SITE II-BAHADURABAD

TEST STRUCTURE B
GENERAL PLAN
CROSS-SECTION,DETAILS

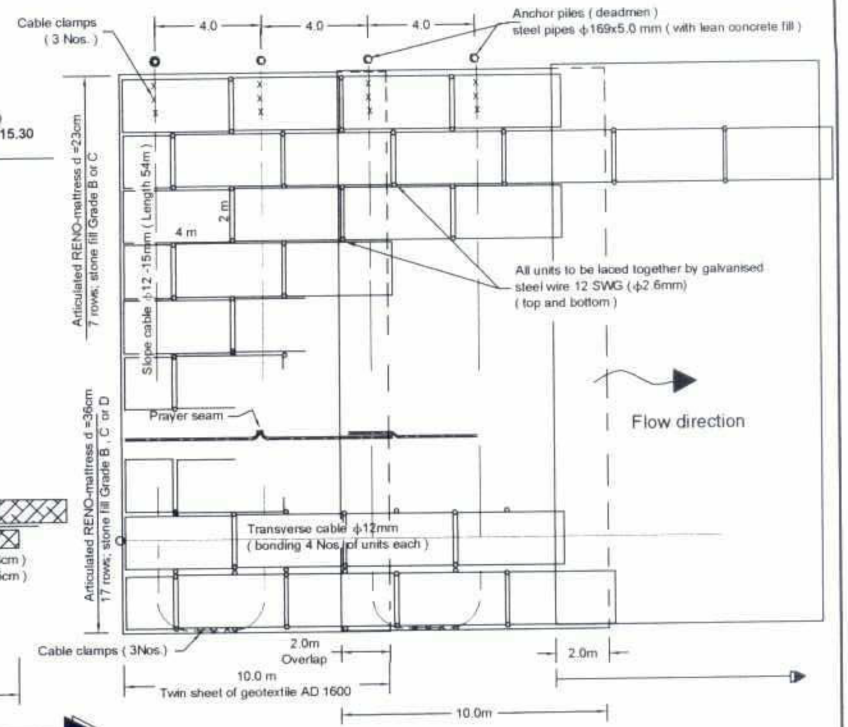
	NAME	DATE	SCALE
DRAWN	ANOWAR	02.10.2000	
CHECKED			DRAWING No. R -A -307
APPROVED			REVISION 1



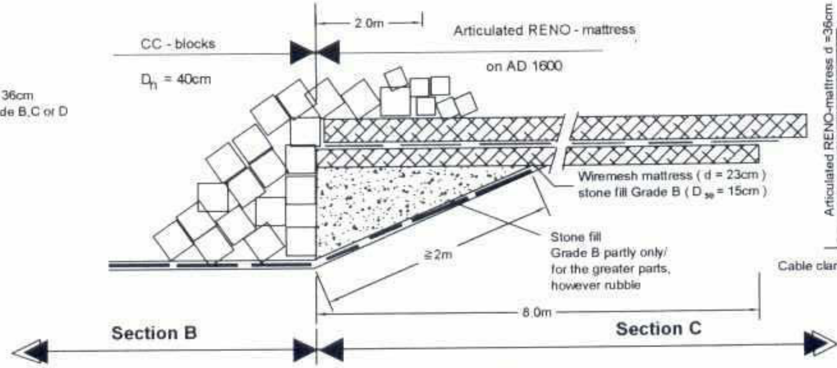
GENERAL PLAN SECTION C



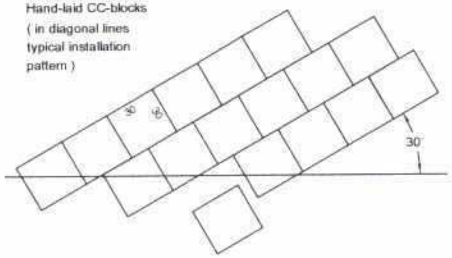
DETAIL - A



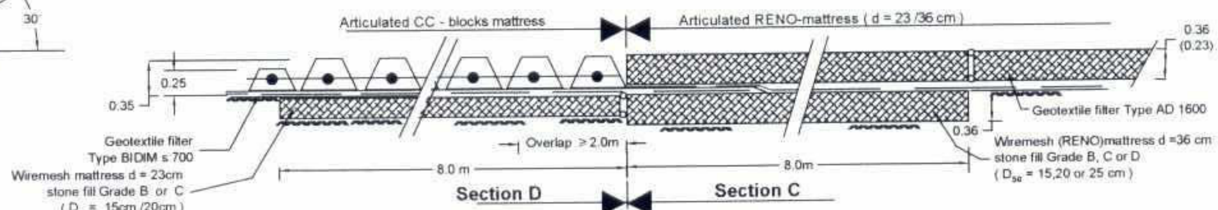
GENERAL PLAN OF ARTICULATED RENO - MATTRESS



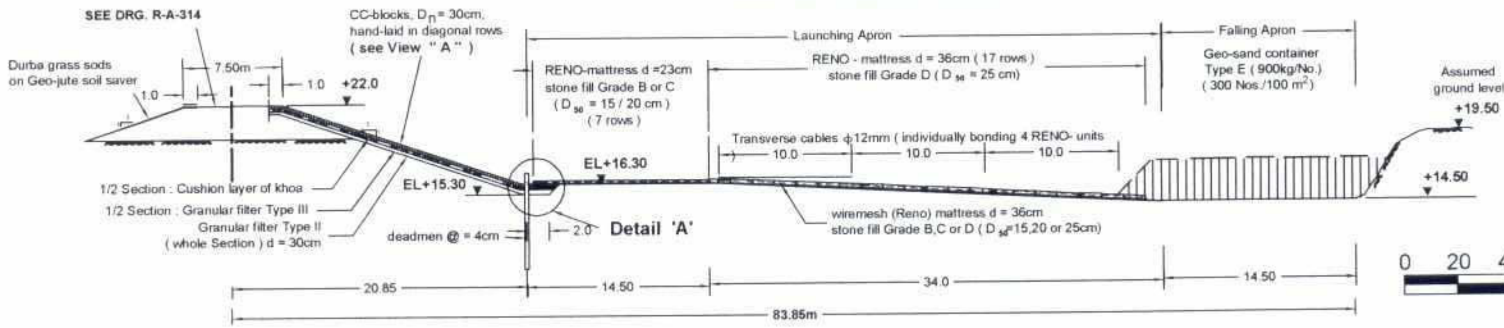
UPSTREAM TRANSITION DETAIL
(below berm level)



VIEW ' A '
Hand-laid CC-blocks
(in diagonal lines
typical installation
pattern)



TRANSITION DETAIL (BELOW BERM) SECTION C/D



CROSS - SECTION C

0 20 40 60 80 100m

Notes :

1. Levels refer to ± 0.0 m PWD.
2. Measurements are shown in meter unless shown otherwise
3. F.L = Finished level, E.L = Excavation level
4. Dredging, excavation, filling and compaction to comply with Specifications,Sections 800 and 900
5. Geotextile filter materials as per Specifications Sections 200 and 1000
6. Revetment materials as per Specifications Sections 200 and 1000
7. Falling apron materials as per Specification, Sections 200 and 1000
8. Reference Drawings
   - R -A - 302 Detailed layout of Test Structures
   - R -A - 304 Geotextile Filter Materials General Arrangement
   - R -G - 014 Rip-rap Gradations

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
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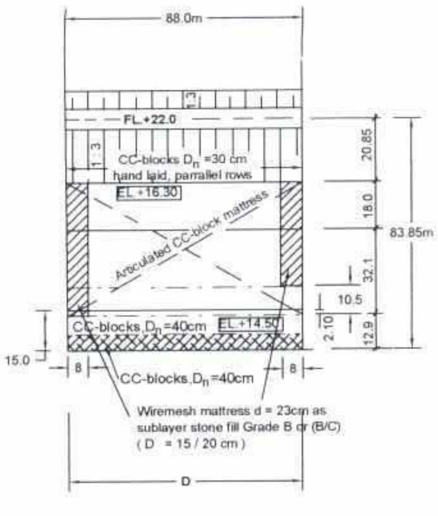
BANK PROTECTION PILOT PROJECT - 21

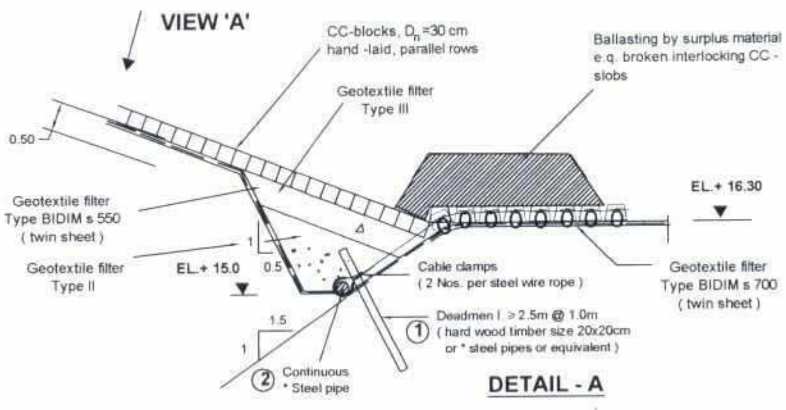
JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II-BAHADURABAD
TEST STRUCTURE C
GENERAL PLAN
CROSS-SECTION,DETAILS

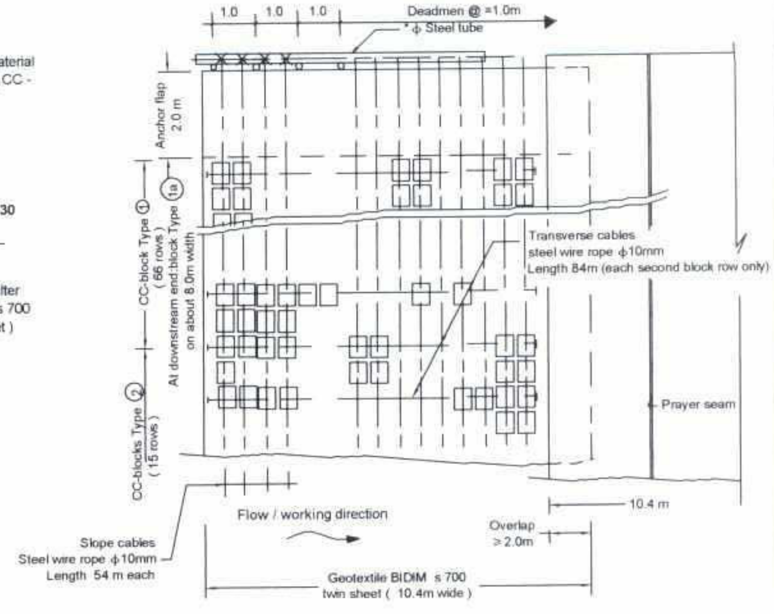
	NAME	DATE	SCALE
DRAWN	ANOWAR	10-10-2000	
CHECKED			DRAWING No. R -A -308
APPROVED			RIVISION 3



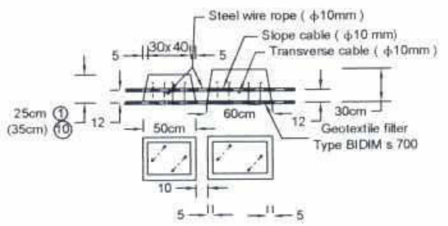
GENERAL PLAN SECTION D



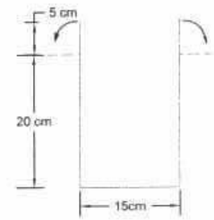
DETAIL - A



GENERAL PLAN OF ARTICULATED BLOCK MATTRESS

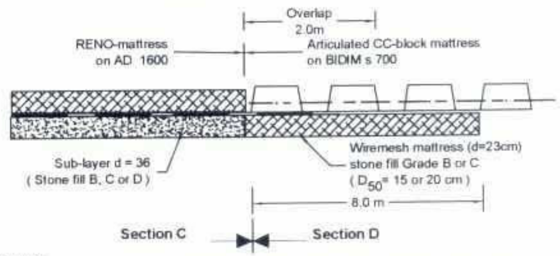


CC-blocks Dimensions for the Articulated Mattress Cast in - Situ (Measurements in Centimeter)



STEEL WIRE NEEDLE dia.4mm (SWG)

(Punch needles through geotextile shape end hooks only thereafter)



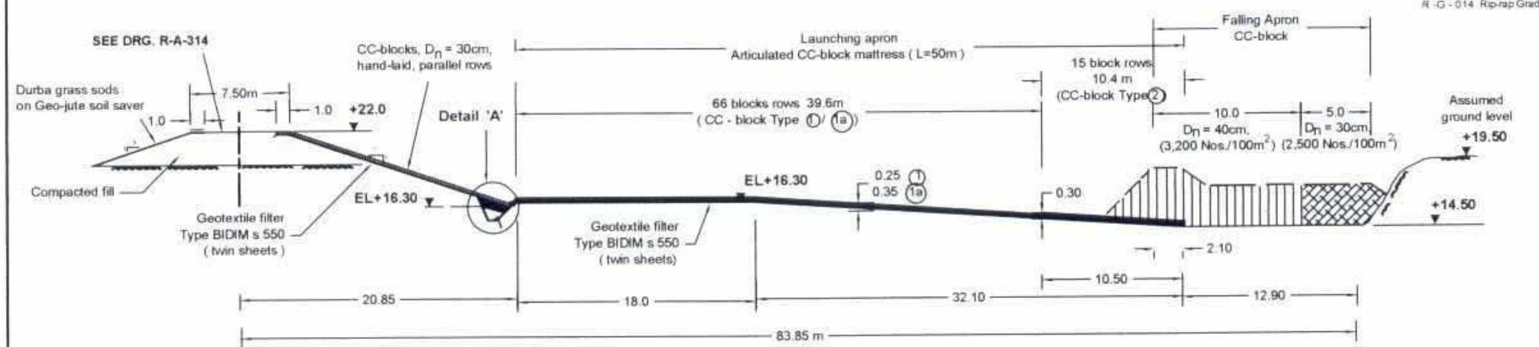
UPSTREAM TRANSITION DETAIL
(Below Berm Level)

STEEL SCHEDULE ANCHORING					
ITEM	QTY	UNIT	SIZE (mm)	WEIGHT/UNIT (Kg)	WEIGHT (Kg)
1	89	Nos.	ϕ169x5.0x2500	50.60	4,500
2	88	Nos.	ϕ169x5.0	20.20	1,780
			Total Weight Section D		6,280

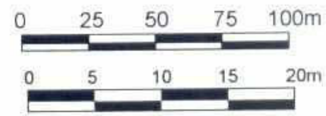
Concrete quality for cast in-situ blocks of mattress: Concrete Class B25, Cement content ≥350kg/m concrete W/C ratio 0.6 Coarse aggregates size 0-20 mm (crushed aggregates)	* STEEL PIPE 169x5mm (To be Grout / Concrete filled after instellation)

Notes :

1. Levels refer to ± 0.0 m PWD
2. Measurements are shown in meter,unless shown otherwise
3. F.L = Finished level, E.L = Excavation level
4. Reference Drawings :
   R -A - 302 Detailed layout of Test Structures
   R -A - 304 Geotextile Filter Materials General Arrangement
   R -G - 014 Rip-rap Gradations



CROSS - SECTION D



GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT - 21

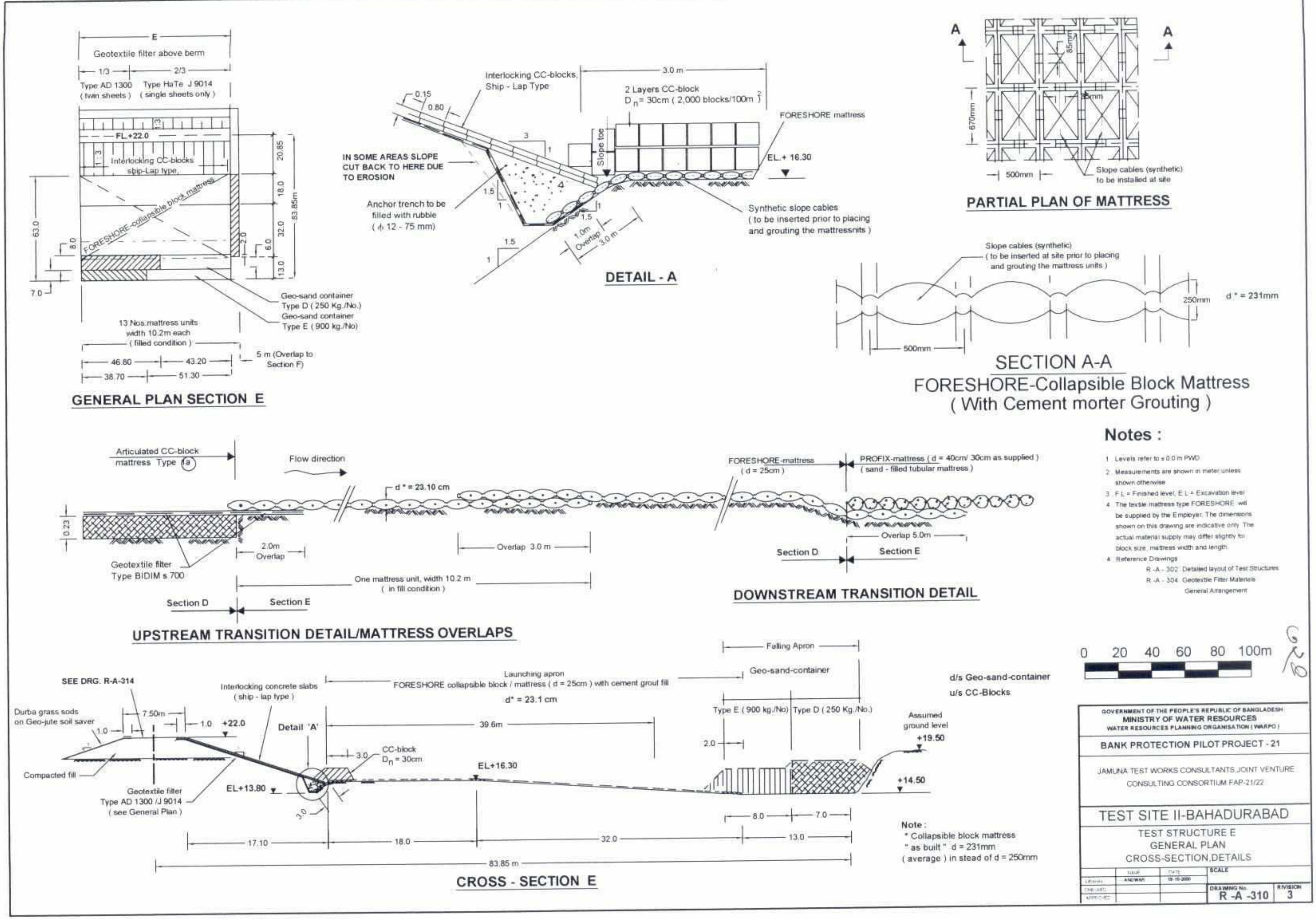
JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

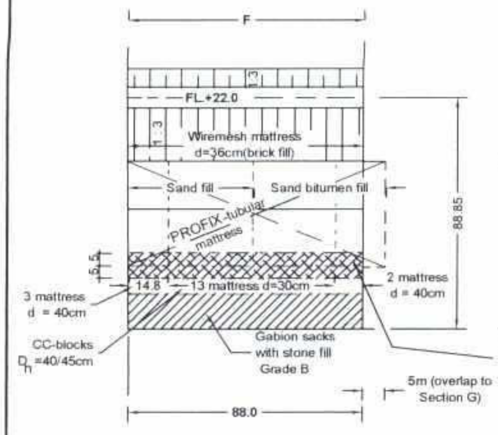
TEST SITE II-BAHADURABAD

TEST STRUCTURE D
GENERAL PLAN
CROSS-SECTION,DETAILS

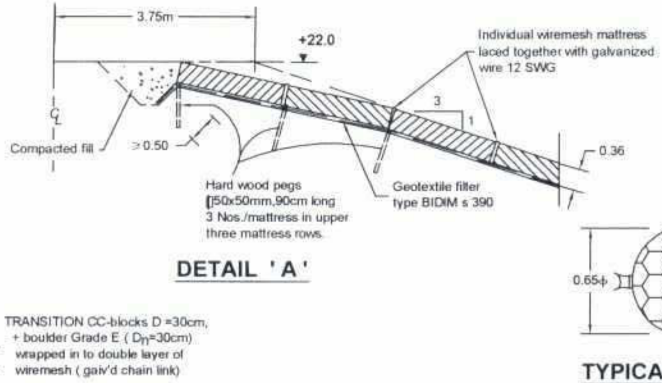
	NAME	DATE	SCALE
DRAWN	ANOWAR	10-10-2000	
CHECKED			DRAWING No. R -A -309
APPROVED			REVISION 3

G R

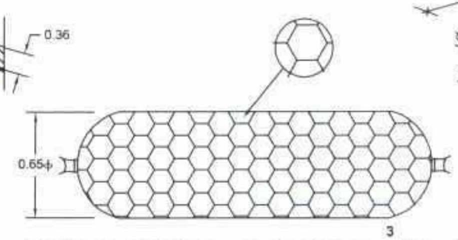

GENERAL PLAN SECTION E
Geotextile filter above berm
Type AD 1300 (twin sheets)
Type HaTe J 9014 (single sheets only)
FL.+22.0
Interlocking CC-blocks ship-Lap type
FORESHORE-collapsible block mattress
Geo-sand container Type D (250 Kg./No.)
Geo-sand container Type E (900 kg./No)
13 Nos.mattress units width 10.2m each (filled condition)
5 m (Overlap to Section F)
83.85m
DETAIL - A
Interlocking CC-blocks, Ship - Lap Type
2 Layers CC-block D n = 30cm (2,000 blocks/100m 2)
FORESHORE mattress
EL.+ 16.30
Slope toe
IN SOME AREAS SLOPE CUT BACK TO HERE DUE TO EROSION
Anchor trench to be filled with rubble (ф 12 - 75 mm)
Synthetic slope cables (to be inserted prior to placing and grouting the mattressnits)
1.0m Overlap
PARTIAL PLAN OF MATTRESS
Slope cables (synthetic) to be installed at site
SECTION A-A
FOREShore-Collapsible Block Mattress (With Cement morter Grouting)
Slope cables (synthetic) (to be inserted at site prior to placing and grouting the mattress units)
d* = 231mm
UPSTREAM TRANSITION DETAIL/MATTRESS OVERLAPS
Articulated CC-block mattress Type (a)
Flow direction
d* = 23.10 cm
Geotextile filter Type BIDIM s 700
2.0m Overlap
Overlap 3.0 m
One mattress unit, width 10.2 m (in fill condition)
Section D
Section E
DOWNSTREAM TRANSITION DETAIL
FORESHORE-mattress (d = 25cm)
PROFIX-mattress (d = 40cm/ 30cm as supplied) (sand - filled tubular mattress)
Overlap 5.0m
CROSS - SECTION E
SEE DRG. R-A-314
Durba grass sods on Geo-jute soil saver
Compacted fill
Geotextile filter Type AD 1300 /J 9014 (see General Plan)
Interlocking concrete slabs (ship - lap type)
Detail 'A'
CC-block D n = 30cm
EL+13.80
EL+16.30
+22.0
Launching apron
FORESHORE collapsible block / mattress (d = 25cm) with cement grout fill
d* = 23.1 cm
Falling Apron
Geo-sand-container
Type E (900 kg./No)
Type D (250 Kg./No.)
d/s Geo-sand-container
u/s CC-Blocks
Assumed ground level
+19.50
+14.50
Note:
* Collapsible block mattress "as built" d = 231mm (average) in stead of d = 250mm
Notes :
1. Levels refer to ± 0.0 m PWD
2. Measurements are shown in meter unless shown otherwise
3. F.L = Finished level, E.L = Excavation level
4. The textile mattress type FORESHORE will be supplied by the Employer. The dimensions shown on this drawing are indicative only. The actual material supply may differ slightly for block size, mattress width and length.
4. Reference Drawings
R -A - 302 Detailed layout of Test Structures
R -A - 304 Geotextile Filter Materials General Arrangement
0 20 40 60 80 100m
GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)
BANK PROTECTION PILOT PROJECT - 21
JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22
TEST SITE II-BAHADURABAD
TEST STRUCTURE E
GENERAL PLAN
CROSS-SECTION,DETAILS
DRAWING No. R -A -310
REVISION 3



GENERAL PLAN SECTION F

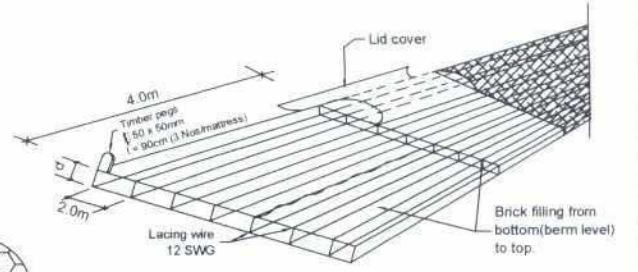


DETAIL 'A'

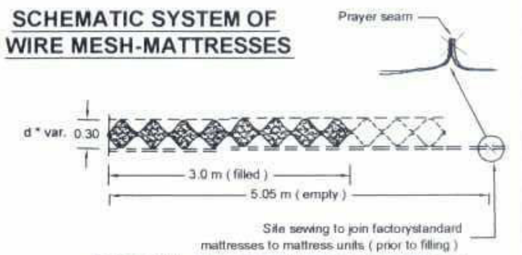


TYPICAL GABION - SACK (0.65 m^3 / No.)

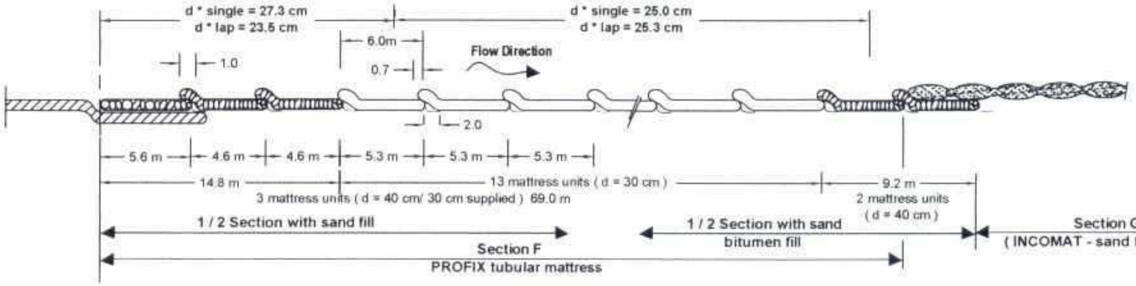
1. To be Site assembled from plain mesh wire sheets, size 2mx2m, wire ϕ2.7mm,PVC- coated,mesh width 80mm (supplied by Employer)
2. To be filled with stone, Grading Range B, (D_{50} = 15cm, W_{50} = 9 kg) and closed with end draw wires tightly.



SCHEMATIC SYSTEM OF WIRE MESH-MATTRESSES

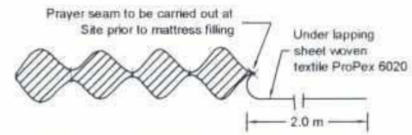


TYPICAL SECTION OF A FACTORY STANDARD MATTRESS



GENERAL CROSS-SECTION OF PROFIX - MATTRESS

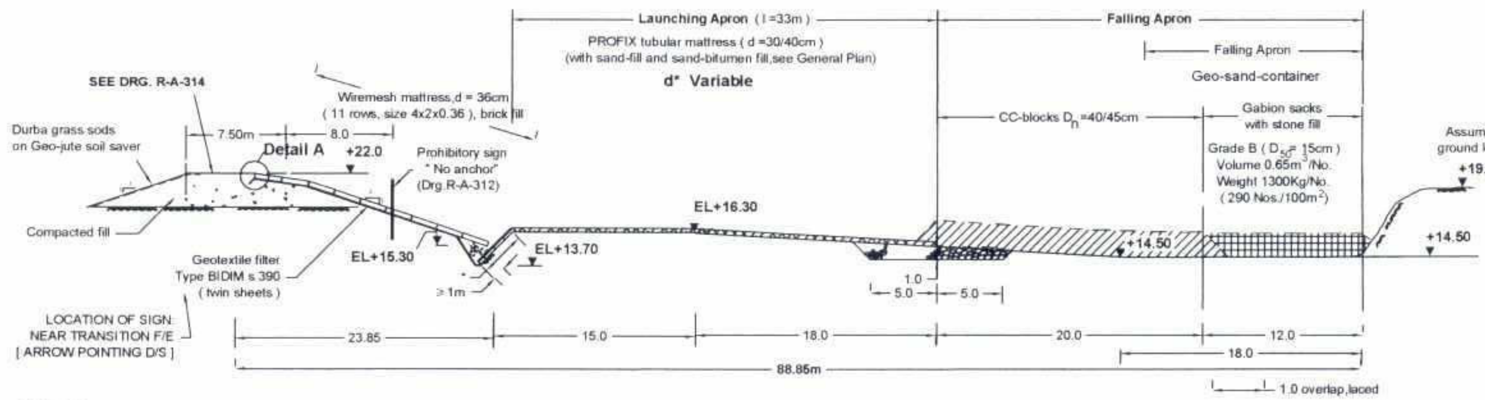
(measurements refer to covered area in filled condition of mattress units)



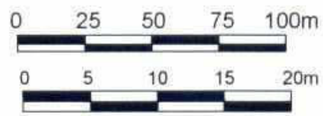
OVERLAP (Under lapping sheet) OF PROFIX-Mattress

Notes:

1. Levels refer to ± 0.0 m PWD.
2. Measurements are shown in meter unless shown otherwise.
3. F.L = Finished level, E.L = Excavation level
4. The textile mattress type PROFIX will be supplied by the Employer. The actual material supply may differ slightly by width and length of individual mattress units.
5. dredging, excavation, filling and compaction to comply with Specification, Sections 800 and 900.
6. Geotextile filter materials as per Specifications, Sections 200 and 1000.
7. Revetment materials as per Specifications, Sections 200 and 1000.
8. Falling apron materials as per specification, Sections 200 and 1000.
9. Reference Drawings :
   - R - A - 302 Detailed Layout of Test Structures
   - R - A - 304 Geotextile Filter Materials
   - R - A - 312 Test Structure G
   - R - G - 014 Rip - Rap Gradations



DETAILED CROSS - SECTION F



* Note:
ANCHOR LENGTH OF PROFIX MATTRESS;
" IN FILLED CONDITION" VARIABLE FROM 0-3m
AS SUPPLIED MATERIAL DID NOT CONFORM
TO ORDER l=36m; FILLED LENGTHS AT TIMES
l ± 30m ONLY ; BUT UNDERLAYING SHEET
ALWAYS l = 36m.

Note:
* collapsible block mattress
" as built " d * = variable as shown

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MINISTRY OF WATER RESOURCES
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BANK PROTECTION PILOT PROJECT - 21

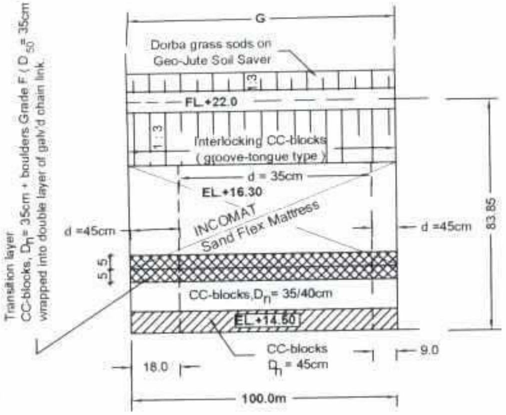
JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II-BAHADURABAD

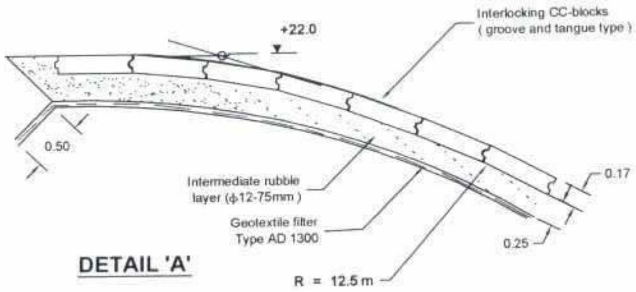
TEST STRUCTURE F
GENERAL PLAN
CROSS-SECTION,DETAILS

	NAME	DATE	SCALE
DRAWN	ANOWAR	23-10-2000	
CHECKED			DRAWING No. R -A -311
APPROVED			REVISION 1

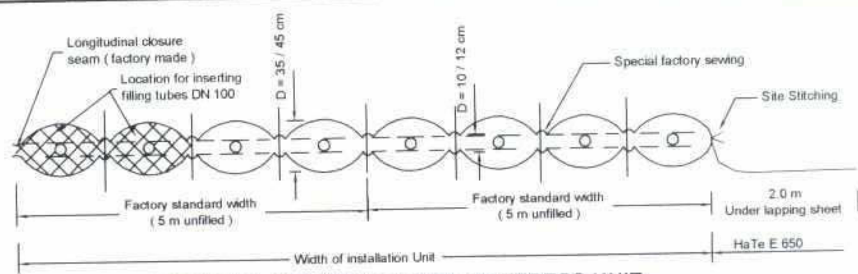
G2G



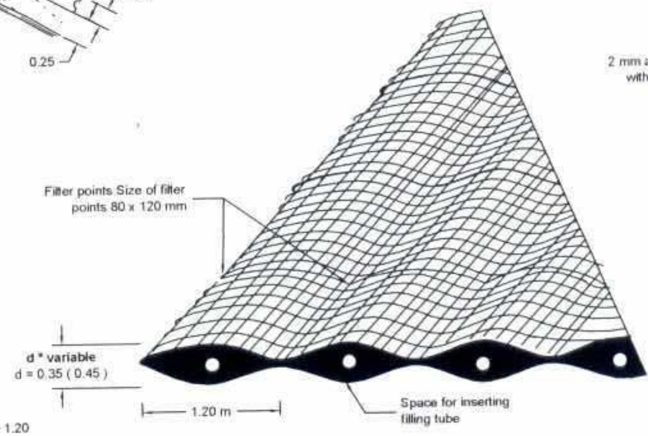
GENERAL PLAN SECTION G



DETAIL 'A'

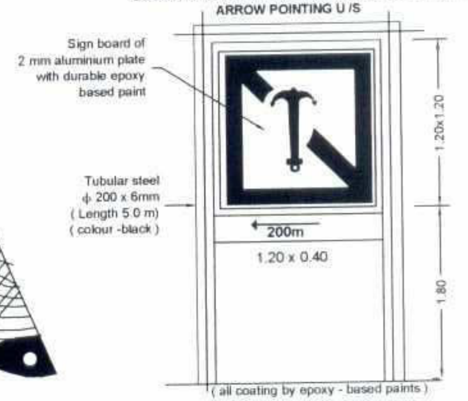


GENERAL SECTION OF ONE MATTRESS UNIT

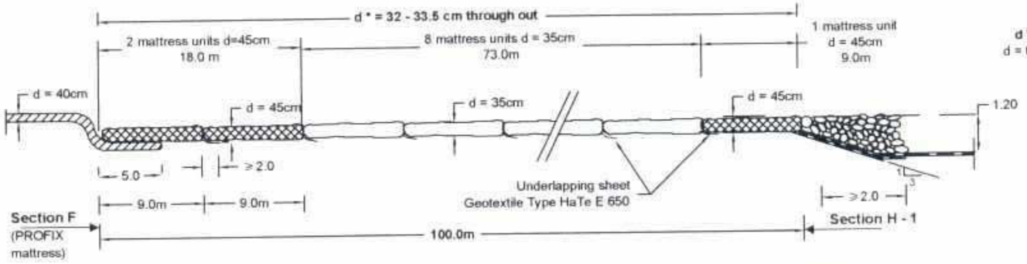


ISOMETRIC VIEW
COLLAPSABLE BLOCK MATTRESS
INCOMAT - Sand Flex

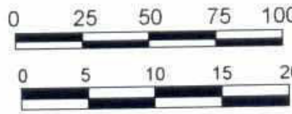
LOCATION : SIGN PLACED NEAR TRANSITION G/H -1
ARROW POINTING U /S



PROHIBITORY SIGN
" NO ANCHORING "

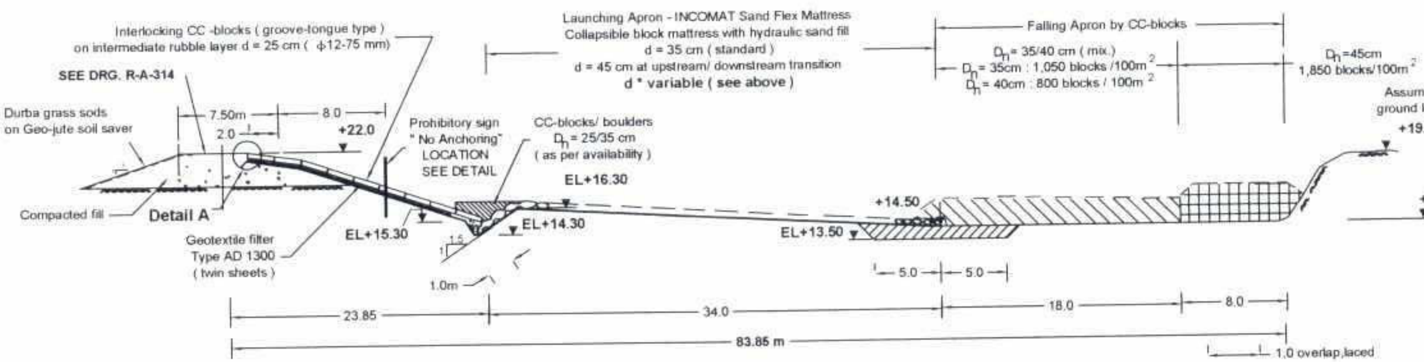


GENERAL CROSS-SECTION OF INCOMAT SAND FLEX MATTRESS
(measurements refer to covered area in filled condition)



Notes:

1. Levels refer to ± 0.0 m PWD.
2. Measurements are shown in meter unless shown otherwise.
3. F.L = Finished level, E.L = Excavation level
4. The textile mattress type PROFIX will be supplied by the Employer. The actual material supply may differ slightly by width and length of individual mattress units.
5. dredging, excavation, filling and compaction to comply with Specification, Sections 800 and 900.
6. Geotextile filter materials as per Specifications, Sections 200 and 1000.
7. Revetment materials as per Specifications, Sections 200 and 1000.
8. Falling apron materials as per specification, Sections 200 and 1000.
9. Reference Drawings :
   - R - A - 302 Detailed Layout of Test Structures.
   - R - A - 304 Geotextile Filter Materials
   - R - A - 312 Test Structure G
   - R - G - 014 Rip - Rap Gradations.



DETAILED CROSS - SECTION G

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

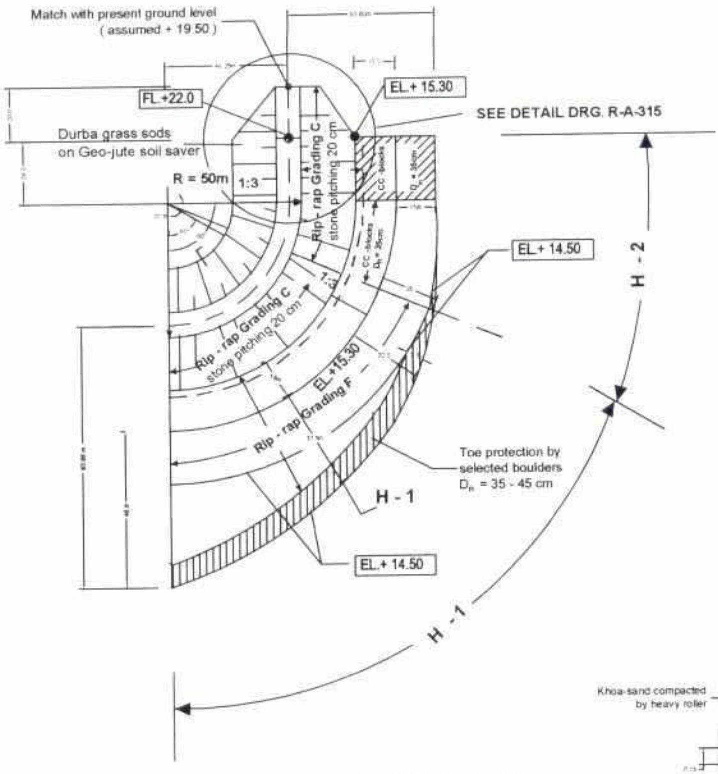
BANK PROTECTION PILOT PROJECT - 21

JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

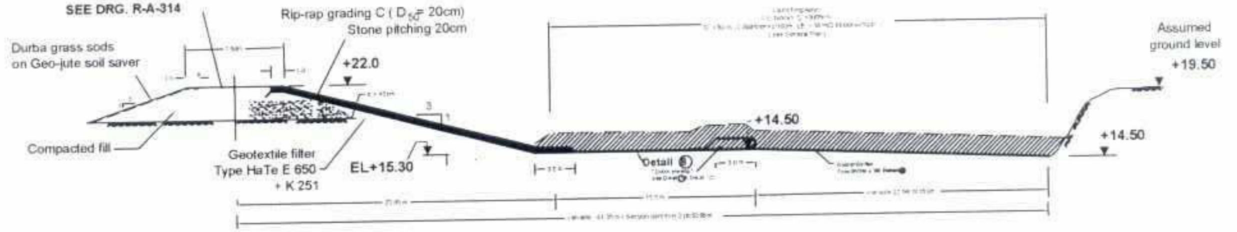
TEST SITE II-BAHADURABAD

TEST STRUCTURE G
GENERAL PLAN
CROSS-SECTION,DETAILS

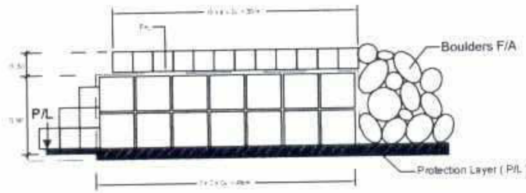
	NAME	DATE	SCALE	
DRAWN	ANOWAR	25-10-2000	DRAWING No. R -A -312	RIVISION 1
CHECKED				
APPROVED				



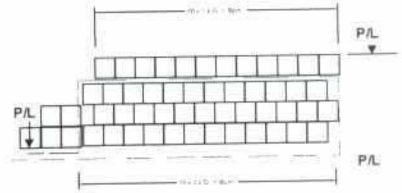
GENERAL PLAN SECTIONS H-1, H-2



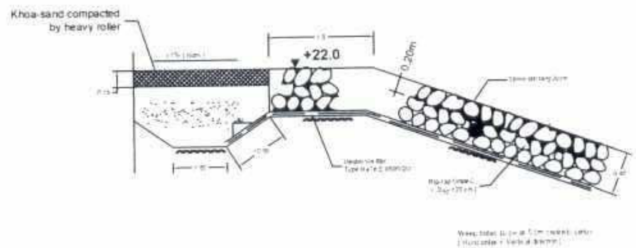
DETAILED CROSS - SECTION H-2



DETAIL "B"



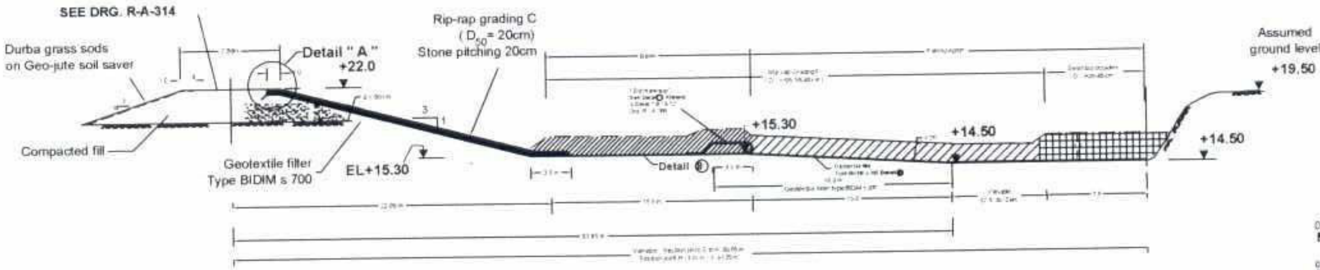
DETAIL "C"



DETAIL "A"

Notes:

1. Levels refer to ± 0.0 m PWD.
2. Measurements are shown in meter unless shown otherwise.
3. Dredging, excavation, filling and compaction to comply with Specification, Sections 800 and 900.
4. Geotextile filter materials as per Specifications, Sections 200 and 1000.
5. Revetment materials as per Specifications, Sections 200 and 1000.
6. Falling apron materials as per specification, Sections 200 and 1000.
7. Reference Drawings :
   - R - A - 302 Detailed Layout of Test Structures
   - R - A - 304 Geotextile Filter Materials
   - R - A - 306 Typical Revetment Details No. 1 to No. 7



DETAILED CROSS - SECTION H-1

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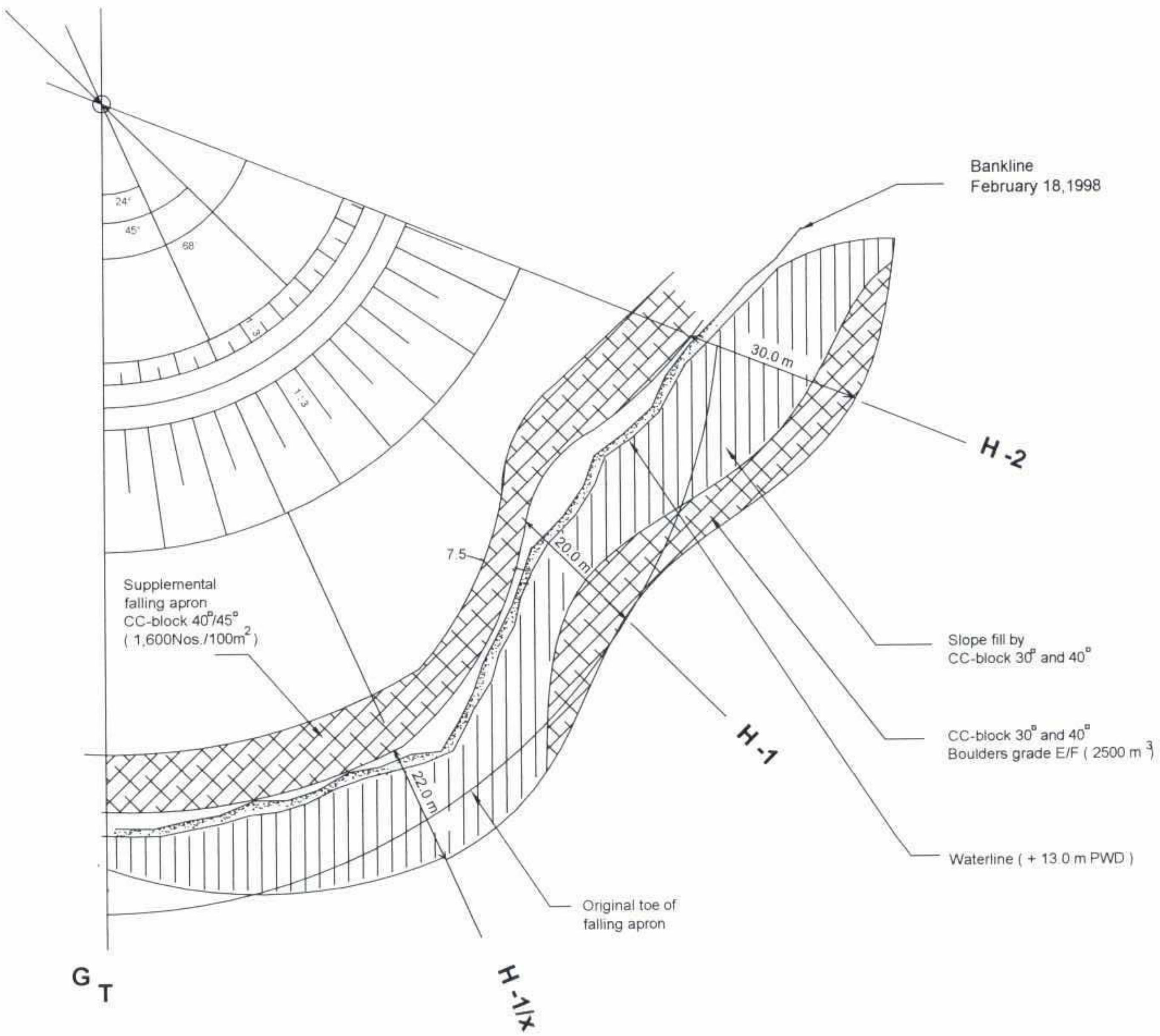
WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT - 21

JAMUNA TEST WORKS CONSULTANTS JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II-BAHADURABAD
TEST STRUCTURE H
GENERAL PLAN,SECTION H-1,H-2
CROSS-SECTION,DETAILS

	NAME	DATE	SCALE
DRAWN	ANOWAR	23-10-2000	
CHECKED			DRAWING No. R -A -313
APPROVED			RIVISION 1



Notes:
1. All measurements are shown in meter.
2. Filling of river bed slope to profile of approx. 1 : 2 (V : H)

0 10 25 50 m

G2H

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

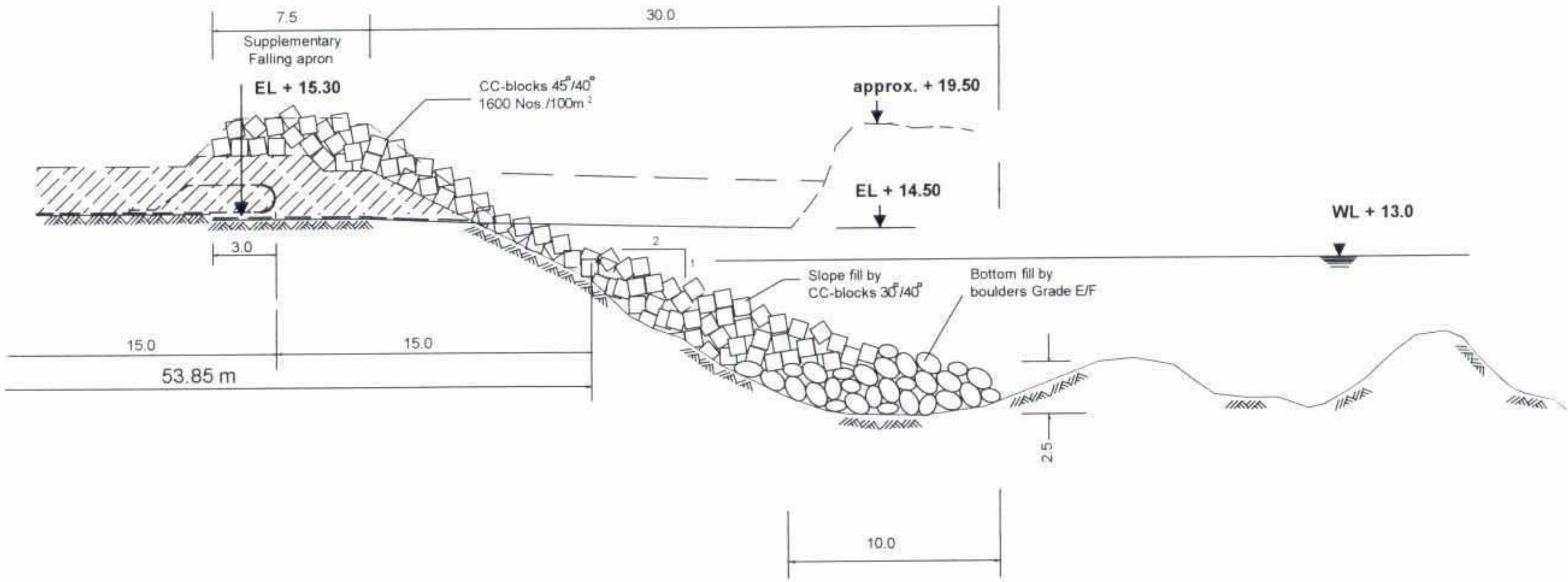
BANK PROTECTION PILOT PROJECT - 21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II - BAHADURABAD
ADAPTATION

LAYOUT PLAN OF SECTION H
(1996/97)

	NAME	DATE	SCALE	
DRAWN	ANOWAR	13-03-2001		
CHECKED			DRAWING No. R-AD-01	REVISION 0
APPROVED				



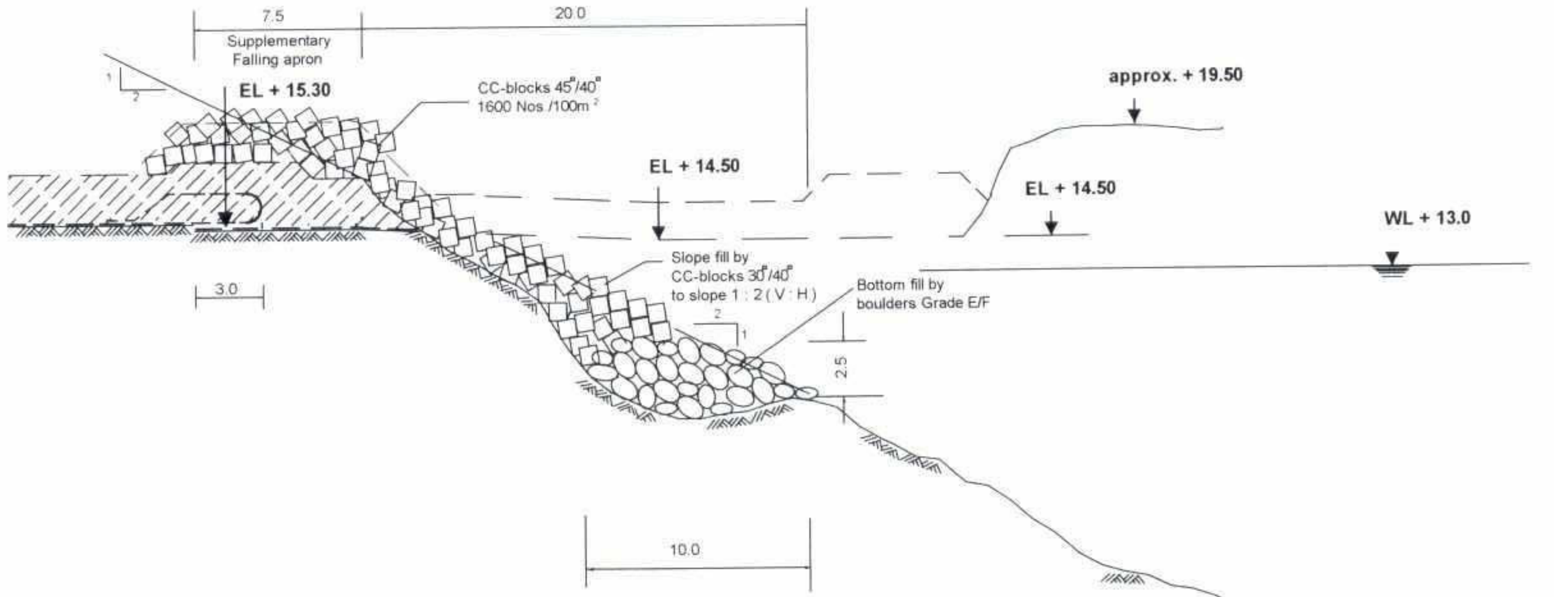
Note:

1. Levels refer to ± 0.0m PWD.
2. Measurements are shown in meter.
3. Filling of river bed slope to profile of approx. 1 : 2 (V : H)
4. Reference Drawing: R - AM -01

0 2.5 5.0 7.5 10.0 m

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH MINISTRY OF WATER RESOURCES WATER RESOURCES PLANNING ORGANISATION (WARPO)
BANK PROTECTION PILOT PROJECT - 21
JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE CONSULTING CONSORTIUM FAP-21/22
TEST SITE II - BAHADURABAD ADAPTATION
DETAILS SECTION H - 2

	NAME	DATE	SCALE	
DRAWN	ANOWAR	14-03-2001		
CHECKED			DRAWING No. R-AD-02	REVISION 0
APPROVED				



Note:

1. Levels refer to ± 0.0m PWD.
2. Measurements are shown in meter.
3. Filling of river bed slope to profile of approx. 1 : 2 (V : H)
4. Reference Drawing: R - AM -01

0 2.5 5.0 7.5 10.0 m

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GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

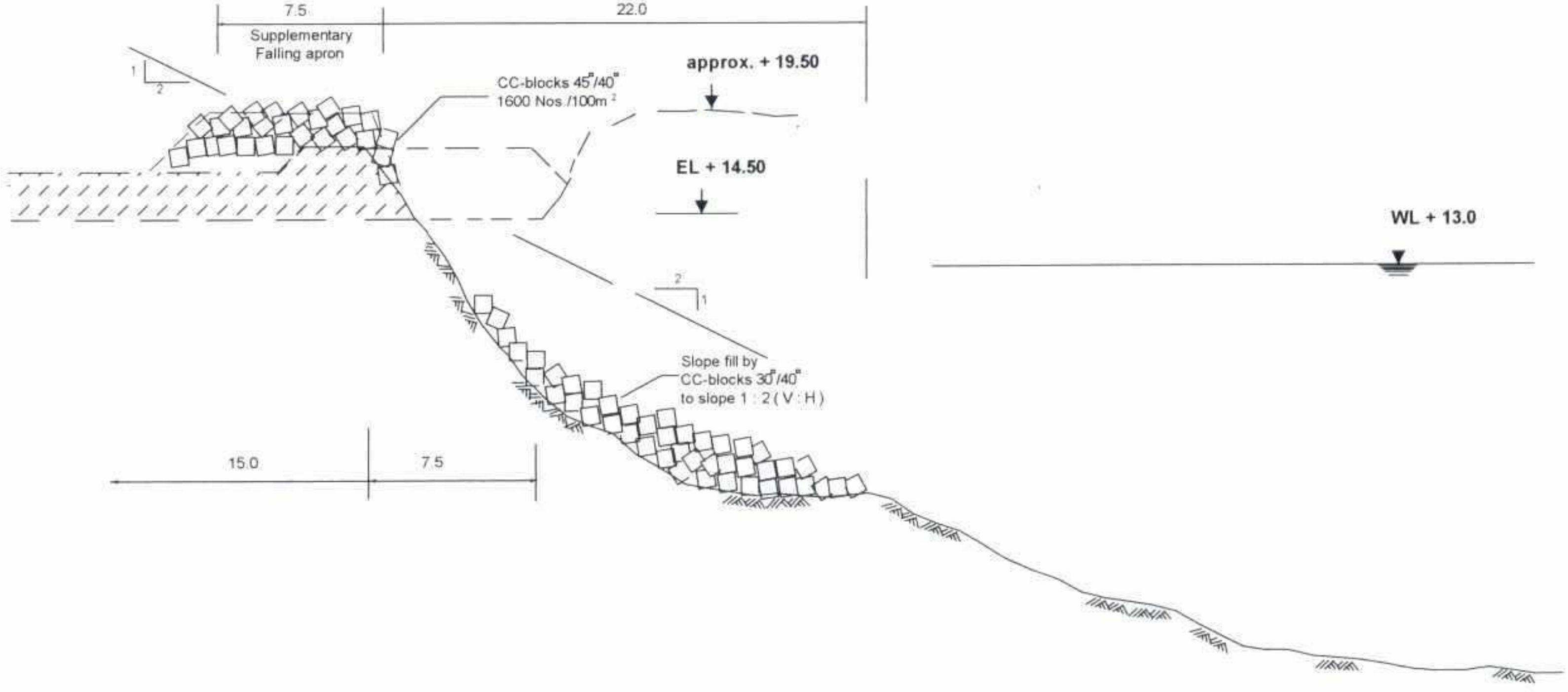
BANK PROTECTION PILOT PROJECT - 21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II - BAHADURABAD
ADAPTATION

DETAILS SECTION H - 1

	NAME	DATE	SCALE	
DRAWN	ANOWAR	15-03-2001		
CHECKED			DRAWING No. R-AD- 03	REVISION 0
APPROVED				



Note:

1 . Levels refer to ± 0.0m PWD.
2 . Measurements are shown in meter.
3 . Filling of river bed slope to profile of approx. 1 : 2 (V : H)
4 . Reference Drawing: R - AM -01

0 2.5 5.0 7.5 10.0 m

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

BANK PROTECTION PILOT PROJECT - 21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE II - BAHADURABAD
ADAPTATION

DETAILS SECTION H - 1 / x

	NAME	DATE	SCALE	
DRAWN	ANOWAR	15-03-2001		
CHECKED			DRAWING No. R-AD- 04	RIVISION 0
APPROVED				

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BANK PROTECTION PILOT PROJECT

FAP 21

FINAL PROJECT EVALUATION REPORT

ANNEX 9: PART B - TEST SITE III AT GHUTAIL

THE REVETMENT TEST STRUCTURE; PROCUREMENT AND CONSTRUCTION REPORT

MAY 2001

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FAP 21 – BANK PROTECTION PILOT PROJECT

FINAL PROJECT EVALUATION REPORT

ANNEX 9: PART B – TEST SITE III AT GHUTAIL

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ATTACHMENT

Attachment 1: see Part A of this Annex
Attachment 2: Selection of Design and Construction Drawings, Ghutail

1 INTRODUCTION

After successful completion of two bank protection structures in the northern reach of Brahmaputra/Jamuna river, decision was taken to build a third structure at Ghutail Bazar following special request from GoB to the funding agencies. Remaining funds designated for the other FAP 21 test structures in the order of DEM 6.5 Million were used for procurement of materials and construction. The limited amount, but as well as the site conditions dictated the layout of the structure. A lower safety level was used, agreed by relevant authorities to provide minimum protection of the area. Further details about the design can be found in Annex 8, Design.

Preparation of the works started early 1999 in studying different design options. The final chosen structure was a revetment built in the dry similar to the structure in Bahadurabad, but making use of only one type of slope protection, falling and launching apron. Mid 1999 after signing the contract, activities of the local subcontractor concentrated on site installation and establishing of concrete yard. Casting of concrete blocks started on 18-8-2000. The final design was completed in October 99 when the bankline after preceding flood was known. Due to further erosion of the bankline and in revision of the initial planning the structure was shifted backwards into the flood plain. This shifting was restricted due to the vicinity of the area to be protected, i.e. the bazar, resulting in a significant shortening of the launching apron.

The final design also deviated in some parts from the initial planning, which caused some problems during execution of the works:

- the length of the structure was reduced mainly at the southern side
- some (small) areas had to be acquired additionally due to the shifting of the structure in direction of the bazar

Both aspects were used by agitated villagers to improve their position in participating in the works.

Nevertheless it was possible to overcome all difficulties and to realise the structure. Works were started in an inauguration ceremony on 17-12-1999 by DC Jamalpur. On 19-1-2000 during the visit of the managing director of one of the partner companies the placement of protective layers was started. All protection elements were placed until 6-5-2000, leaving only the land sided road to be completed. As this activity was hampered during early and heavy rainfall it could only be completed on 7-6-2000.

Equipment left on 17-6-2000 by barge. On 1-7-2000 the Water Resources Minister and the Land Minister with a vast number of high ranking guests attending, inaugurated the structure.

2 PROCUREMENT

Materials used for the revetment structure, namely geotextiles and Reno mattresses as well as boulder were procured from exterior sources. Quotations of different suppliers were obtained in May and June and order was given to DIRD, Dhaka on 7-7-1999 for the supply of the total amount of materials.

Specifications of the used materials are as follows:

Geotextiles

Type	CBR puncture resistance [N]	O_{90} [mm]	Thickness (2kPa) [mm]	Mass [g/m²]
Poyfelt TS70	3,850	0.09	2.9	325
Bidim S82	3,800	0.06	3.4	385
Bidim P70	6,300	0.06	5.3	700

Reno
Specification as per offer were:

- Size: 4 x 2 x 0.3 m
- Mesh Type: 6x8
- Mesh Wire: 2.2 mm
- Selvedge wire: 2.7 mm
- Lacing wire: 2.2 mm

Specification of delivered items as per manufacturing certificate are:

Spec	Wire diam. [mm]	Mean tensile strength [N/mm²]	Elongation [%]	Weight of coating [gr/m²]
min	2.62	380	15	295
max	2.78	500		

Details of shipping are as follows.
Geotextiles:

Brand Name	Size [m]	No of Rolls	Weight gross / net [kg]	Total Area [m²]	Unit Rate C&F Chittagong [USD]	Amount [USD]
Polyfelt TS 70	6 x 100	24	5,069 / 4,680	14,400	0.96	13,824
BIDIM S82	6 x 90	40	8,964 / 8,316	21,600	1.21	26,136
BIDIM P70	6 x 55	18	4,443 / 4,158	5,940	1.95	11,583
Total		82	18,476/17,154	41,940		51,543

Reno mattress:

Brand Name	Size [m]	No	Weight [kg]	Total Area [m²]	Unit Rate C&F Chittagong [USD]	Amount [USD]
Maccaferri 60 x 80	2 x 4 x 0.3	1,980	61,497	15,840	45	89,100

The Reno mattresses were delivered with 72 coils of zinc lacing wire of 25 kg each. Cost for coated wire, preferred for the construction was quoted USD 70 per box but due to the high price discarded.

For conversion 1 USD equals BDT 49 and DEM 1.88.

Additionally thread for sewing the geotextiles together has been procured. In total 118 cones of approximately 860 m length for BDT 500 each, totalling in BDT 59,000 were purchased.

Boulders were procured from Bhutan through Exchange International Ltd. Dhaka, the supplier for Kamarjani and Bahadurabad test sites. After quotation and cost breakdown a unit rate of BDT 2,223 per cubic meter was agreed. The D_{50} size is 20/25 cm ranging from min 7.5 to max 30 cm. The contract had been signed on 23-6-1999. Delivery was foreseen until end of January 2000. Final payment was made on 18-6-2000 based on reception of last stack at the site on 9-6-2000. In total 4025 m^3 were delivered.

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3 EXECUTION OF WORKS

3.1 CONTRACT

After price negotiation, the contract for the execution of works was awarded directly to the consortium The Engineers Ltd., Corolla Corporation Ltd. that had built the structures at the other two test sites. The contract agreement was signed on 23-6-1999. The total contract amount was BDT 161,928,584, including contingencies.

Advance payment of 15% of the contract amount was made against bank guarantee on the same date. An unconditional bank guarantee of BDT 15.3 Million (10% of amount of works) was issued as performance security the same date and remained valid until 30-6-2001.

During interim payment 5% retention money was deducted of which 2.5% were reimbursed upon completion of the works. A bank guarantee of the remaining 2.5% is kept until 30-6-2001.

The final bill was submitted in July and amounts to BDT 148,390,487 Million, which is about BDT 13.5 Million below total estimated contract amount.

3.2 DESCRIPTION OF WORKS

Ghutail bank protection works comprises basically of the same elements as executed at Bahadurabad structure. Thus the works are comparable, however the main difference is the concentration of one element each for each individual protective part. In general the cheapest and easiest to execute, but as proven at Bahadurabad test structure stable solution, had been selected.

As slope protection brick mattressing was chosen, which under local conditions, namely taking into account the low labour cost is a very cost effective solution. The launching apron, i.e. the interconnected part of the main protective works, consists of Reno mattresses. These are galvanized wire-mesh boxes filled with boulders. The outer protective layer, the falling apron, was made of concrete blocks of different sizes from 35 to 45 cm. In terms of monetary value this element is the most valuable as it binds 70% of the total contract amount.

Starting with earth works subsequently key, launching apron, brick mattressing, and falling apron followed. Work proceeded from the central part of the structure in southern and northern direction. The excavated quantities were mainly dumped into the river and used for the build up of the embankment.

3.3 PLANNING

Planning was made on basis of total activities and time availability for the whole of the works. A high flexibility was obtained in working in two directions from the central part of the structure, allowing to shift activities once problems at one side arose (also from disturbance of local people). The planning of the main activities is shown in a bar chart diagram with permanently plotted progress. Details are given in the next figure.

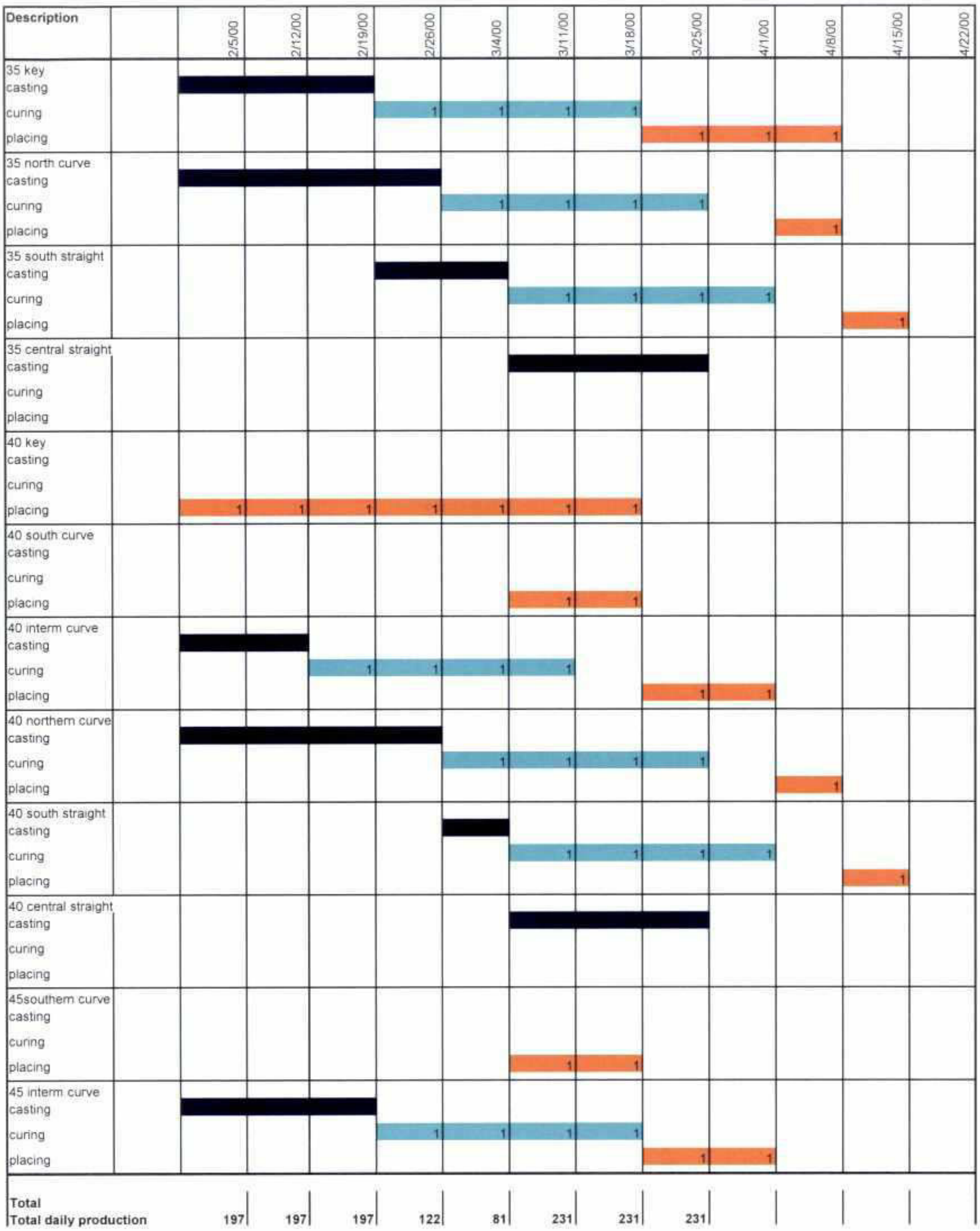
Description	Unit	total qanti-ties		12/11/99	12/18/99	12/25/99	1/1/00	1/8/00	1/15/00	1/22/00	1/29/00	2/5/00	2/12/00	2/19/00	2/26/00	3/4/00	3/11/00	3/18/00	3/25/00	4/1/00	4/8/00	4/15/00	4/22/00	4/29/00	5/6/00
Excavation	m³	72 100.00		0%	6%	13%	19%	26%	32%	39%	45%	52%	58%	65%	71%	78%	84%	91%	97%						
Embankment	m³	29,900.00		0%	8%	16%	24%	32%	40%	48%	56%	64%	72%	80%	88%	95%	103%								
cc-blocks 35 production	m³	6,000.00		0%	0%	0%	0%	8%	16%	23%	31%	39%	47%	54%	62%	70%	78%	86%	93%						
cc-blocks 40 production	m³	11,600.00	44%	48%	51%	55%	58%	62%	65%	69%	72%	76%	79%	83%	86%	90%	93%	97%	100%						
cc-blocks 45 production	m³	6,000.00	49%	53%	56%	60%	64%	67%	71%	74%	78%	82%	85%	89%	93%	96%	100%								
key cc-blocks 35 placing	m³	685.31		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	33%	67%	100%				
key cc-blocks 40 placing	m³	3,391.04		0%	0%	0%	0%	0%	0%	10%	19%	29%	39%	49%	58%	68%	78%	88%	97%						
Reno	m²	10,359.77		0%	0%	0%	0%	0%	0%	0%	0%	11%	23%	34%	45%	56%	68%	79%	90%	102%					
cc-blocks 35 falling apron	m³	4,967.96		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%	22%	32%	43%	54%	65%	75%	86%	97%	108%	
cc-blocks 40 falling apron	m³	6,033.04		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	12%	23%	35%	47%	58%	70%	82%	93%	105%	
cc-blocks 45 falling apron	m³	5,933.58		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%	22%	33%	44%	56%	67%	78%	89%	100%	
brick mattressing	m²	13,867.95		0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	15%	22%	29%	37%	44%	52%	59%	66%	74%	81%	88%	96%
road on crest	m²	3,291.19		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	78%	156%	
turfing	m²	4,643.82		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	75%

planned

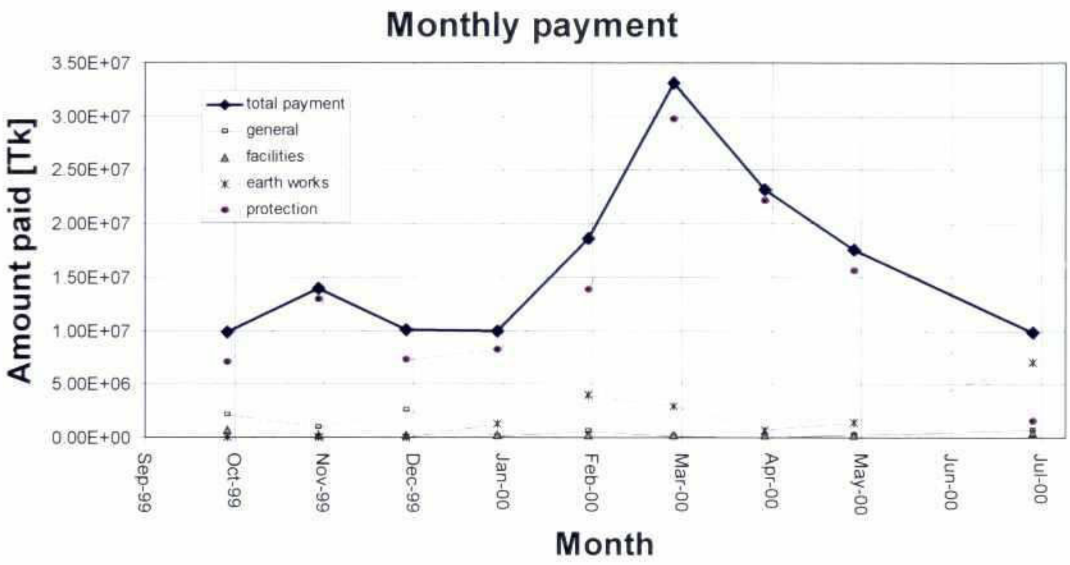
executed

A second main activity was the detailed planning of the casting of concrete blocks. As the 28 day strength had to be waited for, a detailed plan of concreting, curing and placing was made to assure, that sufficient blocks are available in time. Blocks were placed in individual marked areas according to their application at the site. This plan worked well and the falling apron could be placed in time.

The plan was set-up for the second concrete yard taken into operation from January 2000. The quantities of the first concrete yard were considered but not explicitly shown. Details are found in the following graph.



Cost development was plotted as cash flow to see the progress of works in term of financial development. Details about the monthly payment are given in the next graph and show the execution speed. After initial slow progress the maximum could be made in the month of March due to the parallel activities of concreting and placing. In later months the concreting had stopped and due to the dominant percentage of the total works the monthly payment was less.



3.4 MAIN EQUIPMENT

For carrying out the earth works three bulldozer capacity D6, 2 excavators capacity 0.75m³ and 6 dump trucks capacity 10 tons (4) and 6 tons (2) were at the site. Additionally for loading purposes two front-loaders were employed of which an average only one was operational. Apart from this key equipment, five tractors were employed for carrying of cement, spraying the roads, etc.

Equipment arrived at the site in November and left 18-6-2000 by barge.

Breakdown times with the exception of front-loaders were on a reasonable level.

3.5 SITE INSTALLATIONS

Camp facilities of the contractor as well as of JTWC were maintained in Bahadurabad, only adding some workspace at the site. JTWC had a site office consisting of two containers, the contractor had leased two houses, one for office and store purpose, the other one for recreation.

Labour sheds were build as temporary structures, following standard procedure in Bangladesh.

Main works were concentrated in the area of the structure. Additional work space was required for casting and curing of concrete blocks and storing of boulders. The contractor operated two casting yards. The fist from the beginning until end of December, the second from beginning of January until end of the construction period. The areas were just sufficient for the number of cc-cubes required and the supporting activities.

JTWC leased land in the northern and southern part of the structure for storing of boulders during construction period but as well as of the remaining quantities. The lease contracts were made for six months and one year respectively.

3.6 EARTH WORKS

Earth works started on 17-12-2000 with the inauguration of the site by DC. In the next days the areas cleared from houses were immediately levelled and stripped by bulldozer to prevent people to come back and resettle. In the following the embankment was build up by bulldozer in pushing the soil from the area of the launching apron land-wards. This procedure turned out to be very efficient as there was substantial progress and additionally a good compaction of the embankment was obtained. In spreading the soil by bulldozer layers of about 5 cm are build up. The chain of the bulldozer penetrates about 7.5 cm deep thus job training a good and firm compaction.

Activities focussed on the central part of the structure were excavation could also be done by bulldozer in pushing the soil not required for the embankment into the river.

From mid-January excavation started by excavators, as only at this time trucks were available. Excavation by excavator was necessary for the lower strata, which were wet and could not be handled by bulldozer. In total about 50% of the excavation works – and the total build up of the embankment was carried out by bulldozer, the rest by normal excavation.

It must be noted that the excavation process was in no way at an optimum. However, as it was not critical only limited efforts were made to train the contractor. Nevertheless the impression arises that double and triple handling is considered normal and throughout the whole excavation period this was standard procedure.

The longer the excavation process continued the more it became influenced by local people who claimed the soil for development of their land or filling of their ponds and depressions. Finally a distribution system was set-up, based on slips issued by JTWC which precisely noted the number of trucks and the location where to dump. In this way in the southern part of the structure all demands could be fulfilled and significant filling work was done. In the northern part the process ended in chaos, as at the end, when only a few cubic meters were left, some so called leaders placed guards in the trucks to assure that all of the remaining soil goes to their plots. This procedure is also common practice and local people tend to accept it even though momentarily upset.

Photo 3.6-1: Earth Works, General View

Photo 3.6-2: Earth Works , Excavation

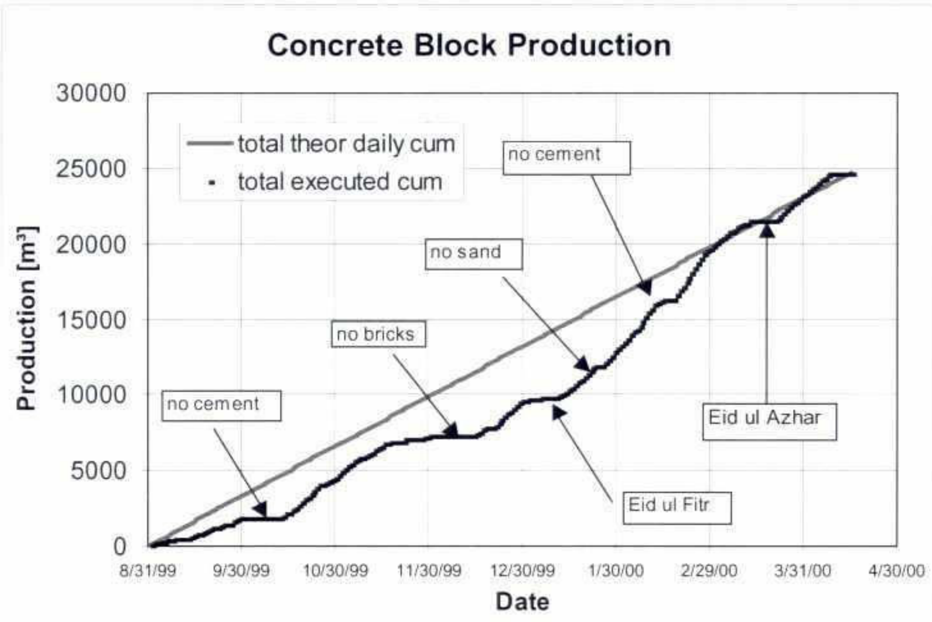
3.7 CONCRETING

Concreting started on 18-8-1999. Initially the work progress was low and effected by non-availability of bricks, cement or sand. After moving to a second bigger yard beginning of January 2000, production increased significantly and could make up some of the delay. Casting in the concrete yard was stopped on 9-4-2000.

In total 24,571 m³ of concrete have been made, of which 23,700 had to be used for the structure and were 500 stacked on the crest for emergency dumping and along the northern road as barrier. The remaining 371 m³ were additionally filled along the transition of falling and launching apron.

As new method part of the falling apron was cast in-situ in the central straight part. This was mainly executed to safe time, as there is no necessity to wait the 28 days curing period. Shutter of 5 to 7 blocks in a row, separated by a steel plate, called stopper was used. Casting was done crosswise, i.e. each subsequent layer of blocks was cast perpendicular to the lower one, separated by 2 cm of soil and a plastic membrane. Thus a better development is expected. Gaps between the shutter were filled with soil and the initial set-up resulted in about 35% voids. Important during the process is to cut all connecting parts between adjacent blocks, resulting from the casting process. Otherwise the blocks do not develop individually. The method was demonstrated during a site visit of CHDE and KfW review mission.

The overall progress is shown in the following figure.



As can be nicely seen, during the first half of 2000 most of the delay, which cumulated to a maximum of nearly 5000 m³ could be made up.

3.8 PROTECTION LAYERS

3.8.1 General

Following the sequence of installation, the protective works are described first. A good progress has been made especially during the beginning, so that intense rainfall from mid-April did not affect the protective works too much.

Details about progress are not mentioned, as under local conditions doubling of placing can easily be obtained in doubling the work force.

3.8.2 Key

Other than in Bahadurabad the transition between falling apron and launching apron was mainly designed to be placed under the end section of the launching apron. This results in much lower levels, which are close to the minimum river level. As all other activities depend on this placement it was done first.

The last four meters under the launching apron were excavated about 1.5 m below level of launching apron and after spreading of the geotextile filled with packed cc-cubes of same dimension as the falling apron. The cubes were packed to assure that

- the geotextile is not destroyed during placement, or expensive additional protective layers have to be foreseen;
- the launching apron has an even base, which can not be obtained when dumping the blocks;
- to fill the maximum blocks required following specifications. Only some small remaining quantities were placed on the top of the Reno mattress.

Initially works had to be executed in the water, as the river level was not deep enough. In some parts the first layer was placed by excavator block per block to assure a regular packing. Generally no difficulties arose and manual packing is well possible. Some irregularities, when the first layer was placed in very soft soil were levelled out by an intermediate sand layer placed on top of the first blocks.
At no time there were problems with damages of the geotextile, thus the applied procedure can be recommended.

Works started on 19-1-2000 and finished 13-4-2000. There was no continuous work due to shifting of activities to other processes, or waiting for excavation to proceed.

3.8.3 Reno

Placing of reno-mattresses is not difficult at all, and can easily be done by unskilled labour. Preparation of the wire mesh cages in the curves took into account that trapezoidal forms must be provided. Due to the flexibility a continuous coverage of the area could be obtained leaving no gaps.

Geotextiles were placed with two meters overlapping (1.5 m in the straight section). This means that in the straight part 25% of the geotextile is doubly placed, in the curves much more, as two meters is the minimum overlap at the outer side under the key, double overlapping at the toe of the embankment in curves with smaller radius exists.

After placing of the prepared wire mesh cages, the bottom and all diaphragms were laced together. Deviating from the specifications two instead of one wire were used to obtain a better strength and to avoid that gaps open between the boxes, which would inevitably lead to local overloading of the geotextile and after rupture to erosion of the subsoil and consequently failure of the apron. Lids were laced with one wire.

Slope cables placed in the boxed to increase the link are anchored every four meters at a four meter long anchor pile, that was driven 3.5 m into the ground. The pile heads in some areas needed significant reinforcement, due to locally hard subsoil. The radial slope cables are placed in the top part of the boxes to take stresses once the box starts to sink down. The wire ropes placed parallel to the toe of the embankment are positioned in the lower part of the boxes, to carry the loads when local sagging occurs. In this way the maximum bearing capacity of each element is expected. The ends of the wire ropes were fixed to anchor plates.

This work was more or less continuously executed from 29-1-2000 and the most difficult was the covering of the mattresses. Finally the last lacing was done on 2-6-2000 when the mattresses were flooded for the first time. After water level receded the covers were finally checked and in some small areas rectified.

Photo 3.8-1: General view of Ghutail Revetment Test Structure with
A: Slope of embankment: Brick Mattress
B: Launching Apron: Wire mesh Mattress (Reno) boulder filled
C: Falling Apron: CC-Blocks

Photo 3.8-2: Closing of Wire mesh mattress

3.8.4 Brick Mattressing

After shaping the slope by bulldozer, dressing was done manually. In the following the geotextile was unrolled, sewn together and the first layer of bricks placed horizontally (runner). Following the second layer was placed on edge in herring bone bond (HBB). Placing on edge was decided during the execution as due to the impossibility of getting bricks of even shape, it was feared that too many gaps would be present. Additionally the placing on edge results in a 50% higher weight per area and thus makes rain-cuts much less likely. After placing all gaps were filled by sandy soil to allow grass to grow and thus to increase the bond between the bricks.

Execution started on 5-2-2000 with placing of the runner. The decision to place the upper layer on edge was taken after KfW visit on 5-3-2000. The work was completed on 5-5-2000.

Photo 3.8-3: Upstream Termination, Brick mattressing on Geotextile Filter Mat

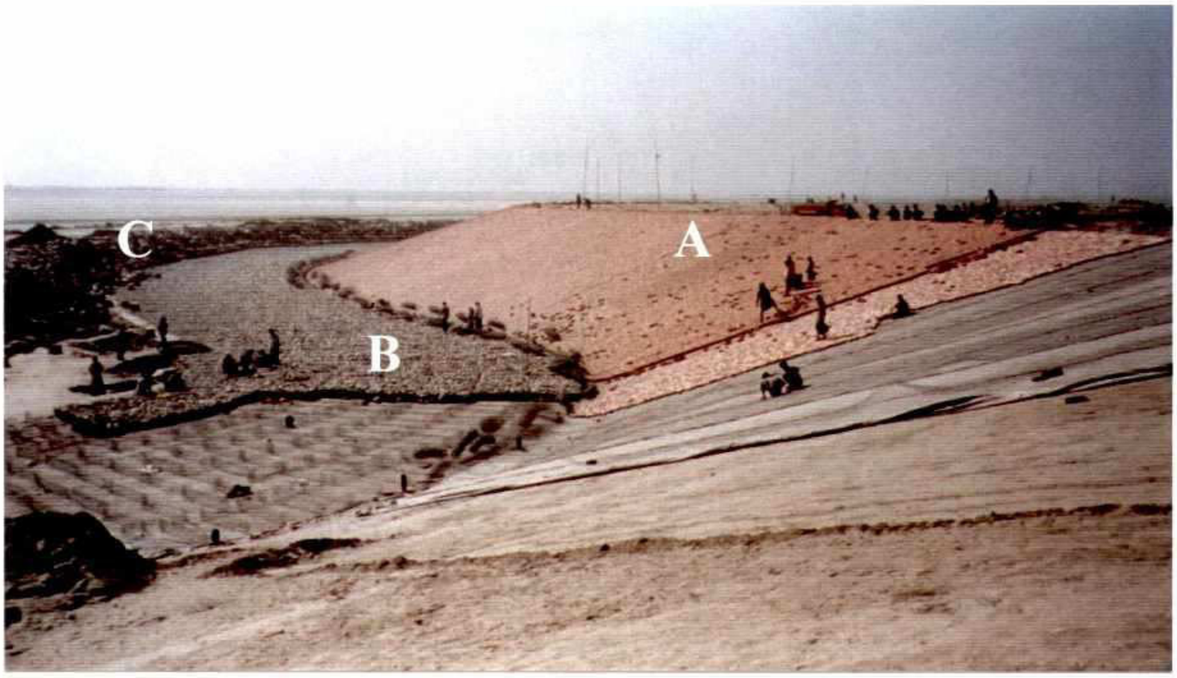


Photo 3.8-4: Downstream Termination
A: Slope: Brick Mattressing on Geo-Textile Filter Mat
B: Launching Apron: Wire mesh Mattress, Boulder fill
C: Falling Apron: CC-Blocks

3.8.5 Falling Apron

Dumping of the falling apron to a height of about three meters, was initially considered a difficulty task. During the execution, however, a method was developed that allowed a fast progress. After excavation of the area and levelling of the ground, dumping started at the outer side from the floodplain level and proceeded towards the launching apron. To avoid that during the initial dumping too much soil falls down, a slight over excavation of 0.2 to 0.5 m in length has been made.

The area between the two different types of blocks was marked by a line of cc-cubes. Once reached, the smaller type was dumped. To allow the access the top was filled with soil, so that trucks and all other vehicles could reach directly the place. Final arrangement was made by front-loader.

A significant part of the carrying and dumping of the cc-blocks was made by local people using small trucks, but also tractors and power trailers.

Part of the falling apron was cast in situ as mentioned above.

Works started on 22-2-2000 with a first dumping test and ended on 25-5-2000 with the last arrangements at the end transitions.

Photo 3.8-5: Downstream Termination
A: Slope: Brick Mattressing on Geo-Textile Filter Mat
B: Launching Apron: Wire mesh Mattress, Boulder fill
C: Falling Apron: CC-Blocks

Photo 3.8-6: Falling Apron: CC-Blocks randomly dumped

Photo 3.8-7: Launching Apron: CC-Blocks, In-situ cast

Photo 3.8-8: Launching Apron: CC-Blocks, In-situ cast

3.8.6 Embankment Finishing

Under this headline all works concerning directly the embankment are summarized. This is turfing, khoa consolidation and placing of concrete cubes for emergency dumping on the crest.

Turfing was affected by the early and heavy rainfalls, as at the time of the execution many areas were under water and it was difficult for the contractor to get sufficient grass sods. Execution was made in the same way as in Bahadurabad. During the heavy rainfalls it was directly visible how good the grass protected the slope, as in the areas without turfing, deep rain cuts occurred that had to be repaired several times. The turfing covered the drain behind the embankment and nearly all the strip up to the road.

Khoa consolidation was started with very much delay as the contractor could not get a roller for the compaction. After finally getting the roller the spreading and compaction was only a matter of the couple of days. Both end sections were made first with the exception of the central part, where due to some problems with land acquisition the embankment was not completed. After last people had shifted their houses on 13-5-2000 the embankment could be completed including finishing works.

The works started on 20-4-2000 with turfing and khoa consolidation in parallel. Works were finished on 25-5-2000 with the placing of the last concrete blocks on the crest.

To protect the embankment four staircases have been build to concentrate peoples movement and to avoid using the embankment slope and destruction of the grass cover.

Photo 3.8-9: Embankment
- **Land sided slope: Grass Sods on Geo-Jute soil saver**
- **Road construction**

Photo 3.8-10: Embankment Crest Finishing with Khoa sand mix

3.8.7 Other Works

Road

Road works were added after discussion during the KfW review mission. The goal is mainly to prevent people from moving up to the embankment and starting to cut berms into the slope to establish their houses. The necessity of this measure has been experienced already during the construction of the road. As people learned that there will be a new road behind the embankment, they virtually over night turned the old embankment, which was the main connecting road, into a housing area, in building sometimes even two lines of huts on the small available strip. After establishing of the road houses developed further to the structure until reaching the edge of the road. Some people even shifted their houses two times, first back for construction of the road and after seeing, that a strip of land is left between road and their fence, back to the road to prevent from squatting by others.

During execution the heavy and long lasting rainfalls hampered the progress significantly. As one example, the contractor had to use about three times the fire-wood normally required to heat the stone chips and bitumen, due to the high moisture content of the aggregates.
The road was made following Water Board standards with sand and brick layer, following khoa and then bituminous carpeting including seal coat. In this way sufficient life time is guaranteed to prevent people from using the crest.

Works started on 27-4-2000 with placing of sand as first layer and finished on 7-6-2000 in the northern part with completion of the seal coat after several long disruptions due to flooding after heavy rainfall.

Photo 3.8-11: Embankment: Land sided slope, road construction

Photo 3.8-12: Road construction: Bituminising

3.9 QUALITY CONTROL

3.9.1 General Supervision

Main works focussed on control of work processes. Once these are optimised a good quality level while achieving a good progress at the same time can be assured. Daily inspection and random control of al different processes was undertaken.

Due to experience with earlier works at the other two test site, the contractors staff was in general very well trained. But during the daily works and considering that every day hundreds of people worked in the concrete yards and at the site in many locations in parallel, it was not always easy to maintain a high quality level. Nevertheless in general an acceptable quality could be guaranteed and following contractors staff, the highest quality was obtained in Ghutail, reflecting the experience everybody gained during the execution of earlier projects.

3.9.2 Concrete and Block Production

Concrete quality has been tested by application of two test methods:
1. crushing test of 15 cm cubes
2. rebound hammer test on randomly selected cc-cubes

1. crushing test
Following specifications three cubes had to be tested with an average strength of 20 N/mm^2 and a minimum of 15 N/mm^2. Tests were undertaken regularly and crushed at the site by a small press in the contractor's site laboratory. The results were satisfactory.

2. rebound hammer test
Randomly selected blocks were sporadically investigated. In general the hammer test were ok.

The difficulty lies in the application of the hammer. Suppliers instructions were followed, however some aspects from experience should be mentioned:
- Wet concrete results in lower strength and thus wet spots must be avoided.
- For security purpose a safety factor of 10% has been applied, i.e. results from the calibration curve were reduced by 10% to reflect the influence of the khoa aggregates. Water Board, however, applies the rating curves directly.

The size of blocks was measured periodically after placing of shutter. In general the blocks are slightly bigger than required, i.e. up to 1 cm. Blocks of the falling apron cast in situ were regularly inspected to assure, that all blocks cast with one shutter were properly separated to assure an individual development.
In December and February the total production has been controlled to assure that daily progress sheets and actual quantities are in line. Deviations are within 1%, sometimes even more was counted than given in the daily progress sheets; so the Contractors figures were considered reliable.

The main aspect during the production of mass concrete is to optimise the processes and to assure that no systematic errors occur. Here main efforts were made and as result a sufficient quality level could be achieved. Very difficult was the control of the mixing ratio. Volumetric gauging was done and the mixing ration specified to be 1:3:6. Initially khoa gauge boxes were overfilled and only after serious intervention, the management ordered to fill the boxes even. Sand had to be overfilled in general to consider the increased void ratio when the sand is slightly humid.

Another problem was the stacking of khoa. The crushed brick chips came from crushing machines and were transported to the top of the stack and dumped down. As this leads to segregation, dumping against the face of the stock was ordered, so that a well distributed grain size distribution is maintained. Additionally, the khoa had to be permanently watered to assure that the brick chips do not absorb the water required for hardening of the cement. Curing in this respect is also very important so that an insufficient water amount can be compensated for as only partly hydrated cement paste with an open pore system develops additional cement gel, that segments the pore system and contributes to higher lifetime.

3.9.3 Boulders

Boulder quality was investigated during initial reception at the Indian border and during placing at the site. Inter alia specific weight, shape, and mainly grain size distribution were controlled. Boulders fulfilled all requirements.

It must be noted that a difference between grading curve of diameter and weight exists. When determining the relationship between both curves it was found that it is based on an elliptic shape of the boulders. Round boulders of the same grading curve do result in lower grading curves by weight, as stones that pass the same sieve diameter are much smaller and thus lighter when of spherical shape.

3.9.4 Bricks

Bricks of all suppliers have been tested on water absorption and crushing strength. Significant variation was found, but the average was ok.

To spot problems with bricks, but also to find bricks of uniform shape for the brick mattressing, a number of brick fields were visited. It must be concluded that never a 100% correct production process was found. Some brick fields had a very good burning process, other a very good clay preparation and moulding. All brick fields had problems to deliver bricks of even size. This is due to the manual production of the bricks. Later the early and heavy rainfalls effected the production significantly.

3.9.5 Others

Cement bags have been controlled sporadically if they have 50 kg weight and if the cement is not hard or has lumps. Cement of different suppliers was sent to BUET for analysis and found to fulfil specifications.

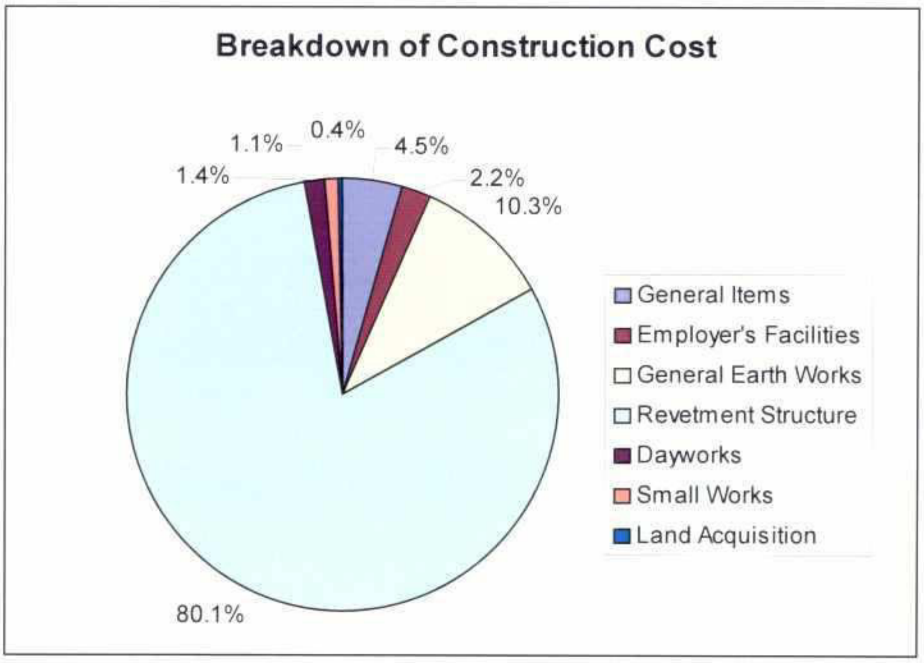
Sand was sieved and, mainly based on fineness modulus, controlled periodically and whenever a new supplier came. The sand was acceptable but fine. Interestingly no difference in the grain size distribution could be found from suppliers 30 km upstream or from the neighbourhood of the construction area.

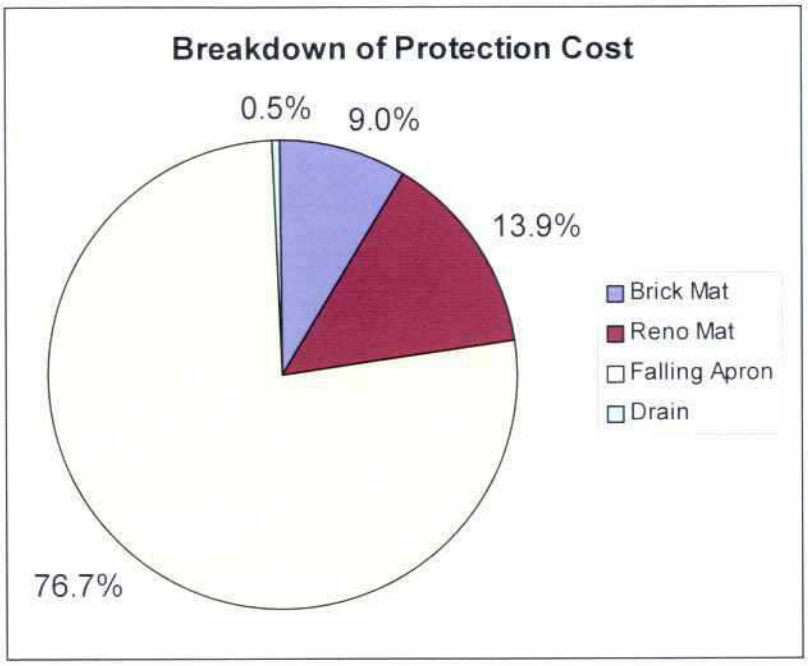
Water of tube wells at the banks of Jamuna river was analysed in BUET and found to be appropriate for concreting.

4 COST BREAKDOWN

Of major interest is the general cost breakdown and an analysis for the major works, i.e. the protective works. The following table and graphs give details.

DESCRIPTION	AMOUNT	TOTAL AMOUNT
General Items	**7,568,905**	**7,568,905**
Employer's Facilities	**3,695,000**	**3,695,000**
General Earth Works		**17,329,004**
embankment works	8,997,924	
land sided protection	1,305,705	
road behind embankment	7,025,375	
Revetment Structure		**134,181,647**
Brick Mat	12,103,655	
Reno Mat	18,586,680	
Falling Apron	102,859,340	
Drain	631,972	
Dayworks	**2,321,030**	**2,321,030**
	total works related	**165,095,586**
Valeport repair	81,938	81,938
Small Works	1,874,297	1,874,297
Land Acquisition	595,430	595,430
	total additional	**2,551,665**
	GRAND TOTAL	**167,647,251**





Non structural cost, i.e. cost that are not related to earth works and the protective works (named revetment structure), total in 9.6% of the cost. This figure is used for later comparison works.

Detailed cost can be broken down per section of the structure. As there are only two standard sections the tabular form is chosen. Works are detailed per one linear meter of structure.

A comparison for the total cost of Ghutail structure protecting about 530 m of bankline for BDT 167.5 Million. Assuming a partition of 50:50 for section A and B with total cost of BDT 195,425 per linear meter including 10% site installation, a total length of 857 m could be protected. The actual figure is only 62% of this due to the termination points. The relationship gets more favourable, the longer the structure gets.

Element		Unit	QTS	Rate	Section A per lin m	Section B per lin m
embankment					**18,456.5**	**18,456.5**
	excavation	m³	135	70	9,450.0	9,450.0
	fill	m³	36	112	4,032.0	4,032.0
	turfing	m²	9.5	71	674.5	674.5
	crest	m²	6	300	1,800.0	1,800.0
	road	m²	5	500	2,500.0	2,500.0
brick mats					**18,414.5**	**18,414.5**
	geotextile	m²	22	119.17	2,621.8	2,621.8
	placing	m²	23.1	17	392.7	392.7
	mattressing	m²	22	700	15,400.0	15,400.0
Reno					**34,191.6**	**34,191.6**
	geotextile	m²	20.32	119.17	2,421.4	2,421.4
	placing	m²	20.32	17	345.4	345.4
	Reno	m²	16	445.593	7,129.5	7,129.5
	boulders	m²	16	882.665	14,122.6	14,122.6
	placing	m²	16	508	8,128.0	8,128.0
	anchors	m	0.25	2750	687.5	687.5
	cc head	m³	0.325	4176	1,357.2	1,357.2
falling apron					**113,699.8**	**99,494.2**
	35 cm	m³/7m	13.50563	4190		56,588.6
	40 cm	m³/5m	10.24	4190		42,905.6
	40 cm	m³/7m	14.336	4190	60,067.8	
	45 cm	m³/8m	12.8	4190	53,632.0	
total					**184,762.4**	**170,556.8**

The next table shows the percentage distribution per element

Element	Section A	Section B	Section A	Section B
	cost in BDT		percentage distribution	
Embankment	18,456.5	18,456.5	10	11
Brick Mats	18,414.5	18,414.5	10	11
Reno	34,191.6	34,191.6	18.5	20
Falling Apron	113,699.8	99,494.2	61.5	58
Total	184,762.4	170,556.8	100	100

Of much higher interest than the simple assembly of figures is to study the sensitivity of the structure to modifications to obtain better and longer lasting alternative solutions. In this respect the following alternatives have been investigated:

1. replacement of brick mattressing by standard BWDB cc slabs of 0.4x0.4x0.2 m;
2. replacement of falling apron by longer launching apron;
3. replacement of galvanized Reno by coated Reno, or ACM

assuming a slope of 1:2 a scour protection of ... m more could have been obtained

1 Concrete Slabs

The first alternative results only in changes of the brick mattressing. BWDB uses generally concrete slabs of 0.4 x 0.4 x 0.2 m size and of approximately 60 kg weight, which are much more resistant than bricks, not at least because local people can not easily steal them.

Concrete slabs would be made of khoa concrete for the same unit prices of concrete and transport as for cc-cubes. Additionally 5% would be added for in-situ concreting in curves to fill gaps.

	Section A	Section B	Section A modified	Section B modified
Embankment	18,456.5	18,456.5	18,456.5	18,456.5
Brick Mats	18,414.5	18,414.5	**22,279.9**	**22,279.9**
Reno	34,191.6	34,191.6	34,191.6	34,191.6
Falling Apron	113,699.8	99,494.2	113,699.8	99,494.2
Total	184,762.4	170,556.8	184,762.4	170,556.8
delta % mat			21%	21%
delta % total			2.1%	2.3%

The very small increase in cost for cc-slabs would have justified this solution. However, only during execution the increase in thickness of the cover layer was decided and thus too late for the change of design.

2 Longer Launching Apron

Assuming that sufficient space is available, which in Ghutail was not the case, the falling apron could be replaced through launching apron. This would provide a higher overall security, as the interconnected elements develop in a more controlled way.

The solution would have an impact on the amount of the Reno mattress as well, as due to the increased length the anchor cost would be increased. 5% of the total length have been decreased to take this into account.

	Section A	Section B	Section A modified	Section B modified
Embankment	18,456.5	18,456.5		
Brick Mats	18,414.5	18,414.5		
Reno	34,191.6	34,191.6	16 m	16 m
Falling Apron	113,699.8	99,494.2		
Total	184,762.4	170,556.8	53.21 m	46.56 m
total length			62.29 m	56.30 m
scour depth 1V:2H			-12.85	-10.18

The design scour depth was –5 m PWD, design high water (DHW) 20.6 m PWD. Significant additional security can be gained when replacing the falling apron by only launching apron in two ways:

1. presupposing the same final slope of 1V:2H, a 30% higher water depth at the termination points or 5 m at the straight section, i.e. nearly 8 m, or 5 more scouring, respectively could be countered, or
2. presupposing the same final level would be achieved a slope of 2.93 at the termination points or of 2.63 in the straight section could be obtained. Considering the risk of liquefaction which requires slopes of minimum 1V:3.5H and experience of the performance of other structures which tends to underwater slopes of 1:6 an increased security level could have been achieved.

3 Coated Reno

The only change necessary for this option is the increase of the procurement price of Reno mattress from USD 45 to USD 70 per element, i.e. a 56% increase.

	Section A	Section B	Section A modified	Section B modified
Embankment	18,456.5	18,456.5	18,456.5	18,456.5
Brick Mats	18,414.5	18,414.5	18,414.5	18,414.5
Reno	34,191.6	34,191.6	**37,965.2**	**37,965.2**
Falling Apron	113,699.8	99,494.2	113,699.8	99,494.2
Total	184,762.4	170,556.8	184,762.4	170,556.8
delta % mat			21%	21%
delta % total			4.1%	4.5%

The very small increase in cost for cc-slabs could have justified this solution especially as a significantly higher life expectance would have been obtained. During procurement, however, the final structural cost were not known and the increase was not accepted as not sufficient funds for the foreseen solution were available.

5 EXPERIENCE AND RECOMMENDATION

Problematic is the land acquisition process, as due to the unpredictable nature of Jamuna river, the bankline and thus final construction site is only known a couple of weeks before starting the works. The local administrative procedure does not allow to get possession of the land in such short a time. Resulting the executing agency must find ways and means to deal with the local people and to satisfy their demands for obtaining and early house shifting.

Revetment structures that cover big parts of the bankline are especially sensitive, as they cannot easily be built out into the river channels. Groyne structures do have a significant advantage in this respect.

Brick mattressing was specified due to the low cost and a reasonably high resistance to wave and flow attack as known from Bahadurabad test site. However, considering the fact that local people once the structure is complete and unattended, tend to use revetments of this type as quarry pit, Water Board has changed the design toward the placement of cc-slabs of 15 or 20 cm thickness and 40 cm dimension in the plain. The weight of these slabs is between 58 and 77 kg and thus difficult to remove. Problematic are the curves where a high number of joints must be sealed with concrete after placement. A cost comparison shows that the price difference would have justified this solution.

Cost analysis reveals further that coated Reno mattresses do not significantly increase the cost and thus could be used as alternative. The same is true for the complete abandonment of the falling apron, whenever possible as a generally higher security level could be obtained.

During construction a main factor was soil distribution among subcontracting part of the works to local parties. Soil distribution could be handled much better than in Bahadurabad due to the direct involvement of JTWC as intermediate agency. Local subcontracting lead to some amazing results, e.g. the fact that the contractor had six trucks at the site, which were not used for the transport of cc-blocks, but lying idle as a local syndicate managed all the job. However, the price level for the local syndicate was such, that even without doing anything the process was sufficiently profitable for the contractor.

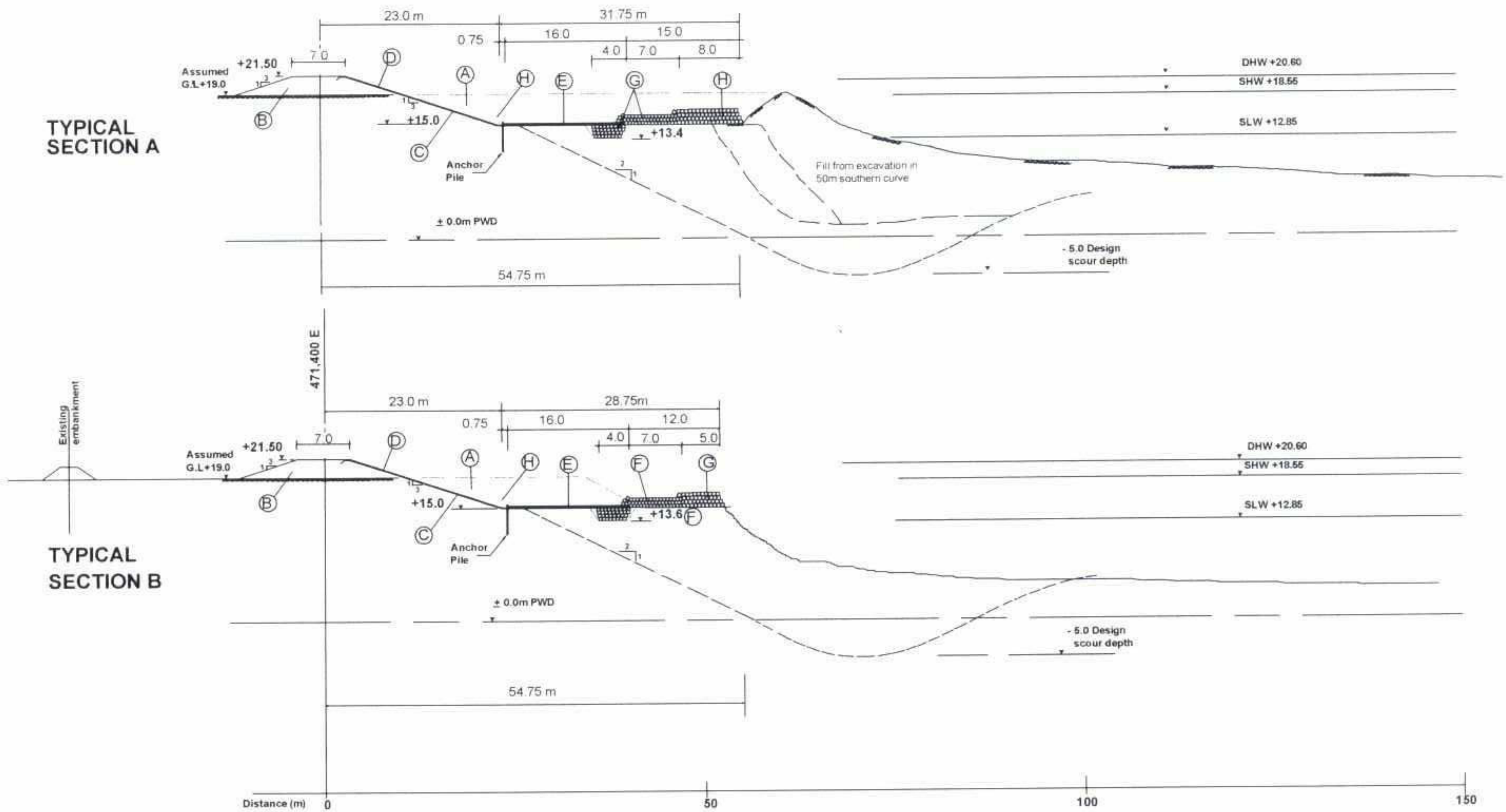
It must be seen clearly, that without participation of the local people, there is no possibility in executing the works.

Attachment 2
Selection of Design and Construction Drawings, Ghutail

ATTACHMENT 2

List of Drawings

Drawing III-R-102:	Detailed layout
Drawing III-R-103:	Modified cross-section A and B



Ⓐ Excavation
Ⓑ Fill, Compact + Profile
Ⓒ Geotextile filter POLYFELT TS-70
Ⓓ Brick mattressing (d=15cm)
Ⓔ Articulated RENO-mattresses d-30cm,rubble-fill Grade B/C (D_{50} =15/20cm) Geotextile filter BIDIM S-82
Ⓕ CC-Blocks 35 ㅁ(45 Nos/m)
Ⓖ CC-Blocks 40 ㅁ(32 Nos/m)
Ⓗ CC-Blocks 45 ㅁ(25 Nos/m)

Notes:

1. All measurements in meter.
2. Levels refer to ± 0.0 m PWD.
3. SLW = Standard Low Water
   SHW = Standard High Water
   DHW = Design High Water

0 5 10 15 20m

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANISATION (WARPO)

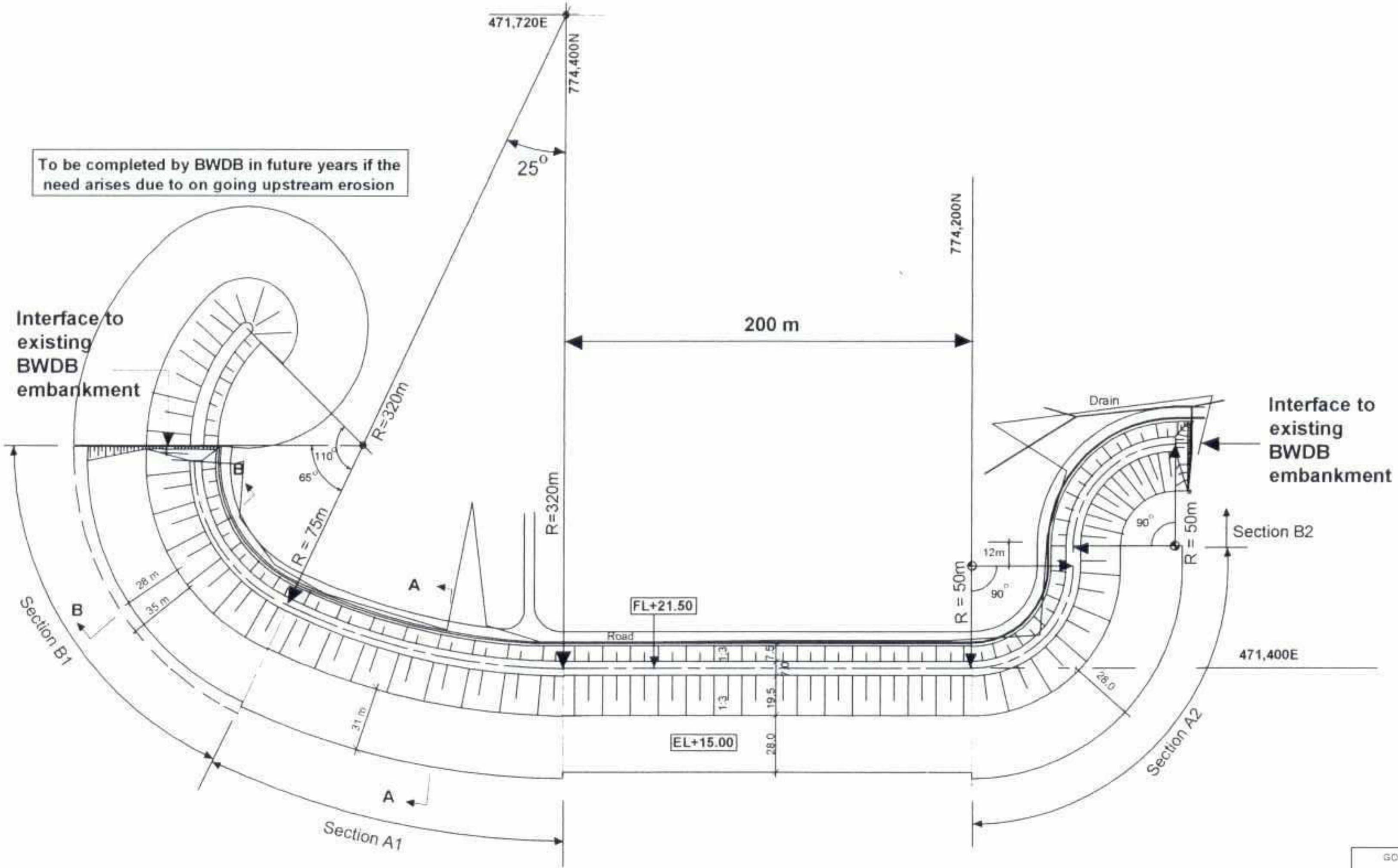
BANK PROTECTION PILOT PROJECT

JAMUNA TEST WORK CONSULTANTS,JOINT VENTURE
CONSULTING CONSORTIUM FAP-21/22

TEST SITE III-GHUTAIL

MODIFIED CROSS-SECTION A & B

	NAME	DATE	SCALE
DRAWN	ANOWAR	07-05-2000	DRAWING No III-R-103 / REVISION 0
CHECKED			
APPROVED			



Notes:

Levels refer to ± 0.0m PWD
Measurements in meter
F.L. = Finished Level
E.L. = Excavation Level

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TEST SITE III-GHUTAIL

DETAILED LAYOUT

	NAME	DATE	SCALE	
	ANOWAR	07-05-2000		
			DRAWING No III-R-102	REVISION 0