BANGLADESH WATER DEVELOPMENT BOARD

Report on the construction of the

FENI RIVER CLOSURE DAM

HASKONING
Royal Dutch Consulting Engineers and Architects

August 1985
REPORT ON THE CONSTRUCTION OF THE FENI RIVER CLOSURE DAM.

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Report drafted by G. te Slaa, Teamleader

August 1985.
CHAPTER 1 - INTRODUCTION.

This report on the construction of the Feni River Closure Dam has been prepared by HASKONING in fulfillment of the Consultant's obligation to submit a 'Final Report at the end of the Consulting Services'. Though strictly speaking the Consulting Services have not yet come to an end, the Consultant found it opportune to submit the 'Final Report' at a time which coincides with the substantial completion of the works. Moreover the experience gained during the construction of the Feni River Closure Dam, as reflected in this report, may soon be put to good use for the design of imminent closure works, such as the proposed Sandwip Cross Dam.

This report does not merely present facts and figures, but also attempts to give the reader an impression of the difficulties which have arisen during the construction of the Feni River Closure Dam, and how they were dealt with.

Chapter 2 deals with certain essential design aspects of the works, but for a detailed discussion of the design reference should be made to the 'Final Design Report', also prepared by HASKONING.

Chapters 4 to 9 deal with the individual activities of the works, such as bed protection works, the sill and the closure itself.

While the various materials for the works are discussed in the relevant chapters on individual components (chapters 4 to 9), chapter 10 gives an impression of the supply situation of the construction materials as an entity. It should be realised that very large quantities of materials had to be supplied within a very short period, and that the logistics formed an essential element in the successful completion of the Feni River Closure Dam.

Chapter 11 discusses some contractual aspects, including some points on which disagreement exists between the BWDB and the contractor. However reasons for the acceptability (or otherwise) of claims fall outside the scope of this report.

Chapter 12 deals with the Consultant's activities during the design and construction stages of the works, while chapter 13 gives principal findings and recommendations for future works.

For those readers interested in the hydraulic aspects of the works annexes A and B have been included. Annex A deals with the function of the Feni regulator prior to and during the closure operation. A listing of the computer program used for the hydraulic and tidal computations, and the results of a typical run have also been included (Annex B).

Lastly some production graphs for some selected key activities can be found in Annex C.

The maps on the next two pages should give a proper idea of the location of the project site.
CHAPTER 2 - DESIGN OF Feni River Closure Dam.

2.1 Introduction.

This chapter highlights the principal considerations which formed the basis for the design of the Feni River Closure Dam. Basic thoughts on the implementation of the design, which are extremely important for closure works, are also discussed. The Final Design Report prepared by the Consultant, dated September 1983, gives more details.

2.2 Function of Feni River Closure Dam.

The Feni River Closure Dam is the last major component of the Muhuri Irrigation Project, which aims to preserve water for irrigation purposes in the dry season (November - March). The basic idea is to form a reservoir, to be fed by the Feni and Muhuri Rivers, from which water can be tapped, through a system of canals, for irrigation of the paddy fields. The Feni River Closure Dam forms the barrier between the sea and the future reservoir.

Prior to the construction of the closure dam, the estuary was subjected to daily flooding by tides. The volume of the tidal prism depended very much on the tidal water levels. For an average springtide it was of the order of 25 million m³.

For the discharge of water during the wet season, when Feni and Muhuri Rivers have their peak floods, a regulator has been provided, which was in the final construction stage when Haskoning took up its assignment for the design of the closure dam. The regulator has been constructed in a building pit on the right bank of the Feni River and was to be connected, at the proper time, to upstream and downstream locations of the future closure dam by means of a diversion channel. This channel had not yet been dredged at that time.

While not its main function, the Feni River Closure Dam also serves as a protection of the project area against tidal waves of extreme height. Even before its completion, the dam has decidedly served this purpose on 25th May 1985, when a severe cyclone caused a disastrously high tidal wave. Thousands of people living in low lying (and exposed!) coastal areas and islands drowned as a result of the tidal wave. However no loss of life or damage occurred in the project area, as the dam prevented the water to enter into the Feni estuary. (Damage to the ongoing works of the dam was minor.)

2.3 Site-configuration.

A layout of the closure site and the now completed closure dam and flank embankments is given on the following page.
At the time of design (2nd quarter 1983) the cross section of the Feni estuary at the projected closure site could be described as:

- a shallow gully along the right bank approx. 150 m wide,
- a (slightly) deeper gully near the left bank approx. 250 m wide,
- a shoal between the gullies, approx. 800 m wide, which fell dry during ebb.

During the tender stage (4th quarter 1983) a new survey was made from which it became apparent that the right bank gully had almost disappeared and that the left bank gully had become substantially deeper and wider. It was also clear that the level of the shoal had become somewhat higher.

These changes had no effect however on the basic characteristics of the closure site. A substantial part of the closure site was still falling dry during low water.

Soil investigations carried out by the BUDB, in accordance with a programme formulated by the Consultant, had revealed that the soil at the closure site consisted mainly of loosely packed silty sand and/or sandy silt, with occasional occurrence of clay. The bearing capacity was generally low.

2.4 Hydraulic Considerations.

Hydraulic considerations play an essential role in developing a feasible closure method. Some considerations for closure works are given hereafter.

a) A closure is very often projected at the narrowest location between the river banks, in order to limit the amount of work involved as much as possible. But exactly at that location the river bed is 'tuned' to a delicate equilibrium. If one would start, for instance, to narrow the river, the result would almost certainly be a deeper riverbed. Thus the initial narrowing operation would, sooner or later, be nullified by nature itself, unless proper precautions are taken or unless the riverbed is highly resistant to scour.

b) Very often it is necessary to 'arrest' the level of the riverbed, so that high current velocities (which are inevitable in the course of the works) do not lead to erosion, and thus to an increase of the cross-section of the river at the closure site. The magnitude of the velocities at all stages of the work should be calculated.

c) Any estuary-closure is a risky affair, since the natural circumstances cannot be controlled, though they can be predicted with a certain probability. The risks should however be minimised by proper selection of the period or season in which the natural circumstances for a closure are the most favourable.

For Bangladesh in general, and the Feni River closure in particular, the most favourable time for closure is during a neap tide in the month of February. The earlier the closure is achieved in this month, the more opportunities exist for completion of the whole dam before the arrival of the wet season; in the worst case a second attempt could be made if the first attempt to close failed for whatever reason.
(Distinction should be made between the closure works itself, which are only aimed at stopping the river flow at the most favourable time, and the entire dam, which will in due course be subjected to much higher water levels and severe wave attack.)

The above hydraulic considerations are of course essential during the design period, but they are equally important during the execution stage. The natural conditions, like the riverbed configuration, may change, which may require an updating of the closure programme and method. Additional hydraulic calculations are often indispensable for an assessment of the new situation.

A policy which is often followed when designing closure works is to determine how far a river can be narrowed before the current velocities, which will increase as a result of this narrowing, exceed a certain maximum allowable value. The remaining opening in the river, called the closure gap, has thereafter to be closed at the most favourable time. The closure method depends very much on the depth of the closure gap, its accessibility by equipment and/or labourers, and available resources, like materials, manpower and equipment.

This idea of initial narrowing was originally adopted for design of the Feni closure. After a large number of hydraulic calculations was made, it became however apparent that no acceptable solution could be found if the river width was initially narrowed. The main reason was that the use of manpower would be impossible as a result of the weights of closure-elements (for instance concrete blocks or selected heavy boulders). These elements should be heavy enough to withstand the (increased) current velocities.

A new closure method was subsequently developed whereby no initial narrowing of the river would take place. This method envisaged the closure of the full river width in a very short time (within one period of low water during a neap tide), whereby thousands of labourers would be employed. In order to limit the walking distances for the labourers and to increase the working space during the closure, it was necessary to stockpile the necessary closure material (clay-filled jute bags) in the river before the actual closure. Stockpiling operations would be possible during low water, when the shoals would become accessible for the labourers.

Inherent to the selected closure method it was the need to protect the riverbed over its entire width with mattresses, so that no scour could take place around the stockpiles (this would have led, among other things, to an unacceptable amount of extra work during the closure itself). Other factors also dictated the need for mattresses; they are fully described in the Final Design Report.

2.5 Geotechnical Considerations.

As already mentioned in section 2.3, loosely packed silty sands or sandy silts were pre-dominantly present at the closure location. During construction of any structure on top of these soils the danger existed for soil slides, mud waves, etc.
The risk of earthquakes in the project area is rather remote, but cannot be ruled out entirely. In case of an earthquake the condition of the subsoil could lead to liquefaction, with disastrous results for the dam on top of this subsoil. No economically feasible method exists for the improvement of the sub-soil conditions. It is however possible to limit damage resulting from earthquakes by taking some precautions.

The package of soil mechanical precautions, to deal with potential earthquake problems, both during and after construction, would comprise a geo-textile fabric at the base of the dam and a core of 'earthquake-resistant' earth, which would not collapse during an earthquake (though it would not be able to prevent all damage).

2.6 Final Design (up to closure).

Both hydraulic and geotechnical considerations led to the requirement of a mattress to be placed on the river bed. The mattress should be strong and durable enough to withstand all forces during and after construction. Moreover it should prevent the fine soil particles to be carried away by the river currents during construction. As these requirements could not be fulfilled by materials available in Bangladesh, it would be necessary to import the required geo-textiles from abroad.

The geo-textile, together with fascines made from bamboo and reed and ballast in the form of boulders from the Sylhet area, formed the 'ingredients' from which the mattresses were to be made.

The developed closure method required uniform flow conditions over the entire river width. It was therefore essential that the bedlevel of the gully (or gullies) would be raised to match the level of the shoal. Raising could only be done after the bed protection over the entire river width was placed. The material placed in the gully (or gullies) will hereafter be referred to as 'sill'.

More or less simultaneously with the construction of the sill, the stockpiles of claybags in the river were to be formed. These stockpiles were projected at 100m intervals, so that the maximum walking distance during the closure operation would not be more than 50 to 60 m. The closure-structure, hereafter referred to as neap tide dam (because it was to be realised during a neap tide), was projected at the seaside of the future main dam and was later to be incorporated in the 'earthquake-resistant' claycore. The philosophy behind this location was that an earthquake might lead to a partial damage of the dam. This damage should not occur at the seaside, but rather at the reservoir side of the dam. Any slope protection works at the seaside would then also sustain little or no damage.

The most critical part of the works would come after the actual closure works (thus after the stoppage of the flow during a neap tide), because large quantities of clay would have to transported and dumped in a matter of a few days time, viz. the period between the (closure) neap tide and the subsequent springtide(s). There was no possibility to stockpile this clay in the river, as in the case of the claybags for the neap tide dam. During the design stage the Consultant devised a round-the-clock working method whereby the work could be executed with local resources (trucks and labour).
2.7 Final Design (remaining works).

The 'remaining' works would be less spectacular than the closure works, but would comprise a very substantial amount of work, ideally to be completed as soon as possible in view of the arrival of the wet season and the pre-monsoon storms, which often cause extremely high tidal waves.

The main elements of the 'remaining' works would be:

a) Construction of the main dam body, high enough to withstand even the severest tidal waves.

b) Construction of a slope protection, both at the seaside and reservoir side of the main dam, to withstand the wave attack from both directions.

c) Construction of embankments, connecting the main dam to the (already existing) regulator on the right bank and to the (also existing) coastal embankment on the left bank.

An artist's view of the works, showing the several construction stages, has been reproduced on the next page.
Diagram showing build-up of 
FENI DAM 
looking towards the right bank
CHAPTER 3 - PROGRESS OF WORKS

3.1 Design Stage.

The Agreement between the BWDB and Haskoning for Consultancy Services for Design and Supervision of construction of the Feni River Closure Dam was signed on 14th January 1983. Immediately afterwards the Consultant sent his design team to Dhaka. Soon after the commencement of the study of the existing data, the design team came to the conclusion that insufficient and/or reliable data were available for a proper design.

After the Consultant had formulated a proposal for the collection of further data, mainly relating to:

- waterlevel and velocitity measurements,
- soil borings and
- laboratory tests on the soil samples,

the BWDB quickly arranged for the execution of that programme. The measurements, borings and tests were carried out by the Hydrology Department and the River Research Institute, both resorting under the BWDB.

Hydrological data became available in April and May 1983, and the results of the laboratory tests on the soil samples in the first week of July 1983.

Meanwhile the Consultant had developed a mathematical model to simulate the water-flow in the Feni estuary, which could also be used to study possible closure methods. The model was implemented on a hand-held HP-41CV computer, which was at a later stage handed over to the MIP Design Cell, together with the accessories (like a printer) and software.

During July and August 1983 the Consultant prepared both the design and the (draft) tender documents. This was a major effort since the time span available was very short. Moreover a serious set-back was experienced when the Consultant had to conclude that the closure method which initially appeared to be feasible, had to be rejected (the reasons for the rejection have been elaborately dealt with in the Final Design Report). Nevertheless the design could be finalised within the scheduled time.

In early September 1983 the BWDB had already studied the design prepared by the Consultant. After some minor modifications were made, the design and tender documents were discussed with representatives of the Worldbank. Around 20th September 1983 agreement had been reached on the final version of the tender documents. These were sent for printing immediately afterwards.

Early October 1983 the documents were ready for collection by prospective bidders, after the necessary announcements had been made in local (English language) newspapers and in the Development Forum of the IDA. Embassies of countries from which interested contractors could be expected were also informed.
3.2 Tender Stage.

The period available for prospective tenderers to study the tender documents and to determine their price for the implementation of the works was three months. In the middle of this period a pre-tender meeting was arranged, in which the tenderers were informed on the design backgrounds. They were also given the opportunity to ask questions. Replies to the questions were given as far as possible during the pre-bid meeting, but the prospective bidders were given to understand that only the written answers, subsequently to be distributed to all those who had collected the tender documents, would be valid.

The date fixed for the opening of the tenders was 10th January 1984. On that day five tenders were received. The tender-evaluation committee, to which the Consultant was advisor, recommended that the Contract should be awarded to M/S Shimizu Construction Company Ltd. from Japan, who was the lowest bidder and who had submitted an administratively correct tender.

This recommendation was not supported by the Consultant, who pointed out the lack of experience of this bidder on similar (really comparable) works and to the apparent wrong interpretation of the scope of work and the workmethods to be adopted. The Consultant’s observations were ignored and the tender of M/S Shimizu was ultimately accepted, after the necessary approvals were given by the Government of Bangladesh and the Worldbank.

The Contract was ultimately awarded to Shimizu on 15th April 1984 and the notice to proceed was issued on 16th April. The time for completion of the works being 460 days, the completion date would be 9th August 1985, subject to possible extensions. (This date has subsequently been shifted to 23rd August 1985).

3.3 Mobilisation Period.

A few weeks before the official Notice of Award had been issued, M/S Shimizu Construction was informed of the BWDB’s intention to award the contract to them. Therefore Shimizu was in a position to start with the mobilisation at an early date. During the mobilisation period the following major activities took place:

- placing orders for supply of boulders,
- placing order for supply of filter fabric,
- awarding sub-contracts to several local contractors for work on the left bank, respectively the right bank; the principal sub-contractors were:
  a) M/S GASMIN on the left bank,
  b) M/S New Generation Contractors on the right bank,
  c) M/S Ahmed Brothers Contractors, also on the right bank.
- setting up of site office and
- site preparation.

A detailed workplan was drawn up by the Contractor and discussed with the BWDB and the Consultant.
3.4 Construction Period.

The initial work programme of the Contractor has been condensed into the schedule on the next page. In August 1984 it was already becoming apparent that the Contractor was not able to follow this programme. At that point of time no physical works were going on. Activities mainly concerned: preparation for future works and the collection of boulders for bed-protection work. No substantial procurement of clay had started at that time.

While the Contractor was warned for the backfall in his programme, no appreciable improvement was noticeable during the subsequent months. The delays were not reduced, but they even increased.

In the beginning of October 1984 the first permanent work was realised, namely the laying of bed-protection mattresses along and in the left bank gully. Shortly afterwards the laying of mattresses at the right bank also started. But by that time the delays so far experienced were reason for the Consultant to raise the 'first alarm flag'. The Contractor's headoffice was subsequently summoned by the BWOB to improve the rate of progress, so that closure could be realised as per the approved programme, implying closure of the Feni River on or around 31st January 1985.

The General Manager of Shimizu, Overseas Department, visited the site around 20th October 1984, and agreed that the production of mattress laying would be doubled, so that any delays which had occurred so far would be compensated. But the means to realise a double production were not provided and during the next couple of weeks no appreciable improvements were made.

In the beginning of November 1984 another alarm signal was given to the Contractor. This more or less coincided with a change in the gully pattern, most noticeable near the right bank, where access to the shoal was temporarily blocked, so that ballast for the bed protection works could not be hand-carried anymore to the appropriate location. The change in the gully pattern took the Contractor completely by surprise, and the works near the right bank came to a complete standstill.

While the changes in the gully pattern had an adverse influence on the progress of the work, the Consultant has always maintained (and still maintains) that these changes were a 'blessing in disguise', as they forced the Contractor to take drastic and effective measures before it was too late.

The most effective measures were the employment of additional floating equipment (barges and tugboats) and the enlistment of a group of specialists from M/S Zinkcon, a Dutch contractor specialised in bed-protection works, who were to advise on (and partly to carry out themselves) the remainder of the marine works. This comprised the laying of mattresses on the shoal (approx. 70% of the work remained to be done at that time) and the construction of the sill in the gullies.

The progress of the work picked up in the beginning of December, but by that time too much delays had occurred to realise the closure on the planned day at the end of January 1985. Instead the target-date to close the Feni River had to be shifted to 28th February 1985.
## Condensed Initial Construction Programme

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Apart from the delays in the bed-protection works, other delays had also occurred, which made a closure date of 31st January 1985 unrealistic. These delays involved mainly the supply of clay for the nap tide dam and the winter springtide dam. Especially at the right bank the supply of clay, in appreciable quantities, did only start in December 1984.

Closure of the Fan River could indeed be realised on 28th February 1985, though the conditions on that day were not as good as expected. As a result of persistent strong winds from a Southern direction the high water levels were higher than expected. Yet the Contractor decided to go ahead with the closure, which was realised in approx. six hours by 12,000 (or so) labourers. The high water on the evening of 28th February reached a very high level (SOB + 2.7 m, while SOB + 1.8 m was predicted), but the completed nap tide dam was not seriously threatened by this high water level. By deciding to go ahead with the closure, rather than to wait for better conditions on the next day, the Contractor gained one extra day for the construction of the winter springtide dam (WSTD).

The WSTD was more or less completed on 8th March 1985, just in time to counter the high water levels of the springtides. The highest springtide level recorded was SOB + 3.9 m, which conformed well to the predicted level.

After the successful closure a vast amount of work was still to be completed. The entire main dam body, flank embankments and slope protection work had still to be realised. In the preceding months not much attention had been paid to the progress of these works, since all efforts had to be concentrated on the closure.

The earthworks suffered mainly from a high moisture content of the fill material, which prevented a proper compaction and also slowed down the earthfill production. There were however no methods available by which the moisture content could be adjusted timely, and the B408 has excised substantial leniency towards the work quality delivered by the Contractor. While it could be argued that the Contractor was bound to realise the required degree of compaction, whatever the circumstances, enforcement thereof would undoubtedly have led to severe delays in the completion of the main dam body. In view of the approaching monsoon season (and pre-monsoon cyclones!) there were no realistic other options, than to go ahead with the earthworks, despite the poor compaction and its inherent effects.

The earth works were substantially completed in the second half of May 1985. At this time the slope protective works were still in full progress, but suffered from severe and frequent rainfall. Nevertheless during dry periods the Contractor realised an adequate production, mainly with labourers and local vehicles (trucks, farm-tractors, etc). The Contractor did however not succeed in properly laying a brickpave at the upper part of the reservoir slopes of both the main dam and flank embankments. The reasons for this were three-fold:

- lack of skilled bricklayers,
- incessant rainfall, which undermined the freshly laid bricks, and
- poor compaction of the earthfill (as already discussed above).
The Consultant suggested that it would be technically better to postpone the completion of the slope protection works, including the pavement on top of the dam, till the next dry season. This would enable the proper construction of the remaining slope protection works, but would have led to some (solvable) contractual complications.

The BWDB however did not opt for a later completion and was in favour of replacement of the brick pavement on the reservoir slopes by turfing. While the turfing will lead to extra maintenance work (cattle on the dam, especially cows and water-buffalos will cause damage to the turfed slopes), the Consultant did not object to this idea, as the chances for water overtopping the dam and the flank embankments are small.

The works were substantially completed in late August 1985, within the contractual time for completion.

Photo no.1 - View of the (almost) completed main dam (seaside)
CHAPTER 4 - CONSTRUCTION OF BED PROTECTION.

4.1 Introduction.

The main function of the bed-protection is to stabilise the river bed (at the location of the closure), so that any activities related to the closure operations, like the construction of the sill in the gullies and the stock-piling of claybags, will not result in changes of the river bed (notably the depth).

The protection consists of a mattress made up of a composite filter fabric, a frame work of bamboos and reedrolls, and a quantity of ballast, mainly in the form of river boulders from the Sylhet area.

Placing of mattresses in the gullies and on the shoals required a different approach:

a) In the gullies the mattresses had to be prefabricated on a special yard, after which they were pulled into the water and placed on the river bed around the slack of high water (the bamboos and reedrolls allowed the mattresses to float until ballast was placed on them.

b) On the shoals it was possible to manufacture the mattresses 'in-situ', thus at the same location where they had to be placed, during the rather long periods of the ebb tide. Ballast could also be placed during these periods.

The placing of mattresses in the gully along the left bank of the Feni River started on 14/11/84 and was completed on 10/12/84. The placing of mattresses from the right bank started on 18/11/84 and was completed on 12/1/85. Two relatively small gullies had to be crossed before 'contact could be made' with the earlier placed mattresses in the left bank gully.

Prior to the placing of mattresses on the river bed, the river banks were protected with similar mattresses in order to prevent that the gullies would change their course at the 'expense' of the river banks and adjacent lands.

4.2 Materials.

The following materials were used in the bed protection works:

a) Filter fabric:

A composite fabric consisting of a woven fabric manufactured by AMOCO from Gronau in West Germany, and a non-woven fabric manufactured by DUPONT de NEMOURS.

Both fabrics were assembled by GOUDERAK BV from The Netherlands. This firm had the overall responsibility for the supply of all fabrics and special tools for sewing mattresses of the required sizes on the site.
The rolls of fabric were approx. 5m wide, whereas the width of the mattresses varied between 30 and 50 m.

HASKONING has, at the request of the BWDB, arranged for the independent testing of the fabrics by:

- The Delft Hydraulics Laboratory and TNO, both of The Netherlands.

The tests indicated that the fabrics from which the samples were taken complied with the requirements of the Specification.

b) **Bamboos and reed:**

Barrack bamboos and reed from local sources were used for the framework on top of the filter fabric. Apart from acting as floating materials for the mattresses in the gullies, the bamboos and reedrods also had to function as a partitioning grid, in order to prevent ballast from being carried away by the strong river currents.

c) **Ballast:**

Ballast consisted mainly of river boulders obtained from the Sylhet area. The grading specified was as follows:

- for the gully areas: $D_{50} = 0.20$ m, grading between $0.10$ and $0.30$ m.
- for the shoal areas: $D_{50} = 0.09$ m, grading between $0.06$ and $0.12$ m.

The ballast on the shoals had to be protected with wire netting to prevent loss of the small sized ballast. This wire netting was attached to the bamboos and reedrods.

4.3 **Bed protection in gullies.**

At the commencement of the works only one gully existed at the closure site, namely along the left bank. While this gully was approx. 600 m wide at the time of the pre-bid meeting in November 1983, it had narrowed to approx. 250 m by the time the contract was awarded. The only feasible method to apply bed protection in this gully was as follows:

a) **Pre-fabricate a mattress on a launching ramp at the left bank near the closure site.** (The ramp was covered by filterfabric in order to facilitate the easy movement of the mattress at the time of launching.) The mattress consisted at this stage of filterfabric, sewn to dimensions of approx. 50 m long by 30 m wide, to which a framework of bamboos (in longitudinal direction) and reedrods (in cross-wise direction) was fixed.

A sinking beam (two interconnected steel pipes, diameter 0.3 m, provided with valves to enable the beam to be filled with water) had to be connected to the mattress before it was launched.
b) Position the following equipment just prior to the actual sinking operation:

- one flat barge (dimensions approx. 50 x 10 m equipped with a crane (with clamshell) and four anchors operated by power-winches and two hoists (the so-called crane barge),

- one flat barge (same dimensions as above) equipped with power-winches only (the so-called tail barge),

- several (three to four, depending on their size) barges loaded with stone of the proper grading.

c) Launch the prefabricated mattresses approx. 30 minutes prior to the slack of high water and bring it into position between the crane barge and the tail barge and suspend the sinking beam to the hoists on the crane barge. Exactly at the slack of high water the sinking beam together with the mattress is lowered as far as possible.

Immediately afterwards a start should be made with the ballasting of the mattress at the 'upstream end', which is the end located at the reservoir side and connected to the crane barge. The first part of the ballasting can only be done by the crane, because no stone barge can be positioned between crane barge and tail barge before the first part of the mattress has been lowered. As soon as this is achieved loading can also be done manually.

Photo no. 2: Launching of mattress.
In view of the necessity to position the mattresses between the barges during daylight, it was not possible to sink more than one mattress per day. A production of approx. 1000 m$^2$ (net) per day could thus be achieved. The sinking of mattresses in the left bank gully commenced on 14th November 1984 and was completed on 16th December.

Twenty two mattresses have been laid in this gully in total. In the course of the laying operations it was found necessary to sink the mattresses in the direction of the main current (which did not run parallel to the river bank), rather than perpendicular to the axis of the future closure dam, as was indicated on the drawings.

For guidance of the sinking operations, which should be regarded as highly specialised work, Shimizu had contracted the services of ZINKCON BV of the Netherlands. This firm initially provided a team of five experts. They have given advice on the actual sinking operations, the preparation works and the type of equipment to be acquired and/or to be prepared by the contractor.

![Photo no.3: Sinking of mattress in gully.](image)

4.4 Bed protection on shoals.

At the time of commencement of the works only a very small gully existed near the left bank. The Contractor considered it possible to cross this gully by laying and sinking mattresses during low tide by using only manual labour. All the ballast had to be carried from the stockpiles to the approximate location where the mattress had to be laid.
The contractor's plans had to be amended for two reasons:

a) The temporary stockpiling of ballast near the sinking location (on an earlier placed mattress) of the mattress to be placed resulted in considerable current contraction. This led in turn to substantial scour along the edges of the earlier placed mattress, so that it became virtually impossible to place the mattress with manual labour only.

b) The right gully of the Feni River rather suddenly increased in size. This resulted in an acceleration of the scour referred to above and aggravated the situation.

As a result of insufficient floating equipment being available on the site, the bed protection works came to a virtual standstill during approximately three weeks. It was only possible to continue with bed-protection work near the right bank, after additional floating equipment was brought to the site, and additional expert services were contracted from ZINKCON.

Photo no.4: Laying of mattress in right bank gully.

After the (relatively small) gully near the right bank was crossed, it became possible to return to the original plan of laying the mattresses during low tide with mainly manual labour. However the ballast was not handcarried all the way from the river bank to the location of the relevant mattress. Instead the ballast was loaded at a temporary jetty on a number of barges; these barges were floated into position during high water and subsequently anchored. As the water level became lower during ebb tide, the barges became stranded, so that it was possible to unload them with labourers and to transport the ballast over a short distance to the location of the mattress.
In this manner it was possible to lay two mattresses per day, having a length of approx. 75m long, and a varying width (from 30 to 50 m). The maximum nett production achieved was approx. 8000 m² per day, so that the delays experienced at the initial stage of the bed protection works near the right bank could (partly) be recovered.

Photo no.5: Laying of mattress on the shoal.

4.5 Construction problems encountered.

Apart from the changes in the gully pattern described in point 4.4, no special problems were experienced during the placing of mattresses on the shoal.

However the following problems were encountered during the placing of mattresses in the gullies:

a) The distribution between flow tide (flood) and ebb tide is, time-wise speaking, very unequal. On the average the flow tide lasts between 2hr 45min and 3 hrs, whereas the ebb tide accounts for the remainder of every full tidal cycle (12 hrs 25 min). However sometimes the flood tide lasts only two hours, which results in higher flood currents at the closure site, even in undisturbed condition. On several occasions the anchors of the crane and tail barges could not hold their load and slipped, so that some opportunities to place a mattress were lost. On other occasions stone barges were swept away from their moorings by the strong flood currents, though this could also be attributed to the poor mooring constructions and unavailability of sufficient (and sufficiently strong) anchor ropes.
3) To replace approx. 50% of the boulders of the middle section of the sill volume by claybags, provided that the upper layer of the claybags would be bundled to bigger units. Boulders would still be required at both sides of the sill.

As a result of the Consultant's suggestions, the Contractor officially proposed to make the above changes. As some cost aspects were also involved, negotiations were necessary to agree on a compensation for certain benefits which the BWDB would have enjoyed in case the sill was constructed as per the original design. (A part of the original sill was later to be removed and the recovered boulders would become the property of the BWDB.)

Agreement on the proposed changes and its financial consequences was reached on 31st December 1984.

In the first half of January 1985 it became apparent that the Contractor had not been able to acquire a sufficient quantity of boulders for even the reduced sill. While the Contractor could be deemed to be solely responsible for this critical situation, it would have served no purpose 'to lean back', as the whole success of the closure operation was at stake.

Therefore the Consultant studied again the possibility of a timely completion of the sill with the limited amount of materials available on the site. As a result certain suggestions which would circumvent the shortage of boulders were made to the Contractor. These suggestions however involved greater construction risks.

Having no suitable alternatives, the Contractor implemented the Consultant's proposals, which essentially meant:

a) Replacement of boulders below a level of SOB -1 m by clay bags. These claybags would not be able to withstand the current forces when the level of the sill would be raised further (up to SOB +0.70 m). Therefore it was necessary to cover the claybags with a mattress (mainly along the slopes of the sill) as soon as the level of SOB -1 m was reached.

b) Reduction of the quantity of boulders to be placed in the upper part of the sill; the width of the two 'ridges' at both sides of the sill was reduced from 10 to 5 m. To compensate for the resulting increased vulnerability of the sill, an outer protection of concrete blocks, 2 m wide, was indicated. The idea to use concrete blocks arose from the fact that the contractor had an ample quantity in stock for the purpose of constructing the slope protection on the main dam and flankembankments. However the Contractor opted for the fabrication of additional concrete blocks in Dhaka and Chittagong, which reached the site in time.

5.5 Actual construction of sill.

Construction of the sill up to a level of SOB -1 m and covering of the (under-water) slopes with mattresses, all in accordance with the second proposal for changes submitted by the Contractor, went reasonably smoothly:
The grouting prescribed was a sand-cement mix, which had to be injected, with suitable admixtures, around high water slack, when current velocities are minimal. Around low water slack no near-zero velocities occur due to tidal bores, which cause an instantaneous reversal of the current direction.

At the time of drafting of the tender documents the maximum height of the sill, including ballast of the bed protection, was approx. 1.2 m. The survey carried out during the tender period revealed that this height had increased to approx. 2.0 m. The results of this survey were communicated to the prospective bidders as part of the tender addendum documents.

5.4 Changes to Sill during the Construction Period.

Around the middle of October 1984 the following had become apparent:

a) The contractor was envisaging to close the opening between each stockpile with the so-called horizontal closure method, which was a deviation from the vertical closure method on which the Consultants had based their design (see also chapter 6). While this deviation by itself could be accepted on technical grounds (after the necessary additional hydraulic computations were performed), it made a part of the sill construction redundant. Instead of a width of 70 m, which was partly necessary for the construction of the NTD assuming horizontal closure, a width of 40 m was now sufficient.

b) The start of the bed-protection works had been delayed for several reasons. Having in mind the planned closure strategy, it was unlikely that closure of the Fená River could be realised in the dry season of 1984 - 1985, if the necessary works to the sill were not reduced to minimum proportions.

c) After the start of the bed protection works, the left gully had deepened substantially (as described in point 4.4), which would have resulted in very time consuming grouting operations, thus jeopardizing the (already postponed) closure date.

The above aspects led the Consultant to think about changes to the sill construction which:

a) Would (at least partly) offset the delays encountered earlier, and

b) Would not affect the integrity of the final cross section of the closure dam.

As a result the Consultant ventilated to the Contractor, after due consultation with the competent project officials, that it would be possible to change the construction of the sill as follows:

1) To reduce the width of the sill from 70 m to 40 m.

2) To delete the grouting of the sill under the neap tide dam, since its function would be 'taken over' by the claybags.
CHAPTER 5 - CONSTRUCTION OF SILL.

5.1 Introduction.

The sill serves only one purpose, namely to create (more or less) uniform flow conditions in the river (at the closure site) over the entire river width. The necessity for the uniformity of the flow followed from the selected closure method. This method envisaged that no appreciable narrowing of the river would take place prior to the actual closure operation. For a comprehensive discussion of the closure method reference is made to the 'FINAL DESIGN REPORT'. It may suffice here to state that an initial (substantial) narrowing of the river prior to closure would have led to undesired flow and scour patterns. Moreover heavy closure units (whether concrete blocks or stones in gabions) would have been required, which would have been too heavy for manual handling.

The closure method envisaged the creation of stockpiles with claybags at regular intervals in the river. At a suitable time these stockpiles were to be transformed (see also chapter 6) into a dam able to withstand the expected (neap) tide at the closure date. For this transformation it was essential that waterlevels and current velocities are more or less uniform over the entire river width during the closure operation. Hence the need to construct a sill in the gullies (on top of the bed protection) to match the level of the (protected) shoals.

The construction of the sill started on 14th January 1985 and was completed on 23rd February 1985.

5.2 Materials.

The following materials were used in the sill:

a) Jute and polyethylene bags filled with clay of medium plasticity.

b) Mattresses of a similar type as used for the bed protection in the gully.

c) Boulders, either loosely dumped from barges or packed in gabions (made in situ with wire netting).

d) A limited quantity of bricks and concrete blocks.

5.3 Description of Original Sill.

The sill as described in the tender documents consists of dumped boulders on top of the bed protection over a width of approx. 70 m, (measured perpendicular to the axis of the closure dam). To prevent leakage of water through the sill after the construction of the neap tide dam (NTD), grouting had to be applied under the location of this (future) NTD.
b) The gully mattresses (30 m • 60 m) were placed in rows of three in the direction of the current, so that it took at least three days to proceed 30 m measured along the axis of the future dam. During this time the edges of the mattresses (especially those parallel to the currents) constituted a change to the bed-roughness, which induced extra turbulence. This resulted in substantial scour along the edges of the mattress, so that it became more difficult to place the next row of mattresses. The difficulties can be described as follows:

b1) The scouring hole (or rather channel) along (a series of) mattresses prevented that the next series of mattresses could be placed with a properly connected overlap; the ballast on the mattress section above the scoured channel resulted in protruding of the reedrolls above the earlier placed mattress (because the reedrolls were rather stiff). On the other hand it was not possible to reduce the stiffness of the reedrolls, because in that case the whole sinking operation would come in jeopardy. It is suspected that at some locations the lack of a proper overlap has resulted in further scour between the mattresses, though this could not be verified by soundings.

b2) The additional roughness to the river-bed introduced by the mattresses has probably also led to a concentration of the currents in the unprotected parts of the gully. As the river bed material in this location was rather loosely packed fine sand and silt, it was easily erodible. Substantial erosion was recorded between the time of commencement of the bed protection works in the gully and the time it was completed. The figure on the next page gives the results of some echo soundings performed at the start and at several intermediate stages prior to completion of the bed protection works.

4.5 Some salient figures.
- Size of mattress in gully: 59.0 m long by 30.5 m wide.
- Size of mattress on shoal: 80.0 m long by 30.5 to 51 m wide.
- Number of barges used: 5 stone barges, one crane barge and one tailbarge, average capacity of stone barge: approx. 90 to 100 m3.
- Number of tugs used: 4 (various sizes)
- Ballast: 400 kg/m2 on gully mattress, 250 kg/m2 on shoal mattress.
- Time required for loading of barge (100 m3) with boulders: 2 hrs by 100 labourers,
- Time required for unloading of barge (100 m3) with boulders and placing on the mattress (shoal area): 4 hrs by 400 labourers,
- Time required for unloading of barge (100 m3) with boulders for placing on gully mattress (after placing the barge in position): 40 minutes by 80 labourers (dumping).
- dumping of claybags for the lower part of the sill took 18 days (from 14/1/85 to 31/1/85).

- placing of the 10 mattresses on the slopes of the lower part of the sill took 10 days (from 25/1/85 to 3/2/85).

Only a limited number of claybags was carried away by the currents, in the Consultant's opinion this was mainly due to dumping in currents of too high velocity.

![Photo no.6: Left bank gully shortly after start of sill construction.](image)

The construction of the upper part of the sill, between levels SOB -1.0 and +0.7 m constituted a closure by itself. Before the level of SOB -1 m was reached, the gully acted as the main channel for the filling and emptying of the Feni River estuary at water levels below say SOB +1 m. By raising the level of the sill above SOB -1 m the cross section of the left bank gully was substantially reduced, so that less water could flow in and out of the estuary. This resulted in an increase of the water level differences at both sides of the sill, which in turn led to an increase in current velocities over the sill. These high current velocities resulted in a substantial loss of claybags, especially when the completion of the upper part of the sill came nearer. (This is understandable, since the more the sill construction advanced, the more the cross sectional area of the gully was reduced and the more the water level differences increased.)

The Contractor did not succeed in completing the sill during the series of neap tides preceding the actual closure closure operations (thus approx. two weeks before closure). This was mainly the result of insufficient equipment being available for the placing of boulders and concrete blocks.
Therefore he had to struggle through a series of springtides preceding the closure operation, while attempting to complete the sill. Almost every tide damage to the (as yet uncompleted) sill occurred (which had to be repaired instantly during low water), but the Contractor still managed to gain more than he lost.

Photo no.7: Sill construction in the most critical stage.

The major part of the damages occurred during the middle stages of the ebb tide, when critical flow was experienced, especially at those locations of the sill which had not reached a sufficient height. An effective repair method was developed, which consisted of making gabions of wire netting filled with boulders at the location where damage was experienced. The 'empty' space between the rows of gabions (at both edges of the sill) was subsequently filled with claybags, which were also covered by wire netting, to prevent individual claybags to be 'washed' away.

The sill was completed just in time to allow the closure to proceed on 28th February 1985 as per the Contractor's revised planning.

In order to create favourable working conditions for the construction of the sill (but also for other purposes), the BWDB and the Contractor had earlier agreed on the opening of the diversion channel ahead of the contractually stipulated time. Annex A deals extensively with the function and operation of the diversion channel and regulator in relation with the essential closure works.
Photo no.8: Final construction stage of sill.
CHAPTER 6 - CONSTRUCTION OF NEAPTIDE DAM (including stockpiles).

6.1 Introduction.

Generally speaking the only suitable period for closing an estuary in Bangladesh is the winter season, lasting from November till March. During this season the following factors are beneficial for closure:

a) Negligible prospects of rain, implying good working conditions and (very) limited discharge through rivers from upland.

b) Low mean sea level, caused by a high air pressure area over the Bay of Bengal and a lower pressure area near Sri Lanka. This results in tidal levels which are substantially lower than in the monsoon period.

c) Surplus availability of labour, partly caused by the fact that in many areas in Bangladesh the agricultural activities are reduced during the winter season.

Closure normally takes place when the tidal conditions are most favourable, viz. from mid January till the end of February of each year, and more particularly during a period of neap tides. During the neap tide(s) the flow has to be stopped and during the subsequent days the closure works have to be reinforced to withstand the spring tide following approx. five to seven days after the closure day.

As a substantial amount of earthwork and slope protection work was required to render the dam suitable for the design conditions (which are much more severe than the conditions existing around the springtide of the closure month), closure could best be achieved at the earliest possible favourable date, thus around the middle of January. This was however prevented by the delays in the progress of the bed protection works and the consequential delay in the start of the sill-construction.

Closure of the river was achieved at the latest possible moment namely at the end of February 1985. The Feni River was closed on 28th February during a time span of six hours only by 12,000 labourers.

6.2 Closure Method.

The closure method on which the design was based envisaged an (almost) instantaneous closure of the river over its entire width. No (substantial) narrowing prior to the actual closure was contemplated. In order to implement this plan it was necessary to create stockpiles of closing materials (clay filled jute bags) at regular intervals in the river, as otherwise the logistic problems on the closure day would be insurmountable:

a) transport distances would be too long, and

b) working space would be insufficient.
The stockpiles had to be shaped in such a manner that they would cause minimal obstruction to the tidal flows. During low water on the closure day the stockpiles had then 'simply to be turned ninety degrees', so that a continuous barrier would be formed. This barrier should be strong and high enough to prevent the flood to re-enter the estuary during highwater on the evening of the closure day and the subsequent days.

Photo no.9: Closure site with stockpiles on the eve of the closure day.

6.3 Materials.

The materials used in the neap tide dam were:

a) Jute and polyethylene bags filled with clay. The weight of each filled bag was approx. 40 kg (dry weight).

b) Filterfabric (composite) of a similar type as used in the mattresses for the bed-protection works.

6.4 Construction of the stockpiles.

Construction of the stockpiles started on 18th January 1985 and was completed on the day prior to the closure. At the right bank almost all gunny bags were carried by labourers over rather long walking distances, sometimes more than 1 km. Initially very favourable conditions existed as the sill in the left bank gully had not yet reached its final height, so that the shoals fell dry at a rather early stage of the ebb tide. During the final stages of the stockpiling works the total labour force on site grew rapidly and reached its peak a few days before the closure day.
Transport from the left bank to the stockpiles in the river was progressing at a slower rate, partly because work to the sill was still in progress, partly because barges had to be used to transport the claybags over the left bank gully.

Ultimately nine out of twelve stockpiles were constructed with bags originating from the right bank, while the remainder came from the left bank.

Photo no.10: Stockpiling work in progress.

During the progress of the stockpiling works a test was carried out to determine the possible rate of production on the closing day. Between two stockpiles (measuring approx. 10 * 60 * 3.5 m (W * L * H)), a small section of neap tide dam was made of approx. 15 m length. This implied that the remaining gap to be bridged between a stockpile and this intermediate section was only 40 m.

It was later decided that similar intermediate sections would be constructed between each pair of stockpiles. The advantages would be:

a) A reduction of the workload on the actual closure day.

b) A clear division of the workload for the groups of labourers working from different stockpiles.

The intermediate sections were constructed on 26th and 27th February, thus in a period just prior to the projected closure date, and after the period of the springtides around 22nd February.
Near the left bank the formation of regularly shaped stockpiles was not possible as a result of the reduction of the width of the sill. Instead, a number of smaller and shorter stockpiles was formed at shorter intermediate distances. This unavoidably resulted in unfavourable flow patterns and high current velocities over the sill, but fortunately no serious damage or other problems were encountered.

The situation of stockpiles and intermediate sections as it existed on the day before the closure is reflected in figure on the next page.

6.5 Closure.

Closure of the Peni River took place on 28th February 1985. During the days preceding the closure, continuous strong winds had caused a substantial set-up of the water level during high water. The water levels were generally 0.5 m higher than predicted in the tide tables published by the hydrographical department of BIWTA.

This was also the case on the morning of the closure day. Yet the Contractor went ahead with the closure, thus accepting the risk of a higher water level than predicted. In the Consultants opinion this was a good decision, as a postponement would have led to a shorter construction period for the winter-spring tide dam (the most critical activity of the entire works), and might further have led to unrest among the labourers, who were only paid for work done (either on a daily basis or on a piece basis).

Photo no.11: Stockpiling work in progress.
Feni River Closure Dam
Situation on 27th February (one day before closure)
Labourers were assembled on both banks around 8.00 am and were assigned to different groups: one group of approx. 1000 men per stockpile. From 9.30 am onwards one group after the other left for their 'own' stockpile. As the water level at the reservoir side of the dam had not yet dropped sufficiently the first groups had to walk through fast flowing water of 0.3 to 0.5 m depth. Around 10.30 am the closure operation started and was without interruption completed in approx. six hours.

In those six hours more than one million bags were placed across the river with a total volume of 20,000 m³. The Contractor had at his own initiative increased the height of the neap tide dam, so that it was not strictly necessary to wait for the lowest neap tides, which were predicted for 1st and 2nd March 1985.

Photo no.12: Labourers 'en route' to their stockpile.

(Note that the water level has not yet fallen sufficiently to start the closure operation.)

The water level in the evening of 28th February rose to SOB +2.7 m or approx. 0.9 m higher than predicted. Apparently the strong winds during the closure day had caused an increase of the set-up. The built-in safety in the design level of the neap tide dam, and the increase in height in order to be able to close ahead of the actual neap tides, have proven to be of great importance!

The completed neap tide dam survived the high tide on the evening of the closure day without serious problems. At some locations leakage of water through, and piping under the dam were noticed, but with some extra attendance these phenomena could not endanger the integrity of the neap tide dam.
Photo no.13: Closure in progress.

6.6 Remainder of Neap tide Dam.

Over the claybags of the neap tide dam a filter fabric had to be placed. The main function of this fabric is to prevent the migration of clay particles of the winter spring tide dam into the voids (between the claybags) of the neap tide dam. This fabric was placed over the neap tide dam in two days' time following the closure and had also a (temporary) protective effect on the neap tide dam during high water and wave attack.

6.7 Other observations.

Filling of claybags and temporary stockpiling them on both river banks started in early December. Before the start of the works some fear existed that clay-filled jute bags, when stocked in the river (and thus subjected to continuous cycles of the tides), might lose some of their strength and that a certain percentage would burst upon rehandling during the closing operation.

This fear proved to be unfounded: during the closure operations hardly any bag appeared to have lost its strength. There was however a problem in another corner! Stockpiling on land during more than two to three weeks proved to be detrimental for a substantial number of jute bags, even to those of superior quality. Visual inspection learned that a fungus had caused disintegration of the jute, so that many bags could not even be picked up without spilling their entire contents over the (land) stockpiles.
Though no exact figures have been recorded it is estimated that from some stockpiles as much as 40% percent of the bags could not be recovered.

Photo no.14: Closure in progress.

In order to limit the feared (as later appeared unfounded) loss of strength of jute in the water, the Contractor had ordered a number of polyethylene bags, which were to be placed in the water earlier than the jute bags. In practice these polyethylene bags proved to be far from ideal. The turbulence of the water around the stockpiles resulted in a suction action, so that many clay particles were lost (this was not the case with the jute bags: the jute fibres swelled when they became wet, so that any openings in the jute fabric became almost hermetically closed).

Moreover the polyethylene bags appeared to be more difficult to handle and had a smaller friction coefficient, so that their use in the neap tide dam had an adverse (though not dramatic) effect on the stability of the neap tide dam.

The jute bags which had formed the inner core of the river stockpiles must have been subjected to some form of anaerobic process, judging by the smell and the change of colour to black. This has however not resulted in any loss of strength.
6.8 Some Salient Figures.

- Size of stockpiles: 50 × 10 × 3.5 m, each containing 100,000 bags.
- Number of bags per m³: from 35 (dry) to 50 (wet).
- Volume of neap tide dam: 20,000 m³.
- Number of labourers working on the actual closure: 12,000.
- Payment on closure day: per group of labourers working from one stockpile.
- Average pay per labourer on closure day: 100 taka.
- Premium per labourer in first finishing group: 30 taka.

Photo no. 15: High water at the end of the closure day.
CHAPTER 7 - CONSTRUCTION OF WINTER SPRINGTIDE DAM.

7.1 Introduction.

After the successful closure of the Fenj River on 28th February 1985, the most critical activity lay still ahead: construction of the winter springtide dam (hereafter mentioned WSTD) in approx. five to seven days time, so that the expected high waters of the springtides around 6th March 1985 would not destroy the efforts of closure day.

Whereas the volume of earth (claybags) for the neaptide dam was 20,000 m$^3$, the volume of earth for the WSTD was approx. 80,000 m$^3$. (This figure is not equivalent to the total volume of the claycore, which is 140,000 m$^3$, including the volume of the neaptide dam). While the daily volume of earth was not more than the total volume of the neaptide dam (which was after all constructed in only six hours), the transport distance was much more: average 1000 m, compared to 50 m for the neaptide dam.

During the design stage the Consultant had considered that it should be possible to construct the WSTD with local resources only. A possible work-plan envisaged the use of 200 local trucks and the same labour-force as used for the closure operation. Working in day and night shifts would be necessary. This plan was however not mandatory for the Contractor, who was free to select his own working method for the WSTD.

Instead of using local trucks the Contractor opted for the temporary importation of large earthmoving equipment. Though some uncertainties existed on their workability on the dam, the total production was just sufficient for raising the level of the closure dam ahead of the springtides around 6th to 8th March 1985.

7.2 Materials.

Only one type of material was used for the WSTD: clay.

More than 50 percent of the volume required originated from hillocks on the left bank, bordering the Chittagong Hilltracts. The Technical Specifications called for a medium plasticity clay with a liquid limit not exceeding 50%. This clay adequately fulfilled the requirements and was sufficiently dry to allow proper compaction.

On the right bank clay of acceptable quality (but only just) was also found, but it had to be excavated in rather thin layers from agricultural land. The moisture content of this clay was higher than that obtained from the hillocks at the left bank. This has led to a decidedly lower earthfilling production, because the higher moisture content prevented a proper compaction. This in turn resulted in a lower bearing capacity of the freshly dried clay, so that the dump trucks could not be loaded to their maximum capacity.
7.3 Construction of WSTD.

The following heavy earthmoving equipment was used for the construction of the WSTD:

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<th>Number</th>
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<td>38 t</td>
<td>30 m³</td>
<td>650 HP</td>
</tr>
<tr>
<td>Compactor</td>
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<td>CAT</td>
<td>815</td>
<td>20 t</td>
<td></td>
<td>210 HP</td>
</tr>
<tr>
<td>Compactor</td>
<td>2</td>
<td>CAT</td>
<td>825</td>
<td>31 t</td>
<td></td>
<td>310 HP</td>
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<tr>
<td>Vibro-compact</td>
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<td>Dynapack</td>
<td>51</td>
<td>15 t</td>
<td></td>
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<td>Excavator</td>
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<td>245</td>
<td>82 t</td>
<td>2 m³</td>
<td>325 HP</td>
</tr>
<tr>
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<td>CAT</td>
<td>225</td>
<td>24 t</td>
<td>1 m³</td>
<td>135 HP</td>
</tr>
<tr>
<td>Grader</td>
<td>2</td>
<td>CAT</td>
<td>16</td>
<td>24 t</td>
<td></td>
<td>250 HP</td>
</tr>
</tbody>
</table>

In addition to the above the necessary support equipment, like fuel and water trucks, was also imported on a temporary basis.

Construction of the WSTD started on the evening of 28th February 1985. On the morning of 1st March it had become apparent that at the left bank, where relatively dry clay was used, a (more than) sufficient production could be made. The Consultant has recorded top productions of one truckload of 30 to 35 m³ per 100 seconds, implying an hourly production (at one bank) of almost 1100 m³.

At the right bank the production was far less, mainly as a result of the higher moisture content of the clay. The trucks could not be loaded to full capacity, but only to 65% or less. The cycle time per trip was also higher because the trucks had great difficulty in driving and manoeuvring on the constantly deforming clay. The Consultant estimated that the production at the right bank was not more than 500 m³ per hour.

The combined production of the left and right bank was however sufficient for a safe overall progress of the works for the WSTD.
The following production rates were recorded on the days after the closure:

1st March: 14,160 m³,
2nd March: 12,260 m³, (cumulative: 26,420 m³),
3rd March: 15,640 m³, (cumulative: 42,060 m³),
4th March: 12,770 m³, (cumulative: 54,830 m³),
5th March: 12,330 m³, (cumulative: 67,160 m³),
6th March: 13,530 m³, (cumulative: 81,690 m³),
7th March: 13,310 m³, (cumulative: 95,000 m³),
8th March: 14,540 m³, (cumulative: 109,540 m³),

During the construction of the WSTD special attention had to be paid to the occurrence of piping at some locations, especially near the sill in the left bank gully. Boulders and bricks, which were dumped out of position, were the likely cause for piping. Piping became apparent at the reservoir side of the neap tide dam during high tides.

After piping at the reservoir was stopped, the danger existed of 'bursting-up' of the lower sections of the WSTD at the reservoir side. This phenomenon was indeed observed in the night preceding the highest spring tide. It could be counter-acted by quickly dumping a thick clay layer at the threatened location.

Good compaction, especially during the first days, was achieved at the left bank. Insufficient compaction was realised at the right bank, where the (relatively) high moisture content of the clay prevented that the specified compaction values were achieved. The need to go ahead with the construction of the WSTD prevented the implementation of additional (and therefore time consuming) compaction measures.

Despite the lesser degree of compaction than specified, the Consultant is of the opinion that no real danger existed (or exists) for the integrity of the WSTD or the entire closure dam. Additional compaction was gradually achieved by the heavy earth carrying dump trucks, which used the clay core as their access road during the construction of the main dam body.

The clay core, including the extra volume which was not essential for resisting the spring tides of March 1985, was completed gradually, along with the earthworks for the main dam body.

7.4 Some Salient Figures.
- Volume of WSTD: 100,000 m³ (excluding volume of neap tide dam),
- Additional volume to complete the clay core: 40,000 m³,
- Recorded average earth moving production: 13,690 m³/day (including night shifts),
- Estimated fuel consumption of all equipment per day: 40,000 litres,
- Minimum cycle time for fully loaded trucks at left bank (one way driving distance approx. 750 m): 10 minutes.
Photo no. 16: WSTD at full height.

(Note that the clay of the WSTD has been temporarily covered by a filter cloth as a protective measure against waves.)
CHAPTER 8 - CONSTRUCTION OF MAIN DAM BODY AND FLANKEMBANKMENTS.

8.1 Introduction.

After the completion of the WSTD, most of the excitement on the successful closure and the subsequent hectic days was over. Though the 'remaining works' would require a lesser demand on the nerves of all concerned, the workload for the main dam body, the flankembankments and the slope protection works (discussed in chapter 9) was enormous. Though no specific date could be indicated by which these 'remaining works' had to be completed (apart from considerations of a contractual nature), it was of utmost importance to complete as much as possible of these works before the onset of the rainy season.

The first rainshowers came in the middle of March. It is the Consultant's opinion that, if the closure date had been further delayed beyond 28th February (implying a postponement of the closure till the next series of neap tides), these rainshowers would have seriously endangered the closure works, and might have led to a complete failure of the already completed parts of the works.

The works to the main dam body and flankembankments comprised mainly the movement of vast quantities of earth, most of which had been obtained from the dredging operations for the diversion channel. This earth movement was realised using the same equipment as utilised for the WSTD.

8.2 Materials.

The Technical Specifications indicated that silty sand (or sandy silt) obtained from the dredging of the diversion channel might be used for the construction of the main dam and the flankembankments. It was however not mandatory to use this material and the Contractor was free to obtain any additional quantity from other approved borrow areas.

Though the Contractor was relatively free to select the source of the borrow material, it was important that the selected material could be properly compacted. The Specification called for a 95% percent compaction when compared with a standard proctor density test.

8.3 Construction of main dam body.

The majority of the fill material came from two areas:

- from the dredging disposal areas, and
- from excavation of the former stockpile area for clay at the left bank.

The materials from both these areas appeared to be too wet for proper compaction. At the right bank the Contractor attempted to achieve drying of the soil by firstly stockpiling it into large heaps (with 09 bulldozers).
However the time available was too short to obtain full of the required moisture content. Should the Contractor have chosen or should he have been instructed, at that time, to employ better or additional drying methods, the result would have been a substantial delay in the completion of the main dam body. With the approaching monsoon season, and possible cyclones and tidal waves in the transition period before the actual monsoon season, there was really no other option than to go ahead with the earthworks.

If the Contractor would have started with the construction of the flank embankments as indicated in his original work programme, thereby using the same equipment as for the main dam body, it is almost certain that additional measures for obtaining sufficiently dry fill material could then have been taken timely.

A part of the main dam body can be deemed to have been compacted more or less up to the standard specified. This part includes the WSTD and most of the fill at the reservoir side up to a level of approx. SOB + 5.0m. This compaction was mainly achieved by the continuous movement of the heavy trucks, bulldozers and compactors. However another substantial part has hardly received any compaction, as could among other things be concluded from regular compaction tests carried out by representatives of the BWDB. Areas of insufficient compaction generally extend from SOB + 5.0 m to the top of the main dam (SOB + 10.5 m), whereby the seaside layers are relatively better compacted due to traffic movements.

The consequences of the poor compaction will become apparent at a later date, namely in the next dry season (1985 -1986), when the soil will dry up and will settle under its own weight. In the course of that dry season it is likely that the major part of the settlements will take place, and that thereafter no serious additional settlement will be experienced.

The expected settlements will become apparent in the finished work, mainly under the road and the slope protection works. Substantial maintenance work may therefore be necessary towards the end of the maintenance period, thus around February 1986. In the Consultant's opinion the Contractor should be held responsible for making good the expected defects.

In May 1985 the Consultant suggested that the best (technical) solution for dealing with the compaction problem would be to postpone work to the upper part of the slope protection and the road on top of the dam until the expected settlements would have materialised. This suggestion was however not adopted by the BWDB, who preferred to have the work completed as soon as possible and to have any repair work done as would become apparent in the dry season (1985 -1986).

The earthworks for the main dam body were substantially completed around 20th May 1985. The large equipment was subsequently re-exported to Japan on a sea-going flat barge, which left the site on 23th May. In a later stage it became apparent that insufficient earth had been carried to the main dam. The deficiency was made up by additional fill which was carried from the right bank by a fleet of country boats, and by local trucks and farm tractors.
Photo no. 17: Work to main dam body in progress.

8.4 Construction of flank embankments.

Placing of fill for the flank embankments was basically similar to that for the main dam body. The same compaction problems were experienced, though to a lesser degree. Fill material for the embankment on the left bank was to a large extent obtained from hand-excavation from the (former) work area close to the seaside of this embankment.

Fill material for the other embankment on the right bank came mainly from the dredge disposal areas.

The earthworks were substantially completed at the same time as the earthwork to the main dam, thus around 20th May 1985.

A graph indicating the filling production versus time is given in Annex C.

8.5 Some Salient Figures.

- Volume of main dam body: 630,000 m³ (excluding WSTD),

- Volume of left flank embankment: 38,000 m³,

- Volume of right flank embankment: 160,000 m³,

- Recorded average earthmoving production: 9185 m³/day (round the clock working).
CHAPTER 9 - CONSTRUCTION OF SLOPE PROTECTION.

9.1 Introduction.

The main function of the slope protection is to protect the earth slopes against the action of waves and, to a lesser extent, to currents along the main dam. Possible wave damage depends very much on the wave heights. The wave height itself is often limited by the prevailing water depth. In front of the main dam, thus at the seaside, the largest depths occur, and the highest wave attack can be expected here. It should also be considered that waves from the Bay of Bengal would refract in the mouth of the (former) Feni estuary and would attack the main dam almost perpendicularly.

The wave attack on the flank embankments would be less in view of the high foreland and/or the more oblique orientation of these embankments relative to the wave crests.

Wave attack on the main dam at the reservoir side is certainly not negligible, especially when the reservoir is operational and strong winds would be blowing in a Southerly direction. The fetch length of the wind is in the order of 12 km, implying that substantial waves could be generated.

Siltation can be expected to occur in front of the main dam, because the Feni River mouth has become an area where the water is almost stagnant during a substantial part of the tidal cycle. The silt suspended in the sea water will therefore have the opportunity to settle down on the river bed. Only a small portion of the silt will be stirred up again when the tidal flood waters start receding.

Siltation in front of the main dam can be measured in several centimeters per day and has resulted in a substantial rise of the (former) river bed since the closure (at present more than 3 m). This can be expected to continue till a level slightly below the highest (normal) spring tide level has been achieved. The process may take only a couple of years.

From the foregoing it may be concluded that the situation with respect to wave attack will improve. However severe storms with corresponding heavy wave attack may also occur in the first couple of years after completion of the dam, and therefore the slope protection has been designed bearing this situation in mind.

The design had to be based on the scarce wave data available and it was not possible to determine the design wave heights (and lengths) without making some educated guesses. With the experience of one heavy cyclone (on 25th May 1985) behind us, it is safe to state that the slope protection is (more than) adequate.

9.2 Materials.

A wide variety of materials was used in the slope protection works. The most important were:

a) Clay as a sub-base under the slope protection.
b) Filter-fabric of the same quality as used for the bed-protection works.

c) Chipped bricks used as filter layer on top of the filter fabric.

d) Brick blocks used at the seaside of the flankembankments (the least exposed parts).

e) Concrete blocks with brick aggregates used for the protection of the main dam (sea side and reservoir side) and the more exposed parts of the flankembankments.

f) Concrete blocks with gravel aggregates used on the location of the heaviest wave attack of the main dam and on the curved portion of the flankembankment on the right bank (adjacent to the regulator).

g) River boulders (in various gradings) at the lower part of all revetments.

The cement prescribed for the concrete blocks was Portland cement with a high resistance against sea water attack. Only a part of this cement was imported from abroad. Importation problems led to a switch to local cement.

9.3 Pre-fabrication work.

Brick blocks and concrete blocks were prefabricated on the site. The brick blocks were all hand-made by using timber forms to ensure (more or less) constant dimensions. 20 numbers of standard size bricks were used to produce one brick block of 0.5 × 0.5 × 0.2 m. Production of brick blocks started on 31/12/84 and was completed on 23/05/85.

Concrete blocks, both with gravel and broken brick aggregates, were manufactured on the site with a (temporarily imported) block-making machine. The concrete plant produced 'zero-slump concrete', which was compacted in special moulds. The blocks were released from the mould immediately after compaction and were left to harden for approximately 24 hours before they were transported to the storage yard.

Setting up of the plant took quite some time and production of blocks did not start before 01/11/84. After the production was completed the concrete plant and block-making machine were re-exported on 23/05/85 (together with the heavy earth moving equipment).

9.4 Construction of slope protection.

The construction of the slope protection of the main dam started immediately after the completion of the neap tide dam. Especially the lower part of the sea side protection caused the Contractor problems. These problems were caused by:

a) Heavy siltation, so that during every period of low water the freshly deposited silt had first to be removed before more slope protection materials could be installed.
b) Wave attack during high water: though the waves were, on the average, not high at all, the breaking of even very small waves caused erosion to the unprotected clay slopes, so that it became very difficult to prepare and maintain a proper base for the slope protection blocks.

Photo no.18: Work to the toe protection of main dam (seaside) in progress.

It is the Consultant's opinion that the Contractor's lack of experience with this type of work was the main cause for the problems. In the Contractor's conception the slope protection works formed a 'horizontal' process, whereby long horizontal stretches, with little height, were completed truly sequentially. Working under tidal conditions however requires a 'vertical' approach, whereby small sections of work are completed from the foundation level to above the high water level within a time span of one tide only. This will eliminate the recurring damage to as yet uncompleted sections of the slope protection.

Work to the slope protection outside the tidal zone was implemented without major problems (apart from delays caused by rain). It is however the Consultant's opinion that a much better quality of work could have been achieved if the Contractor had employed the services of a few experts with experience in similar works. Now the Contractor was 're-inventing the wheel' every time a new activity had to be started. Apart from a better quality, the employment of a few specialists would, in the Consultant's opinion, also have led to substantial savings in costs to the Contractor.

A major problem formed the setting of bricks in clay on the reservoir-side slopes of the flank embankments and the main dam (upper part only). The lack of proper compaction (as discussed in chapter 8) and skilled labour resulted in an inferior product, which was easily affected by the monsoon rains.
Technically the best solution would have been to postpone this work till the next dry season, so that the work could be re-executed under more favourable conditions.

Photo no.19: Slope protection of flank embankment (right bank) almost completed.

This suggestion was submitted to the BWDB, who was however in favour of completion of all the works as early as possible. It was therefore suggested, though not by the Consultant, that the brickwork could be replaced by turfing work, whereby the corresponding savings would be passed on to the BWDB. The Consultant had no objection to this proposal on technical grounds, but warned the BWDB for extra maintenance work in case cattle (especially cows and water buffalos) would be allowed on the dikes.

All the slope protection works, including the pavement on top of the dam were substantially completed at the end of August 1985.
9.5 Some Salient Figures.

- Number of brick blocks: 82,000.
- Number of concrete blocks (brick aggregate): 210,000.
- Number of concrete blocks (gravel aggregate): 209,000.
- Volume of brick chips used in filter layers: 15,000 m³.
- Filter fabric used under revetments: 150,000 m².
- Labour force used for protective works (average): 1000 labourers.
CHAPTER 10 - CONSTRUCTION MATERIALS.

10.1 Introduction.

Most of the materials required for the works have already been discussed in chapters covering the various components of the works. That discussion mainly concentrated on the technical requirements of the materials. This chapter attempts to give an impression of the logistic aspects and problems of the materials for the works as an entity. It should be realised that the time available for the completion of the work was extremely short. For a work of this size it would not be unrealistic to expect that one (dry) season would be used for the collection of all (or most of) the construction materials and that in the next dry season the closure would be realised.

The time set for completion was however extremely short in view of strong pressures to construct the closure dam as early as possible, so that the purpose for which it was to be constructed, namely irrigation, could be served without unnecessary delays. Moreover the estuary had shown a tendency to silt up, so that the storage capacity was becoming smaller every year, thus affecting the benefits of the Muhuri Irrigation Project.

While the closure has been a success and the works have been substantially completed in the construction time available, it is good to realise that the short construction time also meant taking a big risk; the delays experienced during the initial stages of construction could have easily become insurmountable, so that all pre-closure work would have been done in vain. If closure would not have been realised by 28th February 1985, the bed-protection works would probably not have survived the time span required for another closure attempt: one full year.

10.2 Supply of boulders and gravel.

Boulders and gravel were required, in big quantities, for the

- bed-protection works,
- sill in the gullies,
- slope protection works (both at reservoir side and sea-side),
- as coarse aggregate in concrete blocks.

In Bangladesh there is only one source from which boulders and gravel can be obtained in large quantities: the Sylhet area in North-East Bangladesh, where boulders and gravels of varying sizes are collected from a multitude of rivers, most of which originate from India. During every wet season (which in that region is extremely wet: the world’s yearly record for rainfall has been established in Cherrapunji, just across the border between Bangladesh and India) a fresh supply of boulders is delivered 'free of charge' by the rivers. It is 'only' a matter of picking up the boulders and transporting them to the place where they are required.
The snag lies in the word 'only'. It is hardly possible to reach the river beddings with large equipment. Therefore most boulders are collected by small boats, which can produce, including transporting to a storage area, only 0.5 m³ per day.

The total yearly production of the Sylhet area is limited, while the demands for boulders from almost the whole of Bangladesh have to be satisfied from this source. It is clear that a demand for 150,000 m³ of boulders and gravel meant a substantial strain on the market. Nevertheless the Contractor succeeded in placing orders for boulders in time, and delivery to the site started in June 1984.

Boulders were transported from Sylhet to Daudkandi by small coasters over the Meghna River. From Daudkandi, which lies along the main road from Chittagong to Dhaka, the boulders were transported by trucks to Feni (a distance of 100 km). These trucks (from a wide variety of owners) had just carried goods from Chittagong to Dhaka and had no return load. At Feni the boulders were unloaded, all by hand, and later loaded on sub-contractors' trucks and transported to the site.

The roads on both riverbanks from Feni to the worksite are narrow and not designed for heavy traffic of a high density. The first loads of boulders started to arrive in the beginning of the monsoon season, and the trucks caused immediately substantial damage to the road surfaces. Continuous repairs and upgrading were inevitable, for which the Contract had laid the obligation on the Contractor.

10.3 Supply of Clay.

Clay was required for the neap tide dam (in jute bags), the WSTD and as a protective layer under revetments. The total quantity required was around 250,000 m³.

At the left bank clay of good quality was found at some hillocks just East of the main road from Dhaka to Chittagong (approx. 10 km driving distance from the site). The clay was excavated and loaded on local trucks and subsequently transported to the site, where it had to be stockpiled till the start of the construction of the WSTD (a relatively small part had also to be used for the filling of jute bags for the neap tide dam).

An ingenious, but simple, system was developed to load the trucks by labourers: excavation of the hillocks was done in such a manner that almost vertical walls remained. The trucks were manoeuvred between the walls, whereby almost 'nil tolerance' remained. Clay was then loosened from the hillocks with shovels or large chisels and fell straight into the truck, so that manual loading of the trucks could be avoided.

The initial clay transports at the left bank took place during the last months of the wet season; this also caused serious damage to the access road.
At the right bank the supply of good quality clay was problematic. Initially, the Contractor had intended to obtain clay from a borrow area near the access road from Feni to the site (approx. 15 km driving distance). However, the borrow area was inaccessible till well into the dry season. He then set his hopes on clay deposits near Feni (approx. 35 km from the site!), but later probably considered that this would have resulted in substantial extra cost (to him) in view of the long driving distance and the expected extra maintenance cost of the roads.

In spite of the pressing need to start with the clay collection the Contractor continued to search for clay deposits closer to the site and ultimately found what he was looking for at only 5 km driving distance. His gamble paid off and he was able to make up for the lost time by employing a large number of local trucks, including some large Ford trucks rented from the BWDB, just in time for the closure date (which had by then already been postponed from 31st January to 28th February 1985).

10.4 Other materials.

Other materials than clay and boulders, like bricks, cement, sand, filter-fabric and jute bags, were also required in substantial quantities. The procurement of these items stretched the Contractor's purchasing organisation to the limits of its ability, but ultimately all these materials arrived in time. No special problems had to be solved where the transportation of those goods was concerned.

(In this connection it should be realised that the changes to the sill, discussed in chapter 5, implied a substantial reduction of the quantity of materials required. Without this reduction the Contractor would not have been able to supply all the materials required in time.)
CHAPTER 11 - CONTRACTUAL ASPECTS AND METHOD OF MEASUREMENT.

11.1 Introduction.

This chapter gives an outline of some contractual aspects, which were relevant to this very special closure project. Standard contractual matters are not dealt with; for additional information reference is made to literature on the FIDIC Contract.

The Contract between the BWDB and M/S Shimizu was based on the standard FIDIC Contract (third edition), which for the purpose of this project was amended (and re-numbered), to suit the requirements of the BWDB and certain aspects of this particular project.

Any civil engineering project contains risks. It is important that these risks are recognised at the drafting stage of the contract documents, so that, at that time, it can be decided which of the (future) parties to the Contract is deemed to be responsible for a particular risk. This should then be reflected in the text of the contract documents.

For most closures in Bangladesh, if not all, it has been the custom to burden the Contractor with all risks related to a closure. The Contractor would receive his first payment only if he successfully closed the river. For the BWDB this meant that no money would be lost if the closure became a failure, as has frequently happened in the past. The disadvantage was clearly that the Contractor was tempted to take big risks in achieving closure, while the complete burden of financing the closure rested entirely on him.

The practice of burdening the Contractor with all risks has been abandoned in the case of the Feni River Closure Dam. Instead a contract has been drawn up, whereby progressive payments would be made to the Contractor during all stages of the works.

11.2 Major Risks.

Apart from 'normal' construction risks, the following major risks existed for the Feni River Closure (some of these risks were the result of the extremely short construction period allowed to the Contractor):

a) The quantities of building materials, like clay and boulders, were very large. At the time of Contract award it was not entirely clear whether it would be possible to acquire the amount of boulders from the Sylhet area or whether additional sources would be necessary. On the right bank no suitable borrow pit for clay had yet been found close to the worksite.

b) As a result of point a) a relatively minor delay in the acquisition of materials would imply that the closure would not be possible in the ideal month of February 1985. The risks inherent to a closure at a later date would be enormous. (With hindsight it can be stated that a closure attempt in March 1985 would probably have failed.)
c) The risks to achieve the closure by itself, provided all preliminary works would be completed in time, depended very much on the natural circumstances like weather and sea water levels. Generally speaking there would be at least three chances to close the river in the dry season of 1984 - 1985, the last (reasonable) chance being on 28th February or 1st March 1985. With such a critical and labour intensive operation there are always the prospects of labour-strikes. If not dealt with adequately this may lead to a closure failure.

d) After closure would have been achieved (during a neap tide), the most difficult task would still lay ahead. The closure would have to be reinforced in a very limited number of days to counter the spring-tides, which should be expected roughly one week after the days with neap tides. Because of the volume involved (five times more than the volume of the neap tide dam, with no possibility to stockpile the material in the river) round-the-clock working would be essential to realise that work in time.

All of the above risks would be within the control of the Contractor and the contract documents placed the responsibility for these risks on the shoulders of the Contractor.

11.3 Insurances.

Under the terms of the contract, the Contractor was required to insure the works for damages, etc., resulting from whatever risk, except for damages arising from so-called excepted risks. These excepted risks are defined in the standard FIDIC Contract. One of the excepted risks is normally damage 'resulting from a cause solely due to the ...... design of the works'. This by itself is a reasonable exclusion, because the Contractor is not responsible for the design of the works.

However the Contractor would have the responsibility to construct and complete the works, irrespective of the practicability (or 'unpracticability') to implement the design. The Contractor would be entirely responsible for the choice of the working methods and selection of equipment, etc.

Should during construction of the closure works anything go wrong, so that closure could not be realised, all pre-closure works, like bed protection, would soon be damaged by the currents and any evidence on the cause of the failure might soon have disappeared. To avoid that the Contractor's insurance company might argue that the failure was the result of an erroneous design, and would therefore not foot the repair bill (which could be, to say the least, very substantial), the Contractor was not allowed to treat design risk as an excepted risk where it concerned the insurance of the works, during the construction period.

Initially this created some controversy with the Contractor's insurance company, but ultimately the matter was solved, whereby the standard exclusion on design risks was deleted from the policy.

(Note: In the Consultant's opinion the Contractor would anyhow be responsible to first complete the works. The insurance clause was amended to reduce the chances that the insurer might refuse to pay in case of failure.)
11.4 Points of Controversy.

A contract for civil engineering works whereby differences of opinion arise between the Employer and the Contractor is rather a rule than an exception. The contract for the Feni River Closure Dam followed closely 'the rule'.

This report does not attempt to give full details (these are dealt with in correspondence between the two parties and their respective legal advisers), but only lists the main points of controversy. These are:

a) Change in Closure Site Configuration.

The Contractor claims that he could not have foreseen certain changes in the river regime, and that this caused him unforeseeable extra costs for which he should be reimbursed. The BWDB is of the opinion that the contract documents make it sufficiently clear that changes had to be expected and that the Contractor should have allowed for it in his tender price.

b) Excessive Rainfall in 1984.

The Contractor is claiming that excessive rainfall in the mobilisation period has caused him unreasonable delays. To make good the delays he had to accelerate the works to make a timely closure possible, for which he should be reimbursed. The BWDB is of the opinion that the rainfall in the period mentioned by the Contractor was within the range to be expected and that any acceleration cost should be for the Contractor's account.

c) Access Roads.

The Contractor claims that the state of the access roads was considerably inferior to what he could have expected on the basis of the Contract documents. The extra cost for upgrading them and the maintenance cost should therefore be reimbursed to him. The BWDB does not agree with this view and is moreover of the opinion that the Contractor's claim has been grossly inflated.

d) Moisture Content of Sand/silt.

The Contractor has experienced a very high moisture content of the sand/silt on the dredging disposal areas. This caused him to employ additional methods for obtaining dryer soil and led to a loss of production in the transportation of sand/silt from the disposal areas to the main dam. He further claims that the high moisture content is the result from the dredging operations, which continued for a much longer period than indicated in the contract documents.

The BWDB agrees that the dredging operations were going on for a longer time, but this had no adverse effect on the moisture content of the disposal area. The dredge spoil was pumped to the Feni River, rather than to the disposal areas, during the last months of the dredging works. The Contractor is further bound to supply soil with an adequate moisture content (important for good compaction) and should employ, at his own cost, such means as are necessary to achieve this.
e) *Insufficient Quality of the Works.*

Substantial parts of the earthworks have not received proper compaction. As a result, the quality of the slope protection works was adversely affected, and more defects will become visible during the next dry season. The Contractor will be under an obligation to make good these defects. The background of the insufficient works quality has been discussed in earlier chapters. Though some understanding can exist for same, it does not mean that the present situation should be accepted as a 'fait-a-compli'.

While it is not practicable to ask the Contractor to make good the defects at this stage (it would mean demolishing and rebuilding of the majority of the works), the Consultant is of the opinion that, the completion and (in due course) the maintenance certificate should not be issued without a firm undertaking from the contractor to make good defects, resulting from the poor compaction of the earth of the main dam and flank embankments, at his own costs, even when those defects become apparent after the expiry of the Period of maintenance.

11.5 *Method of Measurement.*

Though the contract provided for monthly payments, most of the works had to be carried out on a lump sum basis, with no provision of measurement. The most important lump sum items were:

- Bed protection,
- Sill,
- Neaptide dam,
- Winter springtide dam,
- Main dam body,
- Earthworks for flank embankments.

The works to the slope protection were all re-measured.

No separate payment was provided for mobilisation expenses, but the Contractor was paid an advance of ten percent of the contract sum, after submission of a bank guarantee. Payments were further made in local and foreign currency, approximately in the proportion 45/55 percent respectively.
CHAPTER 12 - CONSULTANT'S ACTIVITIES AND STAFFING.

12.1 Consultancy Agreement.

The Agreement for Consultancy Services for the Feni River Closure Dam was signed on 14th January 1983. Basically the agreement places upon the Consultant the obligation to provide a design and draft tender documents for the Feni River Closure Dam and to assist the BWDB in supervising the execution of the works, whereby the Consultant would be responsible for the advise given to the BWDB.

The original Consultancy Agreement envisaged that the works would be completed by June 1984 and that the Consultancy services would not be required after that date. During the initial design stage it became apparent that insufficient and/or reliable data existed for a proper design. It was necessary to collect additional data, as reported elsewhere in this report. The actual design stage could therefore not start prior to July 1983, and the construction contract could not be awarded before March 1984 (considering the tendering requirements as per Worldbank rules and the time necessary to evaluate the bids submitted by the several tenderers). This automatically implied that a first closure attempt could only be made in early 1985, and that the total works could not be completed before July 1985.

The Consultancy Agreement had therefore to be amended to reflect the later completion date of the Works and the extra man-months required for additional work on the part of the Consultant (the number of man-months was slightly increased from 54 to 60, which is very minor when considering that the duration of the agreement was extended from 18 to 30 months).

The extension to the Agreement was approved by the Government of Bangladesh and the formal First Amendment to the Consultancy Agreement was finally signed on 14th July 1985.

The fact that the Contract was awarded slightly later than scheduled implied a later contractual completion date for the Contractor (9th August 1985 rather than 30th June 1985). This date was later extended to 23rd August 1985 as compensation for some delays beyond the Contractor's control. Moreover some differences of opinion had arisen between the BWDB and the Contractor on the interpretation of certain aspects of the contract documents. As a result some protracted dealings were to be expected between these parties on some extra payments allledged to be due from the BWDB to the Contractor.

In view of the above the Consultant proposed to extend the duration of the Consultancy Agreement again in order to assist the BWDB in their (difficult) dealings with the Contractor (who had incidentely sought the assistance of experienced claim-experts and lawyers). As no increase in the number of man-months was required no separate negotiations on the Consultant's proposal were necessary. The finalised proposals were approved by the Chief Engineer (Project-I) after due consultation with the Board of the BWDB.
12.2 Consultant’s Main Activities.

The main activities of the Consultant are listed below:

a) January and February 1983:

Study of existing data and formulating a programme for the collection of additional data. At this stage three closure design experts, the project sponsor and the teamleader were involved. The closure design experts and the project sponsor stayed in Bangladesh only for a short time.

b) March, April, May and June 1983:

Supervising the collection of additional data and the soil borings, processing of the measurement data into workable design parameters and formulating the laboratory test programme on soil samples (on the basis of the field descriptions of the samples).

At this stage only the teamleader was resident in Bangladesh, while a mathematical model and a computer program were developed in the Consultant’s office in Holland.

c) July and August 1983:

Preparing the Final Design for the Feni River Closure Dam, including the draft tender documents. During this stage seven closure experts came to Bangladesh, including the project sponsor. Despite the very short time allocated for the design period, the Consultant delivered the design and relevant reports to the BWDB in the first week of September.

d) September 1983:

In this month the reports submitted by the Consultant were evaluated by the BWDB and by a visiting team of the Worldbank. After some minor changes, the tender documents were printed and were made available for collection by interested contractors. Only the Consultant’s teamleader was involved in this pre-contract work.

e) October, November and December 1983:

This was the tender period in which interested contractors could study the tender documents, visit the site and decide whether they wanted to submit a bid for the works. On 15th November 1983 a pre-bid meeting was arranged, whereby tenderers were given the opportunity to ask questions and were given some background details of the project.

The Consultant’s teamleader was involved in the preparations for the pre-bid meeting and the drafting of tender addenda. At one stage difficulties arose around the printing of additional tender drawings (1600 drawings were still to be printed), when it appeared that no more printing paper was available in Bangladesh. With the tender opening date approaching fastly, there was no other option than to arrange for the printing of the remaining drawings in Bangkok.
The teamleader traveled to Bangkok on 4th December and returned, with all the drawings printed, on 6th December, after which they were quickly distributed to the tenderers.


Tenders were received on 10th January 1984 and were subsequently evaluated by the tender evaluation committee, to which to Consultant was advisor (but not a member).

A decision on the award of the contract was made in March 1984, of which the selected contractor was informed. The official decision was made known to him in early April 1984.

On the part of the Consultant one closure design expert, who had come to Bangladesh for the occasion, and the teamleader studied the tenders received and formulated the Consultant's advise to the BWDB (which advice was not implemented as far as the selection of the successful bidder was concerned).

g) April, May, June and July 1984.

This period could be considered as the mobilisation period. The Consultant's activities, on the part of the teamleader, consisted mainly of evaluating the Contractor's work programme and advising on possible improvements. During this period the teamleader also enjoyed six weeks home leave in Holland.


This period was the construction period during which the 'bulk' of the work was executed. The Consultant's site supervisory team was reinforced to three on the average: the teamleader, one or two supervisors and one closure construction expert. They were more or less permanently resident on the work site.

Around October 1984 a very critical period had arrived, in which the question could be asked if there were any prospects left for a successful closure in the coming dry season. The root-cause was, in the Consultant's opinion, the underestimation of the works by the Contractor. This was aggravated by certain changes in the gully pattern, but as described earlier this also served to 'awaken' the Contractor.

In an effort to contribute to a solution of the problems, the teamleader traveled to Holland at the end of October for consultation of the Consultant's design experts. As a result of the discussions some modifications were thought to be possible, on which a full report has been given in chapter 5.

During the closure time the Consultants site team was expanded to include the project sponsor and one extra closure expert.

In addition to the regular site staff, the Consultant also arranged for the posting of an extra hydraulic engineer, at their own cost, on the site to assist the staff in their supervision work.
1) September 1985 and Afterwards.

The teamleader and other site staff from the Consultant will repatriate. The teamleader will pay short visits to Bangladesh to assist the BWDB in finalising outstanding contractual and technical matters.

12.3 Staffing.

The following staff of the consultant (in alphabetical sequence) participated in the design and supervision of the project:

- Prof. J. Agema, closure design expert,
- Mr. C. Biemond, closure design expert,
- Mr. N. Broug, closure design expert,
- Mr. J. van Duivendijk, closure design expert & project sponsor,
- Mr. P. Horn, supervisor,
- Mr. C. Klaver, closure construction expert,
- Mr. G. Koopmans, supervisor,
- Mr. W.M. Koster, supervisor,
- Mr. G. Lakenman, trainee,
- Mr. T. van der Meulen, closure design expert,
- Mr. G. te Slaa, teamleader & senior supervisor,
- Mr. E.C. Smith, closure design expert,
- Mr. J. van Westen, closure design expert.
CHAPTER 13 - CONSULTANT'S PRINCIPAL FINDINGS AND RECOMMENDATIONS FOR FUTURE WORKS

13.1 Consultant's Principal Findings.

a) Design Requirements.

During the design stage in Dhaka (July & August 1983) the Consultant's initial approach to the closure issue turned out to be abortive. For a new approach additional hydraulic calculations were indispensible. The mathematical model developed for this project and the availability of software and hardware in Dhaka (which was later handed to the BWDB) proved to be of great value.

b) Construction Time.

The time allowed for the construction of the Feni River Closure Dam was extremely short. While the Contractor has succeeded in the major objective, namely the closure of the Feni River 'around' February 1985, the risks at stake were enormous, and the short time span allowed could easily have led to a failure to close the river. The consequential losses in that case would have been tremendous.

c) Contractor's Experience.

The Contractor selected for the works had clearly no experience in closure works. His selection by the BWDB implied a great risk. The Contractor's lack of experience with this type of civil engineering works and working under tidal conditions in particular, has decidedly led to a loss of quality of the works. This loss of quality will probably have no drastic effects, but extra maintenance work may prove to be necessary to make good deficiencies becoming apparent at a later stage.

d) Marine Aspects of the Works.

Certain changes in the gully pattern of the Feni River proved to be almost fatal for the Contractor. Without advise given by the Consultant on possible changes aimed at overcoming the problems and without extensive assistance from M/S Zinkcon for the marine works, the Contractor would probably not have succeeded in closing the Feni River in the 1984 - 1985 dry season.

e) Infrastructure.

A good infrastructure for a work of this nature is very important. Access roads should be ready at the beginning of the works, requiring little or no maintenance during the progress of the works.
f) **Decisions by BWDB.**

Decisions required from the BWDB were made very quickly, so that the works never suffered from a 'decision vacuum'. It is hoped that the active participation of the BWDB in the project may be repeated in future projects.

g) **Bed Protection Works.**

Apart from a shift in the gully pattern which took the Contractor by surprise and caused a substantial delay to the bed protection works at the right bank, the bed protection works in general were implemented rather smoothly.

h) **Sill.**

The construction of the sill in the gully proved to be the most difficult task. Lack of equipment and materials forced the contractor to use every available means to construct and finalise the sill, which by itself was already a kind of a closure.

i) **Stockpiling of Clay Bags.**

The stockpiling of jute bags under 'dry' conditions created problems. Because of the natural moisture content of the clay, rather humid conditions existed, in which a fungus could develop. This fungus caused a severe loss of strength and resilience of the jute and a subsequent irreparable damage to the jute bags.

The stockpiling of jute bags in the river, on which some uncertainty existed, turned out to be not harmful for the jute bags: to the contrary almost no bags were damaged during the construction of the neap tide dam. It is however not known how long jute bags may be stockpiled under tidal conditions.

Polyethylene bags were less suitable for use in the stockpiles (and in the sill), because substantial amounts of clay were 'sucked' through the openings between the fibres by the currents.

j) **Closure-Method.**

The closure method developed turned out to be highly successful, but is doubtful that this method can be applied elsewhere, as two unique conditions existed at the project site:

- A regulator and diversion channel existed through which the estuary could (partly) be emptied on the closure day. Without the regulator insufficient time would have been available for the closure. Moreover the river bed at the closure site would never have become dry (that means after completion of the sill).

- A substantial part of the river cross section at the closure site fell dry during low water, while the gullies were relatively shallow. This enabled easy access for the construction of bed-protection and stockpiles.
k) **Winter Springtide Dam.**

The construction of the winter springtide dam was a very critical operation, not only in view of the very short time available, but also as far as the equipment selected by the Contractor is concerned. Use of dump trucks with low-pressure tires would have decreased the risks and would also have led to a higher earth movement production, notably on the right bank (where the earth was generally too wet).

l) **Compaction of Earth.**

The compaction of substantial parts of the fill for the main dam has been insufficient. The consequences hereof will not be disastrous, but will become noticeable in due course. Extra maintenance work must be expected, particularly to the slope protection works and the road on top of the dam and flank embankments.

m) **'Cyclone Resistance'.**

The recent cyclone of 25th May 1985, generating a very substantial increase in the high water level (508 + 6.6 m measured water level, which was approx. 3.5 m higher than predicted) caused no substantial damage to the works under construction. This is not surprising, since the dam has been designed for substantial higher water levels and simultaneous wave attack. Also for the possible higher water levels no serious problems are expected, partly based on the recent experience.

13.2 **Recommendations for Future Works.**

Recommendations for future work can mainly be derived from the findings reported above and are as follows:

a) **Design Considerations.**

The closure of the Feni River has been the biggest of its kind in Bangladesh. The workmethod used has not been employed for previous projects in Bangladesh. Despite its success it cannot be concluded that this method would also be suitable for other closures in Bangladesh, unless the circumstances have a resemblance with the conditions prevailing at the Feni closure site.

b) **Construction Time.**

In order to make the risks of a successful closure not bigger than necessary, enough time should be allowed in future projects for the collection of materials and the execution of preliminary work.

c) **Selection of Contractor.**

A prequalification procedure is highly recommended in future to ensure that only genuinely experienced contractors, with proven understanding of comparable natural circumstances, are submitting bids for the works.
d) Changes during Construction.

Closure works have to be realised under natural conditions which are subject to changes. These changes are not always predictable. Sometimes the period allowed for the collection of data and preparation of the design is too short for a proper evaluation of possible changes. Adjustment of the design to accommodate the changes or to reduce the risks may have to be made at any time during the construction. The approach of the BWDB towards such changes should be flexible (as in the case of the Feni River Closure Dam).

In view of the above the design should be such that necessary changes can easily be adopted, as in the case of the Feni River Closure Dam.