CONSTRUCTION OF TAUNSA BARRAGE
REHABILITATION PROJECT WORKS

S.M.A. Zaidi, M. Akhter Chaudhry & Malik Ahmad Khan
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S.M.A. Zaidi¹, M. Akhter Chaudhry² & Malik Ahmad Khan³

SYNOPSIS

Taunsa Barrage soon after its construction in 1958 ran into multiple problems and some routine and extensive repairs were executed during 1959-62 but problems were not solved. Punjab Government constituted committees of experts in 1966 and 1973 but no specific measures, except construction of some river training works were taken to address the problems that continued to aggravate.

Finally, a feasibility study for rehabilitation of Taunsa Barrage was got prepared, which recommended the rehabilitation of the Barrage and some new works.

Consequently, the World Bank indicated their willingness to finance the Project in April 2004 and the Taunsa Barrage Rehabilitation Project was put on fast track and execution of construction works was implemented from June 2005 to December 2008.

This paper presents a detailed introduction to the construction contracts, details of construction of civil and M & E works, quantities of major items of civil works, problems faced, bottlenecks, and constraints encountered during the construction phase and lessons learnt from the project.

INTRODUCTION

The Taunsa Barrage, built across Indus River, is located at about 16 Km north-west of Kot Addu town in Muzaffargarh District. The canal system fed by the Barrage consists of Muzaffargarh, DG Khan and T.P.Link canals. Total Command Area of the Barrage is 2.35 million acres falling in the districts of Muzaffargarh, Layyah, DG Khan, and Rajanpur. It also feeds Taunsa Panjnad (TP) Link for meeting serious shortages in Punjnad canals.

Taunsa Barrage is more than a conventional Barrage because it not only regulates irrigation water supply but also accommodates important transportation and energy infrastructure such as a trans Indus rail road crossing for direct rail link between areas on the left and right banks of Indus River; an arterial road bridge; an oil pipeline of PARCO, a natural gas pipeline of SNGPL and two EHV transmission lines of WAPDA/PEPCO.

¹ Project Manager, Punjab Barrages Consultants & Associate, National Development Consultants.
² Head PMO for Barrages, Irrigation and Power Department, Punjab.
³ Chief Resident Engineer, Taunsa Barrage Project.
The Barrage soon after its construction in 1958 experienced multitude of problems involving excessive sedimentation in the D. G. Khan canal, damage to friction blocks, excessive retrogression of D/S water levels, choking and malfunctioning of large number of pressure pipes, deterioration of gate facilities, defects in the hoisting mechanism and excessive water leakage from gate structures. Some repairs to the D/S skin concrete and friction blocks were carried out as early as in 1959. More recently, damages were restored in 1986, 1994, 1998, and 2003.

Punjab Government constituted committees of experts in 1966, 1973 and 1999 but no concrete measures, except provision of some river training works and routine maintenance, were taken to rectify the defects. The defects, therefore, multiplied.

**IDENTIFICATION OF PROBLEMS AND PROPOSED REMEDIAL WORKS**

Finally a feasibility study conducted by Punjab Barrages Consultants (PBC), a joint venture of NDC and NESPAK in association with M/s Atkins (Global) of UK, confirmed the need for an immediate rehabilitation of the Barrage to restore its designed functions in July 2004. The feasibility study was also reviewed by an International Independent Panel of Experts (POE) comprising international and national experts. Table-1 lists the problems and proposed solutions in an annotated form.

**Table -1: Problems and Proposed Remedial Works**

<table>
<thead>
<tr>
<th>Sr. #</th>
<th>Problems Associated with the Barrage</th>
<th>Proposed Remedial Works/Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Retrogression of levels on the D/S of Barrage and consequential issues</td>
<td>Construction of a subsidiary weir 925 ft D/S of the Barrage to raise tail water levels to safe values.</td>
</tr>
<tr>
<td>2.</td>
<td>Repeated damages to stilling basin appurtenances including rupture of skin concrete and leaking joints of mass concrete.</td>
<td>Grouting of leaking concrete and cavities in or underneath the D/S floor, removal of existing shattered skin and re-laying of new concrete overlay with nominal reinforcement.</td>
</tr>
<tr>
<td>4.</td>
<td>Repeated subsidence of the backfill of left and right flared out walls on the downstream.</td>
<td>Provision of a proper filter and effective seepage control.</td>
</tr>
<tr>
<td>5.</td>
<td>Choking of about 80% of pressure pipes and malfunctioning of the remaining 20%</td>
<td>Provision of vibrating wire piezometers in 10 bays of the Barrage and 7 rows in the new subsidiary weir.</td>
</tr>
<tr>
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<td>Problems Associated with the Barrage</td>
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</tbody>
</table>

**PROJECT FORMULATION AND FINANCING**

PC-1 Form of the Project was approved by ECNEC on December 07, 2004. In May 2005, the World Bank (IBRD) helped to launch the construction phase of Taunsa Barrage Rehabilitation Project with a loan of Japanese Yen 13.10 billion (US $ 123 million equivalent). Similarly, in April 2005, JICA (Japan International Cooperation Agency) agreed to provide a grant of Japanese Yen 4.98 billion for the Project. The GOPunjab contributed Rs 857.86 million for the Project. Total approved cost of the Project was Rs 11,232.38 million as contained in the revised PC-1 approved by ECNEC on August 26, 2006.

**PACKAGING OF CONSTRUCTION WORKS**

It was agreed between the Government and the World Bank (WB) to procure construction works of the Project through International Competitive Bidding procedure. Civil works were packaged into a single Contract named ICB-01 Contract, while M & E works were divided into two components i.e. the WB financed and JICA funded works. The former was designated as ICB-02 Contract and the latter was divided into 4 Contract Packages (CP), namely CP 1 to 4. A brief description of scope of work of these Contracts is as under:

1. **ICB-01 Contract included:**
   - Construction of a 4,346 ft long subsidiary weir 925 ft D/S of the Barrage
   - Protection works U/S and D/S of the subsidiary weir
   - Provision of two fish ladders and a navigation lock along with gate equipment
   - Grouting of cavities under the D/S floor of the existing Barrage
   - Strengthening of Barrage glacis and stilling basin floor
   - Improvement of drainage behind flared out walls of the Barrage
   - Remodeling of existing fish ladders and navigation bay of the Barrage
• Construction of silt excluder in the right pocket
• Remolding of DG Khan canal head regulator
• Installation of Piezometers in the main Barrage and subsidiary weir.

2. **ICB-02 Contract comprised:**

- Replacement of right undersluice gates in Bays # 62-65
- Rehabilitation and increasing the height of main weir gates in # 31 to 65
- Installation of guide frames for bulkhead gates in Bay # 31 to 65
- Rehabilitation of Muzaffargarh canal gates
- Replacement of TP Link and DG Khan canals gates
- Replacement of existing hoists with electrically driven hoists
- Automation and communication system for operation of all the gates of the Barrage and canals and gauges.
- Supply of workshop, survey and discharge monitoring equipment

3. **JICA Component Contracts CP-1 to CP- 4**

- CP-1 envisaged:
  - Replacement of 7 left undesluice in Bay No. 1-7
  - Rehabilitation and increasing height of 22 gates of the main weir in Bay No. 9 to 30
  - Installation of guide frames for bulkhead gates in Bay # 1 to 30
  - Replacement of hoists and superstructure deck
  - Electrification of gate hoists.
- CP-2, Supply of five bulkhead gates
- CP-3, Procurement of two tug boats and three working boats
- CP-4, Supply of one 50 ton truck crane

5.1 **Details of Construction Contracts**

a) **The WB Financed Contracts**

The procurement for civil works i.e. ICB-01 Contract was initiated in July 2004 with a notice for Invitation for Prequalification in the press and the World Bank’s Business news Bulletin. Eleven applicants, including individual firms and joint ventures (JV), from different countries applied for prequalification. Five applicants qualified for bidding of civil works. The Letters of Invitation (LOI) to purchase Bidding Documents were sent to the pre-qualified bidders. A pre bid conference was held on 17 December 2004. Out of 5 pre-qualified bidders, 4 submitted their Bids. The Bids were opened on 14 January 2005.
JV of M/s Descon Engineering Ltd (DEL) and M/S China Gezhouba Water & Power Group Corporation Ltd (CGGC), was declared as the commercially lowest evaluated bidder. Letter of acceptance (LOA) for ICB Contract-01 was issued to JV of DEL-CGGC by Head PMO for Punjab Barrages (the Employer) on 12 April 2005. Notice to commence the work was issued by the Engineer on 10 May 2005.

The procurement process for M & E works was initiated in April 2005 with publication of a notice for Invitation for Prequalification in the press and the World Bank’s Business news Bulletin. Eleven applicants purchased prequalification documents but only eight firms/JVs from different countries applied for prequalification. Out of eight applicants, six firms/JVs were pre-qualified. The LOI to purchase Bidding Documents for ICB Contract -02 was sent to all pre-qualified firms/JVs. Only 4 firms/JVs purchased the Bidding Documents and submitted their Bids: A pre-bid conference was held on 22 December 2005. The Bids were opened on 09 January 2006.

M/s China National Electric Wire & Cable Imp./Exp. Corporation (CNEWC), China was declared as the commercially lowest evaluated Bidder. LOA was issued to M/s CNEWC, China by Head PMO for Punjab Barrages on 11 August 2006. Notice to commence the work was issued by the Engineer on 29 August 2006.

b) JICA Funded Contracts

JICA managed procurement process of CP-1 to 4 and for these Contracts, the Consultants, the Contractors, Suppliers and almost all the materials were procured from Japan under the grant aid agreement.

5.2 Consultancy Services for Construction Supervision

M/s PBC who had provided services for feasibility study and detailed design of Taunsa Barrage, were selected by Irrigation & Power Department and the World Bank to provide construction supervision services ICB-01 & 02 Contracts, based on FIDIC Form of Contract, financed by the WB. Project Manger-PBC was designated as “the Engineer” for administration of the two Contracts.

A consortium of M/S Sanyu Consultants Inc. and Yachiyo Engineering Co. Ltd, Tokyo, Japan provided consultancy services for part of the Project financed by JICA.

6. CONSTRUCTION PROGRAM

Overall duration of construction phase was fixed as 48 months. Implementation schedule for various construction Contracts was based on this timeline keeping in view sequence and timing of different activities and mandatory schedule constraints such as annual flood season and canal closures. Table -2 gives duration of each of the Contract along with other salient data.
<table>
<thead>
<tr>
<th>Sr. #</th>
<th>Contract</th>
<th>Name of Contractor</th>
<th>Contract Signed</th>
<th>Contract Duration (days)</th>
<th>Contract Price (Rs in Million)</th>
<th>Stipulated Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ICB-01</td>
<td>JV of M/s Descon Engineering Ltd Pakistan, and M/s CGGC, China</td>
<td>27 May 2005</td>
<td>1,092</td>
<td>4,866.34</td>
<td>05 May 2008</td>
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<td>2.</td>
<td>ICB-02</td>
<td>M/s CNEWC, China</td>
<td>09 Oct. 2006</td>
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<td>1,870.56</td>
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<td>3.</td>
<td>CP-1</td>
<td>Consortium of Kurtimoto Ltd and Taisei Corporation, Japan</td>
<td>19 Nov. 2005</td>
<td>1,200</td>
<td>1,987.39</td>
<td>June 2008</td>
</tr>
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<td>4.</td>
<td>CP-2</td>
<td>Marubeni Corporation, Japan</td>
<td>17 Nov. 2005</td>
<td>450</td>
<td>400.26</td>
<td>June 2008</td>
</tr>
<tr>
<td>5.</td>
<td>CP-3</td>
<td>Marubeni Corporation, Japan</td>
<td>02 Dec. 2005</td>
<td>480</td>
<td>74.06</td>
<td>June 2008</td>
</tr>
<tr>
<td>6.</td>
<td>CP-4</td>
<td>Mitsubishi Corporation, Japan</td>
<td>02 Dec. 2005</td>
<td>390</td>
<td>32.01</td>
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**Table -2: Salient Data about Construction Contracts**

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**a) ICB-01 Contract**

Tender schedule for ICB-01 Contract was based on three years duration with rehabilitation of Barrage to be executed in three stages and construction of silt excluder in two stages. But based on the re-assessment of site conditions, the Contractor modified his baseline schedule to execute the under water works in two stages with deployment of more resources and working round the clock. The baseline schedule was prepared by using primavera project planner (P-3) software. This baseline schedule was approved by the Engineer and followed by the Contractor. Progress updates were submitted by Contractor on fortnightly basis and under water works were completed according to approved baseline schedule by July, 2007.
b) ICB-02 Contract

The baseline schedule was prepared by using P-3 software. This baseline schedule was approved by the Engineer and followed by the Contractor. Most of the mechanical works were completed by June 2008 and all the works were executed within the stipulated period by 24 December 2008.

Figures 1&2 depicts construction schedule of ICB-01, ICB-02 Contracts and JICA’s component based actual dates of work accomplishment.
### TAUNSA BARRAGE EMERGENCY REHABILITATION AND MODERNIZATION PROJECT
### IMPLEMENTATION SCHEDULE

<table>
<thead>
<tr>
<th>Project Component</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
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<tbody>
<tr>
<td>1. Civil Works, ICB-01</td>
<td></td>
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<tr>
<td>1.1 Mobilization</td>
<td></td>
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<tr>
<td>1.2 Construction of Sub Weir including Temporary Works¹</td>
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<td>1.3 Strengthening of Existing Barrage including Temporary Works²</td>
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<tr>
<td>1.4 Construction Works inUIS Right Pocket including Temporary Works³</td>
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<tr>
<td>1.5 Contract Completion</td>
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<tr>
<td>2. Mechanical &amp; Electrical (M&amp;E) Works</td>
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<tr>
<td>2.1 WB Funded M&amp;E Works-ICB-02</td>
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<tr>
<td>2.1.1 Mobilization for the Project</td>
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<tr>
<td>2.1.2 Right Undersluice Gates</td>
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<tr>
<td>2.1.3 Existing Weir Gates</td>
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<td>2.1.4 Off Taking Canals Gates</td>
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<tr>
<td>2.1.5 Hoist and Electrical Works</td>
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<tr>
<td>2.1.6 Contract Completion</td>
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<tr>
<td>2.2 JICA Financed M &amp; E Works</td>
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<tr>
<td>2.2.1 Procurement under CP-1.2 &amp; 3</td>
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<tr>
<td>2.2.2 Temporary Works, Including Manu. &amp; Transportation of Gate Facilities</td>
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<tr>
<td>2.2.3 Replacement of Left Undersluice Gates (7 No.)</td>
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<tr>
<td>2.2.4 Rehabilitation of Existing Weir Gates (22 No.)</td>
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<tr>
<td>2.2.5 Electrification of Hoists (29 No. Gates)</td>
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<tr>
<td>2.2.6 Replacement of Deck on Superstructure of the Existing Barrage</td>
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</tbody>
</table>

¹ Extension of SRS Guide Banks, Diversion Channel for Silt Ejector of DOG Canal is included in this Component.
² Includes Rehabilitation of SRS Flared Out Walls and Extension of Fish Ladders.
³ Remodelling of DOG Canal Head Regulator & Construction of Silt Excluder are the Major activities in this Sub-Component.
7. CONSTRUCTION OF CIVIL WORKS

7.1 Mobilization of Contractor

The Contractor started the mobilization at site from 18 May 2005 and construction site for project works was handed over to the Contractor on 28 May 2005. As part of project mobilization, the Contractor constructed his camp comprising site office, staff residences A, B and C Type (6 blocks), two mess halls, recreation hall, mosque, site laboratory, labor dormitories (6 barracks), canteen and toilets, E & P workshops, material storage facilities, and pre-casting yard for manufacturing of PCC blocks. Three concrete batching plants (installed capacity of 160m³/hour) and a crushing plant were also installed by the Contractor for project works. Total covered area of Contractor’s camp facilities was 100,452 Sft and all the camp facilities including furniture and fixtures were handed over to the Employer on completion of the Project.

The Contractor, instead of using unreliable WAPDA power supply, used diesel generators to meet his power generation requirements. This arrangement worked very well for a smooth execution of works with round the clock availability of electricity. For this purpose the Contractor purchased 18 generators and rented another 8 with capacity ranging from 60 to 365 kVA. The total power generated by the array was 4.96 MW at a power factor of 0.8.

7.2 Construction Works

Civil works under the project can be divided into two main categories:

i. Strengthening of the existing Taunsa Barrage.

ii. New works involving construction of a subsidiary weir with centre of crest placed at 925 ft D/S of the Barrage gate line.

• Strengthening of the Existing Barrage

These works included:

a) Rehabilitation/improvement of the D/S glacis of the crest block and the stilling basin.

b) Installation of sill beams in Bays # 31-65 of the Barrage

c) Installation of stand pipe and vibrating wire piezometers

d) Remodeling of existing fish ladders

e) Improvement of drainage behind flared out walls of the Barrage

f) Construction of silt excluder in the U/S right pocket

g) Remodeling of DG Khan Canal Head Regulator, including installation of sill beams in Bays # 01 to 07

h) Relocation of outfall reach of escape channel of DG Khan Canal silt ejectors
• **Construction of Subsidiary Weir and Allied Works**

These works comprised construction of:

a) Main body of subsidiary weir, including installation of stand pipe and vibrating wire piezometers

b) Flared out walls, abutment walls, fish ladders on both right and left sides and navigation lock including gate system

c) Extension of D/S Guide Banks

The above mentioned works were accomplished in two Stages. In Stage-01, works located in right half of the Barrage, while in Stage-02 works within left half of the river prism were completed. During Stage-01 following permanent works were accomplished:

- Strengthening of existing Barrage stilling basin in front of Bay No. 65 to 32
- Installation of sill beams in Bays # 31-65 of the Barrage
- Remodeling of existing right fish ladder
- Construction of Silt excluder in U/S right pocket
- Remodeling of DG Khan Canal Head Regulator, including installation of sill beams in Bays # 01 to 07.
- Relocation of tail reach of outfall channel of DG Khan Canal silt ejectors
- Construction of subsidiary weir from RD 0+000 to 2+173
- Construction of right fish ladder including installation of regulating gate system
- Extension of D/S right guide bank

Stage-02 works, consisted of the following permanent works:

- Strengthening of existing Barrage D/S floor in front of Bay No. 01 to 31
- Remodeling of existing left fish ladder
- Improvement of drainage behind flared out walls of the Barrage
- Construction of subsidiary weir from RD 4+346 to 2+173
- Extension of D/S left guide bank
- Construction of navigation lock and fish ladders including installation of regulating gate system.

Construction details of different components of civil works are introduced in the following sections:

7.3 **Care and Handling of Water**

For execution of civil works, temporary works were required and these were grouped under care and handling of water. Construction of cofferdams, un-watering of cofferdam enclosures, installation & operation of dewatering system to keep the sub surface water levels (SSWL) at required depth i.e. 2ft below the concrete bottom level and any other item of work to keep the construction area clear of water were
included under care and handling of water. Protection of completed works during flood was also part of temporary works. The Contractor was responsible for design, construction and maintenance of these temporary works, which were dismantled after completion of civil works under the Project.

The total length of cofferdams was about 8.99 Km, out of which approximately 4.45 Km was constructed for Stage-01 works and remaining 4.54Km for Stage-02 works. During Stage-01, cofferdams were constructed from Bay No. 65 to 26, while during Stage-02 cofferdams covered Bay No. 1 to 40. Cofferdams comprised a trapezoidal section of silt and clayey material embankment with stone protection and steel sheet piles on water side to reduce seepage into the working area. AU-14 type sheet piles (40 ft long) were driven in cofferdams and were removed on completion of permanent works. About 2,219 sheet piles weighing 2,184 tons were used for this purpose. A typical cross-section of cofferdam for subsidiary weir had a top RL of 433 to 434 and top width of 30ft. The supportive stone pad was generally 12 ft wide on the top with side slope of 1:1.

7.4 Strengthening of the existing Barrage

After construction of cofferdams, un-watering, and lowering of groundwater table in the enclosures, the sequence of activities for strengthening the D/S glacis and stilling basin of the Barrage in a typical Bay were:

a) Removing the overburden i.e. sediment laying on the floor
b) Dismantling of impact and cubical blocks
c) Drilling grout holes and installation of packers
d) Grouting of drilled holes
e) Breaking the top layers of concrete and clearing the debris
f) Drilling holes and fixing of Rawl Bolts (120 to 210 per bay)
g) Installation of Piezometers
h) Placing of drainage pipe system, installation of formwork, dowel bars and water stops
  i) Fixing of reinforcement bars
  j) Concreting and surface finish
  k) Stripping of formwork
  l) Curing of Concrete

An account of the execution process of some of the important activities associated with rehabilitation of the D/S glacis and stilling basin of the Barrage follows:

7.4.1 Drilling and Grouting Works

Removal of wet earth/sediment (1,357,500 Cft) and dismantling of the existing impact blocks on the D/S floor of the Barrage preceded drilling and grouting works. Grouting works included consolidation grouting of the existing concrete floor in all right undersluice Bays, contact/fill grouting or interface
grouting of the voids between mass concrete and foundation material and grouting of PVC drain pipes (perforated and blind) placed under the newly constructed concrete floor from Bays # 01 to 65 to arrest and drain out seepage water and to ensure dry working conditions during concrete placement.

PVC Drain Pipes used under D/S Floor of the Barrage to remove Seepage Water and Laying of Rebar in Progress for Strengthening of the Barrage Stilling Basin.

a) Drilling of Grout Holes

The grout holes were arranged in grid pattern and in rows to achieve coherent grouting zone, with grout holes spacing of 13 to 14 ft. and rows spacing 25 to 28 ft. Owing to limitation of old brick formwork, bore holes were drilled through the old concrete slab (acting as grout cap) from toe of D/S glacis to D/S limit of concrete floor for main weir Bays # 09 to 61 to a depth of 8 ft and for left and right undersluices i.e. Bay # 01 to 07 and 62 to 65, the depth varied from 5 to 9 ft. Each panel for main weir section in general had two grout holes, one for injection and one as vent. For undersluice Bays three holes per panel were drilled, two for grout intake and one as vent.

b) Grouting Materials and Mix Proportions

Fine river sand, clay, hydrated bentonite, OPC, and water were the principal materials used for grouting. The grout compositions were as under:

- The grout composition for consolidation and pipes/trenches fill grouting was cement based. Whereas for grouting of voids/channels in the foundation clay-cement based mix was used. Water cement (W/C) ratio of the mix for consolidation grouting varied from 2:1 to 1.7:1. A W/C ratio 0.6:1 to 0.8:1 was adopted for the grouting mix used for filling of drain pipes/trenches.
- The grout mix for contact grouting generally consisted of 30 to 35 % fine river sand, 50 to 55 % clayey silt/silt (passing 200), 10-15 % OPC, 1% to 1.5% hydrated bentonite, water silt/clay ratio generally ranged from 2:1 to 1.5:1 by volume with viscosity of the mix corresponding to a
MARSH, time 35 to 45 sec. Occasionally fine to medium sand was added as a filler material when large amounts of grout were being injected into extensive voids in order to maintain preserve the foundation alluvium characteristics.

An Independent International Panel of Experts (POE), which inspected construction works of the Project during October 2006, suggested that the composition for contact grouting should be river sand and cement instead of silt. It would provide better foundation material. The composition of grout for consolidation grouting should have W/C ratio of 2:1 by volume. The suggested proportions were tested and the most appropriate composition was used as explained earlier.

c) Grout Injection Process
A grout plant comprising a mixer, agitator, and plunger pump was used for injection of grout mix into the drilled holes. The grouting was performed in single stage with grouted sections being 2 to 6 feet long. The injection rate for fill grouting varied from 30 to 40 liter per minute. The effective pressure for fill grouting was 4 to 5 psi, which is less than 1 psi per vertical ft of concrete thickness. The gross pressure was 8 to 10 psi after countering hydrostatic pressure of groundwater. The injection pressure was measured at the header pipe generally placed near the grout hole. Grouting was continued until refusal was reached or vent flow started.

d) Quantities of Drilling and Grouting
Total length of boreholes (2 inch diameter) drilled for grouting of D/S floor of the Barrage was 72,520 inches and a total of 24,458 Cft grout was injected in these holes. Maximum grout was injected in Bay # 07, which amounted to 1,034 Cft, while Bay # 33 consumed 1,022 Cft of the grout mix and minimum of 13 Cft grout was consumed in Bay # 57. Bar chart in Figure-3 shows quantity of grout injected in D/S floor of each Bay of the Barrage. After grouting and removal of packers, the grout holes were plugged with epoxy concrete.

Figure 3: Quantity of Grout Mix Injected in D/S Floor of the Barrage
7.4.2 Preparation for New Concrete Overlay

Breaking and removal of top layer of the existing reinforced concrete skin and lean concrete beneath in the stilling basin of Bay No. 01 to 65 was done with hydraulically operated and excavator mounted hammers and chisels. Removal/cleaning was done through, excavators, front end loaders and manual labor. In the D/S glacis only the 1 ft thick reinforced skin concrete was dismantled and the lower layers were left as they were, because these were constructed as stepped block construction, breaking of which to the required line and grade could pose structural safety problems.

To ensure proper bond between old and new concrete layers Rawl Bolts were installed both in the D/S glacis and stilling basin of the existing Barrage. In the former 2.5 ft long and in the latter 4.5 ft long bolts were used. These bolts were installed in grids of 8x8ft, 6x6ft and 7x7 ft in different locations as per necessary requirement. Two inch diameter and 2 ft deep holes were drilled in the base concrete, the expanding tip placed at the bottom of the hole, tightened through expansion and the annular space between the bolt stem and hole wall was packed with epoxy concrete. The reinforcement steel bars located close to any Rawl Bolts in both the bottom and top layers were welded to it to enhance bond capacity. A total of 3,362 and 4,968 rawl bolts were installed in the glacis and stilling basin respectively.

The stilling basin and glacis/crest blocks were designed as gravity floors and have thus been provided with temperature steel only, but in consideration of provisions of environmental code # 5 bars at 9 inch c/c were provided both ways and in two layers at top and bottom of the concrete blocks. Total steel reinforcement consumed was 1,627 tons. Steel bars were continuous across the construction joints.

At contraction or expansion joints, since the reinforcement bars are discontinued, tie rods 7.81 ft long and 1.25 inch diameter were provided, with one end (6" L-shaped) anchored into one panel and the other straight one enclosed in a sleeve of 1.75 inch diameter filled with grease to slide freely to allow relative
movement of the concrete blocks in horizontal plane and to counter the vertical differential movement. A total of 3,856 dowel bars and 20,670 running ft PVC water stops were used for D/S floor of the Barrage.

Dismantling of Old Concrete Layer from Stilling Basin and D/S Glacis of the Barrage with Chisels mounted on Excavators.

Installed Rawl Bolts, Formwork and Steel Reinforcement in Typical Bays of the Barrage

7.4.3 Instrumentation for the Main Weir

Instrumentation in the main weir comprised peizometer installation underneath the structure at critical points for measuring the water levels at these locations used for computation of uplift pressures underneath the structure to monitor its physical conditions. Two types of Peizometers i.e. vibrating wire (VW) and stand pipe type peizometers were installed under the main weir. These piezometers were imported from Canada and a brief of each type of the piezometers is as follows:

a) The VW piezometer (8 inch long & 1.5 inch diameter with stainless steel filter ~ 50 microns) has a rigid cylindrical body, enclosing the sensing element. All parts of sensors other than the wire are machined from a high-grade stainless steel. A standard internal thermistor
allows measurement of the temperature. The piezometer is also fitted with a surge protector and resists electrical and radio frequency interference as determined by tests compliant to IEEE and CEI specifications. The transducer is fitted with several protections against water intrusion.

b) The standpipe piezometer (length 6 to 12 inch, 3 inch diameter, plastic filter ~ 50 microns) consists of a porous plastic filter inside perforated rigid PVC body and is used with rigid PVC riser pipe. Water enters the riser until water pressure inside the filter equals the water pressure in the soil. The filter is located in a sand intake zone at the location where the residual pressure is to be monitored. The bentonite pellet or chip seal is placed over the sand intake zone and the remaining borehole is backfilled with non shrink grout.

Under the main Barrage, 10 rows of piezometers with 6 VW and 1 stand pipe in each row were installed in Bays No. 3,14,19,23,27,40,46,51,59 & 64. Total number of VW and stand pipe piezometers installed underneath the main Barrage is 70 and 10 respectively. In each row, one piezometer each have been installed along both faces of three sheet piles lines and one VW and one stand pipe piezometers in almost middle of the stilling basin floor. All Piezometer are 1.5 ft below the concrete bottom in coarse sand at each point. Terminal house containing transmitter is located at pier between Bay # 29 & 30 of the Barrage. All the piezometers have multiplexer cum terminal and switching boxes installed in the recess at D/S of the piers at deck level while recess at pier No. 30 has sense-log-cum-transmitter for manual readings. All the piezometers have connections to terminal room, which ultimately extend to main instrument house.
7.4.4 Grades/Classes of Concrete

The following grades (classes) of cement concrete were used for the project works:

<table>
<thead>
<tr>
<th>Sr #</th>
<th>Grade Class</th>
<th>Comp strength @ 28 days psi</th>
<th>Location of Use</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(a) A</td>
<td>4000</td>
<td>Stilling basin</td>
<td>Course aggregate size 1½” down</td>
</tr>
<tr>
<td></td>
<td>(b) AA</td>
<td>4000</td>
<td>Barrage glacis</td>
<td>Course aggregate size 1” down</td>
</tr>
<tr>
<td>2</td>
<td>(a) B</td>
<td>3000</td>
<td>All works</td>
<td>Course aggregate size 1½” down</td>
</tr>
<tr>
<td></td>
<td>(b) BB</td>
<td>3000</td>
<td>All works</td>
<td>Course aggregate size 1” down</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>2500</td>
<td>Rarely used</td>
<td>Course aggregate size 1½” down rarely used</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>2000</td>
<td>Blinding Layer</td>
<td>1½” down</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>1500</td>
<td>Crest block/fill concrete</td>
<td>1½” down</td>
</tr>
</tbody>
</table>

7.4.5 Concreting of D/S Floor of the Barrage

Specially designed and manufactured forms of steel sheets were used for concreting. The compressive strength of concrete was 4,000 psi and its mix design was prepared in accordance with the provisions of ACI code 211.1-91. Table -3 shows mix proportions and compressive strength of various classes of concrete used in the Project works.

Salient Data about Concrete Mix Design
Mix Proportions by Weight for Different Classes of Concrete / m³

<table>
<thead>
<tr>
<th>Agg. Size</th>
<th>% Used</th>
<th>Class A (4000 psi)</th>
<th>Class AA (4000 psi)</th>
<th>Class B (3000 psi)</th>
<th>Class BB (3000 psi)</th>
<th>Class C (2500 psi)</th>
<th>Class D (2000 psi)</th>
<th>Class E (1500 psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Wt. of CA</td>
<td>1204.85</td>
<td>1090.88</td>
<td>1204.85</td>
<td>1090.88</td>
<td>1204.85</td>
<td>1204.85</td>
<td>1204.85</td>
<td>1204.85</td>
</tr>
<tr>
<td>1½”</td>
<td>45%</td>
<td>542.2</td>
<td>-</td>
<td>542.2</td>
<td>-</td>
<td>542.2</td>
<td>542.2</td>
<td>542.2</td>
</tr>
<tr>
<td>¾”</td>
<td>35%</td>
<td>421.7</td>
<td>654.5</td>
<td>421.7</td>
<td>654.5</td>
<td>421.7</td>
<td>421.7</td>
<td>421.7</td>
</tr>
<tr>
<td>⅜”</td>
<td>20%</td>
<td>241.0</td>
<td>436.4</td>
<td>241.0</td>
<td>436.4</td>
<td>241.0</td>
<td>241.0</td>
<td>241.0</td>
</tr>
<tr>
<td>Sand (Kg)</td>
<td>672.7</td>
<td>725.1</td>
<td>741.3</td>
<td>792.6</td>
<td>843.2</td>
<td>847.0</td>
<td>903.7</td>
<td></td>
</tr>
</tbody>
</table>
The concrete was laid in panels in one go and full thicknesses. The machinery used as usual comprised, batching plants and support machinery, like transit mixers, super swingers, mobile and static concrete pumps and other related equipment like vibrators etc.

A total of 1,119,635 Cft of Class-A concrete was placed in the D/S floor of the Barrage. Quality control measures as stipulated in technical specifications of the project were exercised at site by the Consultants staff. Forms were stripped after 24 hours of placement of concrete. Surface finishes of the concrete were checked to ascertain the surface irregularities to be within prescribed limits.

To prevent any significant loss of necessary moisture due to evaporation during the early period of freshly laid concrete, moist curing and liquid curing membrane process was used to keep the exposed concrete surface continuously moist. In case of moist curing, jute bags were removed after 24 hours and concrete surface was kept moist by covering it with wet sand for 14 days. Liquid curing membrane (curing compound) was also used for Barrage strengthening works in the left half.
7.4.6 Navigation Lock
Bay # 8 of the Barrage with a width of 22 ft serves as a navigation lock for water transport like boats, timber etc. To cater for prescribed pond level, the crest level of the navigation lock was raised by 1 ft and new sill beams were installed. Also the glacis and D/S chamber of the navigation lock was raised by 1 ft.

7.4.7 Installation of Sill Beams in Bay No. 65 to 31
Sill beams in the existing crest of the Barrage were corroded and had outlived their useful life. A total of 35 sets of sill beams were installed and these comprised steel I – sections 250X125X10/19 mm and 64 ft long. Sill beams were fixed using joint bars to prevent tilting in the stream flow direction. The new parts were secured through second stage concrete.
7.4.8 Remodeling of existing Fish Ladders

The fish ladders on both left and right side of Taunsa Barrage were extended by 110 ft. The end entry duct for fish tested remain higher than D/S water level for most part of the year due to retrogression of D/S water levels. Both the fish ladders were extended with addition of chambers and placing the lower most entry duct at RL 417 to provide attraction for fish to move up the fish way. Construction activities related to extension of fish ladders are:

a) Excavation for foundation
b) Dismantling of concrete at the interface of old and new concrete
c) Installation of sheet piles with bottom at RL 391.50
d) Base concrete for extended floor
e) Sand filling under floor
f) Laying of filter and PCC block
g) Fixing of rawl bolts in baffle walls
h) Installation of Formwork and fixing of steel reinforcement
i) Concreting of baffle walls
j) Concreting of vertical wall of fish ladder

Quantities for major items of work were as follows:

<table>
<thead>
<tr>
<th>Sr. #</th>
<th>Item</th>
<th>Quantity</th>
<th>Sr. #</th>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dismantling of Concrete</td>
<td>10,207 Cft</td>
<td>4.</td>
<td>Sand filling under floor</td>
<td>21,276 Cft</td>
</tr>
<tr>
<td>2.</td>
<td>Sheet Piles</td>
<td>4,654 Sft</td>
<td>5.</td>
<td>Class-B Concrete</td>
<td>64,667 Cft</td>
</tr>
<tr>
<td>3.</td>
<td>Drilling &amp; grouting 2 inch Φ holes</td>
<td>4,356 Inch</td>
<td>6.</td>
<td>Steel Reinforcement</td>
<td>88,250 Kg</td>
</tr>
</tbody>
</table>

Concreting in Progress for Right Fish Ladder
Placement of PCC Blocks for Right Fish Ladder
7.4.9 Improvement of Drainage behind Flared out Walls

In line with the advice by POE-2 (October 2006), the whole area behind both the flared out walls was paved with 3000 psi concrete sloping away from the flared out wall to a drain near the regulation office plots which conveyed the drainage water to the river through an impervious section drain. This solution was implemented and has performed well. This system can be relied upon for required performance of stopping settlements of backfill behind the flared out walls.

7.4.10 Construction of Silt Excluder for DG Khan Canal

One of the major problems necessitating the project was the excessive silt entry into the D.G. Khan Canal and resultant silting of the canal limiting its discharge capacity to unacceptably low figures. For reduction of silt entry it was decided to construct a tunnel type silt excluder in the right pocket covering two full bays 65-64 and provisions of short stub tunnels in the 3rd (63) to facilitate further extension if needed. The sequence of activities for construction of silt excluder was as follows:

a) Removing the overburden i.e. sediment lying on the floor
b) Lay out of Barrels of tunnels
c) Installation of sheet piles
d) Dismantling of existing PCC blocks
e) Laying of filter and PCC blocks (4X4X2.75 ft)
f) Placement of stone apron for extended portion of the impervious floor
g) Blinding layer concrete
h) Drilling and grouting holes and fixing of dowel bars and reinforcement bars
i) Installing formwork for walls of barrels
j) Placing of reinforcement bars
k) Concreting of barrels walls 
l) Stripping of formwork
m) Installing formwork for roofs of barrels
n) Fixing of reinforcement bars
o) Concreting of barrels roofs
p) Stripping of formwork
q) Installation of mild steel channels for stop logs

The construction of excluder tunnels required anchoring of tunnel walls to the concrete floor. This was achieved through drilling 18” deep 2”Φ holes with spacing of the wall reinforcement bars, inserting the wall reinforcement bars (vertical) into these holes, and packing the annular space between hole and the bars with epoxy concrete. The wall reinforcement was then completed, form works installed and the walls concreted.

The formwork for tunnel roof slabs was then erected, reinforcement placed and roof slab concreted. This roof slab was provided with 3”Φ holes in a regular grid to eliminate the chances of formation of negative pressures in the tunnels and resultant risks. These pressure balancing holes were provided in excluder tunnel roof slab for the first time as an innovation. This innovative step proved its worth in the very first flow season.

Also extension of impervious protection/floor was necessitated to allow the construction of excluder tunnels in front of Bay # 65 and part of 64. One line of sheet piles, 10 ft deep with bottom at RL 407.50 was installed underneath the extended portion of floor for construction of silt excluder to provide cutoff for this new structure. PCC blocks were laid beyond extended portion of impervious floor followed by hand packed stone apron. Quantities of major items of work utilized for construction of silt excluder are given in the following Table.

<table>
<thead>
<tr>
<th>Sr. #</th>
<th>Items of Work</th>
<th>Quantity</th>
<th>Sr. #</th>
<th>Item of Work</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Removal of wet earth from the floor</td>
<td>575,790 Cft</td>
<td>5.</td>
<td>Drilling and grouting 2 inch Φ and 18 inch deep holes in floor</td>
<td>103,122 Inch</td>
</tr>
<tr>
<td>2.</td>
<td>Dismantling of Concrete</td>
<td>15,290 Cft</td>
<td>6.</td>
<td>Class - A Concrete</td>
<td>82,990 Cft</td>
</tr>
<tr>
<td>3.</td>
<td>Sheet Piles</td>
<td>1,870 Sft</td>
<td>7.</td>
<td>Steel Reinforcement</td>
<td>352,432 Kg</td>
</tr>
<tr>
<td>4.</td>
<td>Class - B Concrete</td>
<td>6,380 Cft</td>
<td>8.</td>
<td>Stone Apron</td>
<td>1,036 Cft</td>
</tr>
</tbody>
</table>
7.4.11 Remodeling of DG Khan Canal Head Regulator

In addition to provision of silt excluder in the right pocket, the crest of D.G. Khan Canal was also raised by 1 ft, from RL 433 to 434. This intervention necessitated replacement of existing sill beams in the crest of DG Khan Canal besides other construction activities. Breast wall of head regulator was also raised by 1 ft to correspond to the pond level of RL 447 approved by the competent authority in August 1992. Construction steps were:

a) Roughening of the crest and glacis surfaces of the head regulator with pneumatic hand chisels.

b) Installation of 2.5 ft long Rawl bolts in a grid and embedded in 2 inch Φ and 1.75 ft deep holes drilled with pneumatic drills to ensure bond between old and new concrete.

c) Removal of old sill beams and installation of new ones.

d) Fixing of steel reinforcement and placement of 1 ft. thick Class-A concrete to raise the crest and glacis profile.

Major quantities of items of work used for remodeling of this structure were:

<table>
<thead>
<tr>
<th>Sr. #</th>
<th>Item</th>
<th>Quantity</th>
<th>Sr. #</th>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dismantling of Concrete</td>
<td></td>
<td>3</td>
<td>Steel Reinforcement</td>
<td>28 Ton</td>
</tr>
<tr>
<td>2</td>
<td>Class - A Concrete</td>
<td>9,815 Cft</td>
<td>4</td>
<td>Rawl Bolts</td>
<td>388 No.</td>
</tr>
</tbody>
</table>
7.4.12 Remodeling of Outfall Channel of DG Khan Canal Silt Ejectors

The outfall channel also called diversion channel for the two silt ejectors located at RD 7,500 & 20,800 joined the river at the end of the D/S right guide bank of the Barrage. It was realigned due to construction of subsidiary weir and its right guide bank. The work included 668,160 Cft of earthwork in excavation.

7.5 Subsidiary Weir and Allied Components

A 4,346 ft subsidiary weir (sub weir) was constructed at 925 ft D/S of the Barrage gate line with a crest RL of 424 to raise the tail water level of the Barrage for providing adequate depth in the stilling basin to ensure formation of hydraulic jump at the proper location and satisfactory energy dissipation. The sub weir has a gravity structure and is a sharp crested/glacis type weir.

As already described construction of the weir was undertaken in two stages, namely Stage-01 and Stage-02. Construction periods for the two stages were:

- Stage-01, Right half of the sub weir (RD 0+000 to 2+173) during the first year of the Project i.e. from October 2005 to July 2006.
- Stage-02, Left half of the sub weir (RD 4+346 to 2+172) during the second year i.e. from October 2006 to June 2007.

Construction of sub weir necessitated an accurate layout. A survey grid for horizontal and vertical controls was established. The reference line for horizontal control was the gate line of main weir of the existing Barrage and for vertical control the crest RL of Bay No. 65 in right undersluices, (425 ft amsl).

7.5.1 Care and Handling of Water

Before starting permanent works of the sub weir, it was mandatory to put in place temporary works comprising construction of cofferdams, installation and operation of well system to take out the water and maintain dry working conditions. Temporary works involved construction of cofferdams along with dewatering system. The sub soil water table was lowered by a maximum of 33 ft (RL 430–397).
7.5.2 Construction of Subsidiary Weir

Construction activities sequence for main body of the sub weir was:

a) Earthwork excavation
b) Sheet piling
c) Installation of piezometers
d) Lean concrete
e) Formwork installation and steel fixing
f) Placement of Class-A concrete
g) Stripping of formwork, finishing & curing
h) PCC block and stone apron
i) Plugging of dewatering wells
j) Removal of cofferdams

A brief description of the above activities follows:

a) Earthwork Excavation

Excavation for main body of the sub weir was carried out in two stages i.e. bulk excavation within 1 ft of final excavation line and removal of last 1ft to designed sub grade levels before laying of blinding layer concrete and after installation of sheet piles. Backhoe excavators, front end loaders and dumpers were used for excavation. At designed sub grade levels, earth surface was compacted to achieve 90% maximum modified AASHTO dry density. A total of 17,385,950 Cft of river bed material was excavated for main body of the sub weir from RD 0 + 000 to 3 + 596. The remaining 750 ft (RD 4+346-3+596) reach of the sub weir located opposite Bay No. 1 to 12 required filling.

b) Sheet Piling

The basic purpose for providing sheet plies in a hydraulic control structure founded on incoherent alluvium is to achieve effective boxing for the structure. The sub weir was provided with four sheet piles lines across the flow and two lines on the sides along the flow (below abutment and flared out walls as the main sheet pile grid). Sheet piles were also provided under the divide walls and one line along the flow direction in the middle of the sub weir at RD 2,173. The wall area of sheet piles installed was 414,621 Sft. AU20 type steel sheet piles manufactured by M/S ACRELOR RPS Luxembourg were used for all project permanent works. For driving of sheet piles 2 vibratory hammers/vibro pilers (4 ton each) were deployed at site and a special sealant was used to seal sheet piles interlocks.
c) Installation of Piezometers

Piezometers were installed below the sub weir structure in a way similar to process adopted for the main Barrage. Installation under the sub weir was much simpler as the structure was a new construction. The VW peizometers units were placed in proper locations before laying the concrete. The cables from all peizometer units in a row were encased in pipes and taken to a chase in the crest and through it to the abutment in piezometer cabin. As the weir was constructed in two halves, the cables in each half were all taken to the relevant abutment piezometers cabin where the arrangements for local observation or transmission to main control room were provided. The piezometers were placed in 7 rows, each containing 7 VW peizometers and with row 1 & 7 have one stand pipe type piezometer.
A VW Piezometer before Installation

Installation of VW Piezometer in Progress

d) Lean Concrete

A 3 inch thick layer of lean concrete (class D – 2000 psi) was laid on the compacted sub grade before laying the main structural concrete to serve as a membrane between concrete and sub grade alluvium to avoid mixing of structural concrete with the sub grade alluvium. Total quantity of this concrete was 235,419 Cft. Blinding layer was finished with wooden floats to keep the surface slightly rough to improve bond with the high strength structural concrete overlay.

e) Placement Plan/Layout of Structural Concrete Panels

For construction of the impervious portion of the weir, the area was sub divided into six panels. The U/S impervious protection also termed as floor was designated as panel A. The crest block, a combination of U/S glacis, top and straight portion of crest block and D/S glacis named as panel B, the D/S toe area of the D/S glacis which has the maximum thickness of 10.50 ft labeled as panel C, (also having maximum pour volume of 12,853 Cft), followed by the stilling basin comprising panels D, E & F also referred to as D/S floor. Panels’ arrangement for sub weir is depicted in Figure-4.

f) Formwork Installation and Fixing of Steel

Specially designed and manufactured forms of steel sheets supported by pipe scaffolding were used for ensuring thickness, line and grade of the concrete in the whole sub weir. The floors designed as gravity floors were provided with temperature steel as # 5 bars at 9 inches c/c both ways in two layers near top and bottom of the concrete panels. Steel reinforcement used for construction of sub weir weighed as much as 3,270 tons.

Steel bars are continuous across the construction joints. At contraction or expansion joints, the re-bars were discontinued, and tie rods 7.81 ft long and 1.25 inch diameter were provided, enclosed in a sleeve of 1.75 inch diameter filled with grease to allow the rod slide freely in the sleeve to counter relative movement of the concrete blocks in horizontal plane. These bars were provided at 9 inch c/c. One end of the tie rod was anchored in concrete through a 6 inch L-shaped bend. 18,292 dowel bars were used for contraction or expansion joints with 92,726 ft of PVC water stop.
NOTE:
For compounding purposes subsidiary section was divided into panel A, B, C, D, E & F.
g) Structural Concrete Placement
The concrete placement was done in one single layer for all depths of concrete in the floors and crest blocks to eliminate stratification. The concrete in the main body of sub weir was placed in 858 panels. Class-A concrete was used in floor and top layer of crest block. The concrete placement machinery as usual comprised batching plants and support machinery like transit mixers, super swingers, concrete pumps and other related equipments. Total quantity of concrete used for construction of sub weir was 5,914,271 Cft.

Placement of Class-A Concrete in Progress for Sub Weir with Concrete Pumps

A View of the Completed Portion of Sub Weir

Sub Weir in Operation

h) Surface Finishing
Surface finishing of concrete was done with steel floats according to specification prescribed for various locations.
i) Stripping of Formwork and Curing

Vertical forms were stripped 24 hours after concrete placement. Surface finishes of the concrete were checked to limit the surface irregularities to prescribed limits. To prevent significant loss of necessary moisture due to evaporation during the early period of freshly laid concrete, moist curing and liquid curing membrane process were used.

j) PCC Block and Stone Aprons

The PCC Block apron constituting 4 x 4 x 4 ft concrete blocks laid over graded filter was provided on both sides of the impervious portion of the sub weir. Class B concrete (3000 psi) was used for manufacturing these blocks. A pre-casting yard was established by the Contractor for this purpose. The U/S apron is laid over 1 ft deep inverted filter and is 28 ft wide. A 7.5 ft deep and 2 ft wide concrete curtain wall separates the block and stone apron.

The D/S block apron is laid on 4 layered 2 ft deep filter and it covers a width of 53.66 ft. This apron has been divided into two portions each 28.83 ft wide and separated by a 7 ft x 4 ft concrete curtain wall. The first portion serves as an inverted filter and a safe pressure release area at the end of stilling basin, while the setting block area serves as a settlement indicator and provides an additional safety barrier for filter blocks.

The D/S block apron like the U/S apron is separated from stone apron by a 8ftx2ft curtain wall. Total quantity of Class-B concrete consumed in PCC blocks was 1,532,924Cft. Total quantity of stone apron laid for the sub weir is 3,804,087Cft and 552,128Cft of graded filter laid underneath the Block apron.

**Placement of D/S Block Apron**  **Placement of D/S Stone Apron**

k) Plugging of Dewatering Wells

After completion of the concrete works in the bed, the dewatering wells were plugged properly with special concrete and sawn-off flush with the structural concrete surface.

l) Removal of Cofferdams

On completion of the enclosed works, the coffer dams were removed and the earthwork disposed off properly.
7.5.3 Construction of Allied Works

Fish ladders, flared out walls, navigation lock, gauge wells and water level sensors were also provided in the sub weir.

a) Fish Ladders

Two fish ladders were provided in the sub weir, one each on right and left sides. The design is similar to those already existing in the main Barrage. However, the chamber to chamber drop has been reduced to 9 inches and flow velocity in the chamber has been reduced to 6-7 feet per second to provide easier and improved conditions for fish migration.

b) Flared out Walls

The flared out walls, which provide a transition from vertical abutments to guide banks, are reinforced concrete counter fort type walls.

c) Navigation Lock

A navigation lock was provided in the sub weir at the left flank. The width is the same (22 ft) as that of the main Barrage. Initially, the design envisaged operation of navigation lock only at the time of conveying the river vessels, but on the advice of Panel of Experts the design was improved. Crest level was raised from RL 418 to RL 420 so that the navigation lock keeps discharging throughout the year to ensure that no silt deposits accumulate on the downstream and effect operation of fish ladder. The difference between the existing and new navigation lock is type of gates. The barrage lock has vertical stony type gates whereas the sub weir lock has radial gates.

Class B concrete has been used for all of the above structures. Quantities of various items of work for these structures are given in the following table.

<table>
<thead>
<tr>
<th>Sr. #</th>
<th>Item</th>
<th>Quantity</th>
<th>Sr. #</th>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earthwork Excavation</td>
<td>903,930 Cft</td>
<td>3</td>
<td>Steel Reinforcement</td>
<td>1,258 Tons</td>
</tr>
<tr>
<td>2</td>
<td>Class - D Concrete</td>
<td>13,778 Cft</td>
<td>4</td>
<td>Class - B Concrete</td>
<td>750,622 Cft</td>
</tr>
</tbody>
</table>

d) Gauge Wells and Water Level Sensors

For observation of water levels on the D/S of sub weir, two gauge wells, one each on left and right side were constructed at a distance of 14 ft from the end point of D/S flared out wall.

In addition four VW piezometer type water level sensors (WLS) imported from Canada were installed as an innovation to establish their adequacy as replacement of heavy gauge wells for future projects. Two of these WLS are located
at U/S flanks of sub weir and two close to the newly constructed gauge wells on D/S side of the sub weir.
7.5.4 Extension of D/S Right and Left Guide Banks

The sub weir has been provided with usual length (1,000 ft) guide banks on the D/S. Total quantity of earthwork filling for right and left guide bank is 2,793,969 Cft and 5,163,750 Cft respectively. Required protection involving stone apron (1,204,180 Cft) and stone pitching (364,821 Cft) was also provided on the guide banks.

7.5.5 Major Quantities, Cost and Quality Control Tests

Quantities of Major Items of Civil Works

<table>
<thead>
<tr>
<th>Sr. #</th>
<th>Items of Work</th>
<th>Unit</th>
<th>Quantity Executed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earthwork Excavation</td>
<td>Cft</td>
<td>49,602,536</td>
</tr>
<tr>
<td>2</td>
<td>Embankment</td>
<td>Cft</td>
<td>8,555,909</td>
</tr>
<tr>
<td>3</td>
<td>Dismantling of Existing Stone Pitching</td>
<td>Cft</td>
<td>211,562</td>
</tr>
<tr>
<td>4</td>
<td>Steel Sheet Piles (Wall Area)</td>
<td>Sft</td>
<td>421,129</td>
</tr>
<tr>
<td>5</td>
<td>Class - A Concrete</td>
<td>Cft</td>
<td>7,135,132</td>
</tr>
<tr>
<td>6</td>
<td>Class - B Concrete</td>
<td>Cft</td>
<td>2,414,384</td>
</tr>
<tr>
<td>7</td>
<td>Class - D Concrete</td>
<td>Cft</td>
<td>250,533</td>
</tr>
<tr>
<td>8</td>
<td>Class - E Concrete</td>
<td>Cft</td>
<td>547,103</td>
</tr>
<tr>
<td>9</td>
<td>Steel Reinforcement</td>
<td>Ton</td>
<td>6,623</td>
</tr>
<tr>
<td>10</td>
<td>Dismantling of Concrete</td>
<td>Cft</td>
<td>835,772</td>
</tr>
<tr>
<td>11</td>
<td>Drilling and Grouting</td>
<td>Inch.</td>
<td>179,998</td>
</tr>
<tr>
<td>12</td>
<td>Grouting Cavities under Floor</td>
<td>Cft</td>
<td>24,458</td>
</tr>
<tr>
<td>13</td>
<td>Vibrating Wire Piezometers</td>
<td>No.</td>
<td>123</td>
</tr>
<tr>
<td>14</td>
<td>Stand Pipe Piezometers</td>
<td>No.</td>
<td>11</td>
</tr>
<tr>
<td>15</td>
<td>Stone Apron &amp; Stone Pitching</td>
<td>Cft</td>
<td>5,358,812</td>
</tr>
<tr>
<td>16</td>
<td>Filter Material</td>
<td>Cft</td>
<td>584,715</td>
</tr>
<tr>
<td>17</td>
<td>PVC Water Stop- Type A</td>
<td>Lft</td>
<td>105,838</td>
</tr>
<tr>
<td>18</td>
<td>PVC Water Stop- Type B</td>
<td>Lft</td>
<td>20,759</td>
</tr>
<tr>
<td>19</td>
<td>Rawl Bolts</td>
<td>No.</td>
<td>8,374</td>
</tr>
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</table>
## Final Cost of BOQ Bills/Sub Components

<table>
<thead>
<tr>
<th>Bill No.</th>
<th>BOQ Bill Description</th>
<th>Cost (Rs million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Items, including Care &amp; Handling of Water</td>
<td>1,133.76</td>
</tr>
<tr>
<td>2</td>
<td>Sub Weir, including allied components</td>
<td>2,892.53</td>
</tr>
<tr>
<td>3</td>
<td>Guide Banks</td>
<td>130.45</td>
</tr>
<tr>
<td>4</td>
<td>Strengthening of the existing Barrage</td>
<td>576.89</td>
</tr>
<tr>
<td>5</td>
<td>Silt Excluder in U/S Right Pocket</td>
<td>53.74</td>
</tr>
<tr>
<td>6</td>
<td>Excavation of Diversion Channel</td>
<td>2.60</td>
</tr>
<tr>
<td>7</td>
<td>Remodeling of DG Khan Canal Head Regulator</td>
<td>5.79</td>
</tr>
<tr>
<td>8</td>
<td>Remodeling of the existing Fish Ladders</td>
<td>30.62</td>
</tr>
<tr>
<td>9</td>
<td>Gate Equipment for Sub Weir</td>
<td>39.96</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>4,866.34</strong></td>
</tr>
</tbody>
</table>

Tabulated below is an abstract of tests conducted on various construction materials used on project works.

### Summary of Tests Conducted on Construction Materials

<table>
<thead>
<tr>
<th>Sr. #</th>
<th>Name of Test</th>
<th>No. of Tests</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Required</td>
<td>Conducted</td>
</tr>
<tr>
<td>1</td>
<td>Gradation of Coarse Aggregate</td>
<td>1,012</td>
<td>1,186</td>
</tr>
<tr>
<td>2</td>
<td>Gradation of Fine Aggregate</td>
<td>518</td>
<td>587</td>
</tr>
<tr>
<td>3</td>
<td>Unit Weight of Coarse Aggregate</td>
<td>516</td>
<td>680</td>
</tr>
<tr>
<td>4</td>
<td>Unit Weight of Fine Aggregate</td>
<td>324</td>
<td>449</td>
</tr>
<tr>
<td>5</td>
<td>Sp. Gravity of Coarse Aggregate</td>
<td>494</td>
<td>537</td>
</tr>
<tr>
<td>6</td>
<td>Sp. Gravity of Fine Aggregate</td>
<td>278</td>
<td>329</td>
</tr>
<tr>
<td>7</td>
<td>Sand Equivalent</td>
<td>329</td>
<td>370</td>
</tr>
<tr>
<td>8</td>
<td>Los Angles Abrasion</td>
<td>292</td>
<td>410</td>
</tr>
<tr>
<td>9</td>
<td>Absorption of Coarse Aggregate</td>
<td>494</td>
<td>537</td>
</tr>
<tr>
<td>10</td>
<td>Absorption of Fine Aggregate</td>
<td>278</td>
<td>329</td>
</tr>
<tr>
<td>11</td>
<td>Brick Testing</td>
<td>-</td>
<td>214</td>
</tr>
<tr>
<td>12</td>
<td>Cylinder Testing</td>
<td>31,050</td>
<td>31,593</td>
</tr>
<tr>
<td>13</td>
<td>Cylinder Casting</td>
<td>31,800</td>
<td>32,256</td>
</tr>
<tr>
<td>14</td>
<td>Soundness of Coarse Aggregate</td>
<td>85</td>
<td>63</td>
</tr>
<tr>
<td>15</td>
<td>Soundness of Fine Aggregate</td>
<td>66</td>
<td>69</td>
</tr>
</tbody>
</table>
8. CONSTRUCTION OF M & E WORKS

As already described earlier, M & E works were divided into two components financed by World Bank through a loan and the other by JICA through a grant in aid. Brief details of these works follow.

8.1 Care and handling of Water

Like civil works, M & E works under ICB-02 Contract were accomplished in two stages/working seasons. Care and handling of water included construction of cofferdams, un-watering of cofferdam enclosures to keep the construction area clear of water. For Stage-01, cofferdams were constructed from Bay No. 65 to 59, while during Stage-02 cofferdams covered Bay No. 35 to 53. Cofferdams had a trapezoidal section of clayey material embankment with stone protection. A typical cross-section of cofferdam had a top width of 30ft with a 12ft wide supportive stone pad.

For gates rehabilitation under JICA component, bulkhead gates (BHG) were used as temporary cofferdam instead of traditional cofferdams of earth and stone. This decision was made by JICA keeping in view the limited construction period through repetitive use. A typical BHG had a clear span of 60ft and height of 25ft. Rubber sealing was for water tightness. Weight of 1 BHG is about 133 tons. Each BHG is divisible by three both vertically and horizontally so that it can be divided in to nine blocks to allow its use for other Barrages and these blocks are joined with bolts. The BHG is basically a pontoon maneuvered through tug boats and hydraulic fill control.
8.2 ICB-02 Contract Works

M&E works under this Contract were executed in two Sages. In Stage-01, replacement of right undersluice gates and rehabilitation of weir gates in bays # 31 to 37 and 60 to 61 were completed, while in Stage-02 rehabilitation of gate No. 38 to 59, rehabilitation of canal head regulator gates and gate automation system was installed.

8.2.1 Replacement of Right undersluice Gates

The existing four truss type double leaf roller gates (61.67ft wide & 22ft high) in the undersluice bays were replaced with new single leaf plate girder stoney roller gates (61.67ft wide & 23ft high). Besides the replacement of existing gate leaves the allied components such as roller guard, roller trains, rocker assembly, side seal plates and rubber seals were also replaced.

8.2.2 Rehabilitation of Main Weir Gates

Thirty one (31) main weir gates (31-61) and navigation bay gate (# 08) were included in this Contract and involved rehabilitation of gate leafs, including increasing height by 1 ft, replacement of end beams, roller trains, rocker assembly, roller guard, and side sealing plate and replacement of old hoists with electrically driven ones.

The existing gates were 61.67ft wide and 19 ft high. Rehabilitation was carried out by raising height of gate from 19 to 20 ft. A heightening member consisting of a skin plate, sub vertical girder, beam and diagonal member were welded at the bottom of gate after removal of the existing skin plate.

8.2.3 Replacement and Electrification of Hoists

Hoist is a device used to move (open and close) a gate, including all related equipment necessary for safe operation of a gate. The old manual hoist machines were removed and replaced with new electrically driven hoists and these were installed on top of the Barrage superstructure deck. This modification facilitates better maintenance and operation of gates.

8.2.4 Installation of Guide Frames for Bulkhead Gates

For utilization of BHG, procured under JICA component, for operation and maintenance of the Barrage after completion of the Project, guide frames for BHG were installed on U/S noses of piers of bay 31 to 62 and necessary tests carried out, by installing BHG on these guide frames.

8.2.5 Rehabilitation of Canal Head Regulator Gates

Nineteen (19) gates of three off-taking Canals were included in this sub component. Rehabilitation work included replacement of 7 gates each of TP link and DG Khan Canals and rehabilitation of 5 gates of Muzaffargarh Canal along with replacement of old hoists with electrically driven new ones along with LCPs.
New Gate of for Right Undersluice

Main Weir Gate after Raising at the Bottom

Newly Installed Steel Grating on Deck of Superstructure

Installation of New Hoists for Barrage Gates in Progress

Installation of Guide Frames for BHGs

LC P for TP Link Gates Hoists
8.2.6 Automation of Barrage and Canal Gates

The operation of Barrage and canal gates up till 2006 was purely on manual system. This has been converted into electrically operated automatic system. The lifting motors can be operated from the site panels as well as from the central control room. The gauges and discharge data is acquired through automatic sensors and operation control system to the data storage.

8.2.7 Power Supply for the Barrage

The whole of regulation and automatic operational system uses power supply from two feeders of MEPCO/WAPDA grid, one at the left side and the other on the right side of the Barrage, depending on availability of electricity. To cover the operation requirement in case both the WAPDA feeders are shut down, two generators have been provided, one on the left and another on the right flank. The system thus has four fold operational facility as under:

a) Grid from left
b) If the feeder on left trips, the right side feeder is available
c) If both the grids go out of action, the generator on the left side comes in operation
d) If the left side generator also defaults, the right side generator takes over

The above power supply system is controlled through an automatic change over system.

8.2.8 Lighting System for the Barrage

The old lighting system of the barrage had deteriorated beyond service ability and has been renovated.

8.2.9 Supply of Workshop and other Equipment

The equipment in the existing workshop at Taunsa Barrage had become obsolete and virtually unservicable. To augment and strengthen the existing operation and maintenance (O & M) arrangements for the Barrage, workshop equipment along with survey equipment was procured.

8.2.10 Central Control Room and Data Acquisition System

A Central Control Room has been established on the left flank of the Barrage close to the model building. This structure houses:

a) Main operational control system/devices
b) Data display system
c) The main remote control system
d) Computers workstations
e) Data transmission system
f) System hardware and software  
g) Battery room with change-over system  
h) Required furniture and fixtures  
i) A toilet etc.

Remote operational control system provides for remote operation/raising and lowering of Barrage and Canal gates totaling to 85 (66 Barrage gates, 19 canal head regulator gates and the navigation lock gates). In addition to raising and lowering of gates, the system also monitors the position of each gate.

The data acquisition module through remote monitoring system records the gate opening, water levels and discharge data automatically and preserves in the storage module, for retrieval or transmission as required. The storage module through data transmission module keeps the stored data available to the receiving nodes at PMO Lahore and office of the Chief Engineer D. G. Khan Zone. The receiving node operator has the access to the storage module at the central control room for browsing or retrieving/downloading the gauges, gate openings etc.

8.2.11 List of Inspections / Testing

The following inspections were carried out during the rehabilitation / replacement of gates as a routine:

a) Groove Inspection  
b) Measurement of Thickness of Skin Plate after cutting the Gate Leaf at Bottom  
c) Facing Step Measurement  
d) Roller Train & Gate frame dimensional Measurement  
e) Verticality of Side Sealing plate  
f) Pre-Concrete Inspection of Embedded Parts  
g) Post Concrete Inspection  
h) Pre- Welding Gate Leaf Dimensional Measurement  
i) Welding Inspection (Visual, NDT, Throat Length)  
j) Post – Welding Gate Leaf Dimensional Measurement  
k) Pre – Paint Inspection of Gate Extended Portion and End Beam  
l) Paint Layer thickness Measurement  
m) Hoist Dimensional Check  
n) Inspection for Torque for Tightening of Bolts  
o) Painting and Welding Inspection of Hoist Parts  
p) Bottom / Side Sealing Inspection
q) Bulkhead Gate Guide Installation Inspection
r) No – Load Test (Temperature Rise Test of Hoist)
s) Dry Testing of Gate Equipment
t) Wet Testing of Gate Equipment at Normal Head
u) Wet Testing of Gate Equipment at High Head
v) Testing of Gates under Remote operation
w) Testing of Gates under any given Water Head condition
x) Testing of Gates under any given Water Discharge Test.
y) Electrical Tests including visual Inspection of the Equipment, Automatic Power Change over Test, Lighting System Test.

8.3 JICA’s COMPONENT M & E WORKS

This component of the Project was part of Japan’s Grant Aid Program (GAP) through JICA who were to control implementation of this component. On behalf of the Government of Punjab, PMO for Punjab Barrages was responsible to ensure that the services, products and works are procured and executed in accordance with the Exchange Notes (Grant Aid Agreement), Guidelines of the Japanese GAP and according to the Laws of Islamic Republic of Pakistan. It was divided into four Contract Packages; i.e. CP 1, 2, 3, and 4. CP-1 consisted of construction of M & E works, CP-2, 3, and 4 involved procurement of equipment including BHG along with accessories, Tugboats, working boats and Truck Crane, etc.

In accordance with Grant Aid Agreement with Japanese Government, PMO for Punjab Barrages carried out construction of BHG stock yard at U/S left flank of the Barrage. The yard is 490X295ft with inclination facility and jetty. A brief description of works under this component is:

**Details of Works under Japan Grant Aid Program**

<table>
<thead>
<tr>
<th>Contracts</th>
<th>Works Executed</th>
</tr>
</thead>
</table>
| CP-1      | • Installation of new single leaf plate girder roller gates (61.67ft wide & 23ft high), for 7 left undersluice (Gate No. 1 to 7)  
  • Rehabilitation of 22 (Gate No. 9 to 30) main weir gates, involving increasing height by 1 ft, improvement of end beams, roller trains, rocker assembly, roller guard, and side sealing plate.  
  • Installation of 29 sill beams (Bay No. 1 to 7 and 9 to 30).  
  • Installation of guide frames for BHG at piers in Bay No. 1 to 30.  
  • Installation of 29 electrical hoists and LCPs (Gates No. 1 to 7 and 9 to 30). |
Construction of power receiving facility and power distribution system for electrification of Gate No. 1 to 7 and 9 to 30. Normal source of power is from WAPDA and generator incase of power breakdown.

Replacement of wooden planks of regulating deck superstructure with steel grating for Gate No. 1 to 65

| CP-2 | • Procurement of 5 sets of floating type BHG, including gate guides, accessories, and on the Job training (OJT) of operation staff. |
| CP-3 | • Procurement of 2 Tugboats and 3 working boats including their spare parts and OJT of operation staff. |
| CP-4 | • Procurement of a of 50 ton Truck Crane with spare parts and OJT of Operation of Truck Crane |

9. CONSTRAINTS, PROBLEMS IN EXECUTION AND THEIR SOLUTION

Many problems crop up in construction projects. These are project and location specific and may be unique or even queer sometimes. Majority of these problems are generally new and unforeseen but if a record of all occurrences is maintained for all the projects, it can help many builders to mitigate such occurrences as and whenever they pop up. No doubt all the construction problems, however, complicated or queer they may be, are ultimately negotiated/re-solved, but if solved examples are available on record, a lot of time and brain twisting/scratching can be saved.

“Taunsa Barrage Emergency Rehabilitation and Modernization Project” was unique in nature and a very difficult complex task and thus was more prone to unforeseen and queer problems. Some of the major problems experienced and their adopted solutions are briefly introduced in the following:

9.1 Leakage from D/S floor of the Barrage

The problem of profuse leakage of water from the stilling basin and d/s glacis through concrete was known before starting the construction of project works. Initially the solution was considered to lie in grouting of concrete floor, and this was the first operation to be done. Later when the floor concrete dismantling operation was started, it was observed that either the hydraulic breakers shock or removal of skin concrete exposed/widened the cracks in the underlying mass concrete thus restarting the leakage which though emitted clear water was obstructing the concreting and preparatory process. At some places even installation of Rawl bots was hampered. The situation needed immediate solution. The steps adopted/carried out for proper preparation work to facilitate successful placement of concrete are introduced in the following.
The stilling basin floor and glacis concrete were leaking profusely and at many places springs with substantial discharge indicated the sponginess of concrete and fissures through and through the whole depth of concrete. Many of these were treated with consolidation grouting with good response but at some places the channels/fissures being too large could not be closed and kept bleeding/discharge water. To mitigate these conditions and making the floor panels safe for laying new concrete, chases/small ditches were cut in the lean base concrete and perforated pipes were laid in these ditches and covered with rock fragments filter to protect the pipes perforations from being clogged and allow free flow of clear seepage/leakage water. To avoid the choking of this filter the ditches/drains were covered with polythene sheet covers wide enough only to cover the ditches. The perforated pipes from the ditches of one floor panel were connected to one or two blind pipes at the far end of the stilling basin to carry unwanted leakage discharge out of the floor panel. This provided good clean panel for laying new 4000 psi concrete.

The only other option could be installation of dewatering wells and reducing the subsoil water level to mitigate/neutralize the uplift pressures causing leakage and springs. The snag in this method was that the tubewells had to be installed on the d/s of the stilling basin and outside the impervious portion. The depression head required was likely to effect the subsurface alluvium adversely and the installation and the process of lowering the water table required substantial time which was unaffordable due to emergent nature of works. Thus this option was not tried.

The above details have been recorded as this was an innovative and unique site specific solution to a complex construction problem. But for this the Contractor would have had to resort to a maze of pumped wells to keep the sub-soil water level down, to stop the leakage which would have taken a long time causing unacceptable delays. This method also helped in non-stop smooth working making the timely completion possible at acceptable cost.

9.2 Concreting under severe weather conditions

The ambient temperature at Taunsa Barrage through the year ranges between 0 to 50°C but in exceptional cases the temperature of -2 to 52 °C have also been recorded. The specifications for placement of concrete required the concrete temperature at placement location to be between 5°C to 32 °C thus requiring special arrangements for concrete temperature control.

9.2.1 Hot Weather Concreting

During hot weather, the temperature of concrete at batching plant was kept below 28 °C by using chilled water produced by B.P. Chillers and under further need, ice blocks were added to the water fed to the batching plant. The Contractor had separately acquired a local ice factory in Kot Addu on lease for this purpose. Generally the concrete placement was so timed as to avoid concrete placement beyond ambient temperature of 40 °C.

At higher temperatures, setting retarders were added at the batching plant to control initial setting time of concrete and transit mixer revolving drums were
fully covered with wet burlap/hessian which was kept wet through sprinkling of water at the batching plant and placement locations. From 1200 to 1700 hrs special Awnings (tentage) were used to cover the concrete receiving area and placed concrete in addition to increase in the number of vibrator operators and concrete surface finishers. Curing arrangements were also strengthened in high temperature periods.

9.2.2 Cold Weather Concreting

During winter the concrete placement was so planned, that the operations got finished within acceptable temperatures. However in exceptional cases (which were very few) hot water was fed to the batching plants and concrete placement covered with awnings and finished concrete with polythene sheets. Anyway no concrete placement was allowed /carried out with ambient temperatures lower than 2°C.

9.2.3 Rainy Season Concreting

Generally Taunsa Barrage area receives scanty rainfall during working period of October to June but still some rainfall does occur. Since the timing of rainfall cannot be predicted, concrete placement was avoided in heavily overcast sky. With thin or partial cloud cover, standby arrangements for special awnings and covers of polythene sheets were kept at hand and used in the case of rainfall till final setting of placed concrete.

9.3 Protection of works completed in Stage-01

The construction plan envisaged construction of the sub weir in two stages over two working periods (low flow periods October to June). The right half of the structure (2,173 ft long) was completed in the Stage-01 (September 2005 to July 2006) and had to be opened to flow immediately on completion. This situation posed a very serious rather lethal threat to the forward end of the completed portion of sub weir located in the middle of the river prism. To meet this challenge a genuine innovation was designed and implemented, which worked perfectly and without any moment of concern. This problem was tackled by installation of an additional pile along flow at half the length during construction of right half to protect the constructed half from damages due to floods. Another pile along the flow was installed in the shape of a circular arc with ends of the above mentioned cross pile attached with the centre line off set of 50 ft. The bottom tip of this pile line was driven to RL 371 and the top level was kept at RL 431 (same as the central straight pile). The annular space between these two piles was filled with stone and pit run material. The outer curved pile was also provided stone protection of 50 ft width on the alluvial bed side to mitigate flood scour.

9.4 Traffic Management Plan

Generally in a majority of hydraulic structure projects, traffic management is a non issue topic. Taunsa was an entirely different project. The barrage supports and is supported by an AR Bridge of AA loading (Class 70). This bridge is the only connection between left and right banks of Indus River in DI Khan-DG Khan reach (about 220 km length) and is used by thousands of vehicles of all categories from
both sides and round the clock. In addition, three contractors (all international joint ventures) were working on the barrage complex. DESCON-CGGC JV (civil works contractors) had their three batching plants supported by over 50 vehicles moving across the barrage and earth moving machinery, transport trucks while heavy carriers and cranes of the mechanical contractors i.e. M/s Kurimoto JV for JICA funded and M/s CCC of China for World Bank funded works were also using the bridge for their heavy carriers and cranes both mobile and cross bridge gantry in right undersluces.

Complete stoppage of any sort of traffic was thus out of question. This necessitated a clock work like mechanism for control and regulation of traffic to meet the needs of all stakeholders i.e. the three contractors and general public and private traffic. A detailed traffic control plan was therefore prepared with the collaboration of all the users and implemented immaculately to keep all the works going smoothly specially the concrete placement operation in the left half as all the concrete had to be carried from batching plants on the right side to works in the left half in the second year.

9.5 Canal Closure Program and Communication Strategy

For dissemination of information about annual canal closure to farmers a communication strategy was prepared and implemented. Need for this strategy was felt on the basis of experience of stage-01 works during Rabi 2005-06 closure, when information was disseminated through traditional modes of communications i.e. field offices of Agriculture and Irrigation Department, local media etc. This did not work properly and some information gaps were found. In order to disseminate it widely and also to ensure full participation of stakeholders for smooth program implementation, a multi tier communication strategy and supporting work program were developed for Rabi 2006-07 canal closure. Electronic and print media along with consultation workshops, briefing to local parliamentarians, and distribution of leaflets in canal command area were used for information dissemination to farmers. Another objective of communication program was the flow of information regarding water entitlements and canal water allocation. The program worked well and almost eliminated the canal supply complaints.

Various Supervision Missions of the World Bank visited canal command areas time to time to counter check the farmer's knowledge regarding canal closure program and they showed their satisfaction.

10. LESSONS LEARNT

Based on detailed discussions amongst the government project team consultants, contractor and bank staff, the following inferences or lessons learnt from Taunsa Barrage Project can be drawn for preparation and implementation of similar projects:

Project Design and Preparation:

i. Project Design should include a component of social and environmental management along with mitigation/support measures.
ii. A Communication Strategy and Program about canal closure should be part of the project preparation to ensure a smooth implementation of the Project.

iii. A PMO fully staffed with competent specialists in all aspects/needs should be on board by project approval and a mechanism should be in place to avoid frequent staff turnover.

iv. Key actions such as approval of PC-I, EIA, and convening of POE for review of feasibility study and engineering design should be completed before financing agreements.

v. The procurement process for key works, goods and consultants services required during the first year of the project should be at an advanced stage by project negotiations, so that disbursements commence immediately after effectiveness of financing agreement. Likewise, issues such as processing and decision making about project procurements should be streamlined to avoid unnecessary delays.

vi. It is very advantageous that detailed design, including construction plan is ready before bidding document for procurement works is issued. This plan should encompass coordination and interface issues amongst the contractors regarding access to construction site and movement of heavy machinery, interruption to canals operation and closure of Roads and Bridges for public transport and contractor’s equipment during crucial times.

vii. Location of contractor’s site facilities shall be provided in the bidding documents to avoid variation orders and social disruption.

viii. Detailed engineering design of Employer’s site facilities to be constructed by the contractor should be provided as part of the bidding documents.

ix. Constructability of engineering design should be reviewed thoroughly in design phase for execution of the contract in accordance with schedule.

x. An orientation/training for familiarizing the Employer staff and supervision consultants about financiers procurement guidelines and safeguard policy at project launch would help improve project implementation.

Project Implementation

i. A high-level Project Steering Committee (PSC) and effective coordination mechanism in the government prove to be a main success factor in resolving key issues in a timely manner.

ii. A Project Implementation Plan (PIP) prepared during project preparation would be a very valuable guide for all project staff to avoid ad hoc planning;

iii. A well-thought out planning process is important for proactive environmental and social management;

iv. Procurement for consultancy services and works should be done in time to avoid missing critical working periods such as annual canal closure/low flow period.
v. Supervision Consultants should be properly staffed with contract management, and Environment, Health and Safety (EHS) staff at site.

vi. Contractor’s relations with local community are important for smooth implementation.

vii. International Panel of Experts (POE) is an effective way of independent review and quality enhancement.

viii. Level of commitment and competency of Implementing Agency management and PMO core staff are critical to project success.

ix. There should be certain mechanism built-in the contract document to ensure that the construction contractor fully complies with EMMP of the Project.

x. Implementation of resettlement action plan (RAP) and other project activities involving interaction with local communities should be implemented through the process of social mobilization. Involvements of rural support networks such NRSP, AKRSP, PRSP can provide valuable assistance. Implementing Agency’s (IA) role in such a case shall of a monitoring agency.

xi. A well designed and effective M & E system pays dividend in terms of timely feedback to implementing agencies and allows mid-course corrective measures.

Financial Management

i. It has been felt that anomalies arising due to application of the Government procedures versus financing agency’s procurement guidelines need to be clearly defined.

ii. It is necessary that Provincial Government including the Finance and the Audit Department understand the procedure and discipline intended for implementation of the project, subsequent audit observations discourage the pace of the project.

iii. A sound financial management, accounting and reporting system managed by qualified staff is a key element for a smooth implementation of the project. Consideration should be given to out-sourcing certain aspects of financial management to professional firms, instead of setting up in-house systems.

11. VISITORS TO THE CONSTRUCTION SITE

The following distinguished personalities, professionals and groups visited the project works, showed keen interest in project processes and appreciated / applauded the project set-up, working and quality of works:

1. Two delegations of Pakistan Engineering Congress Member
2. Several World Bank Supervisory Mission
3. Vice President World Bank and Senior Bank officials. He was the most vocal in lauding the quality of project works
4. Professionals from Frontier Works Organization (FWO)
5. Engineers from 2\textsuperscript{nd} Corps Multan
6. Trainee officers from staff college
7. Three International Panel of Experts and many others

In this way Taunsa Barrage Project is one of the most visited and appreciated project in Punjab.
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