R & D Project
On
DEVELOPMENT OF STANDARDISED DESIGN AND DRAWINGS OF A BRIDGE CUM BANDHARA SYSTEM

Final Consolidated Report

Volume-I General Information

Submitted to

Director Project-II
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Preamble

Maharashtra has tradition of constructing Bridge Cum Bandhara (BcB). In such structures bridges are used for dual purpose of crossing the river and also create a limited storage. They are popular as they can serve dual purpose of crossing as well as a water storage structure. Such structures have been used to tap post monsoon flow to create storage not exceeding 3.50m. They are ideal structure for following situations.

i. To tap post monsoon flow to create storage up to 3.5 m The storage is created by fixing needles/gates between bandhara piers to tap last flow.

ii. Stored water is used for drinking and irrigation.

iii. It enhances the ground water which then is available for irrigation as well as for drinking water.

iv. Surplus percolated water out of irrigation activity again joins the river which is tapped and reused for irrigation.

v. Such stored water can be used for artificial recharging the nearby bore wells as well as open well to augment ground water.

The water is stored within the river banks hence does not require additional land acquisition and hence the scheme is popular. Few photographs of Bandhara are shown in Figure 1-5.

Figure 1 and 2  Bridge cum Bandhara on Rock
The report is divided in four parts as below.

**Volume – I General Information** : Volume I gives general information of Bridge cum Bandhara, the structural details, various norms for operations, lifting and placing of gates, water recharging etc. and targeted to take policy decision.

**Volume – II Analysis and Design** : This volume gives general information of analysis and design of key elements of bandhara i.e. pier, raft, gates etc. for various loadings (dead load, water load, earthquake load). Flow charts for various steps are presented.

**Volume – III Government GRs**: This volume gives general information of Government (Maharashtra state) GRs on bandhara related works for information and further action. These GRs will help other states to prepare on similar lines.
Volume – IV Typical Drawings: This volume gives detailed structural drawings for all the types of Bandhara and Structural steel gates.

The sets of drawings available for converting the existing bridge into BCB can also be used for new proposed bridges or bridges under construction to be used as BCB.

2.0 Financial norms

It has been therefore proposed to adopt this system for PMGSY roads at such location where the same is technically feasible and financially justified when compared to norms of prescribed by the respective State Govt. In Maharashtra state, the Irrigation department has norms of cost of water storage projects such as percolation tank, minor, medium, major irrigation storage structure, cement plug, bridge cum bandhara etc. related to storage created or irrigated area created and noting the purpose as drinking water or for irrigations. These norms are different for tribal area, backword area etc. For every bridge cum bandhara, it is practice in Maharashtra to compare the additional cost which has to be compared with these norms and if the cost is within the norms, the project is sanctioned. The recant GR information is attached in Volume-I. In Maharashtra concurrence of state irrigation department is taken for creating such storage. Similar procedure perhaps will have to be followed by other states.

3.0 Type plans for Bridge Cum Bandhara

Type plans have been prepared for following situations.

a. Construction new bridge cum bandana when rock is exposed and storage targeted upto 3.5 m
b. Converting existing bridge into Bridge cum Bandhara when rock is buried
   i. When rock is exposed with storage upto 3.5 m
   ii. When rock is buried with maximum depth of 5 m with storage upto 3.5 m
   iii. No rock but storage upto 2.5 m

The Figure 6 show general information on bandhara covered in this project.
Presently type plans are prepared for above cases and drawings are given in Volume-IV and for other details Volume II may be referred. It may be noted that the set of plans prepared for converting existing bridge into Bridge Cum Bandhara can also be used for new proposed bridges or bridges under construction proposed to be used as Bridge Cum Bandhara.

4.0 Gates

The following material for the gates can be used.
   i. Steel
   ii. Fibre concrete
   iii. FRC gates

Information on automatic gate (Godbole gate) is also presented in para 4.4.

4.1 steel gates

The steel gates (Figure 7) may consists of plates, angles, channels, RHS etc. The detailed analysis and design methodology is presented in Volume-II with various sizes and using different sections. The weight of steel gates depending upon the size may vary from 45-67 kg /sqm. Irrigation departments has also evolved gate of curved shape as shown in Figure 8 with an objective to reduce the weight.
4.2 FRP gates

With an objective to prevent theft of steel gates and to reduce the weight, FRP gates (Figure 9) have been developed, tested by Central Design Organization of Irrigation department and now commercially produced. Typical photographs are given below and detailed technical information is given in Volume II.

4.3 Fibre concrete gate

With an objective to prevent theft of steel gates and to work out economical alternative, VNIT has developed thin fibre concrete gate (with steel fibres and providing minimum 8 diameter bars for lifting purpose) and tested successfully for 3.5m water pressure for a span of 2m. The thickness of these gates varies from 50mm (with angles) to 75mm (without angles) at edges (Figure 10a-10c). It is observed that the edges are protected with edges and it provides smooth surface for rubber seam. The average weight of such gate works out to be 200kg / sqm. The inquiry in the market has revealed that these gates (2.1x0.5m) can be produced @Rs 750/- to Rs 1,500 per gate, with and without edge angles. With the availability of simple lifting equipment handling such gate (having high weight / sqm) may not pose serious problems. The cost being low, the damage to few gates may not affect the operation and maintenance cost substantially. As observed at site the joints can be sealed with ordinary cement mortar. Considering the cost advantage, state government may encourage such gates and may carry out few more lab and field studies.

Figure 10a  Fibre Reinforced Concrete gate  Figure 10b  Cement plaster to gates
4.4. Godbole gates

M/s Godbole gates has developed a patented system called “Godbole gates”, which are being used from last 30 years on various irrigation projects. These gates have the specialty that the gates should open automatically once the level in the lake / dam (designed level) is exceeded. It works on simple works of statics where the hydraulic static pressure, weight of gate and fulcrum position of the gate is so adjusted that the hydraulic force is enough to open the gate once the water level which is targeted as flood level is achieved. Several new models with vertical opening or horizontal opening are developed. Typical photographs are shown in Figure 10d.
Presently the costs of these gates are prohibitive for BCB structures but after further research, the cost can be substantially reduced. There are several areas in the country where the rains are scanty and the total rainfall may not exceed 300-400mm per year in such a situation these gates may prove as ideal as each and every rainfall can be tapped and storage is created.

5.0 Operation and Maintenance

There is a need for proper operation and maintenance manual. Following are few guidelines which can be updated from time to time.

5.1 Storage and protection of the gates

It is necessary to have small storage godowns or some protected open plot (with watch and ward) where these gates can be stored during the monsoon. This can be near the bridge structure or near gram panchayat office / government / private premises. It is advisable to make necessary provision in budget. Figure 11 shows a simple layout plan for storage of needles.

![Typical layout plan for needle stacking](image)

**Figure 11** Typical layout plan for needle stacking

5.2 Damage to rubber seal

Rubber seal provided at the base and side to prevent leakage as shown in Figure-12. This may require changes at frequent interval as a result of damage caused due to handling. The figure also shows the bottom channel for proper fixing of the first gate.
5.3 Damage to Gates

The gates may get damaged / warped due to bad handling and may need replacement.

5.4 Guiding angle at base

It is practice to fix guiding angles or channel at base to ensure that the gates would seat properly and does not lead to leakage of water. These angles may require minor repairs. It is observed that the channel at base needs frequent cleaning though it helps in proper placement of gates. (Figure 12)

5.5 Angle in gate slot

Water may leak through the slot in bandhara piers. A simple steel angle or cold form channel is fixed to cover profile of slot. This is an important operation during construction. Field engineers need to evolve suitable methodology

5.6 Temporary removable bridge

A simple lightweight bridge for a length of appropriate length is proposed which can span at least 4 needle pier. During the operation of lowering or lifting the gates, the removable foot bridge can be placed and few labors can seat on this bridge to guide the lifting/fixing operation. This can then be shifted to next unit

5.7 Average cost of operation and maintenance

Irrigation department based on their experience has worked out the average cost of the operation and maintenance and included in DSR. It is revealed that the average rate of removing the needles, and keeping in godown, re-fixing the same and to carry out repairs to gates including rubber seals comes out to be Rs 500/- per sqm. The typical rate analysis and the wording of the relevant items obtained from irrigation department are attached in Volume-IV.
6.0 Mechanical equipment

It was a practice to restrict the size of steel gate to 2 m x 0.5 so that the average weight of gate doesn’t exceed 80 kg per gate and the lifting and re-fixing the gate was therefore done manually. This is a time consuming job and for a long river may require 10 to 15 days. Any mechanical device such as Mathura crane, hydra available in market can be used for placing and removing of the gates. (Figure 13 and 14)

![Figure 13 Placing of Gates](image1)

![Figure 14 Mathura crane in lifting position](image2)

**Tailor-made economical alternative**

VNIT with the help of local unit has developed a most economical equipment to meet the need operation of fixing and removing needles of bandhara. It consists of hydraulically operated mechanical equipment mounted on four wheel tractor trolley. Equipment has got arrangement of 360 degree rotation with lifting arm of 5m and capacity of 500kg per trip. The equipment is operated on diesel or electrical prime mover. A small generator of small capacity is adequate to give power to this electrical unit. Such equipment can be used to lift the gates from gowdon, keep in tractor / truss and lower at site (Refer Figure 15). The expected cost of such unit is not likely to exceed Rs 5 Lakhs and it should be included as part of project cost. Such simple equipment may be used for other agricultural activities i.e. lifting of grain bags and placing in truck.

![Figure 15 Newly developed tractor trolley](image3)
For Maharathwada region, where the rainfall is very low and rainy days are limited, Mr V B Kotecha, Executive Engineer, Irrigation department, Usmanabad, Maharashtra, has developed a simple mechanical system which allows lower or lifting of the gates in 3-5 minutes. Refer Figure 16. This enables him to tap each and every fall and create a storage which helps in ground water recharging.

![Figure 16 Lifting Arrangement](image)

### 7.0 Working of Bandhara Scheme

The success of the bandhara scheme will depend upon the active participation of local peoples. Government of Maharashtra has already framed guidelines under which irrigation department is already encouraging formation of society of beneficiaries. Such society takes the job of operation and maintenance and has been empowered to collect the charges as prescribed by Govt from the beneficiaries to meet the operation and maintenance. The information on relevant GRs is given in Volume-III.
8.0 Water Recharging

The main advantage of the storage is to allow water to seep into the ground thus recharging the upper ground water table. The water recharging can be accelerated by adopting artificial recharging there by recharge the ground by bore well, tube well or open well (Figure 17 -21). For this purpose we need surplus water and good filtering system. Various filtering systems such as VEE WIRE or natural gravels have been developed and some typical photographs are attached. A policy decision has been taken by Government of Maharashtra to implement various water conservation measures in scarcity affected villages and making additional funds for such areas. Artificial water charging is encouraged in this scheme. There are several villages in Maharashtra which need tanker water in summer for drinking purpose. For such villages more funding intend to be made available by Govt of Maharashtra. It is now proposed by us that the gates may be fixed in month of September upto 1.5m depth so that such stored water is available from first week of September. For the purpose of artificial recharging, help of ground water survey department may be taken to identify such hungry aquifer and such bore well where rates of acceptability is much more.

![Figure 17](image17.png) Raising of water table  
![Figure 18](image18.png) Recharging Tube well  
![Figure 19](image19.png) Typical rainwater harvesting system  
![Figure 20](image20.png) Raising of water table
The science of artificial recharging and rainwater harvesting is well developed in urban areas and also in rural areas. Lots of references are available on internet and there are various agencies and consultants to give proper advices.

9.0 Debris Arrester

Agricultural waste such as dried bushes or branches of trees get carried away may choke up the vents of the bandhara. A system of debris arrester as shown in Figure 22 and 23 is successful in Maharashtra to arrest such floating debris much away from bandhara structure thereby ensuring smooth functioning of bandhara system. In some places it may be necessary to provide debris arrester in some form such as closed spaced vertical poles, concrete columns etc. so as to arrest the floating debris much away from the structure and thereby ensure the smooth functioning of the bandhara. It was a practice to restrict the size of the gate to 2m so that the fixing and removal of the gate is done manually which was possible as average weight of such gate is usually less than 80 kg, however as we are recommending mechanical system, gate size can be increased to 3 m which itself would reduce the phenomena of choking of vents due to floating trees.
10.0 Provision of Overflow weir

Few end spans depending upon the location can be converted as overflow weirs (Figure 24) having lowered weir top by about 100mm. This will ensure that even in accidental cases water will not spill over the gates and thus damage the gates and also further bed level.

11.0 Placing of needles

The needles are removed and stacked suitably before the start of rainy season. The placing of needles starts after receding of the major floods. In Maharashtra the needles are normally fixed in the month of September end. The plates are also fixed in stages till October end. It has been observed that this practice has not caused any damage to structures due to floods. It is however advisable to study the rainfall pattern of last three years to decide ideal time of fixing of needles. It is observed that in south India, the south east monsoon, heavy rains occur in month of November – December, hence in these areas the placing of needles will vary.
12.0 Mitigated measures

A structure planned to create storage of 3.5m depth may have backwater of 2.5 to 4 kM depending upon the slope of the river. There may be a need of simple foot bridge at upstream for peoples crossing the river. Depending upon the local condition, appropriate provision may be made. Few cautionary boards may have to be fixed to warn peoples and specially children.

13. Design of structure

Volume II of the report gives the detailed report on the philosophy of the design and evolved technic are also elaborated. It is noted that user can considered several parameters to evolve most cost effective optimum design. It can also be noted that the design does not requires use of complicated software. The type planes developed by us is using simple excel sheets.

Reference:
2. Ingle R K, Jaiswal M M,’ A Bridge Cum Bandhara System ‘, IRC journal, Indian Highway, Volume no 29
3. IRC: 5 General features of Design
4. IRC: 6 Loads and Stresses
5. IRC: 21 Reinforced Concrete Bridges
6. Irrigation / PWD Maharashtra circulars
R & D Project
On

DEVELOPMENT OF STANDARDISED DESIGN AND
DRAWINGS OF A BRIDGE CUM BANDHARA SYSTEM

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Volume-II General Analysis and Design Aspects

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Introduction

The general analysis and design principals are presented in this volume. The load calculation and analysis is briefed for following structures.

a. Gravity Bandhara
b. Sill beam type bandhara
c. Steel gates
d. Miscellaneous arrangements

2.0 Design assumption and data

The straight length of pier is taken as 1.8 m for storage upto 2.5 m and 2.2 m for storage upto 2.5 to 3.5 m. While lowering the gates they are required to be properly oriented towards slot. The straight length is decided to ensure this operation safely and conveniently. This is normally done manually by labors sitting on bandhara pier. It is proposed to place a temporary light bridge facilitate this operation (Volume-I, section 5.6).

The analysis and design methodology of the above is briefed below.
3.0 ANALYSIS AND DESIGN OF BANDHARA

This part deals with design of bandhara independent of main piers suitable for either intermediate part of bridge cum bandhara or separate.

The following cases are considered:

i. Intermediate piers on raft resting on hard starta

ii. Intermediate piers on PCC raft resting on soft starta (batter on D/S side) for rock at shallow depth

iii. Intermediate piers on PCC raft resting on soft starta (batter on U/S side) for rock at shallow depth

iv. Intermediate piers on raft resting on soft starta with cutoff wall on U/S and D/S

The above cases are designed with needles placed on D/S. The following load are considered for calculation of vertical force (P), horizontal force (H) and Moment (M).

- Dead Load calculating stabilizing vertical load (P) and stabilizing moment (M)
- Shear Key supporting stabilization P, H and M for shear key
- Uplift generating Vertical upward P and negative moment M to be considered for case when water is standing i.e. gates are closed. Uplift is considered 100% at u/s and zero or equal to water depth at d/s
- Passive resistance i.e. horizontal H and resisting Moment M in few cases
- Static weight of Water when gates are closed (P and M)
- Buoyancy is considered when water is at HFL and no gates (negative P and M)
- Moving water case simulates water moving at HFL without gates (H and overturning M)
- Earthquake forces when water depth is 50% of total depth, with assumption that tank full condition and earthquake may not occur simultaneously

The following critical cases are considered.

- Without Gates Full Water
- With Gates Water up to FTL (without earthquake)
- With gates water upto half depth of water (with earthquake)

It is noticed that the design of Bandhara pier is critical when the water is full i.e. static case and the moving water case or earth quake case is not governing. Needle size are kept variables so that within the existing span fixed number of bandhara piers can be accommodated

The analysis and design steps are briefed below for all the cases.
3.1 Intermediate piers on raft resting on hard strata

Figure 1 shows the sketch of bandhara with raft on hard soil strata.

![Diagram of bandhara with raft on hard soil strata](image)

**Figure -1** Bandhara of hard soil showing various parts of bandhara

The flow chart for various calculations is shown in Figure 2a to Figure 2g.

**Figure 2a Dead load calculations**

**Figure 2b Shear key load calculations**
Figure 2c Uplift load calculations

Figure 2d Static weight of water load calculations

Figure 2e Buoyancy load calculations (No gates and Water at HFL Condition)
Figure 2f Moving Water load calculations

Figure 2g Earthquake load calculations
3.2 Intermediate piers on PCC raft resting on soft strata (batter on D/S side)

Figure 3 shows bandhara system on PCC raft resting on soft strata having batter on D/S side.

The flow chart for various calculations is shown in Figure 4a to Figure 4g.
Figure 4b Uplift load calculations

Figure 4c Passive load calculations

Figure 4d Static weight of water load calculations
Figure 4e Buoyancy load calculations (No gates and Water at HFL Condition)

Figure 4f Moving Water load calculations

Figure 4g Earthquake load calculations
3.3 Intermediate piers on PCC raft resting on soft starta (batter on U/S side)

Figure 5 shows the sketch of bandhara with raft on PCC raft resting on soft starta (batter on U/S side).

![Diagram of bandhara with raft on PCC raft]

Figure 5 Bandhara with raft on PCC raft resting on soft starta (batter on U/S side).

The flow chart for various calculations is shown in Figure 6a to Figure 6g.

![Flow chart for calculations]

Figure 6a Dead load calculations
Figure 6b Uplift load calculations

Figure 6c Passive load calculations

Figure 6d Static weight of water load calculations
Figure 6e Buoyancy load calculations (No gates and Water at HFL Condition)

Figure 6f Moving Water load calculations

Figure 6g Earthquake load calculations
3.4 Intermediate piers on raft resting on soft starta with cutoff wall on U/S and D/s

The case is restricted for water depth of 2.5m only. Cut off is taken as minimum equal to depth of water. This is the criterion normally adopted for percolation tank to minimize percolation. Exit velocity is restricted as per guidelines given by Lanes weighted creep Theory, which suggests the weighted creep length \( L_w = \frac{1}{3} N + V \), \( N \) is sum of all horizontal contacts and \( V \) is sum of all vertical contacts. To ensure safety against piping \( L_w \) must not be less than \( C \) times \( H_w \), where \( H_w \) is depth of water and \( C \) is empirical coefficient depending upon the nature of soil as per Table 1.

<table>
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<th>SN</th>
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<th>( C ) (safe weighted creep ratio)</th>
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<tr>
<td>1</td>
<td>Very fine sand or silt</td>
<td>8.5</td>
</tr>
<tr>
<td>2</td>
<td>Fine sand</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Course sand</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Gravel and sand</td>
<td>3-3.5</td>
</tr>
<tr>
<td>5</td>
<td>Boulders, gravel and sand</td>
<td>2.5-3</td>
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<td>Clayey soils</td>
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In the above if we substitute \( A_{us}=3m, A_{d/s} =5, D_s=2.5m \) and \( L_f = 4.9 \), we get \( \frac{2.5(H_w)}{(3+5+4.9)/3+4x2.5} = 2.5/14.3 =1/5.72 \) i.e. suitable for course sand onward however for smaller \( H_w \) the \( L_w \) will be enough for other soil types also.

Khosla’s theory also used in evaluating the depth of cutoff and length of concrete apron to keep exit velocity within acceptable limit.

Figure 7 shows the sketch of bandhara with raft on soft strata with cutoff wall on U/S and D/s.

![Figure 7](image)

Figure -7 Bandhara of on soft starta with cutoff wall on U/S and D/s showing various parts of bandhara

The flow chart for various calculations is shown in Figure 8a to Figure 8g.
Figure 8a Dead load calculations

\[ W_d = \text{Dead wt} \]
\[ W_w = \text{wt of water} \]
\[ W_1 = L_p \times T_p \times (H_w + F_b) \times y_c \]
\[ W_2 = p \times T_p^2 / 4 \times (y_c + F_b) \times y_c \]
\[ W_3 = d_f \times L_f \times B_f \times y_c \]

\[ M\text{(no water)} = W_d \times L_f / 2 \]
\[ W_w = (L_f - c - T_p - x) \times b_f \times h \times 10 - \pi \times T_p^2 / 2 \times 10 \times H_w \times 10 \]
\[ M\text{(water)} = W_w \times (L_f - (K + T_p / 2)) \]

Figure 8b Uplift load calculations

\[ \text{Total seepage length} = \frac{P_u + A_u + s \times d_f}{c + A_d / c + P_d / s} \]
\[ L_1 = \frac{P_u + A_u + s \times d_f}{c + A_d / c + P_d / s} \]
\[ L_2 = L_1 - L_f \]
\[ P_{max} = 10 \times (H_w / L_f) \times L_1 \]
\[ P_{min} = 10 \times (H_w / L_f) \times L_2 \]

\[ \text{Tri. uplift} (F_r) = (P_{max} - P_{min}) \times L_f / 2 \times B_f \]
\[ M_{up} = F_r \times 2 / 3 \times L_f \]
\[ \text{Rect. uplift} (F_r) = P_{min} \times L_f \times B_f \]
\[ M_{rup} = F_r \times L_f / 2 \]
\[ M_{up} = M_{rup} + M_r \]

Figure 8c Static weight of water load calculations

\[ D_f, L_f, H_w, \text{spacing} \]
\[ P_1 = 10 \times (H_w + D_f) \times \text{spacing} / 2 \]
\[ M_{sw} = P_1 / 3 \times (H_w + D_f) \]
**Figure 8d Buoyancy load calculations**

- **START**
  - \( V_1 = \text{Vol. of raft} \)
  - \( V_2 = \text{Vol. of pier} \)
- \( P_1 = 10x(D_f g L_x F_f) \)
- \( P_2 = 10x(H_w + F_b)(x(T_p x^2/4) + (L_p x T_p)) \)
- \( M_1 = P_1 \times L_f/2 \)
- \( M_2 = P_2 \times L_f/2 \)
- \( M = M_1 + M_2 \)
- **END**

**Figure 8f Moving Water load calculations**

- **START**
  - \( L_p, T_0, H_w, D_f, L_f, B_f, H_h, V_m, V_{mean} \)
  - \( V_{max} = V(2) \times V_{mean} \)
  - \( V_t = V_{max}/(H_h + D_f) \times (D_f + H_w + F_b) \)
  - \( V_b = V_{max}/(L_h + D_f) \times (D_f) \)
- Normal current 0 Degree
  - \( P_t = 0.52 \times V_t \times V_t \times 0.66 \)
  - \( P_b = 0.52 \times V_b \times V_b \times 0.66 \)
- Oblique current 20 Degree
  - \( P_t = 0.52 \times V_t^2 \times 0.66 \times \cos^2(\theta) \)
  - \( P_b = 0.52 \times V_b^2 \times 0.66 \times \sin^2(\theta) \)
- Pr. due to \( P_b = P_b \times (H_w + F_b) \times T_p \)
- Pr. due to \( P_t - P_b = (P_t - P_b) \times (H_w + F_b) \times T_p/2 \)
- Pr. on Footing = \( V_b/2 \times 1.5 \times \text{spacing} \times D_f \)
- \( M_{(water)} \) @ pt. O
- **END**

**Figure 8g Earthquake load calculations**

- **START**
  - \( H_w, D_f, Z, J, R, S_a/g, A_h \)
  - \( p = 0.762/2 \times 10xH_w \times A_h \)
  - \( V_b = 0.726p \times (H_w + D_f) \times \text{spacing} \)
  - \( M_t = 0.295p \times (H_w + D_f) \times 2 \times \text{spacing} \)
- \( F_eq(pier) = D(\text{pier}) \times A_h \)
- \( M_t p = F_eq \times (H_w + D_f/2) \)
- \( F_eq(footing) = D(\text{footing}) \times A_h \)
- \( M_t f = F_eq \times (D_f/2) \)
- \( M = M_t + M_t p + M_t f \)
- **END**
Bandhara System With Sill Beam

This system utilizes the massive piers of the bridge and thus can act as two in one system. This system consists of main piers of bridge (may be 8m c/c) and intermediate piers of bandhara connected by sill beam. A longitudinal sill beam, placed on upstream side of pier, connecting all the intermediate and main piers is used. (Ref. Figure 9-11) The tension arising on upstream side is transferred to the sill beam, which acts as upward force at intermediate pier levels and transferred to major piers by means of bending. The main piers are designed as gravity piers. The analysis of this system is presented in this section.

Figure 9  PLAN OF BANDHARA SYSTEM

Figure 10  Plan of Intermediate Pier
ANALYSIS

Salient Data

A Section of bandhara pier and sill beam is given in Figure 12. The Pier of size 1.9m x 0.4m with bracket of 1.5m height and Base slab of 0.7 x 0.3 (thick) size varied Length for single/multiple piers is used. The size of sill beam is 0.75x0.60m. Height of water and free board is 3.5m/3.0m/2.5m and 0.5 respectively. M 30 grade of concrete is considered for this construction. The soil strata assumed to be Hard Rock/soft rock with Modulus of Subgrade Reaction (K_s) as $1.0 \times 10^5$ kN/cum, to be on conservative side.
Assumptions

i. Sill beam, base slab and vertical pier are well connected by reinforcement e.g. all these substructures shall act as one at bandhara pier.

ii. Uplift as density of water times height of water is considered.

iii. Winkler model is used to include soil structure interaction effect.

iv. Sill beam is assumed fixed at end pied. This assumption is valid as end pier is massive and very rigid.

v. Annular filling is to be done for all side of sill beam with concrete to prevent percolation. It will also give fixity to beam from all sides and will not allow to rotate

Detailed FEM Analysis

Finite Element method can be used for analysis of bandhara pier system along with sill beam including soil structure interaction, to achieve more appropriate results. The analysis can be carried out considering the structure as space frame with six degree of freedoms at each node. Structures of bandhara system e.g. sill beam, vertical pier and base slab are discretized into small shell / 3-D BEAM elements. However to account for fixity of beam caused due to annular concrete filling appropriate spring values be considered

Material Used

Concrete: M30
Steel : Fe415
Bending compressive stress = 6cbc = 8.5 Mpa
Tensile stress in steel = 6st = 230 Mpa
M=280/3 6cbc =11
N = 1 / (1+ (6st / m 6cbc)) = 0.29
J = 1- N/3 = 0.903
K = (1/2) 6cbc N J = 1.11

Multiple Intermediate Pier

Figure 13a and Figure 13b shows the discretization of a pier, base slab and sill beam where nodes and elements are indicated. The sill beam is assumed to be fixed in the main bridge pier. The soil below base slab is idealized as horizontal and vertical springs. Vertical Soil springs are attached to nodes of sill beam and base slab. Horizontal soil springs are attached to nodes of sill beam and downstream node of base slab.

The analysis is carried out by using computer program SAP2000 with shell elements to model vertical pier, base slab and 3-D beam element to model the sill beam. Spring elements are used to model soil structure interaction effect.

Soil springs as per Winkler model are attached at nodes of sill beam and base slab, in horizontal and vertical direction, having stiffness, contributory area times modulus of subgrade reaction. Vertical springs that are in tension are removed in next cycle of analysis and the iterative analysis is repeated until all springs comes under compression.
The FEM analysis can give all the forces, displacements and reactions. The analysis need to be checked for $K_s/2$ and $2K_s$ to allow variation in assumed modulus of subgrade reaction of the strata ($K_s$).

**Typical Calculations for Design of sill Beam (3.5m water depth)**

Size = 750 wide x 600 depth

It is seen that majority of cases, the minimum reinforcements governs.

**Minimum Steel for Flexure**

Min steel = 0.85 / $f_y$  
bd = 0.2%  
bd = 900 sqmm

Provide at least 4-20φ (1256 sqmm) bars on each face at top and bottom.

It can be seen that depending upon the span (2.4 to 3.4m) / number of intermediate piers, the sill beam may needs additional steel at support on U/S of beam along vertical face (up to end span/2) and at centre on top face.

**Minimum Steel for shear**

$$A_{sv} > 0.4 \times b \times S_v / (0.87 \times f_y)$$

$$> 0.4 \times 750 \times 200 / 0.87 \times 415$$

$$> 166 \text{ sqmm}$$

Let provide 2L -12 dia links @200c/c.
Approximate Analysis

It is necessary to have an approximate method for designing of such structure. The above detailed analysis is used in arriving at approximate analysis for such type of indeterminate structure. The approximate method is briefed below. It is assumed that sill beam is prevented from horizontal movement in plan due to restrain offered by rock. The annular filling of concrete will not allow it to rotate. However the movement in vertical plain is allowed noting that the side bond may break. Even with this assumption the minimum steel is found to be adequate.

Water pressure = $(3.5 + 0.6) \times 10 = 41 \text{ kN/sqm}$

![SECTIONAL ELEVATION](image)

**Figure 14** Water pressure and c/s of sill beam bandhara

Assuming Span of bridge as 8m, the total horizontal moment (Figure 14) at central intermediate pier = $1/6 \times 10 \times 3.5 \times 3.5 \times 3.5 \times 2.66$ spacing = 190 kN. This moment can be converted into couple of vertical forces, upward at centre of sill beam and downward at CG of triangular distribution of vertical pressure on D/S side of sill beam. Moment due to this vertical force can be calculated using the expression given in Figure 15. Principal of superposition can be used to combine the effect of various loads.

CG between the U and D = $3.7 \times 2/3 = 2.46 \text{ m}$

$U = D = 190 / 2.46 = 78 \text{ kN}$

$M = a (1-a) PL = 0.33 (1-0.33) 78 \times 8 = 137 \text{ kNm}$

$A_{st reqd} = 21000000 / 550 \times 200 \times 0.9 = 1394 \text{ sqmm}$

The steel provided at bottom is $4 - 20\Phi + 2 - 12 \Phi = 1480 > 1394 \text{ sqmm}$. 
Note: If the weight of the water, self weight of sill beam and part weight of Bandhara pier is considered then the force cause because of static water pressure gets compensated and the structure act similar to gravity structure, thus requiring minimum steel in sill beam.

Fixed-End Moments

<table>
<thead>
<tr>
<th>$M^E$</th>
<th>Loads</th>
<th>$M^E$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-\frac{PL}{8}$</td>
<td><img src="image1" alt="Load Diagram 1" /></td>
<td>$\frac{PL}{8}$</td>
</tr>
<tr>
<td>$-a^2bPL$</td>
<td><img src="image2" alt="Load Diagram 2" /></td>
<td>$-a^2bPL$</td>
</tr>
<tr>
<td>$-a(1-a)PL$</td>
<td><img src="image3" alt="Load Diagram 3" /></td>
<td>$a(1-a)PL$</td>
</tr>
<tr>
<td>$-(6-8a+3a^2)\frac{a^2wL^2}{12}$</td>
<td><img src="image4" alt="Load Diagram 4" /></td>
<td>$(4-3a)\frac{a^3wL^2}{12}$</td>
</tr>
<tr>
<td>$-\frac{wL^2}{12}$</td>
<td><img src="image5" alt="Load Diagram 5" /></td>
<td>$\frac{wL^2}{12}$</td>
</tr>
<tr>
<td>$-\frac{wL^2}{20}$</td>
<td><img src="image6" alt="Load Diagram 6" /></td>
<td>$\frac{wL^2}{12}$</td>
</tr>
<tr>
<td>$-\frac{5wL^2}{96}$</td>
<td><img src="image7" alt="Load Diagram 7" /></td>
<td>$\frac{5wL^2}{96}$</td>
</tr>
<tr>
<td>$-b(2a-b)M$</td>
<td><img src="image8" alt="Load Diagram 8" /></td>
<td>$a(2b-a)M$</td>
</tr>
</tbody>
</table>

Note: Positive moment acts clockwise.

Figure 15  End Moments for various loads

The downward load due to self-weight of sill beam and the water load on the sill beam can also be taken in to account assuming them as uniformly distributed loads. This will reduce the moment and shear due to the vertical reaction of pier.
This approximate analysis of the sill beam can be done using the above method for other spans. In case of detailed requirement, the same can be verified using FEM model.

The observations on such bandhara system are summarized below:

1. It is observed that there is considerable saving in material and excavation.
2. The torsion is less if we adopt only single intermediate pier.
3. Reduction in horizontal moment and shears in sill beam is observed when horizontal springs are considered. There is considerable increase in pressure without effect of horizontal springs. Thus economy can be achieved by considering horizontal springs.
4. Uplift affects the vertical moment and shear in sill beam. With uplift both the vertical moment and shear is less as compared with the results of without uplift.
5. Embedment of sill beam in rock shows reduction in forces and pressures with increase in embedment.
6. As these bandhara are situated near Bridges, they are easily accessible. This is added advantage of this system.
5.0 ANALYSIS AND DESIGN OF STEEL NEEDLES

The following needles are designed and drawings are prepared. Other sizes / configuration can be analysed and designed on similar lines.

1. Size 2.0 clear x0.5 m for 3.0 depth of water with angle and RHS sections
2. Size 2.0 clear x0.5 m for 2m depth of water with angle and RHS sections
3. Size 2.0 clear x1 m single gate for 1m depth of water with angle and RHS sections
4. Size 2.0 clear x 2m single gate for 2m depth of water with angle and RHS sections
5. Size 2.0 clear x 3m single gate for 3.0m depth of water with angle and RHS sections
6. Size 2.0 clear x0.5 m for 3.0m depth of water with angle and RHS sections spanning vertically between ISMB 100
7. Size 3.0 clear x 3m single gate for 3.0m depth of water with angle and RHS sections

The following material / sections are used.

i. 3mm plate (being considered as minor structures)
ii. Angle sections ISA 45454@2.7 kg/m ISA 45455@3.4 kg/m
iii. Channel section ISMC 75 @6.8 kg/m
iv. Rectangular Hollow section RHS 50x25x2@2.15 kg/m and RHS 80x40x3.2@5.5 kg/m

Mathematical model

The plate is provided with two side angles (ISA 45454 / RHS 50x25x2) and longitudinally at top and bottom either ISA 45455 / RHS 50x25x2 or channel ISMC75 / RHS 80x40x4/3.2.

The plate is further stiffened by vertical members ISA 45455 / RHS 50x25x2 spanning between two longitudinal members. The RHS sections will be of grade 310 Mpa and angles of grade 250 Mpa. A typical section of a needle is shown in Figure-16.

The mathematical model for bottom and second needle is shown in Figure-17. The plate is modeled with 4 noded plate elements. The longitudinal and end transverse members are modeled as continuous beam element. The central vertical stiffeners are modeled as beam elements simply supported between the two longitudinal members.
For the bottom needle, it is assumed that bottom long edge will fit into the grove of the pier floor and hence hinged boundary condition is assumed. The sides are also assumed as hinged. The top is assumed to be free. For the second gate, the bottom longitudinal edge is assumed to be on roller.

The water pressure is considered as triangular with zero at top and density of water times the height at bottom. The summary of the design of one gate using angles is given below for size 2.0x0.5 m for 3m depth of water with angle and RHS sections.
Check for deflection

Span = 2100mm
Permissible deflection as per purlin (Figure 18) = Span /150 = 14mm > 11mm  OK

Check for Plate stress

Bending Stress (Figure 19a and 19b) = 141 Mpa < 165 Mpa  Ok

Check for Longitudinal Member

Figure 18  Deflection Diagram

Figure 19a  Stress σ₁₁ diagram

Figure 19b  Stress σ₂₂ diagram

Figure 20  Moment Diagram
Bending moment = 3.55 kNm (Figure 20)
Bending stress = 3.55x1000000 / 20300 = 174 Mpa > 165 Mpa but OK with the steel plate contribution.

Check for central vertical stiffeners

\[ \text{Figure 21 Moment Diagram} \]

Bending moment = 0.322 kNm (Figure 21)
Bending stress = 0.322x1000000 / 2500 = 129 Mpa < 165 Mpa OK

Similarly other gates are analyzed and designed. User can design the gates based on available section and various other sizes.

The details of FRP gates is given in Annexure-I for information.
6.0 Miscellaneous Structures

This section explains the design of overflow weir and lifting arrangement equipment etc.

Overflow weir

The overflow weir is suggested on both the abutment sides. On one side the height of weir can be 1.5m and other side it can be equal to FTL of the bandhara.

On the side where the weir height is 1.5m, piers need to be given so that additional needles can be provided to lock this area. (Figure 22)

Pipes of 300mm diameter with operating valves can be provided at ground level in the weirs having depth of FTL so that these pipes can be operated to supply water to villages on D/S side as and when required.(Figure 23)

Figure 22  Proposed overflow weir between P8 and A/R with few gates and A/L to P1 full overflow weir
Nowadays, strong healthy labour is not available for handling material at the site in remote areas. The smallest equipment/crane available in the market for handling material is Hydra of 9 Mt or 12 Mt capacity. But this Hydra is not available in remote areas or in villages. The rent and consumption of fuel is also not affordable for small work and small weight handling.

Presently, following work needs small weight handling equipment.

1. Loading, unloading, transportation and insertion of steel needles in Bridge cum Bandhara.
2. Loading, unloading, transportation and insertion of precast pre-stressed concrete planks and columns for the construction of Boundary wall.
3. Loading, unloading, transportation and placing of concrete block in the construction of R.E. Wall.
4. Loading, unloading of agricultural bags etc.

Hence to cater the above need, we designed and manufactured Tractor trolley mounted equipment which can handle the load up to 200 kg. It is economical Speedy; easy Operation with Remote and 360 degree rotation is possible. (Refer Figure 24)
Figure 24 Stand alone lifting trolley (storage + placement) arrangement

Salient features:-
. Continuous Operation by Remote Control with only two persons
. Capacity - 200 Kg.
. Rotation - 360 degree
. Boom Length - 3.0 M.
. Lift Height – 2.5 M.
. Movable - Manually / With Tractor
. Grab – Simple as per element size.
. Maintenance :- Negligible
. Motor: - one H.P. 240 volts
. Operation: - On Generator

The gates can be stored on ground in temporary shade similar to cycle stand by placing two vertical posts / pipes at distance @ 150 mm c/c
Annexure-I Details of FRP Gate (Informative)

NEW ERA IN IRRIGATION - USE OF ADVANCE MATERIALS

Sudhir Dabhadkar- B.E.(Mech), DBM, ICWA.MIE

In the recent developments in irrigation, the concept of building low height dam all along the river was introduced on the downstream of bigger dam or along the river to store water after rainy season is over so can be used for agriculture purpose as well for drinking.

In India we have rains only 2-3 months and then it is dry weather, so water is needed during lean period. So all 12 months we can cultivate the land get more crops and yield. Also avoid shortage of water for other purposes.

In the past during rainy season and after rainy season the water poured by nature flown through river, nalas, and streams goes to the nearest sea. Almost 90% of such water is wasted and gets un-utilized as this water is does not accumulate at one place the capillary level of water remains unchanged.

So it was thought of well known kings, rulers of ancient days to find the ways and means to utilize this natural resource in proper way and at proper time. So the idea of small height dam /KT wier/ Bandharas emerged.

The small ht/stop dam with low cost is constructed all along the river and near/close point of village. One river may consist of 300-400 such small height dam /stop dam. Such small height dam /stop dam may have small numbers of openings depending upon the width of river/depth of river.

Risk of the out planking, seasonal floods, and soil condition is taken into consideration.

There are small openings of 2.00 mtr wide and number of such openings may vary depending on the need, river width, and risk of outflanking and design of check dam and water required for full irrigation for nearby land/farms for cultivation and drinking.

Height of the dam is determined on storage capacity for required irrigation and for drinking in total lean period, with height varying from 1.5 mtrs to 4.50 mtrs. These openings will have grooves both side to fix the needles.

These barriers are fixed to store the water, to rear side during post monsoon session and during the scarcity of water. The water is released from the main dam during such period or stored when rains are diminishing.

To facilitate the water storage, depending on water level required appropriate size gates/barriers (barge) are fixed into the slot / groove.

In olden days these barge/needles/ gates /barriers are made from wooden planks. These wooden planks are inserted in both the grooves and soil/mud is pressed between the gaps, which act as barrier prevents water flow to downstream. This is done at the end of rainy season period or on lean period. Nowadays scarcity of wood is always there and there is ban for cutting trees, as per environmental laws and rules. It is need have today retain jungles and forest to balance the nature. Some states already shifted to M. S. Fabricated gates with plates & angles/ bars. These are inserted in one of the grooves and as barrier.
Issues with existing gates in wood and MS:

- As scarcity of wood and Govt. ban on cutting trees for environmental reasons.
- In MS-fabricated gates, Weight is 70 kg - 100 kg
- Short life - being in MS getting rusty over period of time.
- Due to polluted water getting corroded / eroded very fast.
- Due to heavy weight removing and fixing cumbersome.
- Storage problem.
- Chances of theft due to resale value.
- Repairs & maintenance every year for year for 30% qty
- Cost of replacement of 30% qty = @200 lacks in every circle.
- Heavy water loss from interface of two gates as its matching is lost due to rusting and wear and tear.
More serious problem noticed was theft of MS gates and selling in scrap market, which is putting whole department’s staff under problem.

With this various kinds of problems and the regular expenses on the repairs, maintenance and replacements of gates every year. Similarly the availability of funds is another issue, so most of such low height dams is either without gates or having major damages due to wear and tear. The irrigation department was looking for the new and advance material.

In year 2009 in gathering of 12-14 Executives Engineers raised this issue was discussed and everybody urged to have some new concept, with some different material, also it was suggested new should have many fold advantages over the existing material. It should be:

- Durable.
- Cost effective
- Longer life.
- Prevention from loss & theft
- Chemically resistance
- Light weight.
- Easy to operate and store.

In recent years the Glass reinforced Plastics is catching the most of the areas where it has replaced MS/Aluminum/ material due to above advantages. Being experts in GRP/FRP manufacturing we suggested go for the FRP/GRP material, which is having all above properties and advantages.

With this in 2009, few of sites were visited and a proper design was made and manufactured similar to existing MS gates.

In order to gain confidence we started very small ht. dams 2.00 mtr high, watched the performance and then moved to 4.50 mtr height dam with high flowing water with heavy water current.

Both the places the performance was excellent and appreciated by the concerned division EE, SE, CE.

We had to wait till 2011 to gain confidence and prove the product viability. The Maharashtra Irrigation dept, well appreciated the concept and started demanding to change from MS to SMC- FRP gates on large scale.

As on date we have, 150 bandharas, where this new concept is introduced on full scale and giving desired performance.

Barring one or two cases, due to fitment error and bandhara is non aligned properly we got negative results.

These type of gates are already used in Japan since 1960. And proved it’s utility. Today business in FRP gates in Japan is reduced due to no replacement required due to its enhance life and no theft; after first five years spent in full implementation.

Govt. of Maharashtra- Irrigation (Water Resources dept.) already given full fledge support and rate approvals and keenly introducing in new as well old bandharas.

We have also introduced this new concept in Kerala state.

First site where we have installed this shutter gates is in Trivandrum, (see photo graphs).and Trichi, (under construction).

Smc-FRP is widely accepted due to its life (no wear and tear), easy to handle, no weathering effect and threat to steal as zero scrap value.

What is – FRP?

- FRP is fiber reinforced plastics. Mixture of Glass Fiber mats# and Resin which gives high strength laminate.
- Light weight.
- Stronger in impact strength.
- Chemically resistance.
- Can be moulded in any shape and colour.

**Advantages**
- Being light wt – removing and fixing is easy.
- As removing and fixing is easy number of labor required at site will be 2-3 nos.
- Saving in labor rate.
- As rubber sealing provided on FRP needle on downstream side, due to compression of rubber under water pressure and wedging from the back side the water tightness is insured.
- At joint a simple water base sealant is applied which makes joints leak proof.
- Simple anchoring is required at rear side to hold the needle tight in the groove. (by way of wooden peg)

Proper rubber gasket between two needles /gates horizontally at interface of needle/gate and interlocking between two needles /gates insures proper fitment and desired water tightness.

**ASSUMPTIONS IN DESIGNING THE FRP NEEDLES/GATES SHUTTER**

1. **General**
   There are many general differences between FRP and traditional metallic materials that have been established for many decades. While carbon steels, stainless steels, and copper-nickel are metals, isotropic, and homogenous, FRP is a composite, orthotropic, and heterogeneous.
   Typical structural materials are normally divided into four basic categories: metals, polymers, Ceramics, and composites. A composite is basically a combination of two or more other structural materials. FRP is a composite of a polymer (the resin) and a ceramic (the glass fibers). When we define composites in this manner, we are normally talking about composites formed on the macroscopic level. If we looked at it from the microscopic perspective, we would have to consider most materials to be composites.
   By forming a composite such as FRP, an engineer can take advantage of the desirable properties of both constituent materials. In FRP, the glass fibers provide the strength and stiffness while the resin matrix acts as a binder providing impact resistance, compressive strength, and corrosion resistance.
   One property of FRP that results from it being a composite is it is non-isotropic whereas traditional metallic materials such as carbon steel are isotropic. When we say isotropic, we mean that the mechanical properties, such as strength and modulus, are the same regardless of direction. In a non-isotropic material, the properties associated with an axis passing through the material will depend on the direction it passes through the material.
   Thus, when you look up the mechanical properties of FRP material, you will often find not one modulus value, but several modulus values, including axial tensile modulus, hoop tensile modulus, and axial compressive modulus. It is extremely important when designing with composites such as FRP that the designer understands the non-isotropic properties of the material and takes this into account in the design process. Treating FRP as an isotropic material would be a poor assumption to make as a design engineer.

A second property that results by forming a composite such as FRP is that the material is now heterogeneous. That is, its composition varies as you move from point to point through the material.
   Traditional metallic materials, on the other hand, are homogenous. To overcome this, most Mechanical properties are averaged. This is achieved by treating the composite as an equivalent Homogeneous material and averaging the properties of the constituent materials. In other words, Instead of examining the composite on a micromechanical level, we eliminate the in homogeneity by moving to the macro mechanical level. Thus mechanical properties such as axial tensile modulus are sometimes referred to as the “effective” axial tensile modulus.

2. **Design Stresses**
   As with design temperature, there is a significant difference between typical allowable stresses in FRP and traditional metallic materials. With fiberglass, design stresses will vary depending on the type of stress. When designing based on short-term hoop strength against Internal pressure, the design stress may vary from 950 kg/sq.cm to 1600 kg/sq.cm.

**Typical Stresses**
SMC-FRP Typically -950 kg/sq.cm to 1600 kg/sq.cm. (From various manufacturers’ data).
3. Design Pressure
Another design variable that differs greatly is the design pressure. Most FRP process needles/gates which are acting as simply supported beam. In low height dams gates or KT wiers the load or pressure depends on the height of water level stored. While pressures in the thousands of kg-sq cm can be achieved with FRP, this is usually only seen in specialized applications such as flat surfaces and gates/needles.

Typical Design Pressures of Process / Material Typical Design Pressures
FRP Up to 50 -65 mm thickness can be used where uniform pressures are applied. Typical example is the Check Dam gate Removable gates, canal gates,

3.1 Density
It is well known that fiberglass reinforced plastics are much lighter than carbon steels and other Metallic piping materials. Densities of these materials are provided in the table below.

FRP – 1.40---1.60 gms/cc.
Source: FRP data is from numerous fiberglass manufacturers.

The FRP designed such way that it should take uniformly distributed load of 45 KN for the maximum water height of 4.50 meters.
A suitable M.S. frame is inside the FRP gates to give additional strength to avoid buckling effect as well flexing. Sufficient ribs are given both sides to form self-reinforcement.
Semi EPDM rubber strips are fixed on two sides and in between two needles/gates to act as seal.
Interlocking arrangement is provided to insure positive sealing between two needles/gates.
As it is proven concept in Maharashtra we also prove in Kerala state.
Composites are composed of:

- **Resins** - The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage. The most common resins used in the production of FRP are ISO (including orthophthalic-“ortho” and isophthalic-“iso”), vinyl esters and phenolics.
- **Reinforcements** - The primary function of fibers or reinforcements is to carry load along the length of the fiber to provide strength and stiffness in one direction. Reinforcements can be oriented to provide tailored properties in the direction of the loads imparted on the end product. The largest volume reinforcement is glass fiber.
- **Fillers** - Fillers are used to improve performance and reduce the cost of a composite by lowering compound cost of the significantly more expensive resin and imparting benefits as shrinkage control, surface smoothness, and crack resistance.
- **Additives** - Additives and modifier ingredients expand the usefulness of polymers, enhance their process ability or extend product durability. Each of these constituent materials or ingredients plays an important role in the processing and final performance of the end product.

<table>
<thead>
<tr>
<th>TYPICAL PHYSICAL PROPERTIES approved by CDA-wing of WRD, Maharashtra State, after Testing the gates, physically as well on stad pro-analysis</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chopped Strand Mat Reinforcement composite Properties</td>
<td></td>
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<tr>
<td>Tensile Strength</td>
<td>1600 kg / sq.cm</td>
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<td>Flexural Strength</td>
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<td>Compressive Strength</td>
<td>1850 kg / sq.cm</td>
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<td>Shearing Strength</td>
<td>1945 kg / sq.cm</td>
</tr>
<tr>
<td>Glass Content</td>
<td>Not less than 30%</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>0.5% @ max-72°F/72 hrs.</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.6</td>
</tr>
<tr>
<td>Izod Impact</td>
<td>1.65 KG-M.</td>
</tr>
<tr>
<td>Water pressure bearing capacity</td>
<td>45 KN /M²</td>
</tr>
</tbody>
</table>
Also the graph showing the Uniform load testing at College of Engineering- Pune, Hydraulic Civil Eng. Lab. Periodically the gates are tested for above value and also for UDL in College Of Engineering-Pune to insure the end performance is satisfactory. The performances at various places is found satisfactory and are having long term advantages so in Maharashtra it is being used widely. Following tests conducted at College of Engineering Pune, for UDL .found results are encouraging.
R & D Project
On

DEVELOPMENT OF STANDARDISED DESIGN AND
DRAWINGS OF A BRIDGE CUM BANDHARA SYSTEM

Final Consolidated Report

Volume-III Government GRs

Submitted to

Director Project-II
National Rural Roads Development Agency
5th floor, 15 –NBCC Tower, Bhikaji Cama Place
New Delhi -110066

Principal Investigator
Dr R K Ingle

Technical advisor
Shri P L Bongirwar

Department of Applied Mechanics
Visvesvaraya National Institute of Technology, Nagpur - 440 010
There are various GR from Maharashtra Government on water and bandhara systems and they are available on Govt web site www.Maharashtra.gov.in. The informative step by step procedure on searching the GR is given below.

Step 1: Search in Google [www.maharashtra.gov.in](http://www.maharashtra.gov.in)

Step 2: Click on the [http://www.maharashtra.gov.in/](http://www.maharashtra.gov.in/)government resolution, we get the following screen. On right top select “Marathi / English.”

Step 3: Enter GR no or search from department name or key wards etc. In the above the GR no 20070124193424001 has been searched.

Step 4: View / Download the required GR.
Information on few GR is given below.

GR NO. 20070124193424001

GR NO. 20070614121939001


Maharashtra Shasan

Jal Sanshadh Vimbhag,

Shasan Niyaath Kr. Mangalsh 9006/(4756/2006)/Loksahiti(Kame)

Mangalsh, Mumbai 400 032.

Dinank - 24.01.2007

Shasan Niyaath

GR NO. 20070614121939001

Maharashtra Shasan

Jal Sanshadh Vimbhag

Shasan Niyaath Krman Maharastra Jalashtree Swabh War Prakruthy-1006/(688/06)/Loksahiti(Kame)

Dinank 14 Jnu. 2007
गृही बापर संस्थाना देशवाट येणार्या देखभाल
dूरस्त्याचे अनुदानाधीनते

महाराष्ट्र शासन
जलसंस्थान विभाग
शासन निर्णायक क्र. पावसे २००७/(३२३/२००७)/सिव.व. (धौ.)
मंत्रालय, मुंबई ४०० ०२२.
दिनांक: २२ जून, २००७

पत्र: पावसांचे विषयांत शासन क्र. पावसे-२००७/(४४२/२००७)/सिव.व. (धौ.), दिव. २३.७.२००७

सिविल व्यवस्थापकात शेतक-याचा सहभाग
पावसांचे प्रकल्पांचे शेतक-याचा सहकारी
पाणी वापर संस्थाना स्थापन करत सिविल क्षेत्र
सिविल व्यवस्थापकाली वस्त्रांकडून हल्लोंतरित
करणारायण.

महाराष्ट्र शासन
पावसांचे विभाग
शासन निर्णायक क्र.पावसे/२००७/(५७६)/सिव (धौ)
मंत्रालय, मुंबई-४०० ०२२.
दिनांक: ५ जून, २००२.

GR NO. 200805271523530001

शासन निर्णाय

महाराष्ट्र जलक्षेत्र सुधार प्रकल्पांतर्गत
पाणीवापर संस्थाना कार्यालयात
इमारत बांधून देणे बाबत

महाराष्ट्र शासन
जलसंस्थान विभाग,
मंत्रालय, मुंबई ४०० ०२२.
शासन क्रमसूची २००७/(४६३/०७)/लाक्ष्यविकास (कामे)
दिनांक २७ मे २००८
महात्मा फुले पाणी वायर संस्था अभियान व त्या अंतर्गत पूर्णस्तनक अहिल्याधेकी होकर पाणी वायर संस्था व्यवस्थापन पुरस्कार स्पर्धा -

महाराष्ट्र शासन
जलसंपदा विभाग
शासन निर्णय क्र. सीडीए-१००५/(४७९/२००५)/लाखौवी(कामे)
मंत्रालय, मुंबई-४०० ०३२
दिनांक : २१ आगस्ट, २००९

वाचावे : जलसंपदा विभाग, शासन निर्णय क्र. सीडीए-१००५/(४७९/२००५)/
लाखौवी (कामे), दि. २१ आगस्ट, २००९

GR NO. 20090821170902001

महात्मा फुले पाणी वायर संस्था अभियान व त्या अंतर्गत पूर्णस्तनक अहिल्याधेकी होकर पाणी वायर संस्था व्यवस्थापन पुरस्कार स्पर्धा राज्यस्तरीय व राज्यस्तरीय छाननी समिती गठित करण्याबाबत

महाराष्ट्र शासन
जलसंपदा विभाग
शासन निर्णय क्र. सीडीए-१००५/(४७९/२००५)/लाखौवी(कामे)
मंत्रालय, मुंबई-४०० ०३२
दिनांक : २१ आगस्ट, २००९

वाचावे : जलसंपदा विभाग, शासन निर्णय क्र. सीडीए-१००५/(४७९/२००५)/
लाखौवी (कामे), दि. २१ आगस्ट, २००९
महाराष्ट्र शासन
जलसंपदा विभाग
शासन निर्णय क्र.सीडीए-2010/(28/2010)/लाखविज(कामे)
मंत्रालय, मुंबई-400 032
दिनांक: 15 फेब्रुवारी, 2010

वाचा: शासन निर्णय, जलसंपदा विभाग, क्र.सीडीए-1005/ (477/05)/
लाखविज(कामे), दि, 21.8.2009

GR NO. 201406251513139627

एक घने मीटर प्रति सेकंड किब्बा त्वचेशा कभी विसर्ग ५०
क्षमतेच्या जितरिका/उपजितरिका/लापुजितरिकांची कामे
पाणी वापर संस्था स्थापन झाल्यावर हाती खेणेबाबत.

महाराष्ट्र शासन
पाटलिपुत्र विभाग.
शासन परिषद्ध क्रमांक : सीडीए २००२/(३२८/२००२)/लाखविज(कामे)
दिनांक : १७/२/२००२.

वाचा :- १) शासन निर्णय क्र.पावारसे/1002/(२४१८/२००२)/सिं.प्र., (शोध), दिनांक २३.६.२००२.
२) शासन परिषद्ध क्र.सोडीए १००२/(१३८/२००२)/लाखविज(कामे), दिनांक १३.८.२००२.

GR NO. 201412061015068426

सर्वसाधारण पाणी - टंकाईयुक्त महाराष्ट्र २०१९
अंतर्गत टंकाई परिसंचायाच्या कार्यक्रमाशी
मात करणासाठी जलयुक्त शिवाय अभियान
राष्ट्रीयवाहत.

महाराष्ट्र शासन
जलसंपदा विभाग
शासन निर्णय क्रमांक: जलन-2014/प्र.क्र.203/जल-७
मंत्रालय, मुंबई-400 032.
तारीख: ५ डिसेंबर, 2014
R & D Project
On
DEVELOPMENT OF STANDARDISED DESIGN AND
DRAWINGS OF A BRIDGE CUM BANDHARA SYSTEM

Final Consolidated Report

Volume-IV Typical Drawings

Submitted to

Director Project-II
National Rural Roads Development Agency
5th floor, 15 –NBCC Tower, Bhikaji Cama Place
New Delhi -110066

Principal Investigator
Dr R K Ingle

Technical advisor
Shri P L Bongirwar

Department of Applied Mechanics
Visvesvaraya National Institute of Technology, Nagpur - 440 010
General Notes for Guidance of Engineers

Introduction

Bridge Cum Bandhara- Maharashtra and few states have tradition of Bridge Cum Bandhara. It is a dual purpose structure which can be used to cross the river and as water storage structure to create storage up to 3.5 m by tapping the post monsoon flow. Typical Bridge cum Bandhara Structure are shown below.

The objectives of these structures are
i. To tap post monsoon flow to create storage up to 3.5 m The storage is created by fixing needles/gates between bandhara piers to tap last flow
ii. Stored water is used for drinking and irrigation
iii. It enhances the ground water which then is available for irrigation as well as for drinking water
iv. Surplus percolated water out of irrigation activity again joins the river which is tapped and reused for irrigation
v. Such stored water can be used for artificial recharging the nearby bore wells as well as open well to augment ground water

Content of this booklet

The booklet contains set of drawings for the following cases.

![Diagram of Bridge Cum Bandhara]

The above set of drawings evolved for converting existing bridge into bridge cum bandhara can also be used for the new bridge which is planned or under construction. Bandhara in these
drawings are secondary structure hence stability of main bridge will not be affected. However additional obstruction created has to be considered.

This booklet contains following drawings:
  i. Standard design of Bandhara structure for above cases
  ii. Set of drawings for needles /gates etc

Additional instructions
  i. The permission from irrigation department/competent authority be taken so that there is no duplication of storage structure.
  ii. The incremental cost should be within the financial norms.
  iii. we have proposed steel gates but alternate to this FRP gates are also developed.
  iv. The gates must be fixed in the last phase of monsoon and must be removed much before onset of monsoon to avoid damage to main structure. Study of rainfall pattern is done to decide time table for placing of gates.
  v. It is advised to use mechanical simple equipment which can be got locally made or use Hydra Crane to expedite fixing and removal operations.
  vi. Proper fenced area with fencing with arrangement to store needles in vertical position need to be made for proper protection.
  vii. Rubber seal may need frequent replacement.
  viii. Mitigate measures such as caution board, realigning the cart track, foot Bridge etc if required will have to be provided.
  ix. For any clarification you may contact Shri P L Bongirwar, technical advisor or Dr R K Ingle, coordinator.
<table>
<thead>
<tr>
<th>SN</th>
<th>Drawing</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GN-01</td>
<td>Type Plan for Bridge cum Bandhara - general Notes</td>
</tr>
<tr>
<td>2</td>
<td>RC-01</td>
<td>Details of Bandhara on soft soil with cutoff walls (General Arrangement)</td>
</tr>
<tr>
<td>3</td>
<td>RC-02</td>
<td>Details of Bandhara on soft soil with cutoff walls (RCC details)</td>
</tr>
<tr>
<td>4</td>
<td>WU-01</td>
<td>Details of Bandhara on weir (U/S slope) for buried rock (General Arrangement)</td>
</tr>
<tr>
<td>5</td>
<td>WU-02</td>
<td>Details of Bandhara on weir (U/S slope) for buried rock (RCC Details)</td>
</tr>
<tr>
<td>6</td>
<td>WD-01</td>
<td>Details of Bandhara on weir (D/S slope) for buried rock (General Arrangement)</td>
</tr>
<tr>
<td>7</td>
<td>WD-02</td>
<td>Details of Bandhara on weir (D/S slope) for buried rock (RCC Details)</td>
</tr>
<tr>
<td>8</td>
<td>RB-01</td>
<td>Details of Bandhara on Exposed Rock (General Arrangement)</td>
</tr>
<tr>
<td>9</td>
<td>RB-02</td>
<td>Details of Bandhara on Exposed Rock (RCC Details)</td>
</tr>
<tr>
<td>10</td>
<td>TBB-01</td>
<td>RCC details of structures for tie beam Bandhara (General Arrangement)</td>
</tr>
<tr>
<td>11</td>
<td>TBB-02</td>
<td>RCC details of structures for tie beam Bandhara</td>
</tr>
<tr>
<td>12</td>
<td>G-1A</td>
<td>Gate for 3m depth of water with rectangular box section</td>
</tr>
<tr>
<td>13</td>
<td>G-1B</td>
<td>Gate for 3m depth of water with Angle / Channel section</td>
</tr>
<tr>
<td>14</td>
<td>G-1C</td>
<td>Single Gate for 3m depth of water with Angle / Channel section</td>
</tr>
<tr>
<td>15</td>
<td>G-1D</td>
<td>Single Gate for 3m depth of water with rectangular box section</td>
</tr>
<tr>
<td>16</td>
<td>G-1E</td>
<td>Gate for 3m depth of water with angle / channel section vertically spanning between ISMB 100</td>
</tr>
<tr>
<td>17</td>
<td>G-1F</td>
<td>Gate for 3m depth of water with rectangular box section vertically spanning between ISMB 100</td>
</tr>
<tr>
<td>18</td>
<td>G-2A</td>
<td>Gate for 2m depth of water with box section</td>
</tr>
<tr>
<td>19</td>
<td>G-2B</td>
<td>Gate for 2m depth of water with Angle / Channel section</td>
</tr>
<tr>
<td>20</td>
<td>G-2A</td>
<td>Single Gate for 2m depth of water with Angle / Channel section</td>
</tr>
<tr>
<td>21</td>
<td>G-2B</td>
<td>Single Gate for 2m depth of water with Box section</td>
</tr>
<tr>
<td>22</td>
<td>G-3A</td>
<td>Single Gate for 2m depth of water with Angle / Channel section</td>
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<tr>
<td>23</td>
<td>G-3B</td>
<td>Single Gate for 2m depth of water with rectangular box section</td>
</tr>
<tr>
<td>24</td>
<td>G-4A</td>
<td>Single Gate for 3m depth of water with Angle / Channel section (WIDTH 3.3M)</td>
</tr>
<tr>
<td>25</td>
<td>G-4B</td>
<td>Single Gate for 3m depth of water with BOX section (WIDTH 3.3M)</td>
</tr>
<tr>
<td>26</td>
<td>MP-1</td>
<td>Type plan for intermediate pier of BCB 2 lane deck – General Arrangement</td>
</tr>
<tr>
<td>27</td>
<td>MP-2</td>
<td>Type plan for intermediate pier of BCB 2 lane deck – RCC Details</td>
</tr>
<tr>
<td>28</td>
<td>DA-1</td>
<td>Typical details for debris arresters</td>
</tr>
</tbody>
</table>
ELEVATION FOR GATE PANEL

SECTION AT X-X

SECTION AT Y-Y

WEIGHT OF SINGLE NEEDLE

<table>
<thead>
<tr>
<th>SR. NO.</th>
<th>DESCRIPTION</th>
<th>NOS.</th>
<th>SIZE/LENGTH</th>
<th>UNIT WEIGHT</th>
<th>WEIGHT</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>SKIN PLATE 3mm THK.</td>
<td>1</td>
<td>2.1 x 1.0</td>
<td>23.55 Kg/sq.m</td>
<td>49.46 Kg</td>
</tr>
<tr>
<td>2</td>
<td>LONGITUDINAL ISMC 75</td>
<td>1</td>
<td>2.1</td>
<td>6.80 Kg/m</td>
<td>14.28 Kg</td>
</tr>
<tr>
<td>3</td>
<td>END VERTICAL ISA 45x45x4</td>
<td>2</td>
<td>0.5</td>
<td>2.70 Kg/m</td>
<td>2.70 Kg</td>
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<tr>
<td>4</td>
<td>LONGITUDINAL ISA 45x45x5</td>
<td>2</td>
<td>2.1</td>
<td>3.40 Kg/m</td>
<td>14.28 Kg</td>
</tr>
<tr>
<td>5</td>
<td>LIFTING HOOKS</td>
<td>2</td>
<td></td>
<td>D.10 Kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TOTAL WEIGHT</td>
<td>80.82 Kg</td>
<td></td>
</tr>
</tbody>
</table>

NOTES
1. ALL DIMENSIONS ARE IN MM AND LEVELS ARE IN METERS UNLESS SPECIFIED OTHERWISE.
3. WELDING SHALL CONFORM TO IS: 816-1959.
4. ALL ELECTRODES SHALL CONFORM TO IS:814 (PART I) 1974.
5. ALL M.S. BLACK BOLTS AND NUTS SHALL CONFORM TO IS: 1563 (PART 1 TO 3) 1984.
7. ALL DIMENSIONS ARE TO BE CHECKED AND VERIFIED BY SHOP LAYOUT.
8. PAINTING: ALL EXPOSED SURFACES STRUCTURES AFTER FABRICATION SHALL BE PAINTED AS PER RESPECTIVE SPECIFICATION.
9. ALL THE STRUCTURES AFTER FABRICATION SHALL BE CONTROLLED AND ASSEMBLED IN SHOP TO MATCH THE MATCHING DIMENSIONS AND CONNECTIONS OF DIFFERENT ERECTION MARKS BEFORE DESPATCH TO SITE.
10. PROPER RUBBER GASKET OF 10MM THICK PROPERLY GLUED SHALL BE PROVIDED AT RELEVANT PLACES TO ARREST LEAKAGE OF WATER.
11. NEEDLES SHALL BE PAINTED EVERY YEAR BEFORE USE.

DEPARTMENT OF APPLIED MECHANICS
VISVESVARAYA NATIONAL INSTITUTE OF TECHNOLOGY
NAGPUR.

TYPE DETAILS FOR STEEL GATES ON BRIDGE CUM BANDIARA.
SINGLE GATE FOR 1M WATER DEPTH WITH ANGLE/CHANNEL SECTION

NATIONAL RURAL ROAD DEVELOPMENT AUTHORITY
MINISTRY OF RURAL DEVELOPMENT, GOVT OF INDIA
R&D PROJECT F No P-17029/04/2007-P-II

TECHNICAL ADVISOR: SHRI P L BONGIRI
FORMER PRINCIPAL SECRETARY, RMD MAHARASHTRA

CHECKED BY: SHRI D K KANHIA
CHIEF ENGINEER (RETD)
RMD MAHARASHTRA

DESIGNED BY: DR R K INGLE

DRG No.: – G-3A
DATE: DEC-2015