



**GOVERNMENT OF INDIA  
MINISTRY OF ROAD TRANSPORT & HIGHWAYS**

**Indian Academy of Highway Engineers  
(campus), A-5, Sector-62,**

**No. RW-NH-34066/59/2015-S&R(B)**

**Dated: April 18, 2017.**

**To:**

1. The Chief Secretaries of all the State Governments / UTs.
2. The Principal Secretaries / Secretaries of all States / UTs Public Works Department dealing with National Highways, other Centrally sponsored schemes.
3. The Engineers-in-Chief and Chief Engineers of Public Works Department of States / UTs dealing with National Highways, other Centrally sponsored schemes.
4. The Director General (Border Roads), Seema Sadak Bhavan, Ring Road, Delhi 110 010.
5. The Chairman, National Highways Authority of India, Plot G-5 & 6, Sector-10, Dwarka, New Delhi 110 075.
6. The Managing Director, NHIDCL, PTI Building, Parliament Street, New Delhi - 110 001.
7. The Chairman, inland Waterways Authority of India, A-13, Sector-1, Noida.

**Sub: Construction of a bridge cum barrage structures on National highways serving dual purposes i.e. to cross the water body as well as to store water on upstream side -reg.**

**Sir,**

In order to save and optimally utilize scarce natural resources like water to cater for drinking (human/animals) and irrigation needs besides other purposes, Ministry has decided that henceforth, the bridge sites for all new bridge structures and old abandoned bridge structures having total length 100 m or less can be used for tapping of water for serving dual purposes i.e. (a) to cross the water body, and (ii) to store water, provided they are technically feasible as decided by the executive agencies.

State PWD will submit the proposal for the construction of above bridge structures along with their recommendations to the Ministry for approval. It must be accompanied by a "No Objection Certificate" (NOC) duly signed by Principal Secretary/Secretary (PWD) after consulting all concerned Central/State departments like Irrigation, Water Resources, Environment, and Local Administration etc. The proposal will be considered in the Ministry subject to its compliance with the technical details enclosed herewith at Annex "A".

**Encl.: Annex "A"**

(Sanjay Garg),  
Superintending Engineer (S,R&T) (Bridges),  
For Director General (Road Development) & SS.  
E-mail: [sanjay.garg1@nic.in](mailto:sanjay.garg1@nic.in)

**Copy to:**

1. All Chief Engineers / Superintending Engineers in Ministry of Road Transport & Highways.
2. All Joint Secretaries in the Ministry.
3. All ROs & ELOs of the Ministry.
4. The Secretary General, Indian Roads Congress.
5. The Director, IAHE.
6. Technical circular file of S&R (B) Section.
7. NIC for uploading on Ministry's website under "what's new".

**Copy for kind information to:**

1. PS to Hon'ble Minister (SRT&H) / PS to Hon'ble MOS (SRT&H).
2. Sr. PPS to Secretary (RT&H).
3. PPS to DG (RD) & SS.
4. PPS to SS & FA.
5. PPS to Coordinators — I/II/III.



(Sanjay Garg),  
Superintending Engineer (S,R&T) (Bridges),  
For Director General (Road Development) & SS.  
E-mail: [sanjay.garg1@nic.in](mailto:sanjay.garg1@nic.in).



**Annex 'A'**

**(Enclosure to Ministry's letter no. No. RW-NH-34066/59/2015-S&R (B)  
dated 18.04.2017)**

1. A bridge structure needs to be constructed on National Highway Network to serve dual purposes i.e.
  - a. to cross the water body; and
  - b. to store water, a scarce natural resource similar to the tradition existing in some of the South Indian States.
2. Total length of the proposed bridge cum barrage structures should be 100 m or less. After getting enough experience, the limit of 100 m will be reviewed.
3. The water can be stored on upstream side up to a height of 3.50 m or less. The height of tapped water shall be fixed in such a way that no additional land acquisition is needed.
4. In case of technical feasibility, Ministry will bear the entire cost of construction as well as operation and maintenance cost during first three years, for such bridge cum barrage structures on any National Highways. Thereafter, their operation and maintenance cost will be borne fully by the State Government (in which the structure is falling) from their own resources. An undertaking to this effect must be attached with the proposal by State PWD on behalf of the State Finance Department.
5. The proposed bridge cum barrage structures should be cost effective and easy in operation & maintenance. Incremental cost of such structure should fulfil the financial norms prescribed by State Government for storage structures.
6. The bridge cum barrage structures will be designed for all applicable forces defined under IRC:6 and additional forces resulting from storage water.
7. The barrage structure need to be constructed on downstream side of bridge structure and the water can be stored upstream by making secondary piers between bridge piers in which gates are fixed in the last phase of monsoon to create storage of water (*typical photos are enclosed*). The tapped water can be utilized to cater for drinking (human/animals) and irrigation needs besides other purposes such as recycling the percolated water in the irrigated area. It may also be used for artificial recharging the nearby bore wells as well as open well to augment ground water.
8. To safeguard navigation potential of river/canal, in the case of the bridges across National Waterways, the navigational clearance must be provided in line with Ministry's circular issued vide letter no. RW/NH-334050/112015-S&R(B) dated 30.11.2016. In case of waterways other than National Waterways also each horizontal span for such dual-purpose bridges should be kept as 20 meter. Whereas, the vertical clearance for each span of such dual-purpose bridges should be taken either as 5 meter above the full tank level (or water surface level) or minimum vertical clearance above HFL determined as per IRC:5-2015,



whichever is higher. The secondary pier system used for storage of water is a secondary structure and is not connected to main bridge which can be dismantled for the zone affecting the ship movement (such as lock and gate zone) as and when waterway is developed and hence these restriction of span and clearance is not applicable to this secondary pier system. Also, for waterways other than National Waterways also, though it is not a legal necessity, the constructing agencies/highway authority are advised to take guidance of IWAI or the concerned State Govt to understand the present and future navigational potential of the waterway and make sincere effort to provide practically possible maximum horizontal and vertical navigational clearances.

9. The bridge cum barrage structures will be designed as water retaining structure and hence, leakage of water through ground by percolations or various components should be minimised by adequate and suitable measures.
10. Time for fixing and removal of the gates in secondary pier system will be decided judiciously based on rainfall data and rain pattern in close coordination with State Irrigation department so that (a) no damage to bridge structure due to floods or else, and (b) to reap out the benefit of dual purpose bridge system in optimized manner.
11. Old abandoned bridges on National Highways having total length 100 m or less are also allowed to be used on dual purpose bridge structures, by State/Central Government authorities.
12. Appropriate provisions for suitable mitigated/relief measures for local affected people such as warning signs, footbridge for ease in crossing the back water zone (if required) or realigning the existing cart track need to be considered and included as an integral part of the project.
13. Paper no. 496 titled as "Dual Purpose Bridge Structure – Crossing and Storage – Need of the Day" published in the Journal of the Indian Road Congress is attached herewith for reference and guidance.
14. Annual feedback need to be submitted by executive agency regarding its functional and structural performance.
15. However, in the beginning, pilot projects in the interested states can be considered subject to their technical feasibility, and prior consent from all concerned local departments.

\*\*\*\*\* **END** \*\*\*\*\*



**Bridge-Cum-Bandhara a/c Addan river Tq. Ghatanji Distt. Yavatmal**



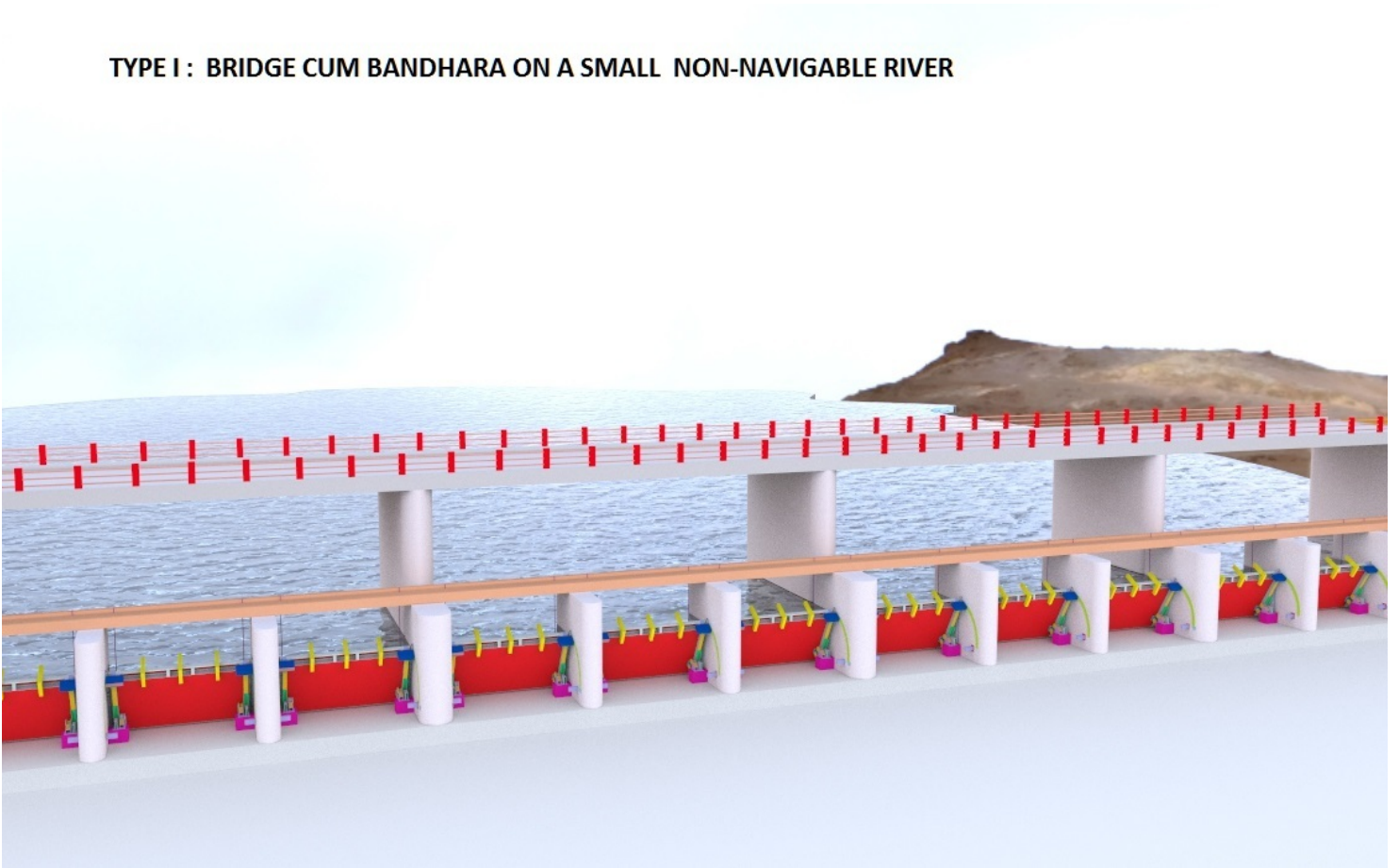


**Bridge-Cum-Bandhara-a/c suryaganga river on SH-6-Warkhed-Bharswadi-Akhatwada-Marda (M.D.R.-39) road near village-Warkhed**

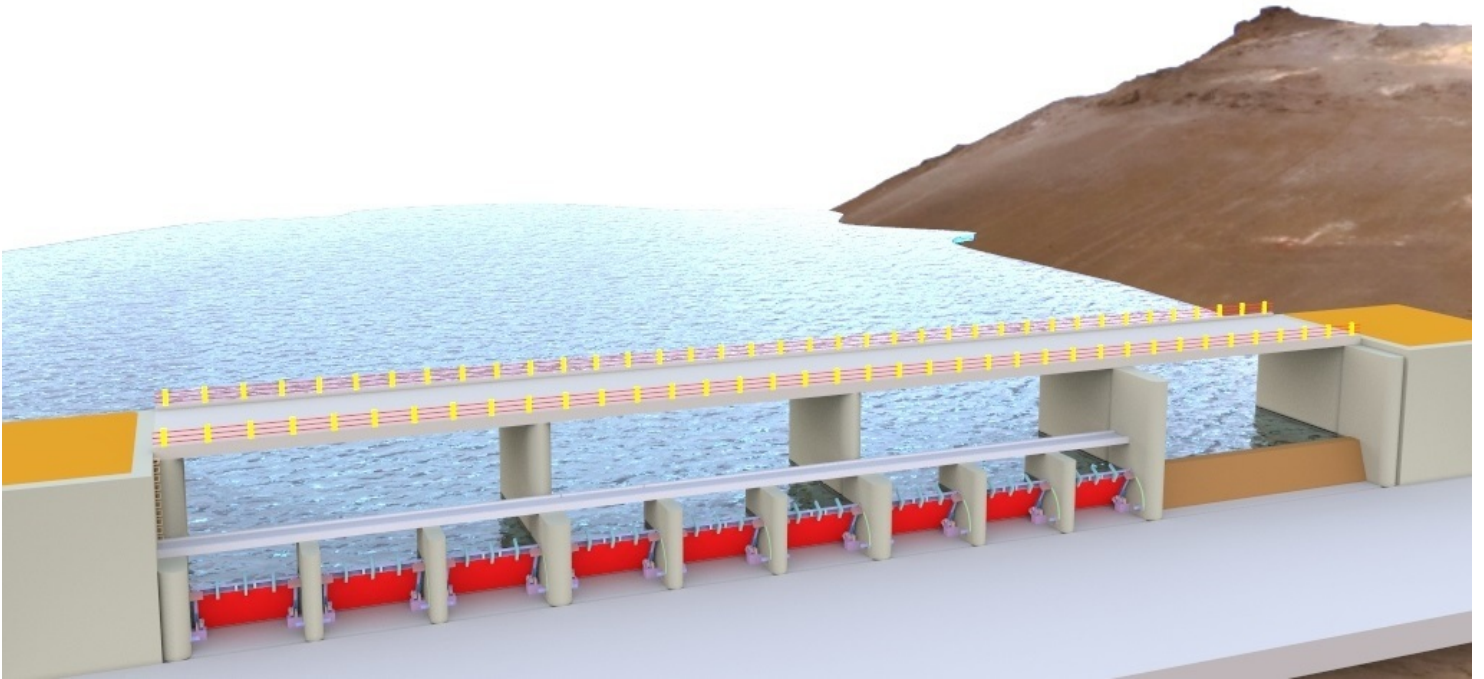


Typical arrangement of Bandhara piers

**TYPE I : BRIDGE CUM BANDHARA ON A SMALL NON-NAVIGABLE RIVER**

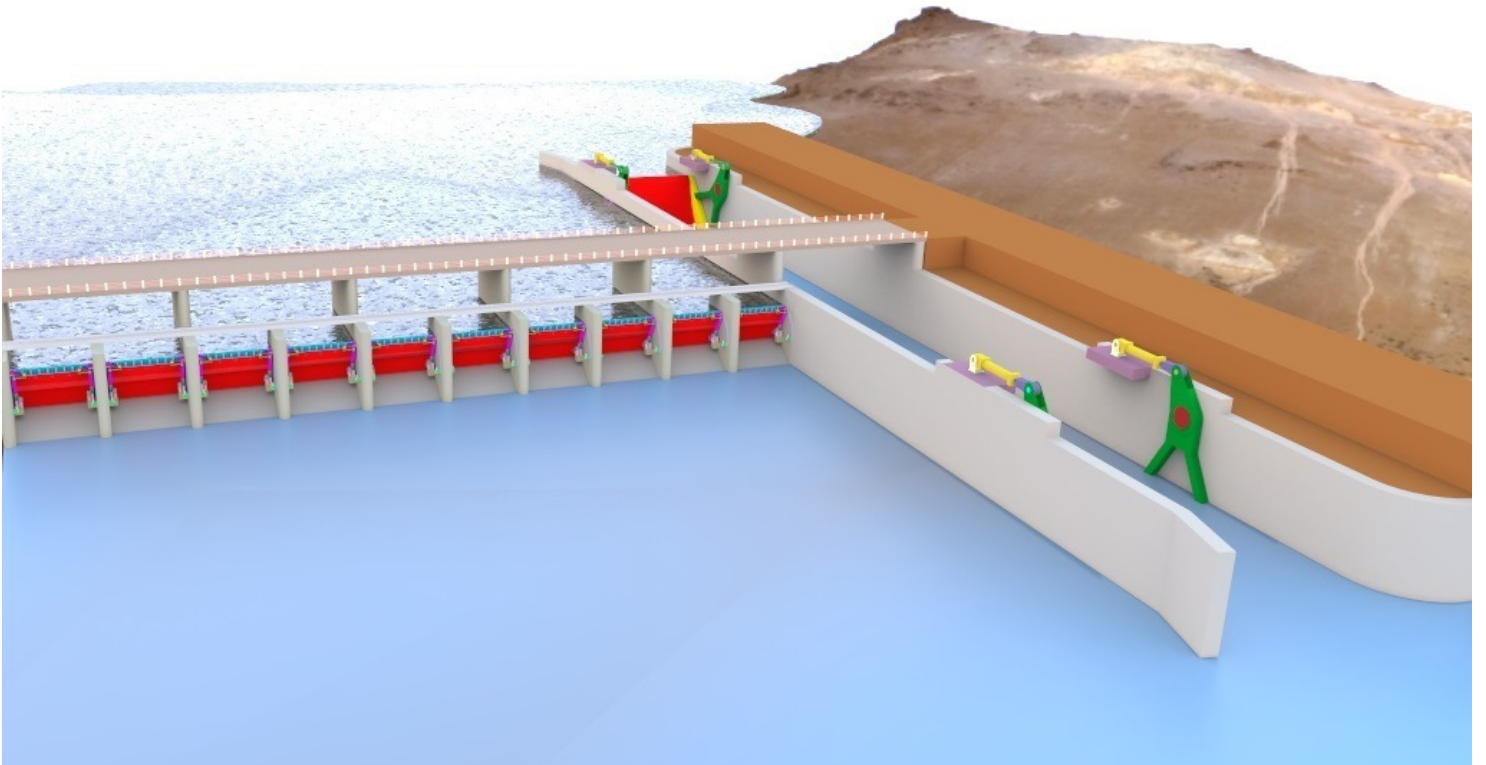


**TYPE II : BRIDGE CUM BANDHARA WITH PROVISION FOR NAVIGATION LOCK**





### TYPE III - BRIDGE CUM BANDHARA WITH NAVIGATION LOCK



Paper No.496<sup>†</sup>

**DUAL PURPOSE BRIDGE STRUCTURE – CROSSING AND  
STORAGE – NEED OF THE DAY**

By

**P.L. BONGIRWAR\*, DR. A.G. NAMJOSHI\*\* & M.M. JAISWAL\*\*\***

**CONTENTS**

	<i>Page</i>
1. Introduction	418
2. Water Shortage	418
3. Water Retaining Structure	420
4. Percolation Tanks, Malgujari Tanks and Natural Lakes	420
5. Bandhara : Kolhapur Type Weir	421
6. Bridge-cum-Bandhara	422
7. Need of New Design of Bridge-cum-Bandhara	424
8. Steel Needles/Gates	425
9. Colcrete	425
10. Pradhan Mantri Gram Sadak Yojana (PMGSY)	427
11. Evolution of Type Plan of Bridge-cum-Bandhara	427
12. Type Plan Cases	429
13. Type Plans and Design Philosophy for New Bridge-cum-Bandhara	432
14. Converting Existing Medium and Minor Bridge into Bridge-cum-Bandhara	437
15. Vented Causeway-cum-Bandhara	441
16. Use of Type Plan	444
17. Cost Comparison	444
18. Case Studies	446
19. Probable Modifications	448
20. Conclusion	451

<sup>†</sup> Written comments on this Paper are invited and will be received upto 2nd January, 2004.

\* Retd. Additional Metropolitan Commissioner (Engineering), MMRDA, Mumbai.

\*\* Consulting Engineer, Dr. A.G. Namjoshi & Associates, Nagpur.

\*\*\* Executive Engineer, MSRDC, Wardha.



## 1. INTRODUCTION

The Bridges are mainly constructed for crossing the rivers during monsoon period. They are, therefore, designed so as to have enough opening to enable water to flow conveniently and the obstruction caused by piers and other structures is minimum. There is, however, a need to re-design the Bridge structure so as to also serve as water storage structure. It is possible to design these bridges for dual purpose, i.e. "Bridge-cum-Bandhara" to have storage upto 4.5 to 5.00 m. The post monsoon flow specially the flow in the river after September is proposed to be used to create storage. Such structure would also be useful in Zone where there is heavy irrigation and percolated water again comes in the mainstream. This percolated water can be stored and recycled for irrigation purpose. Generally after the main monsoon one or two showers usually occurs in the month of September to February and this water also can be stored in all these structures. Appropriate gates and secondary piers are needed to the bridge structure so as to plan it as a storage structure, i.e., Bridge-cum-Bandhara. Gates/Needles should be detachable which can be manually fixed after monsoon or could be automatic. Standard type plans have been evolved for varying situations such as rock exposed, rock at shallow depth or silty clayey soil in bed.

The standard type plans also have been evolved to convert existing bridge structure into Bridge-cum-Bandhara. The water thus stored is available for irrigation and also for the purpose of augmenting drinking water supply to villages. It also recharges ground and adjoining wells and thereby improves water supply substantially so as to meet acute drinking water shortage in the summer.

The Government of Maharashtra has prescribed some norms related to storage for expenditure to be incurred on water storage structure. Several Bridge-cum-Bandhara using new type plans have been successfully constructed and the cost is well within the norms prescribed by the Government. Due to recently constructed BCB additional irrigation facilities has been created and drinking water problem of several villages has been solved and at least a population of 2 lakh has been benefited. Percolated water from irrigation zone when tapped is again recycled and used for fruitful purpose. New construction material such as colcrete, sophisticated curved light gates, simple lifting mechanism have also been extensively used for the construction and operation of these dual purpose structure. Similarly several different arrangement such as anchoring of pier in bed so that it acts as cantilever, gravity structure consisting of heavy weir and anchoring of pier in weir, cut off to reduce percolation, counterfort type pier where stability is ensured due to dead weight of water etc., have been successfully tried. Because of optimum design of structure, it is possible to construct such structure well within the prescribed norms and has proved useful for large number of villages and population.

## 2. WATER SHORTAGE

In most of the urban areas, water supply is much less compared to the needs. More than 50 per cent district headquarters are suffering due to water shortage and the shortage is to the extent of 30 to 40 per cent of the requirement. There are several

district headquarters where the water supply is on alternate day or once in a week and, that too, only for a few hours. In some of the districts in Rajasthan, drinking water is required to be supplied by special trains. A study has indicated that 8 out of 20 river basins are water deficit, which has threatened lives and livelihood of 200 million people. In Bangalore city, water is required to be brought from a distance of 100 km involving huge pumping cost. An estimate has indicated that India's natural precipitation (snow fall and rains) is around 4000 billion cum. This translates into 1869 billion cum water in the rivers and, out of which, 690 billion cum is used in major tanks and 1179 billion cum flows into the sea. The technology of tube well and availability of high capacity pumps along with subsidized power for the agricultural sector has resulted into large scale pumping of under-ground water and as a result the depth of ground water table in the last five years has gone from 15 m to 80 m. In a rich horticulture area of Nagpur and Amravati districts, it is reported that the average depth of bore wells about 30 years back was 25 m to 30 m and now, the average depth of bore wells has gone to 80 m to 100 m. Even though there is exploitation of ground water for irrigation, drinking and other purposes, there is less emphasis on ground re-charging. The re-charging could be by natural process or by artificial process. It can be concluded that the natural percolation system for ground re-charging is inadequate to satisfy the demand and a time has come whereby we have to mostly make use of artificial re-charging and other means of conservation of water to meet the demands. The shortage of water could be revealed from the following figures:

Sr. No.	Name of City	Need in M. lit/Day	Availability	Shortfall in M. lit/Day
1.	Bangalore	840	705	135
2.	Bhopal	335	265	70
3.	Chennai	300	195	105
4.	Delhi	3,830	2950	880
5.	Indore	318	184	134
6.	Jabalpur	239	144.5	94.5
7.	Jaipur	349	36	313
8.	Kolkata	2,258	1568	690
9.	Lucknow	560	440	120
10.	Mumbai	4,000	2970	1,030
11.	Visakhapatnam	305	159	146
12.	Hyderabad	956	770	186

The number of villages requiring tankers during the summer months is increasing day by day. The Government is required to spend a very huge amount on supplying drinking water to the village population. A serious thought is, therefore, required to be given to increase the availability of water to meet the needs and also more emphasis has to be given to various means available for re-charging of ground, so as to improve the availability of ground water which can be drawn for various purposes.

### 3. WATER RETAINING STRUCTURE

The need for storage of water for various purposes, such as, irrigation, water supply, etc., is continuously felt. To meet this need, construction of dams is done. Large dams to store water have been successfully constructed and completed. It has brought large area under irrigation, thereby, increasing the agricultural production. The Government has also defined what is minor, medium and major irrigation project. It is true that the cost of creating irrigation facility per acre for a major irrigation project is less. However, due to environmental awareness, construction of major irrigation projects is facing opposition. It is argued that a major irrigation project results into extensive submergence. It also involves rehabilitation of large population resulting into human sufferings. Since the flow of water in the river after monsoon is minimum and since the flow of water is controlled by the dam, it reduces the water percolation in the river basin downstream to the dam thereby, threatening the water availability for the villages of the area downstream to the dam. It is a common practice to let out water through the dams especially, in the months of February to June to meet this need. Dams are mainly constructed to meet the needs of irrigation. Generally 10 to 15 per cent of water is used for industries and drinking water. There are very few cases where the dams have been constructed only to meet the needs of large industrial area or for the purpose of domestic water supply. There are also a few cases where the dams have been constructed to meet the needs of thermal power stations. However, it is observed that in several cases where the dams have been constructed mainly with objective of creating irrigation facilities, but later on noting the shortage of drinking water, the original objective is required to be changed and these structures now serve mostly the need for drinking water. The need of drinking water is continuously increasing with increase in population in the urban area and reduction in the availability of ground water.

### 4. PERCOLATION TANKS, MALGUJARI TANKS AND NATURAL LAKES

In the districts of Bhandara, Chandrapur and Gadchiroli of Maharashtra there are large number of tanks commonly known as Malgujari tanks. These are rice-growing districts and the soil is silty clayey having very less permeability. To get best yield of rice crop, there is a need to irrigate crops at least 5 to 6 times. In order to ensure availability of water, the concept of Malgujari tank was developed. The natural tank is made at suitable locations with a small spill in the earthen bund with or without a hume-pipe or steel gate. This is known as 'Sandva' or waste weir. A small area of 20-30 acres can be irrigated. An assessment has revealed that there are about 4000 Malgujari tanks in each of these three districts, each catering to the need of about 20

acres. Since the natural soil is silty clayey, water is not lost due to percolation and is available for saving crops.

Large numbers of percolation tanks are constructed in Maharashtra through various schemes including the Employment Guarantee Scheme. The purpose of adoption of percolation tanks is to augment ground water in the area upstream of the tank and make this available for irrigation through open well or tube well. In the percolation tank, simple theory of prevention of seepage of water is made use of. The cut off is made in black cotton soil and in the spill section either concrete or stone masonry is used. The natural B.C. soil which is highly impermeable soil is made use of filling the cut off. The cut off invariably touches either hard rock or soft rock. The site where rock is available at shallow depth is generally selected. It is also observed that if the cut off depth below lowest bed level is equal to depth of water then the loss of water due to seepage is almost negligible. At sites where rock is not available, this technique is adopted. Some of the percolation tanks, which have been constructed have also been used as a source of water for drinking purpose and water supply schemes for villages and small towns. The percolation tank serves as a good structure for recharging of the ground water.

The Govt. of Maharashtra has also realized the importance of water and specially its conservation and recharging. To overemphasize this aspect, the Government has established a separate department in 1992 and is continuously making efforts for water conservation. Various methods such as, contour bunding, stone gabbion, underground weirs, cement plugs, check dams, afforestation etc. are being implemented through this department. Separate grants are also made available to each district. Artificial recharging of the ground is also being extensively done. Several N.G.Os. are also involved in this process of water conservation. Rain harvesting is also encouraged in several places in Maharashtra. Ground water recharging using existing natural basin is also experimented and tried at various places quite successfully. In one of the experiment done in village Pinglai existing bore was recharged by putting nearly 150 million litres surplus water available in the monsoon. As a result, substantial ground recharging could be achieved. The ground water recharging has helped the availability of water to the existing bores with the result that deployment of water tankers in summer months for drinking water was reduced.

### 5. BANDHARA : KOLHAPUR TYPE WEIR

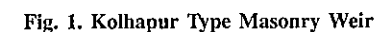
The concept of Bridge-cum-Bandhara is firstly developed in Kolhapur district of Maharashtra. Sugarcane is grown in large scale in major portion of district. It is a small structure mainly constructed out of stone masonry having wide masonry weir at river bed which acts as gravity structure and support the closely spaced stone masonry piers having spacing of 2 m. The stone masonry was adopted considering the availability of stone as a construction material and also the availability of local skill. The piers were spaced at 2 m and a pair of wooden needles was fixed. In between these needles, black cotton soil is filled in. These needles are fixed after monsoon has subsided and storage is created out of post monsoon flow. Since the entire area is



Kolhapur type weir had become popular in the State in 1960s, especially in zone where lot of sugarcane is grown. Concept of KT weir was introduced to recycle the percolated water available out of irrigation which flows back in the river. As explained earlier, it is a water storage structure to arrest percolated water and post monsoon flow. The design consists of construction of gravity weir with pier. The construction was out of stone masonry and local available skilled worker were engaged for construction. The cost therefore was substantially low. The structure was so popular that for many major/minor rivers and its tributaries, series of them were constructed and the backwater of D/S Bandhara would touch the U/S Bandhara. The entire river was thus acting as reservoir. Most of rivers are having exposed rock conditions and hence due to better foundation conditions cost got reduced. A lot of these structures were constructed from budgetary grants. But looking to its economic yield and additional benefits to the farmers, the local sugarcane factories also came forward to fund these structures. Majority of these structures were not located along existing cart track nor along planned road. In order to reduce cost, the superstructure was designed for pedestrian movement and top width was less than 2 m. Wherever location was matching with the road demands were received for designing structure to enable bullock carts, tractors which basically carry agricultural products to cross the river. Some of the structures therefore were designed as single lane road and pier length and slab width was increased.

Since beginning emphasis was put on the availability of construction material and skilled worker to keep the cost minimum and hence this required massive gravity structure. As a result it leads to higher obstruction, high afflux and even erosion to the bed, which necessitate additional protection measures such as long guide walls, anchored returns etc. Availability of good quality construction material/alternate material and good contractors even in the remote areas, prompted us to review and evolve new plans. In our State investment in the road sector has been substantially increased. In addition to this, Government has created separate department to emphasis on water conservation and as such more assured and dedicated funds are available for small water storage structures. This also necessitated re-thinking of earlier design and need for evolving optimum design for Bridge-cum-Bandhara.

It is true that bridges are constructed to enable the crossing of river in the monsoon. They are required to be designed so that minimum obstruction is caused to



the flow during the monsoon period. They, therefore, cannot serve as water retaining structure. However, as demonstrated in Kolhapur type structure, by changing the concept, they can be designed to suit the dual purpose, i.e., Bridge-cum-Bandhara. Here, the bridge structure can be designed for a limited storage to serve as water retaining structure to ensure irrigation for a small area as well as to meet the need of drinking water for animals and human beings. They also serve as an ideal structure to ensure water recharging of the ground. The Govt. of Maharashtra is continuously encouraging construction of such structure and, therefore, has given guidelines for construction of such dual purpose structure. The guidelines specify that as and when if any bridge is constructed, possibility should be explored to construct it as Bridge-cum-Bandhara and both the departments, i.e. Irrigation and P.W.D. should share the cost.

### 7. NEED OF NEW DESIGN OF BRIDGE-CUM-BANDHARA

As has been stated above, the availability of water has to be increased by various means. By changing scope of the existing bridges, they can also be designed as water retaining/water storage structure. In order to keep the cost to the bare minimum, the optimal design of the structure has to be attempted. With the availability of computer, the analysis of structure has become very simple and the optimal design can be evolved by trying various parameters. New construction material has also come in the market which provides ease in construction as well as help in reducing the cost. We have also to keep it in mind that the highly sophisticated construction equipments are not generally available in remote areas. As such, the design should be so evolved so that it can be translated even in the remotest village. Government of Maharashtra has prescribed norms for irrigation/ water storage structure. The norms takes into account the storage created by these structure, cost of irrigation per acre, scarcity prone area, tribal and forest area, population served in case it is constructed for drinking water etc. The expenditure on various structures has to be within the norms considering the parameters mentioned above. It is therefore necessary that cost of BCB is well within these financial norms or it will be difficult to justify its construction. Of course all sites are not suitable for construction of minor, medium or major irrigation project or percolation tanks. However, much efforts are made in evolving ideal type plans by adopting good structural system which can transfer the forces efficiently, new construction material to reduce cost, simple detailing which will not involve highly skilled labour force nor heavy construction equipment's. Due to all these efforts, overall construction cost is substantially low and cost is well within norms. Standardization of various components will further reduce the cost as local contractor will get fully trained with the techniques and would own the necessary shuttering, equipment's etc. Bridge-cum-Bandhara using these type plans can be practically constructed on any streams within the accepted financial norms. It will be interesting to work out the requirement of water for drinking purpose, which will reveal that BCB can conveniently meet this need and hence an ideal structure.

Village population = 1000 souls,	
Water requirement = 70 liters per day, per person	
Width of nalla where BCB is proposed = 10 m	
Slope of river 1 in 1000	
Storage planned 3.5 m in depth	
Yearly water requirement	= $1000 \times 70 \times 250 / 1000$
	= 17500 cum
Storage created	= $10 \times 3.5 \times 3.5 \times 1000 / 2$
	= 52500 cum

Even considering evaporation loss the available water can prove adequate for drinking and other needs. If artificial ground water recharging is adopted this water can be more efficiently used and some land also can be irrigated

### 8. STEEL NEEDLES/GATES

Since beginning a view was taken in BCB that it should be cost effective, convenient in execution and to be constructed out of commonly occurring construction material. It was also thought that the gates/ needles should be simple and it should be possible to fix them manually so as to reduce cost. A simple curvilinear shaped needle is evolved to serve the purpose. 3 mm thick steel plate is bent in curvilinear shape and the same is strengthened with simple bars. The total weight of this needle is less than 70 kg/per square meter. They are therefore convenient to handle manually (Refer Photographs 1&2 of BCB across Man river).

### 9. COLCRETE

Colcrete is a grouted concrete made by introducing 'Colgrout' into the voids of pre-placed coarse aggregate, usually of 40 mm minimum size, by gravity penetration or injection method. Colgrout is the colloidal grout produced by the high speed mixing, in a colcrete mixer, first of cement and water followed by the cement-water colloid with sand.

The Maharashtra Engineering Research Institute has carried extensive applied research on this material and has now evolved specifications, engineering properties, mode of construction etc. Several dams have been constructed using colcrete. It is dense highly impermeable material and exhibit high abrasion resistance property. Since hand broken large size stones can be used, it is quite cost effective and suitable as labour oriented process. It is, therefore, ideal material for villages. Cement consumption is also low. High density of material and ease in construction along with other properties mentioned above makes it an ideal material for gravity structure. It is also used to plug bottom plug of wells P.W.D. has used colcrete for construction of face walls, river bed protections and for retaining wall having height of about 4 m etc.



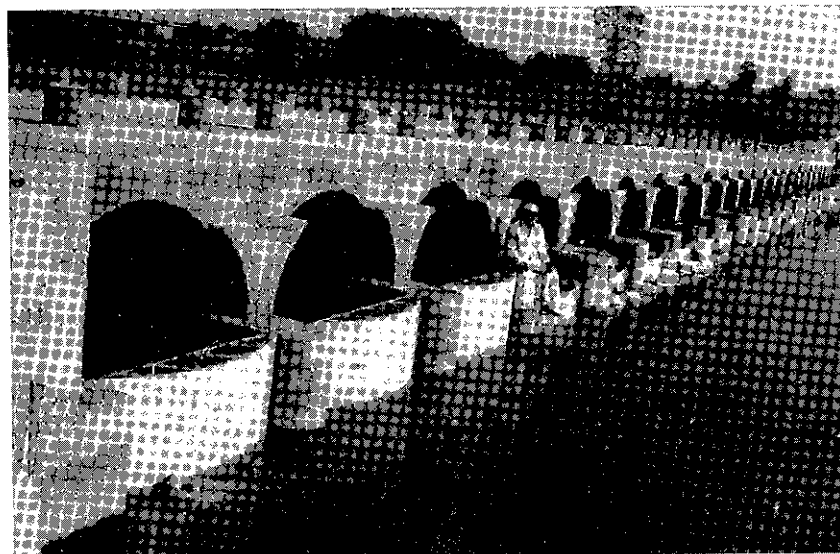


Photo 1

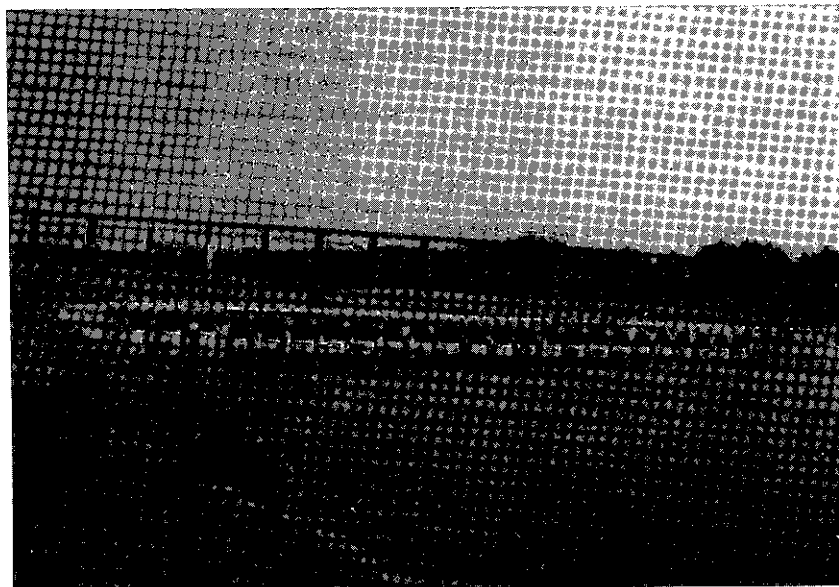


Photo 2

Arch Type Causeway-cum-Bandhara Across Man River Near Village Nagzari on  
Shegaon-Nagzari-Kasura Road in Akola District

As a cost-effective product colcrete can be adopted for construction of weirs, being massive structure in Bridge-cum-Bandhara and also for aprons.

#### 10. PRADHAN MANTRI GRAM SADAK YOJANA (PMGSY)

Rural connectivity is a key component of Rural Development in India. Keeping in view the socio-economic benefits accruing from providing road connectivity to the villages, Government of India have launched the PMGSY in December-2000 with the objective of providing road connectivity through good all-weather roads to all unconnected habitations having a population of more than 1000 persons by the year 2003 and those with population of more than 500 person by 2007. Special funds are made available for construction of large number of roads.

PMGSY also appreciates need for construction of this dual-purpose structure, i.e., Bridge-cum-Bandhara and has allowed construction of such dual-purpose structure. Emphasis has been given to design the bridges as Bridge-cum-Bandhara, where feasible. As most of the villages are located near major/minor river streams, the bridge structures under such rivers should be planned as Bridge-cum-Bandhara which will enhance its utility. This will not only solve communication problem but will also solve drinking water problem.

The new type plans for BCB are evolved with an objective to cover commonly occurring cases. The BCB are scientifically designed as an optimum structure and therefore, proved to be most economical structure. They require least construction material and convenient in execution in remote areas with locally available skilled workers, equipment's and material and hence these type plans would definitely help in meeting the objective of PMGSY.

#### 11. EVOLUTION OF TYPE PLAN OF BRIDGE-CUM-BANDHARA

The bridge structure can be designed as Bridge-cum-Bandhara at an additional marginal incremental cost. The length of the backwater will be equal to  $h*s$  (where  $h$  is the storage depth and  $s$  is the slope of the river) and the total storage will be  $\frac{1}{2} b h s$  (where  $b$  is the width of the river). As such storage is the function of slope. Flatter the slope more is the storage. Type plans are to be evolved for various foundation conditions. Generally ideal foundation conditions, i.e., exposed rock for full width of bed is available in 10 per cent cases and for remaining 90 per cent bridge structures either rock is absent or is at 4 m to 5 m or more depth. It is also observed that whenever rock is exposed the rivers have steep bed slopes of the order of 1:200 to 1:400. They are, therefore, not ideal sites from point of view of storage structure. For remaining cases slope could be 1:800 to 1:2000 and more suitable for Bridge-cum-Bandhara. Such varying foundation conditions and its impact on storage also necessitate re-thinking of Bridge-cum-Bandhara structure and need for appropriate type plans.

The main function of constructing a bridge across the river is to provide facility of crossing the river during floods in monsoon. The main principle in the design of bridge for constructing a stable and durable structure is to cause minimum obstruction

to the flow of the river. In short, the flood water should be allowed to pass freely causing minimum obstruction. However, in case of a Bandhara, water flowing in the stream is to be impounded when rains have almost stopped and no major flow is expected. The post monsoon flow only is generally tapped in BCB. A small overflowing weir with top slightly lower than FTL can be planned in one of the span. This discharging weir does not allow water level to rise beyond FTL. The design philosophy in constructing a bridge and a Bandhara are based on radically diverse principles. The construction of a Bridge-cum-Bandhara, therefore, requires a judicious application of mind while achieving optimum storage of water, together with providing maximum serviceability of traffic plying over the bridge without endangering the safety of the structure.

Design forces required to be taken for typical bridge structure has been defined in IRC Code. The code also has prescribed load combinations and allowed overstressing in few combinations. Forces caused due to various water flow conditions and obstruction caused is worked out and obstruction is to be kept in acceptable limit. This is also necessary to avoid failure of structure due to outflanking. In Maharashtra, we have got large number of submersible bridges. In major areas of the State, most of rivers are having shallow basins with over bank flow of the order of 45 per cent. With the objective of reducing the cost of the structure submersible bridges are constructed. There is well defined policy of functional needs of submersible bridges for different category of road. Normally the condition of water touching bridge deck with full live load is most critical case for submersible bridges.

For a Bridge-cum-Bandhara structure, additional forces which are required to be considered are uplift forces. Uplift force diagram is normally taken as triangular diagram having uplift force factor at u/s section equal to the depth of water and reducing to 0 at toe. The force caused due to uplift also has to be considered in combination of other forces. For small water storage system, it is a practice of Irrigation department for not applying the criteria of over turning. However, while evolving type plans overturning criteria has also been applied as done in other bridge structures. For a case of foundation condition having rock, it is a practice to allow 20 per cent tension area. However, in Bridge-cum-Bandhara this is restricted to 10 per cent.

The other aspects, which have been taken into consideration while evolving the design for Bridge-cum-Bandhara are as under:

- (a) R.C.C. piers for bridge proper and those for fixing of the needles are proposed. The width of the pier is, therefore, considerably reduced and thereby the obstruction caused is also reduced.
- (b) Longer spans (wider openings of vents) are provided for the bridge proper so that load from superstructure slab contributes to the stability of the weir over which it is resting.
- (c) A clear gap of about 1.0 m in case of a submersible bridge and 1.5 m in case

of a high level bridge is provided above the full tank level upto the soffit of the superstructure.

- (d) Steel needles are proposed to facilitate ease in operation and maintenance.
- (e) An afflux is considerably reduced owing to lesser obstruction caused due to the floodwater. This minimizes subsequent requirement of large key walls, the bank and bed protection.
- (f) The general principles of checking of the structural stability for the weir, is the same as that adopted for the K.T. weir by Irrigation Department.

## 12. TYPE PLAN CASES

The type plans have been evolved to meet the various foundation conditions. They have been evolved for the following cases:

- i) **New structure to be designed as Bridge-cum-Bandhara**
  - (a) Exposed rock, (b) Buried rock, and (c) Rock not available but bed is silty clayey
- ii) **Converting existing Bridge into Bridge-cum-Bandhara**
  - (a) Exposed rock, (b) Buried rock, and (c) Silty clayey

The various alternate structural systems have been tried to meet the above needs. With objective to keep cost to minimum while evolving type plan, dimensions of the structure and parameters to be considered had to be carefully done. While evolving type plans, various parameters were so decided that 90 per cent practical cases could be covered. These parameters included various foundation conditions to be taken. On the experience, following parameters for design of type plans of Bridge-cum-Bandhara were considered.

### 12.1. Parameters for Standard Bridge-cum-Bandhara for New Structure and Existing Structure

- 1) **Foundation**
  - (a) Exposed rock – soft, hard.
  - (b) Buried rock – soft, hard.
  - (c) Converting existing bridge.
- 2) **Storage depth**
  - (a) 2.0 m
  - (b) 2.5 m
  - (c) 3.0 m
  - (d) 3.5 m

3) **Type**

- (a) Submersible
- (b) High level

4) **Clearance above F.T.L.**

- (a) 1 m, (b) 1.5 m, and (c) 2 m

5) **Abutment**

- (a) Gravity
- (b) Counterfort type

6) **Piers**

Main piers – R.C.C. Wall type – 0.6 m and 0.8 m width.

Needle piers – R.C.C. Wall type – 0.4 m width

7) **Span**

- (a) 2 bays :  $2 \times 2 + 1 \times 0.4 + 0.6 = 5 \text{ m}$
- (b) 3 bays :  $2 \times 3 + 2 \times 0.4 + 0.6 = 7.4 \text{ m}$
- (c) 4 bays :  $2 \times 4 + 3 \times 0.4 + 0.6 = 9.8 \text{ m}$

8) **Carriageway width**

- (a) Single-lane = 4.25 m
- (b) Two-lane = 7.50 m

9) **Straight length of pier**

Main piers two-lane –  $7.5 + 0.22 + 0.20 + 0.05 + 0.18 = 8.15 \text{ m}$

Single-lane  $4.25 + 0.22 + 0.2 + 0.05 + 0.18 = 5.90 \text{ m}$

Needle piers – 1.5 m

10) **Supporting arrangement of needle pier**

- (a) Span – clear 2 m
- (b) Variable width
  - i) Needle piers connected to main piers through sill beam, sill beam designed for BM, shear and torsion.
  - ii) Needle piers anchored in weir or base slab.

11) **Loading conditions**

- (a) All elements to be checked as per I.R.C. Codes
- (b) Additional loading condition of static
- (c) No  $20^\circ$  variation. And  $20^\circ$  variation
- (d) Triangular uplift pressure diagram – 100 per cent uplift at u/s linearly reducing to zero at d/s.
- (e) Tensile area preferable less than 10 per cent for main pier.
- (f) Additional Safety :-
  - i) Annular filling weight,
  - ii) Passive pressure effect,
  - iii) Stability due to side friction,
  - iv) Additional Anchor roads

12) **Floor protection**

- (a) Exposed rock: 10 cm levelling course – M-10 + 7.5 cm M-15 slab with nominal steel.
- (b) Buried Type: - 15 cm metalling course + 7.5 cm – M-10 concrete + 7.5 cm M-15 with nominal steel.
- (c) Provide pressure relief holes.

13) **Gate spacing**

- (a) 2 m, (b) 3 m, and (c) 4 m

14) **Footing**

- (a) Eccentric, (b) 'I' Type, and (c) Mass concrete

15) **Superstructure**

- (a) Simply supported, (b) Two span continuous, and (c) Three span continuous

16) **Per cent obstruction**

As per normal practice

17) **Water velocity**

2.5 m, 3.5 m, 4.5 m

12.2. **Type Plans for Slab**

While evolving type plan for slab the parameters to be considered are width of slab, number of lanes, loading standards, concrete grade, steel grade and span. Combinations of these parameters are considered to evolve set of type plans to meet the needs.



### 12.3. Type Plan for Piers

For type plans of piers geometric parameters as width of pier, straight length and under material parameter concrete with different grades, stone masonry, etc. are considered. In addition to this height, loading standards and different water velocities are considered. For combinations of these parameter set of type plans are evolved.

From above description of parameters it is obvious that for Bridge-cum-Bandhara besides parameters as geometric, material, height, loading water velocity an additional parameter of storage depth also need to be considered.

Lots of efforts have been taken to evolve type plan for various site conditions. Care has been taken to maintain the size of main piers and Bandhara piers as less as possible so as to cause minimum obstruction, less shuttering cost. Due to standardization of sizes of piers even the shuttering sets once made could be used repeatedly in the remote areas. In addition to normal piers supporting the main structure there will be additional secondary piers required to support/fix needles and these piers will add to obstruction. RCC piers are adopted which allows lesser width of piers and hence less obstruction to flow. Needles are also optimally designed and curved shape is evolved which has reduced thickness of needles substantially thereby making it easy to handle and maintain. Needles so designed are serving the purpose well. Rubber seals are provided at bottom and base and grooves are made to align these needles. Under water pressure the needle rest against the concrete surface and due to rubber seal the entire joint becomes watertight.

## 13. TYPE PLANS AND DESIGN PHILOSOPHY FOR NEW BRIDGE-CUM-BANDHARA

### 13.1 Sill Beam Type (where rock is exposed or at shallow depth)

Exposed rock condition is most favourable foundation condition. The main piers supporting the superstructure is designed for set of actual conditions such as height water velocity, span loading, etc. Depending on actual condition of rock the pier is adequately embedded in rock and the annular filling is done by concrete. This method of construction is not proposed to be changed in Bridge-cum-Bandhara. However, in BCB secondary intermediary piers to fix needles are required. In order to reduce effort in removing rock and to ensure prevention of seepage a unique structural system is thought of. A beam known as sill beam is introduced at upstream which connects the main piers and nominally embedded in rock to prevent seepage. The secondary piers are then connected to this sill beam and secondary piers are then allowed to rest on rock, which is properly dressed to ensure better seating. The static force caused due to water is transferred to gates and then to secondary piers and then through the sill beam to main pier. Since main piers support the superstructure the dead load thus available is enough to resist the static force. Sizes of various elements are not required to be changed to get necessary stability. The normal overturning ratio of 1.5 is also automatically achieved. It may be noted that when the reservoir is full there is no need to consider force caused due to moving water. Special efforts were made to evolve

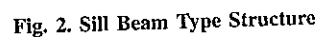
shape of footing to the main piers. The water storage causes uplift and uplift force act as destabilizing forces. Increase in size of footing size increases this uplift force and also reduces dead load stresses at base thereby worsening the situation. Uplift force diagram is triangular in nature and is equal to storage depth at u/s variable width of footing is, therefore, evolved after taking several trials and also considering the ease in construction, Fig. 2.

#### *Special features of type plan:*

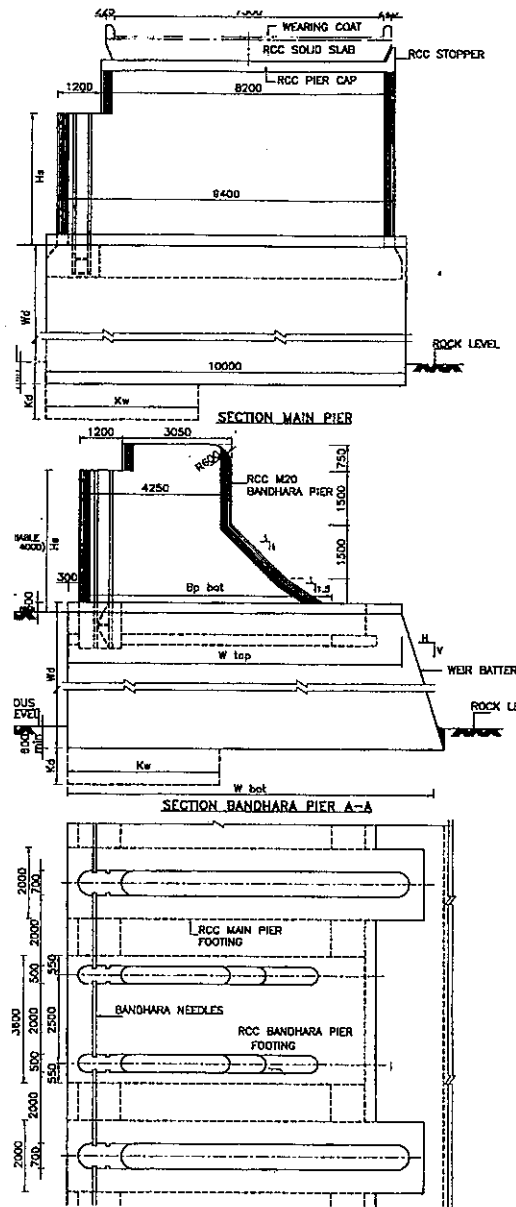
- (a) Main R.C.C. piers are supporting the structure.
- (b) Secondary piers intermittent to main piers are provided to support the needles. Spacing of these secondary piers are governed by the needle size.
- (c) Secondary piers are connected to main piers though sill beam so as to transfer all the static force due to water force to main pier.
- (d) Space frame analysis with stiffness method along with soil structure interaction has been used for analysis of this system.
- (e) Main pier has got the additional dead load of slab, hence there is no need to increase its size to resist the water force.
- (f) Nominal foundations are provided for secondary piers with nominal embedment in rock.
- (g) Sill beam, base slab and piers are structurally connected by reinforcement, i.e., all these there substructure act in unison at Bandhara pier.
- (h) Triangular uplift pressure is considered.
- (i) For reducing uplift pressure and thereby overturning moment to the minimum, unsymmetrical 'T'-shaped footing is designed for the main pier with larger area on d/s side and less on u/s side.
- (j) Sill beam system enables to adopt any size of needles.

### 13.2. Gravity Weir (where rock not exposed and is available at shallow depth below bed level)

Normally in such cases piers are taken upto the founding strata and adequately embedded. However, in BCB the prevention of seepage is also a requirement. To achieve this objective the concept of solid weir upto lowest bed level is introduced. The weir is made massive so as to act as gravity structure and all the forces are resisted due to dead weight of weir. Since this requires massive size a thought was given to reduce the cost. The weir can be constructed in stone masonry, plain concrete or even in plum concrete. It is proposed to adopt colcrete for construction of this weir. With colcrete the construction speed at much less cost can be achieved. Local skilled workers can conveniently carry out this construction. The main piers and secondary piers are anchored in this weir. The section of piers can be substantially reduced. The



- (a) For rivers having sandy beds or soils with poor bearing capacity R.C.C. raft Foundation is provided for bridge structures.
- (b) Adequately designed cut off walls are provided.
- (c) Protected beds (apron) on u/s and d/s side based on Khosla's theory are adopted.
- (d) This type of construction not only arrests the free flow of particles under the bridge foundation but also dampens the seepage flow below the bed in post monsoon period and gives benefit of increase in water table in the adjoining fields.
- (e) Needle piers on u/s side intermittent to main piers are provided founding on raft and connected through sill beam to main piers.
- (f) System can be conveniently used upto limited storage of 2.5 m.



**Fig. 3. Solid Gravity Weir for New Bridge-cum-Bandhara (two lane)**

- (g) Guide walls on four sides adjoining abutments are provided to avoid erosion of banks.
- (h) As a cost-effective product colcrete may be used in the construction of aprons and guide walls.

### 13.4. Prevention of Seepage

Since the BCB is water-retaining structure the prevention of seepage through bed or sides is the main functional requirement. In the first two structures the seepage through bed is not possible as structure is embedded in rock. Water of course can percolate behind abutment. In bridge structure this is also not possible. We normally give right angle returns, which results into increase in seepage path hence prevention. It is, however, proposed to adopt 3 to 5 m guide walls at u/s along bank, which will properly flume the water and also help in preventing seepage.

**14. CONVERTING EXISTING MEDIUM AND MINOR BRIDGE INTO  
BRIDGE-CUM-BANDHARA**

For these cases policy is adopted that a secondary structure touching the main structure should be planned. The new structure, which is basically planned to create storage, should not transfer any force to existing structure and as such there is, therefore, no need to check the stability of old structure. The detailing and construction methodology to be so adopted that the construction of new structure does not cause any damage to existing structure. The excavation of rock near main structure therefore has to be minimum. Since the existing structure may have different span, the type plan should be so evolved that any modular size of gates say 1.75 to 2.75 can be adopted. The existing bridge is proposed to be used for all operational purposes specially for fixing gates. New structure, therefore, has to be touching existing structure. The type plans are evolved with these considerations, as will be obvious from above description the structural system and construction material is so selected that cost is minimum. Following three cases of foundations are possible and different structural system are adopted in each of these cases:

- 1) Rock exposed
- 2) Rock at shallow depth
- 3) Rock not available and hence raft foundation adopted for existing structure

#### 14.1. Rock Exposed

The secondary structure is so designed that excavation in rock is minimum and therefore can be done in proximity of old bridge. The structural system as followed for counterfort retaining walls is adopted. In these structures massive column structure at suitable intervals are constructed along with base slab. There is a vertical wall connecting these columns, which retains the earth. The dead load of the earth adds to the stability of the structure. In this BCB the gates retain the water. There is a base slab connecting the needle piers. The weight of the water on base slab adds to the stability. Fins are added to base slab so as to shift fulcrum point and thereby add to



stability and specially to improve overturning ratio. Needle pier seats on these fins. Base slab width and the dimension of fins especially projection beyond base slab is worked out mathematically so that 1.5 overturning ratio is achieved. Base slab is laid on natural rock so that enough friction is created and hence sliding can be prevented. Long length of base slab would prevent seepage and if necessary we may add a small key at upstream properly embedding in rock which not only will prevent seepage but also improve stability against sliding, Fig. 4.

*Special features of type plan are:*

- This system is preferable when exposed rock is available fairly at one level throughout the bed or rock is available at shallower depth.
- Counterfort type needle piers with R.C.C. raft slab footing with/without key wall are adopted.
- Self weight of water over base slab gives stability to structure.
- System requires considerably less depth and base area compared to that required for masonry weirs.
- As blasting is not possible near existing bridge this system is suitable requiring less time and efforts for excavation in rock.
- No connection with existing bridge and hence stability of existing bridge not affected.
- Existing bridge facilitates operation of needles.
- Bed protection to be given, if needed.
- No connection with existing bridge and hence stability of existing bridge not affected.
- Existing bridge facilitates operation of needles.
- Bed protection to be given, if needed.

#### 14.2. Rock at Shallow Depth

For this situation the ideal structure is a gravity weir. Design principles are same as that of a case mentioned above, i.e., constructing new BCB when rock is at shallow depth. Colcrete weir is suggested which is constructed near the existing structure, Fig. 5.

*Special features of type plan are:*

- New structure touching existing structure and stability of existing bridge not affected.
- Appropriate bed protection measures to be taken.
- Any gate size to suit span can be adopted.
- Nominal embedment in rock considering large size.
- Key at upstream can be given to prevent seepage, if required.
- Soil mass/sand at upstream also retains large quantum of water.

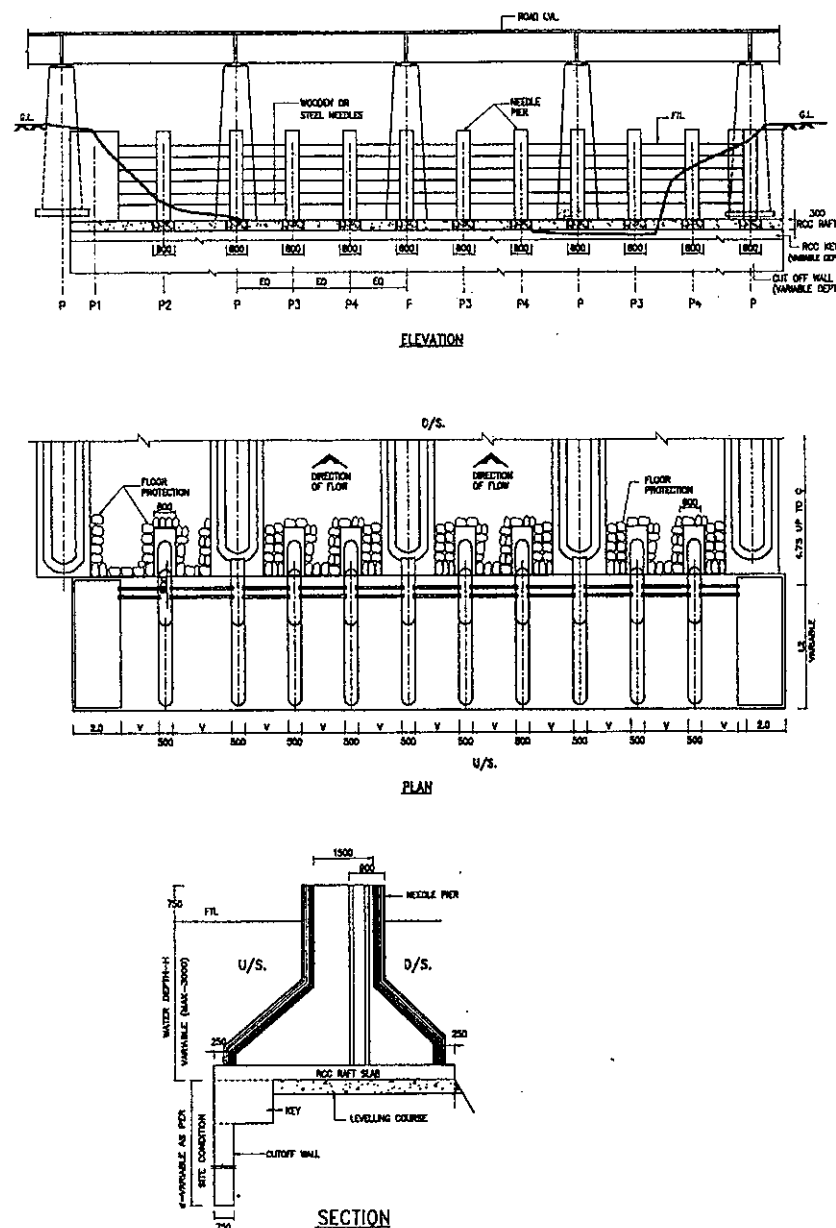
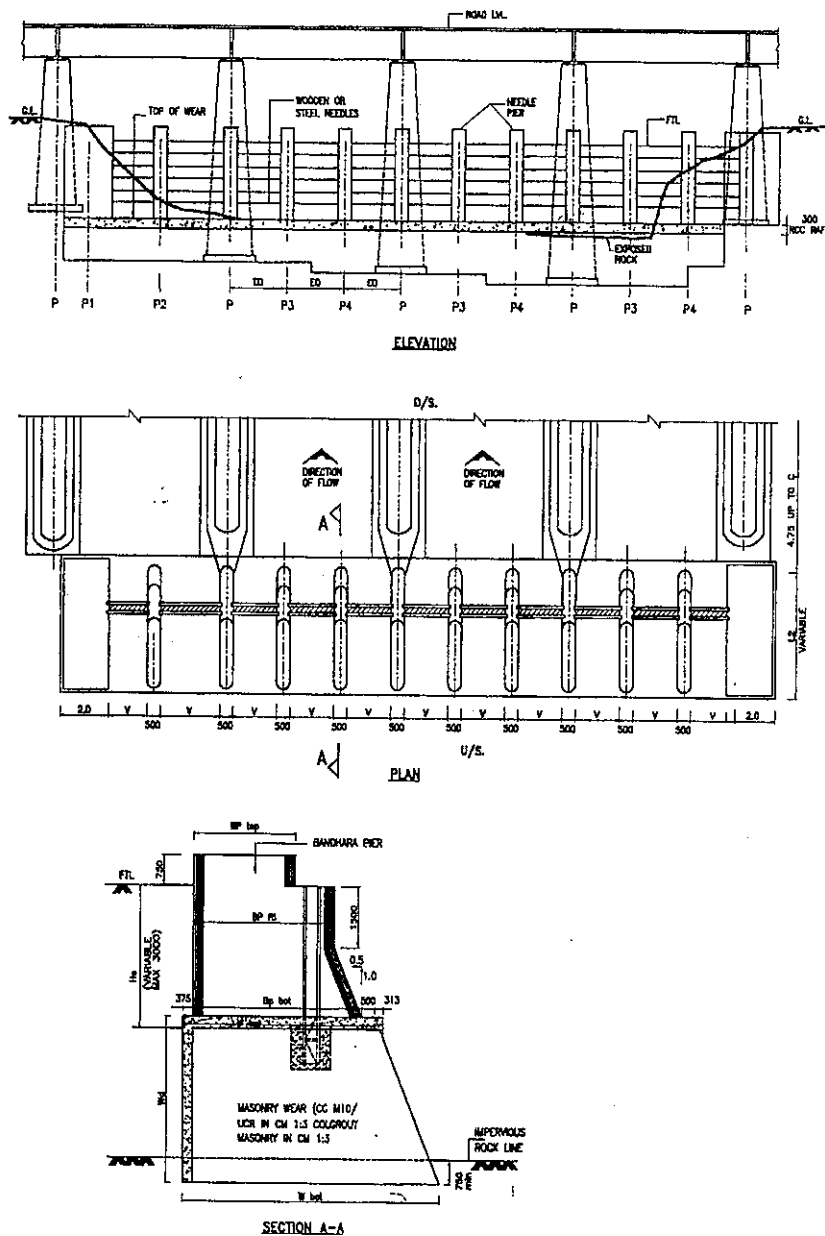


Fig. 4. New Bridge-cum-Bandhara Base Slab Counterfort Needle Pier



**Fig. 5. New Bridge-cum-Bandhara Wier Type for Existing Bridge**

### 14.3. Rock Not Available

As stated earlier raft foundation is most common structural system in Maharashtra whenever rock is much deeper. To convert such structure into BCB and keeping above principles in mind that this will be new structure abutting the existing structure and should not add to additional forces and also should effectively prevent seepage a TEE shaped raft foundation structure is adopted. Sufficient depth of cutoff is taken so as to prevent seepage. The structure is designed similar to counterfort retaining wall and similar to exposed rock case. The needle piers along with gates retain the water. The dead weight of water on raft slab gives overall stability. Dimensions are adjusted to achieve necessary overturning ratio. The cutoff not only prevents seepage but also act as anchor to prevent failure of structure due to overturning, Fig. 6.

*Special features of type plan are:*

- (a) Structure is designed when existing structure on raft foundation.
- (b) Any gate size to suit span can be adopted.
- (c) Deep cut off to prevent seepage. Dead weight of cut-off add to stability.
- (d) Appropriate protection to bed (raft slab) be given.

15. VENTED CAUSEWAY-CUM-BANDHARA

It is generally observed that 70 per cent of planned road length is village road and other district roads. Enough funds are not available to construct appropriate bridge structures so that these roads serve as all weather roads. For 90 per cent of these crossing the flood depth is less than 3 m. Some major streams crossing these roads can be bridged with submersible structure to cover 3 m flood depth which can also meet practical needs. These submersible structures are available after the floods have receded and hence interruption to traffic would be minimum. We can thereby effect saving in cost and more roads can be made all weather. An attempt is made to evolve cost-effective solution for three-meter height structure and a solution of 2 m semi-circle arch is evolved and adopted in large scale in Maharashtra. The drawings of this structure are now included in Rural Road Manual (IRC:SP:20-2002). This drawing can be modified with minimum changes to serve as BCB. Drawing has been evolved of vented arch Causeway-cum-Bandhara, Fig. 7.

*Special features are:*

- Raft foundation with cut off walls and semi-circle arches as superstructure is adopted. Clear opening is 2 m.
- Some loss of water is expected through percolation and evaporation. The behaviour of the system is much better if the soil in bed is silty clay or clayey.
- Storage is restricted to 1.5 m.

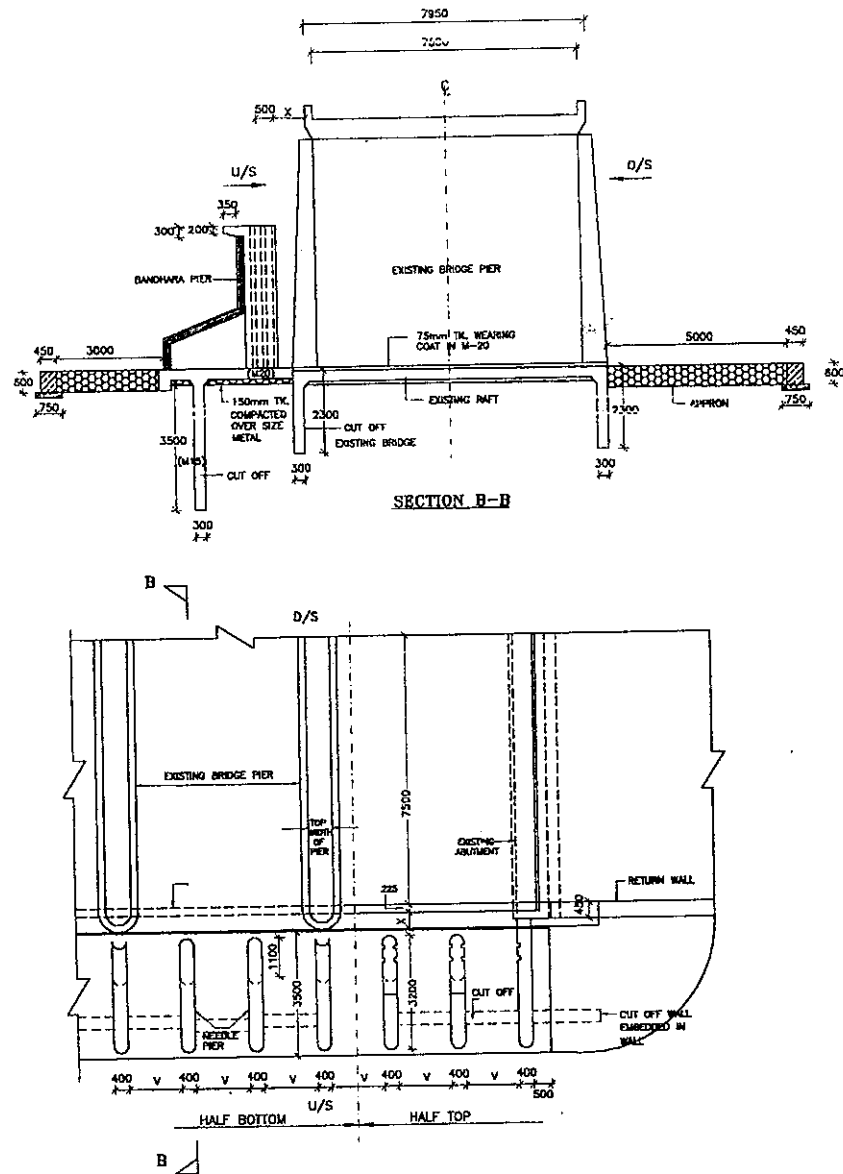


Fig. 6. Raft Type Bridge-cum-Bandhara for Clayey Soil

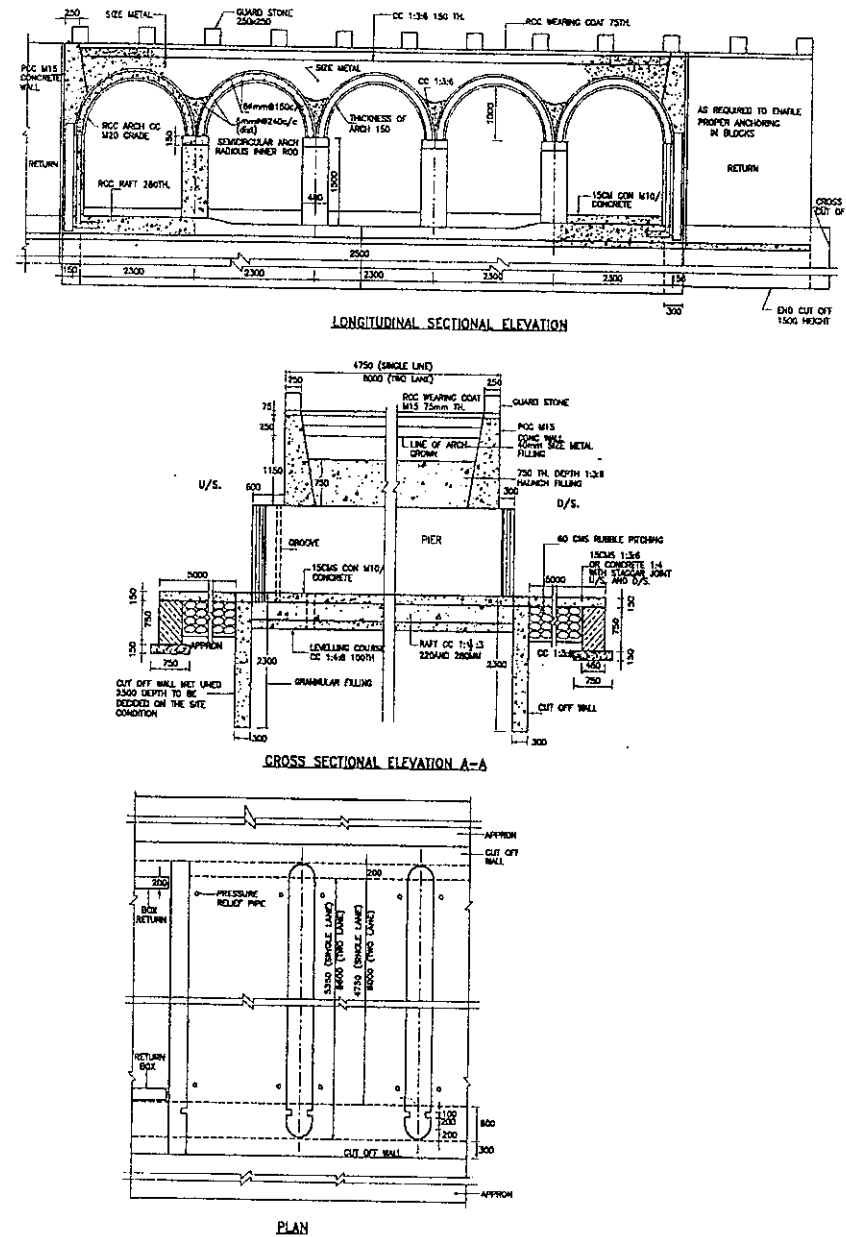


Fig. 7. Semi-Circle Arch Type Bridge-cum-Bandhara



- (d) Guide walls may be provided to guide the flow, if necessary.
- (e) Adequately long box returns are provided keyed in bank.
- (f) U/s and D/s bed protection is provided.
- (g) Since design of bridge is cost effective BCB also is cost effective.

### 16. USE OF TYPE PLAN

Several structures have been constructed using these type plans. The incremental cost of the structures is minimum and it is found that they fulfil the various norms prescribed by Government for water retaining structures. It is now proved that the structures are most optimally designed. New construction material such as colcrete is made use of. Thin R.C.C. piers and optimally designed curved needles to reduce the cost are some of the special features of this design.

### 17. COST COMPARISON

Cost comparison of only bridge, only Bandhara and Bridge-cum-Bandhara for few cases have been given in the Table-1.

TABLE 1. BRIDGE-CUM-BANDHARA - COSTING

Sl. No	Name	Cost of bridge (Lakhs)	Cost of K.T. Weir (Lakhs)	Total cost, if built separately (Lakhs)	Cost of Bridge-cum-Bandhara (Lakhs)	Saving in cost (Lakhs)	Storage capacity (Lakhs cum)	Benefits
1.	Bridge-cum-Bandhara across Purna river near Karatheda (Photos 3&4)	123.48	58.91	182.39	159.88	22.51	13.00	Extra irrigation of 603 ha., water supply to 35000 population (28 villages)
2.	Bridge-cum-Bandhara across Wardha river near Kaudanyapur (Photo 5)	75.00	32.8	107.8	95.71	12.09	12.00	Irrigation of 350 ha., water supply source to Arvi city.
3.	Bridge-cum-Bandhara across Suryaganga river near Varkhed (Photos 6&7)	28.12	12.30	40.42	36.88	3.54	2.70	Irrigation of 70 ha., Ground water table increased, water supply to 3 villages.
4.	Bridge-cum-Bandhara across Pedi river near Ballarkhed	45.76	24.20	69.96	64.90	5.06	6.63	Irrigation of 172 ha., Increase in GWL of wells, Drinking water to catles and animals

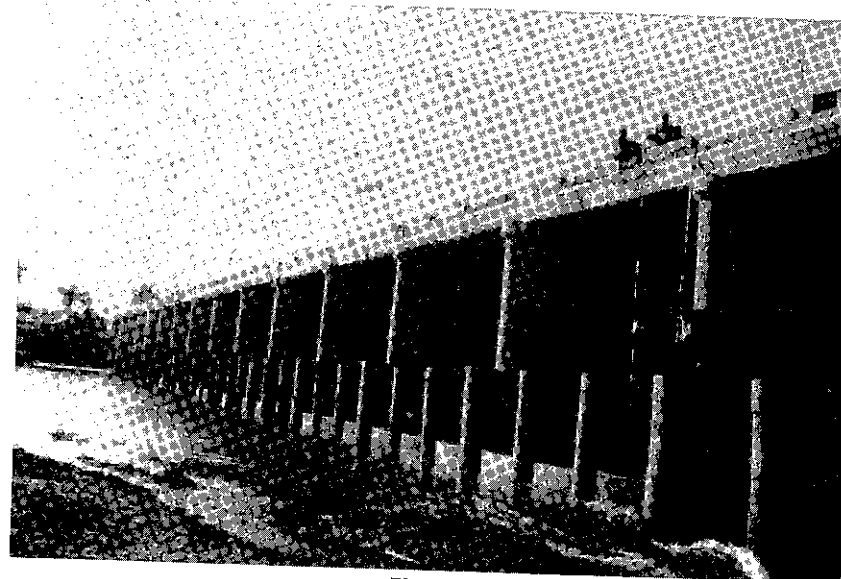


Photo 3

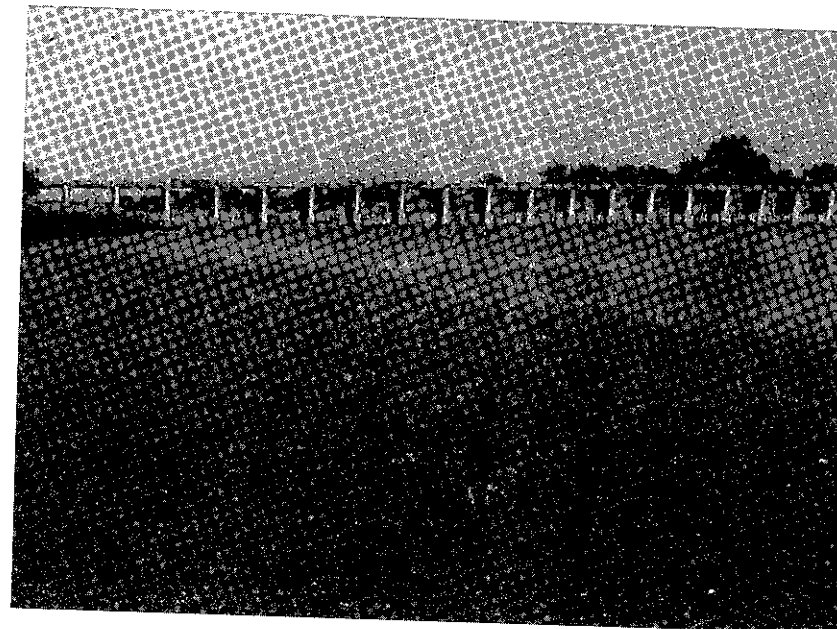


Photo 4

Bridge-cum-Bandhara Across Purna River on Ramtirth-Mhaisang Road Near Karatheda

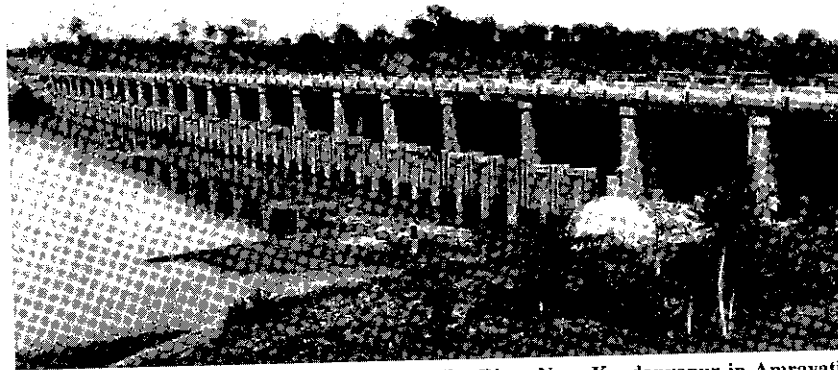


Photo 5. Bridge-cum-Bandhara Across Wardha River Near Kaudanyapur in Amravati District

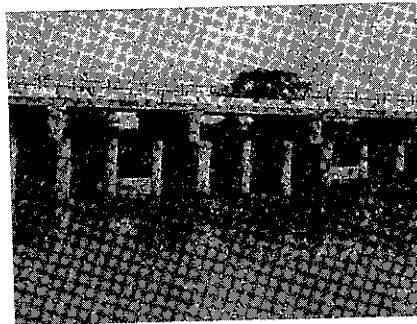


Photo 6

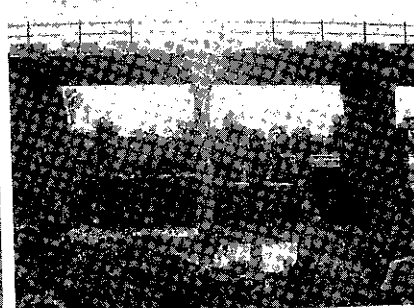


Photo 7

Bridge-cum-Bandhara Across Suryagana River Near Varkhed

## 18. CASE STUDIES

### I. Arch Type Causeway-cum-Bandhara Across Man River Near Village Nagzari on Shegaon-Nagzari-Kasura Road in Akola District (Photos 1&2).

- Shegaon is a major religious centre in Maharashtra State. About 50 Lacs pilgrims every year visit Shegaon.
- Shri Sant Gajanan Maharaj Sansthan has taken the responsibility to make adequate water available to pilgrims, hence structure was evolved to make drinking water available to pilgrims.
- Arch type causeway cum Bandhara has been adopted with cut off walls and

bed protection on u/s and d/s side. 24 spans of 2.3 m c/c have been provided with clear opening of 2.0 m.

- About 1.5 m storage is possible which has helped in solving the drinking water problem of pilgrims and habitants of villages Shegaon, Nagzari and Unadkhed.

### II. Bridge-cum-Bandhara Across Purna River on Ramtirth – Mhaisang Road Near Karatkhed (Photos 3&4).

- The area is mainly saline water tract and the strata in the riverbed at the bridge site comprises of compact clay and sand conglomerate.
- The rock level is about 20 to 30 m deep. Raft foundation with cut off walls had to be adopted for this bridge of length 160 m.
- Bandhara piers are provided in between main piers connected by seal beam. Water storage is 3.5 m.
- Extensive exit velocity calculation based on Khosla's theory was done to decide apron length. Specially designed R.C.C. arrestors are constructed to take care of the choking of Bandhara vents.
- As cost effective product, colcrete has been used in the construction of aprons on d/s and u/s side. Since the riverbed contains finer material it acted as a barrier to the percolation of colgrout get into the bed. Hence, the locally available stones were arranged in the panel and filled with colgrout gel.
- Guide walls have also been constructed in colcrete.
- This was the first attempt in the state and probably in the country to construct such a long bridge-cum-Bandhara on a flexible foundation.
- Due to construction of Bandhara more than 35000 rural population of 28 villages got benefited and their drinking water problem is solved. Now dams on tributary of Purna can be used to their full potential, as water is not to be let out of these dams to meet summer demand. Water of Bandhara is also used for irrigation purpose of the adjoining fields. Total water spread is more than 2.5 km.

### III. Bridge-cum-Bandhara Across Wardha River Near Kaudanyapur in Amravati District (Photo 5).

- Near village Kaudanyapur on the right bank of river well known ancient temple of Vidarbha is situated. Temple is visited by pilgrims throughout the year.
- Sill beam type bridge-cum-Bandhara is constructed across Wardha river which is a major river in Vidarbha of Maharashtra State.

- (c) Span arrangement is 24 spans of 7.4 m c/c. Depth of storage is 3.5 m. Bandhara piers are provided in between main piers connected through sill beam.
- (d) Unsymmetrical 'T' shaped footing embedded in rock is provided for bridge main piers.
- (e) Due to its storage capacity 450 hectors of land could be irrigated. Structure has added to the beauty of historical important place Kaudanyapur from tourist point of view. Boating could also be planned in future for tourist attraction. Sorce of water for Arvi taluqa hq.

**IV. Bridge-cum-Bandhara Across Sipna River on Dharni-Diya-Dharanmahu Road in Amravati District (Photos 8&9).**

- (a) Site is located in remote tribal area with hilly terrain.
- (b) Length of bridge-cum-Bandhara is 120 m with single lane width (4.25 m).
- (c) Cantilever type main pier and Bandhara piers in between main piers is provided. Width of Bandhara pier is only 30 cm.
- (d) Tie beam at top of Bandhara piers is provided which is extended upto center of main bridge pier cap and anchored in the cap.
- (e) Due to its storage capacity, 125 hector of land could be irrigated. Nearly 26 villages got connected due to this bridge-cum-Bandhara and 13000 villagers got benefited. Source of water for Dharani town.

**V. Bridge-cum-Bandhara Across Bordi Nalla near Shirajgaon on Khamgaon-Buldhana Road in Buldhana District (Photos 10&11).**

- (a) Existing bridge has been converted into bridge-cum-Bandhara and the work has been done out of discretionary grants.
- (b) Length of Bandhara is 24 m with storage depth of 3.0 m.
- (c) Bandhara has increased the ground water level of adjoining village and fields. Drinking water problem of village Shirajgaon has been solved and now in summer tankers are not required for drinking water supply.
- (d) Due to this Bandhara about 32 hector land can now be irrigated.

**Drawings and Photographs**

Photographs 1 to 11 are showing structures executed.

**19. PROBABLE MODIFICATIONS**

- 1) In the type plans evolved for various situations grade of concrete for Bandhara pier is taken as M-20 being R.C.C. pier with 0.3 per cent minimum steel as per IRC. However, as it is a secondary structure and stress

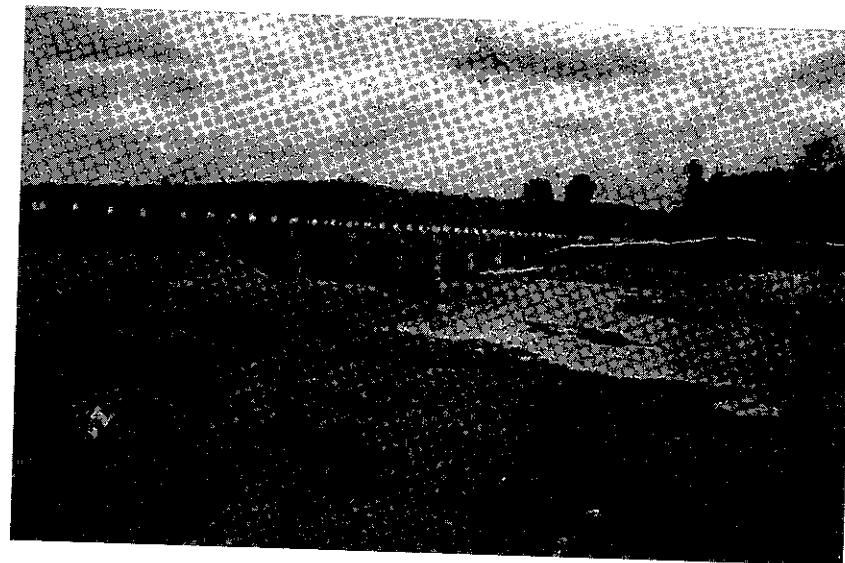


Photo 8



Photo 9

Bridge-cum-Bandhara Across Sipna River on Dharni-Diya-Dharanmahu Road in Amravati



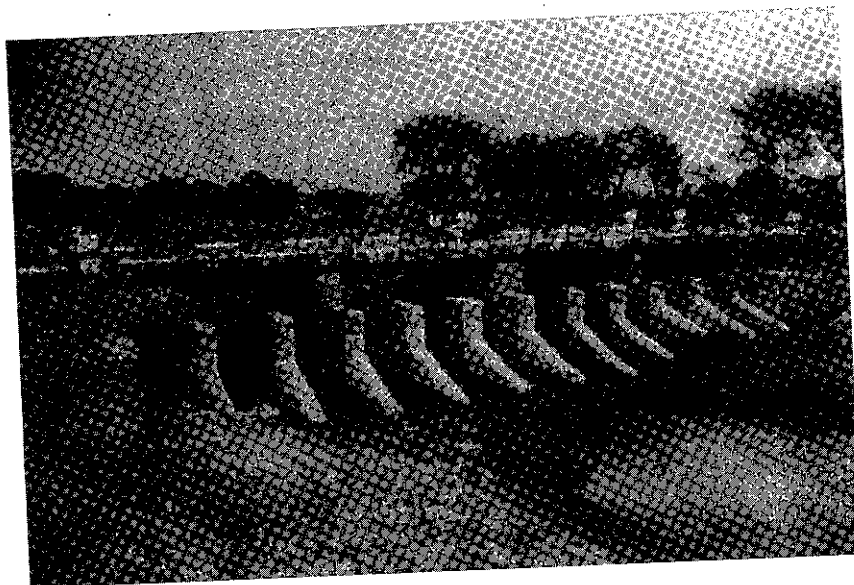


Photo 10

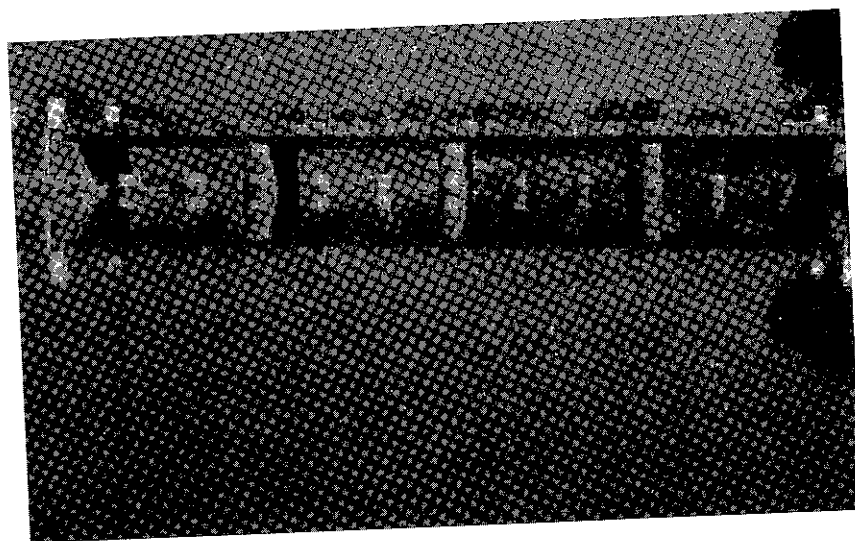


Photo 11

Bridge-cum-Bandhara Across Bordi river near Shirajgaon on Khamgaon-Buldhana Road in Buldhana District

concentration is localized (on u/s face), and hence steel as per actual requirement with minimum of surface reinforcement and extra steel on u/s face. Could be considered. With this, cost of structure can be reduced considerably.

- 2) Main piers have been provided with R.C.C. M-20 and 0.3 per cent minimum steel as per IRC. However, where water velocity is upto 3.0 m/s and structure is of small height, stress level is very less. Steel in this case can be reduced to that actual required (instead of 0.3 per cent) with minimum of surface reinforcement. Extra steel can be provided in the zone where stress concentration is there. Area of this zone is much less compared to total area of pier. This way substantial saving in steel is possible.
- 3) With the use of latest equipments like hydra cranes needles/gates can be modified to 4 m clear span instead of 2 m. with a height of each needle 1 to 1.5 m, instead of present 0.5 m. This will not only minimize the no. of operations, time required to close or open the openings will also be reduced. Also no. of bandhara piers required will be reduced, thereby further reducing the cost of the concrete structure.

## 20. CONCLUSION

Efforts have been made to optimize the structures while evolving the type plans. With the introduction of new construction material like colcrete, automatic closing gates and possible modifications as mentioned in above paras, the cost of construction and operation of these structures can further be reduced. If more and more sites could be identified as feasible for bridge cum Bandhara, extensive use of these structures will be of great help to solve the drinking water problem. This will also help in increasing the ground water table and more water will be available for irrigation. This way some contribution can be made to conserve water for a drought free tomorrow.

## ACKNOWLEDGEMENT

Authors express their deep gratitude to all those who have helped in writing this paper. Special mention has to be made of Design Circle, P.W.D., Maharashtra State, which has taken special efforts for evolving various type plans of bridge-cum-Bandhara.

## REFERENCES

- 1) Optimum Design of Medium Height Bridges-A Pressing Need of Rural Roads by P.L. Bongirwar, Published in International Seminar on Rural Roads.
- 2) India today, weekly magazine, June 9, 2003.
- 3) Type drawing no. BRN/AMR/84/93003 R-1 of P.W. Design Circle, M.S.
- 4) Type drawing no. BRN/AMR/84/93004 R-1 of P.W. Design Circle, M.S.

452. BONGIRWAR, DR. NAMIOSHI & JAISWAL ON  
DUAL PURPOSE BRIDGE STRUCTURE

5) Drawing no. BRN/MR/84/93005 R-1 of P.W. Design Circle, M.S.

Technical paper by I. R.K. Ingle & M.M. Jaiswal published in Indian  
Highways Volume 29 No. 11 November, 2001.

Handbook of Public Works Department.

Type drawing no. BRN/TP/94014 of P.W. Design Circle, M.S.

9) Type drawing no. BRN/TP/94020 of P.W. Design Circle, M.S.

10) Type drawing no. BRN/TP/94021 of P.W. Design Circle, M.S.

11) Type drawing no. BRN/TP/94022 of P.W. Design Circle, M.S.

12) Type drawing no. BRN/TP/94023 of P.W. Design Circle, M.S.

13) Type drawing no. BRN/TP/95027 of P.W. Design Circle, M.S.

14) Type drawing no. BRN/TP/95031 of P.W. Design Circle, M.S.

15) Type drawing no. BRN/TP/95046 of P.W. Design Circle, M.S.

16) Type drawing no. BRN/TP/95047 of P.W. Design Circle, M.S.

17) Handbook for Irrigation Department.