OPTIMIZING THE EXTENT OF MODERNIZATION OF BRIDGES

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ABSTRACT

World is witnessing the era of innovations where concept of bridges is also getting modernized. Great attentions are being paid across the globe to enhance the structural behavior, geometry, durability, riding quality and aesthetics of the bridges. Performance of bridges in high seismic zones is one of the key concerns of bridge professionals across the world.

An initiative, in this regard, has been taken by Uttarakhand Rural Roads Development Agency (URRDA) while proposing 65m span bridge across Gori nadi (river) under PMGSY scheme in the state of Uttarakhand. The bridge which is going to become landmark structure of the country will probably depict the extent till which modernization of bridges can be done. The bridge, which has got altogether a noticeable elegant look, has also got two excellent behaviors merging into it i.e. arch action and frame (integral) action. Arch bridges are well known for their superior behavior since ages and integral bridges, where substructure is monolithically connected to superstructure, are recent trends across the world due to their many inherent features i.e. superior structural behavior under stringent seismic/flood conditions, enhanced durability, no maintenance requirements, improved riding quality and distinct graceful look.

The paper primarily discusses about the features, design and methodology of construction for the bridge. Detailing of various components of the bridge which was found even more challenging and interesting has also been presented in the paper. The bridge has been designed for high seismic forces of zone V.

KEYWORDS: aesthetics, design, detailing, integral bridge, superior behaviour, unsymmetrical bridge

1. INTRODUCTION

Bridge across Gori nadi in the state of Uttarakhand is a unique "unsymmetrical integral arch bridge" where two excellent structural behaviors are merging together i.e. arch action and frame action (Figure 1 to 3). This has added many unparalleled features to the bridge i.e. aesthetics, enhanced performance under seismic/flood conditions, prolonged durability, better riding quality and least maintenance requirements in the absence of the bearings and intermediate expansion joints. The bridge primarily has an unsymmetrical arch on either side of carriageway which is supported over two inclined and one vertical piers. Frame action has been added by integral (monolithic) connection between arch rib, piers and longitudinal beam supporting the deck slab.

Unsymmetrical shape of the bridge along with arch ribs, inclined piers, integral connections and curved haunches offers a distinct graceful look to the bridge which truly merges with the beautiful hilly surroundings. The curved haunches not only improved the aesthetics but also assist in getting smooth and uniform stress flow from one component to other component of the bridge.

Complexity of the shape not only made the structural design interesting but also created challenges during detailing the bridge specifically at places where reinforcing bars were passing in many directions i.e. springing points and at the intersection of arch rib, piers and longitudinal beam. The bridge has been designed based on the Indian standards to carry two lanes of traffic and high seismic forces as it is located in highest seismic zone (i.e. zone V) of the country.

FIGURE 1 Proposed 65m span bridge across Gori nadi, Uttarakhand

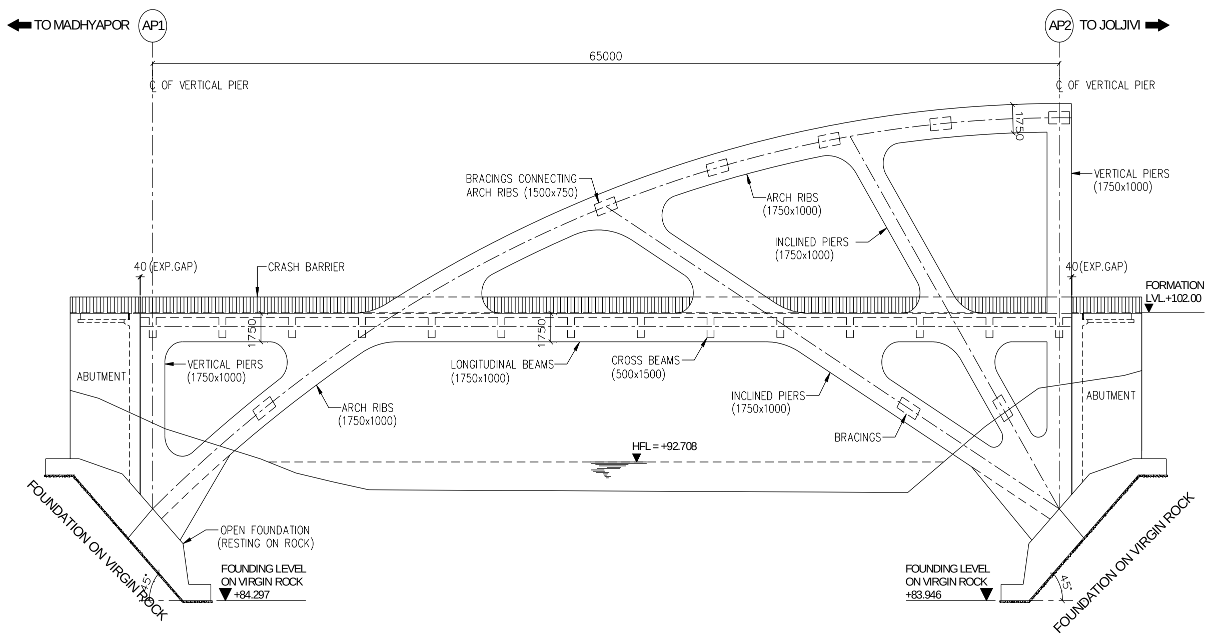

FIGURE 2 Typical elevation of the bridge

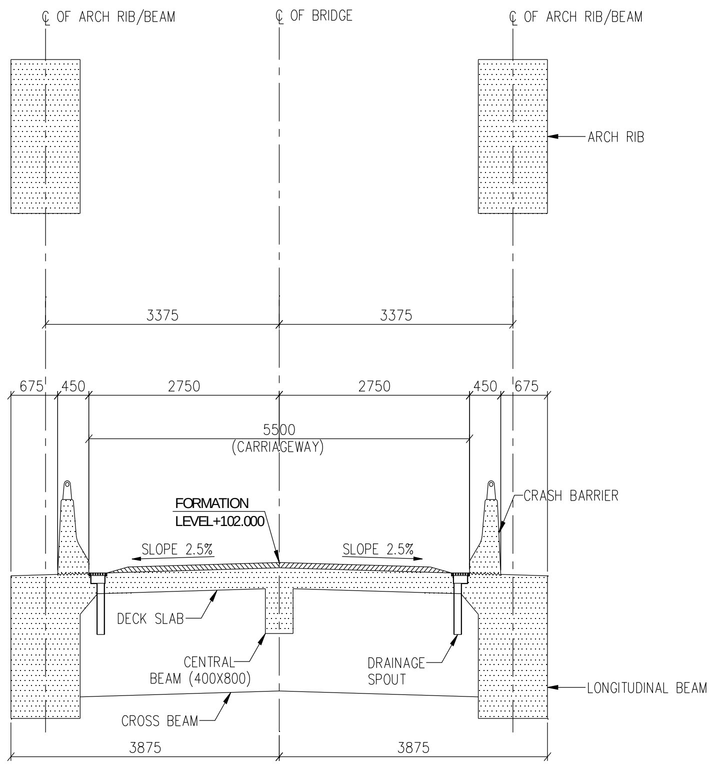

FIGURE 3 Typical cross section of the bridge

2. STRUCTURAL SYSTEM

The bridge principally has a single span of 65m between the springing points of the arch rib/piers. The carriageway width and total width of the bridge is 5.5m and 6.4m respectively which carries two lanes of traffic. Structural system of the bridge primarily consists of part of arch rib on either side of the carriageway which is supported over two inclined and one vertical piers. Longitudinal beams supporting the deck slab are supported over the arch ribs/piers. Thickness of the arch ribs, inclined piers and longitudinal beams is 1000mm. Arch ribs, piers and longitudinal beams have uniform depth of 1.75m. Arch ribs and inclined piers have been braced in the transverse directions with 750mm x 1500mm bracings to have desired lateral stability specifically during transverse seismic conditions. At the deck level, 500mm x 1500mm cross beams have been provided at a spacing of 5m to brace the arch ribs/piers in the transverse directions and to support the deck slab. Thickness of the deck slab is kept equal to 250mm. Founding levels (lowest) on two sides of the bridge are at a depth of 17.70m (grid AP1) and 18.05m (grid AP2) respectively below the formation level of the bridge. Foundation sizes on grid AP1 and grid AP2 are 8.75m(W) x 15.00m(L) and 9.25m(W) x 16.00m(L) respectively.

3. ANALYSIS AND DESIGN

A three dimensional grillage model (Figure 4) was prepared to analyze the bridge for various load effects including high seismic forces.

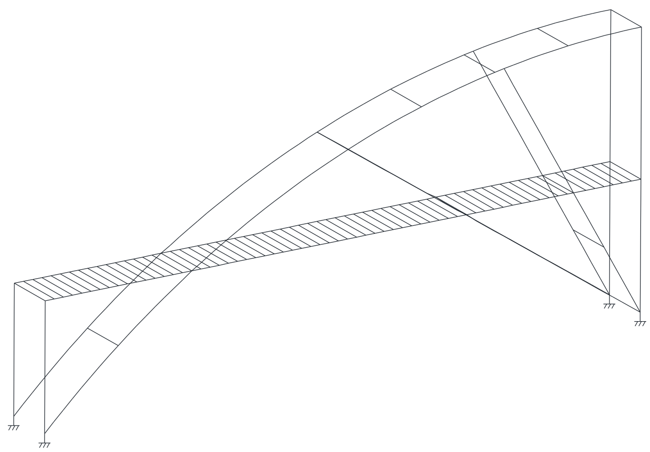

FIGURE 4 Three dimensional structural model of the bridge

Because of the innovations involved, design and drawings of the bridge were independently checked by Indian Institute of Technology, Roorkee where an independent structural model was prepared using different software. The variations in the results obtained from the two models were within 2 to 5%.

The bridge has been designed based on the as per the provisions of Indian standards. Table 1 below defines basic design standards and parameters considered for the bridge.

TABLE 1 Basic Design Standards and Parameters

Basic design standards	Indian standards
Formation level	+102.00m
Founding levels (lowest)	+84.297m (left end, grid "AP1"), +83.946m (right end, grid "AP2")
Type of sub-surface surface strata	Rock
Net safe bearing capacity	60 t/m^2 at founding level
Coefficient of friction	0.50 (between foundation & rock)
Carriageway width	5500mm
Overall deck width	6400mm
Loading considered	Dead load, live loads, braking forces, earth pressure, global temperature change (±35^{o}C), shrinkage (equivalent temperature fall of 17.10^{o}C), differential settlement of supports (12.5mm) and seismic forces (horizontal seismic coefficient of 11.25%)
Modulus of elasticity	Short term modulus of elasticity was considered to analyze the bridge for various load effects except for global temperature change, shrinkage and differential settlement of supports for which long term modulus of elasticity equal to half the short term modulus of elasticity was considered
Moment of inertia	Cracked moment of inertia equal to 0.7 times the gross moment of inertia was considered to take advantage of flexibility of structure specifically for forces due to temperature change

Grade of concrete	M35
Grade of steel	Fe500 grade
Permissible stresses	100% for "Load Combination I" consisting of forces excluding those due to temperature change, shrinkage, differential settlement of supports and seismic forces 115% for "Load Combination II" consisting of forces in Load Combination I & those due to temperature change, shrinkage, differential settlement of supports but excluding seismic forces. 125% (base pressure check) & 150% (structural design) for "Load Combination III" consisting of all forces including seismic forces

Design of foundations, arch ribs, piers, longitudinal beams, bracings connecting arch ribs and most of the cross beams at deck level was governed by load combination including temperature and seismic forces. Design of the deck slab was governed by load combination without temperature and seismic forces

4. DETAILING

Challenges were faced not only while designing the bridge but also while detailing various components of the bridge. As reinforcing bars were passing in many directions at certain places (Figure 5 & 6), there was no other option except to draw each and every bar including the stirrups in the elevation of the bridge.

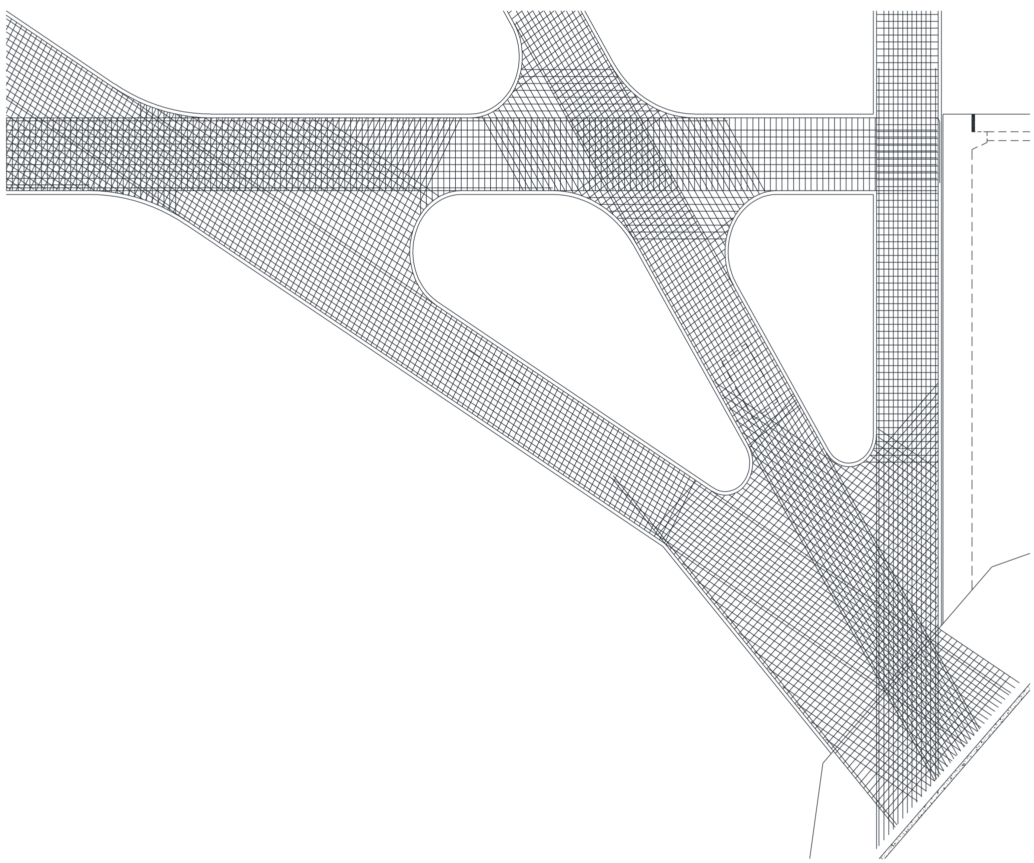

FIGURE 5 Reinforcing bars passing in many directions

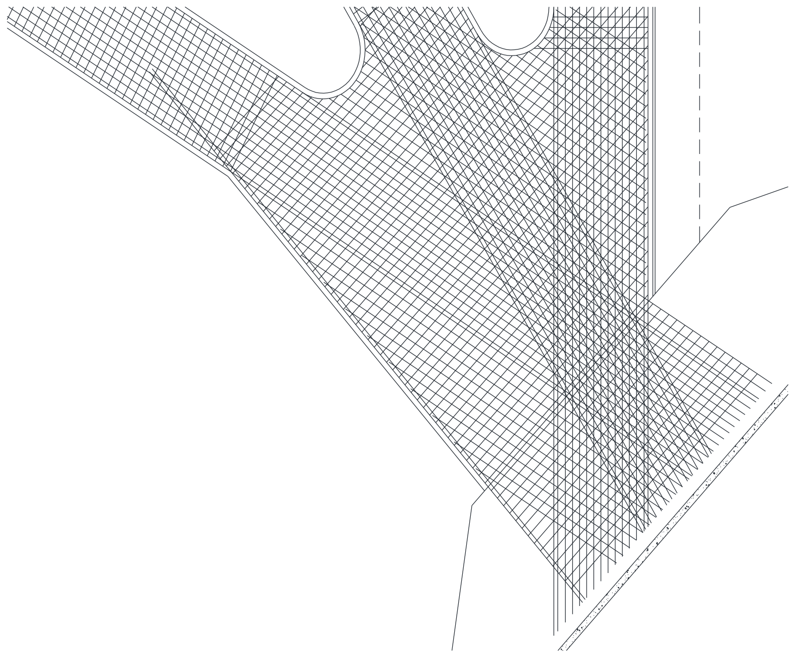

FIGURE 6 Closer view of bars at springing point

Drawing each bar in the bridge elevation was primarily required to make sure that bar spacing is neither too far nor too close at any point to allow free movement of the concrete between the bars and easy compaction of the concrete. Springing points of the arch rib/piers were one of critical locations as shown in Figure 5 & 6 above. Efforts were made to keep the bar spacing between 125-150mm (wherever possible) which is considered to be most ideal spacing of the bars in the structure. Placement and positioning of bars in one of the foundations are shown below in Figure 7 & 8.

FIGURE 7 Placement of foundation reinforcement cage in progress

FIGURE 8 Placement of foundation reinforcement cage in progress

5. CONSTRUCTION

As there were no repetitions involved in the construction process due to single span & irregular shape of the bridge and also as the bridge is being constructed at a remote place, the construction has been proposed over ground supported staging (Figure 9). The cast-in-situ construction could be made feasible by supporting the staging in the central portion over steel truss to allow free flow of water without any interruption. Also, as the river carries significant flow only for a maximum period of three to four months i.e. mid of June to mid of September, the sequence of construction of the bridge has been so planned that the central part of the bridge can be concreted in the dry season.

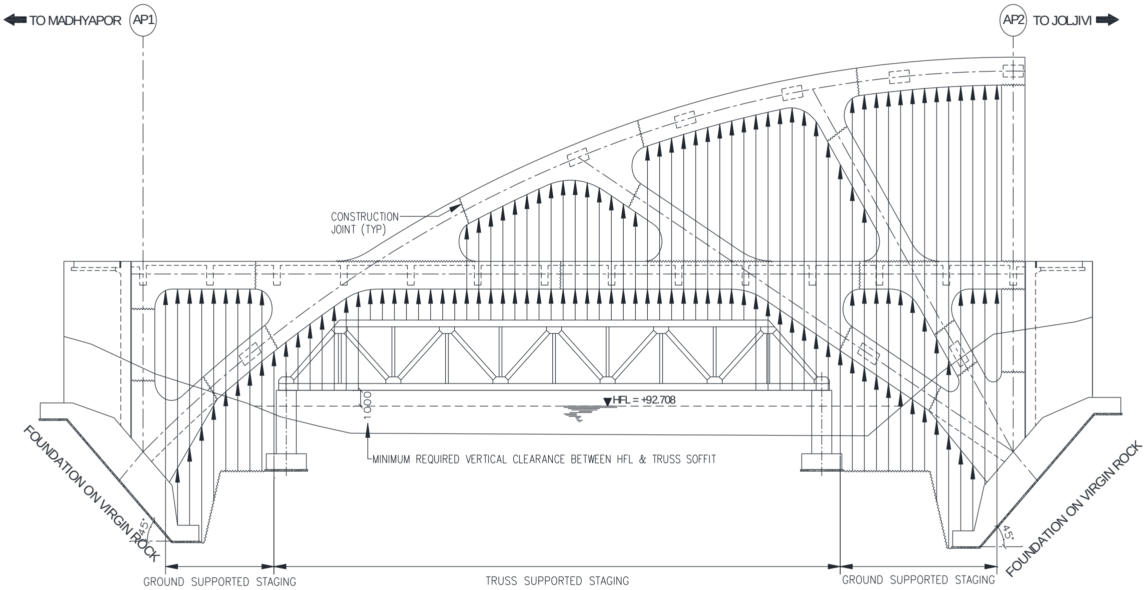

FIGURE 9 Elevation showing sequence and methodology of construction

6. CHALLENGES AND FACTS

Following are some of the challenges and facts associated with bridge:

- Detailing of bridge specifically at the junction of arch rib, piers and longitudinal beams;
- Achieving smooth surface profile at the site due to irregular and variable surface profile of the bridge. In order to achieve the desired surface profile, joint coordinates have been calculated at each corner of every shuttering plate which are going to be checked independently at the site while erecting the formworks;
- Fabrication of the reinforcement cage to the desired profile and placement of the same in required position due to complex geometry and variation in shape & lengths of the bars. Bar bending schedule of every bar has been prepared, independently checked and careful monitoring is going to be ensured during placement of each bar;
- In order to achieve the desired and uniform quality of concrete, the same is being produced from a computer controlled batching plant installed at the site. In order to ensure the desired compaction and soundness of concrete, slump of the concrete is kept relatively high (i.e. about 150mm) using super plasticizers and concreting is going to be done only from preapproved locations. Provision have been made for temporary openings (which can be opened and closed) in the top shutters of inclined members to facilitate easy placement and compaction of concrete;
- The maximum water cement ratio, minimum cement content and maximum cement content has been restricted to 0.45, 380 kg/m^3 and 450 kg/m^3 respectively. The maximum nominal aggregate size has been limited to 20mm;
- In order to avoid slippage of concrete, arch ribs and inclined piers are going to provided with top shutters till heights when their inclination with respect to horizontal became 20^o or less;
- While concreting the sloping members it is going to be ensured that concreting is done from lower end towards the higher end to avoid possible slippage of concrete from higher side towards lower side;
- In order to avoid segregation of aggregates, free fall of concrete is restricted to 1.5m. Wherever needed, chutes are going to be used to avoid free fall of the concrete;
- The orientation of construction joint in any member has kept perpendicular to the member axis and concrete surface is going to be uniformly hacked 10 hours after concreting to form a good construction joint (Figure 10). In order to further improve the bonding between old and new concrete, the old concrete surfaces are going to be applied with bonding agent (Nitobond EP of M/s FOSROC) just before placing the new concrete;
- Before start of every concreting, adequate number of needle and shutter vibrators are going to be ensured.
- In order to ensure desired quality of the cover blocks, they are proposed to be made of pre-packaged, early high strength non shrink mortars only.

FIGURE 10 Proposed hacking and roughening at the location of construction joint

6. QUANTITY OF MAIN ITEMS OF WORK

Concrete in foundations:	560 cum
Concrete in abutments:	240 cum
Concrete in substructure & superstructure:	1050 cum
(arch ribs, piers, beams/bracings and deck slab)	
Fe500 grade steel (all components):	340 ton

7. CONCLUSIONS

The purpose of a bridge is no more limited to carrying the traffic only. With better understanding of the subject, upgraded experience and availability of the software capable of giving accurate & precise results, it is now possible to enhance many features of the bridge i.e. performance, aesthetics, durability, least maintenance requirements, riding quality etc. It is also possible to have any shape or geometry of the bridge which suits to the site conditions. Bridge across Gori nadi is one of the example where many such excellent features could be brought together thereby making the bridge a landmark structure of the country.