INITIATING NEW ERA OF BRIDGES IN UTTARAKHAND

A.K.Dinkar and M.K.Mittal
Uttarakhand Rural Roads Development Agency, Dehradun, India
akdinkar@gmail.com & manishsre26@gmail.com

Alok Panday
Elegant Consulting Engineers, Ghaziabad, India
elegant_alok@hotmail.com

ABSTRACT

Purpose of bridges are no more restricted to carrying the traffic only. There are other concerns also i.e. structural behavior, aesthetics, geometry, durability, riding quality etc. which are being paid great attention all across the globe. 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 while proposing 45m span bridge across Ram Ganga river under PMGSY scheme in the state of Uttarakhand, India. In order to improve the road geometrics, the bridge has been provided in plan curvature. Efforts have been made to add few outstanding features to the bridge i.e. arch action and integral action. Arch bridges are well known for their superior behavior & aesthetics 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. Aesthetics of arch bridges has been added to curved bridge probably first time. Elegance of the bridge has been further enhanced by providing openings in the arch ribs which has also helped in achieving the economy up to certain extent.

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

KEYWORDS

Aesthetics, arch action, curved bridge, design, detailing, integral action, superior behaviour

1. INTRODUCTION

Bridge across Ram Ganga river in the state of Uttarakhand is a unique "curved arch bridge" where two excellent structural behaviors are merging together i.e. arch action and frame action (Figure 1 & 2). 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 arch ribs of varying depth on either side of carriageway which finally

support the deck slab. Frame action has been added by integral (monolithic) connection between arch rib and deck slab.

Plan curvature of the bridge along with varying depth of arch ribs and openings in the ribs, offers a distinct graceful look to the bridge which truly merges with the beautiful hilly surroundings. The varying depth of arch ribs not only improved the aesthetics but also assisted in getting smooth flow of stresses from superstructure to foundations.

Complexity of the shape not only made the structural design interesting but also created challenges during detailing the bridge. The bridge has been designed based on the Indian standards to carry single lane of traffic and high seismic forces as it is located in highest seismic zone (i.e. zone V) of the country.

FIGURE 1 Proposed 45m span bridge across Ram Ganga river, Uttarakhand

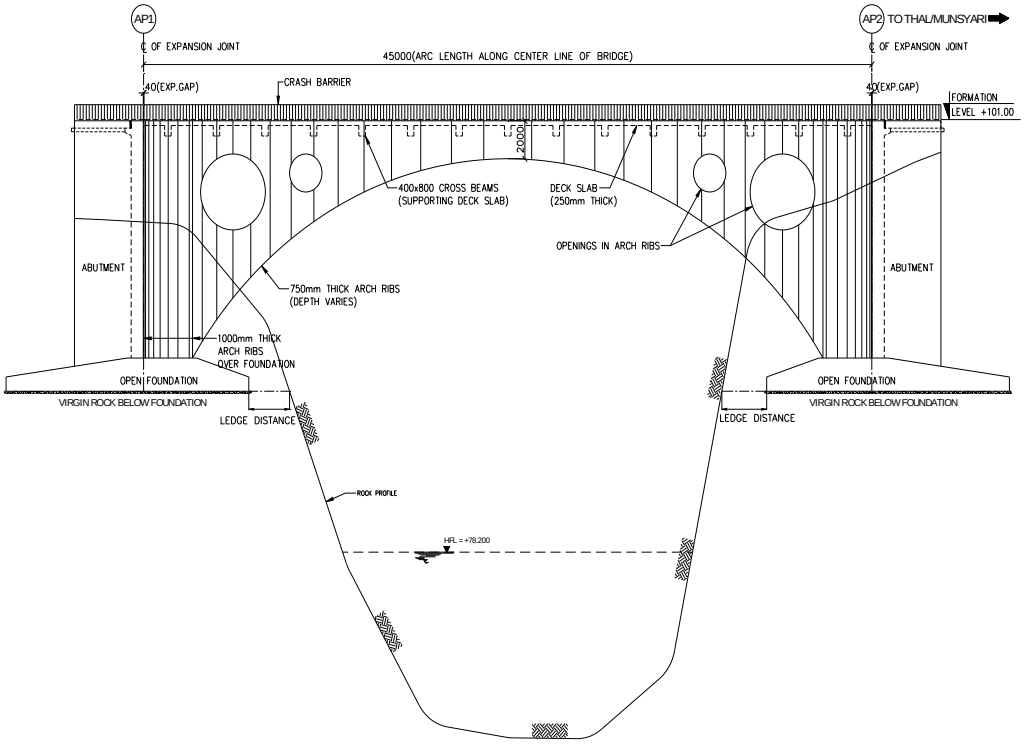

FIGURE 2(a) Typical elevation of the bridge

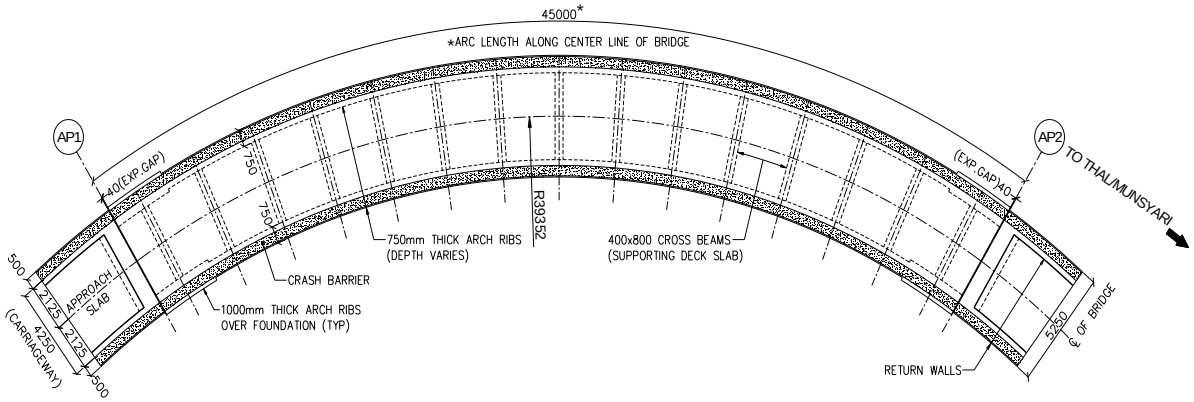

FIGURE 2(b) Typical plan of the bridge

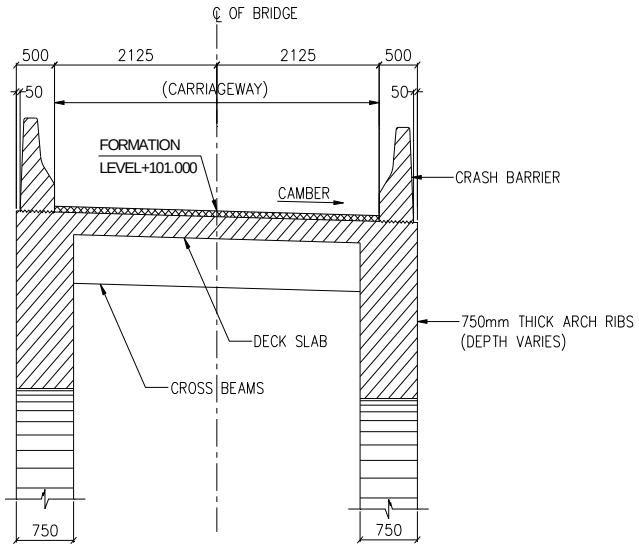

FIGURE 2(c) Typical cross section of the bridge

2. STRUCTURAL SYSTEM

Structural system of the bridge primarily consists of arch ribs of varying depth (Figure 1 & 2) on either side of the carriageway which finally support the deck slab. Curved span of the bridge between center line of expansion joints is 45m. The carriageway width and total width of the bridge is 4.25m and 5.25m respectively which carries single lane of traffic. Bearings which are known to be most fragile element in a bridge have been completely eliminated from the bridge. Expansion joints are provided only at the junction of bridge and approach roads to have smooth transfer of traffic from road to bridge.

Arch ribs of the bridge have varying depth and uniform thickness of 750mm except over foundations where it is 1000mm in 3m width. At the deck level, 400mm x 800mm cross beams have been provided at a spacing of 3m to brace the arch ribs in the transverse directions and to support the deck slab. Thickness of the deck slab is kept equal to 250mm. Founding levels on two sides of the bridge are at a depth of 14.50m below the formation level of the bridge. Size of the foundations supporting the bridge is 8m(W) x 14m(L).

3. ANALYSIS AND DESIGN

A three dimensional grillage model (Figure 3) was prepared to analyze the bridge for various load effects including high seismic forces.

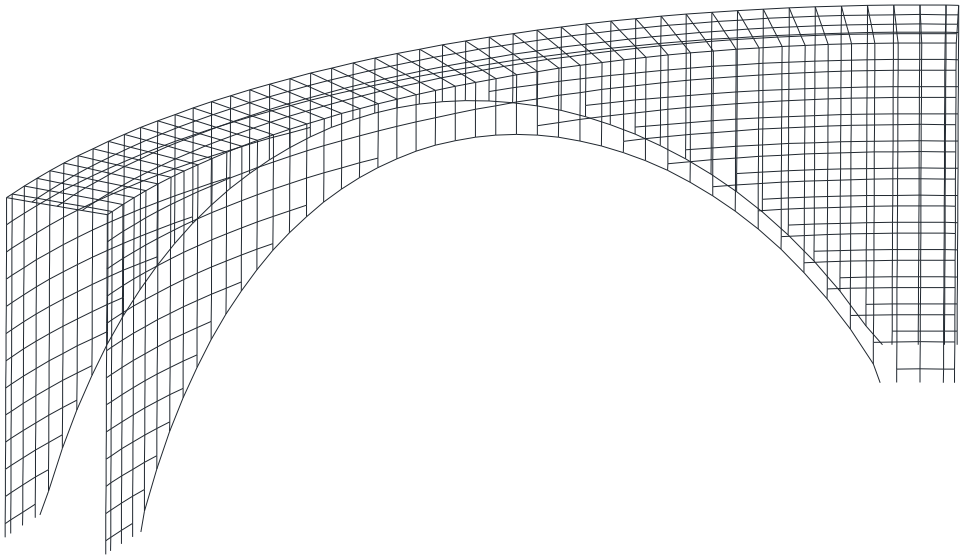

FIGURE 3 Three dimensional structural model of the bridge

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 4%.

The bridge has been designed based on 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	+101.00m
Founding levels	+86.500m
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	4250mm
Overall deck width	5250mm
Loading considered	Dead load, live loads, braking forces, earth pressure, global temperature change ($\pm 35^oC$), shrinkage (equivalent temperature fall of 17.10^oC), 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 and arch ribs was governed by load combination including temperature and seismic forces. Design of the cross beams at deck level and 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. In order to have sufficient clarity each and every bar including the stirrups were drawn in the elevation of the bridge (Figure 4).

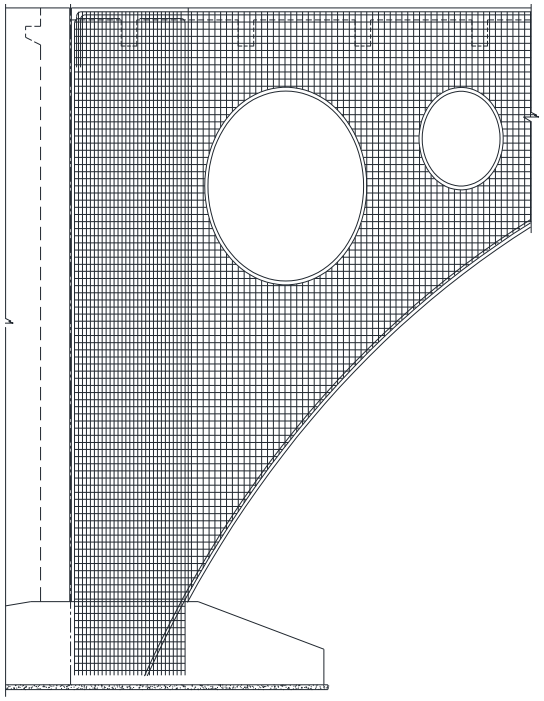

FIGURE 4 Reinforcing bars drawn on bridge elevation

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. 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.

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. The cast-in-situ construction could be made feasible by supporting the staging in the central part 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.

6. CHALLENGES AND FACTS

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

- Detailing of bridge i.e. drawing each bar on bridge elevation;
- Achieving smooth surface profile at the site due to variable depth of arch ribs. 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 side shutters of arch ribs 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;
- 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 5). 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 5 Proposed hacking and roughening at the location of construction joint

6. QUANTITY OF MAIN ITEMS OF WORK

Concrete in foundations:	420 cum
Concrete in abutments:	220 cum
Concrete in substructure & superstructure:	550 cum
(arch ribs, cross bracings and deck slab)	
Fe500 grade steel (all components):	160 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 Ram Ganga river is one of the example where many such excellent features could be brought together thereby making the bridge a landmark structure of the country.