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NEW GENERATION OF FOOTBRIDGES FOR DELHI, INDIA

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1.0 Summary

Tall, long and slender structures are the order of the day. Additionally, footbridges are lightly loaded, which makes them susceptible to vibrations when they are characterised by smaller natural frequencies.
The design issues relating to vibrations in footbridges are two-fold:
- these created by aerodynamic excitation
- these created by footfalls of pedestrians

The modes of vibration that can be caused can be:
- flexural in horizontal direction (both lateral or longitudinal to the bridge)
- flexure in vertical direction
- torsion about the longitudinal axis

Five pedestrian bridges of similar design are in service in the city of Delhi. Five more are in various stages of construction. The concept selected involved a steel arch bridge with a suspended walkway, Fig 1. Arch bridges by their very form are aesthetic to behold and can more easily span across wide roads.

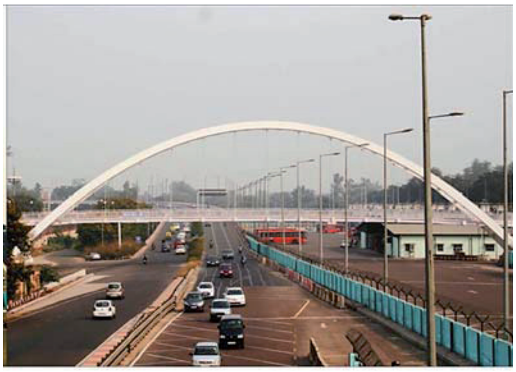


Fig 1 Completed views of the bridges of 80m span

2 Arch Bridge during Erection

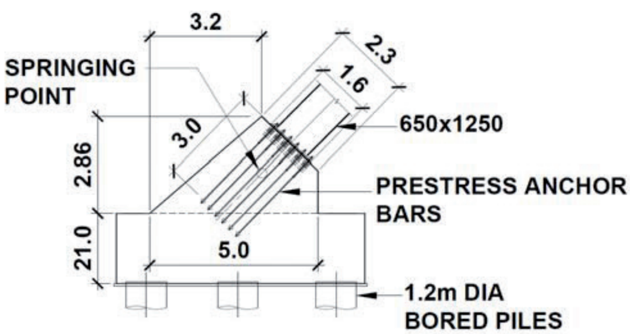


Fig.3. Foundation Connection

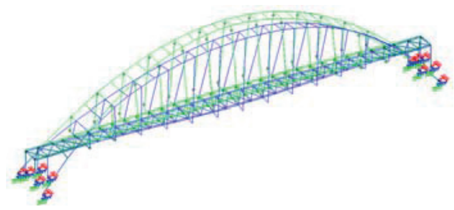
2.0 Special Issues

The designs concept had to cater to arch spans cater to varying from 66m to 90m. The arch and the walkway in structural steel could be manufactured in a quality fabrication shop and then shipped in transportable segments to site and erected by crane. The connections of steel segments (5 nos) were effected essentially by HSFG bolts (Figs 2, 3) and the arch was clamped to the foundations by prestressing. This arrangement permitted dismantling of the bridge and its re-erection at alternative location should this become necessary. Sustainability is described by the buzz words: REDUCE, REUSE, RECYCLE. It would also ensure that the bridge would retain its legacy value.

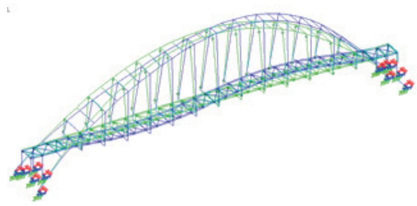
Preliminary design stage investigations were done both for static as well as dynamic loading. The latter consideration revealed that both from the aerodynamic excitation due to wind and pedestrian comfort points of view special attention would be required for the dynamic response of the bridge apart from the gravity loads.

3.0 Dynamic Effects

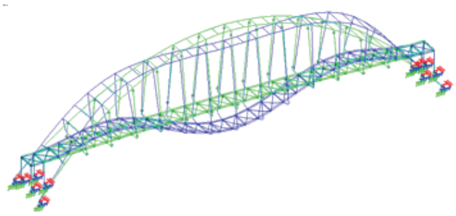
Separate analyses were done for aerodynamic and pedestrian excitation. The British Standard BD 49/01 [1] was employed for the former while specialist literature (HIVOSS) [2] was employed for the latter. The graphical outputs of the frequency analysis are reproduced in Fig. 4.



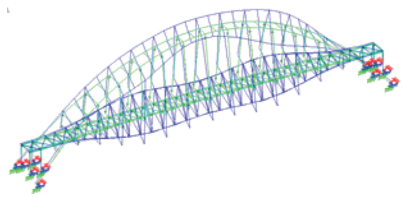
a) LATERAL mode 1,



b) LONGITUDINAL mode 3,



c) VERTICAL mode 5,



d) TORSION mode 15

Fig. 4. Graphical Output of Frequency Analysis

For wind effects the following aspects were checked:

- Aerodynamic Susceptibility Factor
- Vortex Excitation
- Magnification Effects of Turbulence
- Divergent Amplitude Response

The Conclusion of the aerodynamics study was that the selected concept and dimensions were acceptable.

For pedestrian excitation the following aspects were checked:

- Identify the natural frequencies of the bridges in bending / vertical mode, lateral mode and longitudinal mode.
- Evaluate the max and min range that are critical for the bridge and identify if any of the frequencies calculated earlier were in the critical range.
- Evaluate the max acceleration caused by pedestrians on the bridge and ensure that it does not effect their comfort level.

The conclusion of the pedestrian excitation study was that the selected concept and dimensions were acceptable.

4.0 References

[1] *Design Manual for Roads and Bridges. Design Rules for Aerodynamic Effects on Bridges: BD 49/01*. Highways Agency, London. May 2001.

[2] *Human Induced Vibrations of Steel Structures (HIVOSS)*, Design of Footbridges (Guideline-EN 03), Publications office of the European Union, Luxemburg, Sept 2008.