# TRAFFIC INDUCED VIBRATION ANALYSIS OF EXISTING STEEL BRIDGE IN PADENIYA-ANURADHAPURA ROAD

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**Abstract:** The Bridge which is located in Padeniya-Anuradhapura road is a steel truss bridge with three spans of approximately 31m long. It is currently undergoing a development process which includes constructing a new cantilever pedestrian walkway of 1.5m in length of either side of the bridge. Because of this proposed cantilever foot walk static as well as dynamic loading will be changed. In order to ensure that the structure is safe under the additional loads, structural analysis was carried out for static condition as well as for dynamic condition to check the adequacy of structural elements. Analyses of the bridge under static and dynamic loading were done by the finite element (FE) method. The bridge model is such that the structural steel is idealized by beam elements and the deck is represented by shear flexible shell elements. The support with elastomeric bearings is idealized by using an internal element with linear springs. Modelling was carried out using commercial FE software package SAP2000. Based on the results of finite element analysis this paper suggests the effectiveness of using elastomeric bearings for enhancing vibration serviceability hence expanding life span of steel truss bridges.

**Keywords:** finite element (FE) method, elastomeric bearings, base isolation.

## 1. Introduction

The bridge (No. 75/4) located in Padeniya-Anuradhapura road which is currently undergoing a development process including constructing a new cantilever pedestrian walkway on either side of the bridge, will tend to have additional loads. Therefore in order to ensure that the structure is safe under those additional loads structural analysis was carried out for static condition as well as dynamic condition.

Modelling was carried out using commercial FE software package SAP2000 and the results obtained, conclude that there exists a kind of a vibration problem. This vibration issue can be diluted to a certain amount by providing restriction on the speed limits to vehicles or by using a base isolation method such as elastomeric bearings with high spring constant.

## 2. General Information

A truss bridge is a bridge composed of connected elements which may be stressed from tension or compression or sometimes both in response to dynamic loads. Truss bridges are one of the oldest types of modern bridges. The first truss bridge (which was made out of timber) was designed and built in USA in the early of 1820's. Truss bridges became a common type of bridge built from the 1870s through the 1930s. In Japan, the first steel truss bridge for highway is Horonai River Bridge built in 1995. Since then, steel truss bridges have been one of the most popular bridge types for short and medium span highway bridges in Japan. Differently from those types of bridges in Europe, highway bridges in Japan employ elastomeric bearings at the supports to minimize the seismic loads on bridges.

Advantages of such a simplified structural system of steel truss bridges include the simplicity in relation to design, fabrication and the low cost of maintenance and construction. However the wide girder spacing and simplified lateral bracing system may cause problems related to vibration serviceability due to external dynamic loads such as wind, vehicle loads, etc. Yang et al. [1] and Yau et al. [2] have observed that the installation of elastic bearings can increase the dynamic response of a beam under moving train loads through theoretical and experimental studies. This study examines the effects of elastomeric bearings on the vibration of steel truss bridges by means of a three dimensional traffic induced dynamic analysis.

## 3. Methodology

**3.1Bridge Model**

A three span continuous steel truss bridge seated on elastomeric bearings is tested and analysed. The basic properties of the bridge are presented in Table 1. The deck slab is made of a reinforced concrete of 22.5cm thick, and is assumed to act compositely with main girders. Assuming that C deck is uncracked, the full concrete section of RC deck is considered in finite element modelling. The elastomeric bearing is idealized as a spring element. Corresponding spring constants used in the analysis are listed in Table 2[3].

**3.2Vehicle Model**

Two types of vehicles are defined in BS5400 namely HA and HB vehicles. Since the bridge is not designed for HB vehicle we used 20 tonnes HA vehicle as the critical vehicle model for the dynamic analysis.

**3.3Analytical Procedure**

Step 1

Analysed the existing bridge using commercially available FE software package SAP2000 and identified that there is a problem in vibration serviceability of the bridge.

Step 2

Vehicle models mainly concern about two criterions namely, vehicle speed and mass. By the analysis identified a typical vehicle model for the analysis.

Step 3

Analysed the bridge with and without elastomeric bearings with different speeds of the vehicle and identify the critical speed that the vibration serviceability problem of the bridge occurs.

## 4. Results and Discussion

**4.1Analytical Results**

Clause 6.13 of BS 5400:Part2 states that vibration serviceability of highway bridges due to traffic movement are not required to be considered. But however code specifically states that the vibration induced in pedestrian walkways should be considered and check with the maximum value according to the Appendix B of composite version of code BS5400: Part 2.

Fundamental Natural frequency of the bridge (without vibration control measures) in vertical direction in unloaded condition is 1.79Hz (for the time period of 0.56s). Code states that for superstructures with fundamental natural frequency less than 5Hz it should satisfy the maximum vertical acceleration in any part of the structure to $0.5\sqrt{f_o} m/s^2$ (0.8794 $m/s^2$). Dynamic analysis of the existing bridge suggest that even for the lowest speed (20 km/h) actual vertical acceleration is higher than the allowable limit [fig1].

Fundamental Natural (80 km/h) frequency of the bridge (with vibration control measures) in vertical direction in unloaded condition is 1.6Hz. Since the maximum acceleration in pedestrian walkway after installation of vibration control measures (0.23 $m/s^2$) for the maximum speed (80 km/h) is within the allowed limit of acceleration vibration serviceability of the bridge modified with elastomeric bearings deemed to be satisfied. [fig2]

## 5. Conclusion

It is observed from this study that the acceleration response of steel truss bridge with elastomeric bearings is reduced drastically in comparison to the existing bridge. Another interesting fact is that the acceleration response increases with the speed of the vehicle and mass of the vehicle. From the observations it is sufficient to point out that the installation of elastomeric bearings is effective in enhancing vibration serviceability of the bridge.

## References


[1] Yang YB, Lin CL, Yau JD, Chang DW. "Mechanism of resonance and cancellation for train induced vibrations on bridges with elastic bearings." J Sound Vibr 2004; 269: 345-360

[2] Yau JD, Wu YS, Yang YB., "Impact response of bridges with elastic bearings to moving loads". J Sound Vibr 2001; 248 (1):9-30

[3] Chul-Woo Kim, Mitsuo Kawatani, Won-Suo Hsawng., "Reduction of Trafic Induced Vibration of Two-Grider Steel Bridge Seated on Elastomeric Bearing."

Table 1: Properties of bridge model

| | |
|---|---|
| Span length (m) | 31+31+31=93 |
| Width (m) | 8.7 |
| Thickness of deck (cm) | 22.5 |
| Dimension of main girder (mm) | Web 580×20<br>Flange 240×15 |

Table 2: Spring constants of elastomeric bearing (kN/m)

| | |
|---|---|
| Longitudinal | 4.4718 E+02 |
| Transverse | 6.4332 E+02 |
| Vertical | 1.4834 E+06 |

Table 3 - Comparison of Results of the Bridge with and without Base Isolation

| Description | Speed Restrictions (km/h) | | | |
|---|---|---|---|---|
| | Existing Bridge | Modified Bridge | | |
| | | Spring Const: 8000 kN/m | Spring Const: 11000 kN/m | Spring Const: 14000 kN/m |
| 1 20T HA Vehicle | 55 | 65 | 70 | 80 |
| 2 20T HA Vehicles | 30 | 40 | 45 | 50 |
| 1 30T HB Vehicle | Not allowed | - | - | 25 |

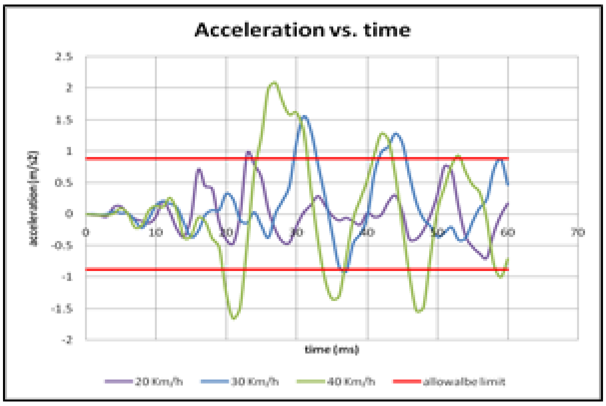


Figure 1: Graphs for the Vertical Accelerations of Existing Bridge

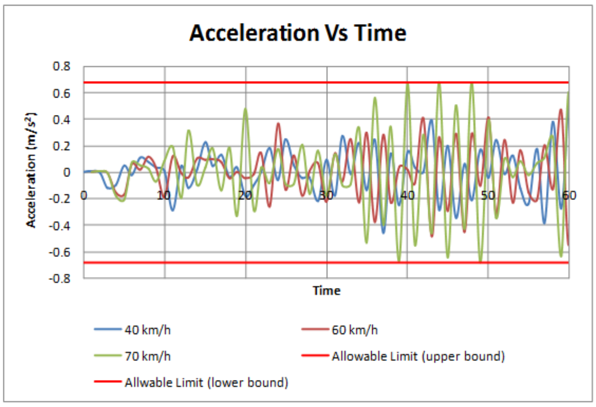


Figure 2 - Graphs for the Vertical Accelerations of Modified Bridge