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ANALYSIS ON LONG SPAN BRIDGE FOR AERO ELASTICITY

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ABSTRACT:
The aero elastic and aerodynamic effects on long-span slender bridges due to traffic has traditionally been neglected as it is assumed that the bridges will be closed to traffic under strong winds. However, with ever changing weather, natural disasters, and important roles of many long-span bridges throughout the United States, the reality is that these long-span bridges are often not closed and there are still many vehicles on the bridges even when considerably strong winds exist. Therefore, to rationally evaluate the aerodynamic performance of a bridge deck, the impacts from stochastic traffic should be appropriately considered as a key part toward any safety or serviceability study. The present study discusses the wind tunnel experimental tests of a long-span bridge section with stochastic traffic. The details of the experimental investigations are reported, including the design and construction of a bridge section model, two-degree-of-freedom testing frame and vehicle models representing stochastic traffic. Several tests were performed to determine a baseline for the bridge section without traffic, under different wind speeds and attack angles. The bridge section was then re-tested with many scenarios representing stochastic and extreme traffic conditions. The aero elastic flutter derivative coefficients were extracted using the iterative mean square method and the values plotted and compared with the baseline results. Under the given reduced velocity range being tested, it is observed that several traffic scenarios increase the aero elastic and aerodynamic effects as the bridge section becomes more susceptible to flutter and vortex shedding. Finally, the statistical descriptions of the flutter derivatives with the presence of traffic on the bridge section model are also made. The total structure analysed by using software E-tabs. The results checked with theoretical results for better conclusions.

Key words: Long span bridge, aero elasticity, E-tabs, Response.

1.0 INTRODUCTION

It is well known that the study of aero elastic effects on bridge structures came into the spot light with the failure of the Tacoma Narrows Bridge. The following in-depth studies of the Tacoma Narrows failure laid the foundation for the current understanding of aero elastic effects on structures. The failure also led to the common practice of wind tunnel testing of long span bridges to further understand the aerodynamic and aero elastic behavior of bridge decks. This thesis will focus on experimentally investigating the aerodynamic performance of a slender long span bridge with stochastic traffic.

Long-span Bridge Aerodynamics:

Throughout the world lighter, slender and longer long-span bridges have been proposed and built such as the current long span record holder, Akashi Kaikyō Bridge in Japan with a 1,991 meter main-span. The design control is more critical as the current long-span bridge designs exhibit large slenderness ratios, flexibility and low structural dampening. Currently feasibility studies have been implemented to explore spans of up to 5,000 meters.

Aerodynamics and Aero elastic Effect:

Wind includes laminar (or smooth) and turbulent flow components. For slender long-span bridges, both laminar and turbulent-induced wind loads will cause the bridge to experience dynamic vibration. For instance buffeting is caused by the unsteady loading on a structure due to velocity fluctuations in the approaching wind. Flow-induced vibration of the bridge deck as a result of aerodynamic effects will modify the flow around the bridge deck, which in turn will change the wind load on the bridge deck.

Case-study bridge

In order to arrive at a quantitative assessment of the sustainability of bridge concepts incorporating FRP bridge decks, a comparative analysis needs to be performed on a well-defined case. For this purpose, a case-study bridge was selected and analyzed with regard to life-cycle costs and environmental impact in terms of carbon emissions. However, before any general conclusions can be drawn, a wide range of bridge types and spans should be studied by performing such analyses.

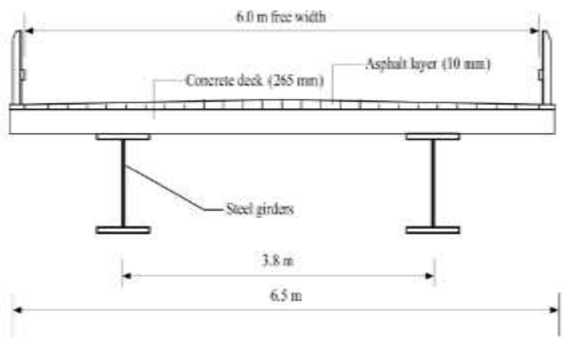

Figure: Cross-section of the old Rokån bridge

Replacing the old concrete deck with a new one was not an option. Due to the high weight of the concrete deck, the load-carrying capacity of the bridge would still have been limited by the capacity of the steel girders.

2.0 LITARATURE REVIEW

[1] Hasan Husnu Korkmaza et al (2005) studied the performance of a precast concrete beam-to-beam connection subject to reversed cyclic loading simulating severe earthquake action. The result indicates that the connections were vulnerable to lateral loads. Connections were subjected to more shear and bending moments. **[2] Pillai and Kirk (1981)** developed a satisfactory ductile, moment resistant beam-to-column connection to be used in earthquake resistant buildings with precast reinforced concrete construction. A satisfactory design for such a connection enabled the performance of the connection to be investigated experimentally. **[3] Dolan and Pessiki (1989)** Demonstrated the feasibility of using models for testing precast concrete connections. Model studies have been examined as an alternative for obtaining basic information about the behavior of precast concrete connections. The advantages of model studies include lower cost, specimens that are more easily manufactured and handled a significant reduction in applied loading, and a corresponding reduction in test apparatus size. **[4] Comair and Dardare (1992)** Carried -out a testing programmer on thread ridded connections with grouted sleeves. It was accepted that this connection system is usually viewed as more economical than other systems used in France. The model test specimen is a beam-to-column interior connection and assumed to be located in the first story of a three-story, two-bay moment resisting frame.

3.0 METHODOLAGY

Long-span bridges are slender, light, and flexible large-scale line-like structures, highly sensitive to wind effects. The main wind-related problems affecting the behavior of such a structure are associated with possible large deflections induced by oscillatory instabilities or by response to the random action of wind gusts (buffeting). These formulas apply rigourously only for a flat airfoil and their use can be extended to real bridge cross-sections with a certain bluffness amount only by employing empirical coefficients, accounting for the actual cross-section aerodynamics and sometimes depending on the bridges The dimensions of the section model were then decided based on the prototype which shares a similar profile of the cross section of the Luling Bridge in St. Charles Parish, Louisiana. The frequencies are different from the actual ones of the Luling Bridge. Based on the initial model parameters an estimated model mass 18-kg was used to determine the appropriate springs in which to suspend the model.

$$f_v = \frac{1}{\tau} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}\ or\ k = (2\pi f_v)^2 m$$

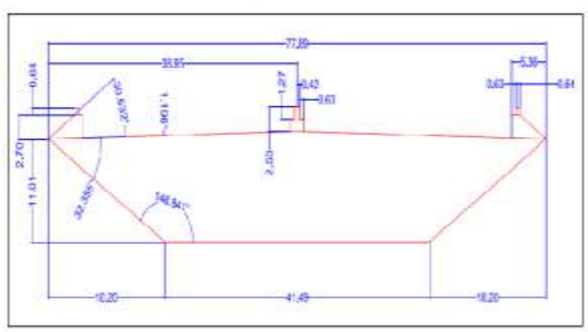

Figure: Dimensioned cross-section of the bridge section model (cm)

Where τ = period, m is the model mass and k is the spring constant which is divided by eight (the number of springs suspending the section model). Furthermore the torsional distance (d = spring spacing) needed to be confirmed using the desired torsional natural frequency (fα) and the spring constant determined from the vertical frequency.

Equipment & Test Setup:

All the tests were conducted at the Engineering Research Center in the Wind Engineering and Fluids Laboratory at Colorado State University. The Industrial Aerodynamics Wind Tunnel (IWT) was utilized, which has the capacity to continuously vary wind speeds up to 24 m/s. The layout and dimensions of the IWT can be seen in Figure

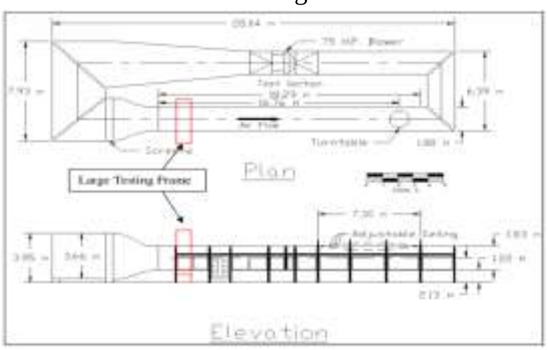

Figure: Industrial Aerodynamics Wind Tunnel

Bridge aero elasticity

The aero elastic stability of line-like slender structures, such as suspension and cable-stay bridges is verified by calculating the critical wind speed. Light structures are sensitive to aero elastic phenomena like galloping, divergence and flutter. Therefore the aero elastic properties of the bridge deck section are needed and are commonly determined in wind tunnel tests. The bridge structural parameters have to be calculated and, furthermore, more aero elastic parameters must be measured.

Thrust bed:

- We have provided thickness of thrust bed 750mm for length of box 11m.
- The reinforcement details of precast box (tunnel), thrust bed is shown in the Drawing sheet.
- Various unexpected situations are likely to occur during the box pushing operations. Since the safety of running trains is directly affected, proper planning and implementation is essential for smooth completion of work. Advance analysis of site, likely problems that may arise and planning to tackle the same will help the executive for speedy and safe completion of the work.

BOX CASTING AND PUSHING

- The RCC Box is cast in segments of convenient lengths of Total pushing length.
- The Box section is designed as per IRS / IRC codes of practice for loading. Concrete grade normally kept as M-30.

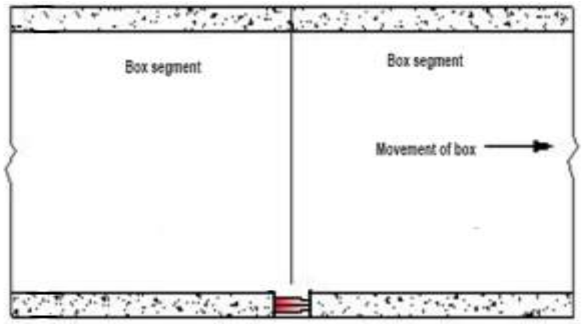

Fig: Precast Box

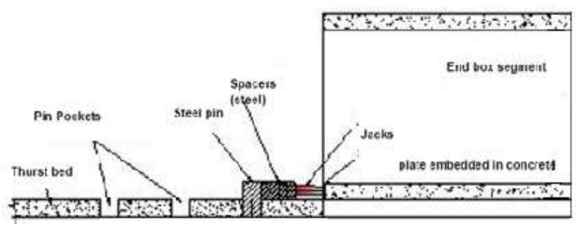

Fig: Precast Box Segment

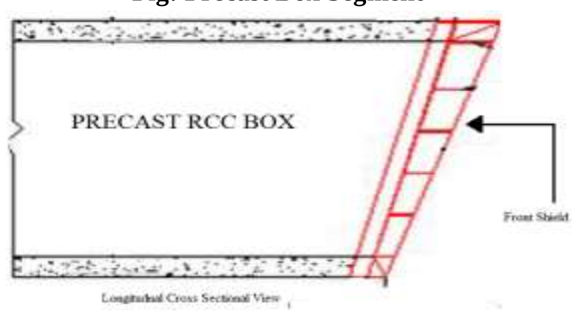

Fig: Front Shield

After the first box has reached the final position, the second box will be pushed in such a way that a gap of approximately 100mm remains between the units. Cleaning the gap will be done and concrete edges will be roughened, reinforcement will be placed in gap and concreted, if required grouting will be done to make the joint water tight. Suitable admixtures will be used in the concrete used for filling the joint to make them water tight.

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MATERIALS USED:

Thrust Bed:

The thrust bed mainly consists of thrust wall, thrust bed with pin pockets on bed, keys for additional resistance. The basic feature of the thrust bed is to provide necessary resistance needed for the jacking operation. For this purpose, a well designed RCC slab will be constructed outside the bridge with its top level being kept exactly at the proposed bottom level of the RCC box.

Front Shield:

It is a MS Plate which is made up of mild steel material and used in the site for cutting the soil surface under the railway track. It has cutting edges in the front which helps to cut the soil and move the box segment easily.

Rear Shield:

It is made up of mild steel will be fixed on rear end of the first unit of the box. This is connected to the back side of the RCC box segment which helps the box to move properly with out and tilting under the railway track.

Drag Sheets / Epoxy Coating: Drag sheets are provided at the top of box if required. Or the top of the box is coated with epoxy coating to reduce the friction between the box and the soil.

Jacking Operation For pushing: the box unit, the jacking (if found necessary to control the alignment) will be placed behind the RCC box along the axis of the pockets and the jacking pins will be inserted in pockets of thrust bed. Jacking rig will help in maintaining the alignment of the box.

Pedestrian Bridges

Havenbrug Harbour Bridge, Holland Designer: Fiber Core Europe, Holland Manufacturer: FiberCore Europe, Holland

- Full FRP design
- Spans 19.4 & 12m, Width 1.52m
- Craned into position in one lift

Figure: Fiber Core Europe Infra Core Inside Technology

4.0 Results

Aerodynamic optimization of the deck the lift, drag and moment coefficient figures are very important for the bridge deck optimization. The moment and lift coefficient slopes are very important for the bridge stability. They must be positive, with the conventions set in Figure 4, to avoid one-degree-of-freedom instability and, in order to have a high flutter velocity; their slopes must be as much as possible lower than the values of a flat plate: 2π for the lift coefficient and $\pi/2$ for the moment coefficient. The slope value to guarantee stability is a function of the ratio between the bridge torsional and vertical frequencies. Another important issue is to take the deck drag as low as possible, because the drag forces on the deck are the most important and are transferred to the top of the towers by the hangers and the main cables, producing a moment that affects the overall tower design.

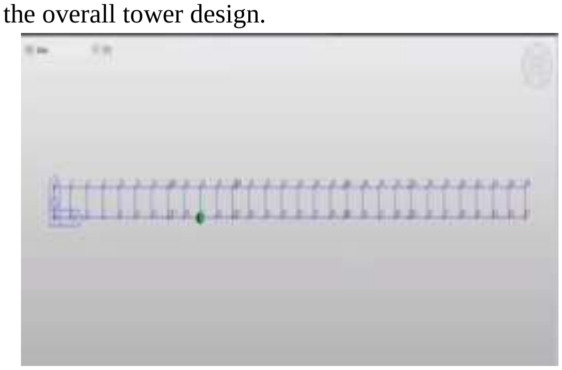

Figure: plane surface

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INPUT LOADING DATA

Table: For the tutorial apply the pre and post composite loads by element beam loads refer to the table below

classification	Right grinder		Left grinder	
	VERTICAL LOAD (FZ)	TORSINAL MOMENT	VERTICAL LOAD (FZ)	TORSINAL MOMENT
Pre – composite Load DL(BC)	-38.96	-1.49	-38.96	1.49
Post-composite load DL(AC)	-18.69	19.69	-18.69	-19.69

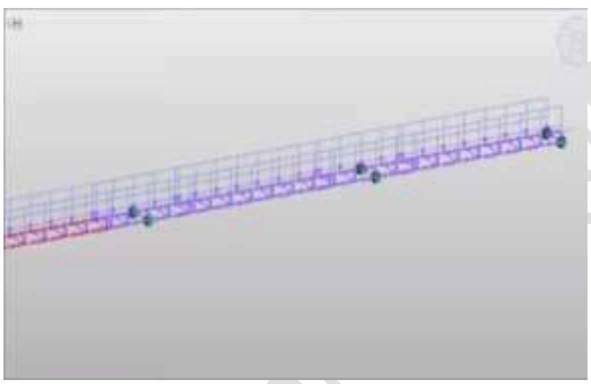

Figure: that applied load of the beam base point

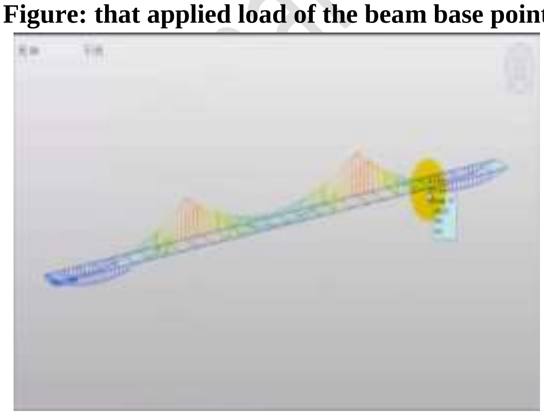

Figure: 3D view of the ascending loads with two points

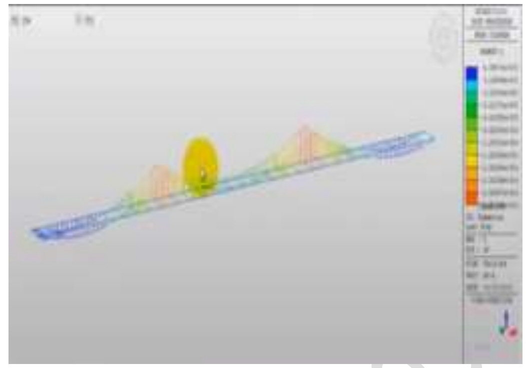

Figure: load applied to middle point in 3D VIEW

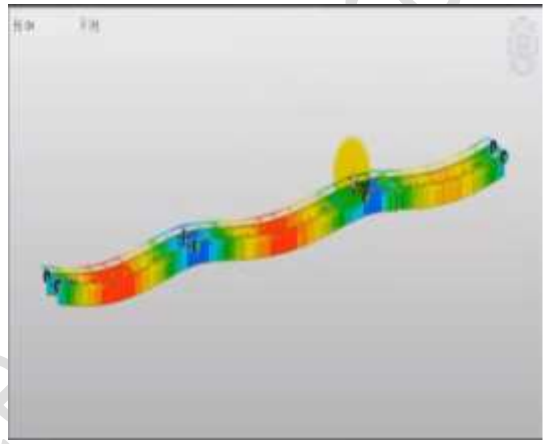

Figure: load applied to all points in 3D VIEW

ROAD OVER BRIDGES:

A bridge is a span structure is built to physical obstacles such as a body of water, valley, or road, for the purpose of passage over the obstacle. Designs of bridges vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed, the material used to make it and the funds available to build it

Fig: I section girder on ROB.

Road under bridges:

The movement of traffic in both perpendicular directions which is above and below is said to be road under bridge. This may vary in location. The road above the water bodies is also said to be road under bridge.

Natural modes:

Natural frequencies f and periods T for the still-air eigen-modes, estimated with the finite element model, are presented in Table 1. Vs-i, Hs-i and Ts-i, with i=1-3, denote the vertical, horizontal and the torsional direction. The frequency ratio between the first torsional and the first vertical mode is The first three symmetrical modes in each direction are presented in figure

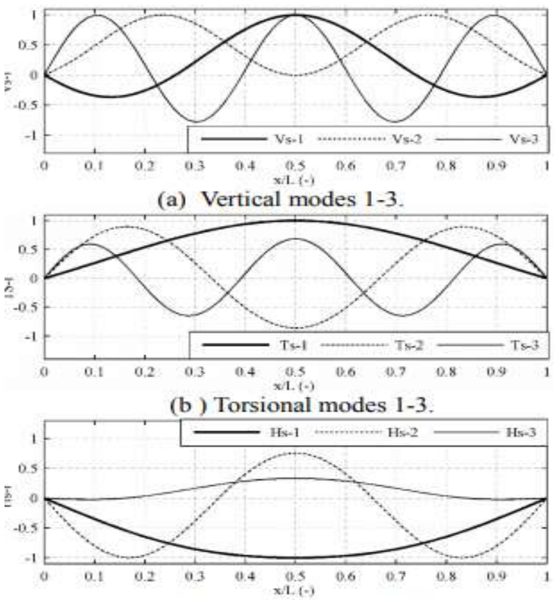

Figure: Symmetrical modes. Vs-i, Ts-i and Hs-i, i=1-3

A horizontal component of the first torsional mode, also identified in is included in The torsional response corresponding to the vertical motion of cable planes of ±1 m is accompanied by the horizontal displacement of 0.16 m at girder mid-span.

Conclusion:

the aero elastic stability of long-span cable stayed bridges has been addressed and a simplified variational formulation for the dynamic problem of the wind-structure coupled system has been proposed. Starting from a continuous model of the fan-shaped bridge scheme with both H- and Ashaped towers, stability limit states, with regard to both torsional divergence and flutter, are identified by singularity conditions of an integral wind-structure impedance matrix. This latter is defined considering a general Scanlan-type representation of the aero elastic non-steady wind loads and introducing integral stiffness properties, which allow to describe the overall dynamic behavior of the bridge by means of simple lumped parameter mechanical systems. Under the assumption of a prevailing truss like bridge behavior, integral stiffnesses have been analytically estimated considering damping-free torsional and flexural (vertical and lateral) bridge oscillations in still air. Clear and useful indications from an engineering point of view have been drawn about the influence on the bridge aero elastic stability of both main structural parameters and deck cross-section aerodynamics, also considering variability of wind incidence direction. Lateral effects, usually a-priori neglected by many authors, have been included in proposed flutter analyses, highlighting that their participation in flutter mechanisms generally cannot be arbitrarily disregarded

REFERENCES

1. Haghani, R., D5.3 - Needs for maintenance and refurbishment of bridges in urban environments. PANTURA 2011.
2. Canning, L., Mount Pleasant FRP Bridge Deck Over M6 Motorway, in Fourth International Conference on FRP Composites in Civil Engineering (CICE2008)2008: Zurich, Switzerland.
3. Canning, L., et al., Progress of advanced composites for civil infrastructure. Proceedings of the Institution of Civil Engineers: Structures and Buildings, 2007. **160**(6): p. 307-315.
4. Knippers, J., et al., Bridges with glass fibre-reinforced polymer decks: The road bridge in Friedberg, Germany. Structural Engineering International: Journal of the International Association for Bridge and Structural Engineering (IABSE), 2010. **20**(4): p. 400-404.
5. Lee, S.W. and K.J. Hong. Opening the gate: Construction of 300 M composite-deck bridge in Korea. in Asia-Pacific Conference on FRP in Structures (APFIS 2007). 2007.
6. Sams, M. Broadway bridge case study bridge deck application of fiber-reinforced polymer. 2005.