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STATIC AND DYNAMIC ANALYSIS OF RCC T–BEAM BRIDGE WITH VARYING SPAN LENGTH AND SPEED OF VEHICLE

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Abstract - Structures generally have two load kinds, i.e. static load and dynamic load. While most structures are built on the premise that all the loads given to the buildings are static and the dynamic load impact is ignored. But sometimes the reason for the catastrophe may be this characteristic of ignoring dynamic loads. Thus, for a different span of the bridge and different speed of the moving vehicle on the bridge deck, dynamic bridge deck analysis is planned.
In this study, the modeling of a T-beam deck slab bridge is done using CSiBridge. The static response of the T-beam deck slab bridge due to IRC Class 70R loading at one instant of time on bridge deck using CSiBridge has been calculated. The free vibrational characteristics of the T-beam deck slab bridge by determining the mode shapes and frequencies using CSiBridge has been carried out to find out the influence of span length on frequencies of the bridge. Further studied the dynamic analysis of T-beam deck slab bridge with emphasis on the evaluation of the dynamic response of bridge deck due to time-varying moving vehicle load is performed and the time-varying displacement and stresses were obtained. At last, the influence of factors like span length and vehicle speed on the T-beam deck slab bridge has been studied.

Key Words: T-beam deck slab Bridge, CSiBridge, Static Analysis and Dynamic Analysis due to moving vehicle load

1. INTRODUCTION

In modern days, all divisions of transport have experienced boundless advances, characterized by the increasingly high speed of vehicles, weight of vehicles and other moving bodies. So nowadays, corresponding structures have been subjected to much more dynamic stress and vibration as comparing old times. The moving vehicle load problem has been the focus of several research efforts. The significance of this problem is shown in several applications in the transportation field. Bridges, runways, overhead cranes, rails, cableways, roadways, launchers, pipelines, and tunnels are examples of structural elements designed to support moving loads.
The dynamic behavior of highway bridges subjected to moving a vehicle is a difficult phenomenon. So the works regarding the forced vibration analysis of structures with moving loads are very limited. Highway bridges are complex structures because they consist of various structural components of different properties. In addition, the dynamic effects are influenced by the interaction between moving vehicles and the bridge structures. When we studied the dynamic behavior of bridge due to moving vehicles, the most important parameters that influence the dynamic response of highway bridges are bridge characteristics- road surface roughness, bridge damping coefficient, etc. and vehicle characteristics- vehicle speed, no. of vehicles, their travel paths, etc. Some other parameters such as the fundamental frequency of the bridge, time step, etc. also have a significant impact on the dynamic response of the bridge.

2. BRIDGE LOADING

2.1 Dead Load and Superimposed Dead Load

The dead load is due to the permanently connected framework and other elements of the structure. Superimposed dead load is the load of gravity of the bridge's non-structural components. Such items are long-term but may change during the structure's lifetime. The road surfacing is the most notable item of the superimposed dead load. Superimposed dead loading during the lifetime of the bridge is particularly susceptible to increase. For this reason, the road pavement is subjected to a particularly high load factor. Bridges among constructions are unique in that a large percentage of loading is attributable to dead and superimposed dead load.

2.2 Live Load

In India, highway bridges are designed in accordance with IRC bridge code. IRC: 6 - 2017 gives the specifications for the various loads and stresses to be considered in bridge design. IRC classify the vehicle load in various categories. In this study, only the 70R wheeled vehicle is taken into consideration.

IRC CLASS 70R LOADING: This loading is to be normally adopted on all roads on which permanent bridges are constructed.

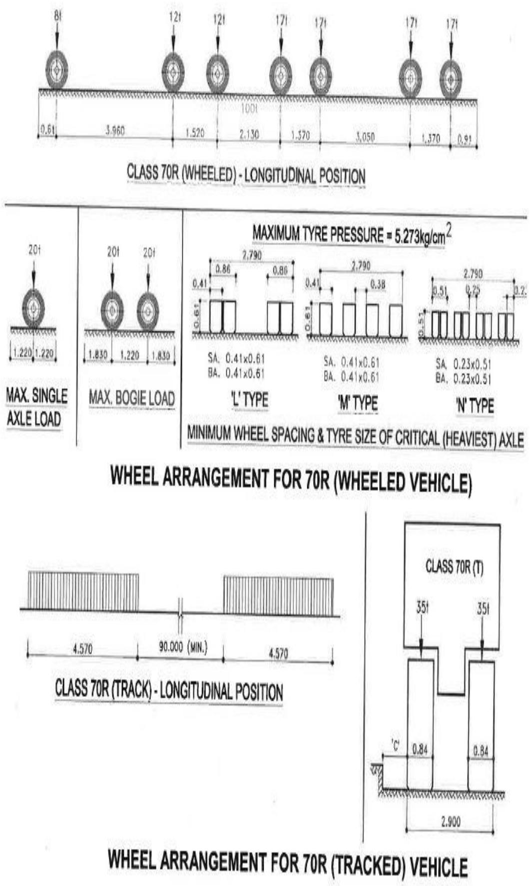

Figure 1 Class 70R Wheeled and Tracked Vehicles

3. BRIDGE MODELING

The spans of different length i.e. 10m, 15m, 20m, 25m and 30m is modeled for varying speed of 40kmph, 80kmph, 120kmph, 160kmph and 200kmph for each span.

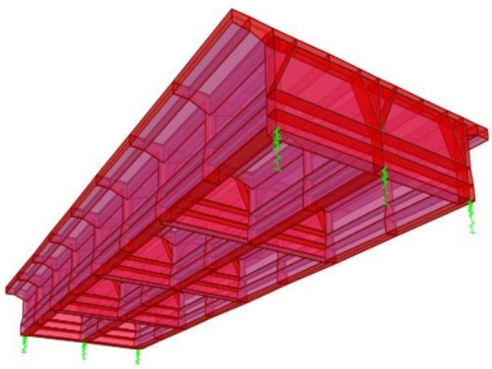

Figure 2 3D View of Bridge Model

3.1 Lanes

Two lanes of traffic are defined with respect to a reference line, which can be a bridge layout line. The transverse position of the lane centerline is specified by its eccentricity relative to the reference line. Width for each lane is 3.5m.

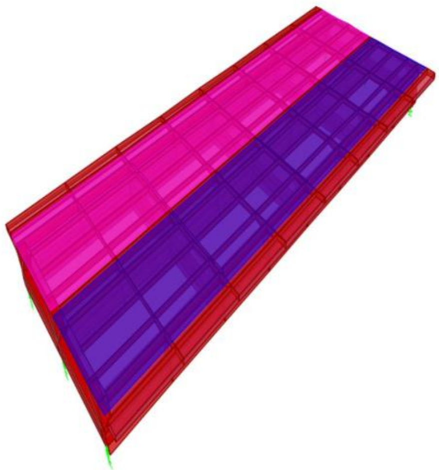

Figure 3 3D View of Bridge Model and Lanes

3.2 Vehicles

Any number of vehicle live loads may be defined to act on the traffic lanes. Standard types of vehicles known to CSiBridge can be used or the general vehicle specification can be used to create user-defined vehicle types. All vehicle live loads represent the weight and are assumed to act downward, in the -z global coordinate direction. Each vehicle definition consists of one or more concentrated or uniform loads.

3.3 Load Case

A load case defines how loads are applied to a structure (e.g., statically or dynamically), how the structure responds (e.g., linearly or nonlinearly), and how the analysis is performed (e.g., modally or by direct-integration). Any load case type can be used when analyzing a bridge model. Response spectrum and time history load case types are useful for dynamic analysis. Staged construction analysis can also be performed.
Moving load cases compute influence lines for various quantities and solve all permutations of lane loading to obtain the maximum and minimum response quantities. Multi-step dynamic load cases can be used to analyze one or more vehicles moving across the bridge at a specified speed. These multi-step load cases are defined using special bridge live load patterns that define the direction; starting time and speed of vehicles moving along lanes.

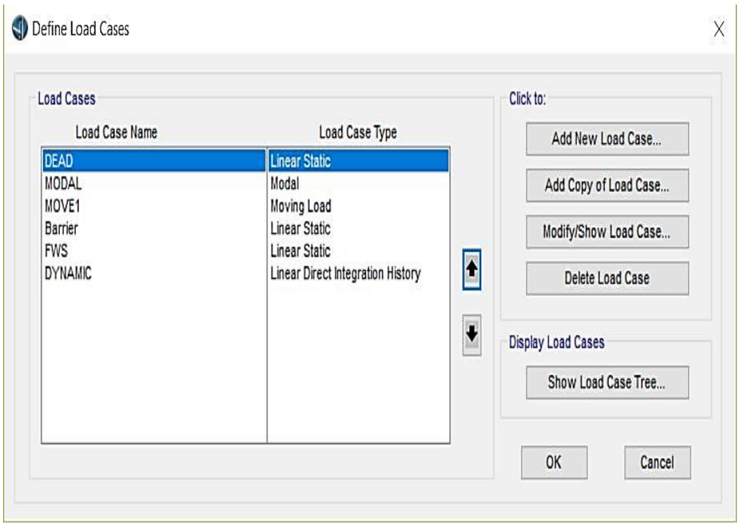

Figure 4 Define Load Cases

4. ANALYSIS RESULTS

4.1 Static Analysis

Static analysis of bridge structure is performed to calculate the vertical displacement and normal longitudinal stress for different span lengths i.e. 10m, 15m, 20m, 25m and 30m. It is observed from the results that both vertical displacement and normal longitudinal stress increase with the increase in span length and its maximum value is obtained at the mid-span of the bridge.

Table 4.1 Maximum Static Response of the Bridge due to IRC Class 70R Loading

Span Length (*m*)	**Max. vertical displacement (*mm*)**	**Max. normal stress (*MPa*)**	**Deflection Span Ratio**
10	1.6768	1.6549	0.16549×10^{-3}
15	7.3173	3.6086	0.48782×10^{-3}
20	20.7611	6.0875	1.03806×10^{-3}
25	46.8092	8.9949	1.87237×10^{-3}
30	90.1037	12.2133	3.00346×10^{-3}

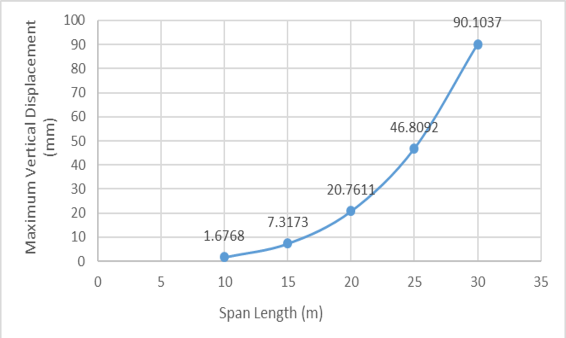

Chart 1 Variation of Vertical Displacement versus Span Length of T-Beam Bridge

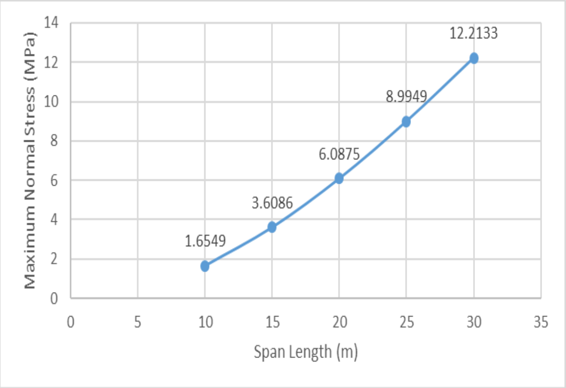

Chart 2 Variation of Normal Stress versus Span Length of T-Beam Bridge

4.2 Modal Analysis

Modal analysis is performed to calculate the natural frequencies of the structure out of which the fundamental frequency of each span is used to calculate the time step for dynamic moving load analysis.

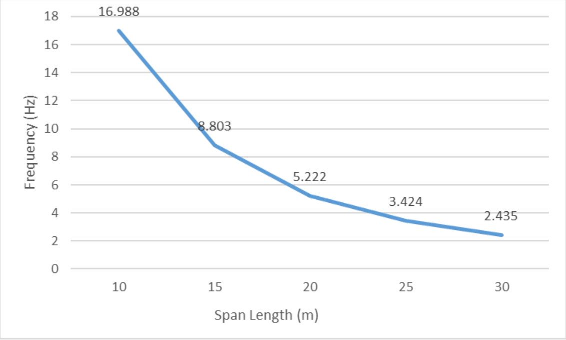

Chart 3 Variation of the Frequency with respect to Span Length

4.3 Dynamic Analysis

Dynamic analysis involves the loads which are a function of time. This analysis is used to found out the dynamic response of a structure when the structure is subjected to time-dependent loads. The dynamic analysis gives the time-varying stresses, strains, displacement, and forces in a structure as it reacts to transient loads.

4.3.1 Influence of Span Length

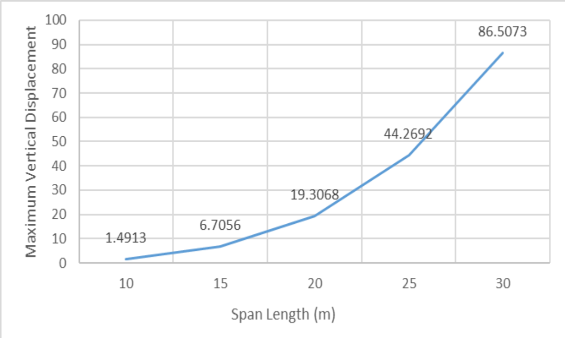

Chart 4 Maximum Dynamic Displacement versus Span Length of the Bridge at 40kmph

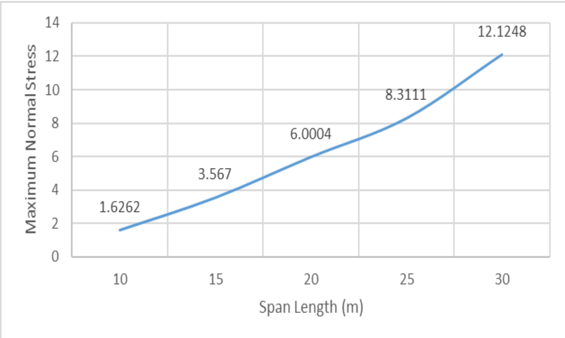

Chart 5 Maximum Normal Stress versus Span Length of the Bridge at 40kmph

4.3.2 Influence of Vehicle Speed

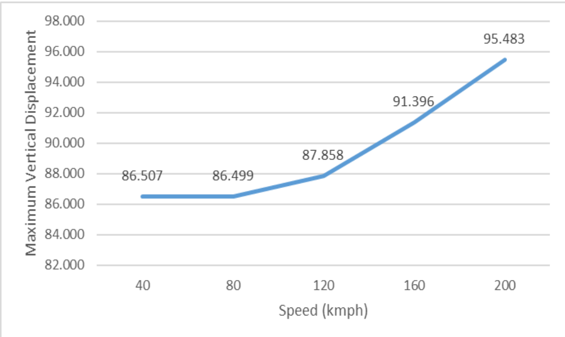

Chart 6 Maximum Dynamic Displacement versus Speed of the Vehicle of 30m span

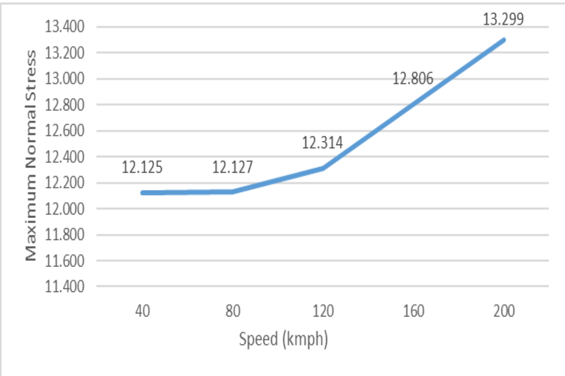

Chart 7 Maximum Dynamic Normal Stress versus Speed of the Vehicle of 30m span

5. CONCLUSIONS

5.1 Static Analysis

It is observed from the results that both vertical displacement and normal longitudinal stress increase with the increase in span length and its maximum value is obtained at the mid-span of the bridge.

- As span length increases from 10m to 15m, the vertical displacement increases 4.36 times and the normal longitudinal stress increases 2.18 times.
- As span length increases from 15m to 20m, the vertical displacement increases 2.84 times and the normal longitudinal stress increases 1.69 times.
- As span length increases from 20m to 25m, the vertical displacement increases 2.25 times and the normal longitudinal stress increases 1.48 times.
- As span length increases from 25m to 30m, the vertical displacement increases 1.92 times and the normal longitudinal stress increases 1.36 times.

Therefore, from the above observation, it is concluded that vertical displacement and normal longitudinal stress increase with the increase in span length but the rate at which it is increasing is reducing as we increase span length.

5.2 Modal Analysis

From the results, it is concluded that frequency is decreasing gradually with the increase in span length.

- As span length increases from 10m to 15m frequency is decreased by 48.18%.
- As span length increases from 15m to 20m frequency is decreased by 40.68%.
- As span length increases from 20m to 25m frequency is decreased by 34.43%.
- As span length increases from 25m to 30m frequency is decreased by 28.88%.

5.3 Dynamic Analysis

- As span length increases from 10m to 15m the vertical displacement increases 4.49 times and normal longitudinal stress increases 2.29 times.
- As span length increases from 15m to 20m the vertical displacement increases 2.88 times and normal longitudinal stress increases 1.68 times.
- As span length increases from 20m to 25m the vertical displacement increases 2.29 times and normal longitudinal stress increases 1.46 times.
- As span length increases from 25m to 30m the vertical displacement increases 1.95 times and normal longitudinal stress increases 1.38 times.
- As the speed of the vehicle increases from 40kmph to 80kmph the vertical displacement and normal longitudinal stress does not increase significantly.
- As the speed of the vehicle increases from 80kmph to 120kmph the vertical displacement increases by 1.57% and normal longitudinal stress increases by 1.54%.
- As the speed of the vehicle increases from 120kmph to 160kmph the vertical displacement increases by 4.03% and normal longitudinal stress increases by 4.00%.
- As the speed of the vehicle increases from 160kmph to 200kmph the vertical displacement increases by 4.48% and normal longitudinal stress increases by 3.85%.

Therefore, from above observations it can be concluded that the results of dynamic analysis of bridge for different span length and uniform speed vary in a similar manner (increasing trend) as that of static analysis and the rate of variation of vertical displacement and normal longitudinal stress for dynamic analysis for different span length at uniform speed is slightly higher than the values of static analysis.

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