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Seismic Analysis and Effect of Different Deck Types Used In Cable-Stayed Bridges

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***Abstract*— Cable stayed bridge had three important superstructure components deck, cables and pylons, these three component are combined in such a way so they can transfer the load to the foundation, in transferring the load, the load comes first to the deck which push the deck down from there load comes to the cable as tensile force and from the cable, the load comes on pylon which transfer the load to the foundation. There are different types of deck and girder used in cable stayed bridge. Cable stayed bridge deck need to be flexible for large span bridge so it can be bear the different type of load and transfer the load easily. Because these types of bridge constructed as River Bridge and there is gaping between the pylons is used for navigation. In the research study analysis had done for three typed of concrete deck section along with girder of different depth and compare them to evaluate which one perform better under the various load combinations of dead, vehicle and earthquake load as per IS 1893:2016. As per analysis result the exterior sloped girder deck type of depth 3m perform efficiently.**

***Index Terms*— Cable - Stayed Bridges, response spectrum analysis, Traffic and seismic Loading**

1. INTRODUCTION

1.1: General

The Cable stayed bridges are recent development for long spans. These composed of no. of cables, deck, pylons and foundations. The basic load bearing elements of the bridge are cables, deck, pylons and foundation. Cables are provided at certain distance along the deck, small the cable distance gives small bending moment in the bridge. As the traffic pushes the deck downwards load comes to the cable as tensile force and from the cable, the load comes on pylon which transfer the load to the foundation. The longitudinal moment increases as the deck becomes stiff. It is thus wise to select the deck to be as flexible as possible. For the purpose of analysis, there are two types of deck along with sloped girder and vertical girder used in cable stayed bridge under various load condition. From the analysis combined loading of seismic and imposed load are critical so there are results discussed for this load combination. CSI Bridge software was used for the analysis work.

2. OBJECTIVES OF THE WORK

- To study the seismic behavior of cable stayed bridge in seismic zone IV with hard soil condition.
- Study the displacement of bridge deck and pylon under vehicular load and seismic load combination and forces developed in various components of the bridge.
- Comparison of two deck profiles of different cross section of different depth

3. STRUCTURAL DETAIL OF THE BRIDGE

The following are the details of the bridge,

- Length of the bridge = 312 m
- Bridge type = Cable-stayed bridge.
- Total width of bridge deck =10m
- Pylon type = H shape pylon of 54m from river bed
- Section of pylon=2.5m×2.5m
- Number of pylons = 2
- Total width of the deck = 10m.
- Depth of the deck slab = 2m and 3m.
- Deck type = (a)vertical exterior box girder deck (b)sloped exterior box girder deck
- Cable arrangement= Regular fan type.
- Width of Carriageway = 7.5m
- Bridge deck design = As per IRC. 112:2011
- Seismic zone = zone 4
- Soil Type= Hard soil
- Importance factor = 1.2
- Loading= 70 R wheeled vehicle as per IRC 6:2017
- Damping=5%
- Cables=0.2mm dia ASTM 416
- The number of cables = 13 on each side of tower

The longitudinal section of bridge is shown in fig3.1 (all dimension in m)

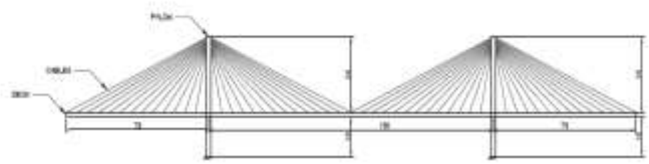


Fig-3.1 longitudinal section of cable stayed bridge (all dimension in m)

The shape of the pylons and arrangement of cables was chosen such that it will prevent serious damage to the structure during an earthquake. The main span of the bridge is 156m and side span of 78m on both the sides. The deck is a cellular vertical box girder deck and sloped box girder deck which is a pre-stressed member perfect for the construction in places with restricted access. The cross section of the deck is shown in fig3.2(a)(b).

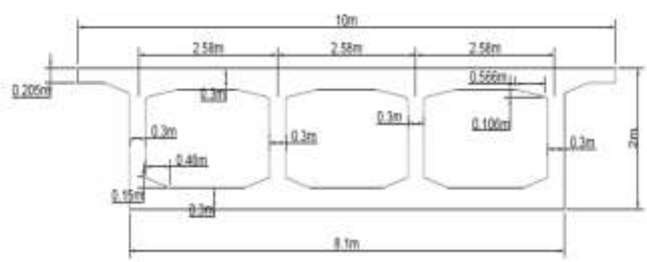


Fig-3.2 (a) Cross Section of the Vertical Exterior Girder Deck

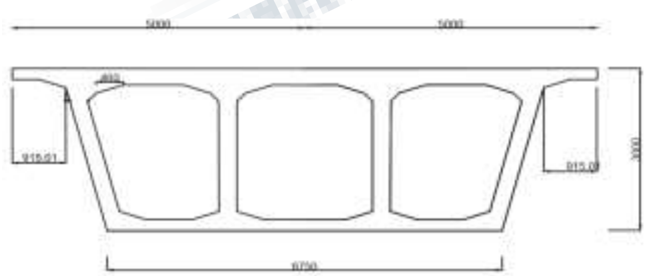
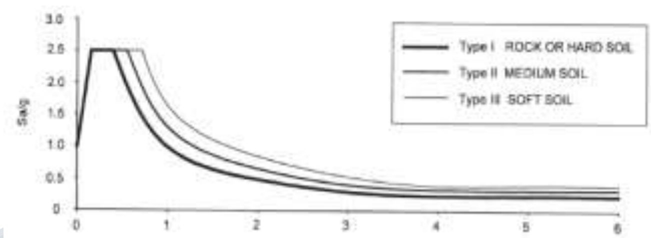


Fig-3.2 (b) Cross Section of the Sloped Exterior Girder Deck (all dimensions in mm)

4. DEFINING SEISMIC LOADS

For the analyses purpose seismic forces considered in the two orthogonal horizontal directions. For the dynamic analysis of the cable stayed bridge a response spectrum function is defined as per IS: 1893- 2016 for a minimum of 5% damping for cement concrete structure as shown in fig4.1. Response spectrum is a means of characterizing an earthquake



Natural time periods T sec
Fig-4.1 Spectra for Response Spectrum

5. DEFINING VEHICULAR LOADS

Vehicle load considered as per IRC-6:2017 clause 204.3 is one lane of class 70R or two lanes for class A vehicle. The width of each lane is 3.5m and 1.2m footpath on both sides. The analysis was done for both vehicles 70 R. In the analysis vehicles 70R moving with speed of 22m/sec in one lane and distance between the vehicle minimum 30m shown in fig-5.1

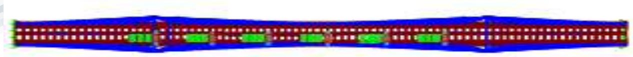


Fig 5.1- 70 R wheeled vehicle moving from one end to the other end of the bridge in lane one of bridge

6. RESULTS AND DISCUSSIONS

Seismic Analysis done for various load combinations as per is 1893:2016. The critical load combination will be combined action of dead load +vehicular load+ earthquake load so for this combination result discussed below.

6.1 Displacement of deck due to imposed and seismic loads

The variation of displacement along the length of bridge due to combined loading seismic and imposed load is shown in fig.6.1. The displacement in vertical girder deck type is greater than sloped girder deck type. It occurs at a distance 156m center of the main span is 221.2mm in vertical girder deck type and 196.4mm in sloped girder deck type.

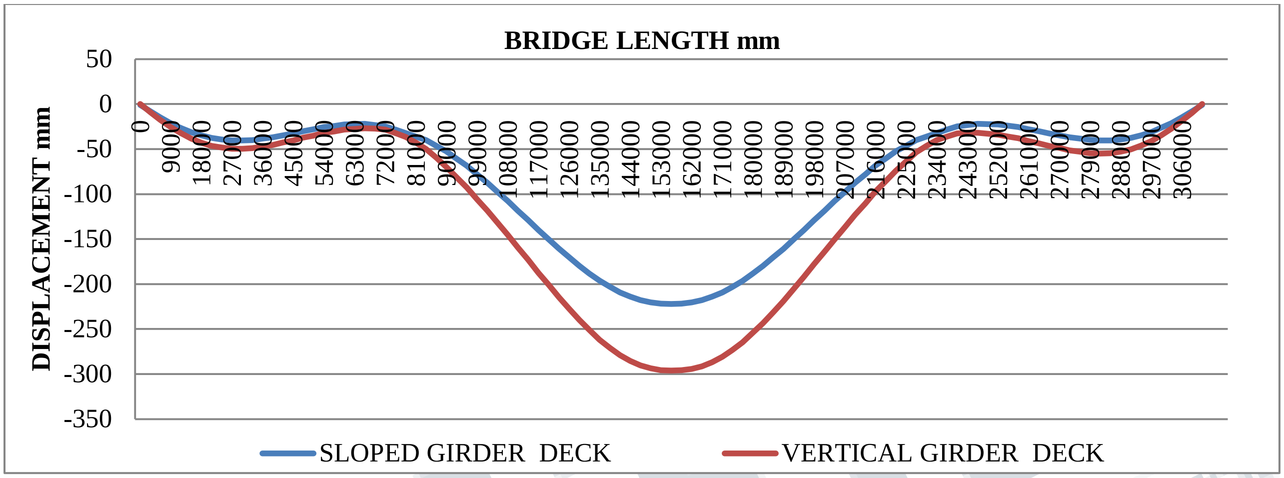


Fig -6.1 Vertical displacement of deck due to imposed and seismic loads consider moving load 70 R wheeled vehicle along the length of bridge

As per the AASHTO12 guidelines the maximum allowable deflection of the bridge structure is given by the formula6,

$$\Delta_{all} = L/400$$
$$= 312/400$$
$$= 0.78\text{m} = 780 \text{ mm}$$

The allowable displacement 0.78m.Hence the displacement of the deck is less than that of the allowable deflection i.e. 221.2mm, 196.4 < 780mm.

6.2 Displacement of occur in exterior left girder due to imposed and seismic loads

The variation of displacement along the length of bridge due to combined loading seismic and imposed load is shown in fig.6.2. The displacement in vertical girder deck type is greater than sloped girder deck type. It occurs at a distance 156m center of the main span is 292.07mm in vertical girder deck type and 222.19mm in sloped girder deck type.

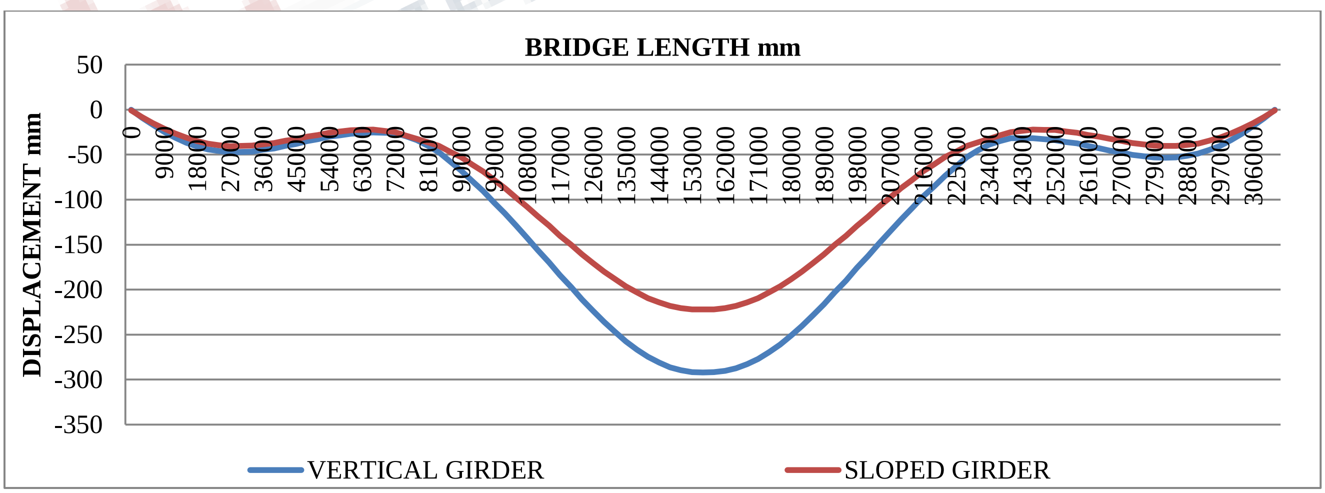


Fig -6.2 Vertical displacement of vertical girder and sloped girder due to imposed and seismic loads consider moving load 70 R wheeled vehicle along the length of bridge

6.3 Axial Force

Axial forces variation in the deck is shown in fig6.3. The values of axial force are considerable for strengthening the cross-section, to provide both strength and stability. The maximum axial force occurs in the vertical girder deck type is greater than sloped girder deck type under combined loading of seismic and vehicular loads.

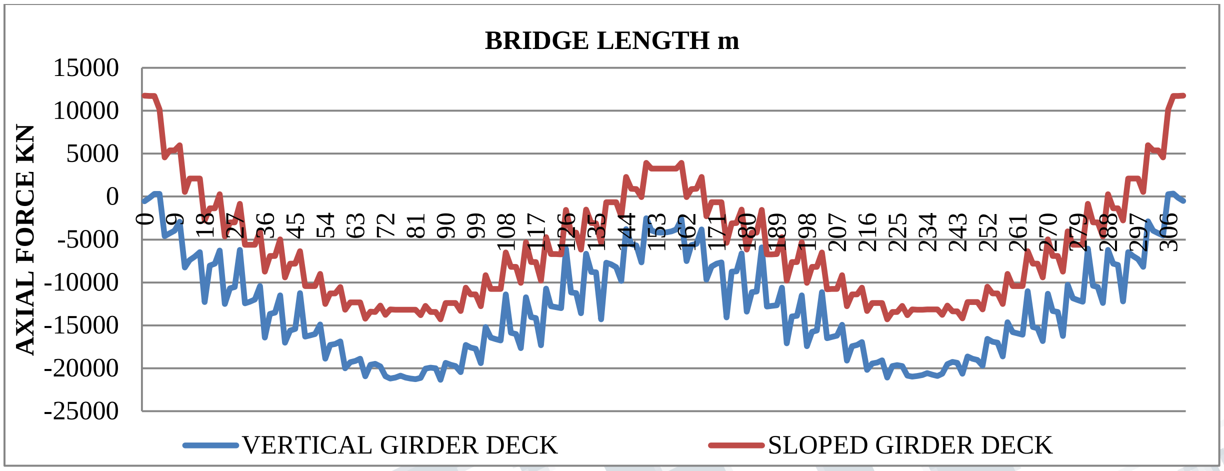


Fig: 6.3 Axial Force on bridge deck due to vehicular and seismic loading

6.4 Displacement of pylon under moving and seismic loads

Pylon is main load bearing component of the bridge so it is required to be stiff so that it can transfer the load to the foundation safely. The variation of horizontal displacement of pylon along the height is shown in fig6.4

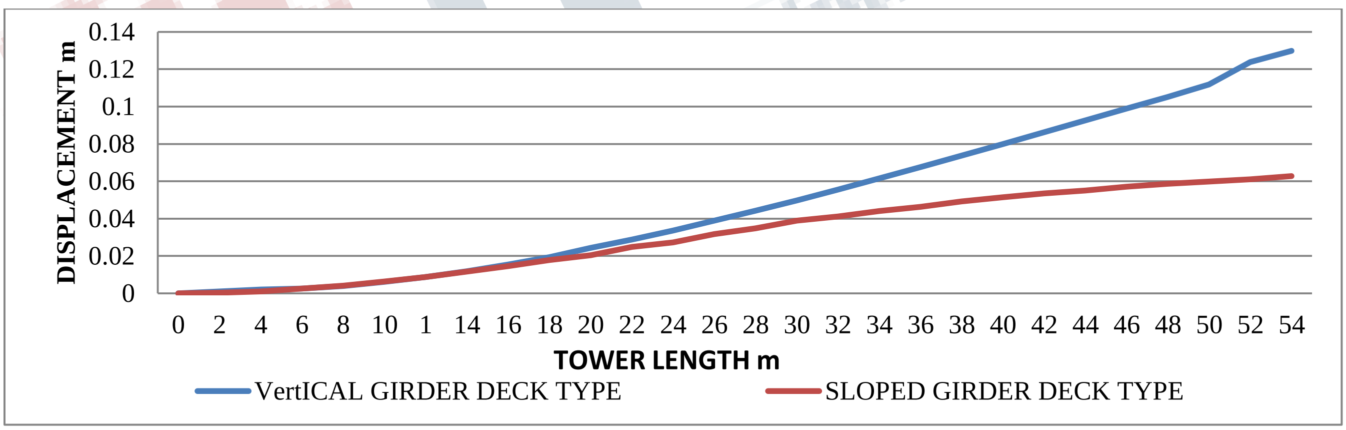


Fig -6.4 Horizontal displacement of pylon due to imposed and seismic loads consider moving load 70 R wheeled vehicle

7. CONCLUSIONS

1. The maximum displacement occur in vertical exterior girder deck type approximately 13% greater than sloped exterior girder deck type
2. The axial force is also greater in vertical exterior girder deck type approximately 35% greater than sloped exterior girder deck type.
3. The maximum displacement occur in pylon of vertical exterior girder deck type approximately 52% greater than sloped exterior girder deck type
4. As per result sloped exterior girder deck type is more suitable for large span bridge than vertical exterior girder deck type.

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