International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 07, July-2019

Analysis of Cable Stayed Bridge for Different Structural Model

Puneet Garg
PG Scholar, Civil Engineering Department
Institute of Engineering and Science,
IPS Academy,
Indore, India.

Rajesh Chaturvedi
Professor, Civil Engineering Department,
Institute of Engineering and Science,
IPS Academy,
Indore, India.

***Abstract*— For longer span, cable stayed bridges are the first choice and to study its behavior under static and vehicle loading is important. Therefore, it becomes essential that the modelling of cable stayed bridge is more realistic and the analysis results are more satisfactory. There are different methods that can be used for structural model but in the present study two different types of structural model viz. Spine Model and Area Object Model are used for analysis of cable stayed bridge. Static analysis and moving vehicle analysis have been done in which IRC Class A vehicle load is applied and their load combination is considered for evaluating the results. The analysis is conducted in CSi Bridge and analysis results are compared with tables and graphs to find out the best structure model for analysis.**

Keywords—Cable Stayed Bridge, Structural Model, Spine Model, Area Object Model, IRC Class A, Finite Element Analysis, CSi Bridge

I. INTRODUCTION

Cable Stayed Bridges have been most recognized and preferred for the span ranging from 200 m to 1000 m. For span of 200 m to 400 m, concrete girder is considered more economical and preferable. It is one of the most modern bridges, consists of a continuous strong beam (girder) with one or more pillars or towers in the middle. Cables are stretched diagonally between these pillars or towers and the beam. These cables support the beam. The cables are anchored in the tower rather than at the end. The tower is responsible for absorbing and dealing with compression forces. The towers are the principle compression members transmitting the load to the foundations. Tension occurs along the cable lines. Cable stayed bridges are highly statically indeterminate structure in which stiffening girder behaves as a continuous beams supported elastically at the points of cable attachments. In this study, cable stayed box girder bridge with two different structural models i.e. Spine model and Area object model are used to model for dead load and moving vehicle load. The finite element analysis is performed in CSi. Bridge and their results are compared to infer which model is more acceptable.

II. MODELLING AND METHODOLOGY

Cable stayed bridge is modelled for two different types of structural model i.e. spine model and area object model. Spine model uses frame object whereas Area object model uses area object with preferred maximum submesh size of 1 m for modelling. These two different modellings provide differ results. Bridge structure analysis software CSi. Bridge is used for the analysis of cable stayed bridge

A. Geometric Description of Cable Stayed Bridge Model

In this study, the cables are arranged in a mixed or fan configuration which are supported by single pylon and that is built into the deck structure. The steel pylon is 50 mm thick with varying diameter of 1.2 m at bottom and 0.6 m at top, overall height of pylon is 55 m in which 45 m is above deck. Total 36 cables of diameter 60 mm are connected to the pylon with maximum height of 42 m and minimum height of 18 m spaced at 3 m intervals on the pylon and 10 m intervals on deck. Concrete deck consist of box shape having two exterior longitudinal girder of thickness 300 mm with top and bottom slab of 300 mm thickness. The total length of bridge model is 200 m with two lanes of width 5.3 m each and total width of deck is 13 m, also have 75 mm thickness of wearing coat and kerb of size 600 mm x 300 mm.

B. Material Properties

M-35 grade of concrete and Fe-415 grade of reinforcing steel are used for members of bridge. Fe-345 grade of steel for pylon is used and tendons are used as cables. Elastic material properties of these materials are taken as per Indian Standard IS code.

TABLE I. STEEL PROPERTIES

Fe-345		
Properties	***Unit***	***Data***
Weight Per Unit Volume	KN/m^3	76.9729
Modulus of Elasticity (E)	KN/m^2	2.10×10^8
Poisson's Ratio, U	Unit less	0.3
Shear Modulus (G)	KN/m^2	80769231
Minimum Yield Stress (F_y)	Mpa	345
Expected Yield Stress (F_{ye})	Mpa	379.5
Minimum Tensile Stress (F_u)	Mpa	450
Expected Tensile Stress(F_{ue})	Mpa	495

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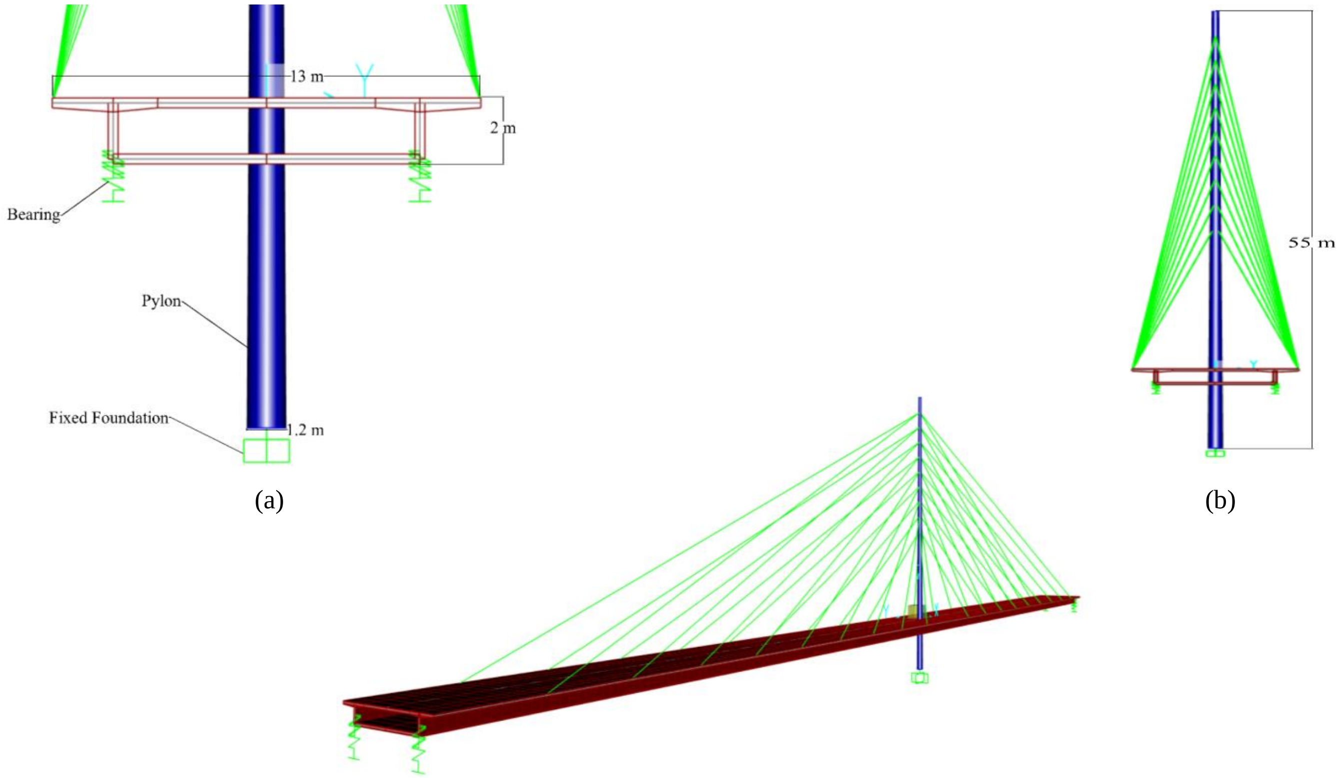

Figure 1: (a) & (b): Cable Stayed Bridge in Y-Z plane
(c): Cable Stayed Bridge in 3-D view

TABLE II. CABLE PROPERTIES

Properties	***Unit***	***Data***
Weight Per Unit Volume	KN/m^3	76.9729
Modulus of Elasticity (E)	KN/m^2	1.965 x 10^8
Minimum Yield Stress (F_y)	Mpa	1689.9052
Minimum Tensile Stress(F_u)	Mpa	1861.5846

C. Bridge Loadings

1) Dead Load

The dead load of the bridge is the bridge itself and all the parts and materials that are used in the construction of bridge. The material and parts that are not self-modelled, their loads are modelled separately to cover entire or actual self-weight of the bridge. The dead loads which are modelled manually are below:

TABLE III. DEAD LOADS

Components	***Unit***	***Data***
Wearing Coat (Asphalt)	KN/m^2	1.65
Handrail (Approximate)	KN/m	1.74
Kerb	KN/m^2	7.2

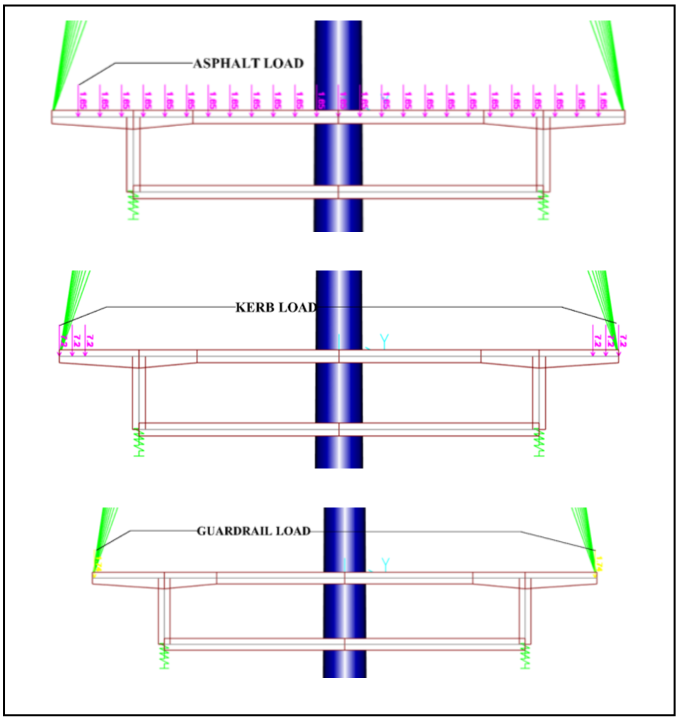

Figure 2: Dead Loads Assign Manually

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2) Live Load

Indian Road Congress IRC: 6-2017 code is referred for the moving load analysis of these cable stayed bridge models. According to IRC specification for two lanes, the live load combination of moving load for two lanes both way traffic is Class 70R (W) on one lane and Class A on both lanes. In this study, two lanes for IRC Class A vehicle load is considered with impact factor of 8.8%. This condition of load is assigned as live load on both lanes of bridge models.

III. RESULT ANALYSIS OF BRIDGE MODELS

Analyzed results of two different models of Cable Stayed Bridge are described on the basis of shear force, bending moment and displacement. These results are evaluated due to the combination of dead load and live load. The below table and figures illustrates the comparison between both modellings of cable stayed bridge

TABLE IV. COMPARED RESULTS OF CABLE STAYED BRIDGE MODELS

Table Head		Cable Stayed Bridge	
		Spine Model	*Area Object Model*
Shear Force (V2) KN	Max (+)	7360.239	6634.082
	Max (-)	7310.39	6634.08
Bending Moment (M3) KN-M	Max (+)	94440.89	94393.74
	Max (-)	117815.1	97796.4
Displacement MM	Max (+)	0	0
	Max (-)	463.922	482.768

A. Shear Force

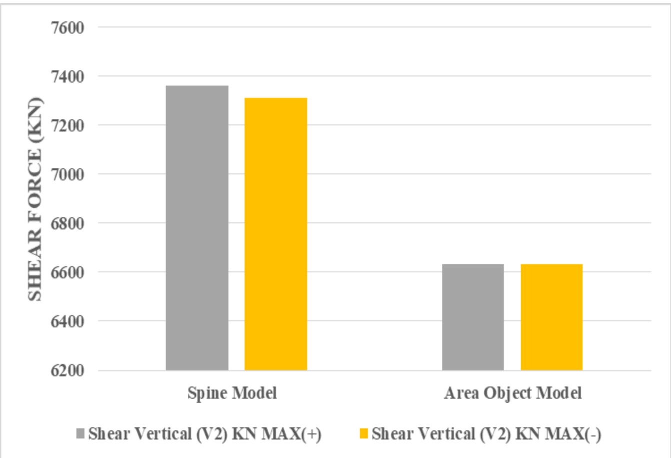

Figure 3: Variation in Shear Force for Cable Stayed Bridge

Cable stayed bridge is analyzed with spine model and area object model. This shear force is developed due to combination of dead load and live load. Figure 2 is showing the variation of shear force in spine model and area object model of cable stayed bridge. The value of maximum positive shear force is 10% less in case of area object model as compared to spine model. The maximum positive and negative shear force in the spine model is 7360.239 KN and 7310.39 KN respectively, in case of area object model it is observed to be 6634.082 KN. It has been observed that the maximum shear force in spine model is at center of the bridge and in area object model it is at ends of the bridge, the reason behind the change in position of maximum shear force is the selection of the structural model for analysis. In spine model, the maximum positive shear force is differ from negative shear force, because spine model is based on frame object whereas the maximum positive and negative shear force in area object model is same because it is based on area object.

B. Bending Moment

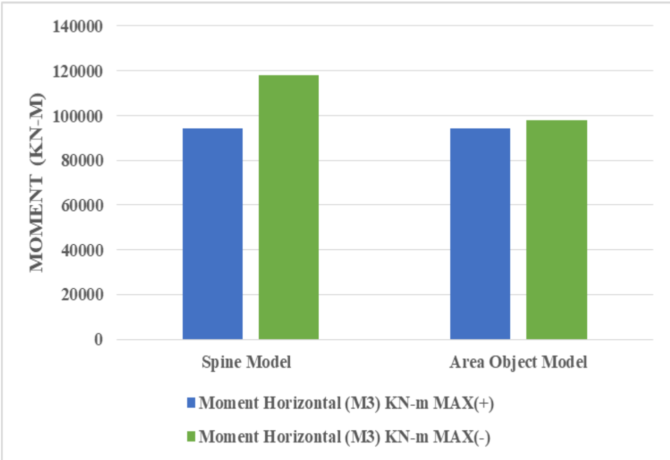

Figure 4: Variation in Bending Moment for Cable Stayed Bridge

Figure 4 shows the comparison of moment about horizontal axis in spine model and as well as in area object model. In spine model and area object model the maximum positive bending moment is almost same i.e. 9440.89 KN-M for spine model and 94393.74 KN-M for area object model whereas the maximum negative bending moment of both models are differ. The value of maximum negative bending moment is 17% less in case of area object model as compared to spine model. The maximum negative moment about horizontal axis for spine model and area object model are 117815.1 KN-M and 97796.4 KN-M respectively. It has been observed that the maximum negative bending moment in both model is at center of the bridge.

C. Vertical Displacement or Deflection

The moving vehicle load considered in the modelling for analysis is two lanes of Class A with impact factor of 8.8%. The maximum deflection is found along the span of bridge for the combination of dead load and live load. Figure 4 shows the variation of vertical displacement of cable stayed bridge models due to combination of both loads. The maximum negative vertical displacement in spine model is 463.922 mm but in area object model it increases to 482.768 mm. The increase in vertical displacement is due to structural model that used in cable stayed bridge i.e. area object model.

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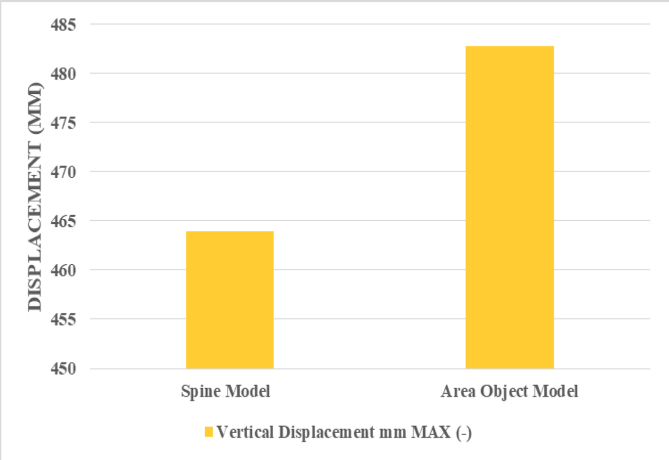

Figure 5: Variation in Deflection for Cable Stayed Bridge

IV. CONCLUSION

The analysis and comparison of modelling of cable stayed bridge between spine model and area object model have provided the following conclusions:

- The shear force in area object model is 10% less than spine model. The shear force produced in area object model is at ends of the bridge which is more acceptable than that produced at center in spine model.
- The maximum positive moment about horizontal axis for both model is approximately same and no much deviation is observed but the maximum negative moment about horizontal axis for area object model is less as compared to the spine model. The reduction in bending moment is almost 17% in area object model.
- The maximum deflection in area object model is comparatively more than spine model. The increasing percentage of deflection in area object model is more than 4%. Hence increase of deflection in area object model is more adequate.

Spine model and Area Object model are the structure model that can be used for the modelling of cable stayed bridge, both structure model have their own significance according to the need. But according to the conclusion, for the modelling of cable stayed bridge, the structure model that gives satisfactory results is Area Object model.

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