ANALYSIS OF CABLE STAYED BRIDGE UNDER THE ACTION OF VEHICULAR AND SEISMIC LOADS

[1]Praveen kumar M, [2]Dr. M Rame gowda, [3]Arjun B

[1]M.Tech, [2]Professor and Head, [3]Assistant Professor
Department of structural engineering, AIT,
Chikkamagalore, Karnataka, India

ABSTRACT: **Cable stayed bridge is an aesthetic icon in the field of Engineering. These long run bridges support the movement of maximum traffic. The Pylons are the load bearing compression members of the bridge. The cables are the diagonal members that channelize the load from deck towards the pylon . Later this load is transferred to the foundation below the pylons. The shape of the pylons and arrangement of cables is chosen in such a way that they should withstand all the various types of loads. An effort was made to evaluated the displacements of the cable stayed bridge deck and pylon under the action of traffic loads and seismic loads.**

KEYWORDS: **Response Spectrum, Truck Loads, Fan type cables**

1. INTRODUCTION

1.1:GENERAL

The Cable stayed bridges provide an outstanding architectural view because of their unique cable arrangements and pylon shapes. These elegant structures are composed of cables, deck, pylons and pile foundations. The Pylons are the main load bearing components of the bridge. As the traffic pushes down the deck downwards it creates a tension force in cables that are anchored to both deck and the pylon. These cables drag down the pylons inducing the compression force and thus the load gets transferred to the substructure. This type of bridge eliminates the necessity of intermediate support girders and thereby reduces the maintenance cost. The pylons or towers are the prominent compression members which facilitate the different arrangement of cable systems. The shape of the pylons and arrangement of cables is totally dependent on the pleasing appearance of the bridge structure. Some of the other factors that affect the cable configuration are clear span, vertical span of the tower and spacing in between the towers. For the purpose of analysis certain preliminary sectional properties are assumed to develop the model using SAP2000. The stress values and displacements produced in the bridge under the given load conditions are evaluated with the codal specifications.

2. OBJECTIVES OF THE WORK

1. Creating the model of Cable stayed bridge using SAP2000 software.

2. Study the displacement of cable stayed bridge, deck slab and pylon under the combined action of seismic loads and imposed loads.

3. Check the response of Cable stayed bridge deck slab under moving loads.

3. DESIGN PARAMETERS OF PROJECT

The plan for the Cable-stayed Bridge is a proposed one and the bridge is a road over bridge as it crosses over the existing road. The bridge is composed of a two lane carriage way to provide the movement of traffic and also with the pedestrian foot paths. The deck section is also provided with an anchorage zone that houses the cable anchorages. The following are the details of the plan,

- Span of the bridge = 250m.
- Bridge type = Cable-stayed bridge.
- Pylon type = Diamond shape pylon.
- Number of pylons = 2.
- Total width of the deck = 13.5m.
- Depth of the deck slab = 2m.
- Deck type = Trapezoidal three voided deck.
- Cable arrangement = Regular fan type.
- Minimum road clearance = 18’ (IRC.SP 054. 2000)
- Bridge deck design = As per IRC. 18 and IRC. 21.
- Seismic zone = zone 3.
- Importance factor = 1.5
- Individual panel length = 50m.

Cable spacing must be minimum to avoid the displacement of the deck. For my project the spacing between the cables is taken as 5m and the inclination of cables will be from 65 to 25 degrees. The inclination of the end cable is 45 degree with respect to the pylon .The proposed plan of the bridge is shown below. This plan was developed using Autocad software which is just a blue print for any structure that needs to be analysed.

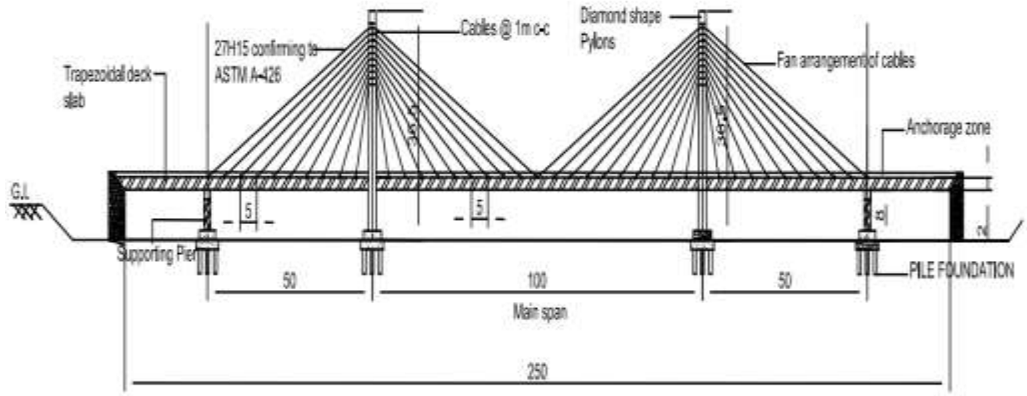


Fig-3.1longitudinal elevation of the cable stayed bridge.

Here the total height of the pylon is 36.5m which is governed by the inclination of cables and the pylon cross section is similar to that of a column. The main span of the bridge is 100m and it consists of a cantilever span of 50m on both the sides. The deck is a trapezoidal three voided cellular slab which is a pre-stressed member perfect for the construction in places with restricted access. The main principle of the bridge erection is posttensioning of pre-stressed deck slabs by using jacking systems. The cross section of the deck is shown below

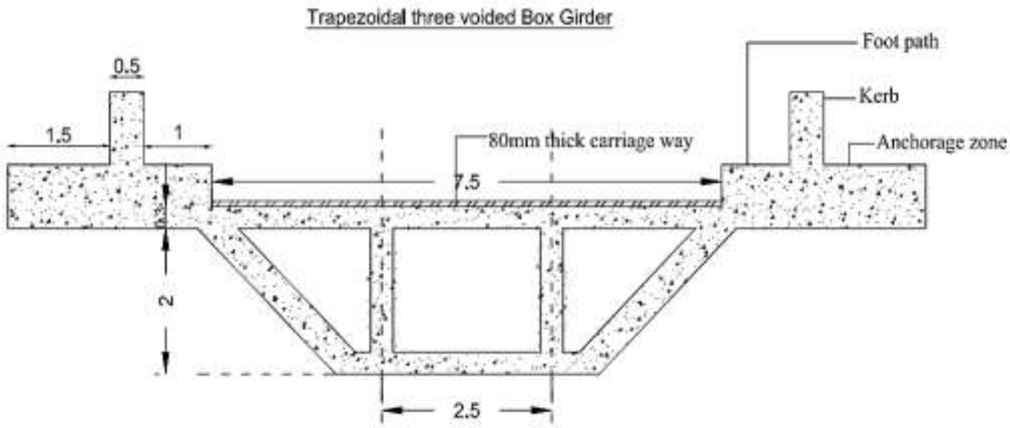


Fig-3.2 Cross sectional details of deck slab.

3.1 MODELLING PROCEDURE IN SAP2000.

- **a.** The bridge co-ordinate data was defined to facilitate the geometry of the bridge and then the sectional and material properties are defined.
- **b.** All the structural components are placed in the grid data system.
- **c.** Various loads and load combinations are defined as per codal specifications.
- **d.** The bridge is analysed for the dynamic effect of the seismic force.
- **e.** Later the bridge is checked for its response under the action of moving truck loads.

The cables stayed bridge with twin diamond shape pylons modelled in SAP2000 is shown below,

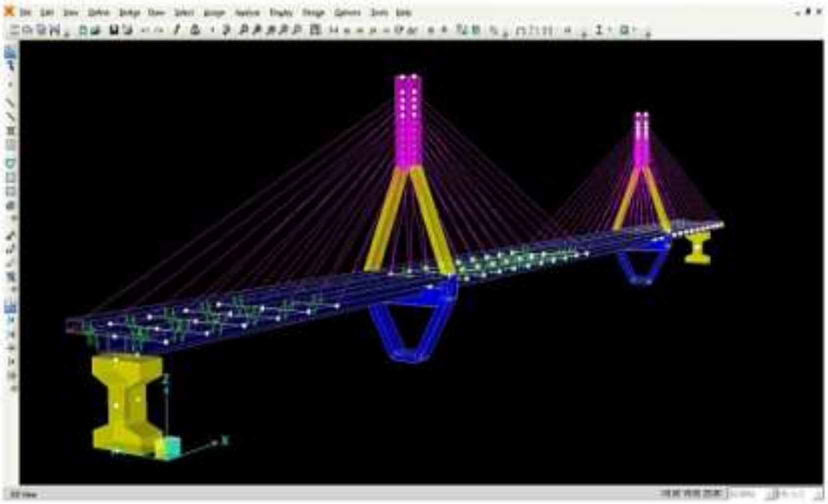


Fig-3.3 Cable stayed bridge modelled in SAP2000.

4. DEFINING SEISMIC LOADS.

As per code IRC: 6 -2000, all bridges are to be designed for seismic zone 3 and above. The seismic force in both x and y direction is applied with a minimum of 5% damping for any concrete structures. The soil type is considered as type II which is a gravely medium hard soil. And the importance factor is taken as 1.5. For the dynamic analysis of the cable stayed bridge a response spectrum function is defined as per IS: 1893- 2002. The response spectrum function is defined for a minimum of 5% damping for cement concrete structure as shown below.

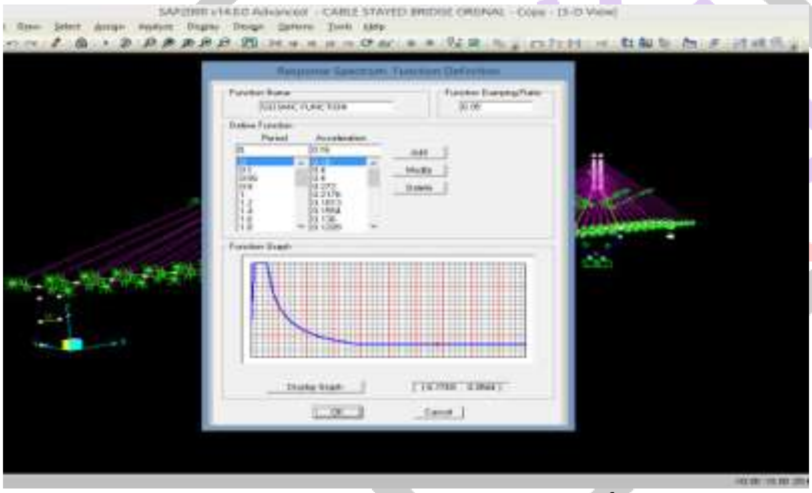


Fig-4.1 Response spectrum function.

5. DEFINING VEHICULAR LOADS.

The response of the bridge deck under moving traffic loads is very important. Even the slightest deflection may result in the collapse of the bridge structure. Recent reports state that the cable stayed bridges are subjected to wave like vibrations when subjected to moving loads. So the bridge must be designed in such a way that its deflections are well under the permissible limits as per AASHTO-LRFD code.

5.1 DEFINING TWO LANE TRAFFIC.

The concerned Cable stayed bridge is having a deck that can facilitate a two lane traffic on it. The width of each lane is 3.5m. In order to define the lane 1 the frame numbers are entered with lane width. And then the second lane is defined where the lane numbering is entered in reverse order so that the vehicles on that lane move in opposite direction to that of the vehicles moving in lane 1. After defining both the lanes the lanes are given different colours so that they are easily differentiable. The vehicles that will be defined in later phase move on these pre-assigned lanes in opposite direction. The figure in the next page shows the lanes on the deck slab of the cable stayed bridge.

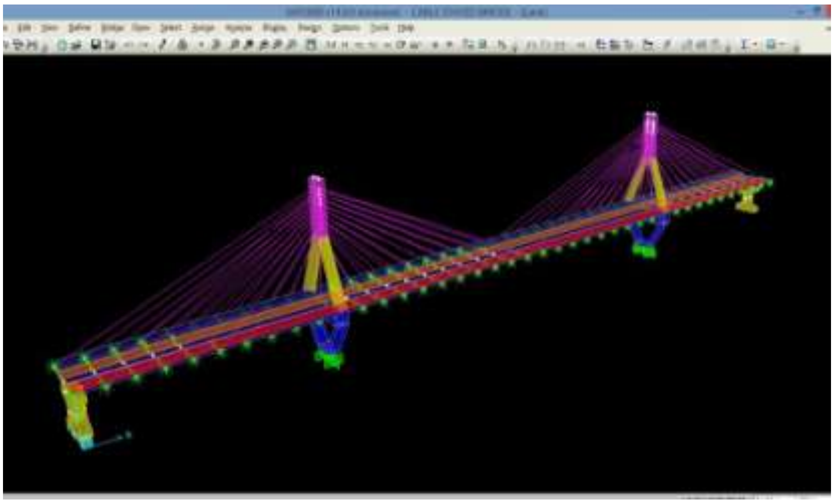


Fig-5.1 Two lane traffic on deck slab.

5.2 RESPONSE OF BRIDGE UNDER VEHICULAR LOADS.

The vehicle designed is the standard Hsn-44 truck as per AASHTO-LRFD guidelines which exerts a load of 180kN/m. The figure below shows the response of the cable stayed bridge under the action of the moving vehicular load.

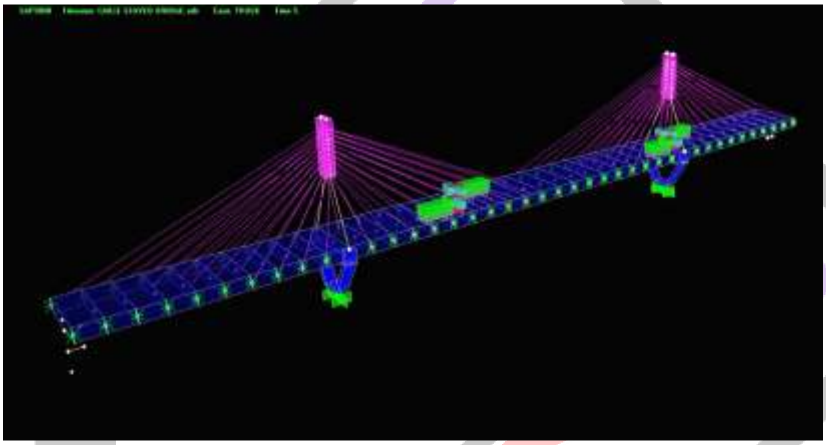


Fig-5.2 Moving trucks on the bridge deck.

6.0 RESULTS AND DISCUSIONS.

As per the objective of this report the displacements of deck slab must be within the allowable limit under the action of both imposed loads with seismic force and moving truck loads.

6.1 DISPLACEMENT OF DECK DUE TO IMPOSED AND SEISMIC LOADS.

The maximum displacement of the deck slab is under the action of imposed loads and the seismic load acting along y direction i.e. due to the third load combination. These values can be plotted graphically using the displacement values obtained from the software analysis. Later the maximum displacement is checked for the safety conditions as per AASHTO guidelines.

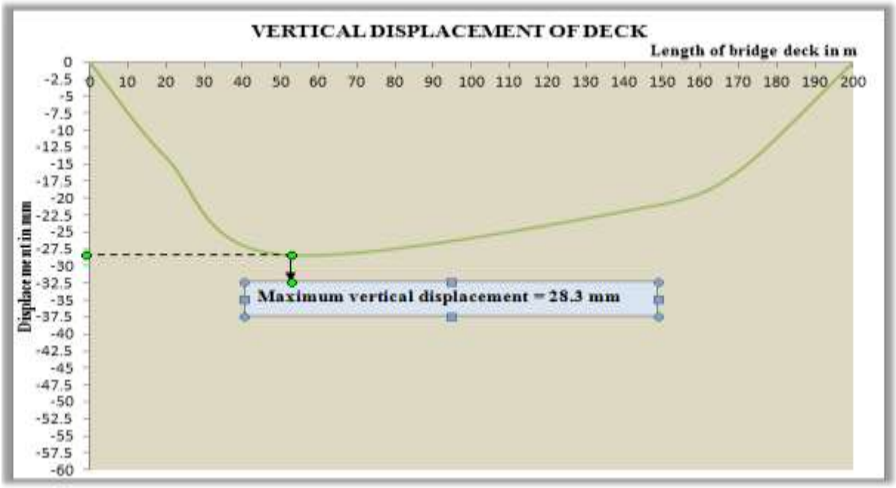


Fig-6.1 Maximum displacement of deck slab under seismic and imposed loads.

The value of maximum displacement must be lesser than the allowable deflection provided for the bridge structures in AASHTO guidelines. As per the analysis the bridge deck undergoes a maximum deflection of 28.3mm which when converted to feet is 0.092ft. Now as per the AASHTO guidelines the maximum allowable deflection of the bridge structure is given by the formula,

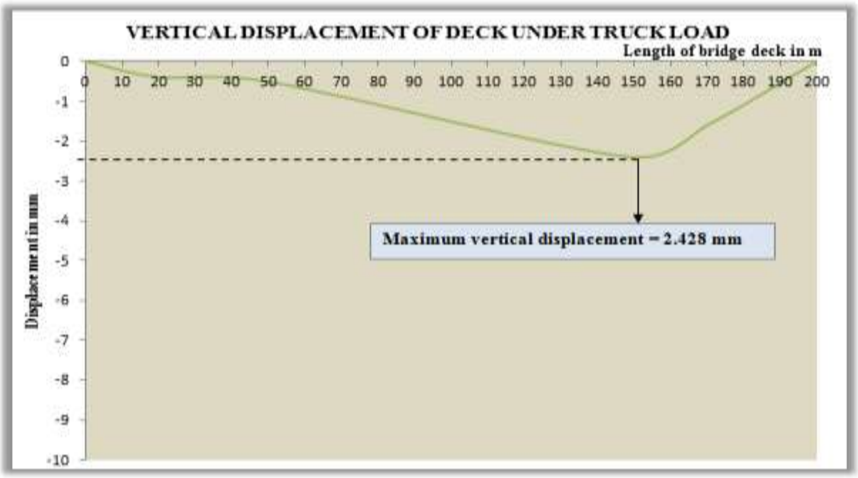
δ_{all} = L/400

= 200/400

= 0.5m

The allowable displacement 0.5m when converted to feet becomes 1.64ft. Hence the displacement of the deck is less than that of the allowable deflection i.e. 0.092 < 1.64.

6.2 DISPLACEMENT OF DECK UNDER MOVING TRUCK LOAD.



The above graph shows the maximum value of displacement of deck slab under the action of trcuk loads. From the analysis the maximum value of displacement is obtained as 2.428mm which is represented in feet's as 0.0086 ft. As per the code the allowable displacement for the deck slab under the moving loads is,

δ_{all} = L/800

= 200/800

= 0.25m

The allowable displacement 0.25m when converted to feet becomes 0.82 ft. Hence the displacement of the deck is less than that of the allowable deflection i.e. 0.0086 < 0.82.

6.3 DISPLACEMENT OF PYLON UNDER MOVNH AND SEISMIC LOADS.

The various loads acting on the cable stayed bridge result in the deflection of its structural members. As the pylon is the most important structural component of the bridge it should experience very minute amount of displacement under the action of loads. Hence the maximum deflection value is obtained from the software analysis. And the deflection values at various heights of the pylon are plotted graphically. The graph below shows the horizontal displacements of pylon under the action of imposed and seismic loads.

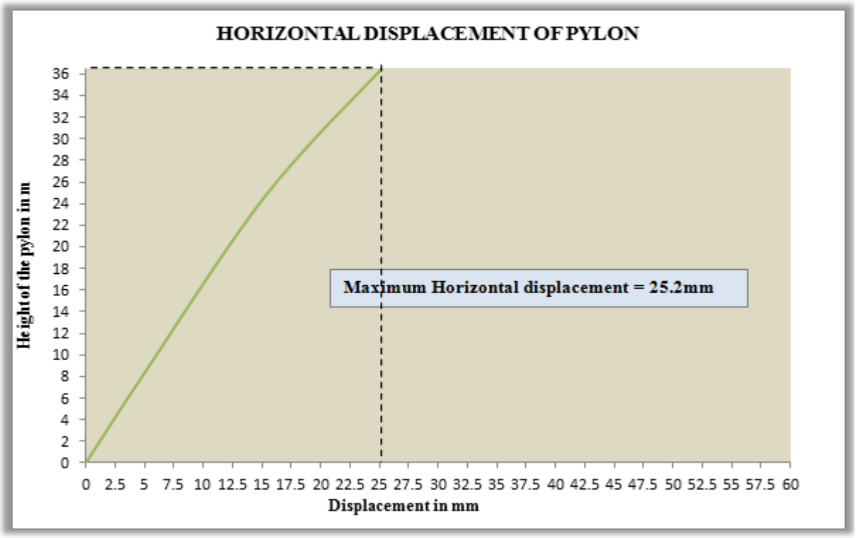


Fig-6.3 Maximum displacement of Pylon.

From the above graph the maximum horizontal displacement of the pylon is 25.2mm. The displacement observed in case of pylon is very minute and hence the pylon performs satisfactorily under the action of imposed and seismic loads.

7. CONCLUSIONS.

a. In this study the response and conduct of the cable-stayed bridge under the action of imposed and seismic loads is found by analysing the structure using SAP 2000 software.
b. The displacement of the cable stayed bridge deck slab under the action of the imposed and seismic loads is observed to be 28.3mm whereas the allowable displacement as per AASHTO code is 50mm, Hence the bridge performs safely under the action of imposed and seismic loads. b.
c. The displacement of the cable stayed bridge deck under the action of moving traffic loads is observed to be 2.428mm which is very less compared to the allowable displacement 250mm. Hence the bridge remains safe under the action of daily traffic loads. c.
d. And then the displacement of Pylon due to the action of seismic and imposed loads is observed to be 25.2mm. The value of displacement obtained is very less compared to the displacements observed in the literatures. Hence the cable stayed bridge with twin diamond shaped tower performs satisfactorily under the action of various loads.

REFERENCE

[1]. Pinaki and Shivanshi: "Analysis of the behaviour of Cable stayed bridge with different types of cables arrangement". Vol. 3, Issue 5, 2016
[2].Desai A K, Savaliya G. M, Vasanwala S.A: "static and dynamic analysis of cable-stayed suspension hybrid bridge & validation, Vol. 6, Issue 11, 2015.
[3].Parag R, Padmakar J and Trupti N: "parametric investigation of cable stayed bridge using macro based program,Vol. 4 Issue 9, 2015.
[4].Siddharth G, Desai G. H and Solanki C. H: "Effect of Pylon Shape on seismic response of Cable stayed bridge with soil structure interaction".Vol. 1, No 3, ISSN 0976 - 4399, 2010.
[6]. Alvarez J.J and Aparicio A. C: "Seismic Response of Cable-Stayed Bridges for Different Layout Conditions: A Comparative Analysis" , 15 WCEW, LISBOA, 2012.
[7]. N. Krishna Raju, "Design of Bridges", fourth edition.
[8]. D. Johnson Victor, "Essentials of Bridge Engineering", Fifth Edition.
[9]. Niels. J. Jimsing, "Cable supported Bridges, Concept and Design".
[10]. AASHTO-LRFD, American Association of State Highway and Transport Officials Bridge design specifications (2012), NW suite 249, Washington D.C, 6th edition.
[11]. IRC:6-2000 , "standard code and specifications for road bridges, Loads and stresses".
[12]. IRC. SP. 054, "Project preparation manual for bridges".
[13]. IRC:18-2000, " Design criteria for pre-stressed road bridges".
[14]. IRC:21-2000, "Standard specifications and code of practice for road bridges".
[15]. IRS-CBC, "code of practice for plain, reinforced & pre-stressed concrete for general bridge construction".
[16]. IS: 800-2007, " General construction in steel-Code of practice".