STRUCTURAL BEHAVIOUR OF CABLE-STAYED BRIDGE UNDER VEHICULAR AND SEISMIC LOADS

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Abstract: In modern days cable–stayed bridge uses are expanding because of their highly appreciable appearance, economic and significantly utilized structural material. The Major components of the cable-stayed bridge are the cables, deck, and pylons (tower) and foundation. The cables support deck and load is transferred from cable to the pylon and from pylon to the foundation. The cables are in tension while pylons are in compression. For the analysis CSI Bridge software was used. Present research focuses on the behavior of the cable-stayed bridge for earthquake load and traffic load in seismic zone IV with hard soil condition. The maximum displacement, bending moment, shear force, axial force will occur at the center of main span at 156 m on the bridge deck in case when the combined load action (vehicular and earthquake). These parameters are discussed in this research paper. The axial forces developed in cables and displacement in pylon was also checked.

Keywords: *Cable - Stayed Bridges, response spectrum analysis, Traffic 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. These fundamental load bearing elements contribute in a definite way to the structural behavior of the whole bridge. As the traffic pushes the deck downwards it creates a tensile force in cables and in the pylons inducing the compressive force and thus the load gets transferred to the substructure. These bridges reduce the number of intermediate supports. The pylons facilitate the different arrangement of cable systems. For the purpose of analysis, preliminary sectional properties were assumed to develop the model. CSI Bridge software was used for the analysis work.

2. Objectives of the work

1. To study the seismic behavior of cable stayed bridge in seismic zone IV with hard soil condition.
2. Study the displacement of bridge deck and pylon under vehicular load and seismic load combination and forces developed in various components of the bridge.

3. Analyses the cable forces developed in the cables.

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.
- Deck type = Box type 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=37 High Stranded Cable of 7mm 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)

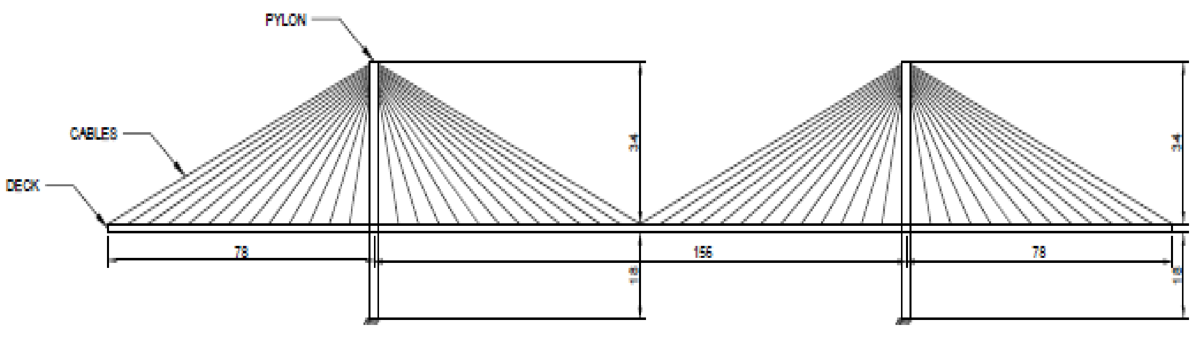


Fig-3.1 longitudinal section of cable stayed bridge (all dimension in m)

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 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.**

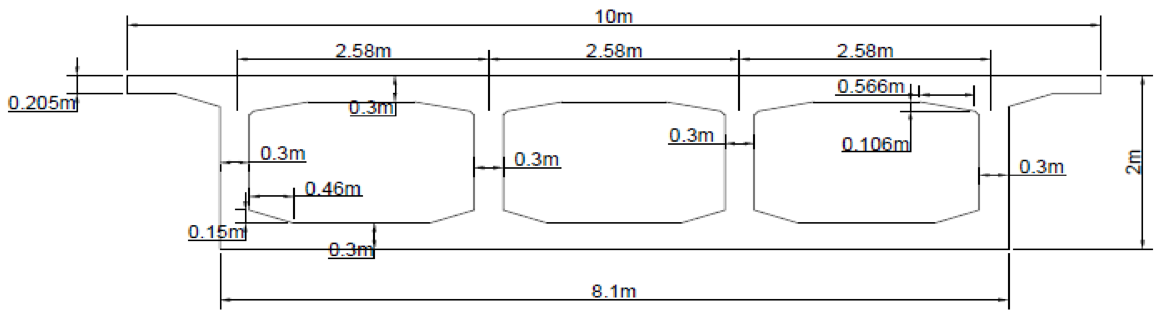


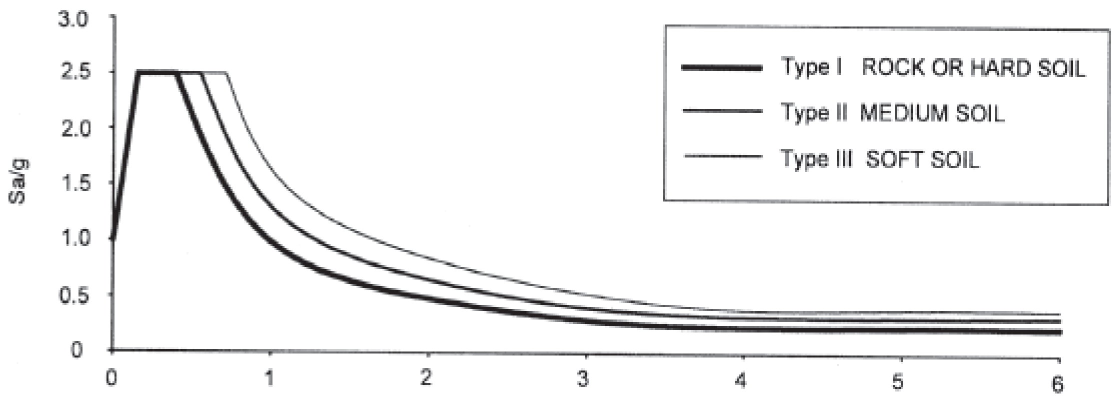
Fig-3.2 Cross Section of the Deck

4. Modeling procedure in CSI Bridge

a. The bridge co-ordinate data was defined to facilitate the geometry of the bridge
b. Define material property and all the structural components
c. Define various loads and load combinations as per code specifications
d. The bridge is analyses for the dynamic effect of the seismic force
e. Later the bridge is checked for its response under the action of various loads.

5. Defining Seismic Loads

Seismic forces shall be assumed to come from any horizontal direction. 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 **fig5.1**. The critical load combination occurs when we considered vehicular load with earthquake load.



Natural time periods T sec

Fig-5.1 Spectra for Response Spectrum

6. Defining Vehicular Loads

Vehicle load considered as per IRC-6:2017, clause 201 for analysis purpose 70Rwheeled vehicle considered and load combination for two lane taken as per 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 shown in **fig-6.1**

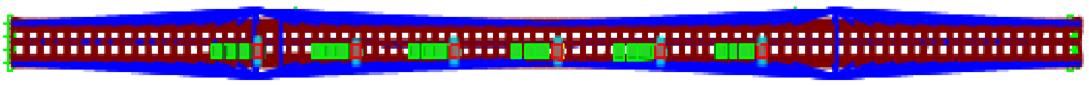


Fig 6.1- 70 R wheeled vehicle moving from one end to the other end of the bridge in lane one of bridge

7.0 Results and Discussions

7.1 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.7.1**. It occurs at a distance 156m center of the main span is 234.2mm.

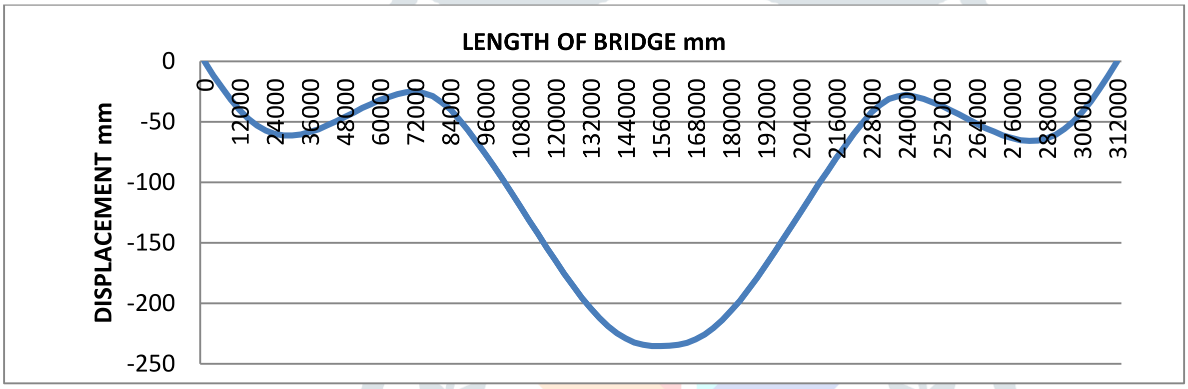


Fig -7.1 Vertical displacement of deck due to imposed and seismic loads consider moving load 70 R wheeled vehicle along the length of bridge

The bridge deck undergoes a maximum displacement of 234.2mm at distance of 156m from left end of bridge. As per the AASHTO[12] guidelines the maximum allowable deflection of the bridge structure is given by the formula[6],

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

The allowable displacement 0.78m.Hence the displacement of the deck is less than that of the allowable deflection i.e. 234.2mm < 780mm.

7.2 Displacement of deck under moving load only

The variation of displacement of deck along length of bridge is shown in **fig.7.2**

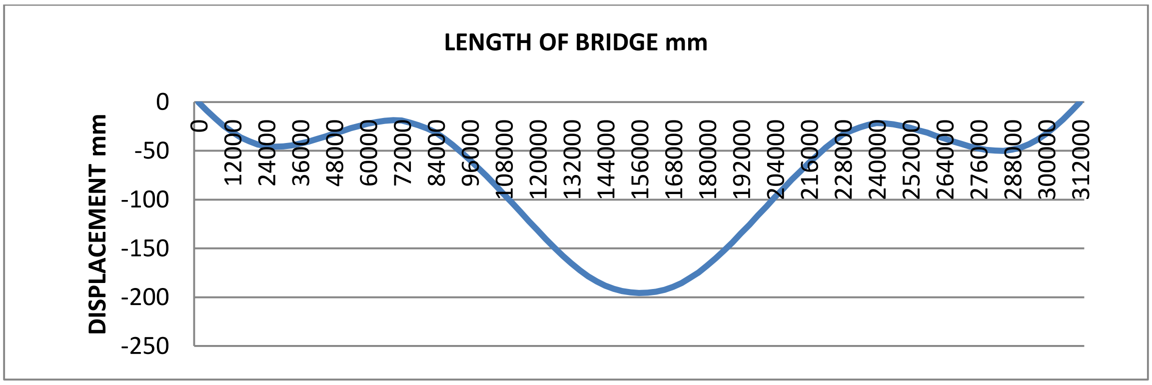


Fig -7.2 Vertical displacement of deck due to moving load 70 R wheeled vehicle in one lane

The maximum value of displacement is obtained as 195.60mm at distance of 156m from left end of bridge. As per the code the allowable displacement for the deck slab under the moving loads is,

$$\Delta_{all} = L/800 = 312/800 = 0.39m$$

The allowable displacement is 0.39m. Hence the maximum displacement of the deck is less than that of the allowable deflection i.e 195.60. < 390mm.

7.3 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 **fig7.3.**

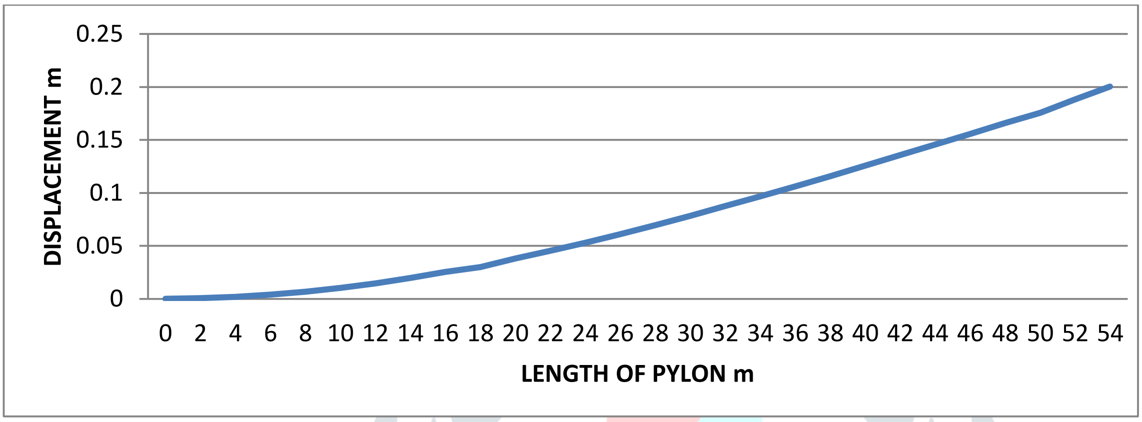


Fig -7.3.1 Horizontal displacement of pylon due to imposed and seismic loads

From the above variation the maximum horizontal displacement of the pylon is 200.3mm at the height of 54m from river bed. The displacement observed in case of pylon is very minute and hence the pylon performs satisfactorily under the action of imposed and seismic loads.

7.4 Bending Moment on bridge deck due to vehicular and seismic loading

The variation of bending moment on bridge deck is shown in **fig: 7.4.** The maximum bending moment occur in the main span at the distance of 165m from left end of the bridge. The value of maximum bending moment is 33627.7KN-m

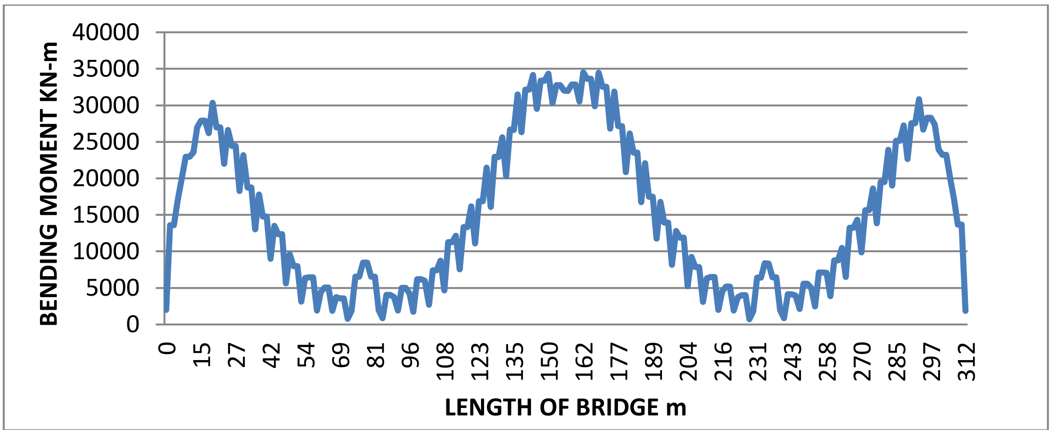


Fig: 7.4 Bending Moment on bridge deck due to vehicular load with seismic loading

7.5 Axial Force on bridge deck due to vehicular and seismic loading

The variation of axial force is shown in **fig: 7.5**. The maximum axial force occurs at the 81m and 237 m from the left end of the bridge is -19747.47 KN, -19491.139 KN and zero at the center of the main span.

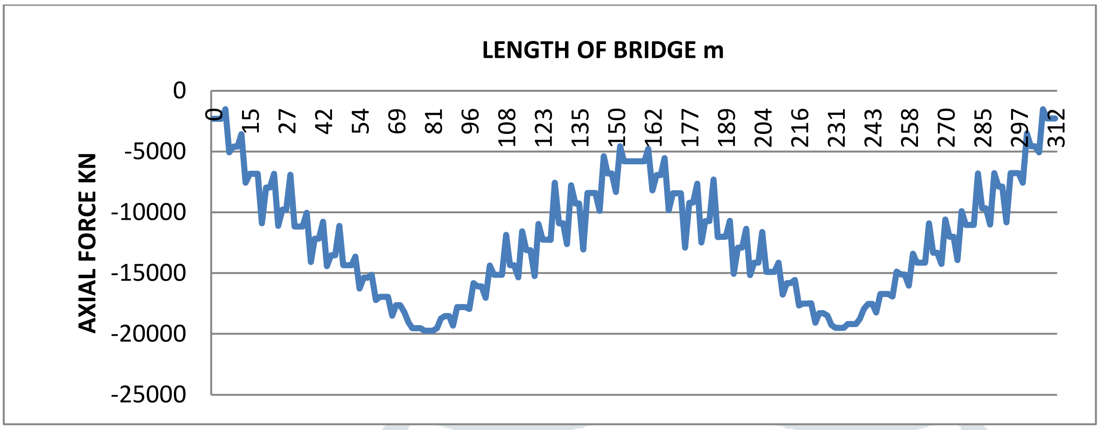


Fig: 7.5 Axial Force on bridge deck due to vehicular and seismic loading

7.6 Shear Force on bridge deck due to vehicular and seismic loading

The variation of the shear force due to vehicular and seismic loading is shown in **fig 7.6**. Maximum shear forces occur at the support that is near the tower of the bridge is 7218.32KN at 186m from the left end of the bridge.

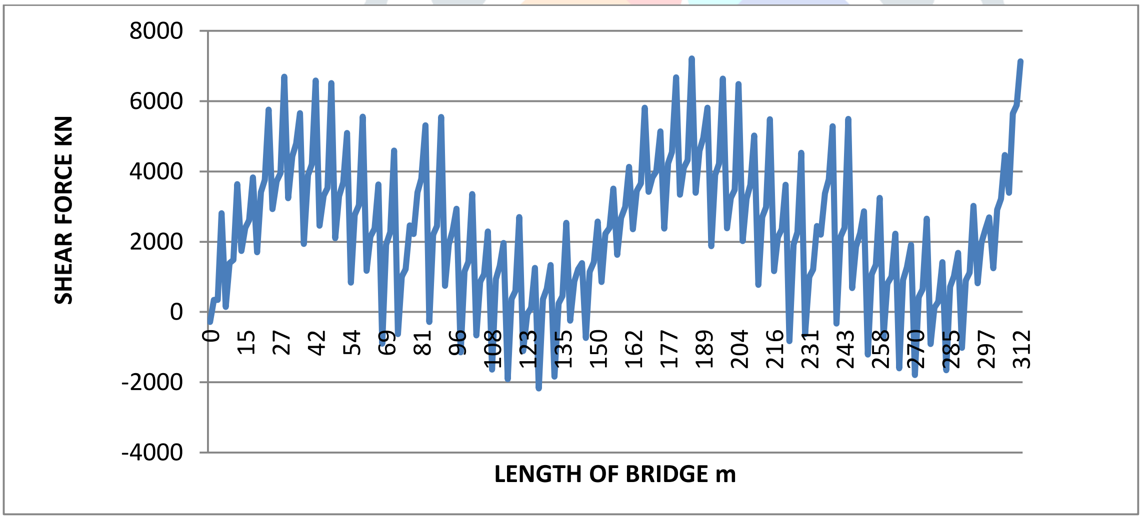


Fig: 7.6 Shear Force on bridge deck due to vehicular and seismic loading

7.5 Axial Force in cables due to vehicular and seismic loading

Cables plays important role while transferring the load from deck to the pylon. Cables were provided at 6m spacing along the deck with diameter 0.2m. The values of axial force developed in each cable are given in **table 7.5.1** and in **fig 7.5** shows the cable number.

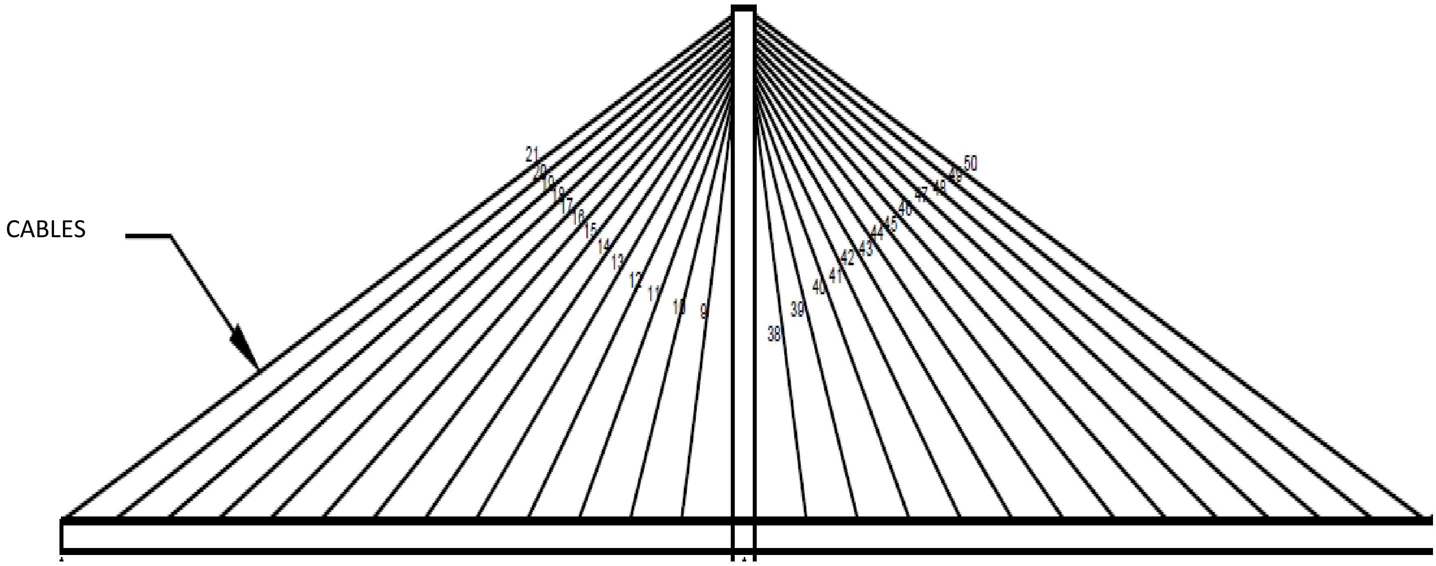


Fig: 7.5 showing cable numbers

Table7.5.1 Axial Force in cables due to vehicular and seismic loading

S. No.	Cable number	Vehicle load and earthquake load(KN)	Cable number	vehicle load and earthquake load (KN)
1	9	3673.22	38	3639.41
2	10	3354. 9	39	3314.70
3	11	3258.18	40	3235.70
4	12	3396.9	41	3407.30
5	13	3642.83	42	3703.56
6	14	3741.60	43	3871.7
7	15	3779.02	44	4012.60
8	16	3671.55	45	4049.15
9	17	3372.57	46	3920.5
10	18	3351.12	47	3690.52
11	19	3465.41	48	3338.19
12	20	3545.62	49	2950.71
13	21	3577.18	50	2562.92

8. Conclusions

1. The maximum displacement of the bridge deck is less than the allowable displacement; hence the bridge performs safely under the action of imposed and seismic loads.
2. The displacement of the cable stayed bridge deck under the action of moving traffic loads is less compared to the allowable displacement 390mm. Hence the bridge remains safe under the action of daily traffic loads.
3. The cable stayed bridge with H shaped tower performs satisfactorily under the action of vehicular and seismic loads.
4. The maximum bending moment occur at the main span when the moving loads at the main span 33627.78KN-m at the centre of the main span.
5. The maximum axial force occurs at the 81m and 240 m from the left end of the bridge when the moving loads at the main span compressive 19747.47 KN, 19491.139 KN and zero at the center of the main span.
6. Cables are in tension as they provide support to the deck and transfer the load from deck to the pylon.

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