BEHAVIOUR OF PEDESTRIAN STEEL BRIDGE SUBJECTED TO SEISMIC LOAD

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Abstract: *A pedestrian steel bridge model was created by using Structural analysis programming (SAP2000). With the similar loading and support conditions the 3D model was analyzed for the different span like 10m, 15m, and 20m. The basic emphasis has been given to decrease the final response of the structural member by optimizing the cross section of steel girder (I section), steel plate thickness. Steel girder and steel plate are used for deck section and M40 grade concrete is used for column section in SAP 2000 structural integrated software and also stiffeners are provided for every 1 meter throughout the length of the span. The steel plates are placed on the I-section ISHB-450 at 92.5kg/m and stiffener are connected in between steel girder. This project looks into the analysis of pedestrian bridge under asymmetrical loads and reviews results for the dynamic loading caused by moving pedestrian and earthquake [zone 4 and soil type-2] for the vertical deflection, shear force in horizontal and vertical direction also bending moments in horizontal and vertical direction. Pedestrian loads are applied on the steel plate (acts as deck) in the form of human induced vibrations by using SAP Software.*

As per IS: 1893-2002 code of practice loads are applied in the combination of dead load, pedestrian load and earthquake in two directions. After analyzing the pedestrian steel bridge structure in 3D model for different span 10m, 15m and 20m results of displacement, shear force in two directions and bending moment in two directions are presented in this project.

According to IS: 875 (Part 3)-1987, if the structural height is less than 10 m there is no need to consider wind load.

Key Words**:** ***SAP2000, ISHB-450, PSB, IS CODE***

1. INTRODUCTION

Suspension structure of pedestrian bridges is among the most elegant and light bridge structures because of their static and dynamic properties, these structures are predominantly used to carry pedestrian and bicycle traffic. The main load carrying members of modern pedestrian suspension bridges are high-strength steel sheets or pre-stressed reinforced concrete structures. Heavy decks and pre-stressing bridge structures requires considerable amount of load carrying structural materials. In recent years, along the ordinary single span suspension bridges, multi-span bridges have been used as well. Asymmetrical loads cause these structures to behave in more complex ways.

Modern footbridges are more and more sensitive to variable load created by moving pedestrians. There are several reasons for that. Quickly expanding road infrastructure, force us to build footbridges just to reconnect one piece of land separated now by the new road or railway. These bridges are delicate because the main live load acting on them comes from pedestrians. Very often there is no place for a pier and long spans are only feasible solutions. It happens often on the highway or in the city centres because of a visual aspects or collisions with underground facilities. Additionally new light and highly stressed materials are used for constructing. Finally lightweight structures are coupled with modern architecture and often armed with cable stays and suspension systems. In consequence mass and stiffness of structures decrease so much that the structures are sensitive to dynamic excitation.

The dynamic problems of footbridges have been subject of recent studies. Main reason of new engineering challenges related to footbridges is their low excitation energy. This makes them vulnerable to vibrations. Periodic load from pedestrians and wind can accelerate a bridge to the level which can be dangerous for structure itself or at least to large to be tolerated. Recent studies describe accelerations criteria admissible for user comfort, but often lack descriptions of loads. Therefore definition of loading is key aspect for proper implementation of these criteria.

The dynamic walking load in the vertical direction is applied on the bridges using two different loading schemes:

(1) a stationary load at the mid-span and

(2) a moving load across the bridge. The response spectrum analysis is carried out using a Generalized Single Degree of Freedom procedure which has been verified by comparing its predictions with the results of a Multi-Degrees of Freedom modelling.

The response spectrum is a plot of the peak value of a response quantity as a function of the natural frequency of the structure. In this study, the response quantity considered is a pseudo force (F), where:

F =GSDF maximum acceleration * GSDF mass

Main aim of this study is to analyse the behaviour of pedestrian steel suspension bridge structure under dynamic walking loads.

2. DYNAMIC RESPONSE UNDER PEDESTRIAN ACTION

This part focuses on the definition of human induced dynamic load in the relation to body weight, pacing rate, density and interaction between pedestrian and vibrating deck (lock in effect).The response of a pedestrian bridge structure can be calculated with a commercial computer FEM programs if the dynamic load is defined. Bachman has defined a pedestrian load function for *2 Hz* frequency. Kerr and Bishop presented experimental results and conclusions for pace rates between *1.6* and *2.2 Hz*.

3. LOAD FUNCTION FROM SINGLE PEDESTRIAN.

A special experiment has been done to develop more universal load functions. The strategy was to examine several humans walking with different pace frequency on the experimental set-up and to develop a load function. The stiff steel double arm lever was constructed. First arm was connected to the digitally driven dynamic hydraulic jack. On the second arm a fitness treadmill with electric steering was placed. Force cells were used as connectors between treadmill and a steel lever. Dynamic load induced by walking person can be measured and stored in data base. Experimental set-up allows additionally to measure loads on the vibrating deck. The interaction between walking person and vibrating structure can be also observed.

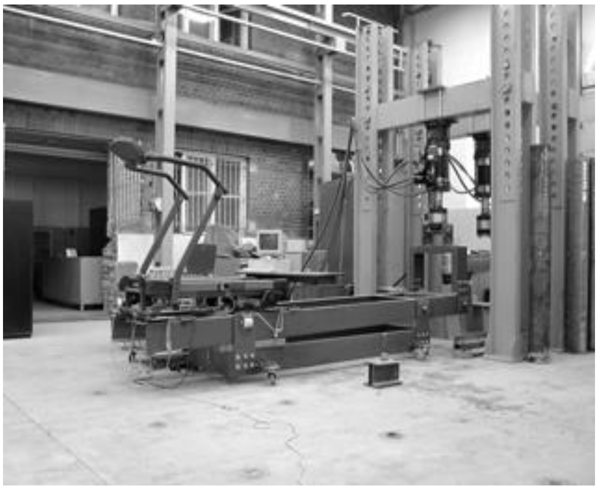

Fig 1: Fitness treadmill on the vibrating lever.

4. MODEL DETAILS

The main girder dimensions of the bridges for the different span are,

(A) I-section- ISHB -450 at 92.5kg/m (from steel table)

Table 1: Properties of I-section

Depth (h)	0.45 m	For different span 10m, 15m and 20m.
Width of flange(b)	0.25 m	
Thickness of flange (t_f)	0.0137 m	
Thickness of web (t_w)	0.0113 m	
Sectional area (A)	0.0117892 m^2	

(B) Circular column- Diameter = 0.4 m
(C) Steel plate thickness- Thickness = 0.01m
(D) Hand rails- Outer diameter = 0.1m

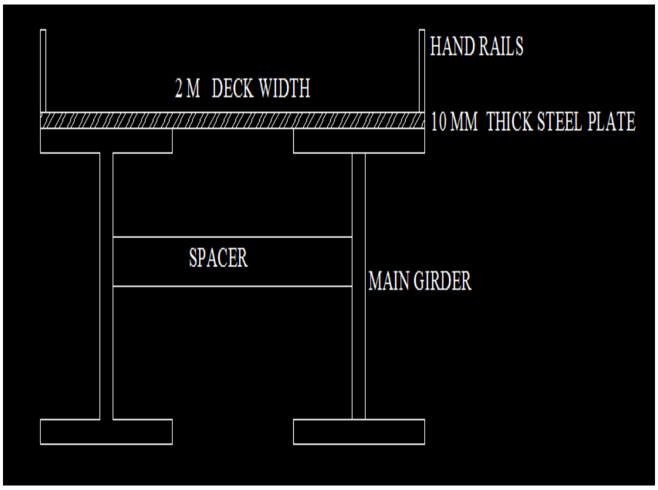

Fig 2: Typical bridge deck cross-section

5. SAP MODELS FOR PEDESTRIAN STEEL BRIDGE STRUCTURE

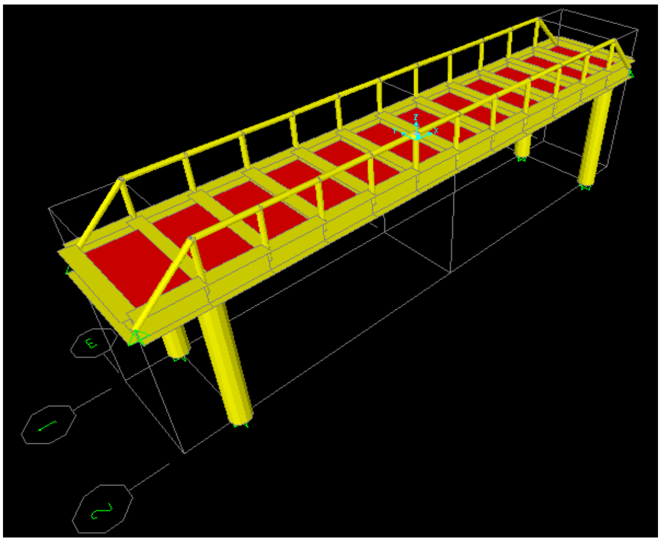

Fig 3: SAP 3D model for 10 m span

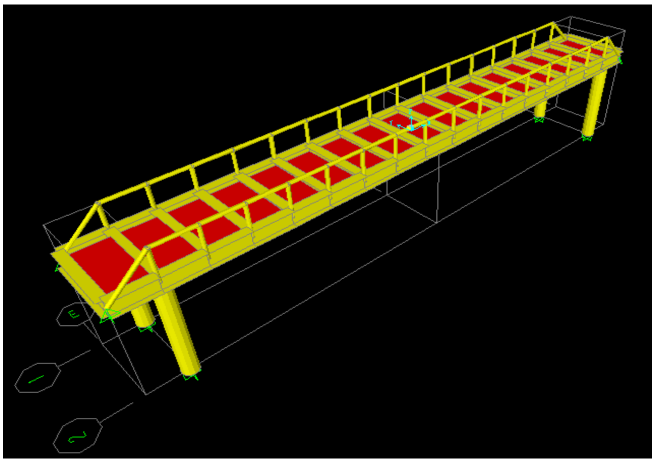

Fig 4: SAP 3D model for 15 m span

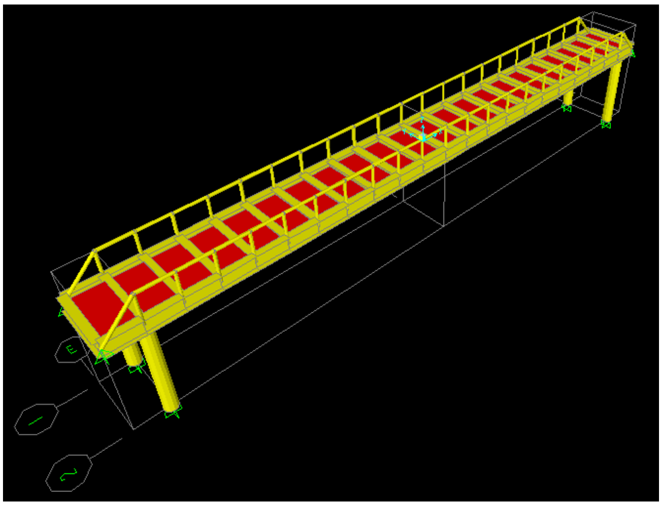

Fig 5: SAP 3D model for 20 m span

6. METHODOLOGY:

A three dimensional pedestrian steel bridge structure model was developed by using SAP 2000 structural integrated software. Initially properties of concrete and steel such as density, modulus of elasticity and Poisson's ratio should be defined. Circular concrete column of diameter 0.4m, steel hand rails of diameter 0.1meter is used in deck section and for I-section ISHB-450 at 92.5 kg/m is used as main girder section , high strength steel plate of thickness 10mm is chosen as optimum thickness of plate and all the data should be clearly defined in the software. Steel girder is used for deck section and M40 grade concrete is used for column section. The stiffeners are provided for every 1m throughout the length of the span. The steel plates are placed on the I-section ISHB-450 at 92.5kg/m.

Taking reference from the paper "Dynamic analysis of pedestrian bridges with FEM and CFD"[1]. The pedestrian loads are applied on the steel plate (act as deck) in the form of human induced vibrations. Pedestrian steel bridge structure under asymmetrical loads i.e, vertical vibration response of foot bridges subjected to dynamic loads induced by walking human is assessed via a Power Spectral Density approach by using SAP 2000 software.

We have taken the frequency in Hertz because a walking person adapts to and synchronizes his/her motion in frequency and phase with vibrating deck. This phenomena depends from the human personal feature and vibration characteristics of the deck (Bachmann).

In this project work, we make an attempt to analyze the pedestrian bridge structure for the severe earthquake condition i.e. we have considered earthquake zone 4 (zone factor 0.24) and medium soil type-II.

Earthquakes are considered both in X direction and Y direction. According to IS:875(part 3)-1987 code of practice, if the height is less than 10m there is no need to consider wind load i.e, minimum 10m height is necessary for considering wind load to any structures.

After defining all the necessary data, then assigning process will start. In the beginning stage of project, analysis was done for different I-section and for different plate thickness. The basic emphasis has been given to minimize the total deflection of the structural member by optimizing the cross section of steel girder, steel plate thickness and material M40 grade concrete.

As per IS 1893:2002 code of practice loads are applied in the combination of dead load, pedestrian load and earthquake in two direction. After analyzing pedestrian steel bridge structure i.e, 3D model for the different span such as 10m, 15m and 20m results are listed. Results of displacement, shear force in X and Y direction and bending moment in X and Y direction are presented in this project work.

7. DIFFERENT LOAD COMBINATION

Table 2: Various load combination

LOAD COMBINATIONS	CODE OF PRACTICE
1.7 (DL+LL)	As per IS:1893-2002 (for Earthquake)
1.7(DL+EQ_X)	
1.7(DL+EQ_Y)	
1.7(DL-EQ_X)	
1.7(DL-EQ_Y)	
1.3(DL+LL+EQ_X)	
1.3(DL+LL+EQ_Y)	
1.3(DL+LL-EQ_X)	
1.3(DL+LL-EQ_Y)	

8. RESULTS AND DISCUSSION

In this paper, results are shown only for 20 meter span.

(a)Displacement Or Deflection

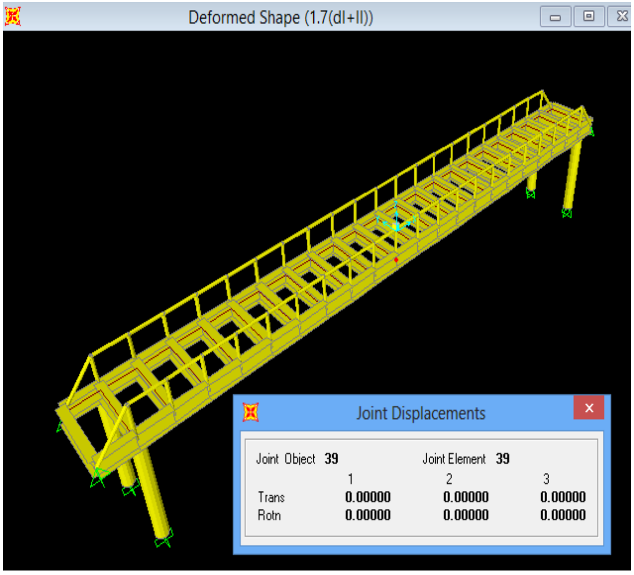

Fig 6: Displacement for 20 m span

Table 3: Displacement for different load combination (20m span)

Load Combination as per IS 1893-2002	Displacement (m)
1.7(DL+LL)	0
1.7(DL+EQx)	0.03281
1.7(DL+EQy)	+0.45068
1.7(DL-EQx)	+0.03281
1.7(DL-EQy)	0.45068
1.3(DL+LL+EQx)	0.03691
1.3(DL+LL+EQy)	0.35404
1.3(DL+LL-EQx)	0.03691
1.3(DL+LL-EQy)	0.35404

From the table 3, for the span length of 20m displacement is zero for the dead and live load combination.

Also for the load combination of dead load, live load and earthquake displacement is negligible.

(b) Shear Force

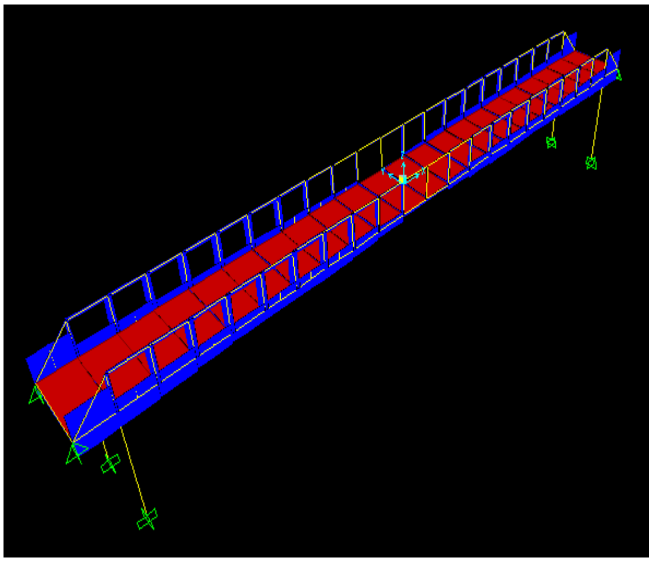

Fig 7: General Shear Force Diagram in SAP 2000 software

Table 4 : Shear Force values for different load combination (20m span)

Load Combination as per IS1893-2002	Support (kN)	Mid (kN)
1.7(DL+LL)	0	0
1.7(DL+EQx)	0.262	0.057
1.7(DL+EQy)	0.986	0.038
1.7(DL-EQx)	0.262	0.057
1.7(DL-EQy)	0.986	0.038
1.3(DL+LL+EQx)	0.919	0.599
1.3(DL+LL+EQy)	1.473	0.585
1.3(DL+LL-EQx)	0.919	0.599
1.3(DL+LL-EQy)	1.473	0.585

From the table 4, for the span length of 20m shear force is zero for the dead and live load combination.

Also for the load combination of dead load, live load and earthquake shear force values is negligible.

(C)Bending Moment:

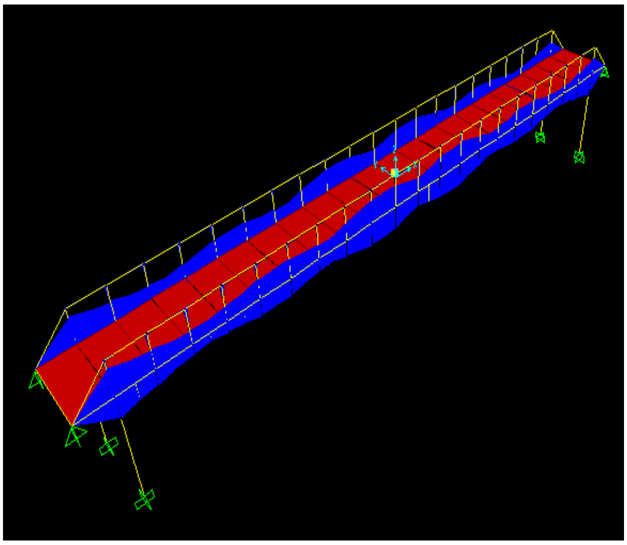

Fig 8: General Bending Moment Diagram in SAP 2000 software

Table 5: Bending Moment values for different load combination (20m)

Load Combination as per IS 1893-2002	Support (kN-m)	Mid (kN-m)
1.7(DL+LL)	0	0
1.7(DL+EQx)	0.0015	-0.0000464
1.7(DL+EQy)	0.0824	0.0267
1.7(DL-EQx)	0.0015	-0.0000464
1.7(DL-EQy)	0.0824	0.0267
1.3(DL+LL+EQx)	0.0027	0.00004308
1.3(DL+LL+EQy)	0.0647	0.0205
1.3(DL+LL-EQx)	0.0027	0.00004308
1.3(DL+LL-EQy)	0.0647	0.0205

From the above table, for the span length of 20m bending moment is zero for the dead and live load combination.

Also for the load combination of dead load, live load and earthquake bending moment values is negligible.

9. CONCLUSION

The main conclusions that can be drawn from this project work are,

- For the I-section, ISHB-450 at 92.5 kg/m the deflection is zero under the load combination of 1.7(DL+LL).
- For the plate thickness of 10mm (thickness of steel plate acts as deck) the deflection is zero under the load combination of 1.7(DL+LL).
- After analysing the 10m,15m and 20m span of 3D model of pedestrian steel bridge structure deflection, shear force and bending moment values are zero for the load combination of 1.7(DL+LL), and also for other load combinations deflection, shear force and bending moment values are negligible. But also we make an attempt by considering earthquake in two direction (Zone-4 and soil type-2).
- All the 9 load combinations are made As Per IS 1893-2002 code of practice.
- The purpose of this project work is to analyze the 10m, 15m and 20m span of pedestrian steel bridge structure only under the load combination of dead load and pedestrian load. In this load condition we obtained satisfactory results.

10. SCOPE OF FUTURE WORK

- Analyze the pedestrian steel bridge structure by taking Composite section.
- Analyze the pedestrian steel bridge structure by taking different sizes and types of sections.
- Analyze the pedestrian steel bridge structure by changing the properties of bridge.
- Analyze the earthquake resistant pedestrian steel bridge structure by providing Dampers or Isolator for different span.

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