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SEISMIC RESISTANT DESIGN OF A SHORT SPAN STEEL FOOT BRIDGES

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Abstract – A Bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for road, a railway, pedestrians, a canal or a pipeline. The obstacle to be crossed may be a road, a river, a railway or a valley. In Other words, bridge is a structure for carrying the road traffic or other moving loads over depression or obstruction. Also a foot bridge or a pedestrian bridge is a bridge designed for pedestrians and in some case cyclist, animal traffic and horse riders, rather than vehicular traffic. Footbridges are small, but important, because they are usually presented in townscapes. The appearance of footbridge, and indeed of any other bridges, in a town, is a major concern for designers. Increasing strength of new structural materials and longer spans of new footbridges, accompanied with aesthetic requirements for greater slenderness, are resulting more lively footbridge structures. In the past few years this issue has attracted great public attention. For the Construction of Foot Bridges, various cost effective, earthquake resistive, environmentally friendly, energy saving materials & techniques were used. Reduction in cost is achieved through effective design, utilization of materials and techniques that are durable, economical, and acceptable by the users and not requiring costly maintenance.

Keywords- Seismic Resistant, Foot Bridges

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INTRODUCTION

- **Aim & Objective:**

Footbridges are smaller lighter structures. They are narrow (about 2m wide) and are usually single span structures that rarely span more than 40m. There are a number of forms of steel footbridge. They provide easy and safe passage for the pedestrians to across the road without obstructing the traffic.

- **Need**

In recent years, there has been a growing trend towards the construction of lightweight footbridges. Due to its reduced mass of such structures, the dynamic forces can cause larger amplitudes of the vibration. The more slender structures become, the more attention must be paid to vibration phenomena.

The increase of vibration problems in modern footbridges shows that footbridges should no longer be designed for static loads only. But fulfilling the natural frequency requirements that are given in many codes restricts footbridge design: very slender, lightweight structures, such as stress ribbon bridges and suspension bridges may not satisfy these requirements. Moreover not only natural frequencies but also damping properties, bridge mass and pedestrian loading altogether determine the dynamic response. Design tools should consider all of these factors. Provided that the vibration behavior due to expected pedestrian traffic is checked with dynamic calculations and satisfies the required comfort, any type of footbridge can be designed and constructed. If the vibration behavior does not satisfy some comfort criteria, changes in the design or damping devices could be considered. The need for construction of Foot Bridges is:

Structural steel has been the natural solution for long span bridges since 1890; Steel is indeed suitable for most span ranges, but particularly for longer spans. So, to overcome all these problems Seismic Resistant Foot Bridges need to be constructed.

LITERATURE REVIEWS

- INTRODUCTION

The following Literature reviews gives ideas related to various design procedures aspects for designing the foot bridges. Also it gives an idea about how to deal with the seismic designs for various types of structures specially foot bridges. What are the new emerging Seismic resistive techniques for the construction of foot bridges and the anti corrosive techniques to make the structures safe from corrosion.

D.Taylor et al [1]

This paper contains the design of a structure or mechanism subjected to shock and vibration can be greatly improved by the addition of isolation or damping devices. Improvement includes: reduced deflection & stresses, reduced weight, Improved Biodynamics, longer fatigue life, Architectural Enhancement and Reduced cost.

M. Constantinou, P. Tsopelas et al [2]

This paper reports on Non-linear analysis of a bridge supported on a sliding bearing with elastomeric restoring springs and viscous dampers. Results were verified with shake table test.

Commentary on Corrosion at Bimetallic Contacts and its Alleviation- BSI Standards [3]

This document shows designers how to avoid corrosion due to the interaction of different metals and alloys at bimetallic contacts. Section one describes the condition that leads to corrosion at bimetallic contacts and methods to alleviate it. The table in section two shows the degree of corrosion likely to occur at bimetallic contacts exposed to atmosphere and water.

D. Taylor et al [4]

This is a one page description of Taylor Devices viscous damping system of earthquake protection.

N.Makris, D.Hill, D.Taylor et al [5]

This paper describes an NSF funded project to investigate viscous dampers with controlled variable damping constant, using electrorheological fluid. Experimental results correlate well with analytical predictions

M. Constantinou, M.Symans, P.Tsopelas, D. Taylor et al [6]

Experimental study of both a moment frame building and a single span bridge, both with and without viscous dampers, are described here. Addition of viscous dampers significantly reduced both drift and shear forces.

Golden Gates Bridge Seismic Retrofit Design Specs [7]

This specification, prepared jointly by TY Lin and Imbsen Associates, describes the requirements for the viscous dampers to be used in the retrofit of the Golden Gates Bridge. The Specification includes wind excitation as well as seismic, and also describes testing requirements

M.Constantinou [8]

This paper by Dr. Michael Constantinou describes the seismic protection of a steel multi girder highway bridge. Three types of base isolators are included ; high damping rubber, lead rubber and friction Pendulum. The effect of added viscous damping is also investigated, and is found to greatly enhance the performance of the isolators, even though the dampers required are rather small.

- RESEARCH METHODOLOGY

The research methodology consist of the following points

- TO DETERMINE RESOURCE AND CONSUMPTION

As due to rapid development of construction industry, first of all findings for various types of resources and their consumptions present impact of the resource will be analyzed.

As the seminar is dealing with the analysis and Design of Foot bridge.

Steel plays a very important role in the construction of Foot Bridges as Steel has good tensile as well as compressive properties. So, for that i am selecting steel as a construction material for analysis and design of Foot Bridge.

As steel is being used for the construction of Foot Bridge we have to know their properties whether it is liable for the construction or not. If so, why?

3.2 Advantages of Steel over Concrete Bridges:

The following are some of the advantages of steel bridges that have contributed to their popularity in many developed countries:

- They could carry heavier loads over longer spans with minimum dead weight, leading to smaller foundations.
- Steel has the advantage where speed of construction is vital, as many elements can be prefabricated and erected at site.

- In urban environment with traffic congestion and limited working space, steel

Bridges can be constructed with minimum disruption to the community.

- Greater efficiency than concrete structures is invariably achieved in resisting

Seismic forces and blast loading.

- The life of steel bridges is longer than that of concrete bridges.

- Due to shallow construction depth, steel bridges offer slender appearance,

which make them aesthetically attractive.

All this frequently leads to low life cycle costs in steel bridges

There are various types of steels available in market but out of them some steels have the good quality they are as follows:

- Materials Used:

Conventional Steel used in bridges:

Steel used for bridges may be grouped into the following three categories:

(i) Carbon steel:

This is the cheapest steel available for structural users

Where stiffness is more important than the strength. Indian steels have Yield stress values up to 250 N/mm^2 and can be easily welded. The steel conforming to IS: 2062 - 1969, the American ASTM A36, the British grades 40 and Euronorm 25 grades 235 and 275 steels belong to this category.

(ii) High strength steels:

They derive their higher strength and other required properties from the addition of alloying elements. The steel conforming to IS: 961 - 1975, British grade 50, American ASTM A572 and Euro norm 155 grade 360 steels belong to this category. Another variety of steel in this category is produced with enhanced resistance to atmospheric corrosion. These are called 'weathering' steels in

Europe, in America they conform to ASTM A588 and have various

Trade names like ' cor-ten'.

(iii) Heat-treated carbon steels:

These are steels with the highest Strength. They derive their enhanced strength from some form of heat-Treatment after rolling namely normalization or quenching and Tempering.

The physical properties of structural steel such as strength, ductility, brittle fracture, weld ability, weather resistance etc., are important factors for its use in bridge construction.

- **Advanced Hollow Steel sections Used for the construction of Steel Foot Bridges:**

Tata Structural Steel Hollow sections command several techno-economic advantages over conventional steel sections. Manufactured from world class Hot Rolled Coils of Tata Steel, it is noted for better compressive strength and enhanced shear capacity among several other advantages. Structures made of Tata Structural Hollow Sections are lightweight and therefore more resistant to seismic forces. Thus it ensures high durability for the structures it supports and is preferred by architects & structural engineers.

Different Product Categories

•Rectangular Hollow Sections

•Square Hollow Sections

•Circular Hollow Sections

•Galvanized Hollow Sections

Brand Benefits

•Conforming to IS:4923 and IS:1161 standards

•Better compressive strength due to lower slenderness ratio and higher yield strength

•Full strength under bending moment, regardless of lateral restraints due to superior torsional rigidity

•Lower drag coefficients of closed structurals help to bypass the fluid currents more effectively than conventional sections

•Enhanced shear capacity due to more effective area under shear

•Due to YST 310 grade, sections can take more tensile loads as compared to ordinary lower grade structural and hollow sections

•The concentric connections of symmetrical hollow sections are extremely efficient in resisting secondary moments

•Because of light weight, the seismic forces on the structure will be less, thereby reducing the weight of the structure

•Manufactured from world class Hot Rolled Coils of Tata Steel

- Design Concept

Earthquakes cause the ground to shake violently thereby triggering landslides, creating floods, causing the ground to heave and crack and causing large-scale destruction to life and property. The study of why and where earthquakes occur comes under Geology. The study of the characteristics of the earthquake ground motion and its effects on engineered structures are the subjects of earthquake engineering. In particular, the effect of earthquakes on structures and the design of structures to withstand earthquakes with no or minimum damage is the subject of earthquake resistant structural design.

To resist this seismic ways there are some provisions made in Indian Standard Code of Practices for Bridges. By using those methods of analysis and Designing we can minimize the effect of seismic ways over Foot Bridges. They are

- Design Philosophy And Methodology

Severe earthquakes have an extremely low probability of occurrence during the life of a structure. If a structure has to resist such earthquakes without any failure, it would require an expensive lateral load resisting system, which is unwarranted. On the other hand, if the structure loses its aesthetics or functionality quite often due to minor tremors and needs repairs, it will be a very unfavorable design. Therefore, a dual strategy, akin to the limit state design, is adopted. The usual strategy is:

'To ensure elastic behavior under a moderate earthquake which has a return period equal to the life of the structure and prevent collapse under the extreme probable earthquake'.

For example, if the expected life of the structure is fifty years, then it is designed to remain elastic under an earthquake, which is likely to occur at least once in fifty years. Thus, no major repair will be necessary as a consequence of such earthquakes during the life of the structure. However, structures are designed to prevent collapse and loss of life under the most severe earthquake. The reason for adopting such a strategy is that it is extremely expensive to design structures to respond elastically under severe earthquakes, which may not occur during their expected life.

- VERIFICATION PROBLEM AND CASE CONSIDERATION

Problem:

Design a Foot bridge with the following given data:

Span = 20m

Width of walkway = 3.5m

N-type lattice Girder with 8 panels laterally supported by rackers.

120mm thick R.C.C slab & Floor finish = 0.8 kN/m²

Live Load = 4.5 kN/m²

The Following are the Design Steps:

1. Given Data:

Span of Bridge =

Width of walkway =

N-type Lattice Girder =

Thickness of RCC Slab =

Loadings:-

2. Geometry of Lattice Girder:

a) Assuming depth of girder = Span/No of panels

{Span/5 ≤ Span/8}

b) Length of panel = Span/no of panels

c) Length of Vertical member.

d) Length of Diagonal member = √(Length of Vertical member)^2 +(Length of panel)^2

Design of Cross Beam:

a) Dead load = (Thickness × Density)

b) Floor finish = (given)

c) Live load = (given)

d) Total load =

e) Load per unit Length = Total load × Length of panel.

Assume self weight of cross beam 0.5 kN/m^2

Total load = Load per unit Length + 0.5.

Factored load = 1.5 × Total load.

f) Maximum Bending moment = Wl^2/8

g) Factored Bending Moment = 1.5 × Maximum Bending moment.

h) Max Shear force = Wl/2

i) Factored Shear force = 1.5 × Max Shear force.

Considering compression flange of beam fully laterally restrained

Plastic section modulus required:-

Zp(req) = M × ϒmo/fy.

Shape factor = Zp (req)/ Ze

Now by using Steel Table:

Select the ISLB Section Whatever the answers comes

Therefore,

Zp (provided) = Ze × 1.14

3. Section Classification according to IS 800-2007

$\epsilon = (250/fy)^{1/2} = 1$

a) Flange Criteria = b/2tf

b) Web criteria = α/tw

If it satisfies then the section is Plastic.

4. Plastic section:-Bb = 1

Check for moment Resistant Capacity

Md = Bb × Zp(provided) × fy/ ϒmo

5. Design of N-Type Lattice girder:-

a) Dead load intensity = D.L due to selfweight × width of walkway/2

b) Self weight of truss in meters = Dead load intensity/10

c) Total D.L = Dead load intensity + Self weight of truss in meters.

d) Factored D.L= Total D.L × 1.5

e) Live load =L.L × width of walkway/2

f) Factored L.L = 1.5 × L.L × width of walkway/2

g) Total factored load = D.L +L.L

h) Load on each node = Total factored load/no. of panels

6. Forces in Chord Members:

In This step ILD Diagrams should be drawn and the answers should be entered in the tables:

Top Chord	Bottom Chord	ILD (Area in m²)	Load in kN	Moment in kN/m (Area × load)	Force = Moment/Depth of panel
(1)	(2)	(3)	(4)	(5)	(6)
				(3)×(4)	(5)/Depth of panel

8. Forces in Vertical member:-

Member	Area		Net Area (N.A)	D.L (N.A ×10.98)	Total force (L.L(N.A ×11.8))			
	+ Ve	-Ve			+ve	-ve	Max	Min
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			(4)=(2)-(3)				(8)=(5)+(6)	(9)=(5)-(7)

9. Forces in Diagonal member:-

Member	Maximum	Minimum
(1)	(2)	(3)
	√2 × (8)	√2 × (9)

10. Design Forces calcuations as discussed earlier :-

11. Design of Chord Member.

Max Force =

Assume the design stress = 90 Mpa

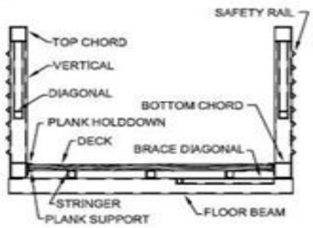
Provide the necessary sections of angles (Single or Double angle section)

12. Now From Steel table Choose ISA For the final Calculations.

13. Seismic Design Calculations were done by using IS Codes specifications.

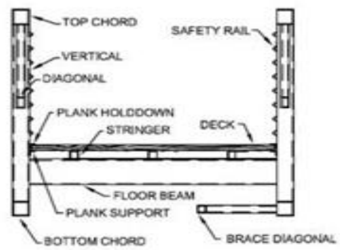
14. Sample Design Detailing:-

Figure 1A



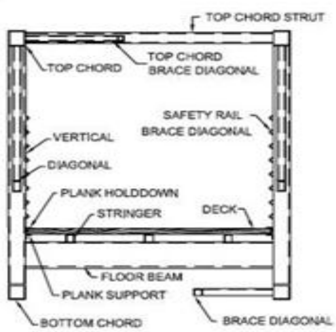
HALF THROUGH UNDERHUNG TRUSS
WITH UNDERHUNG FLOOR BEAM

Figure 1B



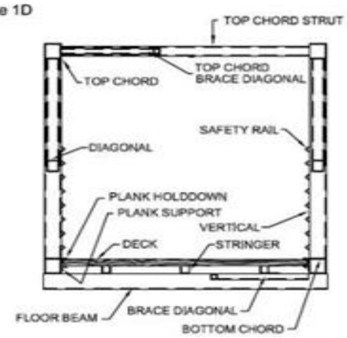
HALF THROUGH H-SECTION TRUSS
WITH RAISED FLOOR BEAM

Figure 1C



FULL THROUGH "BOX" TRUSS
WITH RAISED FLOOR BEAM

Figure 1D



FULL THROUGH "BOX" TRUSS
WITH UNDERHUNG FLOOR BEAM

Design forces:

Top Chord = 455.600 kN

Bottom Chord = - 455.600 kN

Vertical Member = -5.265 kN

199.325 kN

Diagonal Member = 281.888 kN

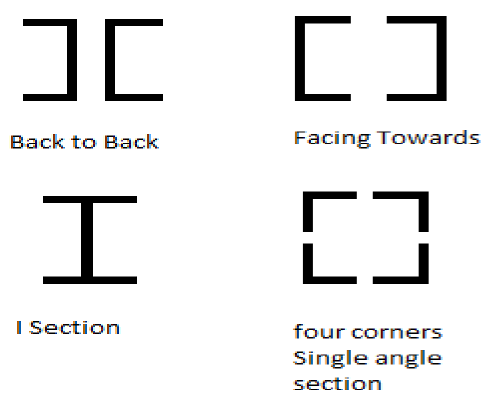
- 7.444 kN

- Seismic Analysis and Design Verification

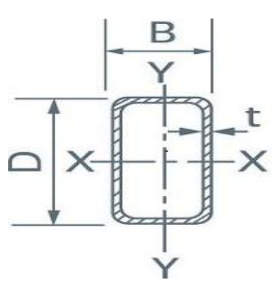
Structures are usually designed for earthquake loading. In conformity with the design philosophy, this check consists of two steps the first ensures elastic response under moderate earthquakes and the second ensures that collapse is precluded under a severe earthquake. Due to the uncertainties associated in predicting the inelastic response, the second check may be dispensed with, by providing adequate ductility and energy dissipation capacity. In this section, the various methods of performing these checks are described. The important factors, which influence earthquake resistant design are, the geographical location of the structure, the site soil and foundation condition, the importance of the structure, the dynamic characteristics of the structure such as the natural periods and the properties of the structure such as strength, stiffness, ductility, and energy dissipation capacity. These factors are considered directly or indirectly in all the methods of analysis.

Similarly every member will be checked for most feasible section. that is most economic and safe

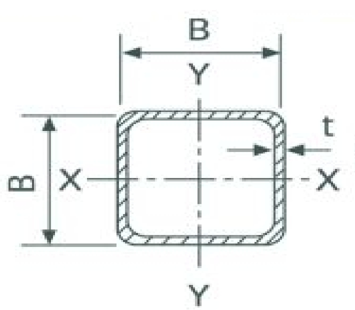
Similarly, various sections such as tubes, hollow rectangular sections, hollow circular section, channel section (facing towards, back to back arrangement and four corners single angle Section).



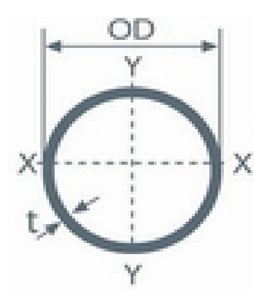
Tata Tisscon Hollow Steel sections



Rectangular Section



Square Section



Circular section

CONCLUSION

On the basis of the work highlighted in this report. It can be conclude that the Foot Bridges should be constructed by considering the Seismic Forces and the various cost effective techniques for safeguarding human life against natural disasters. The Tata Tisscon's Hollow Steel sections used in the study above as an alternative for conventional steel prove to be stronger and strength effective as compared to Conventional steel & more tough and replacing material over conventional steel for the construction of foot Bridges. Also the concept of Modular bridges can be adopted for the construction of Foot Bridges efficiently and effectively so as to save time, money and efforts.

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