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RESOURCE OPTIMIZATION STRATEGY FOR SEISMIC RESISTIVE FOOTBRIDGE

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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: Footbridge, Resource Optimization, Strategy

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INTRODUCTION

General:

Footbridges are smaller lighter structures. They are narrow (about 2m wide) and are usually single span structures that rarely span more than 60m. 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 behaviour 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 behaviour 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 so that the safe and easy passage should be provided for the pedestrians to cross the road without obstructing the traffic.

Earthquake scenario in India:

Earthquakes are natural phenomena, which cause the ground to shake. The earth's interior is hot and in a molten state. As the lava comes to the surface, it cools and new land is formed. The lands so formed have to continuously keep drifting to allow new material to surface. According

to the theory of plate tectonics, the entire surface of the earth can be considered to be like several plates, constantly on the move. These plates brush against each other or collide at their boundaries giving rise to earthquakes. Therefore regions close to the plate boundary are highly seismic and regions farther from the boundaries exhibit less seismicity. Earthquakes may also be caused by other actions such as underground explosions. The Indian sub-continent, which forms part of the Indo-Australian plate, is pushing against the Eurasian plate along the Himalayan belt. Therefore, the Himalayan belt is highly seismic whereas peninsular India, which is not traversed by any plate boundary, is relatively less seismic.

Scope of Work:

The study over here is done for finding most efficient design of foot bridge subjected to seismic forces in zone IV & V of Indian Geographical territory as per IS 1893-2002.

LITERATURE REVIEW:

Avery Louise Bang et.al [1] In this paper it is estimated that about 900 million rural people in developing countries do not have reliable year-round access to road networks, and 300 million are without motorized access (Lebo, 2001). Aid dollars being invested into infrastructure improvements for paved highways and major vehicular bridges are only serving those with a standard of living appropriating vehicle use. **Azita Azarnejad, Ch2m Hill Ken Mcwhinnie et al [2]** Although cable-stayed bridges are usually only considered when long spans are required, there have been several cases where they have been used to span smaller distances. This topic has been discussed by Walter in Cable-Stayed Bridges in a chapter about small and medium spans. **Kei Fung Sameul et al [3]** In this paper , author have done the analysis of the San Francisco Golden Gate bridge in terms of the considerations of construction method, structure, aesthetics, loadings, serviceability, strength, the effect of earthquake, wind ,temperature, creep and durability, intentional damage, possible future changes and construction improvement. Adequate amount of calculations are involved in order to feasibility of the bridge. **Mark R.Capron et al [4]** This paper summarizes the seismic evaluation, retrofit strategy, design, and construction of the seismic retrofit for the Poplar Street Bridge over the Mississippi River at St. Louis. The 660 meter (2,165 foot) structure consists of two parallel five span continuous roadways with orthotropic steel deck and steel box girders. The seismic evaluation considered three levels of design earthquakes and identified deficiencies in the bearings, reinforcement splices in the columns and piers, and one foundation. The retrofit included adding longitudinal shock transmission units, transverse shear blocks, column splice confinement, shear walls, and rock anchors.

DESIGN PHILOSOPHY AND METHODOLOGY

With the previous studies referred related to seismic designing , it is well clear that the seismic resistive behaviour of structure can be enhance if its ductility is increased. Thus, the philosophy adopted for designing over here is to use high ductile material like steel for bridge designing. However, to archive the economy with safety the further method adopted is of applying various steel members and checking its strength behaviour and economy achievement with application. The various types of members used for designing bridge subjected to same loading and locations are as mentioned below:-

- **RECTANGULAR HOLLOW SECTION**

Profile:

Attributes

They have increased tensile capacity because of concentric connections and increased compressive strength because of higher radius of gyration.

They possess full strength under bending moment due to superior torsional rigidity.

Outer smooth profile ensures no trappings of dirt and water, thus reducing chances of corrosion reaction.

HOLLOW CIRCULAR SECTION

- Attributes:

These hollow sections are of high strength.

- They are manufactured with minimum yield strength of 310 Mpa.
- They have a consistent profile.
- They comply with dimensional tolerances as specified by IS: 1161, excluding mass.

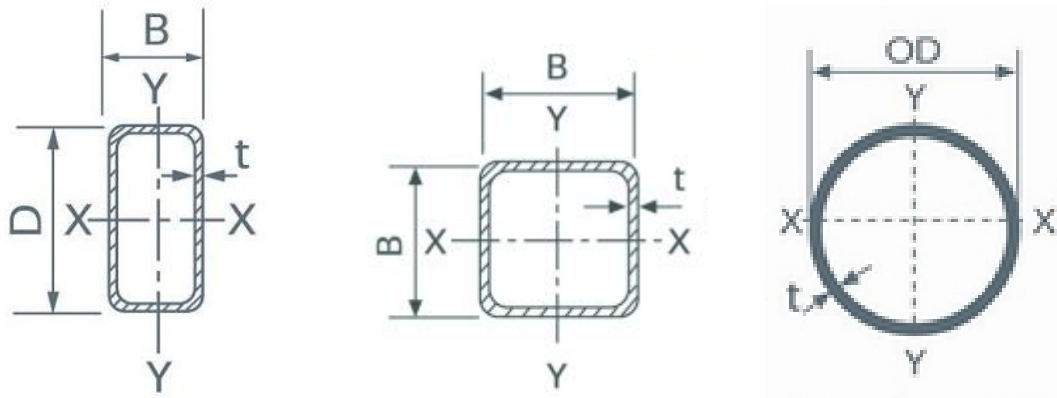
GALVANIZED HOLLOW SECTION

- Attributes:

- These hollow sections are of high strength.
- They are manufactured with minimum yield strength of 310 Mpa.

- They have a consistent profile.
- They comply with dimensional tolerances as specified by IS: 1161, excluding mass.

Hollow Sections Diagrams (IS 4923-1997)



Rectangular Hollow section Square Hollow Section Circular Hollow Section

Fig No: 1

COMPUTATIONAL ANALYSIS AND DESIGNING

For the design, five cases were consider for the Analysis and design of Foot Bridge

- Case 1: Design of Foot Bridge subjected to Gravity loads only
- Case 2: Seismic Load Design with conventional sections
- Case 3: Seismic Load Design using Square tube hollow steel section
- Case 4: Seismic Load Design using circular pipe hollow steel section
- Case 5: Seismic Load Design using rectangular tube hollow steel section

The above specified cases are computationally analysed & designed using STAAD.Pro software and observations are tabulated so as to comment on it and check for the most economical and feasible section for the construction of Foot Bridges

The following is the information which was consider for the analysis and designing purpose

Case 1: Design of Foot Bridge subjected to Gravity loads only

Type of structure is Steel Truss in which various load combinations are used, steel sections used for the analysis purpose are ISMB 400 & ISA150X150X10. Materials used are Steel, Stainless steel, Aluminium, Concrete

The STAAD Generated Load case details are

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset Table No.1

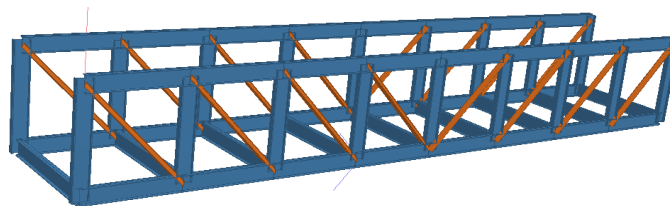
	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	1	2	9:COMBINATION LOAD CASE 9	4.425	-0.730	0.000	4.484
Min X	24	18	9:COMBINATION LOAD CASE 9	-4.425	-0.730	0.000	4.484
Max Y	1	1	3:DL ON CROSS BEAM	0.000	0.000	0.000	0.000
Min Y	12	10	9:COMBINATION LOAD CASE 9	0.000	-27.311	0.000	27.311
Max Z	1	1	3:DL ON CROSS BEAM	0.000	0.000	0.000	0.000
Min Z	1	1	3:DL ON CROSS BEAM	0.000	0.000	0.000	0.000
Max Rst	12	10	9:COMBINATION LOAD CASE 9	0.000	-27.311	0.000	27.311

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A. Table No. 2

	Beam	L/C	d (m)	Axial		Shear	Bending	
				Fx (kN)	Fy (kN)	Fz (kN)	My (kNm)	Mz (kNm)
Max Fx	12	9:COMBINATION LOAD CASE 9	0.000	911.400	28.481	0.000	0.000	0.000
Min Fx	33	9:COMBINATION LOAD CASE 9	0.000	-	0.000	0.000	0.000	0.000
Max Fy	34	5:COMBINATION LOAD CASE 5	0.000	0.000	55.781	0.000	0.000	0.000
Min Fy	34	5:COMBINATION LOAD CASE 5	3.500	-0.000	-55.781	-0.000	-0.000	-0.000
Max Fz	1	3:DL ON CROSS BEAM	0.000	58.188	0.000	0.000	0.000	0.000
Min Fz	1	3:DL ON CROSS	0.000	58.188	0.000	0.000	0.000	0.000

		BEAM								
Max Mx	1	3:DL	ON	CROSS	0.000	58.188	0.000	0.000	0.000	0.000
Min Mx	1	3:DL	ON	CROSS	0.000	58.188	0.000	0.000	0.000	0.000
Max My	1	3:DL	ON	CROSS	0.000	58.188	0.000	0.000	0.000	0.000
Min My	1	3:DL	ON	CROSS	0.000	58.188	0.000	0.000	0.000	0.000
Max Mz	1	3:DL	ON	CROSS	0.000	58.188	0.000	0.000	0.000	0.000
Min Mz	1	3:DL	ON	CROSS	0.000	58.188	0.000	0.000	0.000	0.000



3D Rendered View

Fig.no 2 Design of foot Bridge subjected to Gravity loads only

Case 2: Seismic Load Design with conventional sections

Type of structure is Steel Truss in which 21 load combinations are used and seismic analysis is done, sections used are ISMB 500 ISA 150X150X15, Materials used are Steel, Stainless steel, Aluminium, Concrete

The STAAD Generated Load case details are

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset Table No. 3

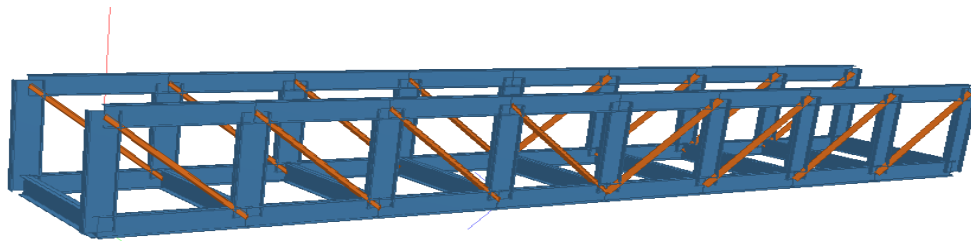
	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	1	2	9:COMBINATION LOAD CASE 9	3.138	-0.518	0.000	3.180
Min X	24	18	9:COMBINATION	-3.138	-0.518	0.000	3.180

LOAD CASE 9							
Max Y	17	13	1:EQX	0.059	0.025	0.000	0.064
Min Y	12	10	9:COMBINATION	0.000	-19.036	0.000	19.036
LOAD CASE 9							
Max Z	1	1	1:EQX	0.000	0.000	0.000	0.000
Min Z	1	1	1:EQX	0.000	0.000	0.000	0.000
Max Rst	12	10	9:COMBINATION	0.000	-19.036	0.000	19.036
LOAD CASE 9							

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A. Table No.4

	Beam	L/C	d (m)	Axial Fx (kN)	Shear Fy (kN)	Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Mz (kNm)
Max Fx	12	9:COMBINATION	0.000	911.400	28.481	0.000	0.000	0.000	0.000
Min Fx	33	9:COMBINATION	0.000	-	0.000	0.000	0.000	0.000	0.000
Max Fy	34	5:COMBINATION	0.000	0.000	55.781	0.000	0.000	0.000	0.000
Min Fy	34	5:COMBINATION	3.500	-0.000	-	-	-0.000	-0.000	-
Max Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max Mx	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Mx	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max My	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min My	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max Mz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Mz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000



3D Rendered View

Fig. No. 3 Gravity Load design subjected to Seismic Loads

Case 3: Seismic Load Design using Square tube hollow steel section

Type of structure is Steel Truss in which 21 load combinations are used and seismic analysis is done, sections used is square tube hollow steel section, Materials used are Steel, Stainless steel, Aluminium, Concrete

The STAAD Generated Load case details are

Beam End Displacement Summary

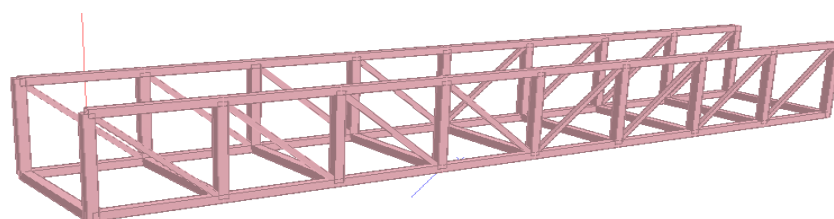
Displacements shown in italic indicate the presence of an offset Table No.5

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	1	2	9:COMBINATION LOAD CASE 9	6.767	-1.049	0.000	6.848
Min X	24	18	9:COMBINATION LOAD CASE 9	-6.758	-1.084	0.000	6.844
Max Y	17	13	1:EQX	0.127	0.054	0.000	0.138
Min Y	12	10	9:COMBINATION LOAD CASE 9	0.005	-37.519	0.000	37.519
Max Z	1	1	1:EQX	<i>0.000</i>	<i>0.000</i>	0.000	0.000
Min Z	1	1	1:EQX	<i>0.000</i>	<i>0.000</i>	0.000	0.000
Max Rst	12	10	9:COMBINATION LOAD CASE 9	0.005	-37.519	0.000	37.519

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A. Table No.6

	Beam	L/C	d (m)	Axial Fx (kN)	Shear Fy (kN)	Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Mz (kNm)
Max Fx	12	9:COMBINATION LOAD CASE 9	0.000	911.400	28.481	0.000	0.000	0.000	0.000
Min Fx	33	9:COMBINATION LOAD CASE 9	0.000	- 563.900	0.000	0.000	0.000	0.000	0.000
Max Fy	34	5:COMBINATION LOAD CASE 5	0.000	0.000	55.781	0.000	0.000	0.000	0.000
Min Fy	34	5:COMBINATION LOAD CASE 5	3.500	-0.000	- 55.781	0.000	-0.000	0.000	0.000
Max Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max Mx	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Mx	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max My	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min My	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max Mz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Mz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000



3D Rendered View

Fig No.4 Design of Square tube hollow steel section subjected to Seismic Loads

Case 4: Seismic Load Design using circular pipe hollow steel section

Type of structure is Steel Truss in which 21 load combinations are used and seismic analysis is done, sections used is Circular pipe hollow steel section, Materials used are Steel, Stainless steel, Aluminium, Concrete

The STAAD Generated Load case details are

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset Table No.7

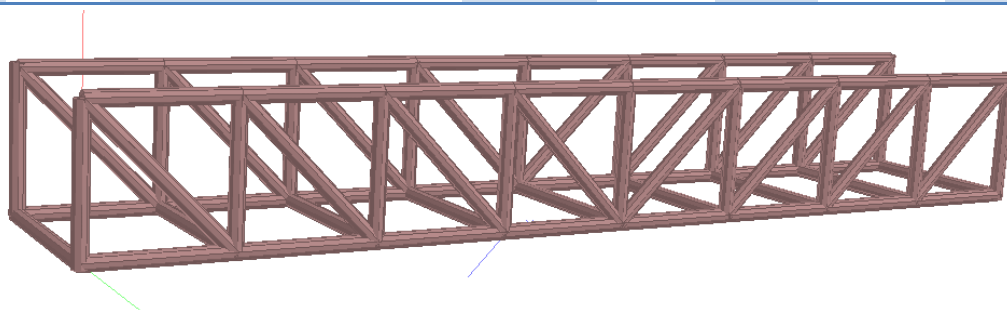
	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	1	2	9:COMBINATION LOAD CASE 9	6.906	-1.071	0.000	6.988
Min X	24	18	9:COMBINATION LOAD CASE 9	-6.897	-1.106	0.000	6.985
Max Y	17	13	1:EQX	0.130	0.055	0.000	0.141
Min Y	12	10	9:COMBINATION LOAD CASE 9	0.005	-38.011	0.000	38.011
Max Z	1	1	1:EQX	<i>0.000</i>	<i>0.000</i>	0.000	0.000
Min Z	1	1	1:EQX	<i>0.000</i>	<i>0.000</i>	0.000	0.000
Max Rst	12	10	9:COMBINATION LOAD CASE 9	0.005	-38.011	0.000	38.011

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A. Table No.8

	Beam	L/C	d (m)	Axial Fx (kN)	Shear Fy (kN)	Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Mz (kNm)
Max Fx	12	9:COMBINATION LOAD CASE 9	0.000	911.400	28.481	0.000	0.000	0.000	0.000
Min Fx	33	9:COMBINATION LOAD CASE 9	0.000	- 563.900	0.000	0.000	0.000	0.000	0.000
Max Fy	34	5:COMBINATION LOAD CASE 5	0.000	0.000	55.781	0.000	0.000	0.000	0.000

Min Fy	34	5:COMBINATION LOAD CASE 5	3.500	-0.000	-	-	-0.000	-	-
Max Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Mx	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max Mx	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min My	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max My	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Mz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000



3D Rendered View

Fig No.5 Design of Circular pipe hollow steel section subjected to Seismic loads

Case 5: Seismic Load Design using rectangular tube hollow steel section

Type of structure is Steel Truss in which 21 load combinations are used and seismic analysis is done, sections used is Rectangular tube hollow steel section, Materials used are Steel, Stainless steel, Aluminium, Concrete

The STAAD Generated Load case details are

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset Table No.9

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	1	2	9:COMBINATION LOAD CASE 9	5.968	-0.925	0.000	6.039
Min X	24	18	9:COMBINATION LOAD CASE 9	-5.959	-0.956	0.000	6.036
Max Y	17	13	1:EQX	0.113	0.048	0.000	0.123
Min Y	12	10	9:COMBINATION LOAD CASE 9	0.004	-34.549	0.000	34.549
Max Z	1	1	1:EQX	<i>0.000</i>	<i>0.000</i>	0.000	0.000
Min Z	1	1	1:EQX	<i>0.000</i>	<i>0.000</i>	0.000	0.000
Max Rst	12	10	9:COMBINATION LOAD CASE 9	0.004	-34.549	0.000	34.549

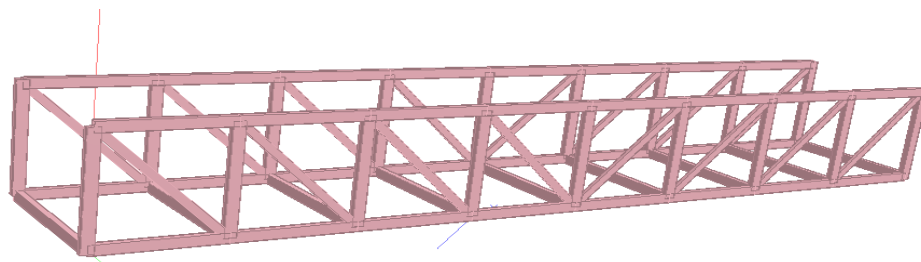
Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A. Table No.10

	Beam	L/C	d (m)	Axial Fx (kN)	Shear Fy (kN)	Fz (kN)	Torsion Mx (kNm)	Bending My (kNm)	Mz (kNm)
Max Fx	12	9:COMBINATION LOAD CASE 9	0.000	911.400	28.481	0.000	0.000	0.000	0.000
Min Fx	33	9:COMBINATION LOAD CASE 9	0.000	- 563.900	0.000	0.000	0.000	0.000	0.000
Max Fy	34	5:COMBINATION LOAD CASE 5	0.000	0.000	55.781	0.000	0.000	0.000	0.000
Min Fy	34	5:COMBINATION LOAD CASE 5	3.500	-0.000	- 55.781	0.000	-0.000	0.000	0.000
Max Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Fz	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max Mx	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Min Mx	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Max	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000

My									
Min	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
My									
Max	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Mz									
Min	1	1:EQX	0.000	-7.690	0.000	0.000	0.000	0.000	0.000
Mz									

a)



3D Rendered View

Fig No.6 Design of Rectangular tube hollow steel section subjected to Seismic loads

Concluding Remark:

From the above analysis and 3D design the following results were found

Table Comparative result of the cases in terms of cost and percentage savings Table No.11

Cases	Sections (in mm)	Total Length (m)	Total Weight (Kg)	Cost Rs/kg	Fabrication Cost (Rs)	Total Amount (Rs/Kg)	Total Expenses (Rs)	% Savings with reference to design	% Savings with seismic	% Savings with reference to design	% Savings with Gravity
Case 1	ISMB400	214.07	10971.43	32.9	10	42.9	470674.34	29.45		0	
Case 2	ISMB500	214.07	15553.42	32.9	10	42.9	667241.71	0		0	
Case 3	TUBE 132x132x5	214.07	7442.7	31.69	12	43.69	347508.53	47.86		26.16	
Case 4	OD=273 ID=267	214.07	7317.89	32.54	15	47.54	347892.49	47.86		26.08	
Case 5	TUBE 220x140x8	214.07	8288.86	31.69	12	43.69	362140.29	45.72		23.05	

Case 1: Design of Foot Bridge subjected to Gravity loads only
Case 2: Seismic Load Design with conventional sections
Case 3: Seismic Load Design using Square tube hollow steel section
Case 4: Seismic Load Design using circular pipe hollow steel section
Case 5: Seismic Load Design using rectangular tube hollow steel section

CONCLUSION:

While carrying out designing considering various members and sections for the same foot bridge subjected to seismic forces , it has been marked that with change in material and maintaining same required strength , bridge can be turned as light weight and economical upto saving in range from 23 to 27 %. As in Table no.11 above it is very clear that the bridge designed with Hollow sections is more economical and light weight as compared to conventional steel sections. Similarly, the bridge designed seems to be most economical when material adopted is Hollow steel section and thus for same set of forces and locality, there is high scope of achieving safe and economical foot bridge design.

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