Design and Analysis of Foot Over Bridge Using STADD Pro

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Abstract: ***Foot over bridges are essential for providing a safe passage across highways and obstacles. Lightweight yet sturdy structures are required due to lower transportation loads and the necessity for long clear spans. Steel designs prove economically advantageous and aesthetically pleasing, ensuring quick and extensive installation. However, seismic vulnerability remains a concern for many bridges. This project aims to address this issue by designing earthquake-resistant foot overbridges. The focus is on employing STAAD Pro for truss construction, emphasizing the role of a skilled structural engineer in the competitive market. The design process involves manual load calculations and STAAD Pro analysis, considering various loads such as dead, live, and wind pressures. Adhering to IS 875 specifications, the project employs a trial-and-error approach to optimize steel components, ensuring compliance with safety standards for structural integrity in construction.***

Keywords: foot over bridge, STAAD PRO Analysis Steel Tusses

1. Introduction

The meticulous design and analysis of a steel truss bridge are integral steps preceding its construction, particularly when tasked with connecting two distinct zones separated by an obstruction, be it a road, railway, or any physical hindrance. In past centuries, bridge designs relied on manual calculations; however, the advent of sophisticated software has revolutionized the designing and analyzing processes. For spans between 10 and 25 meters, a steel truss footbridge emerges as the optimal choice, especially in scenarios where constructing temporary backings for pillar-style footbridges is impractical, such as when building wharfs. Additionally, consideration for docks is essential for spans exceeding 10 meters where feasible. Key factors include the availability of necessary steel sections at major asset hubs, ensuring greater consistency in fit and size compared to timber segments, thus facilitating the production of standard truss layouts. Furthermore, the ease of joint creation in steel trusses compared to timber ones is a noteworthy advantage. The construction process involves creating a conventional outline in a medium-sized workshop and then transporting it to the site in carefully calculated pieces. Assembling the components and installing a wood deck can be executed on-site, guided by knowledgeable experts and skilled artisans. The scaffold transportation can be segmented into three levels:

Individuals are transported together after being predrilled at a workshop. Each piece travels 24 kilometers, starting from a rocky terrain and ending at the footbridge location, necessitating meticulous on-site assembly and accurate probing of workshop apertures.

ii. In the workshop, boards are crafted from cut and welded steel parts, then pierced for assembly into catapults. Delivered to the site, these boards are assembled using darts, significantly reducing the need for pre-penetrating and on-site group work. Boards can weigh up to 100 kg.

iii. Workshops assemble boards into modules, delivered to the site for simultaneous recording. This method requires minimal on-site labor, but due to the substantial weight (300 to 400 kg), it is only practical if trucks have direct access to the footbridge site.

Risk-based roadway planning incorporates quantitative and qualitative accident analysis evidence, considering future traffic buildup, predicting traffic levels, and suggesting suitable junctions. Physical traffic control involves the construction and management of lights at crossroads, adapting to traffic volume and optimal timing. Signal control at junctions, determining the Green Period, considers traffic volume every fifteen minutes, employing various signal design strategies. The weight-age analysis technique, utilizing the accident cost ratio, is instrumental in establishing road safety and is known as road safety Management. scope of construct pedestrian overpasses in urban areas to alleviate traffic congestion, reduce accidents, and facilitate secure pedestrian crossing in busy locations. Objectives include simulating steel truss bridge design using STAAD Pro, creating an accessible, affordable, safe, and easy-to-install steel truss bridge for pedestrian use, and generating plans, elevations, and sections using AutoCAD. the advantages of the Foot Over Bridge, it emerges as the most affordable, easy to install and maintain, safer than other bridges, and boasts a flexible design and structural concept. In conclusion, the comprehensive approach to design, analysis, and implementation positions the Foot Over Bridge as a viable solution to urban infrastructure challenges, ensuring safety and accessibility for pedestrians.

2. Literature Review

Shubhank Gupta et al. analyzed and designed a 50-meter steel-truss railway bridge in 2017, dividing it into segments for cost-effectiveness. Staad Pro was used, following Indian Roads Congress and Indian Railway Standard Code.

J. Blanchard, B. L. Davies, and J. W. Smith proposed limiting footbridge deck shaking under pedestrian load, calculating maximum vertical acceleration using early human resistance investigations. Results confirm safety under static stacking conditions, excluding wind-related vibration.

Goyal, Pradeep K., and Kumar, Ramesh utilized Staad Pro in 2017 for a 350-meter steel arch bridge in Jaipur, complying with Indian standards and factoring in wind, seismic stress, live, and dead loads.

The Rochefort-Martrou Transporter Bridge, built by Ferdinand Arnodin in 1900, spans the Charente River, costing 586599 French francs. Standing 59 meters tall and 139.916 meters wide, it operated until 1967, designated a historic monument in 1976, renovated in 1996, and remains a tourist attraction.

3. Methodology

This project's goal is to outline a foot over scaffold, along with association and foundation areas of interest, and to dissect it. Below these basic requirements are taken into consideration.

Broad writing reviews that referenced books and specialist articles failed to understand the subject's central premise.

Choosing an appropriate foot over scaffold model.

Calculating loads and selecting preliminary cross-segments of various auxiliary people.

Geometrical demonstration and a fundamental analysis of the foot over scaffold for various stacking scenarios in accordance with IS Codal arrangements.

Results interpretation. For reaching the Aforementioned locations, the following exploration must be finished:

Using STADD, a foot over bridge is now displayed and examined as a three-dimensional construction.
Arrangement of Foot Over Bridge
A 43-meter-high footbridge is studied and planned. The tower's configuration is as follows:
Bridge span is 43 meters.
Bridge height is 7.5 meters.
Walkway width: 3 meters
Each truss has a 3 m separation.

4. Analysis of Bridges

Introduction to Bridges
A bridge is a building constructed to span a dip, gap, or obstruction like a river, channel, canyon, valley, road, or railway with vehicles, trains, or other moving goods. The type of bridge is chosen to satisfy the demand based on the objective and the obstruction. A bridge is referred to as a highway bridge if it was built to carry cars, and a railway bridge if it was used to carry trains.

Analysis and Design
Staad Pro is utilized during the analysis and design processes.

Staad Pro was used to make a model of the Foot over Bridge, and the distance between the nodes is shown by the lines linking them.

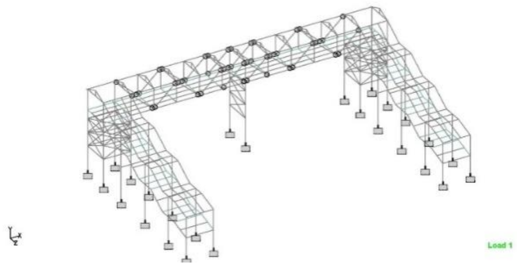


Figure 1.1: Structural Modal

STAAD Pro software was used to draw the structure model displayed in the previous illustration. In order to properly execute the nodes, the software's X, Y, and Z axes are used to create the nodes. Once the nodes have been coordinated, they are connected using the "Add Beam" option in the toolbar. By choosing this, you can join the nodes to form a beam or column element. This structure has beencreated using a series of nodes.

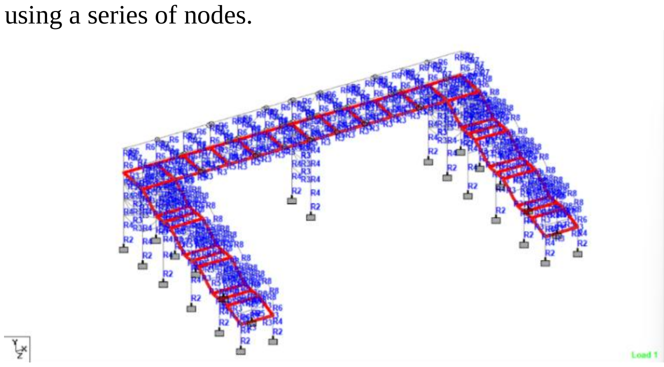


Figure 1.2: (Show Loading of Structure)

Table 1.1: (Type of Support)

Supports

Node	X (kip/in)	Y (kip/in)	Z (kip/in)	rX (kip ft/deg)	rY (kip ft/deg)	rZ (kip ft/deg)
37	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
38	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
39	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
40	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
41	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
42	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
43	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
44	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
45	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
46	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
47	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
48	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
50	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
51	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
52	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
53	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
55	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
56	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
57	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
58	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
60	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
61	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
62	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
65	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
66	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
83	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed

As diverse steel structural sections and other characteristics can be observed in the 3D rendering view in the Staad pro software. The Following Elements Make Up the Model

Total Number of Nodes	637
Total Number of Beams	1110
Total Number of Plates	868

In this case, steel plates with a 2 mm thickness are utilized as a floor to support the area loads and movement loads on the bridge, according to the specifications set to the construction by the staad pro software.

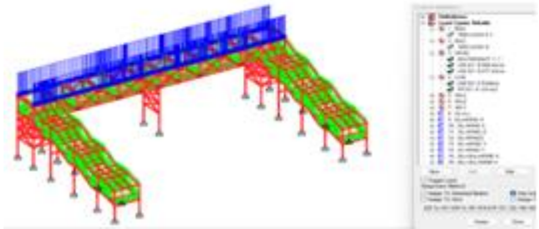


Figure 1.3: (All Loads)

The red lines in this illustration depict the steel beams and column bending moments that were determined through structural analysis. The process of building a structural model begins with the creation of the model, followed by the assignment of its properties, loading conditions, and analysis to be used in the post-processing and designing of the structure.

When the analysis is finished, the software provides an output file with the results, detailing each member's stress and strain reactions and whether it is safe to proceed with additional design work on that member. From there, the analysis moves on to the next stage. If the member fails, the output of such elements is not visible on the modeling view, but the given deflection and bending moments are shown in the output file. The given bending moment is given in millimeters in both the figure and the output report.

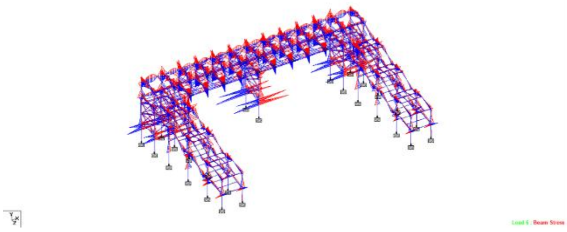


Figure 1.4: (Beam Stress Graph)

Figure depicts the stresses placed on each beam during the analysis of the structure; the figure's output depicts how each beam responded to the loads. The beams of the staircase are the most affected element in this diagram, where the red lines indicate negative stress and the blue lines indicate positive bending stress. The pattern formed according to the strains placed on the member; the greater the rise, the greater the stress placed on that member; hence, by being aware of this, additional analysis and design processes are initiated.

Every single member can be shown with its stresses clearly in the modeling view, allowing us to understand how the load is acting. on that specific member, we can either utilize this to improve or adjust the member's attributes and lessen the stresses that are imposed on the member, or we may use the staad pro program to shorten the clear span of the model.

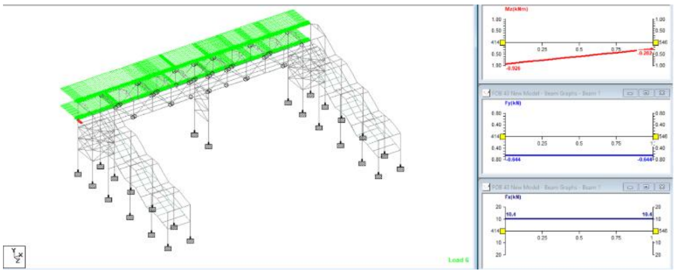


Figure 1.5: (Graph of B/M & S/F)

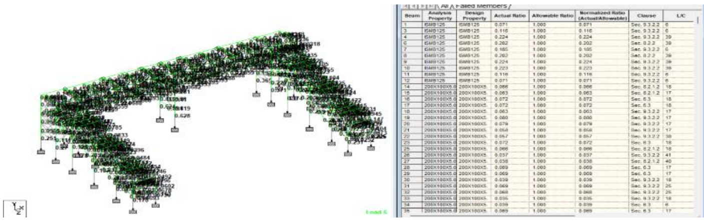


Figure 1.6: (Utility Check)

Table 1.3: (Loading Summary)

L/C		Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	Loads	20.368	0.000	0.000	0.000	167.451	60.413
	Reactions	-20.368	0.000	-0.000	0.000	-167.451	-60.413
	Difference	0.000	0.000	-0.000	0.000	0.000	-0.000
2	Loads	0.000	0.000	20.368	-60.413	-310.158	0.000
	Reactions	0.000	-0.000	-20.368	60.413	310.158	-0.000
	Difference	0.000	-0.000	0.000	0.000	-0.000	-0.000
3	Loads	0.000	-1310.662	-0.000	12615.106	0.000	-20578.080
	Reactions	-0.000	1310.662	0.000	-12615.106	-0.000	20578.080
	Difference	-0.000	0.000	-0.000	-0.000	0.000	0.000
4	Loads	0.000	-1860.821	0.000	14880.162	0.000	-29214.882
	Reactions	-0.000	1860.821	-0.000	-14880.162	0.000	29214.882
	Difference	-0.000	-0.000	-0.000	-0.000	0.000	0.000
5	Loads	147.840	0.000	0.000	0.000	1389.178	256.640
	Reactions	-147.840	0.000	-0.000	0.000	-1389.178	-256.640
	Difference	0.000	0.000	-0.000	0.000	0.000	-0.001
6	Loads	0.000	0.000	203.840	305.760	-3200.289	0.000
	Reactions	0.000	-0.000	-203.840	-305.760	3200.289	-0.000
	Difference	0.000	-0.000	0.000	-0.000	0.000	-0.000
7	Loads	0.000	0.000	0.000	0.000	0.000	0.000
	Reactions	0.000	0.000	0.000	0.000	0.000	0.000
	Difference	0.000	0.000	0.000	0.000	0.000	0.000

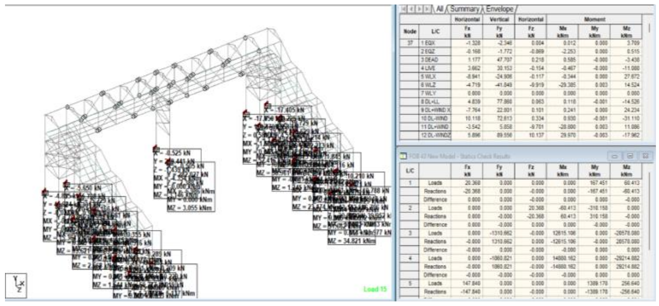


Figure 1.7: (Reaction on Support)

Design of Footing

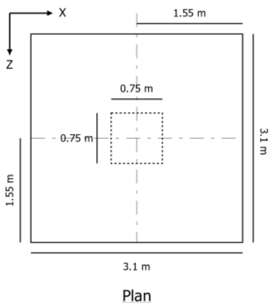


Figure 2.1

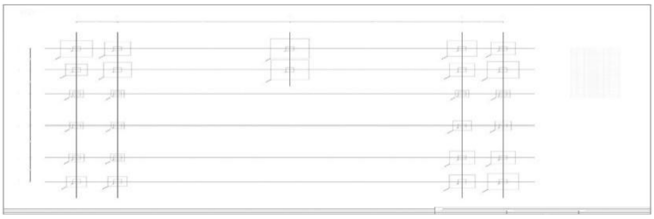


Figure 2.1: Footing Plan

Input Data:
The Minimum Footing Width Z (Fw)=900 mm
the minimum footing length (X(Fl))=900 mm
the minimum footing Thickness (in mm) =305 mm
eccentricity along X =0.00 mm
eccentricity along z=0.00 mm
Dimensions of Column
Shape of Column= Rectangular
Length of Column= 0.75 m
Width Of Column= 0.75 m
Pedestal
Pedestal Include=No
Design Parameter
Concrete and Rebar Property

Unit Weight of Concrete=23.60KN/M3
Concrete Strength=28 N/MM2
Steel Yield Strength=415 N/MM2
Minimum Size of Bar=12 mm
Maximum Size of Bar=60 mm
Minimum Size of Pedestal Bar=6 mm
Maximum Size of Pedestal Bar=32 mm
Minimum Spacing Of Bar=50 mm
Maximum Spacing of Bar=450 mm
Clear Cover Of pedestal =50 mm
Clear cover of footing= 50 mm

Soil Properties
Type Of Soil= Cohesive
Unit Weight of Soil=17.60 KN/M3
Bearing Capacity of Soil=120.00 kPa
ultimate loads For
bearing capacity of soil =2.00
Type Bearing Capacity of Soil =Gross Bearing Capacity
Soil Surcharge =0.00 KN/M2
Height of Soil = 500.00 mm
Depth Type =Fixed
Top Cohesion =0.00 KN/M2
Minimum Slab Area in Contact for Service Loads Percentage=0.00
Minimum Slab Area in Contact for Ultimate Loads Percentage=0.00

Overturning and Sliding
Friction Coefficient=0.5
Safety Factor Against Sliding= 1.5
factor of safety against overturning=1.5

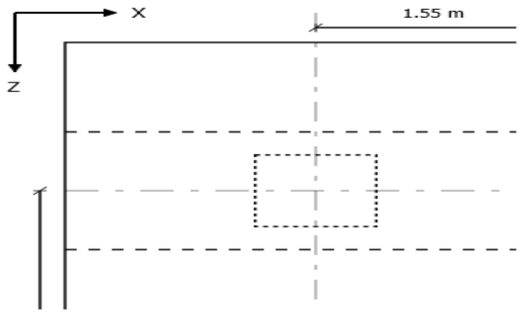
Final Footing Measurement
Footing Weight + Pedestal=69.17KN
Soil Weight above footing=79.62KN
Buoyancy Uplift Force=0KN
Effect of adhesion=0KN

Critical Load case and governing safety factor for tipping and sliding in the X direction.
Length = 3.1 MTR
Width = 3.1 MTR
Depth = .3 MTR
Area = 9.61 M2

The Ultimate Load Case controls depth.

Final Height of soil = 0.50 meters, critical load case for sliding along X-direction= 131 kilograms. The governing disruptive force= 12.95 KN
Governing Restoring Force=25.57 KN

Sliding Ratio Minimum for the Critical Load Case=1.97
the Critical Load Case for Overturning About X-Direction=131
Overturning Governing Moment: =32.40 KNm
resisting moment =122.16 KNm,
Critical Load Case Minimum Overturning Ratio: =3.77
Critical Load Case and the Overturning and Sliding Z Direction Safety Governing Factor
Case of Critical Load for Sliding in the Z-Direction =131
Disturbing Force in Government =9.91KN
Regulation of Restoring Force =25.57 KN
For the Critical Load Case, the Minimal Sliding Ratio2.58
Critical Load Case for Z-Directional Overturning=131
The Governing Overturning Moment=16.31KN
Minimum Overturning Ratio for the Critical Load Case =1.57
The Governing Resisting Moment=25.57 KN
Moment Calculation
Check Depth Again Moment



Critical Load =
Effective Depth=D-(cc+1.5xdb)= 0.24m
Governing Moment=72.53KN-M
From IS 456:2000
Limiting factor = 700(1100+(.87 x fy)) =.48
Limiting factor 2=.36 x fck x KUmaxx (.42 x KUmax) = 3857.61 KN/M2
Resistant of limiting moment = RU max x B x d2
=671.69KNM
M_u<= M_{umax} hence, safe
Check Trial Depth against moment (About X Axis)
Effective Depth =D-(cc+1.5 × db) =0.24
Mu =60.22
From IS 456:2000
Limiting factor = 700(1100+(.87 x fy)) =0.48
Limiting factor 2=.36 x fck x KUmaxx (.42 x KUmax) = 3857.61 KN/M2

Resistant of limiting moment = RU max x B x d2
=671.69KNM
M_u<= M_{umax} hence, safe
Critical Load no = #215
Critical section's distance along Z and DZ from the top left corner = .94 m
Shear Stress (Tv)=107.85 KN/M2
Shear Force (S) =79.24KN
Steel Content (Pt)=0.1847
Clause 40 of IS 456 2000, Table 19
Concrete's Shear Strength (Tc) =321.30KN/M2
According to IS456 -2000 Clause No. 40.5.1, Shear Enhancement Factor (if considered) is applied Tv<(Tc) hence, safe
Critical Case Load = #215
Critical section's distance along X, DX from the top left corner =94m
Shaping Force(S)=94.77KN
Steel Content As A Percentage =0.18
Shear Stress (Tv) =128.99KN/M2
According to IS 456 2000 Clause 40 Table 19
Shear Strength of Concrete (Tc) = 321.30 KN/M2
Shear Enhancement Factor (if considered) is added to (Tc), in accordance with IS 456 -2000 Clause No. 40.5.1 and Fig. 24
Tv<Tc, making the structure safe.
Critical Case Load = #215
Critical section's distance along X, DX from the top left corner =94m
Shaping Force(S)=94.77KN
Steel Content As A Percentage =.18
Shear Stress (Tv) =128.99KN/M2
According to IS 456 2000 Clause 40 Table 19
Shear Strength of Concrete (Tc) = 321.30 KN/M2
Shear Enhancement Factor (if considered) is added to (Tc), in accordance with IS 456 -2000 Clause No. 40.5.1 and Fig. 24
Tv<Tc, making the structure safe.
the Critical Load Case = #215
shear force S) is 173.52 KN
shear stress (Tv) is 179.78 KN/M2.
As stated in IS 456 2000 Clause 31.6.3.1,
Ks is equal to min [0.5+,1] = 1.00.
Shear Strength (Tc) = 0.25×fck = 1322.88 KN/M2
Ks x Tc = 1322.88 KN/M2
Tv<= Ks x Tc hence, safe
Reinforcement Calculation
Determining the maximum bar size on the X axis
Bar diameter equal to maximum bar size (db): 25 mm
as per Clause 26.2.1 of IS 456 2000
Growth Length(ld) = db×0.87×fy4×bd = 0.95 m
Length Allowed (ldb) = (B-b)2-cc = 1.12 m
Safe since ldb>= ld.
on the Z axis
Bar diameter equal to maximum bar size(db): 25 mm
as per Clause 26.2.1 of IS 456 2000
Growth Length(ld) = db×0.87×fy4×bd = 0.95 m
Length Allowed (ldb) = (H-h)2-cc = 1.12 m
Safe since ldb>= ld.
About X-Axis Flexure
Design for Parallel Z-Axis Bottom Reinforcement 12 - 12XZ
Regarding the X Axis (Mx)
As to Clause 26.5.2.1 of IS 456 2000

Critical Load Case = #215
The Minimum Area of Steel (Astmin) = 1135 mm2
The Calculated Area of Steel (Ast) = 1135 mm2
The Provided Area of Steel (Ast,Provided) = 1357 mm2
If the steel area is acceptable, Astmin=Ast
Size of Selected Bar (DB) = 12
Minimum permitted spacing (Smin) is 50.00 mm.
Selected spacing (S) is 297.84 millimeters.
Smin = S = Smax, and the maximum bar size was chosen. The bolstering is approved.
According to reinforcement spacing increment, the given reinforcement is
12 @ 295mm o.c.
Flexure Regarding Z-Axis
Design for Parallel to X Axis Bottom Reinforcement 12 - 12XZ
For the time being, Z Axis (Mz)
As to Clause 26.5.2.1 of IS 456 2000
Calculation of Crack Width (for Mz)
Concrete's elastic modulus (Ec) =26457513.11 KN/M2, according to Clause No. 6.2.3.1
Steel's modulus of elasticity (Es) = 200000000.00 KN/M2, according to Annexure F.
Neutral axis depth (Xu) = 0.11 m Clause No. G-1.1.a in Annexure G
the effective MOI (Ieff) = 1651544891.95 mm4
Steel Strain Average at Considered Level (m) = 0.00 X 10-5
The closest tension rod's distance (acr) =0.16 meters.
Annexure F: Crack Width (Wcr) =0.00 mm
from Clause No. 35.3.2 of IS 456-2000
Section is uncracked.
Calculation of Crack Width (for Mx)
Concrete's elastic modulus (Ec) =26457513.11 KN/M2, according to Clause No. 6.2.3.1
Steel's modulus of elasticity (Es) = 200000000.00 KN/M2, according to Annexure F.
Neutral axis depth (Xu) = 0.11 m Clause No. G-1.1.a in Annexure G
the effective MOI (Ieff) =1651544891.95 mm4
Steel Strain Average at Considered Level(m)=0.00X10-5
The closest tension rod's distance (acr) =0.16 meters.
Annexure F: Crack Width (Wcr) = 0.00 mm
from Clause No. 35.3.2 of IS 456-2000
Section is uncracked.

5. Results

1) A 43 m long foot over bridge is studied and designed. The tower's configuration is as follows:
   Span length= 43m
   Height of FOB=7.5m
   Size of pedestal= 300*300
2) Using IS: 875(Part 3)1987 and STADDPro V8i, wind load is computed. The structure is under a total wind load of 1.4 KN/M2.
3) The amount of the wind load acting on pedestrians crossing a bridge will already be quite low. Although the construction is more open and has more apertures, high-intensity winds and earthquakes are the major

causes of the towers' demise. Therefore, earthquake and wind loads should be given a high safety factor.

6. Conclusion

In today's quickly changing construction business, understanding the methods for building, and designing bridges, such as foot over bridge structural components, columns, beams, loadings on foot over bridge, etc., is crucial. So, accurate guesswork is required throughout the footbridge's design and analysis.

If we can discover a way to enhance the existing ineffective design or uneconomical manner of the foot over bridge, there is a lot of potential for cost and resource savings. The truss in the building of the footbridge was historically made of just angle sections, but now days numerous sections are preferred because of their low labor and material costs.

The footbridge will experience less wind stress than the towers since it has more apertures, however towers typically collapse due to earthquakes and strong winds, hence the towers require a high safety factor.

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