Analysis and Design of Structural Steel Bridge of 75m Span By Using Staad.Pro

Rajasekhar Rekha[1], D. Appanna[2]
[1]Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[1, 2] Lenora College of Engineering, Rampachodavaram

Abstract- *This report details out the salient information about a structural bridge of an effective span of 75m designed to support the traffic loads arising out of a 4-lane flyover(supported at the bottom chord level of the truss) and a 2-lane metro rail (supported at the top chord level of the truss). While deciding the type of the bridge i.e., a single trussor multiple individual trusses and the material of construction i.e., a structural steel or reinforced concrete bridge various important constraints such as the construction feasibility, flexibility for future enhancements or up gradation for the bridge loading, land availability etc. are considered and based on these factors a reasonably economical and easy to construct option is considered for the final design. As the bridge is required to support the loading from both the metro rail traffic and road traffic arising from the flyover, the bridge design is necessary to comply with the requirements stated both in the IRC (Indian Roads Congress) and the IRS (Indian Railway Standards) although there are subtle differences in verification for criteria like the slenderness calculation, crack width calculation and load combinations. In order to satisfy these requirements, a common approach is considered which results in a conservative design.*

I. INTRODUCTION

As the bridge is required to support the loading from both the metro rail traffic and road traffic arising from the flyover, the bridge design is necessary to comply with the requirements stated both in the IRC (Indian Roads Congress) and the IRS (Indian Railway Standards) although there are subtle differences in verification for criteria like the slenderness calculation, crack width calculation and load combinations. In order to satisfy these requirements, a common approach is considered which results in a conservative design. Since the loads to be supported on the bridge are considerably larger, it is important to choose the geometry of the bridge such that it not only should satisfy the space requirements (both in the width direction and the height direction) but also should help in reducing the forces in the members so that structural steel members can be designed economically. Hence, as first step the cross sections are considered based on the minimum space requirements for the flyover (since this run at the bottom chord level). However, the Forces resolved into the truss members such as the chord members are directly proportional to the height of the truss resulting in an increased height of the truss. Further, in order to reduce the overall weight of the structure, a high strength material is considered for the design.

ADVANTAGES OF STAAD.Pro SOFTWARE

- It does not involve any manual calculations.
- The visual interface is user-friendly.
- It is based on the latest programming technology that enables to create of an exact 3d model of the required building or structure.
- It is suitable for almost all types of materials including concrete, steel, aluminum etc.
- Faster methods of designing a structure.
- This software contains all the necessary tools required to design a structure. It works in sync with other programs such as STAAD.pro foundation, STAAD. pro offshore and ram for designing foundation, offshore structure and steel structure. Other than building bridges, pipes, shear wall etc can also be designed.
- It can be used to calculate reinforcement for concrete beams, columns and shear walls. · A large variety of design codes are available which determines drift, deflection and depth of any construct.
- It is developed with an open architecture called open STAAD.
- 10 Pre-built models of different structures are available for remodeling purposes. New templates can also be added as per requirements.
- We can get shear and moment values at every 1/12th section of the member.
- For seismic design, both static analysis and response spectrum can be performed.
- You can design structure for different types of load such as dead load, live load, wind, load etc.
- International country codes are available.
- The results are sturdy.
- Designs can be imported from Autocad.

LIMITATIONS of STAAD.Pro SOFTWARE

- It gives uneconomical results for multi-story structures.
- Limitations in modeling. Curvy boundary, parabolic beam etccan not be modeled effectively and analyzed efficiently.
- Analysis of complex structures can be tedious. Require proper skills.
- Proper detailing of reports is not available.
- Not for brick masonry works. Not for costing and estimating.

II. REVIEW OF LITERATURE

2.1 Research Article Volume 7 Issue No.11
ANALYSIS OF STEEL FRAMES USING DIRECT ANALYSIS METHOD BY USING STAAD Pro V8iSoftware

KasaNavin Kumar1, Gowlla Jyothsna2 JASC: Journal of Applied Science and Computations Volume VI, Issue VI, JUNE/2019 ISSN NO: 1076-5131.

To investigation the seismic conduct of G+9 steel frame building working by utilizing IS 1893:2002 2. The parameters like deflection, shear, bending, Drift values are studied at each individual story for checking the stability of steel frame structure. 3. In the present study a G+9 story steel frame structure was analyzed by using direct analysis method inSTAAD Pro V8i Software. 4. To examination the structures in STAAD Pro V8i Software.

2.2 Analysis of Steel Framed Structure using STAAD Pro and ROBOT Software

SALEM R.S GHDOURA1, VIKAS SRIVASTAVA2 international Journal of scientific engineering and technology research ISSN 2319-8885 Vol.05,Issue.07, March-2016, Pages:1442-1449

To determine the instability behavior of steel members using STAAD Pro and ROBOT software. To provide appropriate section using software analysis. To compare the design proficiency of the software’s

2.3 International journal of advanced technology in engineering and science Vol. no.4, Issueno.10, October 2016 www.ijates.comDESIGN AND ANALYSIS OF INDUSTRIAL BUILDING WITHGABLED ROOF BY USING STAAD PRO M. Suneetha1, Gillela. NareshKumar Reddy2

A strengthened solid outline must fulfill the accompanying practical target: 1) Under the most exceedingly bad arrangement of stacking, the structure must be sheltered 2) Under the working burden, the disfigurement of the structure must not disable the appearance, strength and execution of the structure and 3) The structure must be sparing, that is, the variable of security ought not be too expensive to the degree that the expense of the structure gets to be not allowed without extra real preferred standpoint aside from vigor. 4) These necessities call for good appraisal of the meaning burdens, right choice of materials and sound workmanship. To guarantee these, the different components shaping the strengthened cement and the solid itself must finish different tests as nitty gritty in the controlling code of practice.

2.4 International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Assessment and Design of Steel frame Structure, consists Performance of Connection Joints with Tekla& Staad Pro L.Vimala, T.Naresh Kumar, S.M.V.Narayana, J.ChinnaBabu

The aim of this project work is to analyse a 7-storeyed commercial building for different load combinations using STAAD Pro software. And behavior of connection of bolts.

2.5 International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211 Volume 9, Issue 7 July -2021, Impact Factor: 7.429, Available online at: www.ijaresm.com

Design and Analysis of Oil Refinery Steel Structure Using Staad Pro Software with Alteration to Conventional Steel Sections Bhalerao Rupali Alish1, Dr. M.P. Wagh2 Review of related literature helps the researcher to understand the topic better. The researcher can collect the all the relevant information on the research topic. The review is always helpful in finding out what were their methods used, what were suggestions given for further research. The review of related literature certainly makes new researcher well equipped with previous background of the topic and area of research. It makes researcher more critical and provides sound foundation and deep insight into the problem. A careful review of the research journal, books, thesis and other source of information on the problem to be investigated is one of the important steps in planning of any research study.

2.6 International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 08 Issue: 05 | May 2021 www.irjet.net p-ISSN: 2395-0072

Design of a 6-storeyed steel structure using StaadPro Software Atika Pathan1, Nidhi Sonavane2, Praduman Singh3 An industrial steel building design was performed using StaadPro software. The building comprises structural steel for the superstructure and concrete for substructure. The structure comprises 2 bay frames, 7.5m each. There are a total 6 number of floors spaced at 3.6m, on which different equipment rests. Also, a stair is provided in a 4m bay i.e., besides the main bay for accessing the floors. A gable frame supports the top roof of the building. The foundation is at 3m below the ground level.

III. METHODOLOGY

The Project designed is for a bridge of single effective span of 75m.

3.1 Site Condition

Site location =Hyderabad (Choose)
Maximum ambient temperature = +45 °C
Minimum ambient temperature = +08 °C
Seismic zone as per IS1893 = II
Basic wind speed = 44m/s.

3.2 Design parameters

Type of bridge
2-Level bridge over existing road or junction
Verticals, top and bottom chords, diagonals, stringers, cross girders, plate girders, top and bottom chord plan bracings =E350
Alignment =Straight and level
Number of spans =Single span
Span dimension =75m effective span
Function =To carry two tracks of Metro at upper deck and 4-lane road at the lower deck.
Design life =50years (assumed)
Metro loading Axle load of 16MT per RDSO(Research Design Standards Organization)
Train design speed = 80kmph
Road deck width =16.5m
Roadway arrangement = 4-lane traffic with crash barrier
Roadway loading= Class A& Class 70R per IRC standards Additional loading

Wind loads per IS: 875 Part 3

Seismic loading per IS: 1893= Zone- II
Material of construction Structural steel for truss

Density for load calculations

Concrete = 25kN/m^3
Structural steel =78.5kN/m^3
Wearing course =24kN/m^3

3.3 General Analysis & Design Exclusions:

Owing to the complexity involved in the analysis and design, following are excluded while carrying out the design of the bridge. Though the design of concrete or composite components of the bridge is neither carried out nor presented in this report, the material grades, codes and specifications applicable etc., to these components are listed down for completeness and informational purposes.

1. Fatigue analysis of the bridge
2. Design of connections
3. Design of pier and pier cap.
4. Elements of composite sections.
5. Response spectrum analysis for the bridge (if applicable).
6. Design of bearings.

3.3 Loading and Load Combinations:

The various permanent, variable and accident loads acting on the bridge are described in this chapter. The permanent loads are due to the self-weight of the truss; deck slab and road and rail fixtures while the live loads are due to metro and roadway. Whereas loads due to wearing course, crash barrier, parapet, cable tray, weight of cables, tracks, plinths, rail fixtures are considered under Super Imposed Dead load (SIDL). Variable loads are due to wind and earthquake. Secondary effects due to temperature, creep and shrinkage of concrete are also described. Accidental loads are due to vehicular impact on crash barrier or pier (ignored in this assessment).

Table: Load combinations

Limit State	Loads	G I	G II	G VI
		Normal	Wind	EQ
SLS COMBINATIONS	Dead loads (DL)	1.0	1.0	1.0
	Super imposed dead load (SIDL)	1.2	1.2	1.2
	Wind Load (WL)		1.0	
	Earthquake (EQ)			1.0
	Live Load (LL)	1.1	1.0	0.5
Limit State	Loads	G I	G II	G VI
		Normal	Wind	EQ
ULS COMBINATIONS	Dead loads (DL)	1.25	1.25	1.25
	Super imposed dead load (SIDL)	2.00	2.00	1.50
	Wind Load (WL)		1.60	
	Earthquake (EQ)			1.50
	Live Load (LL)	1.75	1.40	0.50

Table: Material Properties

Material	**Modulus of elasticity**
Steel (Es)	: 2.11x105 N/mm2
Concrete (Ec)	: 32500 N/mm2

Sl. No.	Loading Cases	Effective Section
1	Permanent loads Self-weight of truss Dead load of RC deck SIDL due to WC parapets etc., on Highway SIDL due to rail track, stringers, sleepers etc. Effects of creep & shrinkage of concrete deck on composite truss	Steel Steel Steel Composite (n=2) Steel Composite (n=2) Steel Composite (n=2)
2	Live Loads Train Live Load Highway vehicle load	Steel Composite (n=1) Steel Composite (n=1)
3	Transient load Wind load on Steel Composite truss Seismic loading	Steel Composite (n=1) Steel Composite (n=1)
4	Erection Erection stage loading on steel truss Erection stage loading on composite truss	Steel Steel Composite (n=1)

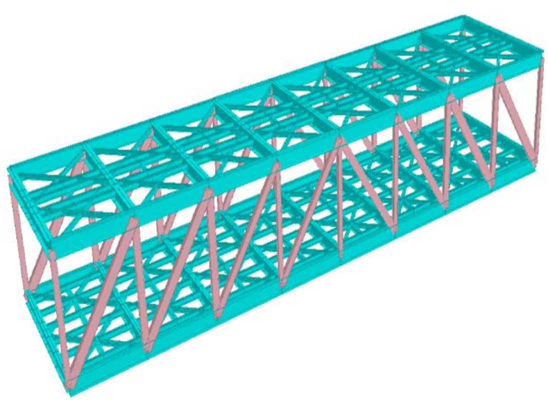


Fig shows Rendered 3d View

IV. RESULTS AND DISCUSSIONS

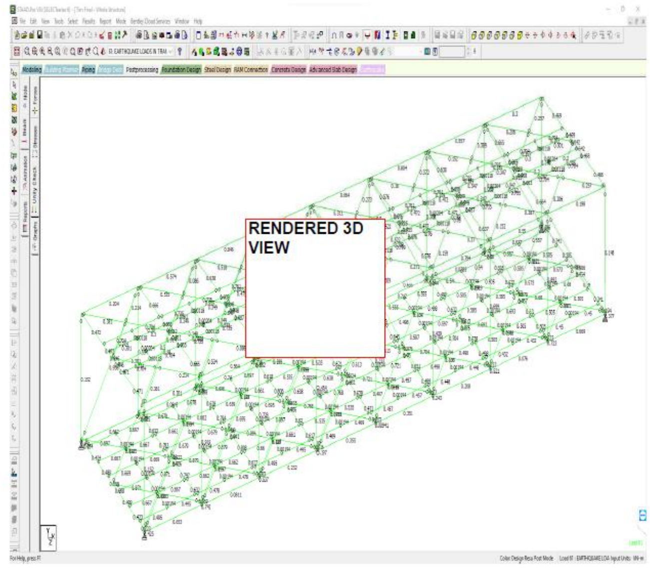
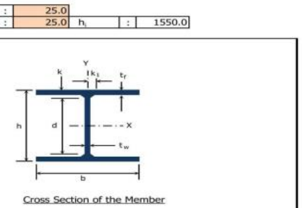


Fig 4.1 Utility Ratios –Isometric View

Unity check for strength cases is the ration between the required resistance. Similarly for serviceability load cases it is the ration deflection and allowable deflection. From the design results.the member with maxim utilization ratio and the corresponding load combination is considered for the manual verification. The combined check is performed for considering axial tension moments, axial compression and bending moments separately as specified in the respective design codes. The values of these unity checks should be less or equal to 1.0 to comply with the requirements.

Fig 4.2 Bottom Chord



BOTTOM CHORD

Cross Section Details:

h	:	1600.0	t_f	:	25.0			
b	:	600.0	t_w	:	25.0	h_i	:	1550.0

Calculation of C.G.

Part		Area (mm^2)	y (mm)	x (mm)	Ay (mm^3)	Ax (mm^3)
Web	:	38750.0	800.00	300.00	31000000.0	11625000.0
Top flange	:	15000.0	12.50	300.00	187500.0	4500000.0
Bottom flange	:	15000.0	1587.50	300.00	23812500.0	4500000.0
	:	68750.0	**800.00**	**300.00**	55000000.0	20625000.0

Moment of Inertia:

Part		I_{xi} (mm^4)	I_{yi} (mm^4)	A_ix^2 (mm^3)	A_iy^2 (mm^3)
Web	:	7758072916.7	2018229.2	0.0	0.0
Top flange	:	781250.0	450000000.0	0.0	9302343750.0
Bottom flange	:	781250.0	450000000.0	0.0	9302343750.0
	:	7759635416.7	902018229.2	0.0	18604687500.0

Geometric Properties:

A_g	:	68750.0 mm^2	Z_{ex}	:	9699544.3 mm^3
h	:	1600.0 mm	Z_{ey}	:	3006727.4 mm^3
b	:	600.0 mm	Z_{px}	:	33635416.7 mm^3
t_f	:	25.0 mm	Z_{py}	:	3161458.3 mm^3
t_w	:	25.0 mm	r_x	:	619.258 mm
I_x	:	26364322916.7 mm^4	r_y	:	114.544 mm
I_y	:	902018229.2 mm^4	y	:	800.0 mm

Material Properties:

Component	Database	Grade	Permissible Stresses (N/mm^2)		Elastic Modulus (N/mm^2)
			Yield Stress	Ultimate Stress	
Main Member	IS 2062	E350	350	490	2.00E+05

Material Safety Factors

γ_{M0}	γ_{M1}
1.10	1.25

Results Summary:

	Axial Tension (kN)	Axial Comp. (kN)	Shear (kN)		Bending (kNm)	
			Major Axis	Minor Axis	Major Axis	Minor Axis
Design Force	7993.0	7993.0	60.0	1.0	215.0	10.0
Design Capacit	21875.0	12768.7	7830.3	6062.2	3086.2	956.7
Utility ratio	0.37	0.63	0.01	0.00	0.07	0.01

	Axial Tension & Bending	Axial Compression & Bending
Combined chec	0.4	0.70

75m Final - Beam End Forces:

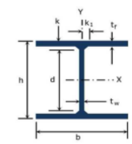
All / Summary / Envelope

Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
266	506 LOAD G	264	7992.303	11.578	0.917	1.984	0.648	-214.181
		265	-7992.303	59.596	-0.917	-1.984	-9.246	-10.901

BOTTOM HORIZONTAL

Cross Section Details:

h	:	1500.0	t_f	:	40.0			
b	:	600.0	t_w	:	40.0	h_i	:	1420.0



Cross Section of the Member

Calculation of C.G.

Part		Area (mm^2)	y (mm)	x (mm)	Ay (mm^3)	Ax (mm^3)
Web	:	56800.0	750.00	300.00	42600000.0	17040000.0
Top flange	:	24000.0	20.00	300.00	480000.0	7200000.0
Bottom flange	:	24000.0	1480.00	300.00	35520000.0	7200000.0
	:	104800.0	**750.00**	**300.00**	78600000.0	31440000.0

Moment of Inertia:

Part		I_{xi} (mm^4)	I_{yi} (mm^4)	A_ix^2 (mm^3)	A_iy^2 (mm^3)
Web	:	9544293333.3	7573333.3	0.0	0.0
Top flange	:	3200000.0	720000000.0	0.0	12789600000.0
Bottom flange	:	3200000.0	720000000.0	0.0	12789600000.0
	:	9550693333.3	1447573333.3	0.0	25579200000.0

Geometric Properties:

A_g	:	104800.0 mm^2	Z_{ex}	:	12734257.8 mm^3
h	:	1500.0 mm	Z_{ey}	:	4825244.4 mm^3
b	:	600.0 mm	Z_{px}	:	48482666.7 mm^3
t_f	:	40.0 mm	Z_{py}	:	5178666.7 mm^3
t_w	:	40.0 mm	r_x	:	578.972 mm
I_x	:	35129893333.3 mm^4	r_y	:	117.528 mm
I_y	:	1447573333.3 mm^4	y	:	750.0 mm

Material Properties:

Component	Database	Grade	Permissible Stresses (N/mm^2)		Elastic Modulus (N/mm^2)
			Yield Stress	Ultimate Stress	
Main Member	IS 2062	E350	350	490	2.00E+05

Material Safety Factors

γ_{M0}	γ_{M1}
1.10	1.25

1.0) Axial Tension:

1.1) Limit State of Tensile Yielding:

Design tensile strength T_{dg} = $f_y A_g/\gamma_{M0}$ = 21875.0 kN

1.2) Limit State of Tensile Rupture:

Design tensile strength T_{dn} = $0.90\ f_u A_n/\gamma_{M1}$ = 24255.0 kN

2.0) Axial Compression:

Axial compressive strength of the member is calculated using following expression:

$$f_{cd} = \frac{f_y/\gamma_{m0}}{\phi + \left[\phi^2 - \lambda^2\right]^{0.5}} = \chi f_y/\gamma_{m0} \le f_y/\gamma_{m0}$$

f_{cd} = 185.73 N/mm^2

Design compressive strength, P_d = 12768.7 kN

Where

ϕ	:	$0.5[1+\alpha(\lambda-0.2)+\lambda^2]$	=	1.11	
α	:	imperfection factor (for *buckling class c* - I section)	=	0.49	
λ	:	$\sqrt{(f_y/f_{cc})}$	=	0.93	
f_{cc}	:	$\pi^2E/(KL/r)^2$	=	407.84	N/mm^2
K	:	effective length factor	=	0.85	
L	:	unsupported length of the member	=	9.4	m
r	:	least radius of gyration	=	114.54	mm

3.0) Shear:

Design shear strength of the member (major axis) V_{dy} = $A_{vy}\ f_{yw}/\sqrt{3}$ = 7830.3 kN

Design shear strength of the member (minor axis) V_{dx} = $A_{vx}\ f_{yw}/\sqrt{3}$ = 6062.2 kN

Shear area A_{vy} = 38750.0 mm^2

Shear area A_{vx} = 30000.0 mm^2

4.0) Flexure:

Design felxural strength of the member is calculated using the following expression:

$$M_d = \beta_b Z_p f_y / \gamma_{m0}$$

Description	Z_p	Z_e	β_b	M_d
Major axis	33635416.7	9699544.3	0.3	3086.2
Minor axis	3161458.3	3006727.4	1.0	956.7

Results Summary:

	Axial Tension (kN)	Axial Comp. (kN)	Shear (kN)		Bending (kNm)	
			Major Axis	Minor Axis	Major Axis	Minor Axis
Design Force	1.7	1.7	130.0	267.0	13764.0	363.0
Design Capacity	33345.5	34341.3	11477.7	9699.5	15426.3	1647.8
Utility ratio	0.00	0.00	0.01	0.03	0.89	0.22

	Axial Tension & Bending	Axial Compression & Bending
Combined check	0.9	0.92

75m Final - Beam End Forces:

All / Summary / Envelope

Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
66	483 LOAD G	37	-1.698	129.214	-266.827	0.071	30.584	-13585.523
		41	1.698	-112.144	266.827	-0.071	362.985	13763.524

Fig 4.3 Bottom Horizontal

1.0) Axial Tension:

1.1) Limit State of Tensile Yielding:

Design tensile strength T_{dg} = $f_y A_g/\gamma_{M0}$ = 33345.5 kN

1.2) Limit State of Tensile Rupture:

Design tensile strength T_{dn} = $0.90 f_u A_n/\gamma_{M1}$ = 36973.4 kN

2.0) Axial Compression:

Axial compressive strength of the member is calculated using following expression:

$$f_{cd} = \frac{f_y/\gamma_{m0}}{\phi + \left[\phi^2 - \lambda^2\right]^{0.5}} = \chi f_y/\gamma_{m0} \le f_y/\gamma_{m0}$$

f_{cd} = 327.68 N/mm²

Design compressive strength, P_d = 34341.3 kN

Where

ϕ	:	$0.5[1+\alpha(\lambda-0.2)+\lambda^2$	=	0.50	
α	:	imperfection factor (for *buckling class c* - I section)	=	0.49	
λ	:	$\sqrt{(f_y/f_{cc})}$	=	0.14	
f_{cc}	:	$\pi^2E/(KL/r)^2$	=	17345.51	N/mm²
K	:	effective length factor	=	0.85	
L	:	unsupported length of the member	=	1.5	m
r	:	least radius of gyration	=	117.53	mm

3.0) Shear:

Design shear strength of the member (major axis) V_{dy} = $A_{vy} f_{yw}/\sqrt{3}$ = 11477.7 kN

Design shear strength of the member (minor axis) V_{dx} = $A_{vx} f_{yw}/\sqrt{3}$ = 9699.5 kN

Shear area A_{vy} = 56800.0 mm²

Shear area A_{vx} = 48000.0 mm²

4.0) Flexure:

Design felxural strength of the member is calculated using the following expression:

$$M_d = \beta_b Z_p f_y / \gamma_{m0}$$

Description	Z_p	Z_e	β_b	M_d
Major axis	48482666.7	12734257.8	1.0	15426.3
Minor axis	5178666.7	4825244.4	1.0	1647.8

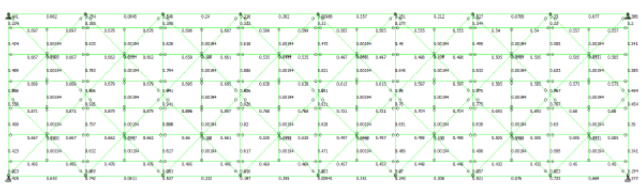


FIG 4.2 UTILITY RATIO OF BOTTOM PLAN

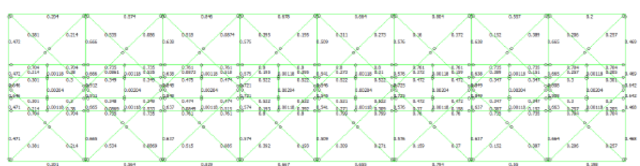


FIG 4.3 UITILITY RATIO OF TOP PLAN

Lenora college of Engineering

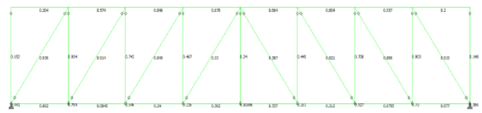


FIG 4.4 UITILITY RATIO OF ELEVATION

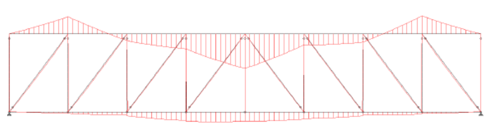


FIG 4.5 BENDING MOMENT DIAGRAM OF LOAD CASE 506

Department of Civil Engineering Page | 68

Lenora college of Engineering

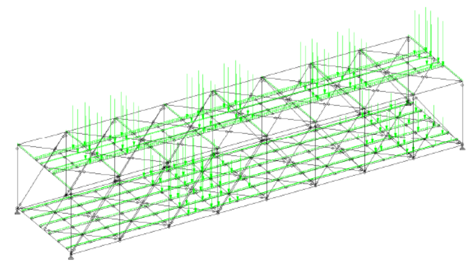


FIG 4.6 LOADING DIAGRAM LOAD CASE 506

Department of Civil Engineering Page | 69

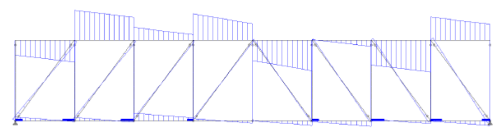


FIG 4.7 SHEAR FORCE DIAGRAM OF LOAD CASE 506

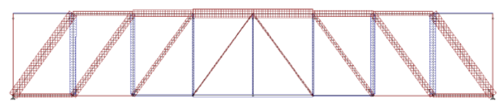


FIG 4.8 AXIAL FORCE DIAGRAM OF LOAD CASE 506

Department of Civil Engineering Page | 70

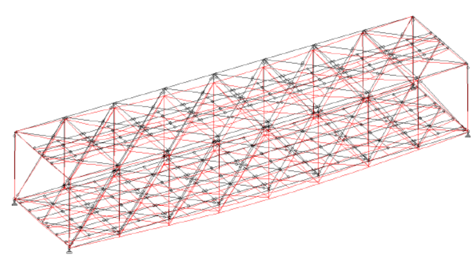


FIG 4.9 BENDING MOMENT DIAGRAM OF LOAD CASE OF 506 OF ISOMETRIC VIEW

Department of Civil Engineering Page | 71

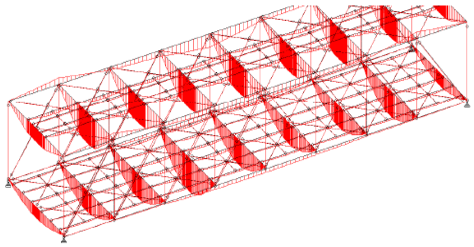


FIG 4.10 DEFLECTION DIAGRAM LOADE CASE 506

Department of Civil Engineering Page | 72

Lenora college of Engineering

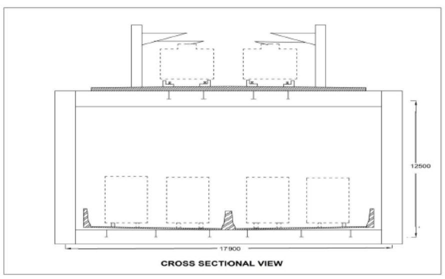


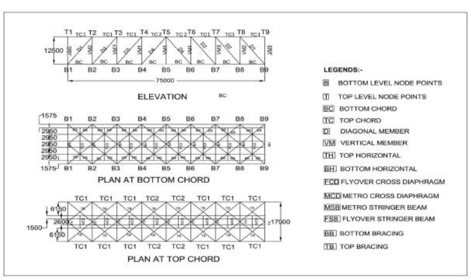
FIG 4.11 CROSS SECTION VIEW

Department of Civil Engineering Page | 73

Lenora college of Engineering

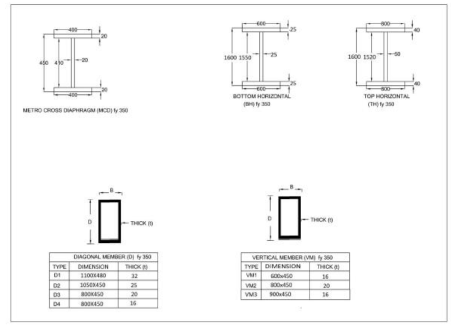
FIG 4.12 DIMENSIONS OF MEMBERS

DRAWINGS

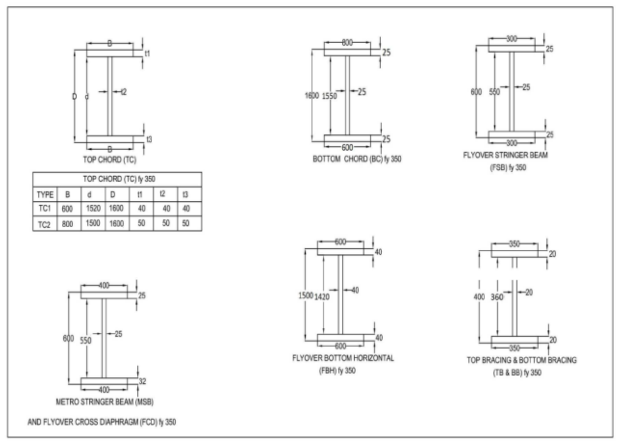


Department of Civil Engineering Page | 74

Lenora college of Engineering



Department of Civil Engineering Page | 75



V. CONCLUSIONS

1. Bridges carrying considerably heavier loads are quite common nowadays especially the combination of a multiple lanes of road traffic and metro or rail traffic.
2. The heavier the loads are, the higher the cross sectional dimensions. Initially the assessment started by considering the regular rolled sections. However, since the external forces are considerably high, the cross size of the bridge will be abnormally large and hence an alternative built-up sections of standard shapes such as I, C and Box sections are used for the assessment.
3. Although final design comprises of purely built-up sections, the cross section sizes of each type of member such as chord main members, cross girders are more than 1mand also the thickness of the plates are exceeding over 32mm and up to 50mm. Owning to the fact that, this type of construction requires skilled workmanship and also availability of larger thickness plates is difficult, alternative solutions may need to be explored to make the design, fabrication and election feasible.

REFERENCES

Codes and Specification:

[1] The following codes will generally be applicable for design, material, fabrication and erection, except in cases where special mention is made in this report.

Indian Railways Standards Codes and Specification (IRS)

[2] Indian Railway Bridge Rules, specifying the loads for design of Superstructure and substructure of Bridge including Chapter-VII for the rule for the opening of Railway adopted in 1941- Revised-2014 incorporating up-to date corrections slip no.48.
[3] IRS: Specification for steel Bridge code Revised (including Correction Slips up to no.21)
[4] IRS: Welded Bridge Code for Steel bridge girder (Revised 2001)
[5] ·IRS Substructure and foundation code-Bridge adopted 1936- Revised -1985 (hereinafter referred to as 'Substructure Code") with up-to-date correction slip no.22
[6] Metro Rakes Schedule of Dimension for Standards Gauge.
[7] Indian Railway code of practice of Plain/Reinforced and Prestressed concrete for general/bridge construction (concrete bridge code) September 2014 including correction slip no.13.
[8] Indian railways bridge Manual 1998. IRS: codes for Earthquake Resistant Design of Railways Bridges (Seismic code)-2017.
[9] IRS Manual of Design and construction of well and pile foundation 1985. Indian Roads Congress Codes and Specification (IRC)
[10] IRC-5-2015 Standard specification and code of practice for road bridge section-I

General features of design

[11] IRC-6-2017 Standard specification and code of practice for road bridges for section-II

Loads and stresses.

[12] IRC-112-2011: Code of practice for concrete road bridge.
[13] IRC-24-2010 Standards specification and code of practice for road bridges -section Vsteel Road Bridge. IRC-83 (Part-III)-2002: Standard specification and code of practice for road bridge –section-IX bearings Part III, POT, POT cum PTFE, PIN and Metallic Guide Bearings.
[14] IRC-22-2008: with amendments2015: standards specification and code of practice for road bridge section VI- composite construction.

Indian Standards codes & specification (IS)

[15] IS:800-2007 : Code of practice for general construction in steel IS:2062-2011 : Steel for General Structure purpose-specification
[16] IS:875 - Part 3 : Wind loads on buildings and structures.
[17] IS:1893 - Part 1 : Criteria for earthquake resistant design of structures.
[18] IS:1161-1998 : Steel tubes for structural purposes.
[19] IS:1024-1999 : Use of welding in Bridge and Structural subject to Dynamic loading – code of practice.
[20] IS:1261-1959 : Seam Welding in Mild Steel.
[21] IS:1367 : Technical supply condition for Threaded steel fasteners.
[22] IS:9595 : Metal Arc Welding of carbon and carbon Manganese steels recommendations
[23] IS:3502-1994 : Steel Chequered plates – Specification
[24] IS:7205-1974 : Safety code for erection of structural steel work.
[25] IS:7215-1974 : Tolerance for fabrication of steel structures
[26] IS:1786-2008 : High strength deformed steel bars &wires for concrete.
[27] IS:432-1982: Mild Steel, Medium tensile steel bars and hard drawn steel wire for concrete reinforcement.
[28] SP(I) : Structural steel sections.
[29] IS:8629 (Parts I to III) Protection of iron and steel structures from atmospheric corrosion (Reaffirmed 2002)
[30] IS:3757-1985 High strength Bolts.
[31] IS:4000-1992 : High strength bolts in steel structures.