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Analysis and Design of Deck Slab Bridge

Iqra Zaffar[1] and Priyanka Singh[2]

[1,2]Galgotia University Greater Noida, UP
E-mail: [1]zaffar.iqra@yahoo.in, [2]priyankasingh@galgotia university.edu.in

Abstract—*Bridges are the lifelines and supporters for the improvisation of the road network. Not only do the bridges help in traffic flow without any interference but also maintain the safety of roads. Due to this reason the bridges design has gained much importance. This paper is basically concerned about the analysis and design of Deck Slab bridge by STAAD Pro using IRC Loading. which contains a span of 100m X 16m and has a 4-girder system. The objective is to check the result for particular input design, properties and parameters and the approach has been taken from AASHTO standard design. The nodal displacement, beam property, vehicle loading details, concrete design can be easily found out performing the analysis and design method.*

Keywords*: IRC Loading, 4girder System, AASHTO, design specifications, STAAD Pro.*

1. INTRODUCTION

In Past, advanced mathematical methods were used for the analysis of the large structures such as Bridges, buildings etc. Those methods are elaborated techniques. So it takes too much time for designer to concentrate on the calculations. Nowadays, STAAD. Pro Software is being widely used for the analysis and design of buildings, towers etc. In this project, STAAD Pro. has been used for the analysis and design of a deck slab bridge in connection with STAAD beava. It becomes much more easier to assign the properties and other specifications in creating deck slab by the STAAD Pro. software. The various properties are to be considered in the analysis and design of the deck slab of a bridge which include section property, plate thickness, dead load, live load etc. Dead Load consists of its own weight and portion of weight of superstructure and fixed loads also. Live loads are caused by vehicle moving over the bridge

Live loads have four types of standard loadings for which the road bridges are designed. These include

(i) IRC Class 70R Loading (ii) IRC Class AA Loading (iii) IRC Class A Loading (iv) IRC Class B Loading

(i) IRC Class 70R Loading is applied for permanent bridges and culverts. Bridges designed for this type of loading is checked for Class A loading.

(ii) IRC Class AA Loading is adopted within municipal limits for existing and industrial areas.

(iii) IRC Class A loading is adopted for all roads on which permanent bridges and culverts are to be constructed.

(iv) IRC Class B loading is adopted for timber bridges.

2. METHODOLOGY

The project gives an idea about the analysis and design of Deck Slab Bridge using IRC Loading 70R by STAAD.Pro V8i. Here the model is being designed as per IRC 70R loading which is applicable on all roads on which the permanent bridges and culverts can be constructed. Analysis and Design process by STAAD Pro determines the performance of Structures. The designing by the software saves the design time and by this way we can check the safety of the structure very easily.

3. DESIGN EXAMPLE

Design RCC deck slab for the span of 100m.The width is taken 16m. The Supports are fixed. Use dead load (DL) and IRC Class 70R (displacement Y+ve and Y-ve) Loading as live load LL by STAAD. Pro using following input values:

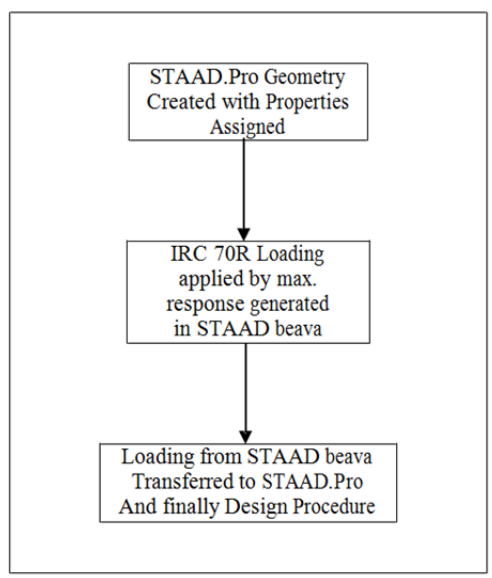

Fig. 1: Analysis and Design Flow Chart

Table 1

Structure Type	SPACE FRAME

Number of Nodes	1728	Highest Node	1728
Number of Elements	590	Highest Beam	2188
Number of Plates	1600	Highest Plate	2190

Table 2

Number of Basic Load Cases	3
Number of Combination Load Cases	0

Table 3

Type	L/C	Name
Primary	1	DL
Primary	2	IRC: ULS CLASS 70R LOADING N21: DISF
Primary	3	IRC: ULS CLASS 70R LOADING N166: DIS

Table4

Supports

Node	X (kN/mm)	Y (kN/mm)	Z (kN/mm)	rX (kN`m/deg)	rY (kN`m/deg)	rZ (kN`m/deg)
26	Fixed	Fixed	Fixed	-	-	-
27	Fixed	Fixed	Fixed	-	-	-
28	Fixed	Fixed	Fixed	-	-	-
29	Fixed	Fixed	Fixed	-	-	-
30	Fixed	Fixed	Fixed	-	-	-
31	Fixed	Fixed	Fixed	-	-	-
32	Fixed	Fixed	Fixed	-	-	-
33	Fixed	Fixed	Fixed	-	-	-
34	Fixed	Fixed	Fixed	-	-	-
35	Fixed	Fixed	Fixed	-	-	-

Table 5

Materials

Mat	Name	E (kN/mm²)	ν	Density (kg/m³)	α (/°C)
1	STEEL	205.000	0.300	7.83E+3	12E -6
2	STAINLESSSTEEL	197.930	0.300	7.83E+3	18E -6
3	ALUMINUM	68.948	0.330	2.71E+3	23E -6
4	CONCRETE	21.718	0.170	2.4E+3	10E -6

Table 6

Section Properties

Prop	Section	Area (cm²)	I_{yy} (cm⁴)	I_{zz} (cm⁴)	J (cm⁴)	Material
6	Cir 2.00	31.4E+3	78.5E+6	78.5E+6	157E+6	CONCRETE
7	Rect 1.00x1.00	10E+3	8.33E+6	8.33E+6	14.1E+6	CONCRETE
8	Rect 1.00x1.00	10E+3	8.33E+6	8.33E+6	14.1E+6	CONCRETE
9	Rect 0.50x0.50	2.5E+3	521E+3	521E+3	879E+3	CONCRETE

Table 7

Plate Thickness

Prop	Node A (cm)	Node B (cm)	Node C (cm)	Node D (cm)	Material
1	30.000	30.000	30.000	30.000	CONCRETE
2	30.000	30.000	30.000	30.000	CONCRETE
3	30.000	30.000	30.000	30.000	CONCRETE
4	30.000	30.000	30.000	30.000	CONCRETE
5	30.000	30.000	30.000	30.000	CONCRETE

Table 8

Selfweight : 1 DL

Direction	Factor
Y	-1.000

3.1 Design Procedure

STAAD.Pro. in space is Operated with units Metre

and Kilo Newton. The geometry is drawn and the section properties are assigned. Fixed Supports are taken. Quadrilateral meshing is done followed by assigning of plate thickness.3D rendering can be viewed for the geometry. Loads are defined by the loads and definitions. By Post Processing mode, Nodal displacement, Max. Absolute Stress distribution for the bridge can be viewed. Run analysis is operated.

Max. Response by the IRC Class 70R loading is done by STAAD.beava. The deck is created in bridge deck processor, this being the first step of STAAD.beava. In

STAAD.beava, roadways, curbs, vehicular parameters are provided. Lastly transfer of load is done into STAAD Pro. for further analysis and design. All the Max. response criteria are checked Mx,My,Mz stresses etc for different members elements.The load positions and reactions, beam forces and moments,etc. are determined.The concrete is designed as per IS Code.

3.2 Fig. s in STAAD.Pro.

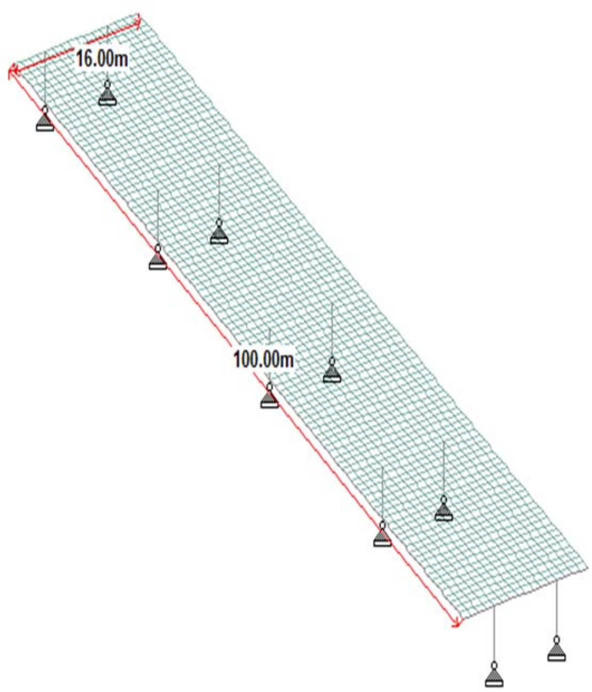

Fig. 2.Geometry

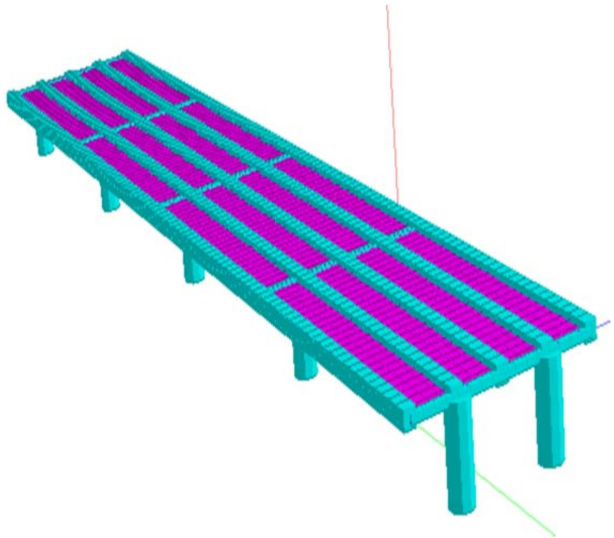

Fig. 3 3D Rendering View

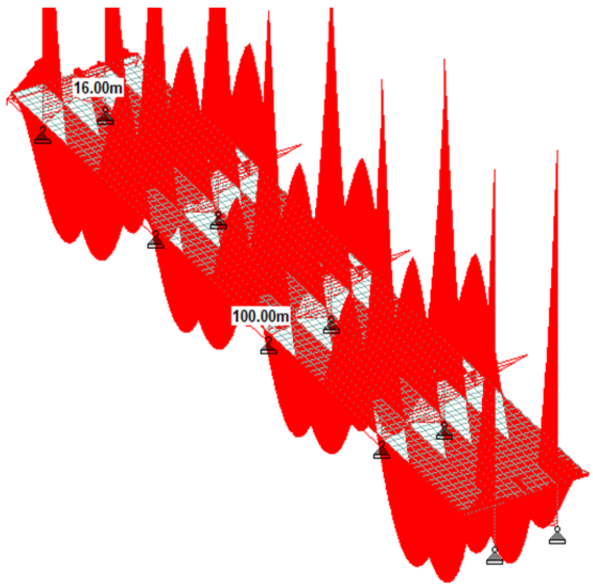

Fig. 4 Bending Z

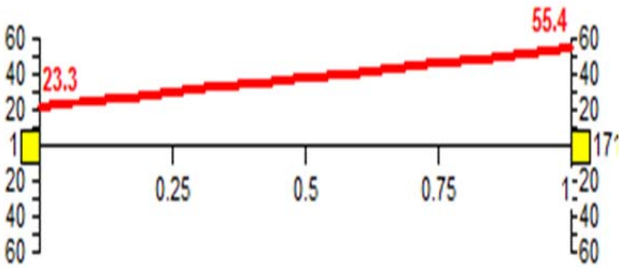

Fig. 5 Mz(kNm) Beam Graph

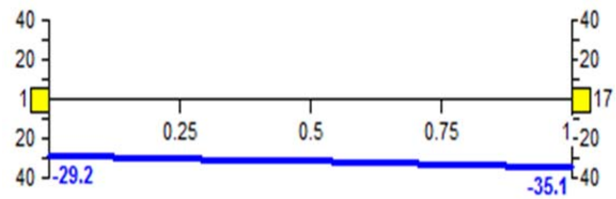

Fig. 6 Fy(kN) Beam Graph

Fig. 7 Fx(kN) Beam Graph

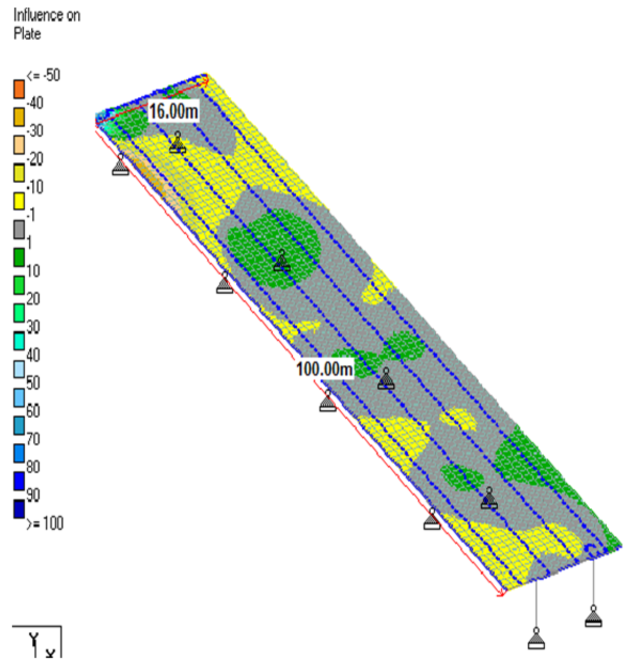

Fig. 8 Plate Stresses

4. RESULTS AND DISCUSSION

The output data for the IRC Class 70R bogie loadings are considered which include nodal displacement, nodal displacement summary, beam forces, beam end displacements, beam end displacement summary, reactions, reaction summary, axial forces, beam moments, live load effect and many more by STAAD. Pro V8i. As all of them cannot be described in this paper, the data result tables being very large, some of the glimpse of the output results in the tabular forms is provided in this paper.

4.1 Tabular-result

Table 9

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	52	2:IRC: ULS CLA	3.707	0.172	-1.084	3.866	0.001	-0.000	0.000
Min X	2	2:IRC: ULS CLA	-6.141	-0.079	-1.794	6.398	-0.001	-0.000	0.001
Max Y	5	2:IRC: ULS CLA	-6.102	3.665	-0.404	7.129	-0.000	-0.000	0.001
Min Y	1529	1:DL	0.015	-51.203	-0.287	51.204	-0.000	0.000	-0.005
Max Z	24	3:IRC: ULS CLA	0.129	-0.062	1.135	1.144	0.001	0.000	0.000
Min Z	1	2:IRC: ULS CLA	-6.126	-20.562	-2.212	21.569	-0.000	-0.000	0.005
Max rX	113	1:DL	0.016	-16.167	0.367	16.172	0.005	0.000	-0.004
Min rX	1662	1:DL	0.016	-16.168	-0.367	16.172	-0.005	-0.000	-0.004
Max rY	1725	1:DL	0.030	-0.133	-0.403	0.425	-0.002	0.000	0.000
Min rY	1720	2:IRC: ULS CLA	-6.137	0.623	-1.660	6.388	-0.001	-0.000	0.000
Max rZ	457	1:DL	-0.034	-18.416	0.184	18.417	-0.000	0.000	0.008
Min rZ	468	1:DL	0.034	-18.416	0.184	18.417	-0.000	-0.000	-0.008
Max Rst	1529	1:DL	0.015	-51.203	-0.287	51.204	-0.000	0.000	-0.005

Table 10

Beam Displacement Detail Summary

Displacements shown in italic indicate the presence of an offset

	Beam	L/C	d (m)	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	68	2:IRC: ULS CLA	0.100	3.707	0.193	-1.077	3.865
Min X	2	2:IRC: ULS CLA	0.000	-6.141	-0.079	-1.794	6.398
Max Y	9	2:IRC: ULS CLA	0.000	-6.102	3.665	-0.404	7.129
Min Y	334	1:DL	0.900	0.014	-51.205	0.289	51.206
Max Z	40	3:IRC: ULS CLA	0.000	0.129	-0.062	1.135	1.144
Min Z	1	2:IRC: ULS CLA	0.000	-6.126	-20.562	-2.212	21.569
Max Rst	334	1:DL	0.900	0.014	-51.205	0.289	51.206

Table 11

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	39	52	2:IRC: ULS CLA	3.707	0.172	-1.085	3.866
Min X	2	2	2:IRC: ULS CLA	-6.141	-0.079	-1.794	6.398
Max Y	9	5	2:IRC: ULS CLA	-6.102	3.665	-0.404	7.129
Min Y	1930	1529	1:DL	0.014	-51.203	-0.287	51.204
Max Z	40	24	3:IRC: ULS CLA	0.129	-0.062	1.135	1.144
Min Z	1	1	2:IRC: ULS CLA	-6.126	-20.562	-2.212	21.569
Max Rst	1930	1529	1:DL	0.014	-51.203	-0.287	51.204

Table 12

Beam Maximum Forces by Section Property

Section		Axial	Shear		Torsion	Bending	
		Max Fx (kN)	Max Fy (kN)	Max Fz (kN)	Max Mx (kNm)	Max My (kNm)	Max Mz (kNm)
Cir 2.00	Max +ve	3.4E+3	371.059	869.892	0.000	4.35E+3	1.86E+3
	Max -ve	-109.032	-371.059	-869.892	0.000	-4.35E+3	-1.86E+3
Rect 1.00x1.00	Max +ve	584.572	1.3E+3	49.518	583.174	41.139	3.98E+3
	Max -ve	-135.926	-1.3E+3	-49.518	-583.174	-41.139	-1.48E+3
Rect 1.00x1.00	Max +ve	462.787	993.027	49.398	583.175	41.065	3.82E+3
	Max -ve	-67.577	-1.13E+3	-49.398	-583.175	-41.065	-1.48E+3
Rect 0.50x0.50	Max +ve	98.918	311.248	29.913	127.003	19.825	723.443
	Max -ve	-79.206	-311.248	-29.913	-127.004	-19.825	-206.531

Table13

Plate Centre Principal Stress Summary

	Plate	L/C	Principal		Von Mis		Tresca	
			Top (N/mm^2)	Bottom (N/mm^2)	Top (N/mm^2)	Bottom (N/mm^2)	Top (N/mm^2)	Bottom (N/mm^2)
Max (t)	589	1:DL	-9.113	17.125	15.024	14.832	17.341	17.125
Max (b)	589	1:DL	-9.113	17.125	15.024	14.832	17.341	17.125
Max VM (t)	589	1:DL	-9.113	17.125	15.024	14.832	17.341	17.125
Max VM (b)	589	1:DL	-9.113	17.125	15.024	14.832	17.341	17.125
Tresca (t)	589	1:DL	-9.113	17.125	15.024	14.832	17.341	17.125
Tresca (b)	589	1:DL	-9.113	17.125	15.024	14.832	17.341	17.125

Table14

Reaction Summary

	Node	L/C	Horizontal	Vertical	Horizontal	Moment		
			FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	29	1:DL	371.059	3.4E+3	103.452	0.000	0.000	0.000
Min FX	28	1:DL	-371.059	3.4E+3	103.452	0.000	0.000	0.000
Max FY	29	1:DL	371.059	3.4E+3	103.452	0.000	0.000	0.000
Min FY	29	2:IRC: ULS CLA	64.323	-109.032	53.277	0.000	0.000	0.000
Max FZ	35	1:DL	176.342	1.77E+3	869.892	0.000	0.000	0.000
Min FZ	27	1:DL	176.342	1.77E+3	-869.892	0.000	0.000	0.000
Max MX	26	1:DL	-176.342	1.77E+3	-869.892	0.000	0.000	0.000
Min MX	26	1:DL	-176.342	1.77E+3	-869.892	0.000	0.000	0.000
Max MY	26	1:DL	-176.342	1.77E+3	-869.892	0.000	0.000	0.000
Min MY	26	1:DL	-176.342	1.77E+3	-869.892	0.000	0.000	0.000
Max MZ	26	1:DL	-176.342	1.77E+3	-869.892	0.000	0.000	0.000
Min MZ	26	1:DL	-176.342	1.77E+3	-869.892	0.000	0.000	0.000

Table15

Base Pressure Summary

	Node	L/C	FX (N/mm^2)	FY (N/mm^2)	FZ (N/mm^2)
Max FX	26	1:DL	0.000	0.000	0.000
Min FX	26	1:DL	0.000	0.000	0.000
Max FY	26	1:DL	0.000	0.000	0.000
Min FY	26	1:DL	0.000	0.000	0.000
Max FZ	26	1:DL	0.000	0.000	0.000
Min FZ	26	1:DL	0.000	0.000	0.000

4.2Vehicle Loading

The loading vehicle details are given: Design Code = IRC Chapter 3

Loading Class = Class 70R Loading

Max. Effect = 9.39626m

Unit of Length = m Unit of Force = kN Combination Factor = 1

No. of Traffic Lanes = 6

Traffic Lane number 1

Lane Factor = 1

The loading vehicle details are

Width = 2900

Front Clearance = 31675

Rear Clearance = 31675

No. of Axles = 3

Vehicles travel in the roadway direction

Table 4.2.1

Vehicle No.	Position x	Position y	Orientation
1	17.171	0.05	0

End Lane

Traffic Lane No. 2

End Lane

Traffic Lane No. 3

Lane Factor 1

The loading vehicle details are

Width = 2900

Front Clearance = 31675

Rear Clearance = 31675

No. of Axles = 3

Vehicles travel in the roadway direction

Table 4.2.2

Vehicle No.	Position x	Position y	Orientation
1	11.9501	88.219	1.5708
2	11.9501	49.689	1.5708
3	12.05	-4.35305	1.5708

End Lane

Traffic Lane No. 4

Lane Factor 1

The loading vehicle details are

Width = 2900

Front Clearance = 31675

Rear Clearance = 31675

No. of Axles = 3

Vehicles travel in the roadway direction

Table 4.2.3

Vehicle No.	**Position x**	**Position y**	**Orientation**
1	8.0501	97.7264	1.5708
2	8.05005	50.1894	1.5708
3	7.95	-2.85188	1.5708

End Lane

Traffic Lane No. 5

Lane Factor 1

The loading vehicle details are

Width = 2900

Front Clearance = 31675

Rear Clearance = 31675

No. of Axles = 3

Vehicles travel in the roadway direction

End Lane

Traffic Lane No. 6

Lane Factor 1

Table 4.2.4

Vehicle No.	Position x	Position y	Orientation
1	3.9501	99.728	1.5708
2	3.95005	49.689	1.5708
3	4.05	0.650844	1.5708

2. It cuts time and gives safe values required for its design.

3. By this approach of design, maximum loads created by STAAD. beava are transferred into STAAD.Pro. and the analysis and design is then carried out.

4. Max Bending Moment or Axial Force, deflection, plate stresses, moment about local x-axis, y-axis z-axis of the plate (Mx,My,Mz),load positions are carried out and the

The loading vehicle details are

Width = 2900

Front Clearance = 31675

Rear Clearance = 31675

No. of Axles = 3

Vehicles travel in the roadway direction

Table 4.2.5

Vehicle No.	Position x	Position y	Orientation
1	-1.74491	88.7194	1.5708
2	-1.74495	50.1894	1.5708
3	-4.43844e-006	-4.35305	1.5708

End Lane

4.3 Concrete Design Details

The concrete is designed for element no. 61 which gives

the following result:

For FY:413.682MPA; FC:27.579MPA; Cover(top):19.05mm; Cover(bottom): 19.05mm Longitudinal Direction-only minimum steel required; Transverse Direction – only minimum steel required;

Table 4.3.1

LONG.REINF (SQ.MM/MM)		MOM - X/LOAD (kN- MM/MM)	TRANS.REINF (SQ.MM/MM)	MOM-Y/LOAD (kN-MM/MM)
Top	0.540	24.16/2	0.540	0
Bottom	0.545	54.76/1	0.782	1

5. CONCLUSION

1. Analysis and design of the Deck Slab Bridge as per IRC codes (here IRC 70R loading) can be easily done by STAAD.Pro. in connection with STAAD.beava. mechanism is well understood.

6. The maximum resultant nodal displacement is for node 1529; 0..015mm in x, -51.203mm in y and -.287mm in x.

6. THE MAXIMUM RESULTANT BEAM DISPLACEMENT IS FOR BEAM

334; equivalent to 51.206

8. The maximum resultant beam end displacement is for beam 1930 and node 1529 equivalent to 51.204.

9. The maximum and minimum values for beam maximum forces by section property are computed for axial, shear and bending.

10. The effect of vertical loading for 6 traffic lanes showing width, front clearance, rear clearance, no. of axles, positon in x, position in y with orientation can be determined. The orientation varies from 0 to 1.5708.

11. The concrete design for element 61 gives the top and bottom longitudinal reinforcement is 0.540 and 0.545. The top and bottom transverse reinforcement are 0.540 and 0.780 for element 61. Similarly, for other element, it can be found out.

12. It is must for today's engineers, designers, research scholars to make an effective contribution to what is the purpose of each high quality design and for the improvement of quality of environment in which we all are residing. Thus evolution of software must be properly used so that it meets the beneficiary needs.

7. ACKNOWLEDGEMENTS

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