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ANALYSIS AND DESIGN OF BRIDGE COMPONENT USING STAAD PRO

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Abstract: In this study the T-beam bridge is to be analysis and design on the staad pro software. A T-beam bridge is composite concrete structure which is composed of deck slab, longitudinal girder and cross girder. This project looks on the work of analysis and design of bridge deck and girder on software staad pro v8i. The bridge model is taken of a particular span and carriageway width the bridge is subjected to IRC loadings like IRC Class AA tracked loading etc. In order to obtain maximum bending moment and shear force from the analysis it is observed and understand the behavior of bridge deck and girder under different loading condition and comparing the result. The different codes of design will be use in this project they are IRC 5-2015, IRC 6-2016, IRC 112-2011, IRC 21-2000. In this study bridge slab is design by pigeauds method and longitudinal and cross girders is design by courbon's method and IRC class AA tracked loading and class A loading will be used.

Index Terms - T-beam bridge, Staad.pro software, IRC Codes, IRC class AA tracked loadings, pigeauds and courbon's method, bending moment and shear force.

1 INTRODUCTION:

A bridge is a structure having a total length above 6m for carrying moving loads or pedestrian load and across the obstacle, a bridge is a structure which is built over an obstacle and hence providing a passage without obstructing the object. The passage may be for a railway, a road, a pipeline, a valley, or a canal. The development of the country based on the infrastructure available in the country. Highway which allows the flow of human beings and vehicles is a major part of infrastructure. the construction of bridge is necessary where there is a heavy traffic congestion which results in delay for the passengers. Construction of bridge will reduce the delay and allow the vehicles to travel without interruption. And It is also important to select the suitable type deck slab for different spans keeping good appearance and economy in consideration and construction. The planning of these structures has two important parts first is Traffic Assessment and second is layout and Structural design. As per IRC 92-1985, the bridge design is preferred when the [Passenger Car Unit] value at the intersection exceeds 10,000. IRC codes are developed and used from time to time based on the research work carried out all over the world. There are many different type of bridge designs that each have it's particular reason for design, the designs of bridges depending on the function of the bridge, the nature of the terrain where the bridge is constructed, and the material used to make it, and the funds provided to build it. Deck slab is that part of the bridge which transmitted the load passing the same to the substructure. T-beam are so called because the longitudinal girders and deck are cast monolithically i.e at the same time to form a T shaped bridge structure. A T-beam or beam and slab is constructed when the span is between 10-20 meter. The bridge deck essentially consists of a concrete slab monolithically cast over longitudinal girders so that T-beam formed. The number of longitudinal girders depend on the width of road. Three girders are normally provided for two lane road bridge. IRC 21-2000 code is used for designing RCC road bridges and IRC 112 are used for precast bridges design. Indian Roads Congress introduces new code of practice i.e. IRC 21 for designing of road bridges in India it is based on the w.s.m and IRC 112 is based on the limit state method. The Superstructure consists of longitudinal girder, cross girder, deck slab, cantilever portion, handrails, and wearing coat kerb and crash barrier, bearings etc. Cross beam are provided mainly to stiffen the girders and to minimized torsion in the exterior girders these are essential over the supports to prevent lateral spread of the girders at the bearings another function of the cross beams is to equalize or balance the deflections of the girders carrying heavy loading with those of the girders with less loading. The web of the beam below the compression flange are provided to resist shear stress. The bridge superstructure and other component of bridge, is subjected to a set of loadings condition which the component must with stand and effectively take the load. The design of bridge is based on these loadings. These loads may vary depending on duration, direction of action, type of deformation and nature of structural action such as (shear, bending, torsion etc.). In bridge there are mainly two type of loading first is dead load which is self-weight of bridge acting as a UDL and second is live load which is consider as vehicle load which act as a point load on the bridge and the other type of loading like wind load and impact load etc. which are taken in to the account according to the situation. In order to form a consistent basis design, the IRC has developed a set of standard loading condition, which are taken into account and use while designing while designing a bridge. IRC has developed four type of live load condition they are,

(1) IRC Class 70R Loading: IRC Class 70R Loading is applied for permanent bridges and culverts. Bridges designed for class 70R loading is checked for Class A loading.
(2) IRC Class AA Loading: IRC Class AA Loading is adopted within municipal limits for existing and industrial areas.
(3) IRC Class A Loading: IRC Class A loading is adopted for all roads on which permanent bridges and culverts are to be constructed.
(4) IRC Class B Loading: IRC Class B loading is adopted for timber bridges.

1.1 Objective:

1) Analysis and design of bridge using staad pro and result are compared with manually
2) To understand the effects class A and class AA of loading condition
3) In this T beam Bridge the bridge deck is design by pigeaud's method and longitudinal and cross girder is design by courbon's method it is carried out under standard IRC loadings.
4) In this project a comparative study on the behavior of simply supported RC T-beam Bridge with respect to bending moment, shear force and area of steel under standard IRC loading.

2 METHODOLOGY:

2.1.1 In this study A typical tee beam bridge is considering having the component longitudinal girder, continuous deck slab and cross beam, the cross girders are provided a lateral rigidity to the bridge deck. The deck slab is design by pigeauds method and the longitudinal and cross girder is design by courbon's method the particular bridge model is taken then that model is analysis and design on the staad pro and also analysis and design with manually. Result are comparing between staad pro and manually with considering the class A and class AA tracked loadings.

2.1.2 Staad pro procedure:

Staad pro in space is Operated with unit meter and Kilo Newton. the properties of section are assigned to the bridge. Fixed Supports are taken. Quadrilateral meshing is done by ¼ of the dimension taken followed by assigning of plate thickness.3D rendering can be viewed. Loads are taken by the loads and definitions. By Post Processing mode, Nodal displacement, Max. Absolute Stress value for the bridge can be viewed and Run analysis is operated. Then go through the bridge model creating a deck defining proper carriageway width in define road way after that IRC loading are applied and then run as load generator after that for concrete design code IS 456 is used that code is applied on all the element and finally run and analysis command is used to compare the result.

2.2.1 Slab:

The wheel load is partially considered as a concentrated load on slab. This load is get dispersed with its effect along spanwise and width wise. Thus, the load will get distributed along a particular span and width of the slab. there are three method available for analysis of slab subjected to concentrated loads.

1) Effective width method: This method is applicable to one-way slab which are supported on two opposite edge.
2) Pigeauds method: this method is used for two-way slab which is supported on all four edges.
3) Westergaards method: this method is use in particular condition so it is rarely adopted.

2.2.2 Pigeaud's method:

In this method short span and long span bending moment coefficient are read from curve developed by M. Pigeaud's. these curves are used for slab supported on all four edges restrained comer and subjected to symmetrically placed loads distributed over some well define area. The pigeaud's has given the curve for calculation bending moment but for shear force nothing is mentioned by pigeauds so the shear force is calculated by effective width method.

Considering Poisson ratio = $\mu = 0.15$

$V = l + 2t$

$U = b + 2t$

Short span moment=Mb= $W (m_1 + 0.15\, m_2)$

Long span moment =Ml= $W (m_2 + 0.15\, m_1)$

Where, M_1 = Short span moment

M_2 = Long span moment

μ = Poisson's ratio = 0.15 (as per IRC:112)

m_1, m_2 = moment coefficient from Pigeaud's curve

2.3.1 Girders:

The bridge load is transfer from deck to the superstructure and then supporting substructure element. It is very difficult to imagine how these loads get transferred If a vehicle is moving on the top of a particular beam, it is reasonable to say that, this particular beam is resisting the vehicle load. However, this beam is not alone; it is connected to adjacent members through the slab and cross girders which help to transfer the load to the sub-structure. This connectivity allows different members to work together in resisting loads in this study there are the t-beam bridge is designing that is slab and beam. For determining the fraction of the load carried by the longitudinal girders are find by several methods which have been suggested. Among them, the rational ones are:

1) Guyon-Massonet Method
2) Hendry-Jaegar Method
3) Courbon's Method.

2.3.2 Courbon's method:

In this paper we are adopted courbon's method to design the bridge girder. Courbon's method popularly used due to simple process. When the live loads are positioned nearer to the center of gravity the live load acts eccentrically with the center of gravity of the girder system. because of the eccentricity, the load sheared by each girder's is increased or decreased depending upon the position of girders. This method is simplest and is applicable when the following conditions are satisfied.

i. Ratio of span to length should be within 2 to 4
ii. Cross girders have depth should be at least 0.7 times that of longitudinal girders
iii. At least five symmetrical cross girder connecting longitudinal girder are present.

$$P_i = \frac{P}{n}\left[1 + \frac{n.e.d_i}{\sum d_i^2}\right]$$

Where,

P = total concentrated live load

n = number of longitudinal girders

e = eccentricity of live load with respect to axis of bridge or center of bridge

di= distance of girders from the axis of bridge.

I = Moment of Inertia of each longitudinal girders

2.4 Loadings**:**

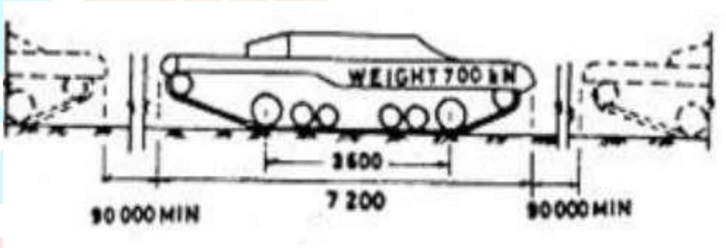
2.4.1 Dead load:

The dead load on a superstructure is the aggregate weight of all superstructure elements such as the deck wearing coat, railings, parapets, stiffeners and utilities.

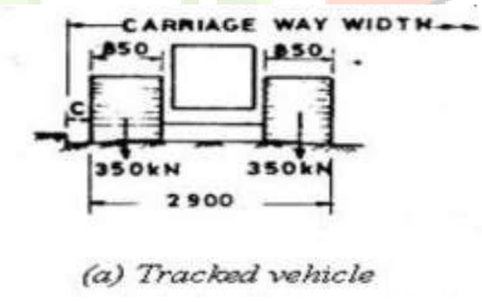
2.4.2Vehicle live load:

class AA tracked vehicle loading

axle load (ton)	ground contact area	
	w (mm)	l (mm)
350 kn	0.85	3.6



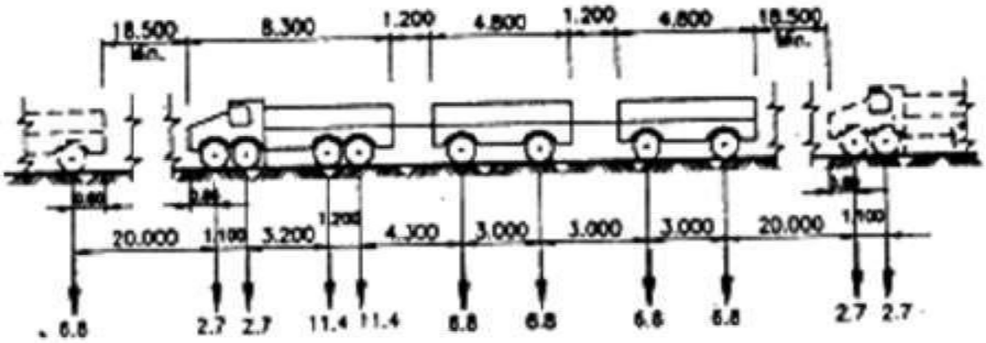
class AA tracked loading



elevation of class AA tracked loading

class A vehicle loading

axle load (ton)	ground contact area	
	b (mm)	w (mm)
11.4	250	500
6.8	200	380
2.7	150	200



Class A loading

2.4.3 Impact effect: Impact factor is considering as per IRC 6-2016

i. Impact factor for class A loadings for reinforced concrete bridge = (4.5/6+L)
ii. Impact factor for class AA loadings for tracked vehicles = 25 percent for span up to 5m linearly reducing to 10 percent for span up to 9m

2.4.4 The self-weight of bridge in staad pro is taken as:

direction	factor
y	-1.000

2.5 Minimum clearance for class AA loading and A loadings:

Class AA loadings

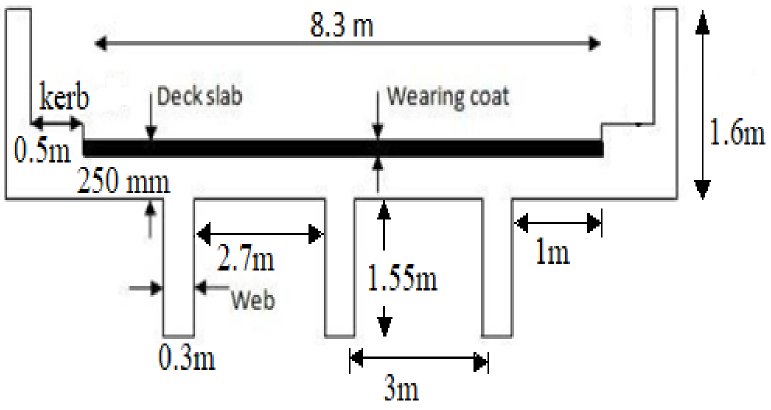
carriageway width	minimum value of c in (m)
single lane bridges up to width of 5.3 m	0.3
multi lane bridges more than 5.3 m	1.2

Class A loadings

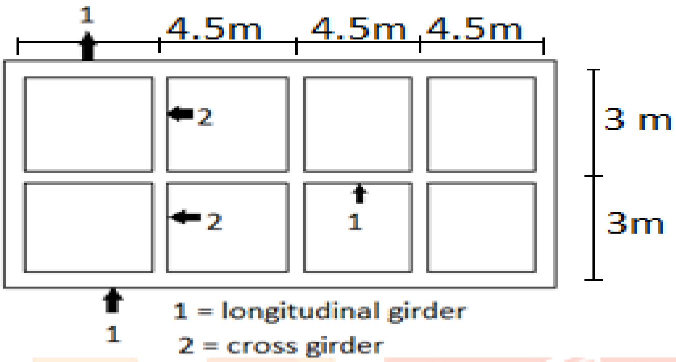
clear carriageway width	g	f
5.5m to 7.5m above 7.5m	uniformly increasing from0.4m to1.2m	150 mm for all carriageway width

2.6.1 Model

i. Clear Roadway = 8.3m (two lane bridge)
ii. Span of T – Beam = 18m
iii. No. of Longitudinal girders = 3
iv. c/c of Longitudinal girders = 3m
v. Thickness of deck slab = 250mm
vi. Thickness of wearing coat = 80mm
vii. Width & depth of Long girder = 300mm, 1.55m
viii. Width & depth of cross girders = 300m, 1.55m
ix. Live Load = IRC class A loadings and class AA loadings
x. μ = 0.15
xi. kerb wide 500mm and depth 600mm
xii. Number of cross girders =5
xiii. Spacing between cross girder = 4.5m c/c spacing
xiv. Railing = 0.7 KN/m
xv. Use M35 grade of concrete, Fe415 grade of steel
xvi. design constant: m=8.115, k=0.32, j=0.893, q=1.643.



cross section of a bridge deck



Plan of bridge

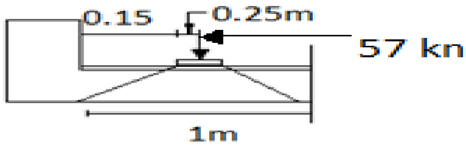
2.6.2 Deck slab:
Total dl on slab = 108.13kn
u/b = 1, v/l= 1, k=0.667, 1/k=1.50
mb = 108.13(0.047+0.15*0.02) =5.406kn*m
ml = 108.13(0.02+0.15*0.047) =2.924kn*m
Taking continuity effect=0.8 = ml=2.339, mb=4.324
Shear force= wl/2 = 5.35 (total w =6.25+1.76=8.01, l=2.7)

IRC class AA tracked vehicle loadings (live load): As the live load is IRC class AA one wheel can be accommodated centrally on the panel so as to produce maximum bending moment.
u/b= 0.34, v/l= 0.84, b/l=k=0.7
ml=350(0.039+0.15*0.098) =18.795kn*m
mb=350(0.098+0.15*0.039) = 36.34kn*m
Applying the impact factor=25% and continuity factor 0.8 are consider
mb=1.25*0.8*36.34=36.34
ml = 1.25*0.8*18.80=18.80
Total B.M on the short span =36.34+4.324=40.664
Total B.M on the long span = 18.80+2.33=21.13
Total shear force =62.689kn
Check for depth = M.R =qbd^2, d=157.31mm, d provided= 204mm
Ast along short span = Ast= 1119.85 -12mm @ 100mm c/c spacing
Ast along long span =Ast= 581.90minclm -12mm @ 150mm c/c spacing

IRC class A vehicle loadings (live load):
Intensity of wheel on small area of contact = (57/0.66*0.41) =210.64kn/m^2
Centrally placed concentrated load is = 210.64*0.66*1.61=223.14kn
Here, u/b=0.22, v/l= 0.36, k=0.7mba= 223.14(0.17+0.15*0.09) =42.78kn*m
mla = 223.14 (0.09+0.15*0.17) =26.93kn*m
Moment for the arrangements:
u/b= 0.22, v/l=0.175, k=0.7, m1=0.19, m2=0.11
mbb=22.67, mlb= 15.21
mb=22.45kn*m, ml=13.73kn*m (including dl)
Total shear force =35.14kn
Check for depth= M.R =qbd^2, d=116.92 d provided= 204mm

Ast along short span =Ast=611.38 -12mm@170mm c/c spacing
Ast along long span= Ast=399.6 -10mm@170mm c/c spacing

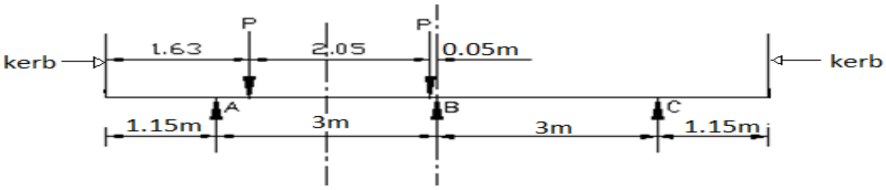
2.6.3 Design cantilever portion by class A loading



Cross section of cantilever portion

Total dl load on cantilever = 16.45kn, B.M due to dead load=14.11
Distance of C.G of the wheel from the edge of the cantilever =1000 - 400=600
Dispersed length of the load along the span=500+2*(0.25+0.08) =1.16
Total concentrated load =w/2*1.16=114/2*1.16=49.137
Effective width =1.2*x+b1=1.13
Impact factor =4.5/6+l=4.5/6+1.5=0.6, considering impact effect 0.5.
Live load =43.47, B.M due to dead load= 37.81
Total B.M= 51.95kn*m
Design shear force= 89.37kn
Check for depth =MR=qbd^2, d=177.81mm, d provided 204mm
Ast main =1430.65, 12mm@ 75mm c/c spacing
Ast distribution = 410.34, 8mm @ 120mm c/c spacing

2.6.4 Design of longitudinal girder:
Design of longitudinal girder for class AA tracked loading

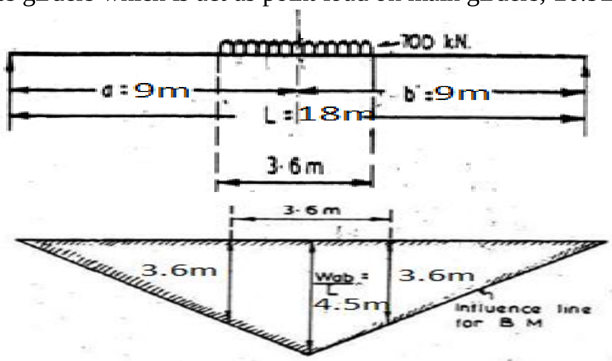


Arrangement of IRC class AA tracked loading

Using courbon's method taking out reaction

$$P_i = \frac{P}{n}\left[1 + \frac{n.e.d_i}{\sum d_i^2}\right]$$

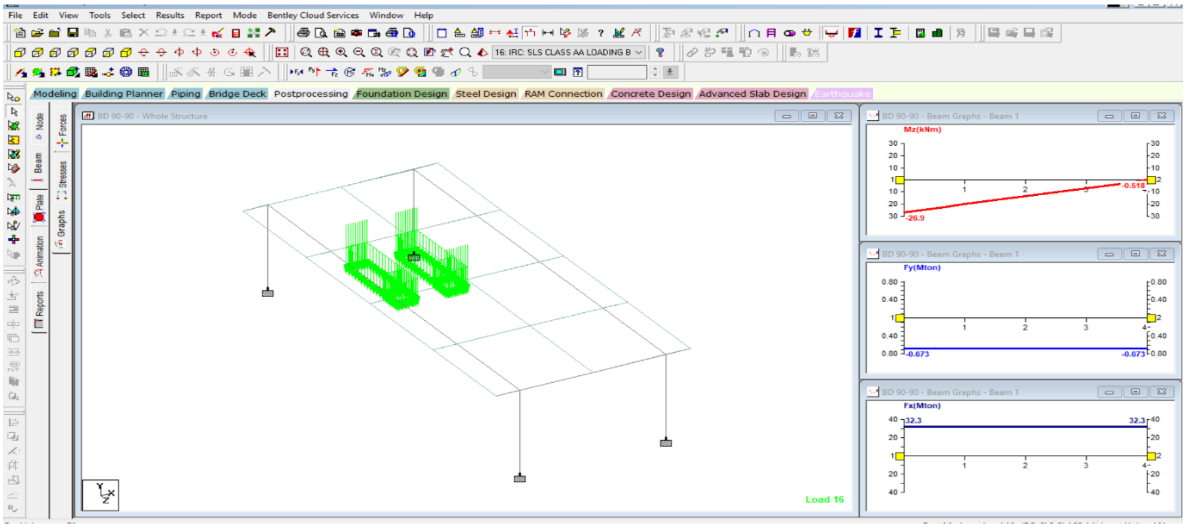
n=3, e=1.075, di=3
Reaction on outer girder = 1.167*w/2, 0.58w
Reaction for inner girder =di=0, 0.33w
Total dl on the on all girder = 83.36
This dead load is assumed to be taken equally by 3 girders we have=83.36/3=27.786 kn
The depth of the girder is taken as 10 cm per meter=18*10=180, 180-25=155cm, 1.55m
The self-weight of rib per meter length = 0.3*1.55*25=11.625
The weight of the cross girder also acted on the longitudinal girder in the form of concentrated load assumed the same dimension of cross girder (excluding the rib of main girder) = 62.77kn, this load is taken equally by main girders= 62.77/3 =20.92kn
Total udl on each girder = 39.41 kn/m, cross girders which is act as point load on main girders, 20.92kn



Arrangement of IRC class AA tracked loading

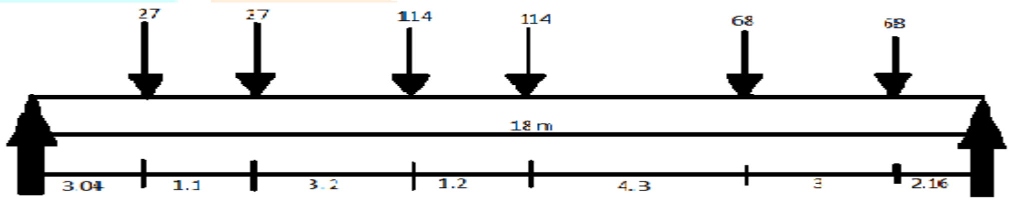
B.M max of dl=1784.38 kn.m, S.F max of dl=386.07kn
Live load: the maximum live load B.M occur when IRC class AA vehicle is centrally placed on the girder
Live load B.M =intensity of load *area cover by udl= (2*trapezoidal area *load)/3.6=2835kn .m
Impact factor is taken as 1.1
B.M for inner girder=1030kn.m, B.M for outer girder= 1808.73 kn.m, max B.M =1808.73+1784.38(dl+ll) =3593.11kn*m
Maximum shear force will be developed in the girder when live load is near the girder. This load will be place between the support and the exterior girder.

Reaction on outer girder =w1= (350*2.53)/3=295.16kn, w2= (350*0.48)/3=56kn, total on outer girder=349.99kn
Reaction on inner girder=w1= (350*0.475)/3=55.416kn, w2= (350*2.525)/3=294.58kn, total on inner girder=351.16kn
Max S.F on outer girder (349.96*16.2)/18=314.996, max S.F on inner girder = (351.2*16.2)/18=316.04, total S.F(dl+ll) =702.11kn
Ast = 13921.38, 11 number- diameter 40mm, stirrups=10mm @250 c/c spacing provided at support, and at center 10mm @300mm c/c spacing.



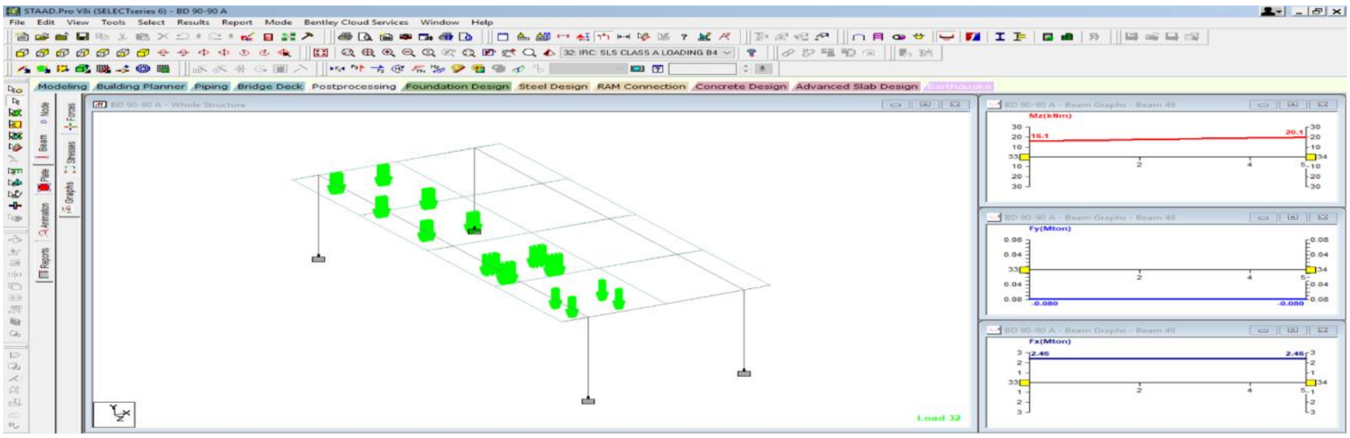
Class AA tracked loading in staad pro

Design of longitudinal girder for class A loading



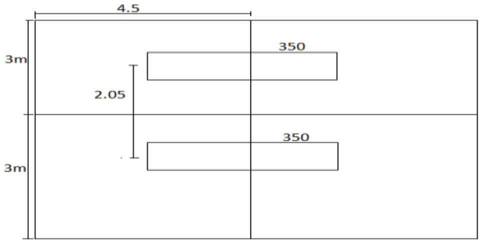
Arrangement of class A loadings

Reaction for outer girder=1.83 w1=0.915, reaction for interior girder= 1.33W1=0.667W
The absolute maximum bending moment always occurs under the wheel load and not in between the wheel load is occur at a section near the center of span under the heavier load which is near the center of gravity of the loading system consider
Total of load =27+27+114+114+68+68=418, x=6.42m
The c.g of the loading lies at a distance of 6.42 -91.1+3.2+1.20=0.92, impact factor=4.5/ (6+18) =0.1875
B.M due to live load (27*1.59) + (27*1.64) + (114*3.325) + (114*4.48) + (68*2.20) + (68*0.70) =1174.18
B.M of outer girder=0.915*1.19*1174.18=1278.50kn*m, B.M for inner girder = 0.667*1.19*1174.18=931.98
Total max B.M moment (dl=ll) = 1278.50+1784.38=3062kn*m
Reaction on outer girder w1= (114*1.9)/3=72.2kn, w2= (114*0.7)/3=26.6 total w=98.8kn
Reaction on inner girder w1= (114*1.1)/3=41.8, w2= (114*2.3)/3=87.4 total w =129.2kn
Ast = 11100.6, 10 number- diameter 40mm, stirrups=10mm @250 c/c spacing provided at support, and at center 10mm @300mm c/c spacing.



Class A loading in staad pro

2.6.5 Cross girders design:



Design of cross girder for class AA tracked loading

Total dl on slab = 23.638kn/m
As an approximate the reaction on each girder is given by, = (23.638*6)/3=47.28
Live load bending moment and shear force for class AA loading occur for the position of the load as shown in fig
The maximum load transfer to the cross girders= (350*2.1)/3=245, assuming equal reaction on each girder = (245*2)/3=163.33kn
Live load shear force =1.1*163.33=179.66, max B.M due to L.L =354.83, max B.M due to D.L =47.27
Design B.M =402.10kn*m, design shear force= 226.93knm
Area of steel = 1557.92, 5 number - 20mm diameter, stirrups 10mm diameter @ 300mm c/c spacing

2.6.6 design of kerb:
As the kerb is also a part of the deck slab the vehicular load will have influence in generating B.M in the kerb this bending moment is normally taken as 50% of the live load obtained for the slab.
Total dead load on kerb=8.2
Bending moment due to dead load= 22.68
Bending moment from slab =51.95*0.5=25.975
Design moment (dl+ ll) = 48.655 kn.m, safe in depth
Area of steel: 487mm^2, 3numbers, diameter 16mm, stirrups 8mm-@300 c/c spacing

3 RESULTS AND DISCUSSION:
3.1 The output data for the IRC Class AA tracked and class A loadings are considered from staad pro which include, nodal displacement summary, beam end force summary, reaction summary, axial forces, beam moments, live load effect and many more effect are consider by staad Pro. As per IRC 6-2016 bridge design for class AA loadings should be checked for class A loadings also as it is found that under certain cases heavier stress may occur under class A loadings. And as given in IRC 6-2016 for class A loading that this type of loading is adopted on all roads in which permanent bridge are constructed.

3.2 Result of deck slab panel:

Staad pro result in maximum plate corner displacement Y mm

Slab bending moment and shear force result

class of loadings	bending moment(kn.m)	shear force(kn)	depth(mm)	area of steel (mm)
class aa tracked	40.664 along short span	62.689	safe	12mm @ 100mm c/c spacing
	21.13 along long span			12mm @ 150 c/c spacing
class a loading	22.45 along short span	26.28	safe	12 mm @ 170c/c spacing
	13.73 along long span			10 mm @ 190 c/c spacing

As the result are showing that the heavier stress is develop in class AA tracked loading, the depth in both the type of loading is safe.

3.3 Design of cantilever portion:

As the minimum clearance of class AA tracked loadings from kerb is 1.2m. and the minimum clearance available for cantilever is 1m so design for class A loadings

class of loadings	bending moment (kn.m)	shear force (kn)	depth(mm)	area of steel (mm)
class a	51.95	89.37	safe	main 12mm @75mm c/c spacing
				distribution 8mm @120mm c/c spacing

3.4 Result of longitudinal girder:

Bending moment and shear force value of longitudinal girder

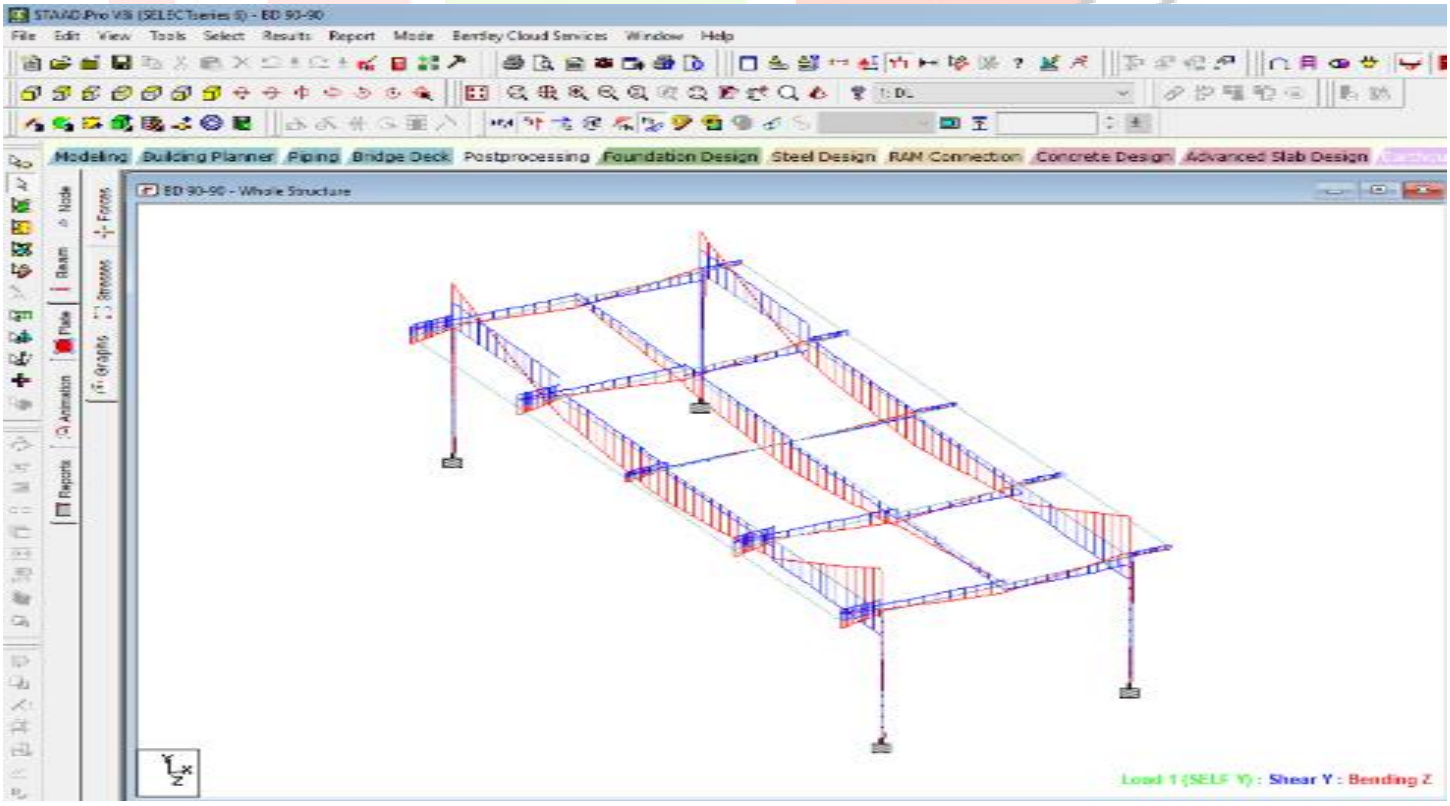
class of loading	bending moment (kn.m)	shear force (kn)	depth (mm)
class aa tracked (og)	3593.11	701.06	1550
class aa tracked (ig)	2814.00	702.11	1550
class a loadings (og)	3062.88	486.07	1550
class a loadings (ig)	2716.37	506.65	1550

Staad pro result

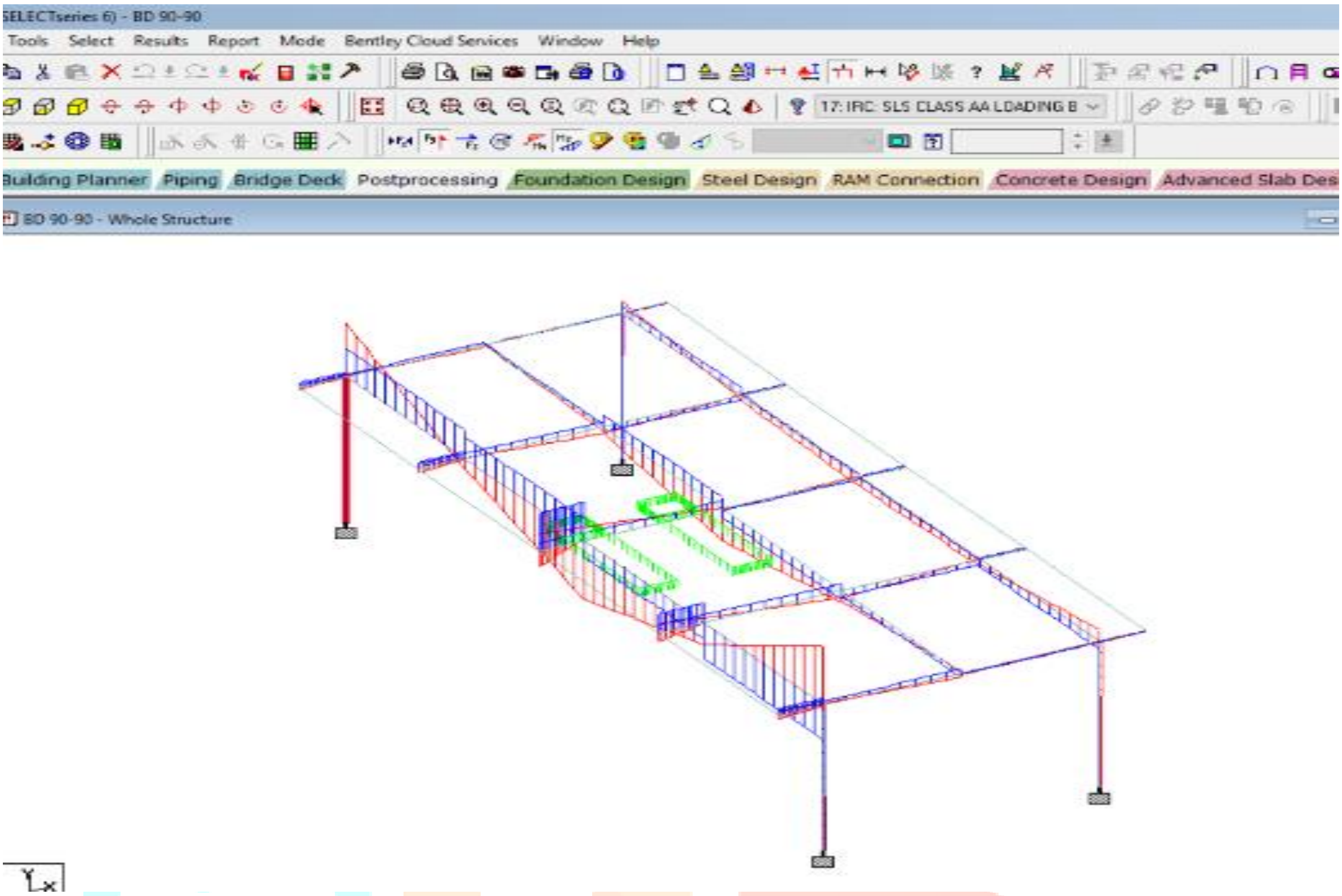
class of loadings	bending moment (kn.m)	shear force (kn)	depth (mm)
class aa tracked (og)	3315.26	688.39	1550
class aa tracked (ig)	2679.65	691.76	1550
class a loadings (og)	2843.92	465.12	1550
class a loadings (ig)	2508.46	487.54	1550

Result of cross girder

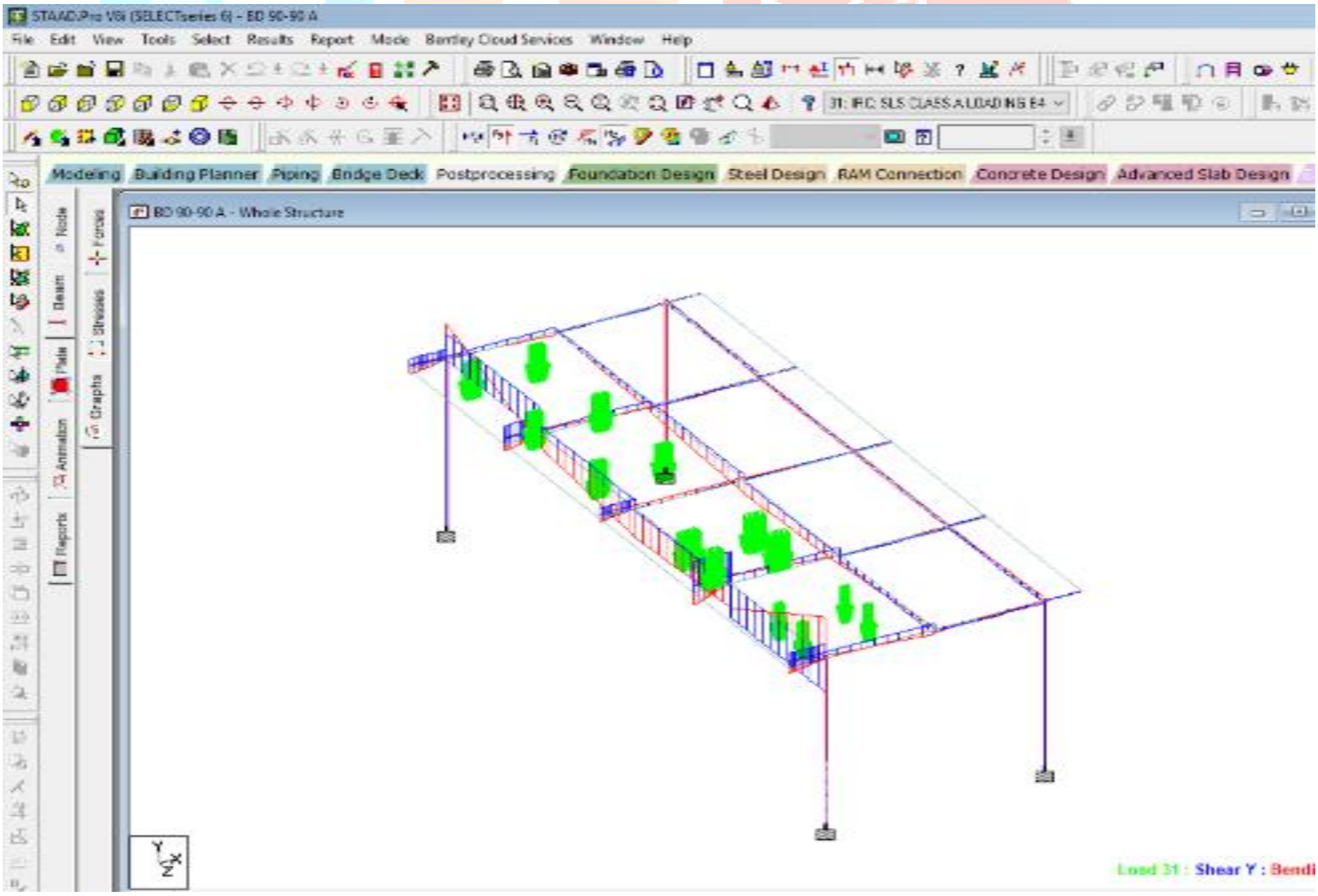
class of loadings	bending moment (kn.m)	shear force (kn)	depth (mm)
class aa tracked loadings	402.10	226.93	1550
staad pro result	370.287	204.36	1550



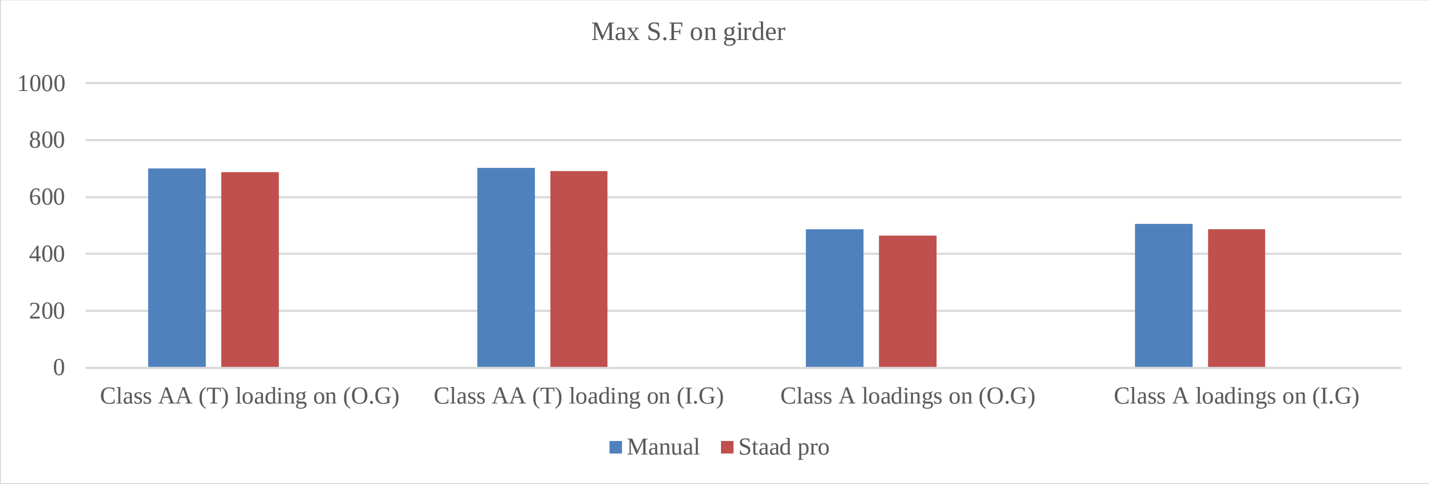
Bending moment and shear force due to dead load



Live load class AA tracked loading bending moment and shear force



Live load class A loading bending moment and shear force



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In this paper the analysis and design of Bending Moment and Shear force has been studied. from above graphs results of bending moment and shear force are compared by manual and STADD Pro. It is also observed that the density of concrete taken in the STAAD pro is 24kn/m^3, where the density of concrete taken manually is 25kn/m^3.

4 CONCLUSIONS

1. The specified reinforcement and spacing for the bridge are going to be figure out by analysis the value from staad pro.
2. This will give the entire study and behavior of bridge Structure under different IRC loadings condition on staad pro.
3. The software are very helpful for constructing the economically bridge structure.
4. It’s observed that the design mixture of concrete taken in the staad pro is M30, manually design by M35
5. Maximum BM occurs within the class AA Tracked loading vehicle so this loading is the most crucial case for maximum BM in longitudinal girder
6. The bending moment value occur in the outer girder is above the bending moment value occur within the inner girder.
7. The shear force value occur within the inner girder is more than the shear force value within the outer girder.
8. Maximum SF occurs for class AA Tracked vehicle loading so class AA Tracked vehicle loading case is the most crucial case for optimum Shear force in longitudinal girder.
9. Within the design of slab panel, Maximum shear force and the maximum bending moment value occur in the in the class AA tracked loading hence class AA tracked vehicle case is the most crucial case in the term of maximum shear force and bending moment.
10. According to the courbon’s method, the very best importance given to the Outer Girder and Second for Inner Girder.
11. Here we will clearly see the effect of the pigeauds method over the effective width method within the slab panel where the pigeauds method will be used for higher span, and use for two-way slab also.
12. The staad pro result nearly reaches the values obtained by courbon’s method for class AA tracked vehicle and for class A loading, for class AA Tracked and class A loadings the staad pro result is reduced by 5% to 10% as compared to courbon’s method.

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