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DESIGN AND ANALYSIS OF VOIDED DECK SLAB

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Abstract:Nowadays due to improvement and challenging situations in bridge design as voided slab becomes more popular.It is most advanced method which will improve productivity and reduce cost and time. Circular voids are often incorporated into concrete bridge decks to reduce their self-weight without greatly reducing their flexural stiffness.However, the voids within the structure and the analysis of the structure incorporating voids within the deck slab offers many advantages over a conventional solid concrete slab such as lower total cost of construction, reduced material use, and increased structural efficiency. However, the voids within the structure complicate the analysis of the structure. In this thesis, a manual analysis for both longitudinal and transverse directions of voided slab bridges is done as per the industrial standards. For transverse analysis, the bridge is idealized as a unite a nd analyze during STAAD pro software. The detailing of the complicated structure is also included to understand how the reinforcement is placed in the structure.

Index Terms- Voids, Longitudinal Analysis, Transverse Analysis, STAAD Pro, IRC loading (i.e. 70R loading & CLASS AA loading)

I. INTRODUCTION

These days, bridge construction plays a vital role in the development of cities and thus, has achieved great significance. They serve a free and undisturbed movement for traffic. It also plays an important role in the development of trade and industries, enhancing the progress of the nation. A prestressed concrete slab constitutes a great portion of bridges all around the world. Prestressed concrete was introduced into bridge construction in the very early period. In past decades wide varieties of new techniques have been developed. Along with new developments in technologies, spans became longer and the aesthetics and appearance of bridges became more important. Prestressed concrete bridges include a wide variety of different forms like cast-in-situ or precast concrete; continuous or cable-stay; simply supported; box-girders, slabs, or beams. Among a wide variety of prestressed concrete bridges, a study on solid and voided slabs has been carried out. A comparison regarding forces and moment in both cases for different spans and sections is done; thus, analyzing both cases for a better section to be used. Nowadays voided slab bridge is one of the advanced types of slab design that is useful for different purposes in the construction industry. For spans greater than 15 m, the dead load of a solid slab becomes more and to lighten the structure voids rectangular or circular cross sections are provided near the neutral axis. If the depth and width of voids are less than 60% of the overall structural depth, their effect on stiffness is small and the deck behaves effectively as a plate. Voided slab decks are usually constructed with cast-in-site concrete with permanent void formers or they can be precast pre-stressed concrete box beams post-tensioned transversely to show continuity in the transverse direction. It is one kind of slab which is constructed with voids and it is a precast concrete slab. They are considered self-weight-reducing bridges. Voided are considered as 60% of the thickness of this slab and they are circular in cross-section. Due to this treated as a single plate and the concept of theories of plates is applicable. If the voids are more than 60%, act as cellular. Incorporating voids in the deck increases the cost due to the complexity involved in the reinforcement designed to resist transverse bending.

However, the self-weight and area to be prestressed are reduced without affecting the second moment of the area. Also, shuttering costs are less when compared to cast-in-situ sections. If the designer wishes to reduce the structural depth this can be adapted providing proper stays when the concrete is poured and preventing floatation.

Comparison between normal deck slab with voided deck slab

a). Normal Slab bridges

Solid slab decks comprise a solid section, without beams or voids. This type of deck is commonly used in the construction of short-span bridges and culverts. As the slabs are solid, the cross-section from any point is a homogeneous structure. The construction of solid slab bridge decks is straightforward and easier. Also, the formwork required is very simple and easy. As the structure is solid and the cross-section homogeneous, the layout of reinforcement becomes very easy. There is no congestion of reinforcements created and thus, placing concrete becomes one and major backdrop of solid slabs is a very large volume of concrete. This affects cost and self-weight both. Due to high concrete volume, these slabs have a greater self-weight. This can be avoided to a certain extent by providing suitable variations in the thickness of the slab. But this shall be checked properly before commencing. Another method to reduce self-weight is by providing voids in the slabs. This is explained in voided slabs.

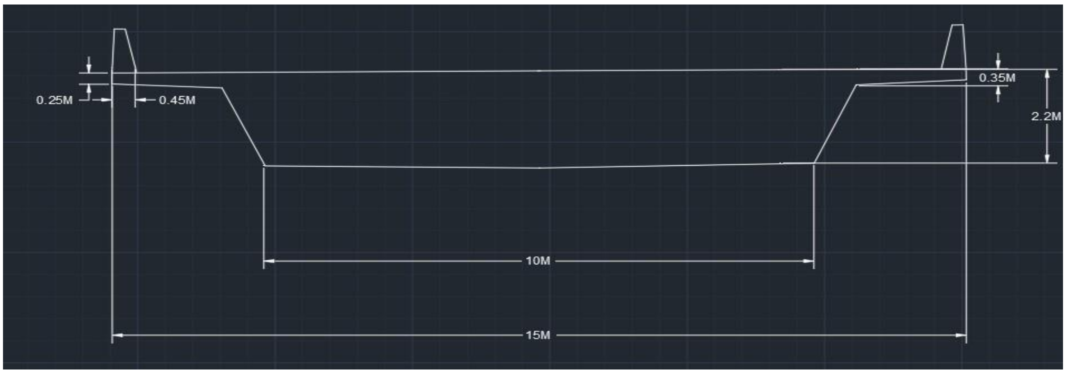


Fig.1. Normal deck slab.

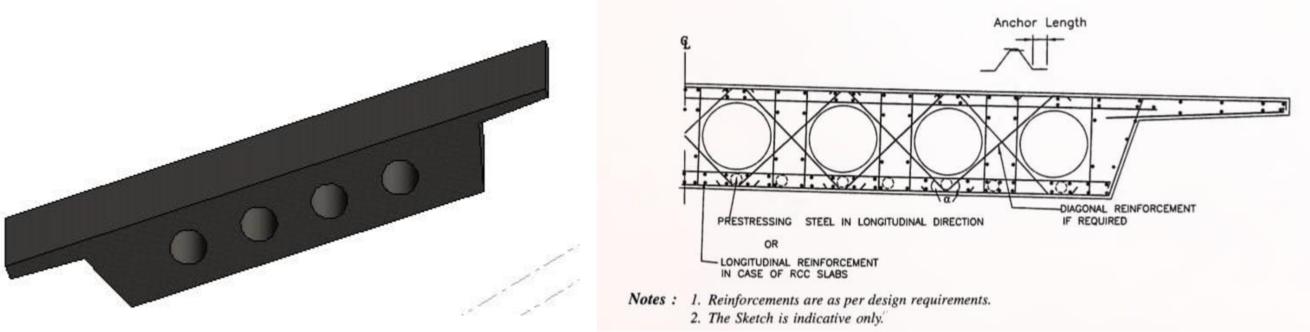
b). Voided slab Bridges

Voided slabs are characterized by the presence of voids within the Slab. As was discussed in the solid slab section voids in the slab help reduce the self-weight of the structure. Thus, the major function of voided slabs is to reduce the concrete volume and thereby decrease the self-weight of the slab. When the concrete is being cast, the void formers are subjected to large buoyancy forces. These buoyancy forces are resisted by straps tied to a barrier below the formwork.

If proper care is not taken during this process, it can create major difficulties; sometimes to the extent of demolishing the slab. Hence, it should be properly designed and the formers to be used must be sufficiently rigid, thoroughly sealed, and tied before commencement.

The voids are usually cylindrical and are constructed using hollow thin-walled steel sections placed in the slab. If designed properly, it can reduce the self-weight of the slab up to 35% as compared to the solid slab for the same section and span. The voided slabs can be modeled and designed by the method same as that is used for solid slabs in case of void diameters less than 60% of the depth of the slab. The voids can be rectangular or circular. For slabs provided with circular voids, the center-to-center spacing of the voids should not be less than the total depth of the slab. In the case of circular voids, the ratio of the diameter of the void to the total depth of the slab shall not exceed 75 percent to avoid a transverse distortional effect. The thickness of the web shall be as per clause 9.3.1.1 of IRC: 18-2000 for prestressed concrete slabs and as per clause 305.2 of IRC: 21-2000 for reinforced concrete slabs.

For reinforced concrete slabs: The thickness of concrete above the void shall not be less than 200 mm and that below the void shall not be less than 175 mm. For prestressed concrete slabs: If the cables are not located in the flanges, the thickness of the flange shall be governed by the provision as in per clause 305.2 of IRC: 21-2000 for reinforced concrete slabs If the cables are located in the flanges (not in the web region), the thickness of flanges shall be by the clause 16. 1 of IRC: 18-2000.



Notes : *1. Reinforcements are as per design requirements.*
2. The Sketch is indicative only.

Fig 2.Voided slab with reinforcement details as per IRC : 18-2000.

Forces acting on voided slab Bridge Loading

The following loads are to be considered in the design of a bridge superstructure

1.Dead Load and Superimposed Dead Load

For most of the bridges self-weight is the dominant loading. weight of the footpath, curb, crash barrier, handrail, wearing a coat, and permanent fittings like lamp posts and ducts are included under superimposed dead loads, which are in addition to the self-weight of the structure.

2. Live Loads

Bridge girders carry loads that roll over them from one end to the other. The Indian Road Congress in its code of practice for road bridges specifies different types of vehicular loads to be considered by giving wheel loads. The two IRC loading standards considered for the design are:

1. 70R Wheeled loading
2. Class AA loading

3. Impact Load

The impact load due to the collision effect shall be taken by an increment of live load as an impact factor expressed in terms of the percentage of live load. Impact factors for different classes of loadings are specified in IRC: 6-2014.

4. Temperature Stresses

Provisions shall be made for stresses or movements resulting from variations in the temperature. The effect of temperature difference within the superstructure shall be derived from positive temperature difference which occurs when solar radiation and other effects cause a gain in heat and reverse temperature differences which cause heat to be lost from the top surface. positive and reverse temperature differences for the design of concrete bridge decks shall be assumed according to Fig. 10 (a) of IRC: 6-2014.

5. Reduction in Longitudinal Effect

According to IRC: 6-2014 Cl 205, reduction in the longitudinal effect on bridges having more than two traffic lanes due to the low probability that all lanes will not be subjected to the characteristic loading simultaneously.

6. Live load Combination

The live load combination shall be as per Table 2 IRC: 6-2014 based on the number of lanes and the carriageway width. For a carriageway width of less than 13.1 m, the higher among the two combinations is taken

i. 1 lane of 70R +1 lane of class A
ii. 3 lanes of class A

The maximum of the above two combinations is taken for the final live load, bending moment, and shear force in the longitudinal direction

Advantages

•Reduction in dead up to the weight of 35% allows cost reduction in substructure i.e. footing and Piers. The structural engineer can lighten the floor by efficiently using the concrete. More

• Reduced concrete usage- The use of 1 kg recycled plastic void former can replace 100 kg of concrete thereby, leading to environmentally sustainable reduced carbon emissions during construction. It became green construction energy and carbon emissions. It allows longer spans between columns without increasing the thickness of the slab by large. Voided slabs can take advantage of post-tensioned reinforcement benefits to provide a thin slab with a greater span.

▪The elimination of down stand beams allows the quicker and cheaper erection of shuttering and services. Flat-plate construction eliminates beams and drops, resulting in reduced floor-to-floor heights.

- Some voided-slab systems can reduce construction time, especially precast systems or those placed on flat-plate forming systems.

Objectives

(i) To perform a manual analysis for different loading combinations as per IRC loading criteria.
(ii) To obtain the critical load positions that cause severe distress in the structure.
(iii) To get an overall idea of how the complicated bridge structures are designed in the industry.
(iv) Apply the concept in the design of bridges.
(v) Calculating maxlive load and BM max as per IRC loading conditions.

Problem statement

Through this project, working on the design and analysis of a cast-in situ voided slab bridge deck. It is considered a self-weight-reducing structure and not only economical but also reduces carbon emissions during construction. Voids within the deck slab offer many advantages over a conventional solid concrete slab like lower total cost of construction, reduced material use, and increased structural efficiency. This type of deck reduces weight of floors of its superstructure and also permits engineers to reduce columns, walls, and foundations by as much as 40%, although concrete can’t be removed from all locations in a floor slab; voids are omitted near columns to maintain punching-shear capacity

II.MATERIALS

Various types of void formers have been used, spirally wound sheet metal being an early form. The voids became full of water during construction which resulted in the overstressing of the deck. The use of expanded polystyrene overcomes the problem of water logging since the material consists of a series of small closed cells whose porosity is less when compared to the total volume. It also has the advantage of being readily cut using hot wire in a factory or using a hand saw in sit. Void formers are required to possess the necessary rigidity and integrity of dimensions in addition to being watertight. the void formers may be manufactured from materials, such as steel sheets, cardboard, fiber-reinforced cement, timber, expanded polystyrene, HDPE, etc. They are generally corrugated for rigidity. Special machines are available for the manufacture of corrugated steel void formers, identical to those used for the manufacture of prestressing cable ducts.

Fig.3 Especially wound metal sheet

III.RESEARCH METHODOLOGY

Problem dada for analysis

The voided slab bridge considered here is a RCCsimply supported bridge of span 60 m.
1 Carriageway width =14.1 m
2 Overall width = 15 m
3 Width of crash barrier = 0.45m.
4.Thickness of wearing coat=75 mm
5.Cantilever portion of deck=2 m
6. Thickness of cantilever deck slab=0.35 m

7. Depth of voided slab =2.1 m
8. No of circular voids in the deck=4
9. Grade of concrete=M60
10. Grade of steel =Fe 500
11. width of bearing=500 mm
12. Use 32 mm diameter bar and k=3

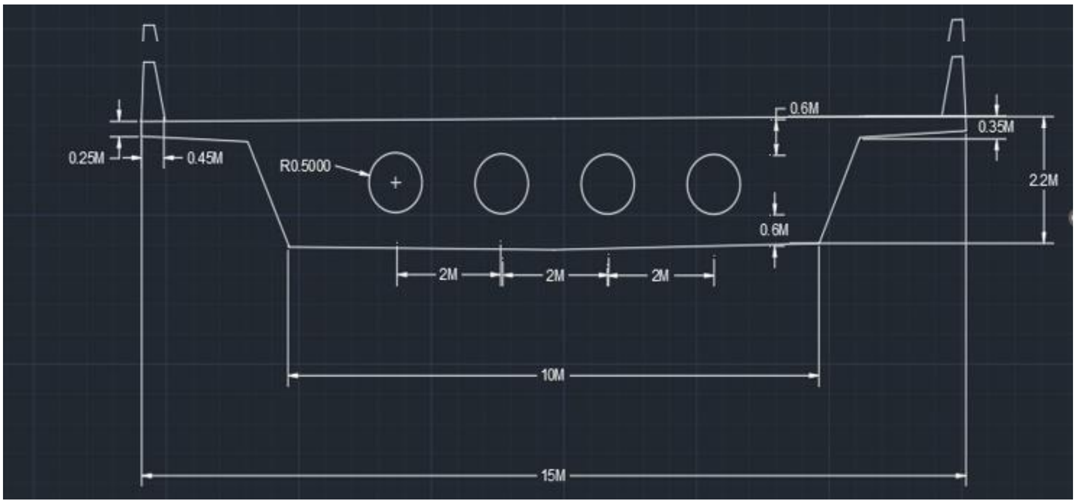


Fig.4 Details of voided deck slab

Analysis of Voided deck slab bridge.

The analysis is done separately for both longitudinal and transverse directions.

Longitudinal Analysis

In longitudinal analysis, the bending moment and shear force due to dead load and live load are found in the longitudinal direction. The effect due to impact, and temperature stresses are also included and a reduction is done in the longitudinal effect as all the lanes will not be subjected to characteristic loading.

Longitudinal Analysis and Transverse Analysis Both Deck Sab.

The analysis is done separately for both deck slab bridge voided slab deck bridge and normal slab deck bridge which is performed on STAAD PRO VI Software. Not only for longitudinal but also transverse direction analysis.

Longitudinal Analysis

In longitudinal analysis, the bending moment and shear force due to dead load and live load are found in the longitudinal direction.

Transverse Analysis

For analysis, various load positions for various types of loading are checked and the maximum response has to be found. For this, the wheel load of the vehicle is moved transversely such that it acts as a uniformly distributed load occupying different positions on the deck, and the maximum response can be calculated for each loading case. Since it will be getting computer analysis programs such as STAAD can be used. To analyze the effect due to live loads, the first unit load is run to obtain the influence ordinates.

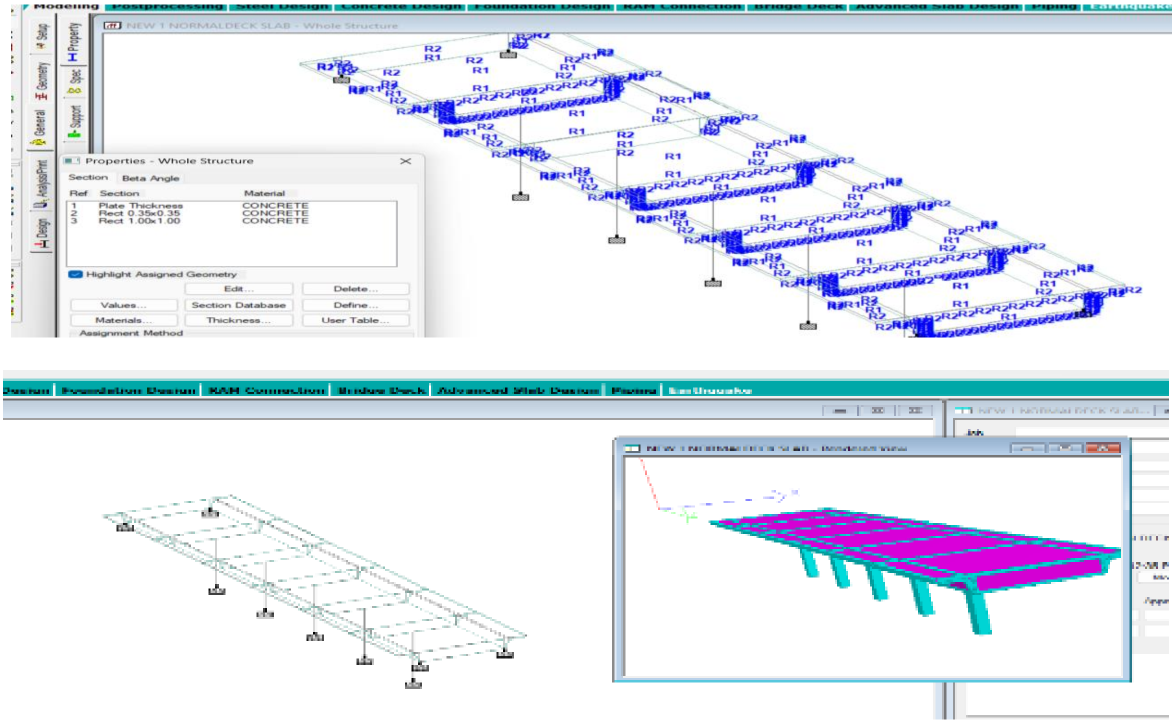
Then at each position of loading and combination, the effective width and equivalent concentrated load per meter run is calculated. Effective width for each location of load is calculated and thus each wheel load is converted to wheel load per unit width of the slab. For transverse analysis, live load is required which is getting from IRC code for standard live load. Following are two IRC loading standards considered for the design are:

1. 70R Wheeled loading
2. Class AA loading

The wheel load of the vehicle is moved transversely having different positions on the deck and the maximum response can be calculated for each of the loading cases. Since it will be tedious to manually calculate the response at every 0.1 m, a computer analysis program such as STAAD can be used. In voided deck slabs due to the impact of temperature stresses and the effect of live and various load combinations usually, cracks are generated inside voids. sometimes they are not so harmful and can be removed by applying mortar but many times they get dangerous and produce serious damage to the structure. To avoid these cracks usually rectangular shear reinforcement is provided around the voided section.

Detail Design of Normal deck slab bridge.

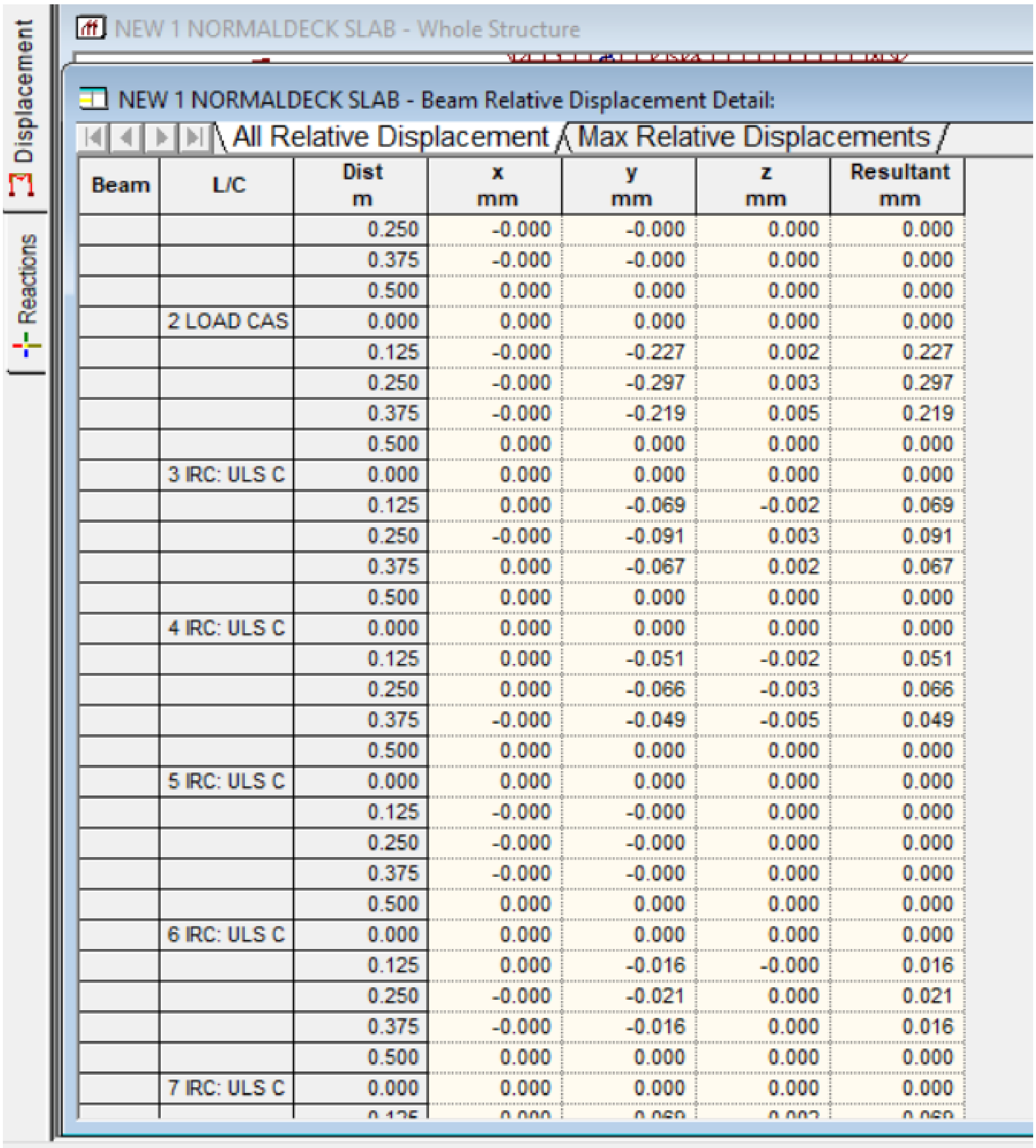
Once we prepared the geometry for the deck slab IRC load is applied on the deck slab as the effect of load following results are obtained in the case of normal deck slab



Ref	Section	Material
1	Plate Thickness	CONCRETE
2	Rect 0.35x0.35	CONCRETE
3	Rect 1.00x1.00	CONCRETE

Fig.5.: Detail design of normal deck slag

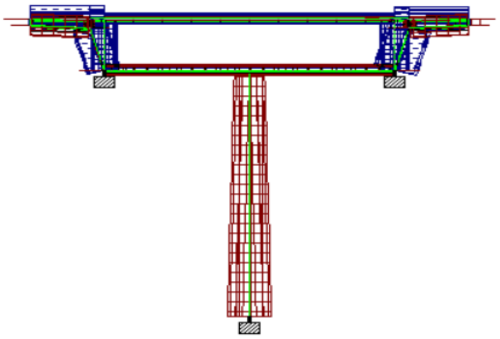
Table.1 Displacement table(Normal deck slab)



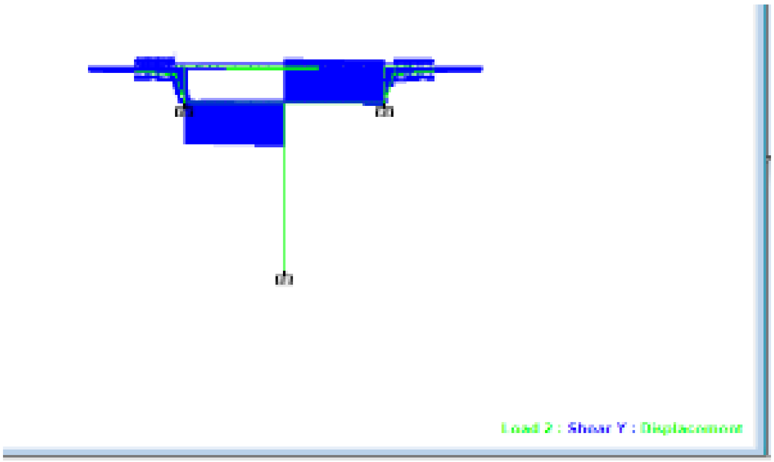
NEW 1 NORMALDECK SLAB - Whole Structure

NEW 1 NORMALDECK SLAB - Beam Relative Displacement Detail:

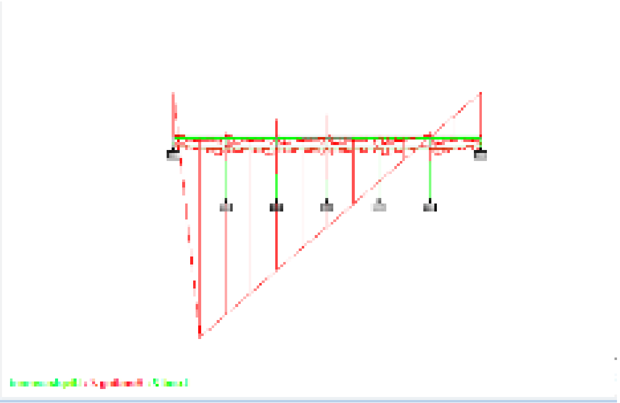
Beam	L/C	Dist m	x mm	y mm	z mm	Resultant mm
		0.250	-0.000	-0.000	0.000	0.000
		0.375	-0.000	-0.000	0.000	0.000
		0.500	0.000	0.000	0.000	0.000
	2 LOAD CAS	0.000	0.000	0.000	0.000	0.000
		0.125	-0.000	-0.227	0.002	0.227
		0.250	-0.000	-0.297	0.003	0.297
		0.375	-0.000	-0.219	0.005	0.219
		0.500	0.000	0.000	0.000	0.000
	3 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.125	0.000	-0.069	-0.002	0.069
		0.250	-0.000	-0.091	0.003	0.091
		0.375	0.000	-0.067	0.002	0.067
		0.500	0.000	0.000	0.000	0.000
	4 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.125	0.000	-0.051	-0.002	0.051
		0.250	0.000	-0.066	-0.003	0.066
		0.375	-0.000	-0.049	-0.005	0.049
		0.500	0.000	0.000	0.000	0.000
	5 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.125	-0.000	-0.000	0.000	0.000
		0.250	-0.000	-0.000	0.000	0.000
		0.375	-0.000	-0.000	0.000	0.000
		0.500	0.000	0.000	0.000	0.000
	6 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.125	0.000	-0.016	-0.000	0.016
		0.250	-0.000	-0.021	0.000	0.021
		0.375	-0.000	-0.016	0.000	0.016
		0.500	0.000	0.000	0.000	0.000
	7 IRC: ULS C	0.000	0.000	0.000	0.000	0.000



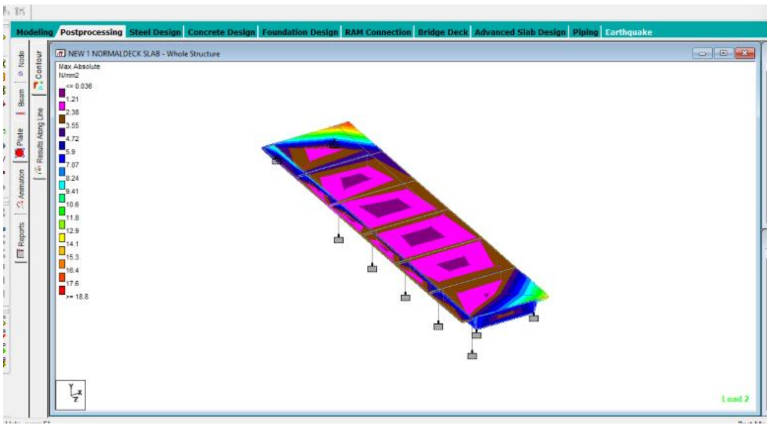
a) Axial Force Diagram



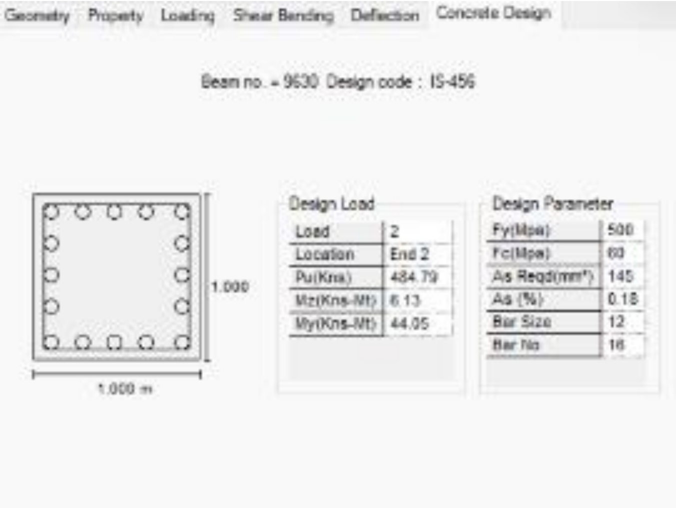
b) SF Diagram



c) MAX BM DIAGRAM



d) STRESS DIAGRAM



Beam no. = 9630 Design code : IS-456

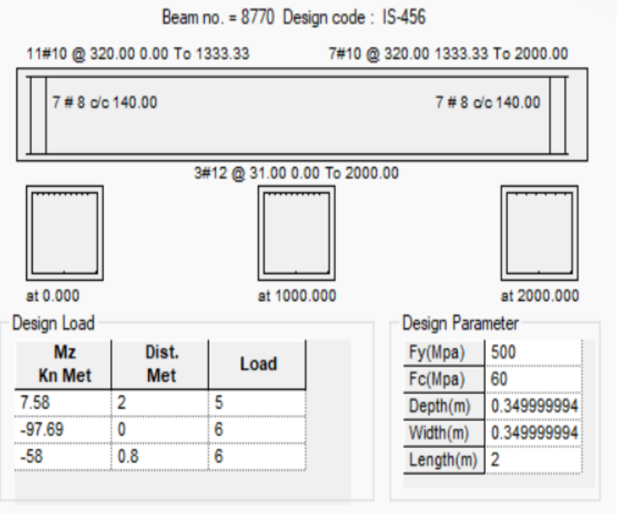
Design Load

Load	2
Location	End 2
Pu(Kns)	484.79
Mz(Kns-Mt)	6.13
My(Kns-Mt)	44.05

Design Parameter

Fy(Mpa)	500
Fc(Mpa)	60
As Reqd(mm²)	145
As (%)	0.18
Bar Size	12
Bar No	16

e) COLUM DETAILS



Beam no. = 8770 Design code : IS-456

11#10 @ 320.00 0.00 To 1333.33

7#10 @ 320.00 1333.33 To 2000.00

7 # 8 c/c 140.00

7 # 8 c/c 140.00

3#12 @ 31.00 0.00 To 2000.00

at 0.000

at 1000.000

at 2000.000

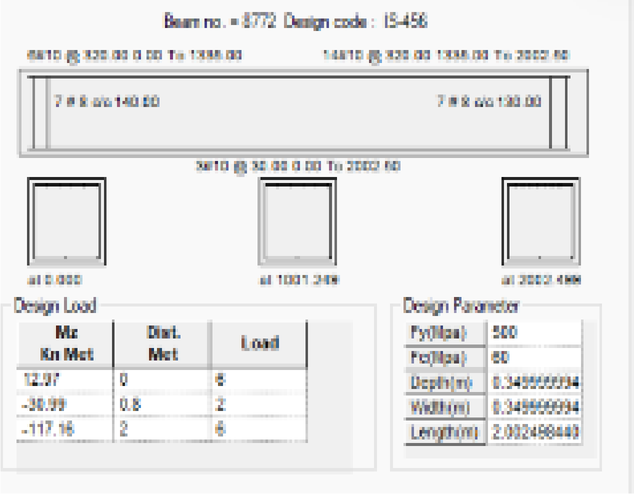
Design Load

Mz Kn Met	Dist. Met	Load
7.58	2	5
-97.69	0	6
-58	0.8	6

Design Parameter

Fy(Mpa)	500
Fc(Mpa)	60
Depth(m)	0.349999994
Width(m)	0.349999994
Length(m)	2

f) BEAM DETAILS



Beam no. = 8772 Design code : IS-456

6#10 @ 320.00 0.00 To 1335.00

14#10 @ 320.00 1335.00 To 2002.50

7 # 8 c/c 140.00

7 # 8 c/c 130.00

3#10 @ 30.00 0.00 To 2002.50

at 0.000

at 1001.249

at 2002.499

Design Load

Mz Kn Met	Dist. Met	Load
12.97	0	6
-38.99	0.8	2
-117.16	2	6

Design Parameter

Fy(Mpa)	500
Fc(Mpa)	60
Depth(m)	0.349999994
Width(m)	0.349999994
Length(m)	2.002498440

g) CANTILEVER BEAM

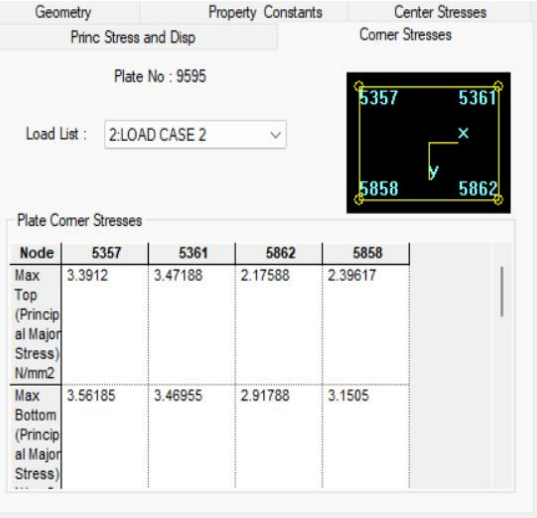


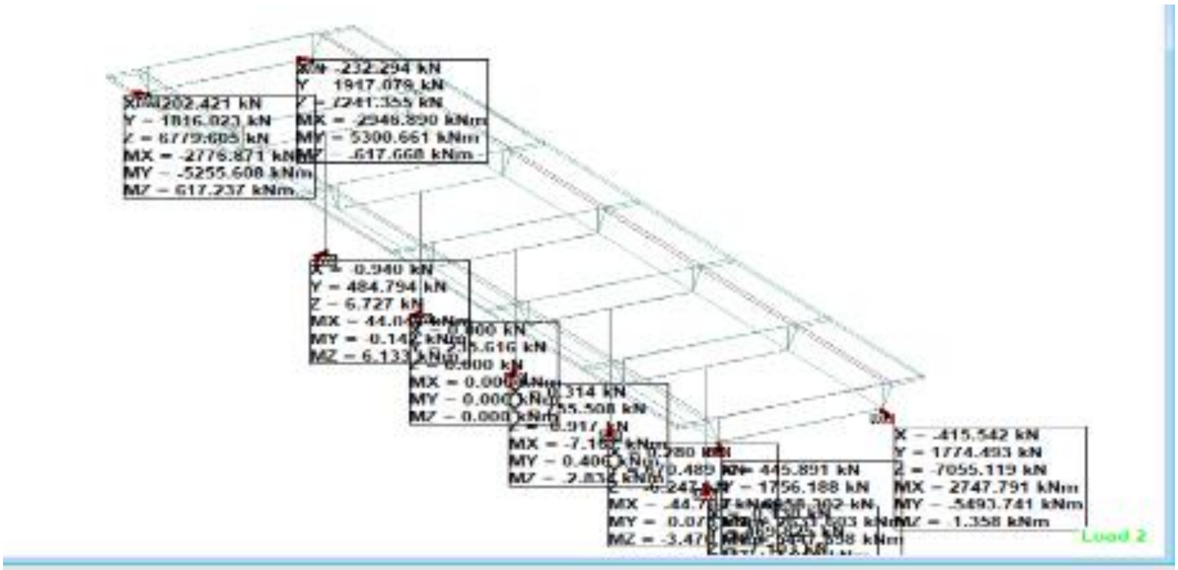
Plate No : 9595

Load List : 2:LOAD CASE 2

Plate Corner Stresses

Node	5357	5361	5862	5858
Max Top (Principal Major Stress) N/mm2	3.3912	3.47188	2.17588	2.39617
Max Bottom (Principal Major Stress)	3.56185	3.46955	2.91788	3.1505

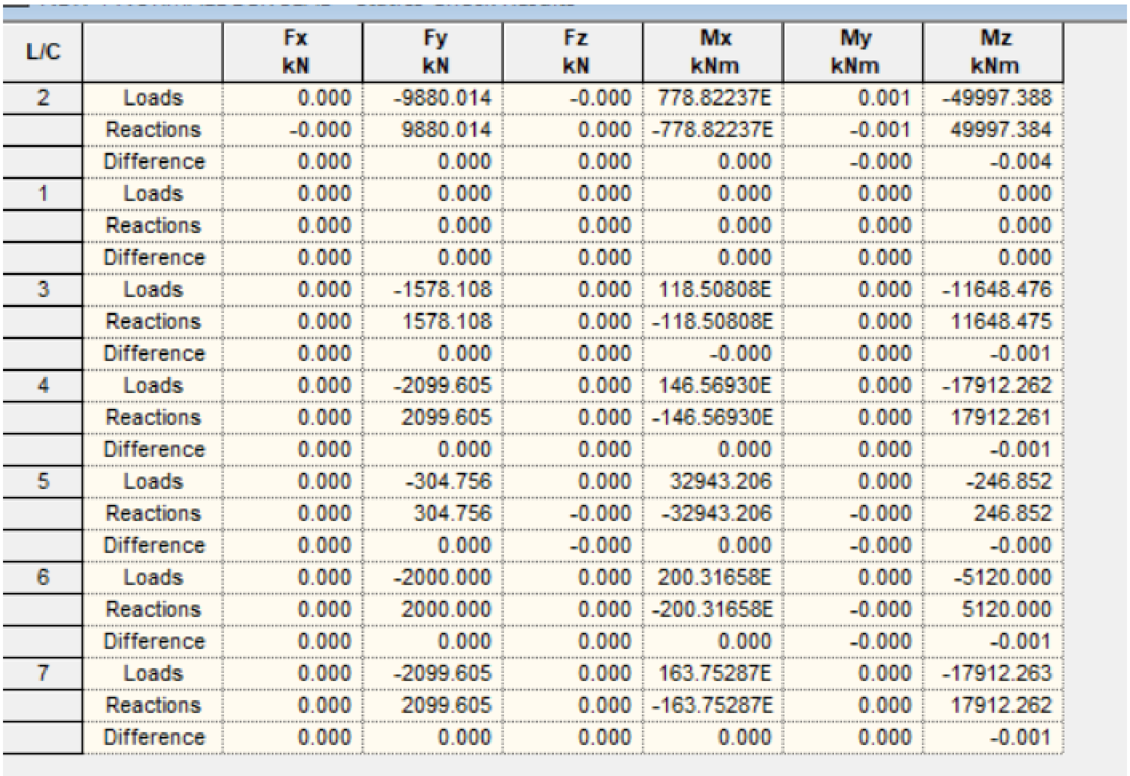
h) DECK STRESS



i) **SUPPORT REACTIONS**

Fig 6; Results of normal deck slab analysis on STAAD Pro.

Table2:Reaction table(Normal deck slab)



L/C		Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
2	Loads	0.000	-9880.014	-0.000	778.82237E	0.001	-49997.388
	Reactions	-0.000	9880.014	0.000	-778.82237E	-0.001	49997.384
	Difference	0.000	0.000	0.000	0.000	-0.000	-0.004
1	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
3	Loads	0.000	-1578.108	0.000	118.50808E	0.000	-11648.476
	Reactions	0.000	1578.108	0.000	-118.50808E	0.000	11648.475
	Difference	0.000	0.000	0.000	-0.000	0.000	-0.001
4	Loads	0.000	-2099.605	0.000	146.56930E	0.000	-17912.262
	Reactions	0.000	2099.605	0.000	-146.56930E	0.000	17912.261
	Difference	0.000	0.000	0.000	0.000	0.000	-0.001
5	Loads	0.000	-304.756	0.000	32943.206	0.000	-246.852
	Reactions	0.000	304.756	-0.000	-32943.206	-0.000	246.852
	Difference	0.000	0.000	-0.000	0.000	-0.000	-0.000
6	Loads	0.000	-2000.000	0.000	200.31658E	0.000	-5120.000
	Reactions	0.000	2000.000	0.000	-200.31658E	-0.000	5120.000
	Difference	0.000	0.000	0.000	0.000	-0.000	-0.001
7	Loads	0.000	-2099.605	0.000	163.75287E	0.000	-17912.263
	Reactions	0.000	2099.605	0.000	-163.75287E	0.000	17912.262
	Difference	0.000	0.000	0.000	0.000	0.000	-0.001

Detail design of voided deck slab bridge.

After IRC class 70R load applied following results are generated on STAAD Pro for slab with circular voids.

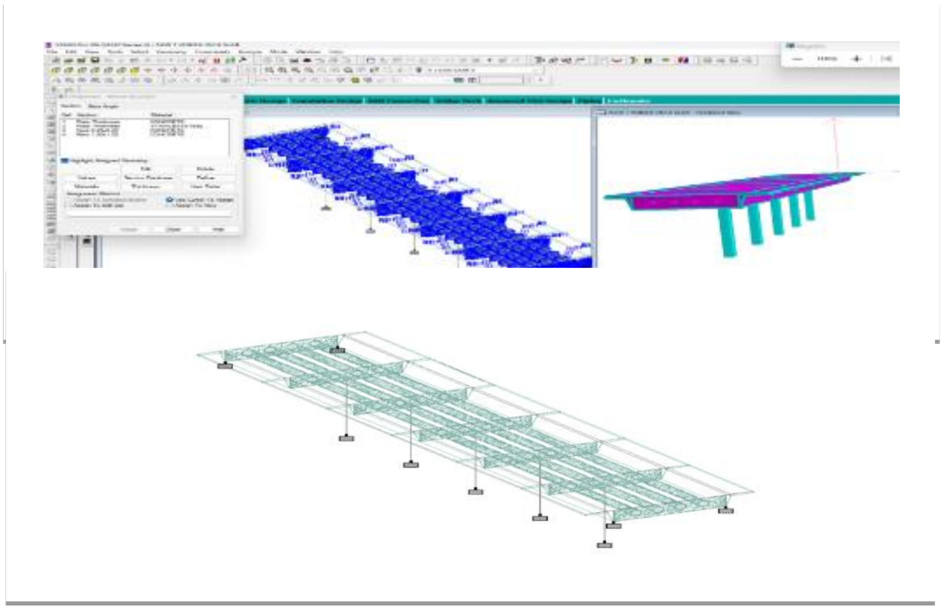
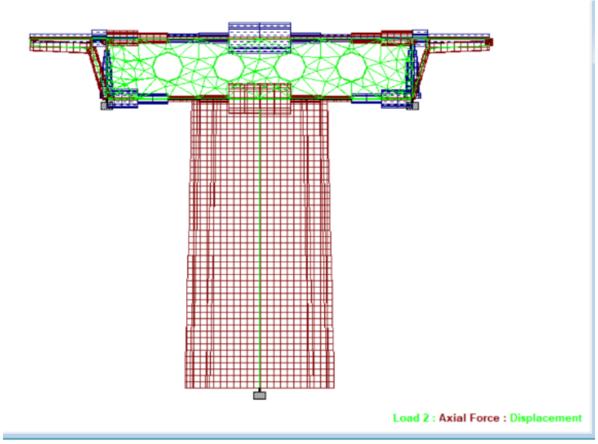
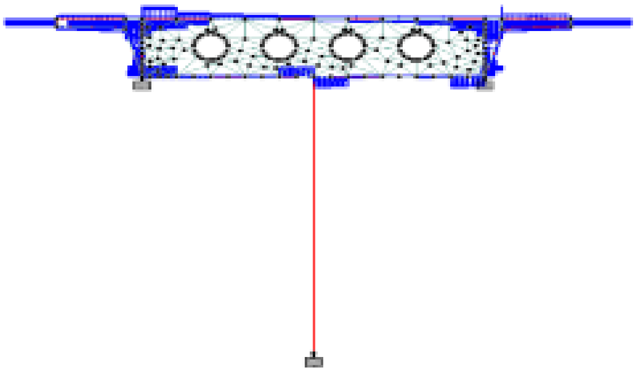


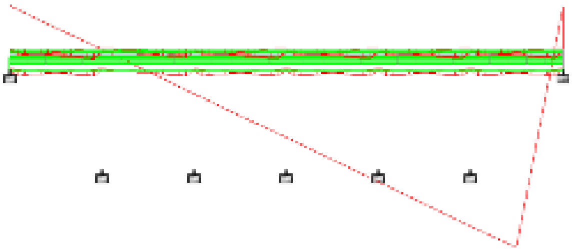
Fig.7:-Details of voided deck slab with circular voided deck slab.



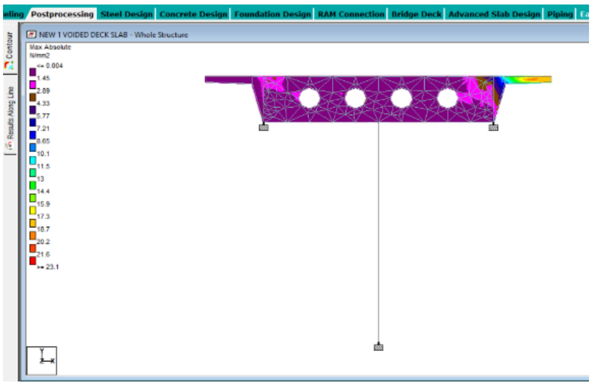
a) AXIAL FORCE DIAGRAM



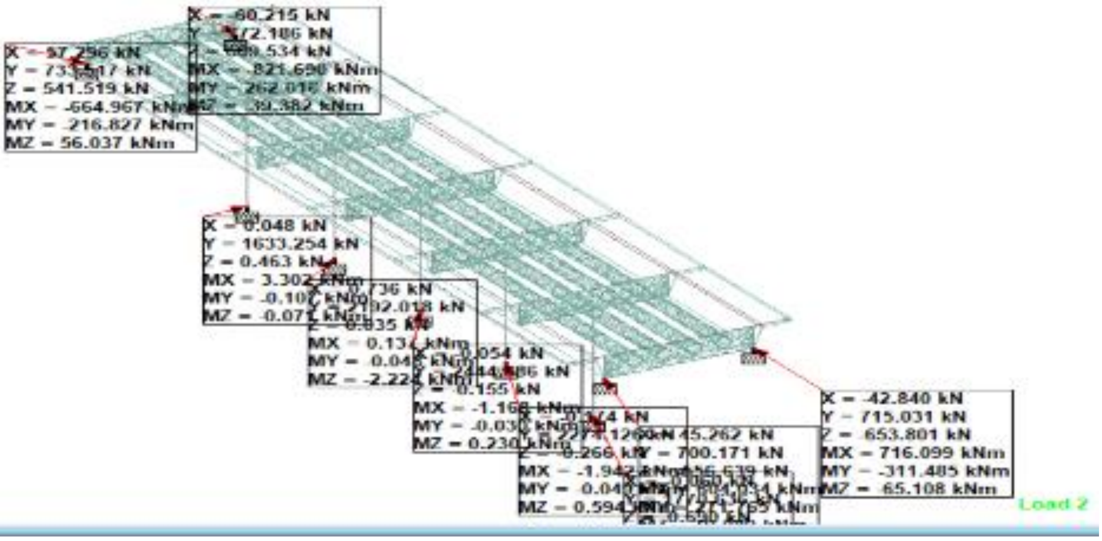
b) SF DIAGRAM



c) BM DIAGRAM



d) SLAB STRESS



`

e) Support Rection

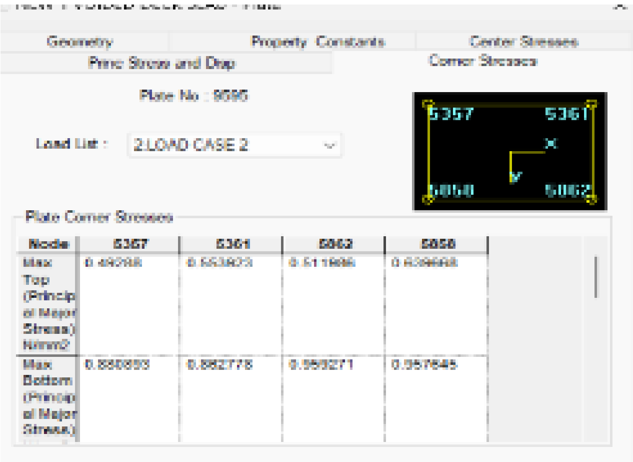


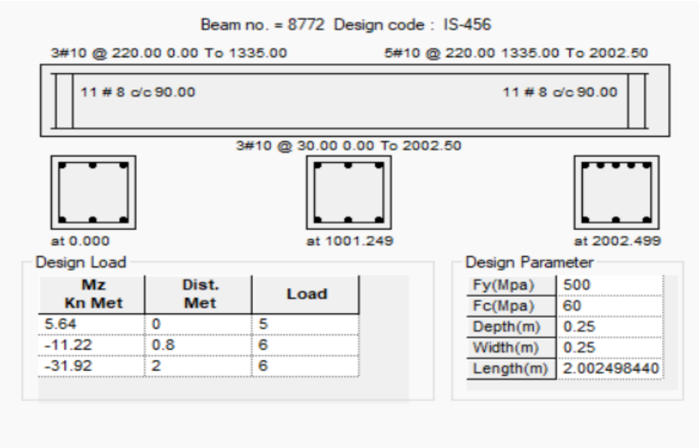
Plate No : 9595

Load List : 2:LOAD CASE 2

Plate Corner Stresses

Node	5367	5361	5862	5858
Max Top (Principal Major Stress) N/mm2	0.492988	0.553823	0.511986	0.636668
Max Bottom (Principal Major Stress)	0.880893	0.882778	0.959271	0.957645

f) PLATE STRESS



Beam no. = 8772 Design code : IS-456

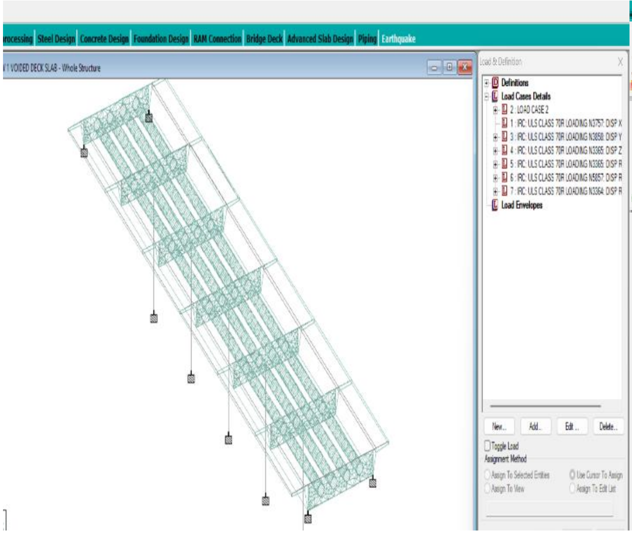
Design Load

Mz Kn Met	Dist. Met	Load
5.64	0	5
-11.22	0.8	6
-31.92	2	6

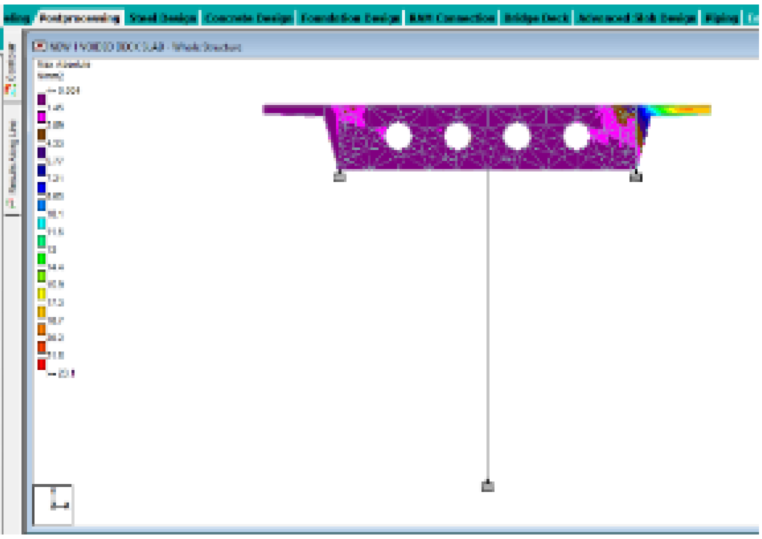
Design Parameter

Fy(Mpa)	500
Fc(Mpa)	60
Depth(m)	0.25
Width(m)	0.25
Length(m)	2.002498440

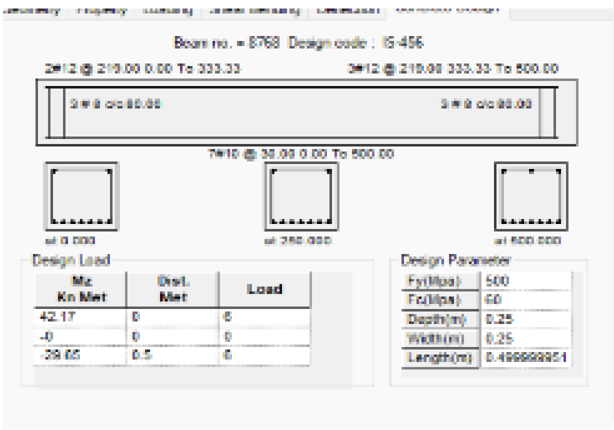
g) CANTILEVER BEAM



h) IRC 70R LOADING



i) Plate stress



Beam no. = 8768 Design code : IS-456

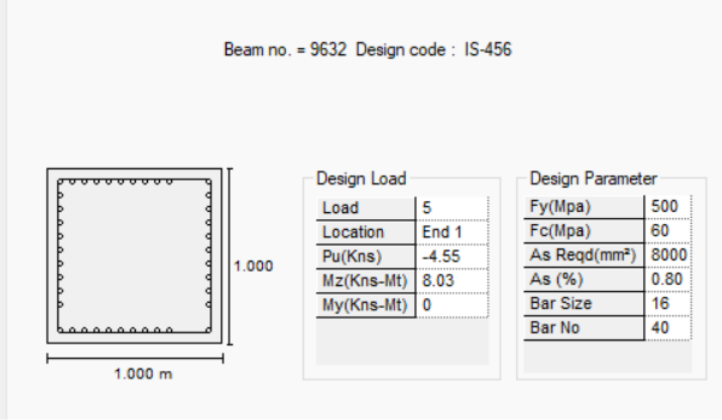
Design Load

Mz Kn Met	Dist. Met	Load
42.17	0	6
-0	0	0
-28.65	0.5	6

Design Parameter

Fy(Mpa)	500
Fc(Mpa)	60
Depth(m)	0.25
Width(m)	0.25
Length(m)	0.499999951

j) Beam Details



Beam no. = 9632 Design code : IS-456

Design Load

Load	5
Location	End 1
Pu(Kns)	-4.55
Mz(Kns-Mt)	8.03
My(Kns-Mt)	0

Design Parameter

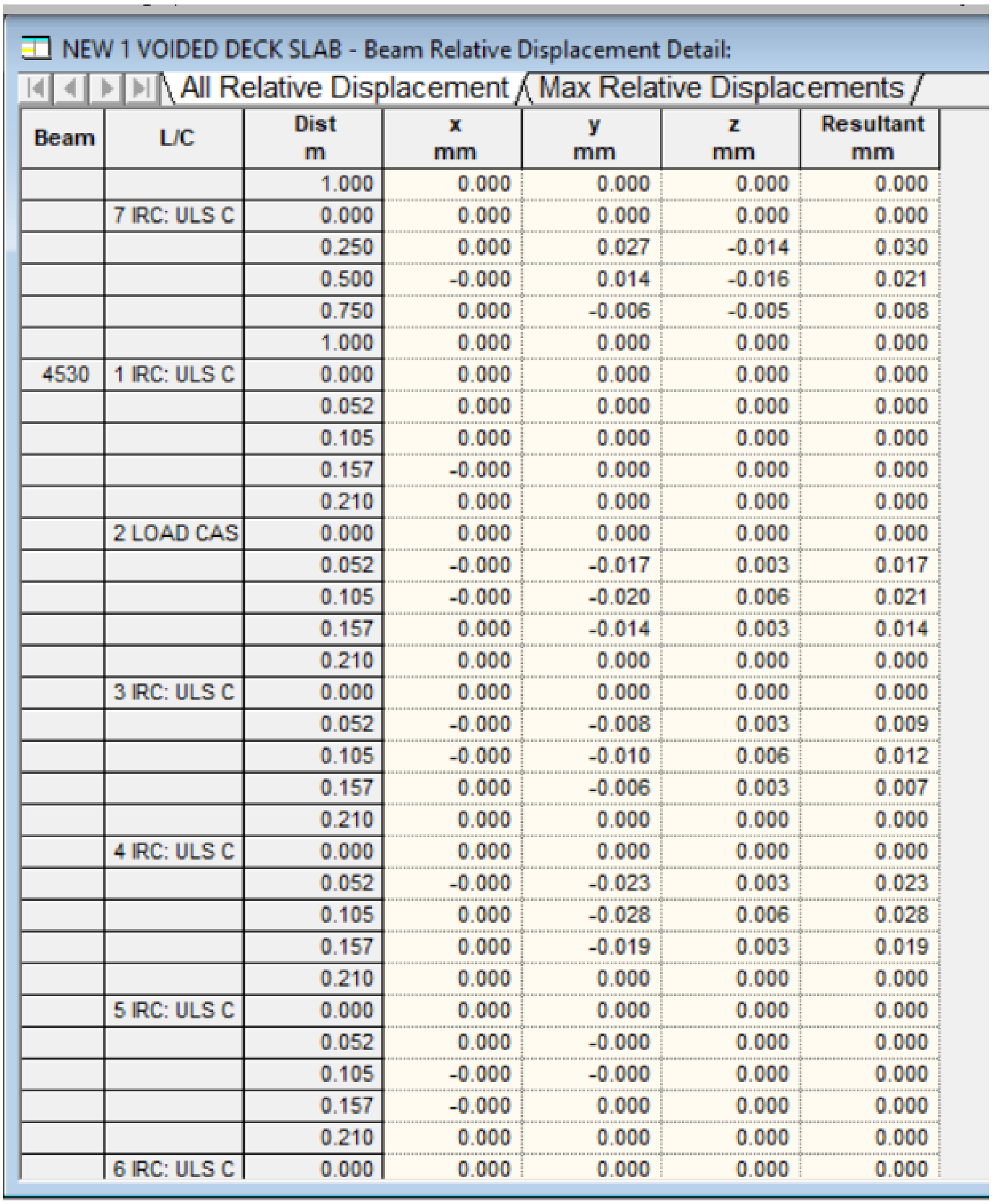
Fy(Mpa)	500
Fc(Mpa)	60
As Reqd(mm²)	8000
As (%)	0.80
Bar Size	16
Bar No	40

k) Colum Details

Fig 8: Results of voided deck slab analysis on STAAD Pro.

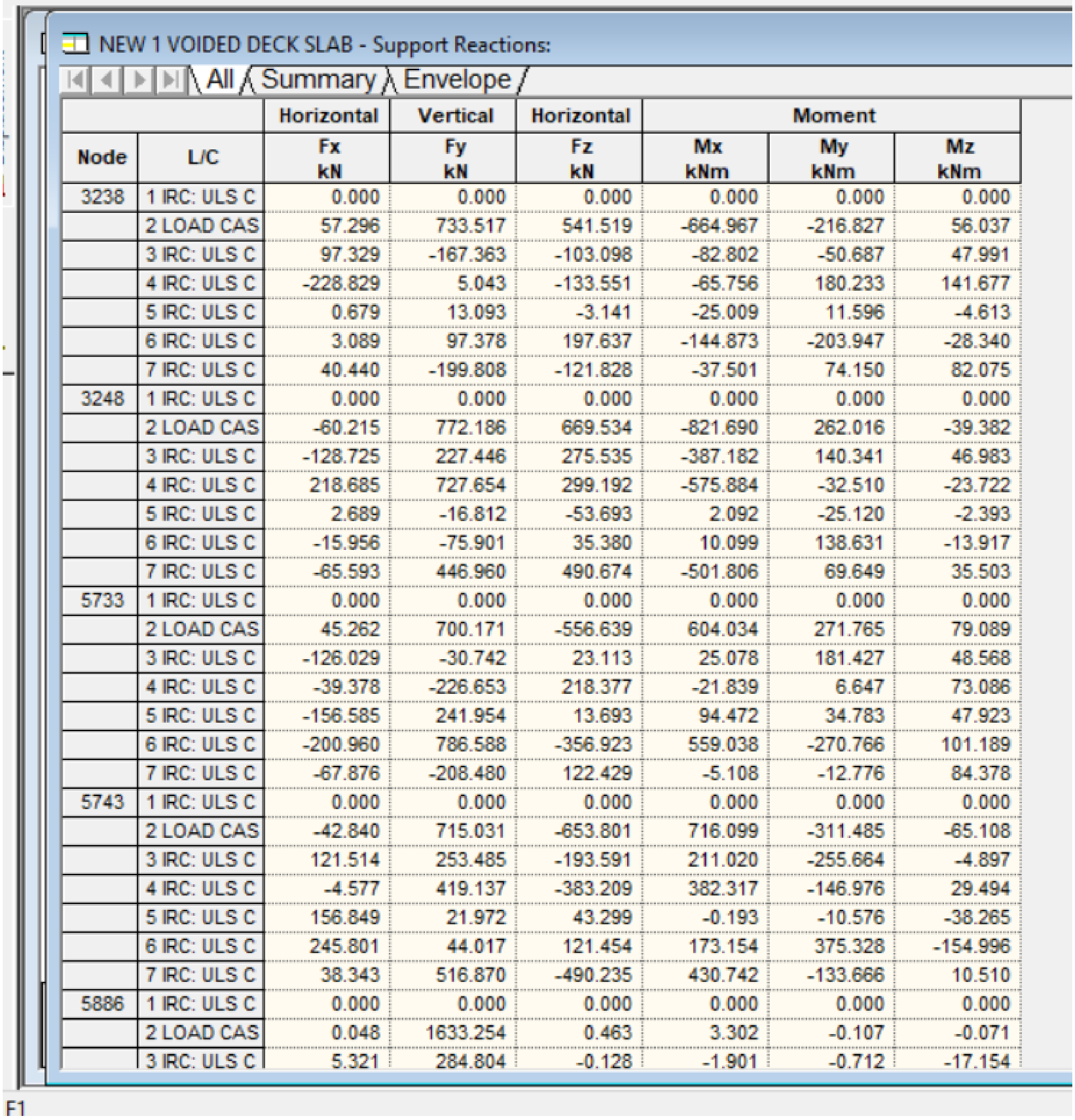
.

Table 3. Displacement table(voided deck slab)



Beam	L/C	Dist m	x mm	y mm	z mm	Resultant mm
		1.000	0.000	0.000	0.000	0.000
	7 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.250	0.000	0.027	-0.014	0.030
		0.500	-0.000	0.014	-0.016	0.021
		0.750	0.000	-0.006	-0.005	0.008
		1.000	0.000	0.000	0.000	0.000
4530	1 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.052	0.000	0.000	0.000	0.000
		0.105	0.000	0.000	0.000	0.000
		0.157	-0.000	0.000	0.000	0.000
		0.210	0.000	0.000	0.000	0.000
	2 LOAD CAS	0.000	0.000	0.000	0.000	0.000
		0.052	-0.000	-0.017	0.003	0.017
		0.105	-0.000	-0.020	0.006	0.021
		0.157	0.000	-0.014	0.003	0.014
		0.210	0.000	0.000	0.000	0.000
	3 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.052	-0.000	-0.008	0.003	0.009
		0.105	-0.000	-0.010	0.006	0.012
		0.157	0.000	-0.006	0.003	0.007
		0.210	0.000	0.000	0.000	0.000
	4 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.052	-0.000	-0.023	0.003	0.023
		0.105	0.000	-0.028	0.006	0.028
		0.157	0.000	-0.019	0.003	0.019
		0.210	0.000	0.000	0.000	0.000
	5 IRC: ULS C	0.000	0.000	0.000	0.000	0.000
		0.052	0.000	-0.000	0.000	0.000
		0.105	-0.000	-0.000	0.000	0.000
		0.157	-0.000	0.000	0.000	0.000
		0.210	0.000	0.000	0.000	0.000
	6 IRC: ULS C	0.000	0.000	0.000	0.000	0.000

Table 4. Reaction table(voided deck slab)



		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
3238	1 IRC: ULS C	0.000	0.000	0.000	0.000	0.000	0.000
	2 LOAD CAS	57.296	733.517	541.519	-664.967	-216.827	56.037
	3 IRC: ULS C	97.329	-167.363	-103.098	-82.802	-50.687	47.991
	4 IRC: ULS C	-228.829	5.043	-133.551	-65.756	180.233	141.677
	5 IRC: ULS C	0.679	13.093	-3.141	-25.009	11.596	-4.613
	6 IRC: ULS C	3.089	97.378	197.637	-144.873	-203.947	-28.340
	7 IRC: ULS C	40.440	-199.808	-121.828	-37.501	74.150	82.075
3248	1 IRC: ULS C	0.000	0.000	0.000	0.000	0.000	0.000
	2 LOAD CAS	-60.215	772.186	669.534	-821.690	262.016	-39.382
	3 IRC: ULS C	-128.725	227.446	275.535	-387.182	140.341	46.983
	4 IRC: ULS C	218.685	727.654	299.192	-575.884	-32.510	-23.722
	5 IRC: ULS C	2.689	-16.812	-53.693	2.092	-25.120	-2.393
	6 IRC: ULS C	-15.956	-75.901	35.380	10.099	138.631	-13.917
	7 IRC: ULS C	-65.593	446.960	490.674	-501.806	69.649	35.503
5733	1 IRC: ULS C	0.000	0.000	0.000	0.000	0.000	0.000
	2 LOAD CAS	45.262	700.171	-556.639	604.034	271.765	79.089
	3 IRC: ULS C	-126.029	-30.742	23.113	25.078	181.427	48.568
	4 IRC: ULS C	-39.378	-226.653	218.377	-21.839	6.647	73.086
	5 IRC: ULS C	-156.585	241.954	13.693	94.472	34.783	47.923
	6 IRC: ULS C	-200.960	786.588	-356.923	559.038	-270.766	101.189
	7 IRC: ULS C	-67.876	-208.480	122.429	-5.108	-12.776	84.378
5743	1 IRC: ULS C	0.000	0.000	0.000	0.000	0.000	0.000
	2 LOAD CAS	-42.840	715.031	-653.801	716.099	-311.485	-65.108
	3 IRC: ULS C	121.514	253.485	-193.591	211.020	-255.664	-4.897
	4 IRC: ULS C	-4.577	419.137	-383.209	382.317	-146.976	29.494
	5 IRC: ULS C	156.849	21.972	43.299	-0.193	-10.576	-38.265
	6 IRC: ULS C	245.801	44.017	121.454	173.154	375.328	-154.996
	7 IRC: ULS C	38.343	516.870	-490.235	430.742	-133.666	10.510
5886	1 IRC: ULS C	0.000	0.000	0.000	0.000	0.000	0.000
	2 LOAD CAS	0.048	1633.254	0.463	3.302	-0.107	-0.071
	3 IRC: ULS C	5.321	284.804	-0.128	-1.901	-0.712	-17.154

Calculation of maximum live load and bending moment as per IRC Class AA loading

Before starting the calculation, we will study about living load as per IRC Class AA track loading, live loads are those caused by vehicles that pass over the bridge are dynamic. Thus to make them deterministic for different standard loading conditions as IRC loadings. In IRC Class AA loading trails of track vehicle of 700 KN and wheel vehicle of 400 KN with certain

the ground contact length is 360 mm and spacing of the vehicle is 1.2 For calculation following condition must be given,

The voided slab bridge considered here is an RCC simply supported bridge of span 60 m.

1 Carriageway width =14.1 m
2 Overall width = 15 m
3 Width of crash barrier = 0.45m.
4.Thickness of wearing coat=75 mm
5.Cantilever portion of deck=2 m
6. Thickness of cantilever deck slab=0.35 m
7. Depth of voided slab =2.1 m
8. No of voids in the deck=4
9 Grade of concrete=M60
10.Grade of steel =Fe 500
11.width of bearing=500 mm
12. Use 32 mm diameter bar and k=3 also cover 40mm on each side.

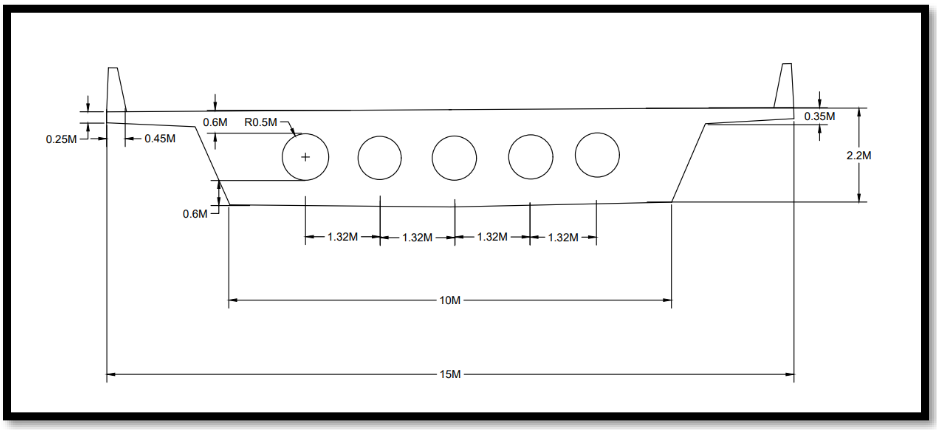


Fig.9: Bridge deck details.

Solution;

Step 1: Find effective depth of slab.

D effective =Depth of deck slab -[0.5(bar dia.)+ cover]

=2100-[0.5(32)+40]

=2044 mm=2.044 m

Step 2: Effectivespan of slab

a) Clear span+ width of bearing. =60+0.500=60.5 m

b) Clear span+ effective depth =60+2.044=62.044m

Take less value for further calculations as effective span length =60.5m

Step3; Effective length of load.

For IRC Class AA loading

Effective length of load =3.6+2(0.075)+2(2.1)

=7.95 m

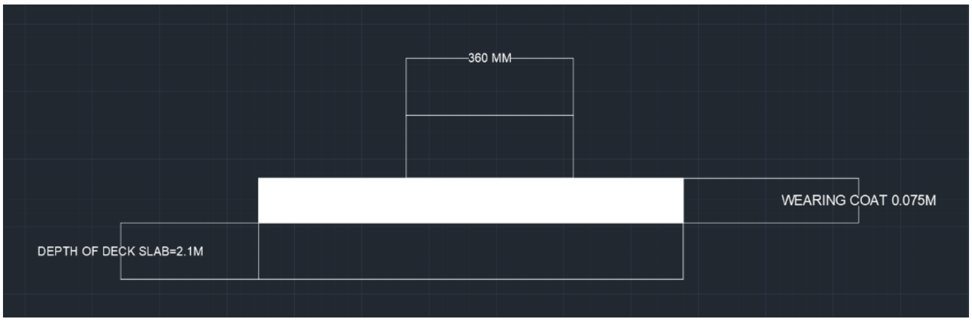


Fig.10**.** Effective length of load.

Step4; Effective width of load. (be)

Effective width of load. (be)=K× X × [1-(X/L)]+bw

Therefore X=60.5/2=30.25 m

bw=0.85+2(0.075) =1

be= 3×30.25÷ [1-(30.25/60.5) +1=46.375 m

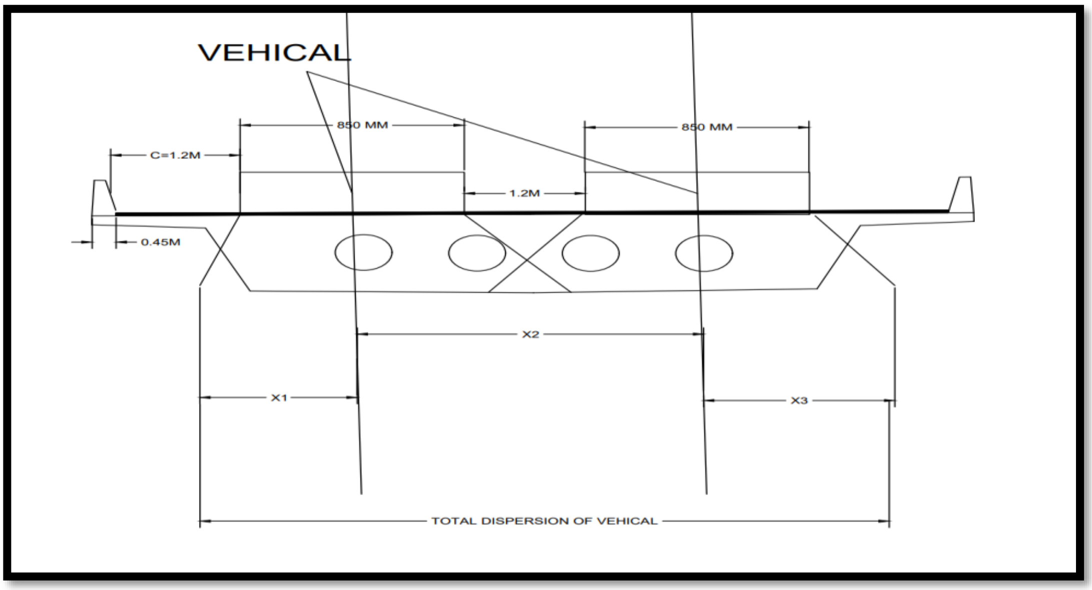


Fig.11: Effective width of load.

Which is dispersion for one wheel.

Total dispersion

X1=0.45+1.2+(0.85/2)

=3.075 m

X2= (0.85/2)+1.2+(].85/2)

=2.05 m

X3=be/2=46.375/2=23.1875m

Total dispersion =X1+X2 +X3

=2.075+2.05+23.1875

=27.3125m

Step5 Total dispersion area

Total dispersion area =7.95×27.3125=1582.73 mm. Sq

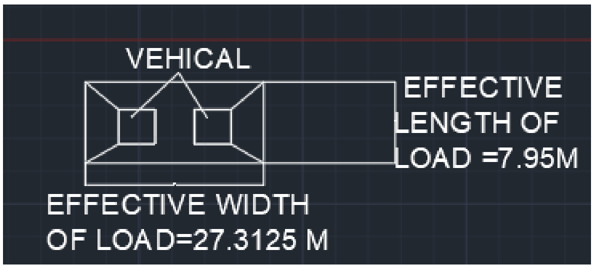


Fig.12:Total dispersion area

Step6; Live load intensity

Live load =[Total load/ dispersion area)

Total load = impact factor × 700 KN

Impact factors;

As per IRC impact factor for class AA track vehicle IRC gives 25% for 5m span and 10% for 9m span as impact factor.

We will find out for 60.5 m span Impact factors get decrease linearly to 10% increase in length. By interpolation method

5m	0.25
9m	0.10
60.5m	x

Then x= -1.8

OR

Impact factors =25-(15/4)[L effective -5]

=25-(15/4)[60.5-5]

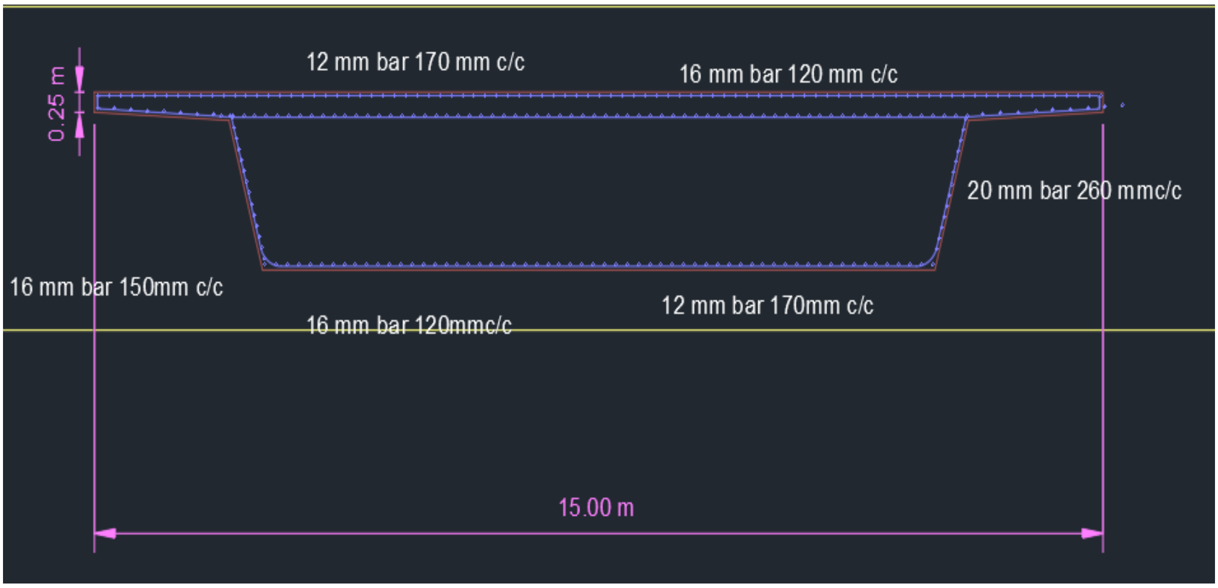
=-194.37 %= -1.9

Live load intensity =(-1.9×700 /(7.95×27.3125) = -6.125 KN/Sq.m

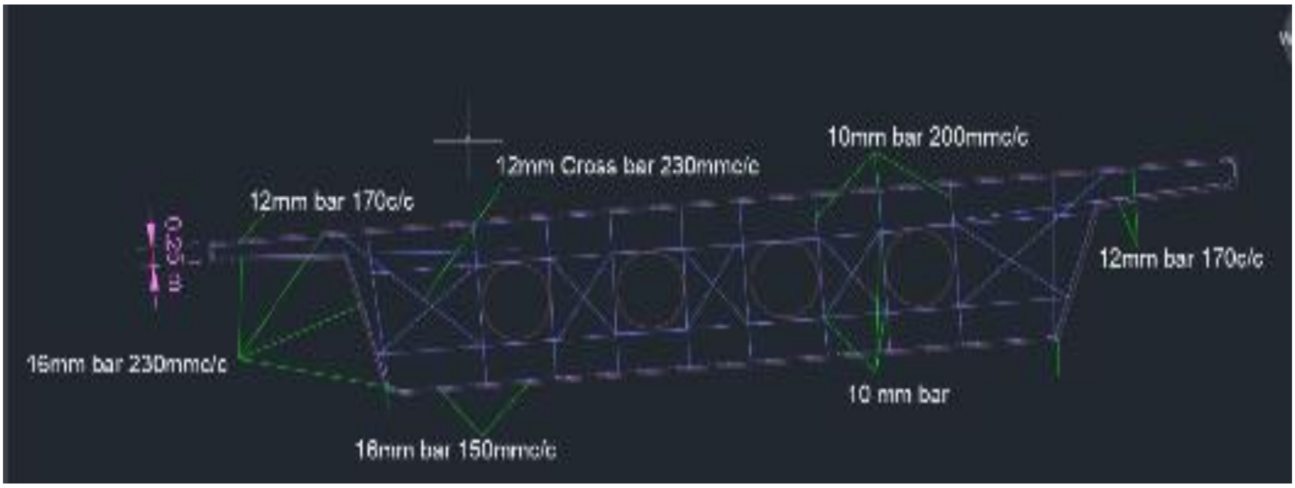
For 1 m span live load = -0.1020 KN/Sq.m
Step 7: Maximum live bending movement.
BM max=[(-6.125)(7.95/2)(60.6/2)] - [(-6.12)(7.95/3)(7.95/4)]
= -688.17 KN -m

Reinforcement details.

To avoid cracks due to thermal expansion longitudinal as well as transfer rebars are provided. Sometime crack are generated in circular voids to avoid it shear rectangular reinforcement are provided around circular voids. The minimum longitudinal reinforcement in slabs shall be as per Clause 305.19 of IRC:21- 2000. The minimum reinforcement shall be provided according to the method of analysis adopted. Curtailment of reinforcement shall be as per Clause 305.7 of IRC:21-2000.From the following reinforcement detailing we understand reinforcement arrangement in both deck slabs are as follows



Normal deck slab



Voided deck slab

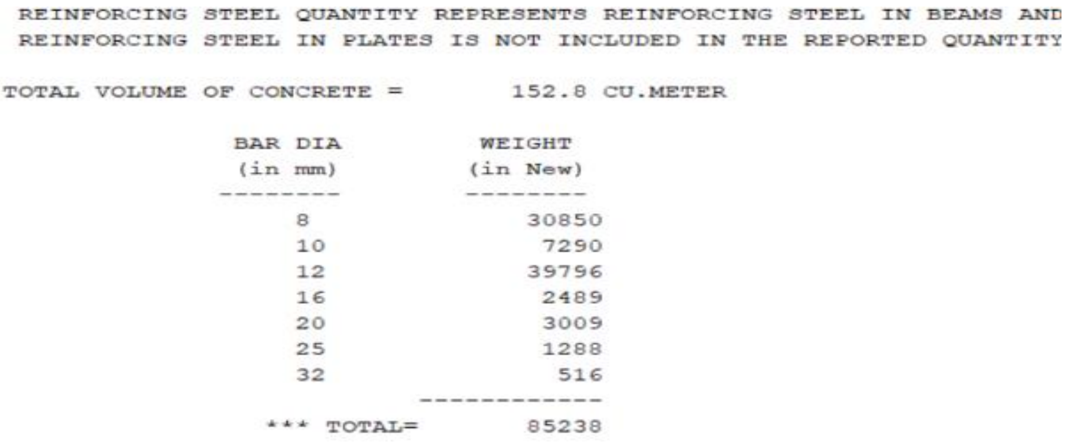
Fig..13: Reinforcement detail

Percentage analysis of concrete design

In its last stage after completing all forces applied and analysts concrete design is performed in this M60 great of concrete is used and Fe 500 is preferred as well as a 32 mm bar diameter used with a 40 mm cover on each side. From the following pick, we will noted that concrete is utilised in both cases (unite CU.M).In the case of a normal deck, Slab bridge concrete is needed which is equal to 153.8 cu. meter. Similarly in the case of voided deck slab design with the Same IRC loadings amount of concrete needed is 101.2 cu. meter.

Table5.5;Concrete results

Sr.no.	Parameter s	Normal deck slab	Voided deck slab	Present age
1	Concrete Cu.Meter	152.8	101.2	66.2%
2	Reinforcement weight (Kg)	8691.65	8958.71	3.07%



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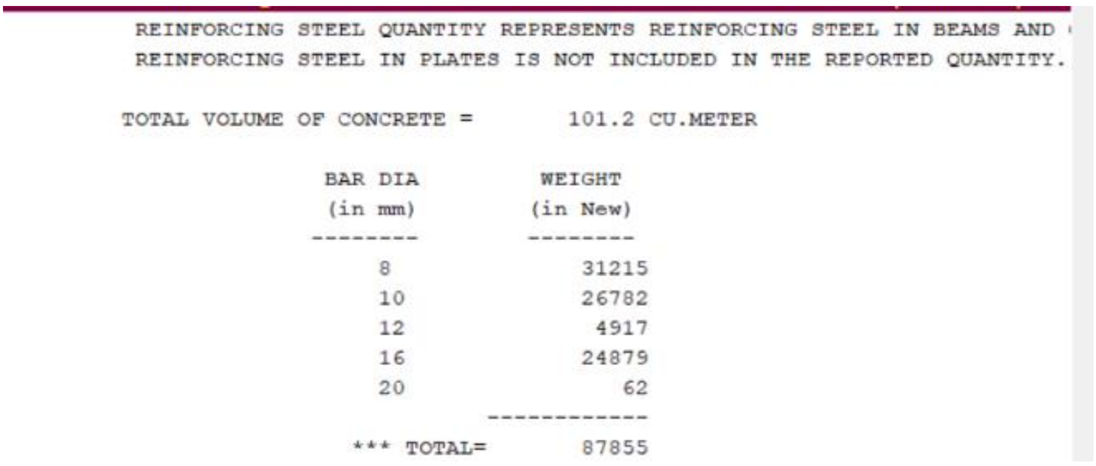
 REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND
 REINFORCING STEEL IN PLATES IS NOT INCLUDED IN THE REPORTED QUANTITY

TOTAL VOLUME OF CONCRETE =       152.8 CU.METER

              BAR DIA          WEIGHT
              (in mm)         (in New)
             --------         --------
                  8              30850
                 10               7290
                 12              39796
                 16               2489
                 20               3009
                 25               1288
                 32                516
                            ------------
              *** TOTAL=         85238
```

A). voided deck slab.



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        REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND
        REINFORCING STEEL IN PLATES IS NOT INCLUDED IN THE REPORTED QUANTITY.

       TOTAL VOLUME OF CONCRETE =       101.2 CU.METER

                     BAR DIA          WEIGHT
                     (in mm)         (in New)
                    --------         --------
                         8              31215
                        10              26782
                        12               4917
                        16              24879
                        20                 62
                                   ------------
                     *** TOTAL=         87855
```

B). Normal deck slab

Fig 14: Concrete design

Finally, after analyzing all report following results are noted in the case of both deck slabs. IRC class AA loading condition, as well as IRC 70R loading, is applied for analysis in both cases i.e. normal deck slab as well as a voided deck slab.

Table 6: Overall results

Sr.No.	Parameter's	Normal deck slab	Voided deck slab
1	Design geometry detailing	Simple	Complicated
2	Load applied	DL & IRC 70R loadings	DL & IRC 70R loadings
3	Maximum live load and BM for IRC class AA loading	-	LL=-6.125 KN BM max= 668.17 KN-M↓( )
4	Support Rection & Displacements	Maximum	Minimum
5	BM & slab stress	Max BM=860.45 KN-M(END) Slab stress=18.8 N/MM^2	Minimum BM=440.56KN-M (END) Slab stress=23.1 N/MM^2
6	Concrete (M60 & Fe 500) and Rebars weight	152.8 cu.meter& 8692 kg	101.2 cu.meter& 8959 kg

CONCLUSION

The conclusions arrived after the analysis and design of the Voided slab bridge can be summarized as follows:

- ✓ The design of the bridge superstructure is a work that requires great expertise and also knowledge to foresee unexpected situations that may come during the construction stage. Providing circular voids is a critical task.
- ✓ The longitudinal moments are the governing moments and if the main bending has to suffice it should not fail in the transverse direction.
- ✓ Transverse analysis makes the whole structure as a single unit thereby taking care of the stresses due to individual loadings.
- ✓ Detailed analysis of the various IRC loadings has helped in understanding the critical load position.
- ✓ The percentage of concrete saved by volume is approximately 60% as compared to a normal deck slab. However, the reinforcement requirement is increased in the voided deck slab.

ACKNOWLEDGMENT

I would like to thank respected **(Dr.) M. P. Wagh** for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a project report. It helped me a lot to realize of what we study for. Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs. Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end. Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free. Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

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[3] Design of Prestressed Concrete structures - T. Y. Lin

[4] Bridge Superstructure – By N. Rajagopalan