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Modelling and Analysis of I-Girder Bridge Deck Using Grillage Analogy

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Abstract: The majority of highway bridges are girder type structures, either single spans or continuous spans. Determining the principal effects of the various loading combinations can often be achieved with a 2-dimensional analytical model but for overall absolute analysis which is actually more complicated a 3-dimensional model is needed. This paper elaborates the correct analysis and modelling techniques for typical prestressed concrete bridge deck girder by using grillage analysis. The structural model is developed as per FE discretization in Staad Pro software. For the purpose of analysis, dead load (self- weight, wearing coat, super imposed dead load, footpath live load) and vehicular live loads are considered as per IRC: 6-2016. A series of applications are executed in order to verify the efficiency and the accuracy. Linear static analysis is carried and the design values of bending moment and shear force for the class A 70 R tracked vehicle are computed.
Keywords: Grillage Analogy, Discretization, Vehicular Live Load, Wearing Coat, Impact Factor

I. INTRODUCTION

Grillage analysis is one of the most popular computer-aided analysis using Staad Pro software for analysing bridge decks. Basically in the grillage technique of analysis bridge deck is converted into a network of grillage concentrated beams at discrete nodes. Bridge loading is very complex and it is difficult to analyse every load cases for the continuous system. So, what we do we idealize the bridge deck into equivalent grillage. The grillage analogy method uses stiffness approach for analysing the bridge deck. The whole bridge deck is divided into numbers of longitudinal and transverse beams. The actual deck loading is converted into equivalent nodal loading. The application of grillage analysis come into account as for in case of short spans, a solid reinforced concrete slab, generally cast in-situ method rather than precast process is preferable as simplest design. It is also cost effective, since the flat, level soffit means that false work and formwork are also simple. For larger spans, the reinforced slab has to be thicker to carry the extra stresses under load. This extra weight of the slab itself then becomes a problem, which can be solved in one of two ways. The first is to use prestressing techniques and the second is to reduce the deadweight of the slab by including 'voids', often expanded polystyrene cylinders. Up to about 25m span, such voided slabs are more economical than prestressed slabs. The requirement of analysis is the evaluation of internal member forces, stresses and deformations of structures. After the analysis, distribution of member forces will be computed.

II. GRILLAGE ANALYSIS

For any given deck, there will invariably be a choice amongst a number of methods of analysis which will give acceptable results. When the complete field of slab, pseudo-slab and slab on girder decks are considered, grillage analogy seems to be completely universal with the exception of Finite element and Finite Strip methods which will always carry a heavy cost for a structure as simple as a slab bridge. The grillage analogy method can be applied to the bridge decks exhibiting complicated features such as heavy skew, edge stiffening, deep haunches over supports, continuous and isolated supports etc. The grillage analysis programs are 10 more generally available and can be run on personal computers. The method has proved to be reliably accurate for a wide variety of bridge decks. The method consists of converting the structure into a network of skeletal members rigidly connected to each other at nodes. The structure will have three degrees of freedom at each node i.e. freedom of vertical displacement and freedom of rotations about two mutually perpendicular axes in the horizontal plane. In general a grillage with 'n' nodes will have 3n degrees of freedom. All span loadings are converted into equivalent nodal loads by computing the fixed end forces and transferring them to global axis.

III.OBJECTIVES

A. To validate the comprehend property of grillage analysis by study.
B. To analyse the bridge deck using grillage analogy.
C. To produce output that can be used in section analysis and design that is bending moments and shear forces.

IV. GRILLAGE MODELLING

1) Model Discretization: Formulation of a mathematical model using discrete mathematical elements and their connections and interactions to capture the prototype behaviour is called Discretization. Here are some basic guidelines to form grillage model,

a) Grid lines are placed along the centre line of existing beams. Grid lines are of two types:
- Longitudinal grid lines: These are along the longitudinal axis of bridge or along the traffic direction. Location of these lines is at centre line of girders and edge beams. If there are isolated bearing grid lines are provided along the line joining the centre line of bearings.
- Transverse grid lines: Provided at each end connecting the centre of bearings. If there are transverse beams provided at centre line of transverse beams.

b) Number and spacing of grid lines:
- Odd no of longitudinal and transverse grid lines should be provided.
- Minimum three no. of longitudinal grid lines and five no. of transverse grid lines generally adopted.

c) For better results span to width ratio of bridge deck should preferably lie between 1.0 to 2.0

2) Model layout: For creating layout of model in staad pro software following guidelines are followed, For section under consideration span/width ratio of 50/12 is 4.167 and the spacing of longitudinal grid lines as 2.850 as per section shown in fig no. 1. The spacing of transvers grid lines comes out 11.875. So the no of parts in which longitudinal grid lines is divided is approximately 4. So the no of nodes to be inserted are 4-1 = 3. After forming a mesh apply support conditions to form a whole basic model for further application of load case details and analysis.

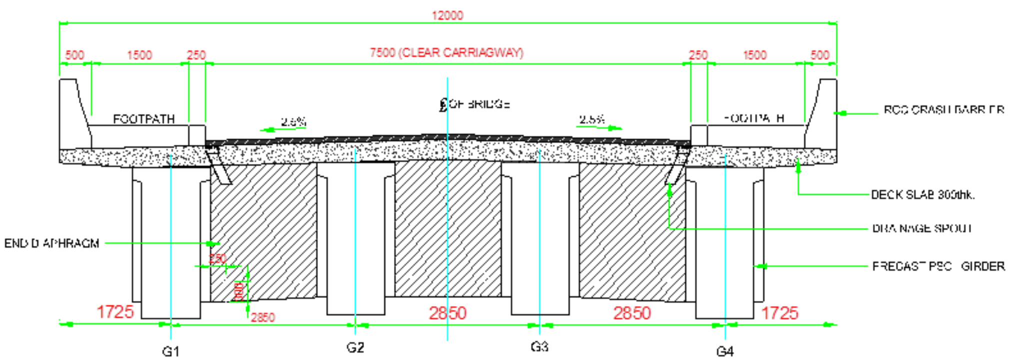

Fig. 1 Sectional view of deck slab

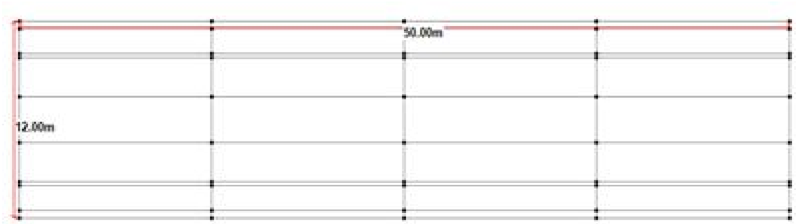

Fig. 2 Grillage model

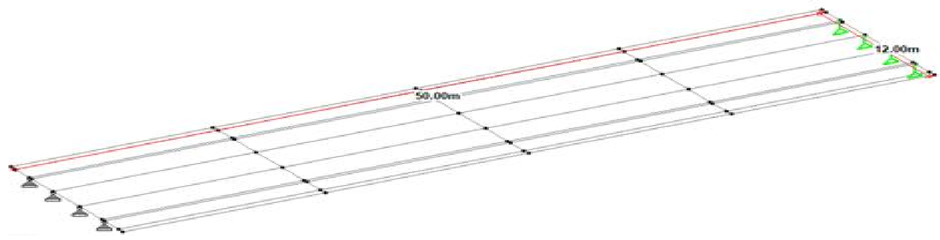

Fig. 3 Grillage model

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3) *Apply Sectional Properties:* After formation of mesh of grid lines material properties should be given to each and every member. By dividing into sectional properties as,

a) Inner, outer, end and edge cross sectional girders as prismatic concrete girders
b) Transverse corner members as rectangular concrete girders

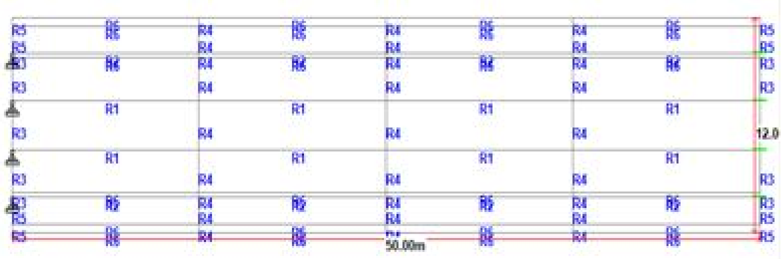

Fig. 4 Sectional properties model layout

4) *Define loadings*: Types of loading: Dead load includes self-weight, super imposed dead load, Live load and Vehicular load as per IRC-6 2016. Figure showing the detailed cross section of deck slab, cross barriers and foot path. From that calculate the dead loads. The thickness of the deck slab is varying as per the 2.5% camber requirement. The appropriate depth for each Longitudinal and transverse members are calculated and the property of each member is defined as a Rectangular Section. Linear analysis is performed for dead load and vehicular live loads as per IRC-6 2016 using STAAD Pro.

A. Dead load Calculations

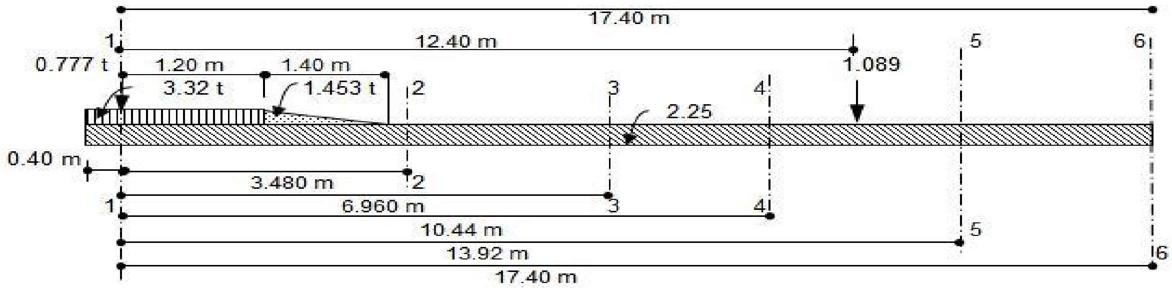

Fig. 5 Detailed cross section of deck slab, cross barriers and foot path.

Table I
General Details

Grade of concrete	M 40
Grade of steel	Fe 500
Unit weight of RCC	2.5 t/m^3
Unit weight of PCC	2.5 t/m^3
Vehicular traffic for two lane bridge as per IRC-6 2016	Class A Vehicle
	70 R Wheeled Vehicle
	70 R Tracked Vehicle

Table II
Self Weight Load Calculations

Thickness in m	Intensity of load in t/m^2	Spacing of transverse in m	Load on transverse in t/m
0.3	0.3*2.5	0.6/2=0.3	0.225
0.3	0.3*2.5	0.6/2+0.88/2=0.74	0.555
0.3	0.3*2.5	0.88/2+0.88/2=0.88	0.660

Table III
Load Due To Wearing Coat

Intensity of load in t/m^2	Spacing of transverse in m	Load on transverse in t/m
0.195	0.3	0.0585
0.195	0.74	0.1443
0.195	0.88	0.1716

Table IV
Load Due To Foot Path

Intensity of load in t/m^2	Spacing of transverse in m	Load on transverse in t/m
0.630	0.3	0.189
0.630	0.74	0.466
0.630	0.88	0.554

V. ANALYSIS OF STRUCTURE

After the defining the all necessary data and assigning them for each and very members we will apply all load cases on model. For analysis combinations of the load cases are shown below.

Table V
Load Cases

Load case no	Load cases
1	Structural imposed dead load
2	Super structure dead load
3	SSDL+SIDL

Then we will run software and analysed, the software will take all the necessary information and do computation which is based on finite element analysis.

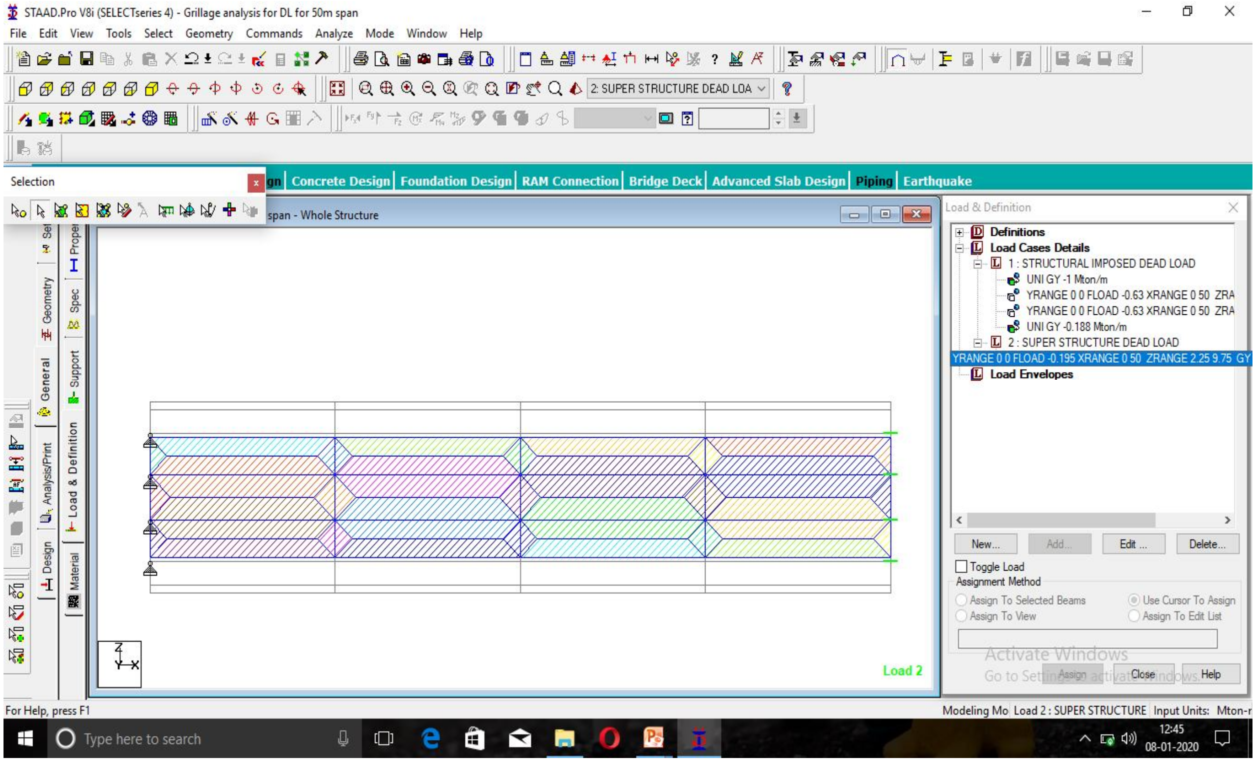

Fig. 6 SSDL Loading on Structure

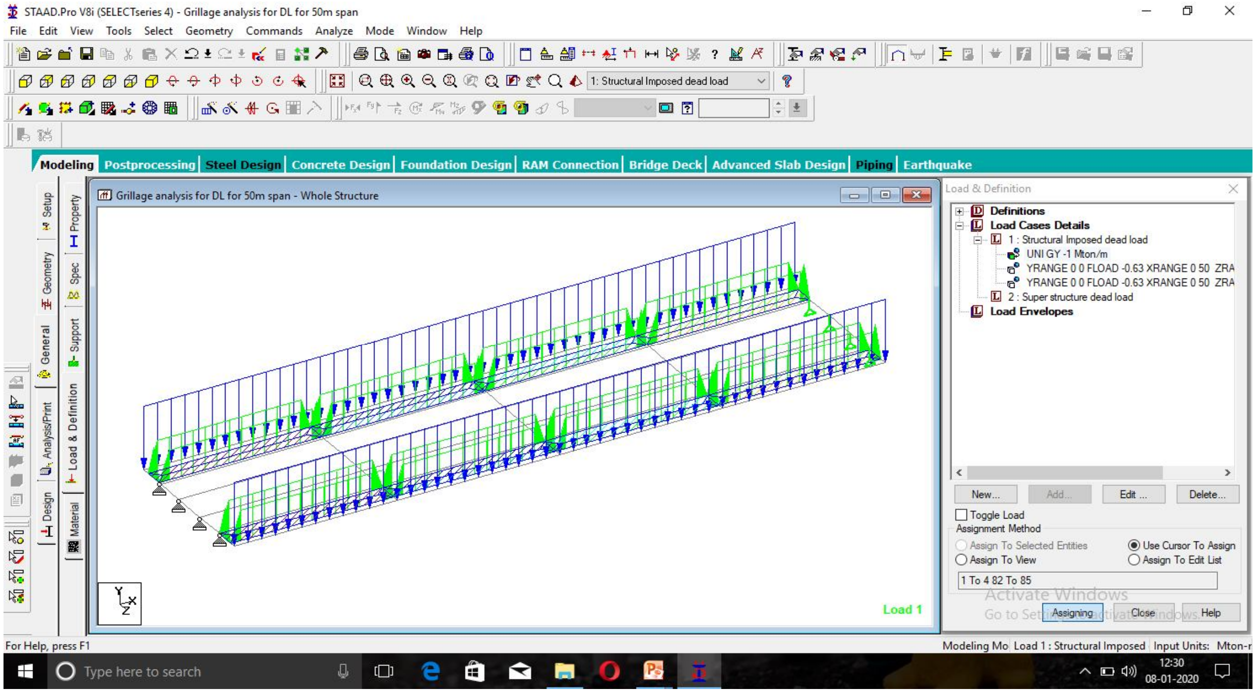

Fig. 7 Crash Barrier Loading on Structure

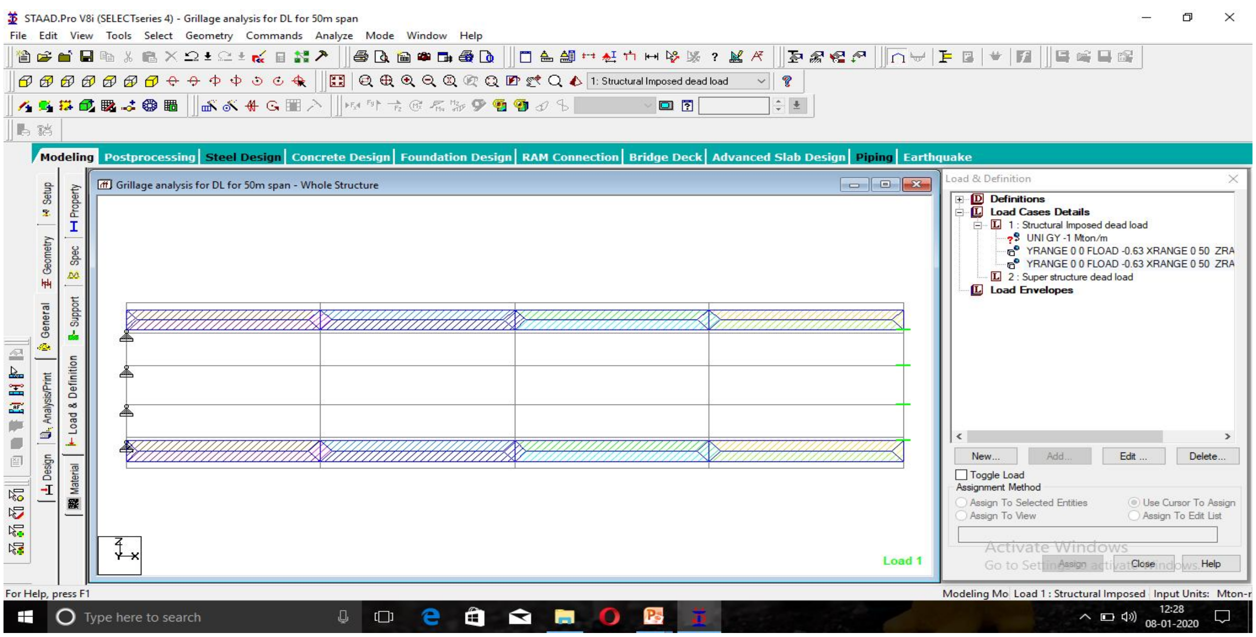

Fig. 8 Footpath Loading on Structure

B. Vehicular Load Calculations:

The live load with appropriate impact factor is moved on the deck slab using vehicular load option.

Table VI

Calculation of Impact Factor (I) as Per Clause NO 208 IRC-6 2016

For class A vehicles	4.5/(6+L)=4.5/(6+50)= 0.08035%
For 70R tracked vehicles	10%
For 70R wheeled vehicles	15%

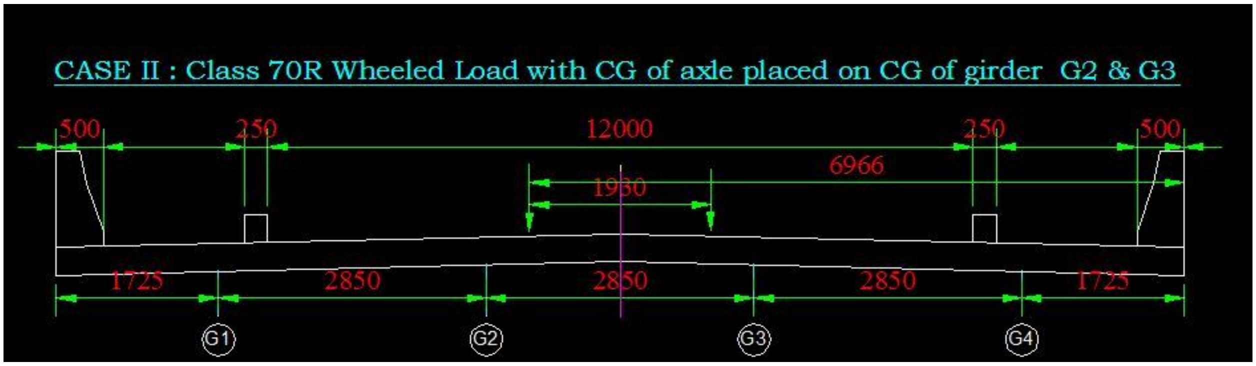

Fig. 9 vehicular loading as per IRC 6 2016

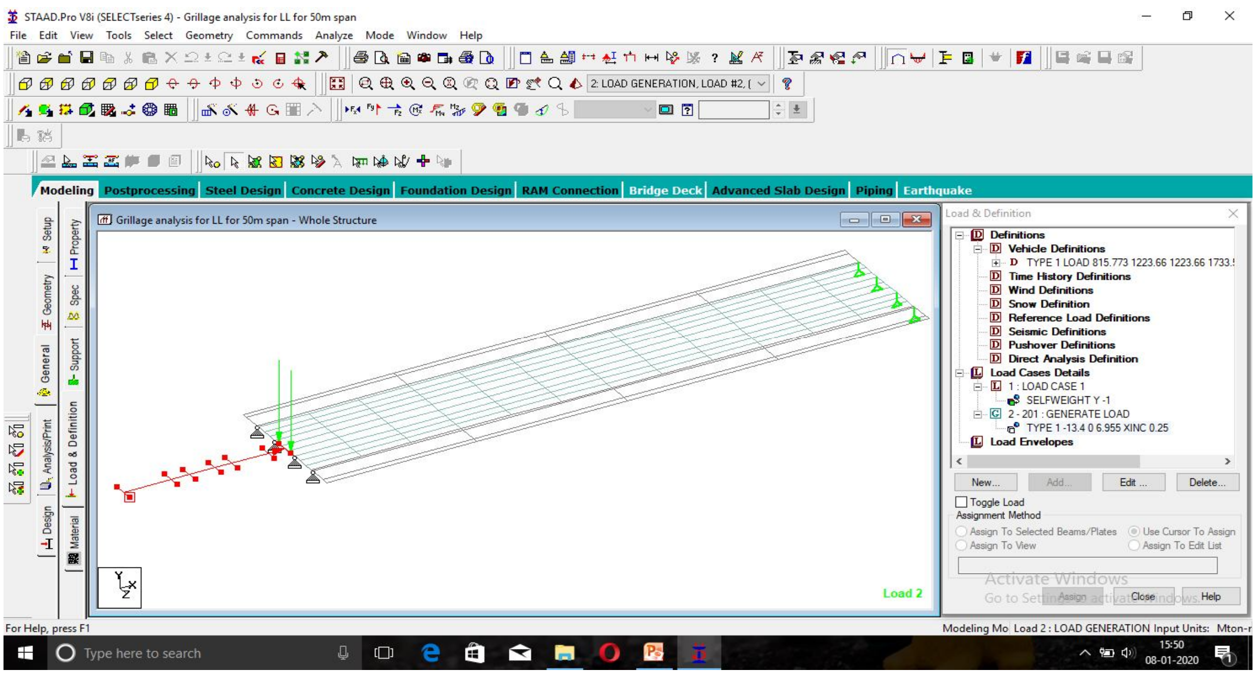

Fig. 10 vehicular loading on structure

VI. RESULTS AND DISCUSSION

The Critical BM and SF for deck is obtained at various sections for each of the loadings and compared to get the Critical Forces. We get different values for different loading condition, that is vehicular live load due to 2 class A, 70R tracked vehicle, 70R Wheeled vehicle. Out of these the one giving maximum bending moment and shear force values is considered for design of the deck slab. The total design value= (max dead load value + max vehicular live load value).

TABLE VII

Factored Values

Factored bending moment	563.453 KN/m
Factored shear force	420.018 KN

VII. CONCLUSIONS

A. Grillage model is the most popular computer-aided method for analysing bridge decks. This is because it is easy to understand and use. This has been proved to be accurate for a wide variety of bridge types and any type of loading conditions.

B. Grillage model values are dependent upon the specifications of individual grillage beams.

C. The maximum values of bending moment and shear force are 563 kNm and 420 kN, for 70R tracked vehicle.

D. The finer grillage mesh, provide more accurate results.

VIII. ACKNOWLEDGMENT

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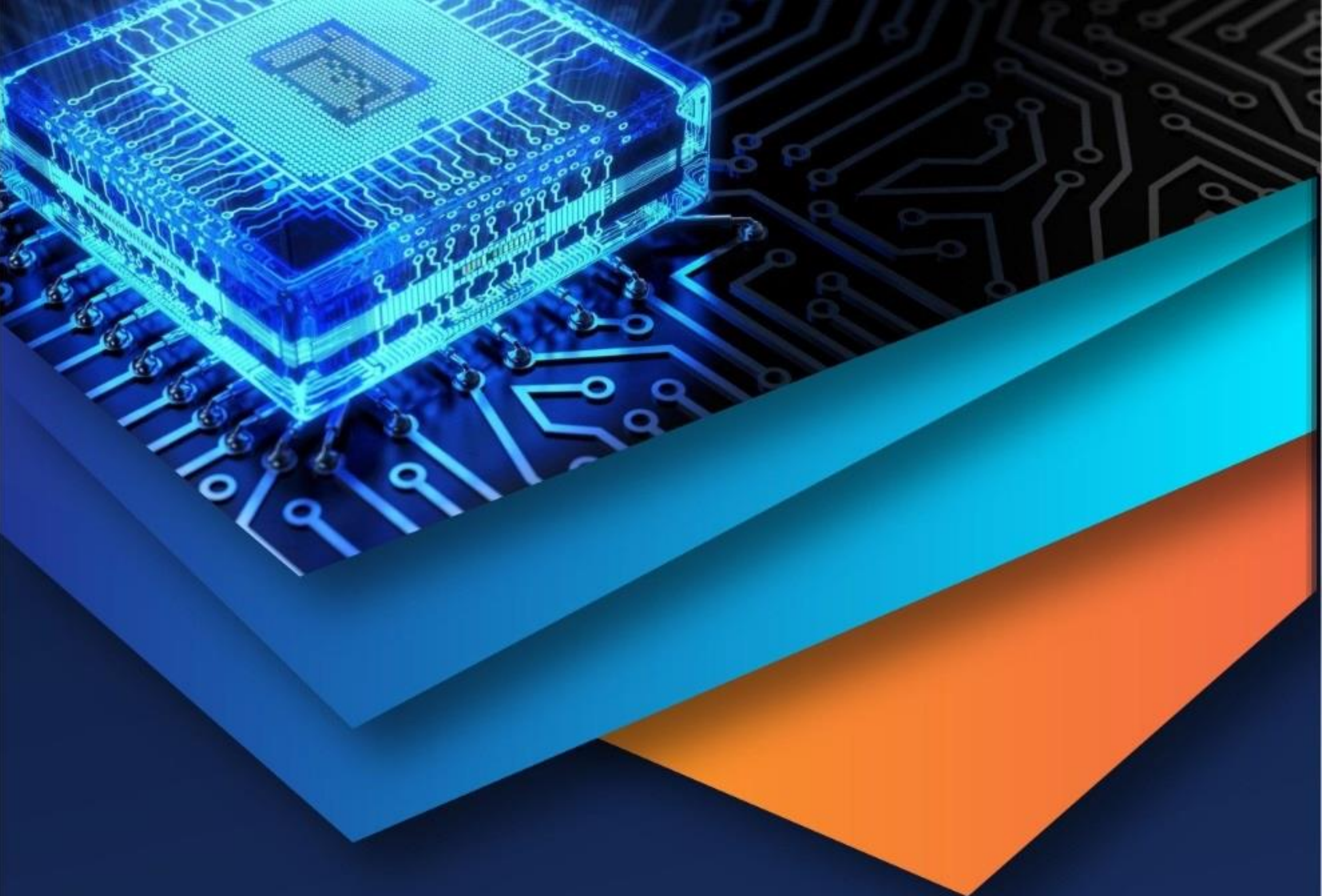

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