ANALYSIS AND DESIGN OF BRIDGE DECK USING GRILLAGE METHOD - AS PER IRC

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Abstract:- *Analysis and design of bridge deck using grillage method is considered. The structural model is developed as per FE discretization in Staad Pro. 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: 6-2014. Linear static analysis is carried. The design values of bending moment and shear force for the class A 70 R tracked vehicle are arrived.*

Key Words: Grillage model, Discretization, Impact factor, wearing coat, Vehicular live load

1. INTRODUCTION

Grillage analogy is probably one of the most popular computer-aided analysis for analyzing bridge decks. The method consists of representing the actual decking system of the bridge by an equivalent grillage of beams. The dispersed bending and torsional stiffness of the decking system are assumed, for the purpose of analysis, to be concentrated in these beams. The actual deck loading is replaced by an equivalent nodal loading.

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 ascertained.

1.1 Types of modelling:

It is a procedural way of establishing three mathematical models, such as

1. A structural model
2. A material model
3. A load model

1.1.1. Types of loads

1. Permanent Loads
2. Transient Loads

1.1.2. Modeling discretization

Formulation of a mathematical model using discrete mathematical elements and their connections and interactions to capture the prototype behavior is called Discretization. For this purpose:

1. Joints/Nodes are used to discretize elements at primary locations in structure at which displacements are of interest or at locations of change in geometry.
2. Elements are connected to each other at joints.
3. Masses, inertia, and loads are applied to elements and then transferred to joints.

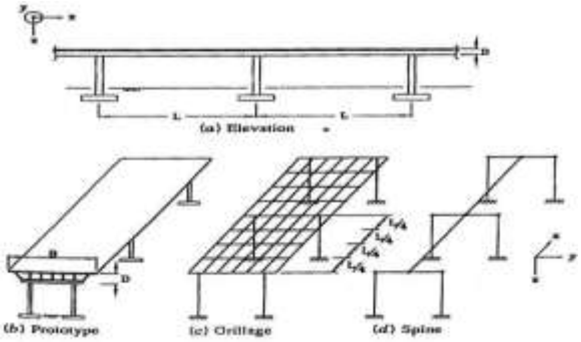

Figure 1: models of super structure (Priestley, et al 1996)

1.1.3. Spine model

Spine Models with beam elements are generally used for ordinary bridges.

1. The effective stiffness of the element may vary depending on the structure type.
2. Spine model can't capture the superstructure carrying wide roadway, high-skewed bridges. In that case grillage model is used.

1.1.4. Grillage model

Grillage model is the most used computer-aided method for analyzing bridge decks. If the load is concentrated on an area which is much smaller than the grillage mesh, the concentration of moments and torque cannot be given by this method and the influence charts can be used.

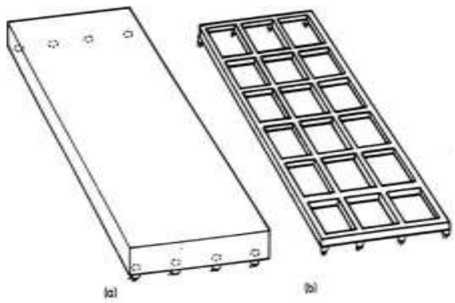

Figure 2: (a) Prototype deck slab model and (b) equivalent grillage model (Source: Bridge Deck Behavior - E.C.Hambly)

1.1.5. Plate element model

The other method used in modeling the bridges is by using the plate/shell elements model the bridge deck.

2. Analysis and design of RC solid deck slab

2.1 Introduction:

For short spans, a solid reinforced concrete slab, generally cast in-situ rather than precast, is the simplest design. It is also cost-effective, since the flat, level soffit means that false work and formwork are also simple. With 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

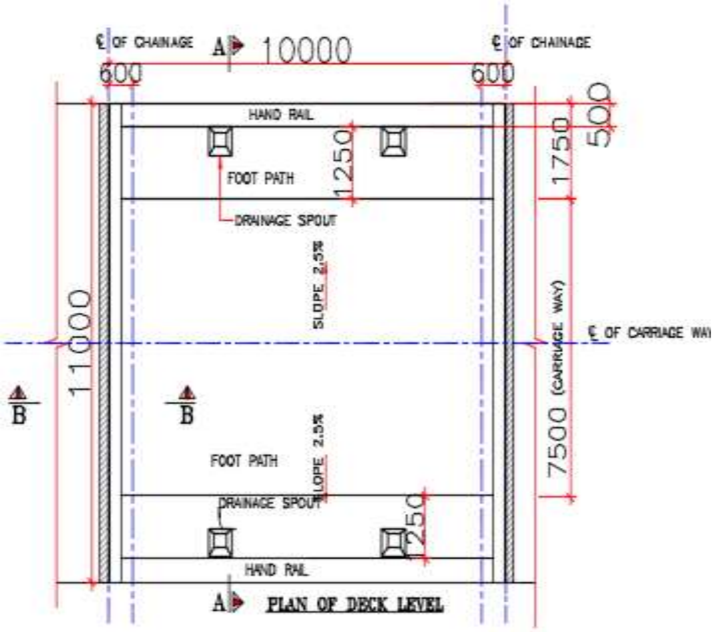

Figure 3: Plan view of Reinforced concrete solid slab

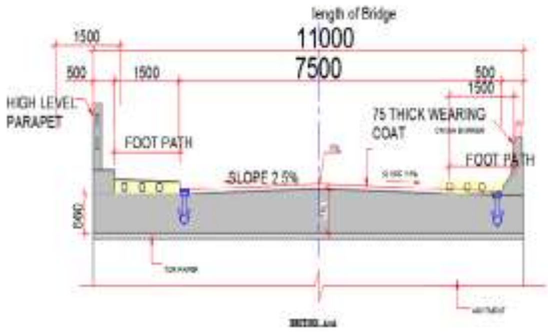

Figure 4: C/S view at A-A of Reinforced concrete solid slab

2.2 Structural analysis:

Linear analysis is performed for dead load and vehicular live loads using STAAD Pro**.**

Table 1: General Details

Grade of concrete	M 40
Grade of steel	Fe 500
Unit weight of RCC	25 kN/m^3
Unit weight of PCC	22 kN/m^3
Vehicular Live loads considered for 3 Lane traffic according to IRC:6-2014	Class A Vehicle
	70R Wheeled Vehicle
	70R Tracked Vehicle

2.3 Idealization of deck in Staad Pro:

The RC solid Slab deck is modelled as "Grillage". The slab deck is divided into longitudinal and transverse grillage beams with appropriate properties.

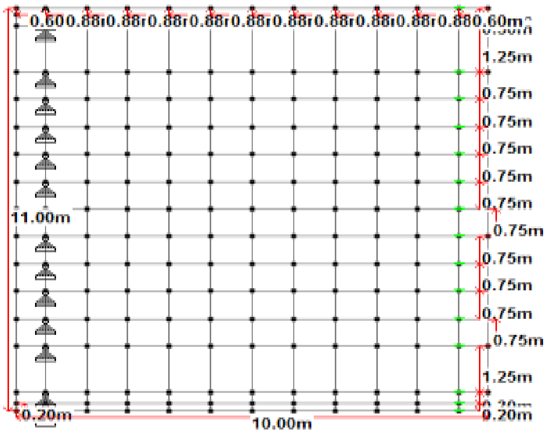

Figure5: Deck slab grillage model

Member property of deck slab:

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

Table 2: Self weight load calculation (25 kN/m³)

Thickness in m	Intensity of load in kN/m²	Spacing of transverse in m	Load on transverse
0.66	0.66x25=16.5	0.6/2=0.3	4.95
0.66	0.66x25=16.5	0.6/2+0.88/2=0.74	12.21
0.66	0.66x25=16.5	(0.88+0.88)/2=0.88	14.52

2.4 Dead load calculation:

Table 3: Summary of load due to wearing coat (2 kN/m²)

Intensity of load in kN/m²	Spacing of transverse in m	Load on transverse kN/m
2	0.6/2=0.3	0.6
2	0.6/2+0.88/2=0.74	1.48
2	(0.88+0.88)/2=0.88	1.76

Table 4: Summary load due to Foot path live load (FLL) (5 kN/m²)

Intensity of load in kN/m²	Spacing of transverse in m	Load on transverse kN/m
5	0.6/2=0.3	1.5
5	(0.6+0.88)/2=0.74	3.7
5	(0.88+0.88)/2=0.88	4.4

Table 5: Summary of self-weight load calculation

Transverse member load				
Sl.No	Thickness in meters(m)	Edge Member	Member Along support	Remaining Members
		0.300	0.74	0.88
1	0.66	4.95	12.21	14.52
2	(0.66+0.675)/2	5.01	12.34	14.67
3	(0.675+0.694)/2	5.13	12.66	15.059
4	(0.694+0.713)/2	5.27	13.0	15.47
5	(0.713+0.731)/2	5.415	13.357	15.884
6	0.731+0.75)/2	5.55	13.699	16.291

Load due to crash barrier = 7.75 kN/m, applied on edge members along longitudinal direction

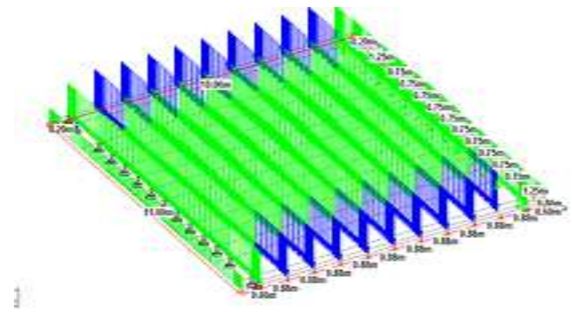

Figure 6: Dead load on grillage model consideration in staad pro:

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

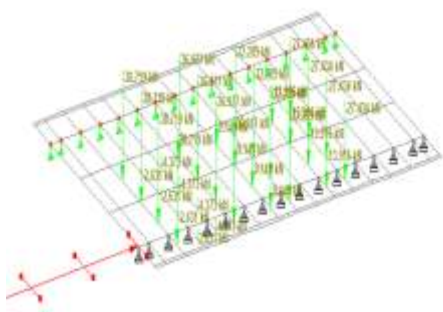

Figure 7: 2 Class A vehicle positioned at minimum edge clearance as per IRC

Table 6: **Calculation of Impact Factor (I) as per CL 211.1 IRC: 6-2014**

For class A Vehicles	4.5/ (6+L) =4.5/ (6+10) = 28.12 %
For 70R Tracked Vehicle	10%
For 70R wheeled Vehicle	25%

2.5 Summary of forces

The Critical BM and SF for deck is obtained at various locations 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)

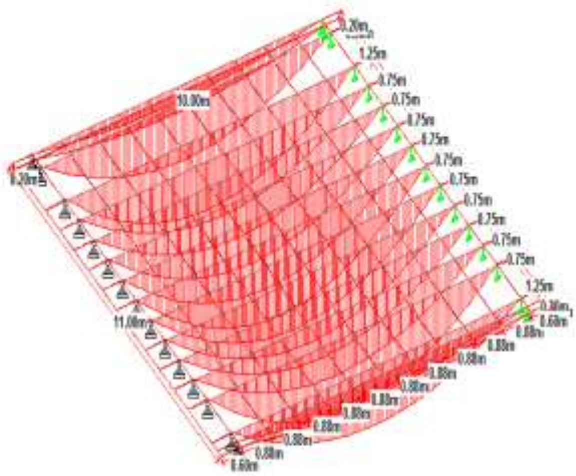

Figure 8: BM due to 70R tracked vehicle placed on Reinforced concrete slab

Table 7: Summary of Design Values

Factored Bending moment (kN-m)	463.838
Factored Shear force(kN)	316.018

CONCLUSIONS

1. Grillage model is the most popular computer-aided method for analyzing bridge decks. This is because it is easy to comprehend and use. This has been proved to be accurate for a wide variety of bridge types.
2. Grillage model values are dependent upon the property specification of individual grillage beams.
3. The maximum values of bending moment and shear force are 464 kNm and 316 kN, for 70R tracked vehicle.
4. The finer grillage mesh, provide more accurate results.

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