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Analysis of Prestressed Solid And Voided Slab type Bridge Superstructure on Curved Alignment

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Abstract* - When Solid slab becomes uneconomical we have to go for the next alternative to make our deck economical as well as safe. The object of the paper is to analyze prestressed horizontal curved solid and voided slab for 25m bridge span using grillage analogy method. The analysis presented illustrates the behavior of bending moments, Shear Force, displacement due to change in curvature for various load conditions of solid and voided deck slab. Slab analyzed under various loading conditions as per IRC and results has been compared to know the effect of the curvature on bridge deck. Width of the deck slab keep constant (12m) for various degree of curvature (15°, 30°, 45°, 60°) and analysis has been done in STAAD Pro. In each analysis, the behavior of deck slabs was investigated, and maximum bending moment, max shear forces and displacement developed in members were observed.

Keywords – Prestressed Slab Type Bridge Superstructure, Solid Slab, and voided slab, Curved Alignment, STAAD Pro

I. INTRODUCTION

Bridge is life line of road network, both in urban and rural areas. Horizontally curved bridges are the most feasible options at complicated interchanges or river crossings where geometric restrictions and constraint of limited site space, make difficult the adoption of standard straight superstructures. Contrary to straight bridges, a very limited documentation on the study of horizontally curved bridges has been available. Generally for construction of a medium bridge idea for selection depends upon various factors. When Solid slab becomes uneconomical we have to go for the next alternative to make our deck economical as well as safe.

Bridge design is an important as well as complex approach of structural engineer. As in case of bridge design, span length and live load are always important factor. Bridge design is an important as well as complex approach of structural engineer. As in case of bridge design, span length and live load are always important factor. These factors affect the conceptualization stage of design. The effect of live load for various span are varied. In shorter spans track load govern whereas on larger span wheel load govern. Many methods are used in analyzing bridges such as grillage and finite element methods. Generally, grillage analysis is the most common method used in bridge analysis. In this method the deck is represented by an equivalent grillage of beams.

There is a very limited knowledge available about curved bridges, both in standard specifications and literature. In this paper, analytical results of curved bridges are show in charts and tabular form for a various parameters such as shear, bending and displacement for curved bridges. This type of work can be also useful for preliminary design of horizontally curved bridge.

Hence to fill in the void for the realistic analysis, the work on the parametric study of curved bridges is performed. Various behaviors like bending, shear, displacement of horizontally curved prestressed bridges is presented. In this study for analyzing of bridge grillage analogy method is used using STAAD Pro. Eight models are prepared for 25m span lengths keeping the same material properties with varying degree of curvature from 15° to 60° at 15° increment for different load conditions and load combinations. Charts & tables for various parameters of curved bridges are presented in this paper.

II. VOIDED DECK SLAB

- **Need of Voided deck Slab**

Slab bridges are under-used principally because of lack of refinement of the preliminary costings carried out by most of the contractors or Estimators. The unit costs of formwork, concrete, reinforcement and prestress tendons should be clearly be lower for a solid slab deck than for more complex cross sections such as voided slab or multicellular slab decks. However in early stages of the project when options are being compared, this is frequently overlooked.

Slabs allow the designer to minimize the depth of construction and provide a flat soffit where this is architecturally desirable. Their use is limited principally by their high self-weight. Typical medium-span concrete bridge decks with twin rib or box cross sections have an equivalent thickness (cross section area divided by width) that generally lies between 450mm and 600mm. Thus when the thickness of slab exceeds about 700 mm, the cost of carrying the self-weight tends to outweigh its virtues of simplicity.

- **Voids Shape and Material**

Voids may be circular, quasi-circular such as octagonal, or rectangular. Rectangular voids are assimilated to multi cell Boxes.

- **Methods are used to Create Voids**

The commonest is to use expanded polystyrene, which has advantage that it is light easy to cut. In theory, Polystyrene voids can be made of any shape, either by building up rectangular sections, or by sharping standard sections. In practice, the labour involved in building up or cutting sections is not economical there for cylindrical voids are usually used, these cylinders may be cut away locally to widen ribs, or to accommodate prestress anchors, drainage gullies etc.

- **Development of Voided Slabs**

The development of voided slab is similar to that of solid slabs. In decks where the maximum stress on the top and bottom fibers is less than the permissible limit, it is cost effective to create side cantilevers and to remove material from the center of wide slabs, creating effectively a voided ribbed slab.

- **Criteria for making Voided Slab**
  - Center to center spacing of voids shall not be less than the total depth of slab.
  - Ratio of void to the total depth of slab shall not exceed 75%.
  - The thickness of the concrete above the voids where cables are not located shall not be less than 200 mm.
  - The thickness of the concrete below voids where cables are located shall have 75mm minimum clear cover measured from outside of sheathing.
  - The thickness of web shall not be less than 200 mm plus diameter of duct hole. Where cables cross within the web, suitable thickness over the above value shall be made.

III. GRILLAGE ANALOGY METHOD

The grillage analogy method is a computer-oriented technique and is being used in the analysis and design of bridges. With the use of computer facilitates, the investigation of several load cases can be done in very short time as compared to manual methods. The method consists of rigidly connected beams at discrete nodes i.e. idealizing the slab by an equivalent grillage. The deformations at the two ends of a beam element are related to the bending and torsional moments through their bending and torsional stiffness.

Idealization, as number of longitudinal and transverse beam elements in a single horizontal plane, rigidly interconnected at nodes. Transverse beams may be orthogonal or skewed with respect to the longitudinal beams, so that skew, curved, tapering or irregular slabs can be analyzed by this method.

In a simple grillage analysis, each beam is allotted a flexural stiffness in the vertical plane and a torsional stiffness. Vertical loads are applied only at the nodes. Computer software is used to determine the displacements (rotations about the two horizontal axes and the vertical displacement) at each node and the forces (bending moments, torsional moments and vertical shear forces) in the beams connected to each node.

Software's like STAAD Pro or SAP2000 can be used for grillage analogy modeling method.

Following points give a summary of the guidelines to convert an actual bridge deck into a grid for grillage analysis:

- Grid lines are placed along the center line of the existing beams, if any and along the center line of left over slab, as in the case of T-girder decking.
- Longitudinal grid lines at either edge be placed at 0.3D from the edge for slab bridges, where D is the depth of the deck.
- Grid lines should be placed along lines joining bearings.
- A minimum of five grid lines are generally adopted in each direction.
- Grid lines are ordinarily taken at right angles.
- Grid lines in general should coincide with the CG of the section. Some shift, if it simplifies the idealization, can be made.
- Over continuous supports, closer transverse grids may be adopted. This is so because the change is more depending upon the bending moment profile.
- For better results, the side ratios i.e. the ratio of the grid spacing in the longitudinal and transverse directions should preferably lie between 1.0 to 2.0.

General steps for grillage analogy method:

1. Idealization of physical slab into equivalent grillage.
2. Evaluation of equivalent elastic inertias of members of grillage.
3. Application and transfer of loads to various nodes of grillage.
4. Determination of force responses and design envelopes and
5. Interpretation of results.

IV. DESCRIPTION OF BRIDGE SUPER STRUCTURE

A simply supported two lane span of 25m solid and voided slab is considered. Railing, footpath, crash barrier, lane dimensions are considered as per IRC: 5-1998. Voids dimensions are considered as per IRC SP: 64-2005. The bridge superstructure with 2 lane carriageway of 7.5 m width with footpath with prestressed solid slab is taken. On two side of carriage way crash-barrier with 0.45 m width and footpath with 1.5m width and parapet with 0.3m width provided.

- **CROSS SECTION OF SLAB**

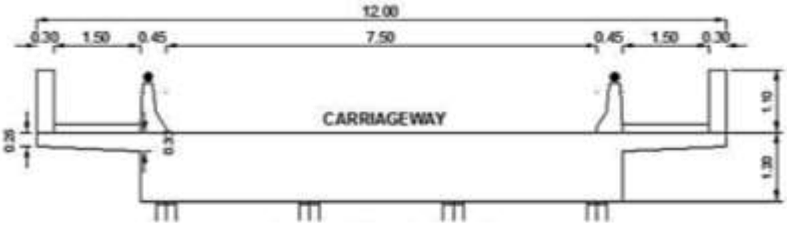

Figure 1. Cross Section of 25m Solid Slab

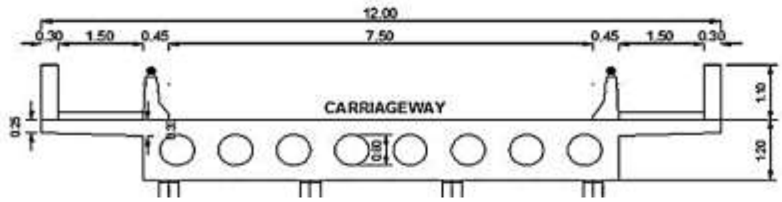

Figure 2. Cross Section of 25m Voided Slab

- **ELEVATION OF SLAB**

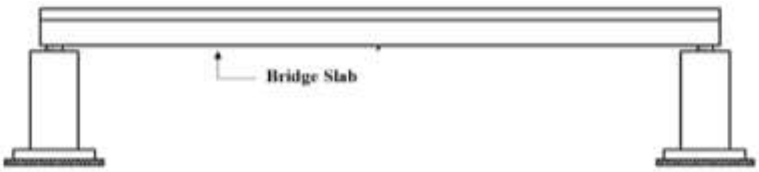

Figure 3. Elevation of Slab

Table 1. Dimension of Slab Type Superstructure

	Solid slab	**Voided slab**
Span (M)	25m	25m
Depth (M)	1.2	1.2
Width (M)	8.4	8.4
Void Diameter(M)	-	0.6
No. Of Void	-	8
Area (M^2)	10.08	7.818

- **LOADS**

The following loads are considered:
1) Dead load: The dead load includes self-weight of the slab type superstructure.
2) SIDL: Weight of crash barrier, parapet and wearing coat is considered in SIDL.
3) Live Load: IRC loading for two lane bridges are considered, which are as follows:
    - One lane of Class-70R wheel loading
    - Two lane of class-A loading

4) Load Combination: Following load combinations are carried out and worst effect is considered in the analysis.
    - DL + SIDL + LL (Maximum of Class 70R, Class A)

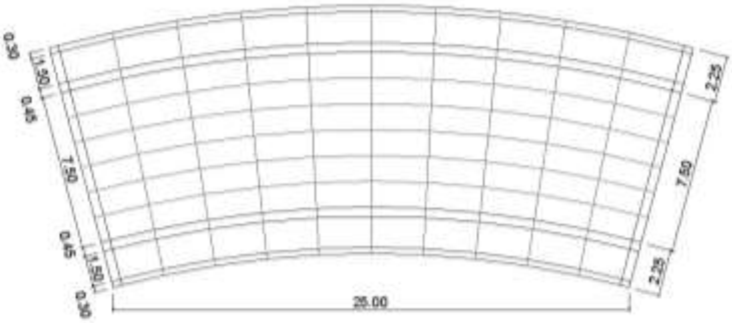

Figure 4. Grid Mesh (25m Span, 30° Degree Curvature)

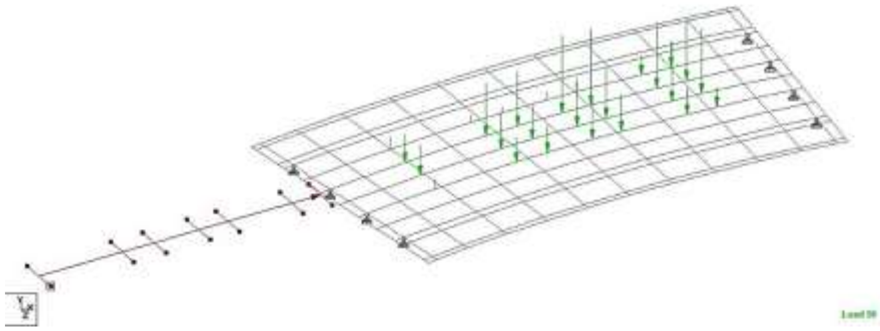

Figure 5. Live Load (Class 70R)

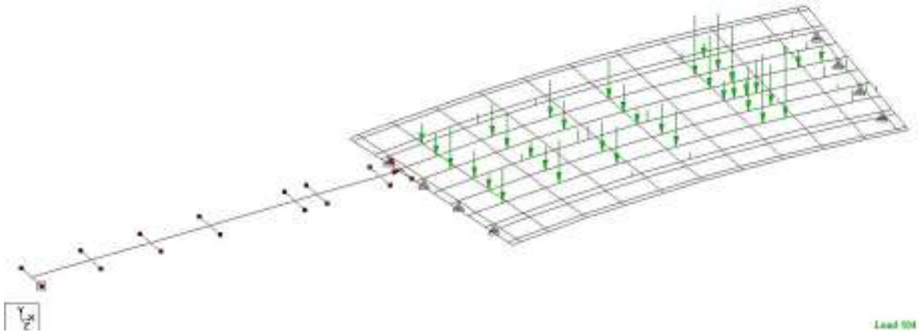

Figure 6. Live Load (Class A)

V. ANALYSIS RESULTS

The results are collected for a 25m span with varying degree of curvature (15° to 60° at 15° increment). Results are taken for DL + SIDL + LL (Max.). The values of maximum B.M., S.F., and displacement are collected for entire Section of which maximum B.M. and displacement occurs at mid span, maximum S.F. at edge near supports.

Table 2. Max. Bending Moment of Solid and Voided Slab (T.M)

25m Span	Degree Of Curvature			
	15° Degree	30° Degree	45° Degree	60° Degree
Solid Slab	2652.61	3097.36	3673.15	4432.66
Voided Slab	2253.92	2630.58	3117.61	3759.14

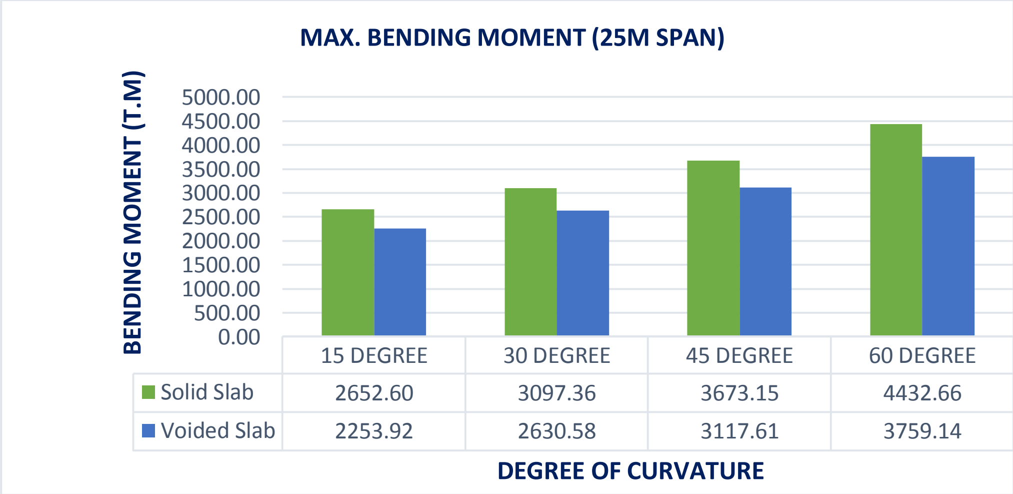

Figure 7. Max. Bending Moment of Solid and Voided Slab (25m Span)

Table 3. Max. Shear Force of Solid and Voided Slab (T/M width)

25m Span	Degree Of Curvature			
	15° Degree	30° Degree	45° Degree	60° Degree
Solid Slab	79.31	97.93	119.57	149.68
Voided Slab	68.39	84.02	102.17	126.17

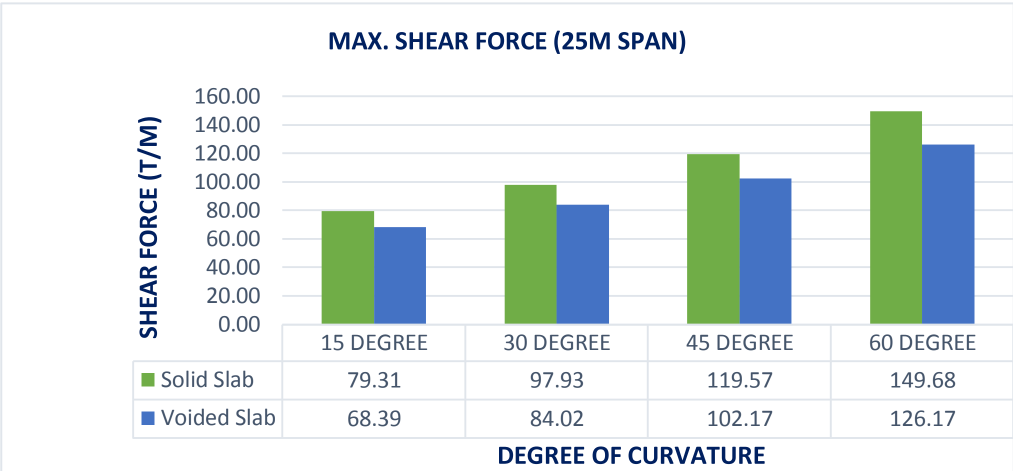

Figure 8. Max. Shear Force of Solid and Voided Slab (T/M width)

Table 4. Max. Displacement of Solid and Voided Slab (M)

25m Span	Degree Of Curvature			
	15° Degree	30° Degree	45° Degree	60° Degree
Solid Slab	0.089	0.129	0.192	0.294
Voided Slab	0.076	0.109	0.163	0.250

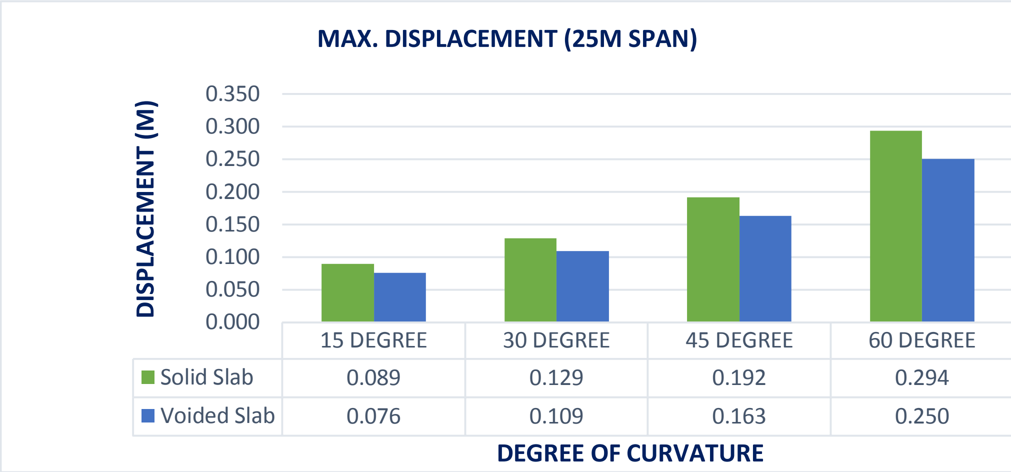

Figure 9. Max. Displacement (25m Span)

VI. CONCLUSION

Eight Models were prepared for solid slab and voided slab keeping the same material properties with varying degree of curvature from 15° to 60° at 15° increment for different load conditions and load combinations. Loads, load combinations and end conditions were applied to the models as per IRC specifications. STAAD Pro Software was used for the analysis. The conclusions obtained from the present study are shown in tables and graphs above and can be described as below.

1. As per above graph it has been concluded that the bending moment, shear force and displacement of slab type superstructure is increase with increasing in degree of curvature.
2. Bending moment, shear force and displacement of voided slab is lower than solid slab.
3. Due to voids self-weight of voided slab decrease about 23% than solid slab.
4. Max. Bending moment and displacement obtain at center of span length.
5. Max. Shear force obtain at outer edge of curvature near the support.
6. Max. Displacement obtain at center span outer edge of curvature.
7. Due to increasing in span and degree of curvature bending moment shear force and displacement is increase.
8. For 25m span voided slab is better than solid slab in term of bending moment, shear force, displacement, self-weight.
9. The benefit for grillage analysis is that it is easy to use and comprehend.

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