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[Kamlesh et al., 5(8), Aug 2020]

ISSN : 2455-9679
Impact Factor : 3.340

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"CRITICAL ELEMENT ANALYSIS OF PRESTRESSED CONCRETE BRIDGE DECK USING GRILLAGE DESIGN TECHNIQUES"

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ABSTRACT

In this study, the behaviour of bridge deck composite pre-stressed post tensioned girder with reinforced concrete deck slab will be analysed under various loading combinations of the bridge structure such as self-weight of the whole bridge super structure, super imposed dead load and live load over the bridge deck were taken into account to design the critical element of the bridge deck girder by using the latest computer method of STAAD V8i, the grillage model of the whole bridge structure were created and this model were analysed under both later and longitudinal forces of the deck slab and the deck and girder were designed for various critical combination loading of the structure.Additional bridge physical girder may also be set in order to improve the accuracy of the results and ultimate load carrying capacity of all the bridge decks.

The maximum bending moment, shear force and deflection curves are plotted from the results of grillage element analysis. Accordingly the pre-stress post tensioned longitudinal and transverse girders were designed to produce maximum moment of resistance to the actual bending moment received from the grillage model analysis and the check for various stresses and deflection of the bridge deck girders with composite action of the bridge structure were analysed, the stress for various loads like slab load, girder load and moving load, were also analysed.

Key Words: *Bridge deck girder; reinforced concrete composite deck slab; grillage analysis; STAAD Pro*

I. INTRODUCTION

Bridge structures are developing day to day as fast as the traffic volume increases in the nation. The diversity of sites increasingly challenging the ingenuity of engineers to produce new design methodology for the bridge structure, the method of analysis have developed equally rapidly, with the use of computer methods the accessibility of micro computers is making it progressively easier for engineers to analyse bridge with complex cross-sections, complicated skew bridge structure, curved and continuous bridge structure span. In the past considerable amount of theoretical and experimental research was required to develop the design methods. Today, however, several have been developed to such usable from that with an understanding of physical behaviour. It is mainly used for accurate application of complicated structures. The grillage analysis is much easier to check the computer data, the grillage method of analysis can be used to analyse the numerous load cases and the results produce much easier then hand calculation. This thesis

ISSN : 2455-9679
Impact Factor : 3.340

concentrates on the simpler computer calculation of grillage method of analysis for prestressed concrete bridge deck structure is represented by equivalent beam elements. Most structural engineers have an initiative feel for how beams react to the various forces of bending, shear and torsion, and they can use physical reasoning.
A bridge deck can be considered to behave as a beam when its length exceeds its width by such an amount that when loads cause it to bend and twist along its length, its cross-section displaces bodily and do not change shape, the most common beam decks are either reinforced or prestressed concrete. The primary structural member of bridge deck is a grid of two or more longitudinal beams or transverse beams with diaphragms supporting the running slab. Loads are distributed between the main longitudinal beams by the bending and twisting and bending of the transverse beam, bridge decks are most conveniently analysed with the conventional computer method of grillage analysis. The prestressed post tensioned girders are used in the building and bridges. Usually, the cantilever is provided with the back span to reduce the torsion in the supporting member. In a bridge, the cantilever is a part of the "balanced cantilever "girder. Prestressed concrete is ideally suited for the construction of medium and long span bridges. Ever since the development of prestressed concrete by freyssinet in the early days, the material has found extensive application in the construction of long-span bridges, gradually replacing steel which needs costly maintenance due to the inherent disadvantages of corrosion under aggressive atmospheric conditions. Solid slabs bridges are used for the span range of 10 to 20m. Prestressed concrete is ideally suited for long span bridges in which girders are precast and the deck slab monolithic construction with the precast post tension girders.

II. LITERATURE REVIEW

Sabeeh and Ammar (2008) the analysis principle was used to analyze anisotropic plates (having different properties and geometries in different directions), the model consists of four side beams with flexural rigidity and torsional rigidity and two diagonal beams with only flexural rigidity. The substitute grid framework is analyzed t give the same deformation and deflections of the orthotropic plate elements of the modelled bridge. Applicability of the suggested procedure in the analysis of actual bridge decks is investigated using STADD Pro 2006 program. The results show that the suggested procedure is an acceptable procedure which can be adopted to analyze this type of bridge deck. It is found that the modified grillage method gives simpler method and adequate results when compared with the Finite Element Method or orthotropic plate theory solved using Finite difference Method for this type of bridges. Hambly (1991) He shows how complex structures can be analysed with physical reasoning and relatively simple computer models, and without physical reasoning and relatively simple computer models, and without complicated mathematics, in recent years the computer methods of the grillage and space frame have become very popular and accessible as microcomputers and software have developed rapidly. The visual displays of modern programs can provide an engineer's with a comprehensive picture and understanding of the behaviour of his structure. At the design stage this helps him to manipulate his design and so economize in the use of construction materials. During the assessments of old bridges he can examine alternative load paths with ease and so determine the reserves of strength as the structure changes. The improvements in facilities since the publication of first edition now enable the author to analyse in one hour a deck which previously took several days. Doug Jenkins (2010) In spite of the increases in computing power, bridge deck analysis methods have not changed to the same extent and grillage analysis methods remains same for the standard procedure for most structures. In this paper the advantages and disadvantages of using more complex analysis procedures are examined. Alternative grillage analysis and comparison of design actions and deflections from alternative analysis methods, analysis of secondary effects and non linear analysis. The advanced analysis in the design office.

III. GRILLAGE ELEMENT MODELING

3.1 Geometry of Straight Mesh Element Model

The straight mesh element model of grillage decks the transverse members of the longitudinal girders should be

ISSN : 2455-9679
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arranged perpendicular to the cross members (see Fig.3.1) and the transverse cross girders must be perpendicular to the longitudinal girder of the deck slab to achieve the correct magnitude for moments and deflections. Essentially the computer aided method for the analysis of bridge decks. The total number of longitudinal members varies depending on width of deck. The spacing should not less than two times the thickness of the slab or three times the thickness of the slab and the spacing of the grillage model should not greater than1/4 to 1/8 of effective span for isotropic slab. The spacing of the slab should be enough to represent the loads distribution along longitudinal members closer spacing required in regions of sudden change e.g internal supports. The deck with contiguous beams at very close centres. Since a grillage with longitudinal members coincident with all the beams can easier to use a fine mesh than to work out the characteristics of grillage members representing two or more beams. Since beam-and Slab decks have poor distribution characteristics, it is important not to place longitudinal grillage members much further apart than about 1/10 of the span. Since during the transverse flexure, the thin slab flex with most of the bending over the width of the thin slab. Accordingly the transverse members representing the thin slab will behave much lower stiffness's than the members representing the thin-thick slab of the prototype. However, processing of the grillage output is then much more cumbersome. It is place longitudinal members of nominal stiffness along the outer edges of the deck to define the overall width for loading

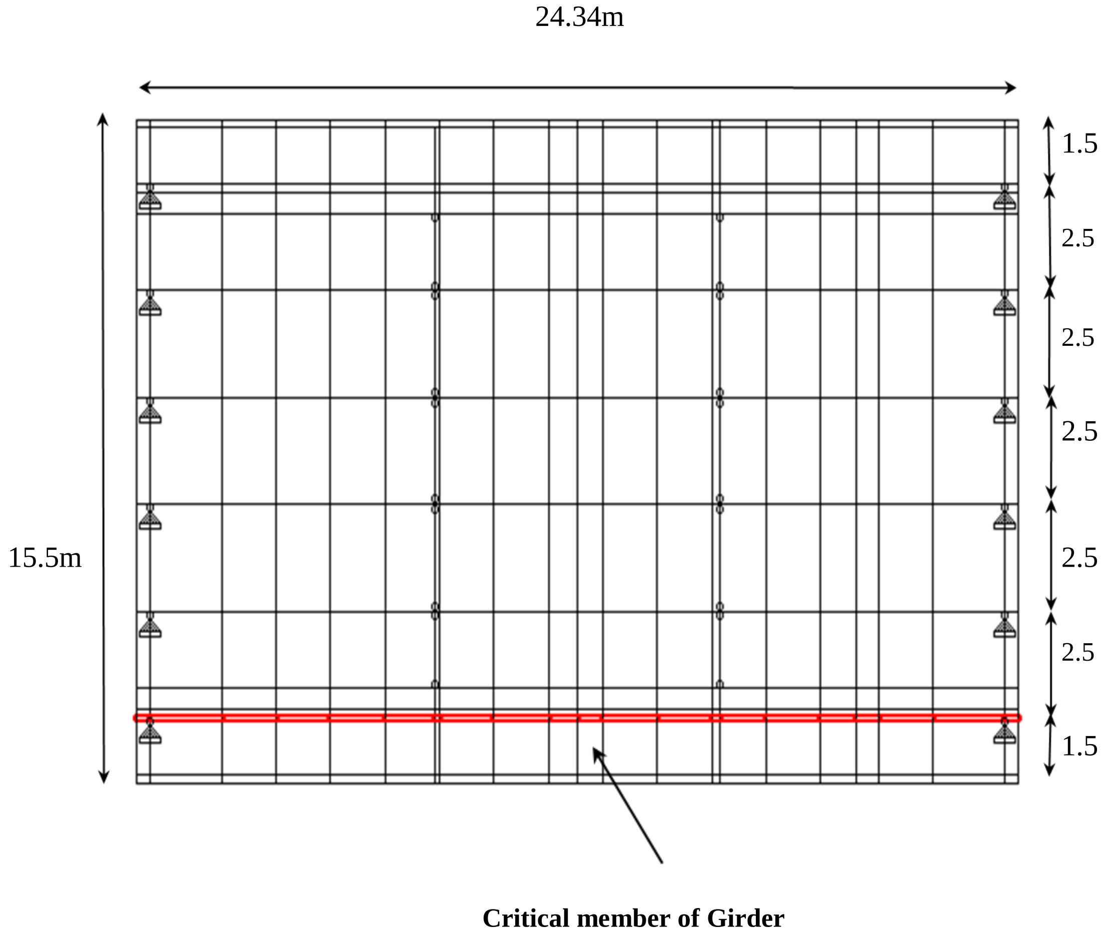

Figure 1: Geometry of Straight Mesh Element

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IV. METHODOLOGY USED FOR MODELLING

In STADD V8i, the Space frame model of the bridge deck was created by following procedure grillage straight element mesh analysis. The cross section of the assumed bridge deck span in transverse side is 15.5m. The longitudinal direction span is 24.340m and 6 longitudinal girders with deck slab the spacing of the transverse grillage member shall not be less than 1/10 of the effective it must be 1/4 to 1/8 of the effective span of the bridge deck shall be arranged in the grillage analysis. When intermediate cross girders exist in the actual deck, the transverse grid lines represent the properties of cross girders and associated deck slabs. The grid lines are along the centre line of the cross section. The grid lines are placed in between these transverse physical cross girders, if after considering the effective flange width of these girders portions of the slab are left out. If after inserting grid lines due to these left over slabs, the spacing of transverse grid lines is greater than two times the spacing of longitudinal grid lines, the left over slabs are to be replaced by not one but two or more grid lines so that the above recommendation for spacing is satisfied. The logical choice of the longitudinal grid lines for T-beam or I beams decks is to make them coincident with the centre lines of physical girders and these longitudinal members are given the properties of the girders plus associated portions of the slab, which they represent. Additional grid lines between physical girders may also be set in order to improve the accuracy of the result. The transverse grid lines are also place at abutments joining the centre of bearings. A minimum of seven transverse grid lines are recommended including edge grid lines. It is advisable to a light the transverse grid lines normal to the longitudinal grid lines where ever cross girders do not exist. It should also be noted that the transverse grid lines are extended up to the extreme longitudinal grid lines. In skew bridge, with small skew angle say less than 15° and with no intermediate diaphragms, the transverse grid lines are kept parallel to the support lines. Additional transverse grid lines are provided in between these support lines in such a way that their spacing does not exceed twice the spacing of longitudinal lines, as in the case of the right bridge discussed above. In skew bridges, with higher skew angle, the transverse grid lines are set along abutments. Put the grillage along the line of strength (prestress beam edge beam etc). After creating the geometry of mesh element modal the properties of grid lines representing the slab only are calculated in the usual way ie:I=bd3/12 and $J=bd^3/6$. If the construction materials have different properties in the longitudinal and transverse directions, care must be taken to apply correction for this. The section properties of the girders shall be applied over the straight element mesh model. And the same way the sectional property of the slab were calculated and applied over the slab mid and cantilever panel of the element bridge deck straight mesh element analysis, then the self weight of the main girders are calculated from their unit weight multiplied by the volume of the prestressed concrete material to get self weight the same way the cross girders were calculated and the self weight were found. The self weight of the slab also found by the same way and applied over the grillage mesh element lines of cross girders and longitudinal girders with composite slab cross sectional properties of girder composite weight were applied along the longitudinal girders lines of grillage straight mesh element analysis. After assigning the sectional property and self weight, then the supper imposed dead load, live(moving) load as per IRC-6-2010 clause 207.1.3 page12 were calculated and the calculated loads were applied over the deck slab straight mesh element modal.

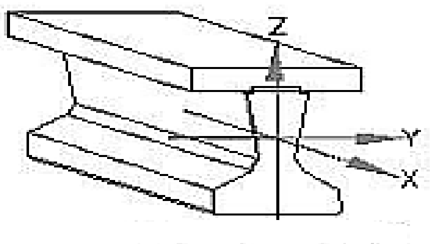

Figure 2: Local Member Axis of Longitudinal Girder

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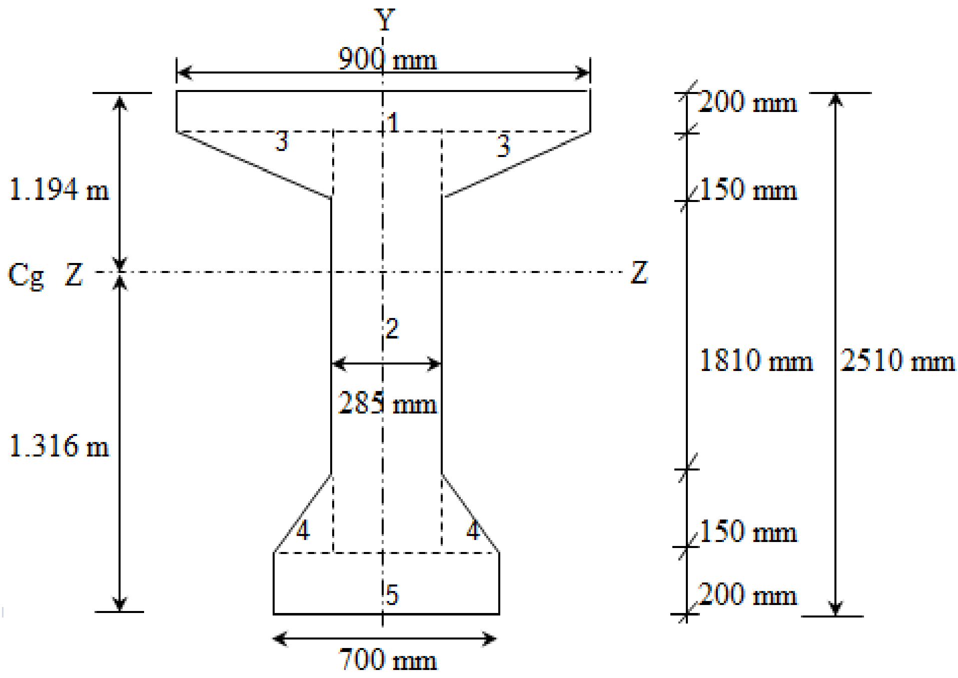

Figure 3: Section of Mid Girder

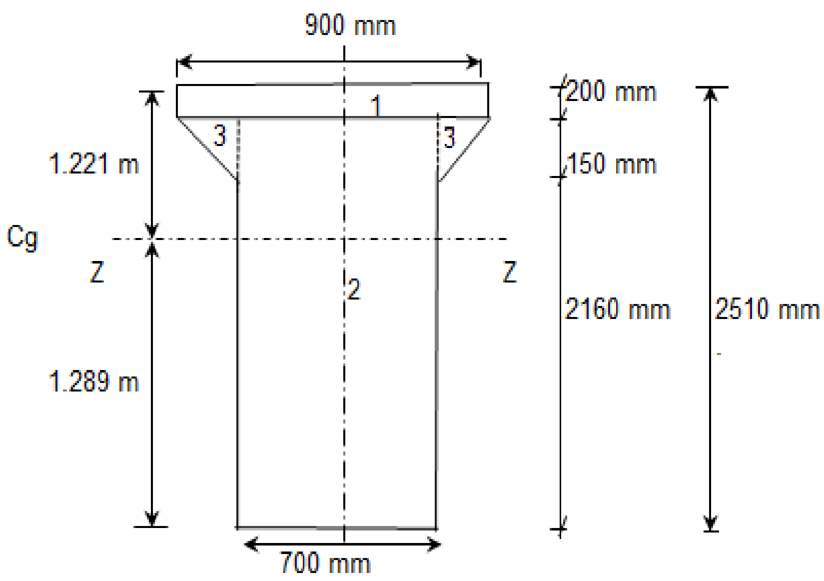

Figure 4: Section of End Girder

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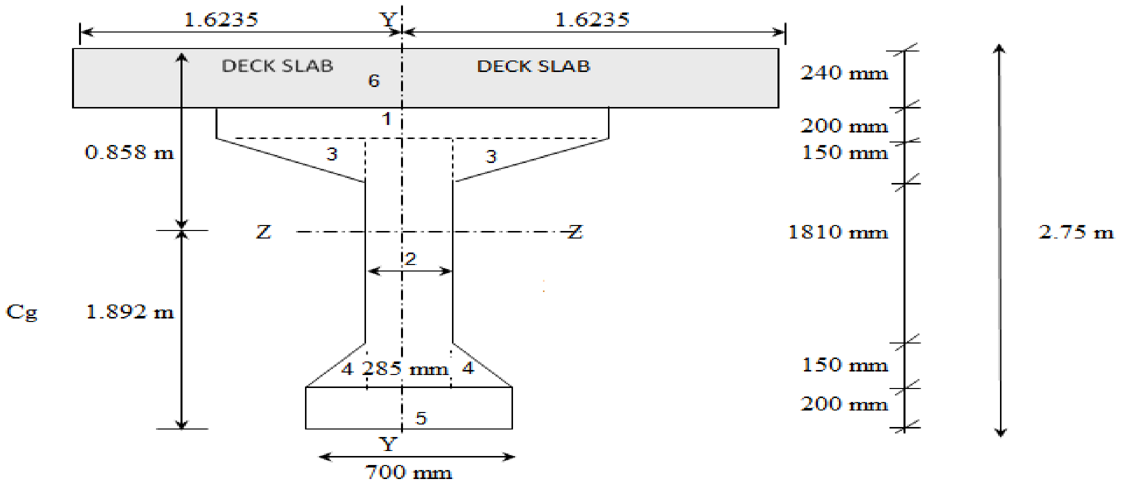

Figure 5: Composite Section of Mid Girder

Table 1: Dead Load, Super Imposed Load and Live load

Description	Total Load
Self Weight of Girder Alone	
Self weight of girder end section	45.30kN/m
Self weight of girder tapering section	35.13 kN/m
Self weight of girder running Section	24.97kN/m
Composite Properties End Girder	
Self weight of girder end section	69.93kN/m
Self weight of girder tapering section	59.76kN/m
Self weight of girder running section	49.59kN/m
Composite Properties of Intermediate Girder	
Self weight of girder End Section	64.78kN/m
Self weight of girder tapering section	54.61kN/m
Self weight of girder running section	44.54kN/m
Self weight of cross girders	19.48kN/m
Self weight of parapet load	15.3kN/m
Self weight of foot path load	15.623kN/m
Foot path live load as per IRC-6-2000 Cl 209.4	3.56kN/m
Moving vehicle load shall be placed as above as per IRC 6-2010	

V. RESULT AND DISCUSSION

The bridge was subjected to moving load, dead load, and super imposed dead load. The load was applied over the bridge structure based on the latest relevant code of IRC. The maximum bending moment and deflection of critical member were analyzed and results were taken from STADDV8i grillage analysis method. Then the critical element of the girder was designed as a prestressed post tensioned girders. The downward deflection due to moving load dead load

ISSN : 2455-9679
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super imposed load were taken and the upward deflection due to prestressed concrete were checked the deflection in bridge girder comes within the limits of permissible deflection as per IS 456-2000. The ultimate bending moment due to dead load, live load and super imposed load of bridge girder choosen section has received from grillage analysis method in staad v8i. The moment of resistance due to prestress concrete and steel gives maximum moment of resistance when compare to total downward bending moment. Hence the structure stable in service condition to resist the bending moment. The results are compared and the tables are shown below.

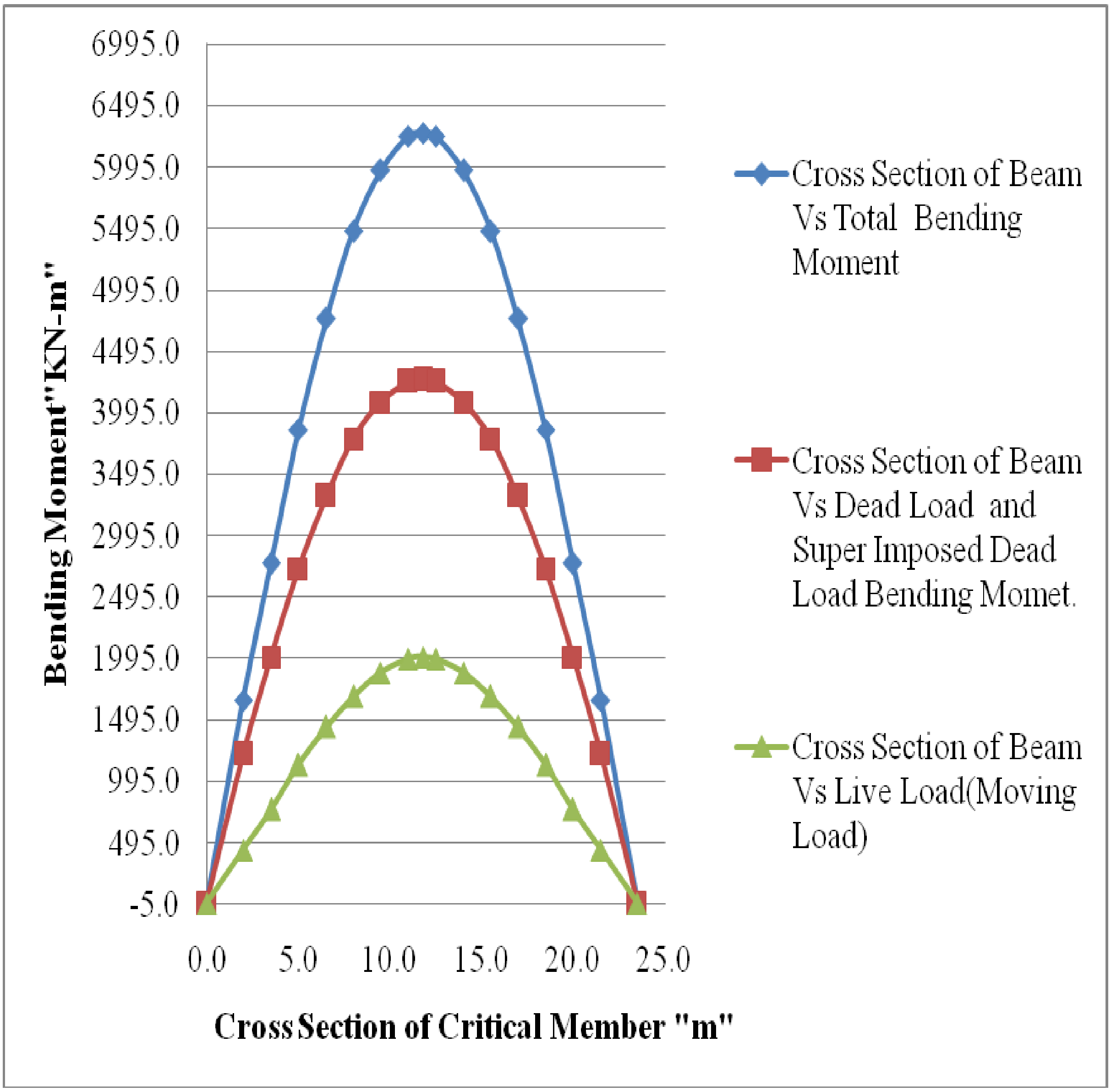

Figure 6: Total Downward Bending Moment of the Choosen Section

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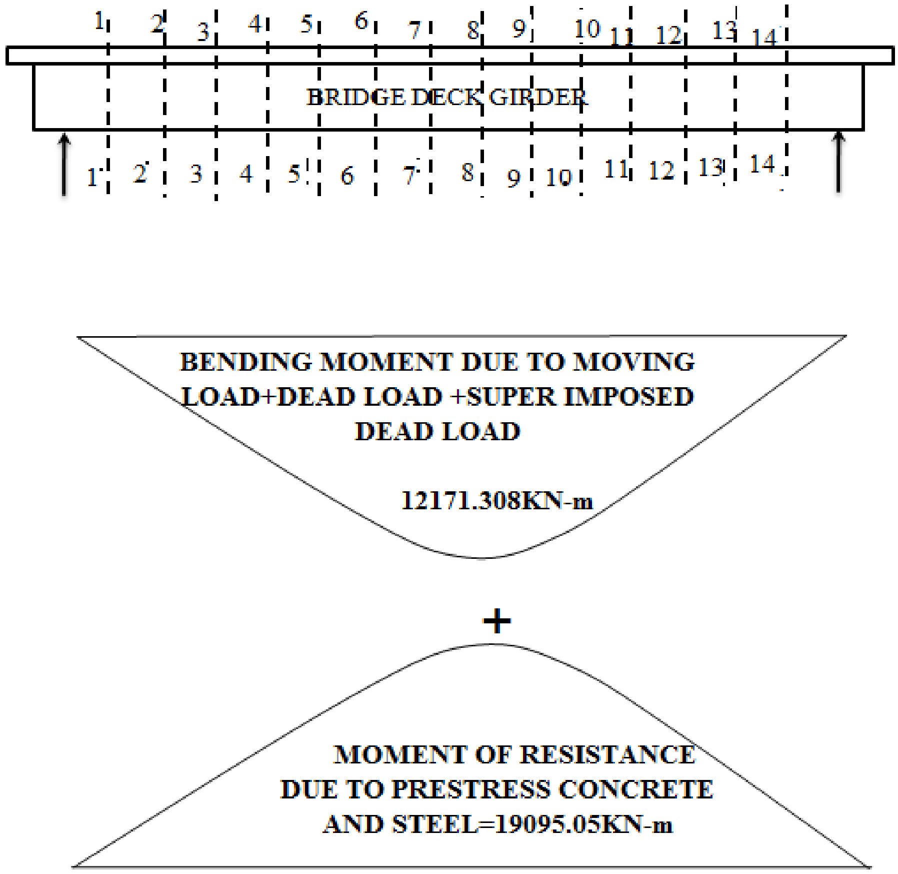

Figure 7: Ultimate Downward Bending Moment and Ultimate Moment of Resistance (Table 8.2) Due to Prestress and Steel

In this study, the behaviour of Bridge deck girder were analysed and examined under dead load, super imposed dead load, moving load condition. The grillage mesh element of the bridge deck were created using STADD V8i. The prestresed post tensioned bridge deck girders are designed for various load combination.

- The maximum bending moment of the deck girder critical section were checked by using the method of grillage analysis.
- Prestress Post Tensioned girders were designed for critical element
- The downward deflection due to applied load over the critical section at service stage and upward deflection due to prestressed post tensioning were checked. The net deflection is within the permissible limit of IS-456-2000.
- Stress due to dead load and live load for the prestress post tensioning were checked
- The reinforcement details and cable profile were prepared for girder and slab.
- The bridge structure facility is important for ongoing road transport system hence the need of bridge design is more helpful to the nation. The grillage method gives far more accurate results with easy calculation, also this method is economical by saving the time of design with accurate results.

ISSN : 2455-9679
Impact Factor : 3.340

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