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Analysis of Plate Girder Bridge for Class-AA Loadings (Tracked Vehicles)

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ABSTRACT

A bridge is a means by which a road, railway or other service is carried over an obstacle such as a river, valley and other road or railway line, either with no intermediate support or with only a limited number of supports at convenient locations.

Strength, safety and economy are the three key features that cannot be neglected before the finalization of types of bridges. While deciding the types of bridge, spans and other parameters are to be studied carefully to meet out the need of suitability to site conditions. The scope of this thesis is to confine to the design aspect related to variable parameters. Depth of web, thickness of web, width of flange and span of bridges are the variable parameters considered during the design of plate Girder Bridge.

The use of steel often helps the designer to select proportions that are aesthetically pleasing. Structural steels have high strength, ductility and strength to weight ratio. Thus it has become the obvious choice for long span bridges as steel is more efficient and economic. Among the various types of bridges plate girder bridges, truss bridges and box girder bridges are more commonly used. As the cost of steel is rising we have to reduce the amount of steel used without affecting the strength of section. In this thesis a plate girder bridge is designed as per the Limit state method using the IS 800:2007, IRC: 24-2000 and analysed by SAP-2000. Basically the Indian standards are derived from the British Standards. The basic concept is the same. Only the values of various parameters vary according to the design and fabrication/ erection practices existing in India. Design calculations are carried out for simply supported single span. Seismic and wind effect is not taken in to account at design stage. To clarify the design procedure and the current state of practice, a comprehensive literature search and survey were conducted. Recommendations pertaining to best practices for planning, design, and construction activities, as well as applications and limitations are also provided.

Based on the design results, conclusions are arrived at to know the behaviour of plate girder bridges when designed using Indian code.

Keywords: *Steel bridges, design comparison, Welded Plate Girder, Indian Road Congress*

1. INTRODUCTION

Bridge plays a vital role to overcome the obstacles without dismantling. Plate Girder Bridge is the most common type of steel bridge used for railways and highways Plate girder bridges are commonly used for river crossings and curved interchange ramps. The plate girder are often used in structures having span varying from 15 to 30 m. Plate girders became popular in the late 1800's, when price of steel dropped and it was economically possible to use steel instead of cast iron. By 1950's Plate girders were first assembled by bolting web and flanges together with help of angle profiles. There could be multiple flange plates on top of each other when needed. As the bending moment fell along the span, the outer plates were stopped or 'curtailed'. When welding became popular there was no need for the angles anymore. Curtailment of the flange area is achieved in welded construction by using thinner or narrower flange plates in regions of reduced bending moments, butt-welded to each other at the ends. The outer plates are made successively narrower than the inner ones, to which they are connected by fillet welds along the longitudinal edges. The outer plates are discontinued as the bending moments fell along the span.

Welded plate girders replaced riveted and bolted plate girders in developed world due to their better quality, aesthetics and economy. Normally plate girders are provided with intermediate of edge stiffeners to reduce the thickness of web plate and also to resist the buckling strength of web. A plate girder is basically an 'I' sec beam, It is a deep flexural member. This built up beam carries maximum load as compared with rolled section beam, when the load is heavy and span is large, plate girder is the most economical structure. Plate girder provides maximum flexibility by changing the various dimensions of component, economy can be achieved.

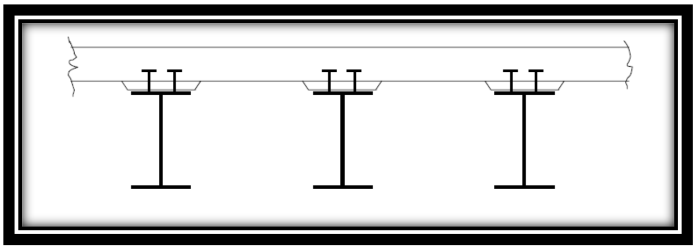

Fig.1. Plate girder bridge section

2. INDIAN ROAD CONGRESS

The Indian Road Congress (IRC) has formulated standard specifications and codes of practice for road bridges with a view to establish a common procedure for the design and construction of road bridges in India. The specifications are collectively known as the Bridge code. Prior to the formation of the IRC bridge code ,there was no uniform code for the whole country. Each state (or province) had its own rules about the standard loading and stresses.

The Indian Roads Congress (IRC) Bridge code as available now consists of eight sections as below

Section-I- General features of design

Section-II – Loads and stresses

Section- III – Cement concrete(Plain and reinforced)

Section- IV – Brick, stone and block masonry

Section –V –Steel road bridges

Section –VI –Composite construction

Section- VII – Foundations and Substructures

Section-VIII –Bearings

3. REVIEW OF LITERATURE

In order to better understand the current state of practice within the India, United States and the world, a survey was conducted where the current study may be most useful for this project.

The following information is provided as an overview of the technical literature available on this topic; the coverage is broad and includes historical background, studies that focus on detailed technical issues related to the design and analysis that provide overview information.

An overview of the journals studied is briefly discussed below.

Plate girders bridges are designed by a trail and-error approach due to the complexity of the design rules. The design of a composite girder is a tedious and time-consuming job for the designer. (1) Bhatti (1995) introduced the structural mass minimization, in the context of a highway bridge composite welded plate girder. (2) Adeli and Kim (2001) developed a cost objective function which includes the costs of concrete, steel beams and shear studs using neural dynamics model programming. (3) Kravanja and Šilih (1992) applied the structural optimization method rather than classical structural analysis. (4) Neal and Johnson (1992) concludes that composite trusses of spans exceeding 18 m are generally the most economic structural systems, while for spans between 12 and 15 m, the cost is determined by floor height limitations. (5)Razani and Goble

(1966) were the first to attempt cost optimization of steel girders. (6) Holt and Heithecker (1969) studied the minimum weight design of symmetrical welded plate girders without web stiffeners. (7) Annamalai et al (1972) studied cost optimization of simply supported, arbitrarily loaded, welded plate girders with transverse stiffeners. (8) Anderson and Chong (1986) presented the minimum cost design of homogeneous and hybrid stiffened steel plate girders. (9) Yoshiaki Okui, (2011) "Recent Topics of Japanese Design Codes for Steel and Composite Bridges". This paper gives an overview of Japanese design codes for steel and composite bridges are given. Also some important topics discussed in Standard Specifications for Steel and Composite Structures published by JSCE are introduced. The positive bending moment capacity of composite steel girders is examined through parametric study employing elasto-plastic finite displacement analyses. (10) Swapnil B Kharmale,(2007).``Comparative study of IS 800(Draft) and Eurocode3 ENV 1993-1-1'' . In this comparative study IS: 800 (Draft) & Eurocode3 are compared. The limit state design of steel structures and comparison of design methodology for basic structural element by both codes are done. (11) Akira Takaue, (2010)"Applied design codes on international long-span bridge projects in Asia". In this report, several bridge types and application of the design codes relevant to steel or composite structures utilized in international long-span bridge construction projects executed in Asian region in cooperation with Japanese consultant firms are introduced. (12) Subramanian. N, (2008) "Code of Practice on Steel Structures -A Review of IS 800: 2007". This paper reviews the important features' of IS 800:2007. These include advanced analysis methods, fatigue provisions, durability, fire resistance, design for floor vibrations etc. (13) Arijit Guha and Ghosh M M,(2008) "IS: 800 - Indian Code of Practice for Construction in Steel and its Comparison with International Codes". The authors in this paper discusses that IS 800-2007 (LSM) is mostly based on international standards with load factors and partial safety factors suiting Indian conditions. The code has been mainly modelled in line with the Euro codes, with some additional references taken from the existing British Codes also. (14) Krishnamoorthy. M and D.Tensing, (2008). "Design of Compression members based on IS 800-2007 and IS 800-1984 - Comparison". This paper discusses the design methodologies for the steel structures namely, working stress design method and limit state design methods are briefly explained. (15) Hermin Jonsson, Johan Ljungberg, (2005). ``Comparison of design calculations for the railway bridge over Kvillebecken''. The aim of this thesis wok is the comparison of design calculations between Swedish and European standards. (16) Ajeesh ss and sreekumars,(2011). ``Shear behaviour of hybrid plate girders''. The objective of this paper is to investigate shear behaviour of hybrid plate girder under varying parameters such as aspect ratio, slenderness ratio and yield strength of web panel using finite element method. (17) Marta sulyok, Theodore V Galambos,(1995). ``Evaluation of web buckling test results on welded plate beams and plate girders subjected to shear''. The purpose of this paper is to report values of reliability indices of welded beams and plate girders subjected to shear and combine bending and shear which are designed as per the load resistance and factor criteria according to the American institute of steel construction (AISC) and Cardiff model accepted by the Euro code 3. (18) Granath (2000) addresses the issue of establishing a service load level criteria for web plates by developing an easy, closed form design method for evaluating steel girders subject to patch loading. The method is based on the premise that no yielding is allowed in the web plate. (19) Rosignoli (2002) presented a very detailed discussion of local launch stresses and instabilities in steel girder bridges. The author discussed the factors that contribute to a complex state of stress in the bottom flange of launched steel girder bridges.

4. LOADS, LOAD COMBINATIONS & PARAMETERS

Loads On Bridges:

The following are the various loads to be considered for the purpose of computing stresses, wherever they are applicable.

- Dead load
- Live load
- Impact load
- Longitudinal force
- Thermal force
- Wind load
- Seismic load
- Racking force
- Forces due to curvature.
- Forces on parapets
- Frictional resistance of expansion bearings
- Erection forces

Load Combinations:

Sr. No	Load combination	Loads
1	Stresses due to normal loads	Dead load, live load, impact load and centrifugal force
2	Stresses due to normal loads + occasional loads	Normal load as in (1) + wind load, other lateral loads, longitudinal forces and temperature stresses.
3	Stresses due to loads during erection	-
4	Stresses due to normal loads + occasional loads + Extra-ordinary loads like seismic excluding wind load	Loads as in (2) + with seismic load instead of wind

Design parameters

For effective design of plate Girder Bridge, following parameters are considered:

1) IRC: 24-2000
2) Span: 15m, 20m, 25m & 30m
3) Boundary conditions: Simply supported
4) Depth of web: Variable
5) Loading: IRC: 6-2000
6) Thickness of web: Variable
7) Design method: LSM
8) Flange area: Variable
9) Code: IS-800-1984
10) Flange thickness: Variable
11) Vertical stiffeners: At equal intervals

5. DESIGN EXAMPLES

Design of two lane bridge girders for class-AA loadings (Tracked Vehicles)

Span= 20m

Deck Bridge

Deck concrete= M-30

Select plate Girder Bridge

Footpath width= 1.5m

Carriageway width= 7.5m

Kerb height= 300mm

Total width= 7.5+2(1.5) = 10.5m

Spacing of girder= 6.25m

Spacing of cross beam= 4m

Design of deck slab is not part of the problem; however the RCC slab is designed as continuous slab with 4m spans and footpath designed as cantilever slab.

The RCC slab details are,

Main deck slab= 300mm thick.

Footpath = 200mm thick.

6. STRUCTURAL ANALYSIS AND MODELLING USIING SAP-2000

6.1 SAP Design Module:

a) Bridge Geometry

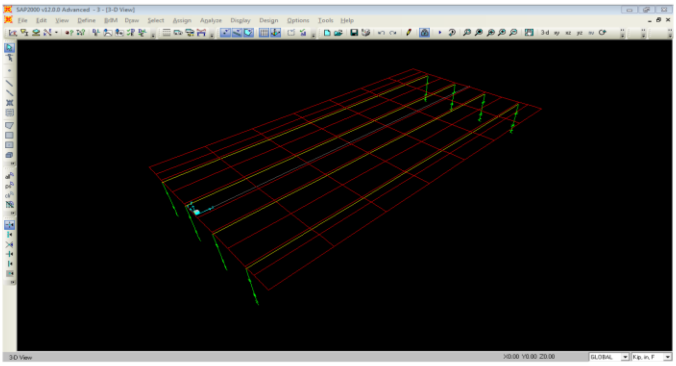

Fig.2. 3D-View

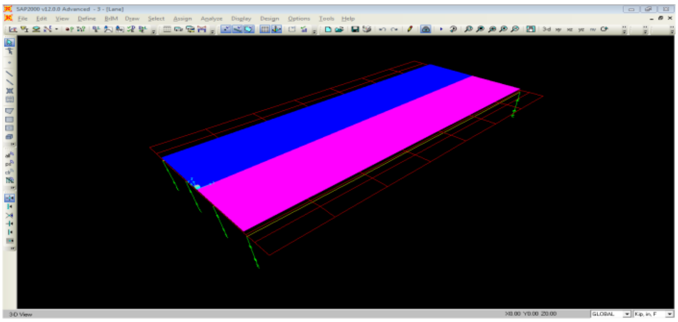

Fig.3. Lane View

6.2 Deformed shape of the bridge

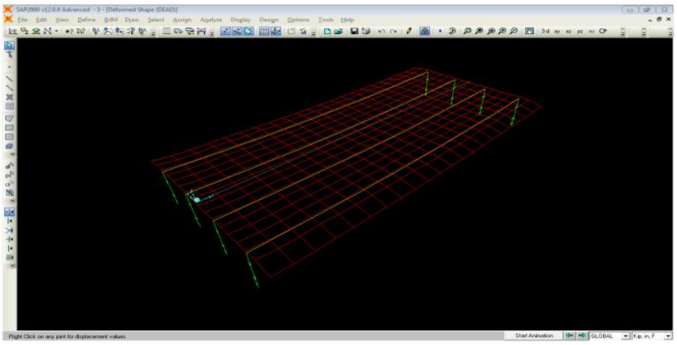

Fig.4.a. Dead Load

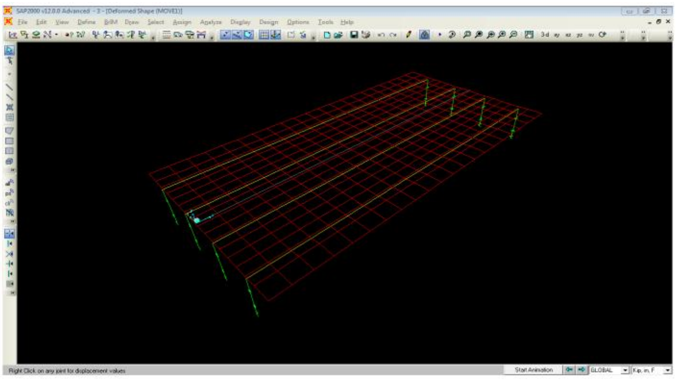

Fig.4.b. Moving Load

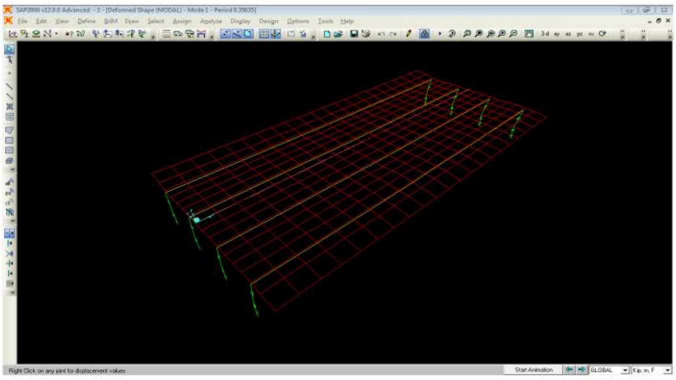

Fig.4.c. Modal Load

6.3 Joint reactions on the bridge

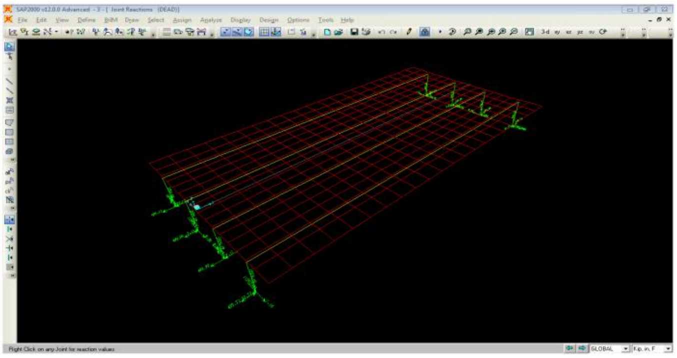

Fig.5.a. Dead Load

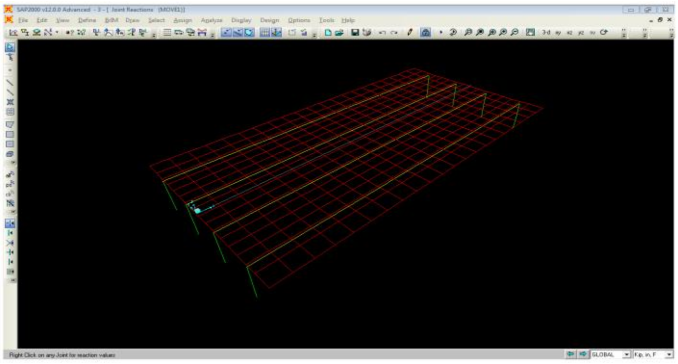

Fig.5.b. Moving Load

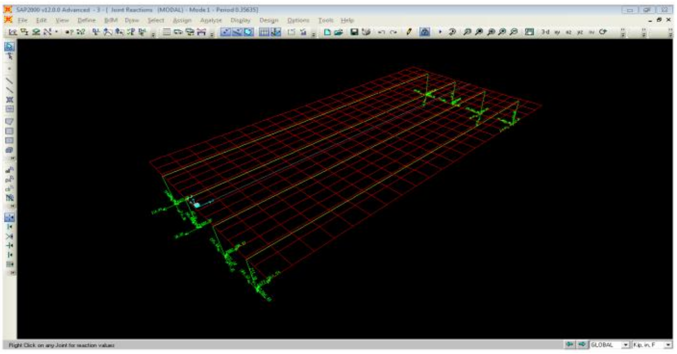

Fig.5.c. Modal Load

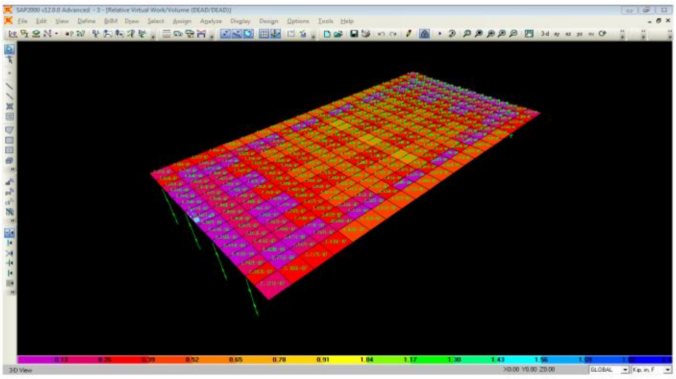

Fig.5.d. Relative virtual work done

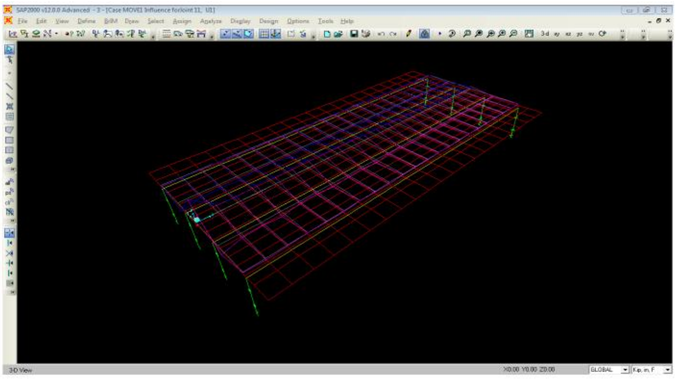

Fig.5.e. Case move influence for joints

6.4 Axial force (P) of entire section and all girders

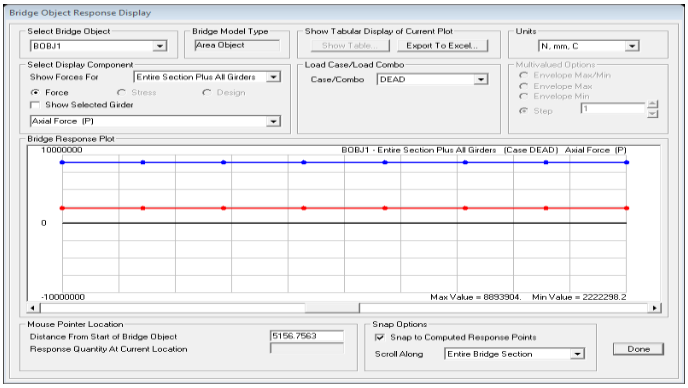

Fig. 6.a. Dead load

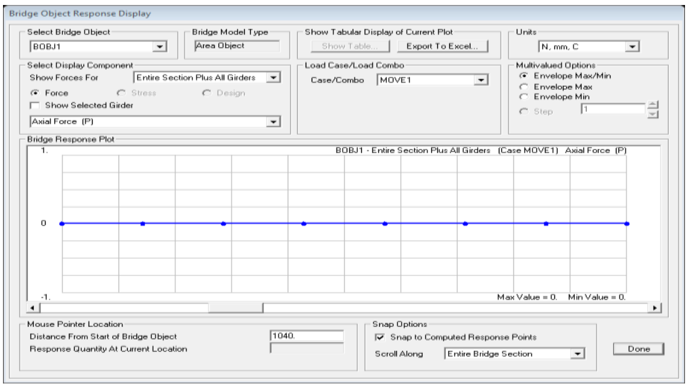

Fig. 6.b. Movingl load

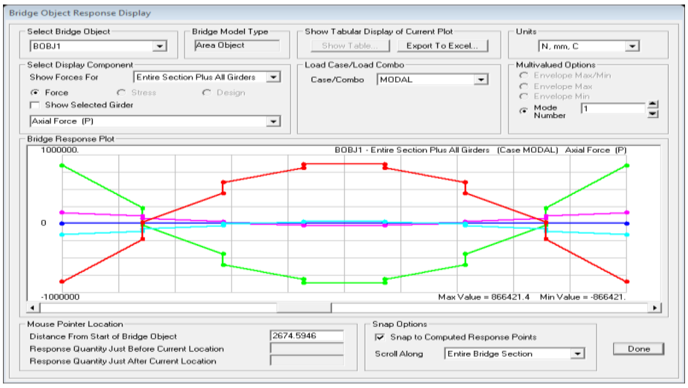

Fig. 6.c.. Modal load

6.5. Vertical shear (V2) of entire section and all girders

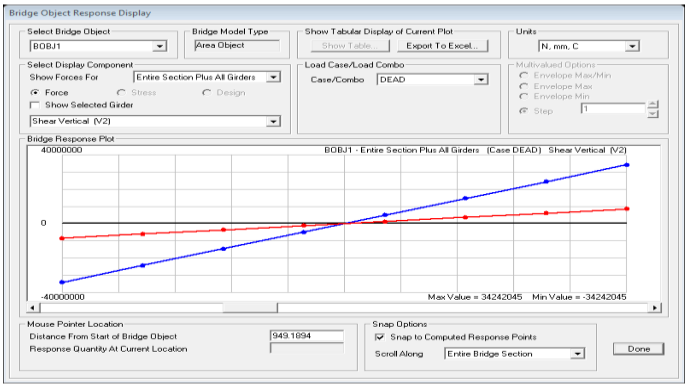

Fig. 7.a. Dead load

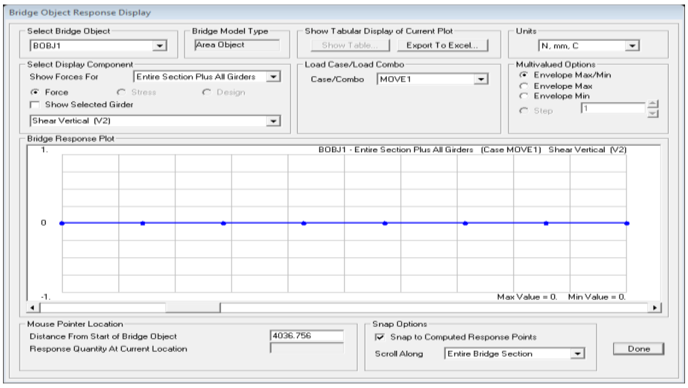

Fig. 7.b. Moving load

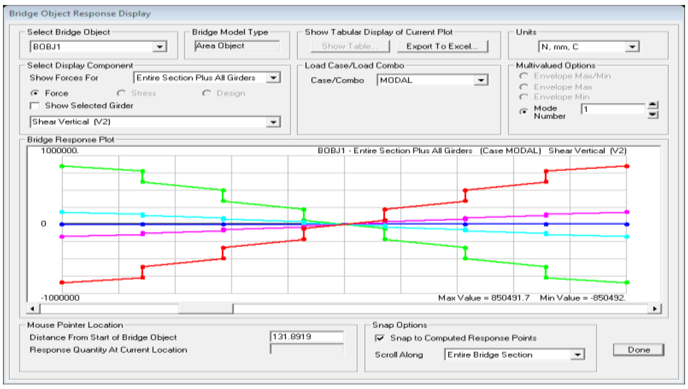

Fig. 7.c. Modal load

6.6. Shear horizontal (V3) of entire section and all girders

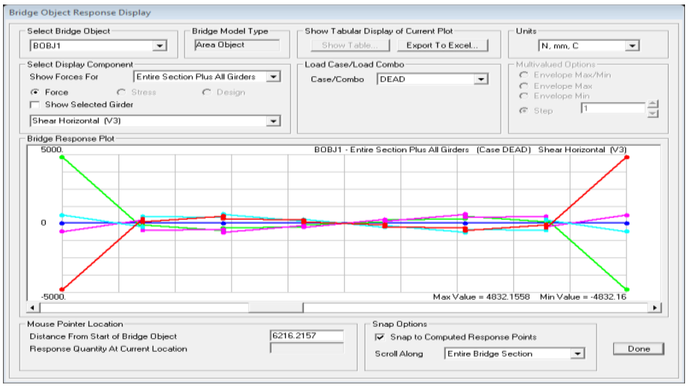

Fig. 8.a. Dead load

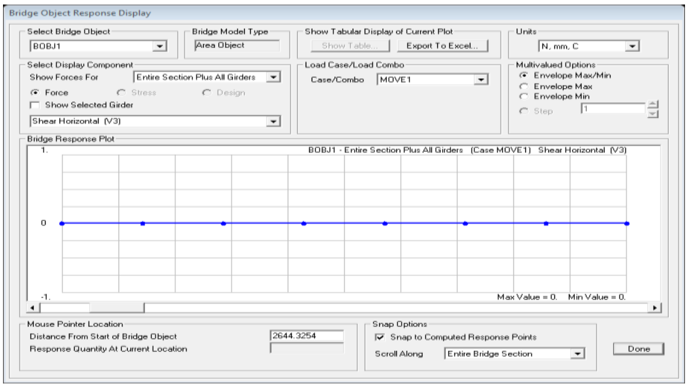

Fig. 8.b. Moving load

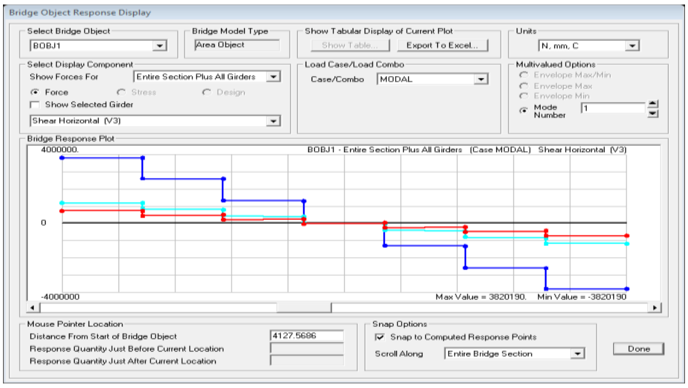

Fig. 8.c. Modal load

6.7. Torsion (T) of entire section and all girders

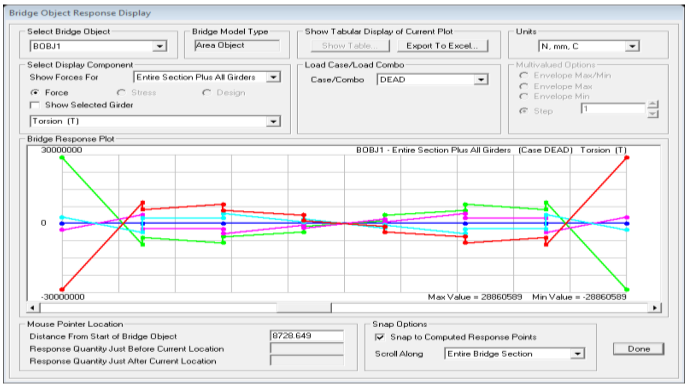

Fig. 9.a. Dead load

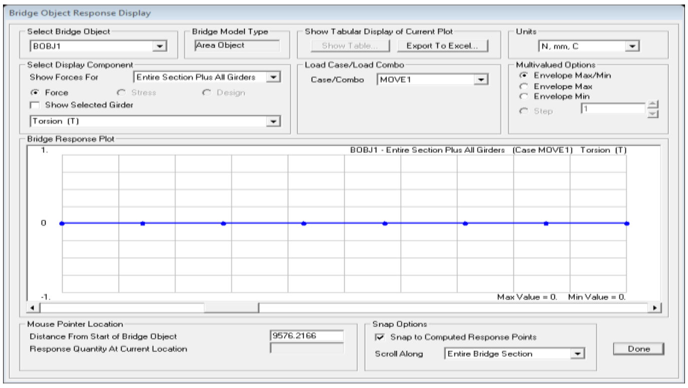

Fig. 9.b. Moving load

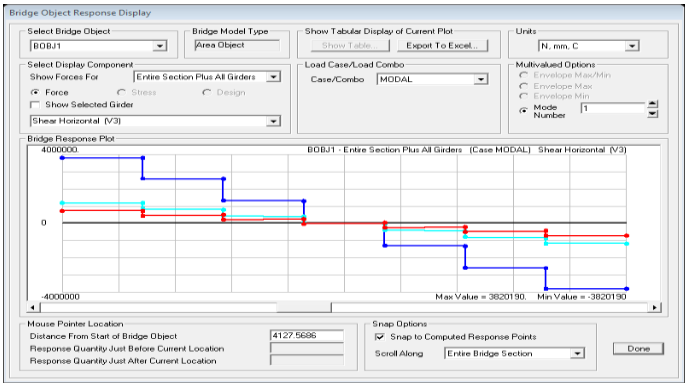

Fig. 9.c. Modal load

6.8. Moment about vertical axis (M2) of entire section and all girders

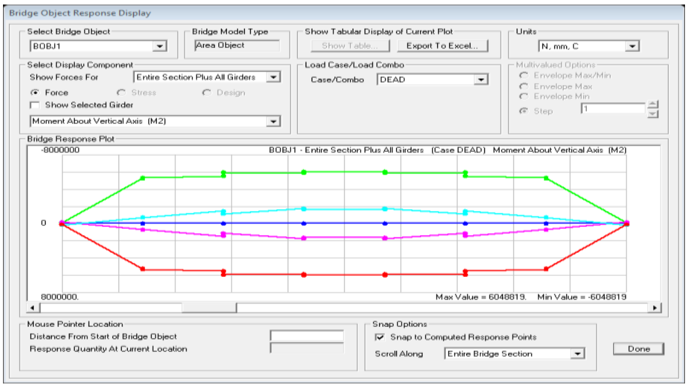

Fig. 10.a. Dead load

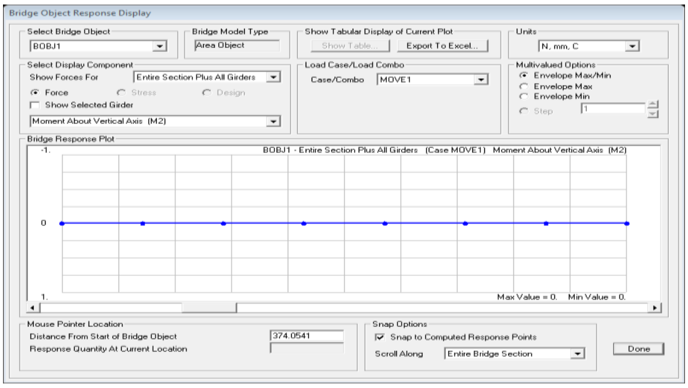

Fig. 10.b. Moving load

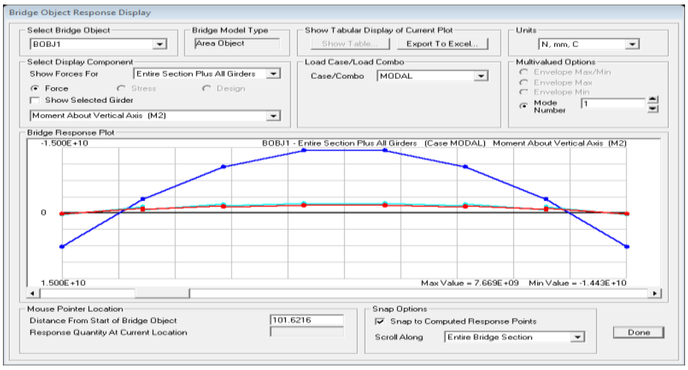

Fig. 10.c. Modal load

6.9. Moment about horizontal axis (M2) of entire section and all girders

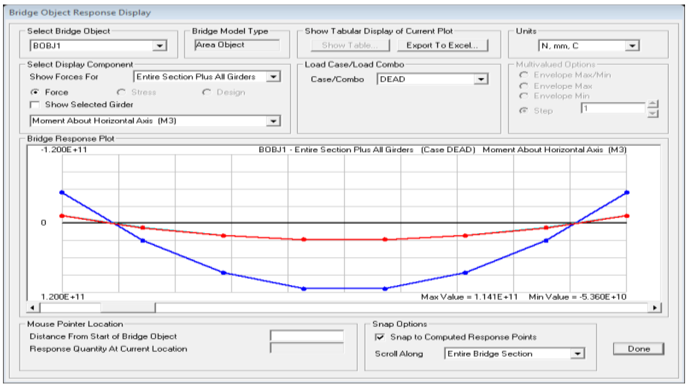

Fig. 11.a. Dead load

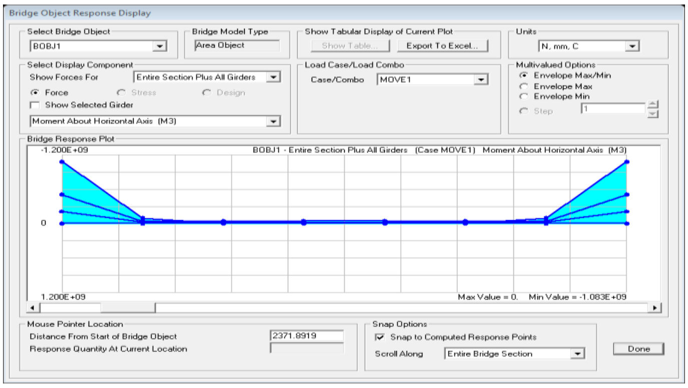

Fig. 11.b. Moving load

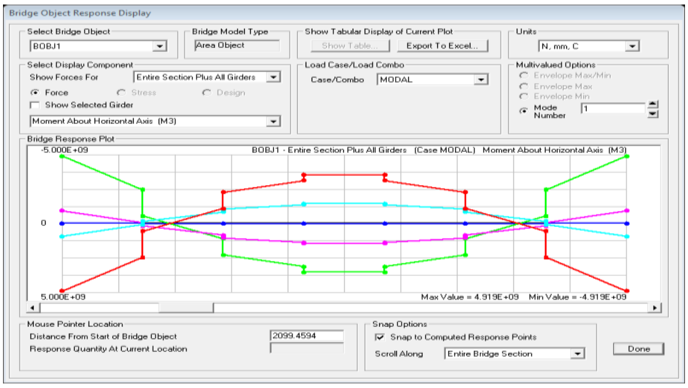

Fig. 11.c. Modal load

6.10. Tabulated results of entire girder sections:-

Table-2 For dead load

Distance	ItemType	P	V2	V3	T	M2	M3
mm		KN	KN	KN	KN-mm	KN-mm	KN-mm
0		8893.90	-34242.05	0.00	0.00	0.00	-53599207.00
2857		8893.90	-24458.60	0.00	0.00	0.00	30258862.46
2857		8893.90	-24458.60	0.00	0.00	0.00	30258862.46
5714		8893.90	-14675.16	0.00	0.00	0.00	86164241.98
5714		8893.90	-14675.16	0.00	0.00	0.00	86164241.98
8571		8893.90	-4891.72	0.00	0.00	0.00	114116931.70
8571		8893.90	-4891.72	0.00	0.00	0.00	114116931.70
11429		8893.90	4891.72	0.00	0.00	0.00	114116931.70
11429		8893.90	4891.72	0.00	0.00	0.00	114116931.70
14286		8893.90	14675.16	0.00	0.00	0.00	86164241.98
14286		8893.90	14675.16	0.00	0.00	0.00	86164241.98
17143		8893.90	24458.60	0.00	0.00	0.00	30258862.46
17143		8893.90	24458.60	0.00	0.00	0.00	30258862.46
20000		8893.90	34242.05	0.00	0.00	0.00	-53599207.00

Table-3 For Moving load

Distance	Item Type	P	V2	V3	T	M2	M3
mm		KN	KN	KN	KN-mm	KN-mm	KN-mm
0	Max	0	0	0	0	0	0
0	Min	0	0	0	0	0	-1083049.96
2857	Max	0	0	0	0	0	0
2857	Min	0	0	0	0	0	-92878.17
2857	Max	0	0	0	0	0	0
2857	Min	0	0	0	0	0	-92878.17
5714	Max	0	0	0	0	0	0
5714	Min	0	0	0	0	0	-1099.38
5714	Max	0	0	0	0	0	0
5714	Min	0	0	0	0	0	-1099.38
8571	Max	0	0	0	0	0	0
8571	Min	0	0	0	0	0	-1099.38
8571	Max	0	0	0	0	0	0
8571	Min	0	0	0	0	0	-1099.38
11429	Max	0	0	0	0	0	0
11429	Min	0	0	0	0	0	-1099.38
11429	Max	0	0	0	0	0	0
11429	Min	0	0	0	0	0	-1099.38
14286	Max	0	0	0	0	0	0
14286	Min	0	0	0	0	0	-1099.38
14286	Max	0	0	0	0	0	0
14286	Min	0	0	0	0	0	-1099.38
17143	Max	0	0	0	0	0	0
17143	Min	0	0	0	0	0	-92878.17
17143	Max	0	0	0	0	0	0
17143	Min	0	0	0	0	0	-92878.17
20000	Max	0	0	0	0	0	0

Table-4 For Modal load

Distance	Item Type	P	V2	V3	T	M2	M3
mm		KN	KN	KN	KN-mm	KN-mm	KN-mm
0		0.00	0.00	3820.19	28911527.74	7668896.25	-0.36
2857		0.00	0.00	3803.26	28777839.63	-3222582.01	0.17
2857		0.00	0.00	2610.85	19761801.06	-3223912.57	0.20
5714		0.00	0.00	2592.74	19618786.22	-10658228.30	0.62
5714		0.00	0.00	1328.82	10059968.66	-10659504.90	0.63
8571		0.00	0.00	1309.96	9911145.39	-14429520.70	0.87
8571		0.00	0.00	9.56	75391.88	-14430027.80	0.86
11429		0.00	0.00	-9.56	-75391.85	-14430027.80	0.86
11429		0.00	0.00	-1309.96	-9911145.38	-14429520.70	0.83
14286		0.00	0.00	-1328.82	-10059968.70	-10659504.90	0.60
14286		0.00	0.00	-2592.74	-19618786.20	-10658228.30	0.56
17143		0.00	0.00	-2610.85	-19761801.10	-3223912.57	0.14
17143		0.00	0.00	-3803.26	-28777839.60	-3222582.00	0.10
20000		0.00	0.00	-3820.19	-28911527.70	7668896.23	-0.42

7. CONCLUSION

It is concluding that the Steel is being used on highway and railway bridges successfully all over the world because of its inherent quality of better strength, resistance against fracture toughness, weld ability and a very good resistance against weathering / corrosion. The weight of the structure is reduced tremendously reducing the cost of substructure and foundations and over all reduced life cycle costs. Its introduction on highway and Indian railways will be a very good decision for the up gradation of the present technology of design, fabrication and maintenance of steel bridges.

In comparison to the developed countries, the steel being used in plate girder bridges is of inferior quality.

The SAP analysis results indicate that the designed plate girder bridge is stable in bending moment, shear force, and deflection.

This dissertation work gives basic principles for portioning of plate girder to help designer..

It is the most economical bridge in terms of construction and cost. Relation for Area of Flange to Bending Moment V/s Span bears a constant ratio. Thickness of Web varies linearly with Span for the constant Web depth. Keeping the depth of web constant, Shear and Bending Stress increases with increase in Span length. With depth of web to thickness of Web ratio remains the same, flange area varies as per the variation of span. Using the vertical stiffeners, the Wt. of Girder is controlled with span variation. The thickness of Web plate varies linearly for depth to thickness ratio of Web.

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