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Comparative study of Conventional Bridge with Innovative Bridge for Optimization

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ABSTRACT

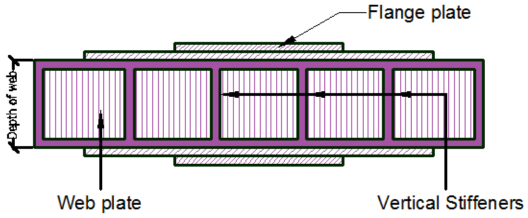
Bridges are highly investment structures and an important landmarks in any country. Besides being vital links in transportation system, strength, safety and economy are the three key features that can not be neglected, before finalization of types of bridges, the responsibility of structural engineer is to take care of financial requirements and site conditions also.

The paper deals with economy of steel plate girder bridge of conventional shape. To investigate an economy, it was proposed to innovate the shape of steel plate girder bridge. Optimization of innovative shape of plate girder bridge is tested by selecting various parameters and compared with conventional plate girder bridge.

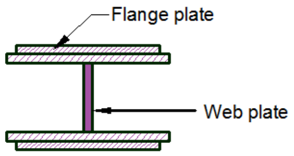
Comparative study is carried out by designing the conventional plate girder bridge with innovative shape of plate girder bridge by selecting different parameters. These parameters are: span – 10 m to 50 m, web plate thickness – 10 mm to 15 mm, depth of web – varying from 1.0 at crown to 1.8 m at support in innovative shape and 1.4 m constant for conventional plate girder bridge. Fy – 250 N/mm^2 to 400 N/mm2, loading – Railway – broad gauge main line.

All the designed data are compared categorically. Graphical presentations are prepared to study the cost effectiveness influence line diagrams are drawn and studied for suitability and optimization. It was observed that the innovative plate girder bridge is most economical as compared with conventional plate girder bridge.

Keywords – Af = Area of flange, Bf = Width of flange, DW = Depth of web, ILD = Influence line diagram, TW = thickness of web



Longitudinal Section



Cross Section

Fig. 1 Conventional plate girder bridge

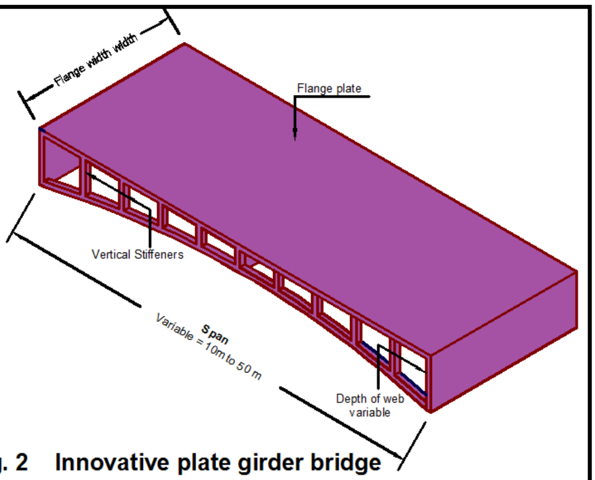


Fig. 2 Innovative plate girder bridge

I. INTRODUCTION

Bridge plays a vital role to overcome the obstacles without dismantling. Steel plate girder bridge is the most common steel bridge adopted traditionally. To reduce the thickness of web plate, vertical and horizontal stiffeners are provided. Bridges can be designed considering the most economical aspects with elegancy. Self weight of structure is directly proportional to span length. It is the basic fact that web resist the shear and flange takes the bending. Looking towards the maximum and minimum value of bending moment and shear force, as per locations, it is proposed to modify the shape of conventional shape girder to achieve an economy.

Parametric study of conventional plate girder bridge is carried out with innovative shape of plate girder bridge. The aim of this paper is to carry out the parametric study of conventional plate girder bridge with innovative plate girder bridge. Conventional plate girder of constant web depth of 1.40 m, is compared with innovative plate girder with depth of web at the support is 1.80 m and at crown it is taken as 1.00 m. The scope of this paper is to investigate an economy between conventional plate girder and innovative form of plate girder bridge by changing various parameters.

II. DESIGN PARAMETERS

Span : 10 m, 20 m, 30 m, 40 m & 50 m
Web plate thickness : 10 mm, 11 mm, 12 mm
13 mm, 14 mm & 15 mm
Fy : 250 N/mm^2,300 N/mm^2,350 N/mm^2,400 N/mm^2
Boundary conditions : Simply supported
Loading : Railway Broad gauge, main line
Stiffeners : Only vertical stiffeners
Earthquake zone : Zone - II
Depth of web : Varying from 1.00 m to 1.80 m for
Innovative bridge
1.40m constant for conventional
plate girder bridge
Design method : Working stress method
Seismic & wind effect : Not considered
Codes : IRC – 6, IRC – 24, IS – 800, IS – 875
Wind effect : Neglected.

III. METHODOLOGY

All the design calculations are carried out for the following cases. For each case, other given parameters are considered with permutations and combinations and the design calculations are carried for conventional plate girder bridge and innovative plate girder bridge, using working stress method.

A. CASE – 1

Span : 0 – 10 m
Fy : 250 N/mm^2,300N/mm^2,350 N/mm^2,400 N/mm^2
Web thickness : 10 mm, 11 mm, 12 mm, 13 mm
14 mm & 15 mm
Web depth : 1.40 m constant for conventional
Bridge 1.00m to 1.80 m from crown
to support for innovative bridge
Loading : Broad gauge, main line
Impact factor : as per standard railway norms

B. CASE – 2

Span : 0 – 20 m
Fy : 250 N/mm^2,300 N/mm^2,350 N/mm^2,400 N/mm^2
Web thickness : 10 mm, 11 mm, 12 mm, 13 mm
14 mm & 15 mm
Web depth : 1.40 m constant for conventional
bridge
1.00m to 1.80 m from crown to
Support for innovative bridge
Loading : Broad gauge, main line
Impact factor : as per standard railway norms

C. CASE – 3

Span : 0 – 30 m
Fy : 250 N/mm2,300 N/mm2,350 N/mm2,400
N/mm2
Web thickness : 10 mm, 11 mm, 12 mm, 13 mm
14 mm & 15 mm
Web depth : 1.40 m constant for conventional
bridge
1.00m to 1.80 m from crown to
Support for innovative bridge
Loading : Broad gauge, main line
Impact factor : as per standard railway norms

D. CASE – 4

Span : 0 – 40 m
Fy : 250 N/mm2,300 N/mm2,350 N/mm2,400
N/mm2
Web thickness : 10 mm, 11 mm, 12 mm, 13 mm
14 mm & 15 mm
Web depth : 1.40 m constant for conventional
bridge
1.00m to 1.80 m from crown to
Support for innovative bridge
Loading : Broad gauge, main line
Impact factor : as per standard railway norms

E. CASE – 5

Span : 0 – 50 m
Fy : 250 N/mm^2,300 N/mm^2,350 N/mm^2,400 N/mm^2
Web thickness : 10 mm, 11 mm, 12 mm, 13 mm
14 mm & 15 mm
Web depth : 1.40 m constant for conventional bridge
1.00m to 1.80 m from crown to Support for innovative bridge
Loading : Broad gauge, main line
Impact factor : as per standard railway norms

IV. OBSERVATION

All the related data regarding the design of both the bridges are compiled categorically. The observed data are prepared to study the cost effectiveness. Graphical representations for different parameters including influence line diagrams are shown to draw the final conclusions

ϖ CONVENTIONAL PLATE GIRDER BRIDGE

Table 1 Span v/s Gross M.I. (in mm^4)

Fy → / Span ↓	250 N/mm^2	300 N/mm^2	350 N/mm^2	400 N/mm^2
10.0 m	9.15x10^9	8.82x10^9	8.82x10^9	8.82x10^9
20.0 m	2.25x10^{10}	1.91x10^{10}	1.670x10^{10}	1.492x10^{10}
30.0 m	4.35x10^{10}	3.622x10^{10}	3.116x10^{10}	2.74x10^{10}
40.0 m	6.75x10^{10}	5.50x10^{10}	4.733x10^{10}	4.13x10^{10}
50.0 m	1.075x10^{11}	8.80x10^{10}	7.434x10^{10}	6.418x10^{10}

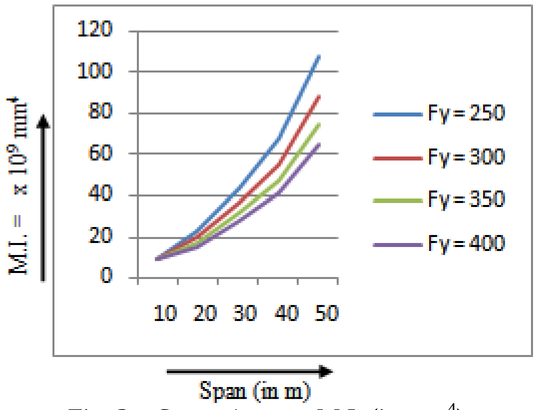


Fig. 3 Span v/s gross M.I. (in mm^4)

ϖ INNOVATIVE PLATE GIRDER BRIDGE

Table 2 Span v/s Gross M.I. (in mm^4)

Fy → / Span ↓	250 N/mm^2	300 N/mm^2	350 N/mm^2	400 N/mm^2
10.0 m	1.12x10^{10}	2.30x10^9	8.76x10^9	1.05x10^{10}
20.0 m	1.63x10^{10}	1.50x10^{10}	1.40x10^{10}	1.34x10^{10}
30.0 m	2.47x10^{10}	2.175x10^{10}	1.97x10^{10}	1.82x10^{10}
40.0 m	3.85x10^{10}	3.25x10^{10}	2.85x10^{10}	2.56x10^{10}
50.0 m	5.92x10^{10}	4.95x10^{10}	4.26x10^{10}	3.67x10^{10}

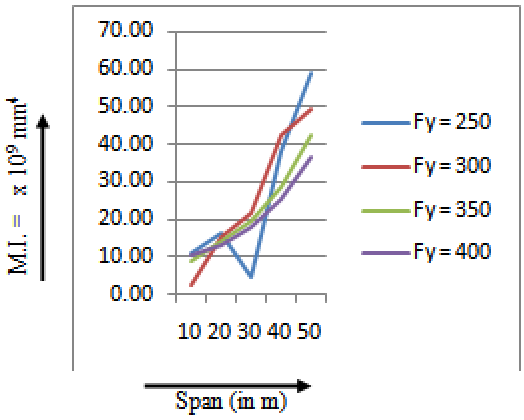


Fig. 4 Span v/s gross M.I. (in mm4)

CONVENTIONAL PLATE GIRDER BRIDGE

Table 3 Span v/s Area of Flange

Fy → Span	250 N/mm^2	300 N/mm^2	350 N/mm^2	400 N/mm^2
10.0 m	6327	5272	4519	3954
20.0 m	19152	15960	13680	11970
30.0 m	37928	31607	27091	23705
40.0 m	57685	48071	41204	36053
50.0 m	87421	73415	62927	55061

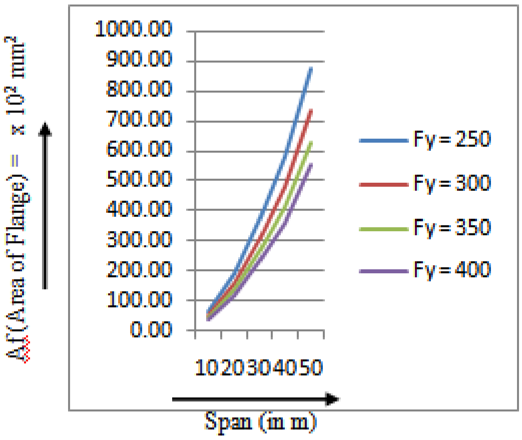


Fig. 5 Span v/s Area of flange

INNOVATIVE PLATE GIRDER BRIDGE

Table 4 Span v/s Area of Flange

Fy → Span	250 N/mm^2	300 N/mm^2	350 N/mm^2	400 N/mm^2
10.0 m	8857	7381	6327	5536
20.0 m	26813	22344	19152	16758
30.0 m	53097	44247	37926	33185
40.0 m	89085	74238	63632	55678
50.0 m	135517	112931	96798	84698

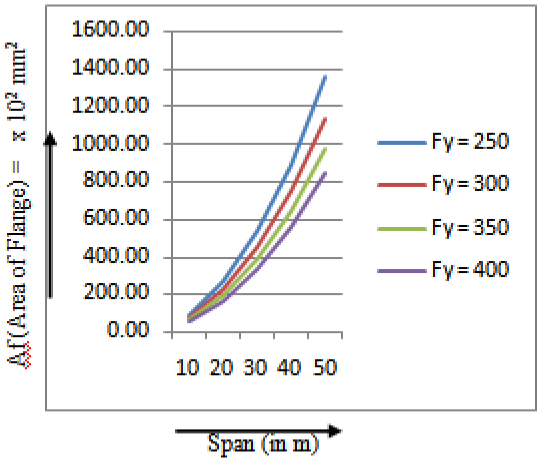


Fig. 6 Span v/s Area of flange

CONVENTIONAL PLATE GIRDER BRIDGE

Table 5 Span v/s Shear stress

Span → Plate thickness	10.0 m	20.0 m	30.0 m	40.0 m	50.0 m
10 mm	48.17	68.79	89.23	122.50	149.43
11 mm	43.79	62.54	81.12	111.36	134.53
12 mm	40.14	57.32	74.36	102.08	124.52
13 mm	37.06	52.92	68.64	94.23	114.95
14 mm	34.41	49.14	63.74	87.50	106.73
15 mm	32.12	45.86	59.49	81.67	99.62

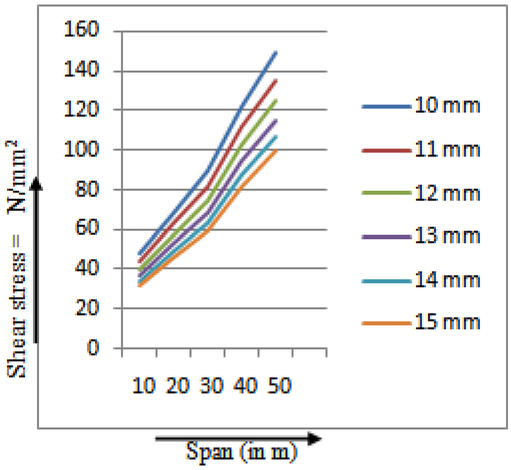


Fig. 7 Span v/s Shear stress

INNOVATIVE PLATE GIRDER BRIDGE

Table 6 Span v/s Shear stress

Span → Plate	10.0 m	20.0 m	30.0 m	40.0 m	50.0 m
10 mm	37.47	53.50	69.40	87.12	105.36
11 mm	34.06	48.64	63.09	79.20	95.78
12 mm	31.22	44.59	57.84	72.60	87.80
13 mm	28.82	41.16	53.39	67.02	81.05
14 mm	26.76	38.22	49.57	62.23	75.20
15 mm	24.98	35.67	46.27	58.08	70.24

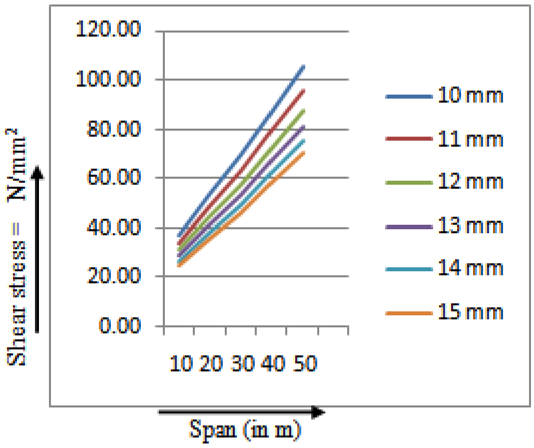


Fig. 8 Span v/s Shear stress

ϖ CONVENTIONAL PLATE GIRDER BRIDGES

Table 7 Span v/s Bending stress in N/mm^2

Fy → Span ↓	250 N/mm^2	300 N/mm^2	350 N/mm^2	400 N/mm^2
10.0 m	114.90	119.20	119.20	119.20
20.0 m	144.70	169.30	192.70	215.00
30.0 m	154.20	182.60	210.30	237.20
40.0 m	157.40	187.50	216.90	245.90
50.0 m	158.60	189.20	221.00	251.40

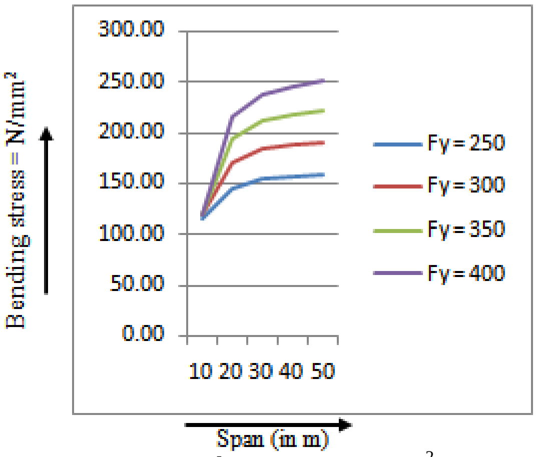


Fig. 9 Span v/s Bending stress in N/mm^2

¬ INNOVATIVE PLATE GIRDER BRIDGES

Table no. – 8 Span v/s Bending stress in N/mm^2

Fy → Span ↓	250 N/mm^2	300 N/mm^2	350 N/mm^2	400 N/mm^2
10.0 m	135.30	156.60	176.40	183.60
20.0 m	154.10	182.50	210.10	237.00
30.0 m	158.50	189.30	219.70	249.50
40.0 m	158.70	190.80	222.50	253.90
50.0 m	156.10	189.10	221.70	254.10

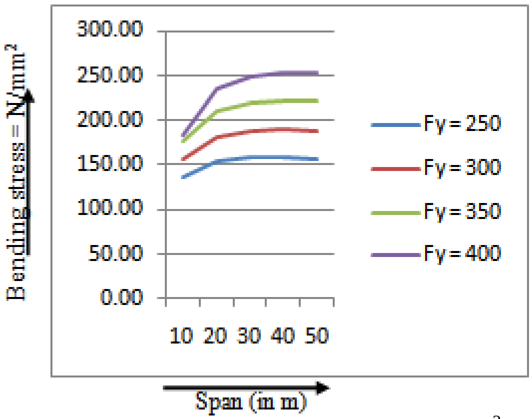


Fig. 10 Span v/s Bending stress in N/mm^2

ϖ CONVENTIONAL PLATE GIRDER BRIDGE

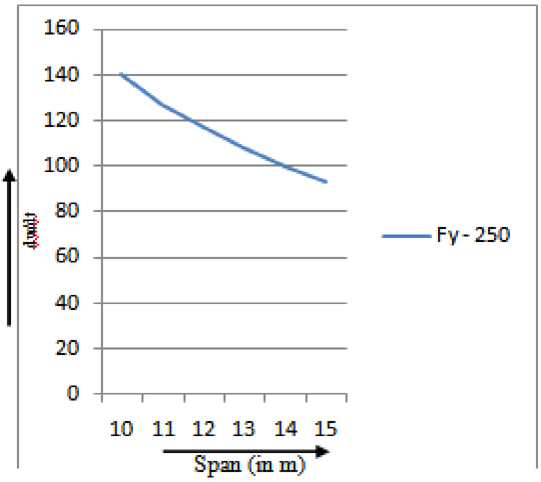


Fig. 11 Span v/s (dw/dt) for all span 0 – 50 m

¬ **INNOVATIVE PLATE GIRDER BRIDGE**

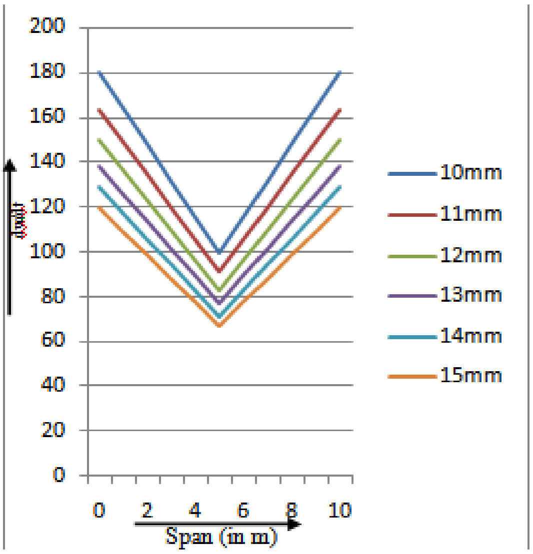


Fig. 12 Span v/s (dw/tw) [span 0 – 10 m]

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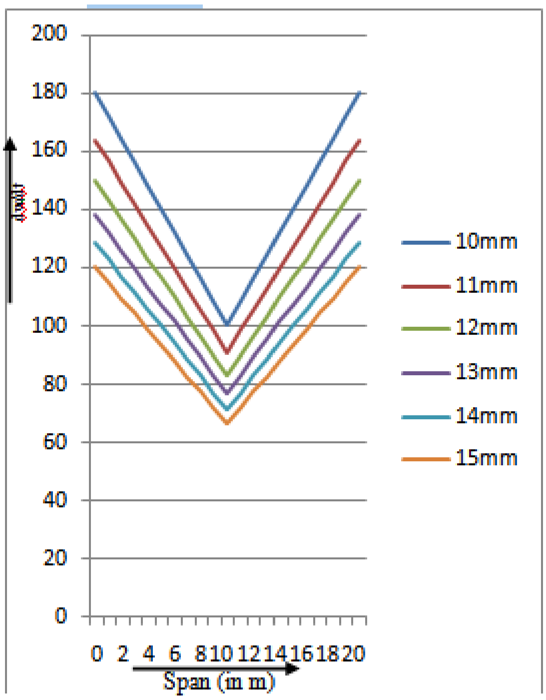

Fig. 13 Span v/s (dw/tw) [span 0 – 20m]

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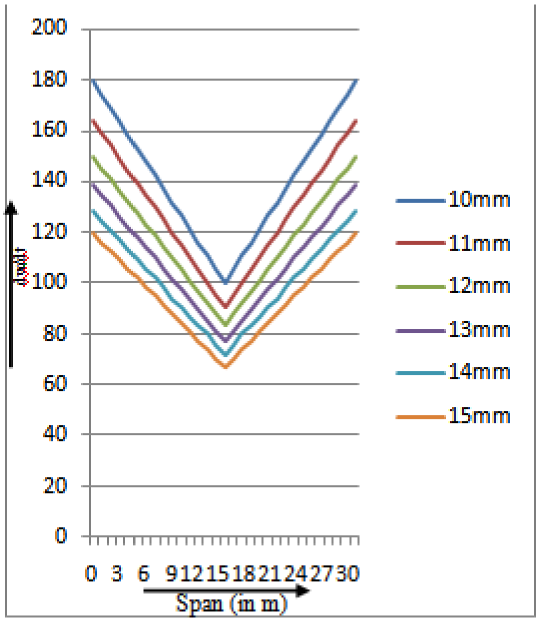

Fig. 14 Span v/s (dw/tw) [span 0 – 30m]

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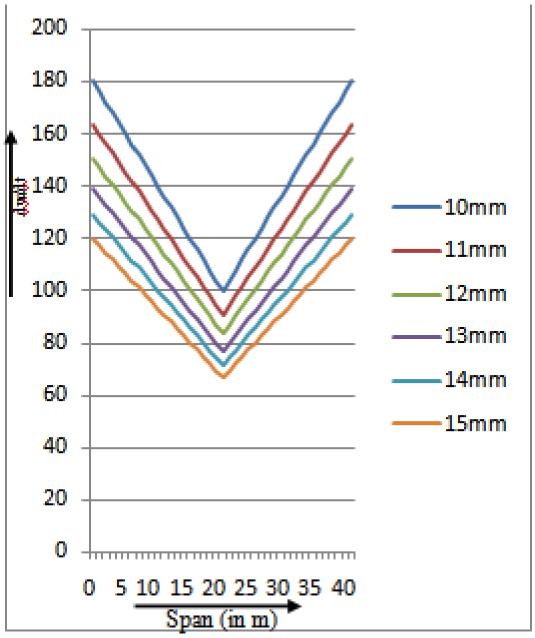

Fig. 15 Span v/s (dw/tw) [span 0 – 40m]

- **INNOVATIVE PLATE GIRDER BRIDGE**

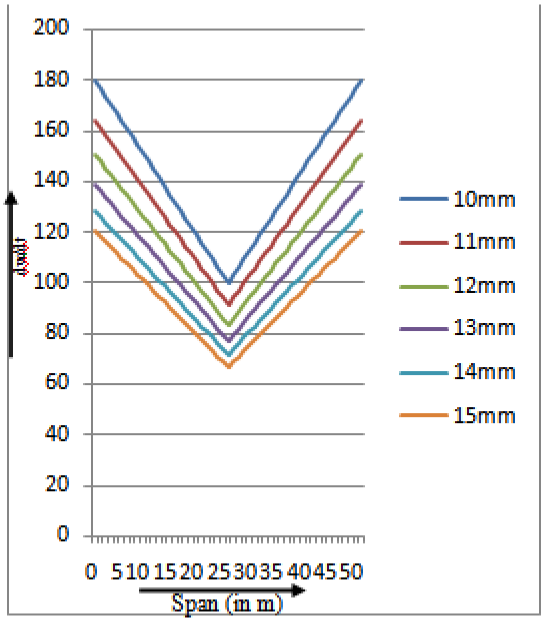

Fig. 16 Span v/s (dw/tw) [span 0 – 50]

V. RESULT & CONCLUSION

W.

- For Conventional plate girder bridge, Gross M.I. increases of the span for every 10.0 m interval by 55 % for the same span But an increase of Fy from 250 N/mm^2 to 400 N/mm^2 with an increment of 50 N/mm^2, Gross moment of inertia decreases by 11.20 %
  For the span varying from 10 m to 50 m (with an equal interval of 10.0 m each), the value of gross moment of inertia increases by 45 %

- For innovative plate girder bridge for increase of Fy from 250 N/mm^2 to 400 N/mm^2 with an equal interval of 50 N/mm^2, Gross M.I. decreases by 11.94 % for each span length

- For innovative plate girder bridge for every increase of Fy (from 250 N/mm^2 to 400 N/mm^2 at an equal interval of 50 N/mm^2), area of flange decreases by 16.70 %

- For conventional plate girder bridge, shear stress decreases by 10 % for every 1 mm increase of web thickness. Shear stress increases by 2.0 N/mm^2 per metre increase of span

- For innovative plate girder bridge, the shear stress decreases by 10 % for per mm increase of web plate thickness. metre 10 mm to 15 mm, the shear stress decrease by 3.0 N/mm^2

- For conventional plate girder bridge, the bending stress increases by 30 N/mm2 for every increase of Fy at an equal interval of 50 N/mm^2 starting from 250 N/mm^2 (for 10 mm web plate thick)

- For innovative plate girder bridge, the bending stress decreases by 2.0 N/mm^2 per mm increase of web plate thickness

- In a conventional plate girder bridge for the span 10 m to 50 m and web thickness 10 mm to 15 mm, vertical stiffeners are required to be provided throughout the span.

- But in the case of innovative plate girder bridge, from 10 m to 50 m span and web thickness 12 mm to 15 mm, about 35.6% of span length, no stiffeners are required to be provided.

- It is concluded that an innovative plate girder bridge is most economical as compared with conventional plate girder bridge.

VI. REFERENCES

[1.] R.P. Knight, “Economical steel plate girder bridge” national Bridge Conference june – 1 – 1983

[2.] Savite Maru. “Comparative study of the analysis and Design of T – Beam Girder and Box Girder Superstructure” IJREAT International journal of Research in Engineering & Advanced Technology, Vol – 1, Issue 2, April – may, 2013

[3.] J.P. Boyer; AISL Engineering Conference, Omaba, Nebr, in May, 1964

[4.] S. Mizukami, Nippon steel technical report no 82, July 2005

[5.] Vedat Togan. “Bridge truss optimization under moving load using continuous and discrete design variables in optimization methods ”Indian concrete journal of Engineering & material science” Vol – 16, Aug 2009, pp.245 – 258

[6.] M.B. Sarkar. “Comparison of Design Standards for steel Railway Bridges”. “International journal of Engineering Research and Applications (IJERA)” Vol – 3, Issue 2, March – April 2013, pp. 1131 – 1138

[7.] D.J. Victor, (1973), “Essentials of bridge Engineering”, Oxford and IBN