Analysis of Pre-Stressed Concrete I Girder by Varying the Length to Depth Ratio for Various Spans of the Bridge.

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Abstract : This paper implements an revolutionary operations for analysis and design of Pre Stressed Concrete –I (PSC-I) Girder based on varying the sectional dimensions, No. of Girders, L/d ratio. The grillage analogy method is used to finding out the results by using computer programming/ software. The results are judged on the basis of maximum Bending moment, shear force and deflection of girder. The overall comparison gives the best suitable and economical section of PSC-I girder.

***Index Terms* - Pre-stressed Concrete - I girder, Minimum Cost design, Design variables, Number of girders, L/d ratio, Maximum bending moment, Maximum Shear force, Deflection.**

I. INTRODUCTION

Bridges have been constructed by human being beings from ancient times, with the preliminary aim for crossing over the obstruction, being extremely simple. With the advancement of development, more useful methods were discovered in constructing bridge that were based on the optimum utilization of construction materials to build bridges. As the time goes the use of pre-tensioned I-beam girders with cast-in-place concrete deck grew rapidly. These types of pre-tensioned I-Beam Girder with cast-in-place are designed as simply supported span bridge up to the 1960's. [1]

The Girder Bridge, is a solid structure that is the simplest compared to all the bridge shapes. It is strong and economical, being supported by piers or Abutments to carry the vehicular traffic. The bridge is subjected to Compressive and tensile forces due to which a strong beam/Girder is crucial to stand firm against the bending and twisting due to heavy loads on the bridge. Vehicular traffic load transferred from Girder to pier/Abutment. Due to this the top portion of the bridge is under compression which gets shortened, while the bottom portion under tension thus stretched and prolonged. Pre-stressed concrete (PSC) I-girder bridge systems are suitable as short to medium span 20m - 60 highway bridges because of their structural efficiency, moderate self weight, low initial cost, fast construction, ease of fabrication, long life expectancy, simple deck removal, and replacement, low maintenance[2].

Large numbers of design variables are involved in the design process of the PSC I-girder bridges, and all variables are related to one other, leading to numerous alternative feasible designs[2][5]. So there is scope on work with such issues and to find most economical section for number of span with the different specifications. The numbers of researchers have studied the process of optimization of Pre-stressed I-Girder. To achieve minimum cost of bridge Jones developed a program to design as simply supported I girder beams [3]. Yu et al. presented the optimum design of precast box shaped girder bridge beams by using general geometric programming. Cohn and Lounis realized minimum cost design of middle and short span highway bridges constituted by post tensioned I girders and reinforced concrete slab [4]. The Sohel Rana have an objective of to minimize the total cost of the bridge superstructure system by considering cost of fabrication, material and installation with the design parameters such as sectional properties, tendon properties. After that he implemented this experimental program to a real life project which shows to 35% reduction in total cost of project [5]. The report by the Federal Highway Administration Georgetown Pike McLean, which contains assessment of effect of high performance concrete on the structural performance on the bridge and cost of the bridge with height performance concrete Deck and high strength concrete girders by considering effect of losses in the pre-stressing. Shohel Rana with R. Ahsan and S.N.Ghani presented another paper with reference to previous paper (2003) "Design of pre-stressed concrete I-girder bridge superstructure using optimization Algorithm", in which they have made comparison between Conventional design process and Optimum design process by using optimization algorithm called (EVOP) Evolutionary Operation is used[6]

II. PROBLEM STATEMENT & METHOD

2. 1 Description of Project

The analysis and designing of various bridge spans such as 36 m, 40m, 45m and 50m is considered. The superstructure of PSC I girder is proposed. For the analysis of the live load and SIDL is carried in a STAAD.Pro8 with a grillage analysis. This design note is for the design of the Precast PSC I girders for 7.5 m carriageway. The girders are designed as a simply supported (By using Limit State Method). For the analysis, different arrangements of I-Girders are referred i.e. Four girder arrangements and five girder arrangements, with the L/d ratio 16 and 20 respectively. The objective of paper to select the optimized I girder section amongst the mentioned arrangement and also assess the effect on Maximum Live load and Dead load Bending moment, Shear force and deflection of members kept in given limits by changing the sectional properties and no of I-girder. The grade of concrete referred M40 and grade of steel FE500.

2.2 Loading Consideration

The following loads and load combination as per IRC: 6-2017 have been considered as given below:
Dead Load (Self weight of structure, Superstructure, SIDL), Live load (The bridge is designed for the vehicular loads live load for carriageway of 7.5 m.), Loading Cases :- Class 70 R Wheeled (Critical= 1000 kN), Class 70 R tracked (700 kN) , Class A (554 Kn) .

2. 3 Details of I Girder

The dimension of I girder are to be finalized by referring IRC 112, which is combination of IRC 18 & IRC 21. Following calculation is made while deciding size of I girder.
Thickness of Web-According to IRC 21, the thickness of the web shall not be less than 200mm plus diameter of duct hole. Here we are considering the 19 T-13 Cable for Pre-stressing purpose which is having the diameter of duct is around 90mm, according to which the thickness of web come to 300 mm.
Thickness of Top Flange – According to IRC 21 Following equation used to find thickness of Top flange.

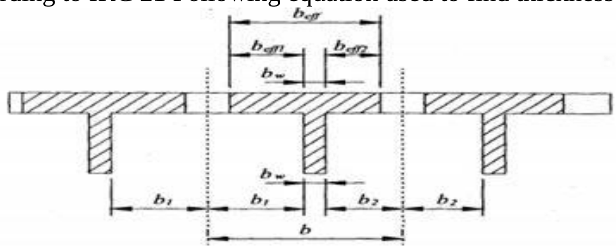


Figure 1 Thickness of top flange

beff	=	(a) For I Girder				
beff	=	Σ beff, i	+	Bw		(1)
beff,i	=	0.2bi	+	0.1lo	or 0.2lo	(2)

Thickness of Deck slab – According to IRC 21 it should be minimum 200mm.Other dimension are fixed by using following figure from IRC 21-2000

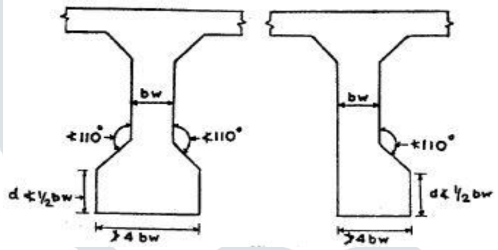


Figure 2 Minimum dimension of I section as per IRC 21-200

2.4 Cross Section of I Girder

As The Bridge on River Godavari at Nanded is a live project, before deciding any arrangement of girder it is very important to do the a research and development for various options. For that to reduce the concentration of huge amount of bending moment on four girders one has to increase the numbers of girder along with reducing the depth of girder to Control the value of dead load bending moment. Following are the two options for the girder arrangement are considered for the project as shown in Fig. 5 and 6 with their cross sectional dimensions as shown in Fig 3 and 4.

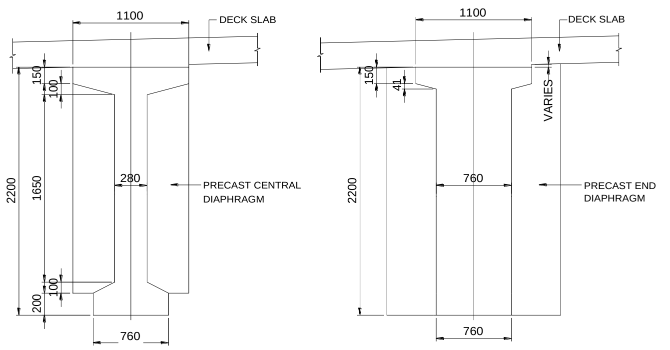


Figure 3 Cross sectional details of I girder for Four Girder Arrangement

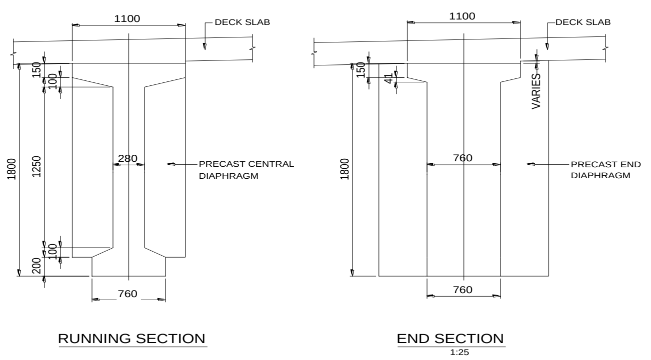


Figure 4 Cross sectional details of I girder for Five Girder Arrangement

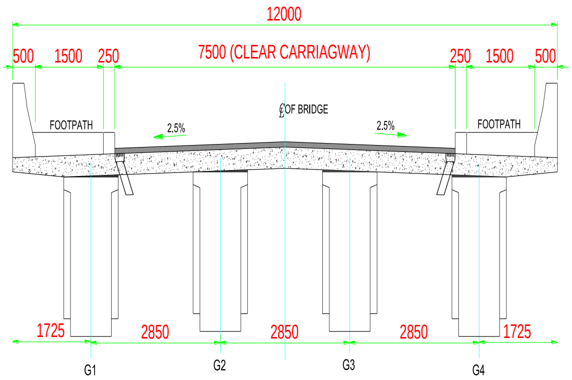


Figure 5 C/S Along Transverse direction for Four Girder Arrangement

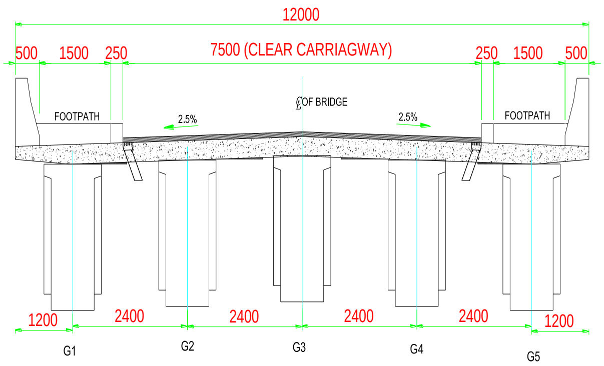


Figure 6 C/S Along Transverse direction for Four Girder Arrangement

2.5 Design Data

Table no 1 Variable design Data

Sr.No.	Span of Bridge	Depth of Girder (For 4 Girder)	Depth of Girder (For 5 Girder)
1	36 m	2.2 m	1.8 m
2	40 m	2.4 m	2.0 m
3	45 m	2.7 m	2.25 m
4	50 m	3.0 m	2.5 m

Table no 1 shows that, by varying the L/d Ratios of the bridge span the variable depths for four and five girders system are calculated.

2.6 Modeling

For calculation of Live Load Bending Moment STAAD Pro.8 software is used, for that firstly the deck slab grillage model for span 36 m, 40m 45m and 50m are prepared as shown below, which content a combination of longitudinal and transverse members. For grillage analysis the whole span is get divided in to the 10 equal segments by 9 no of cross girder. Also the End Diaphragm are provided at the both ends, and two no's of Intermediate Diaphragm are provided at a distance 12.4 m from the each end of the span. As we consider the span as simply supported, so here provide one end as hinged and other as roller supports. From application of loading consideration the line of crash barrier, line of footpaths and line of Road side curb is also marked at an distance 250mm, 2000mm and 2125mm from the end of the span as shown in figure no 7 and 8..

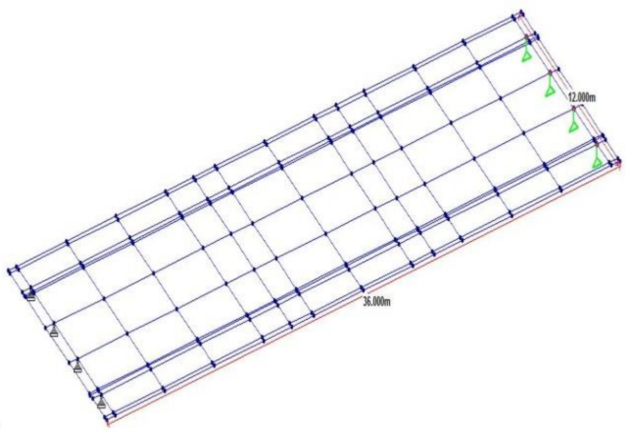


Figure 7: Model 1 - 36m span with Four Girders

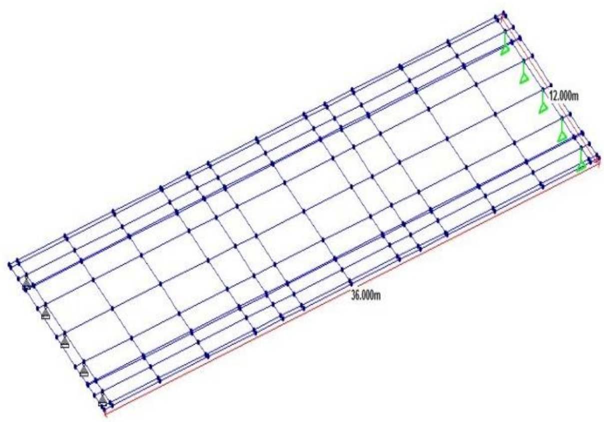


Figure 8: Model 2 - 36m span with Five Girders

III. RESULTS & DISCUSSION

3.1 Results And Discussion For Four Girder Arrangement

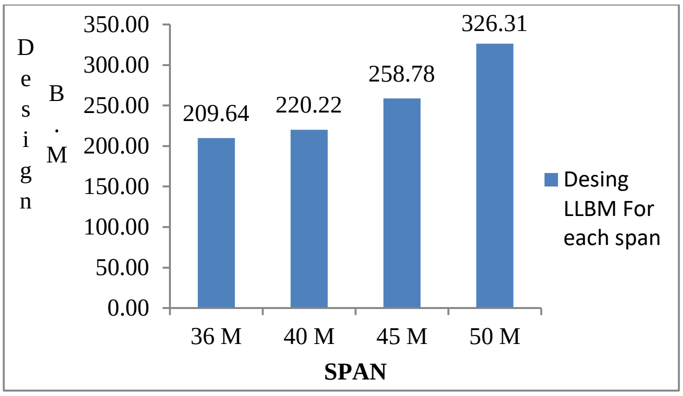


Figure 9 Maximum Bending moment in girder due to live load for each span

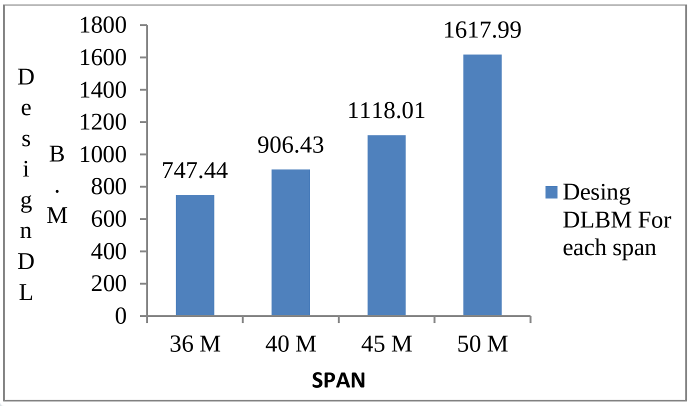
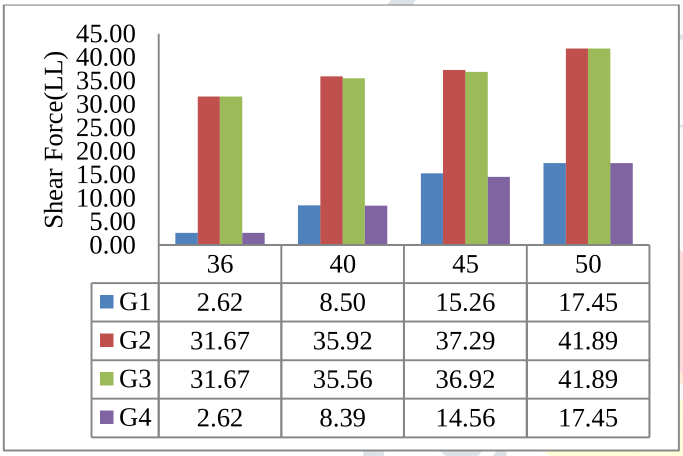
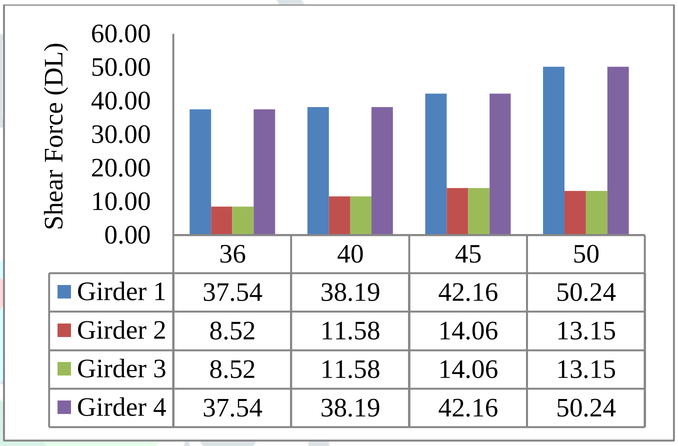


Figure 10 Maximum Bending moment in girder due to Dead load for each span



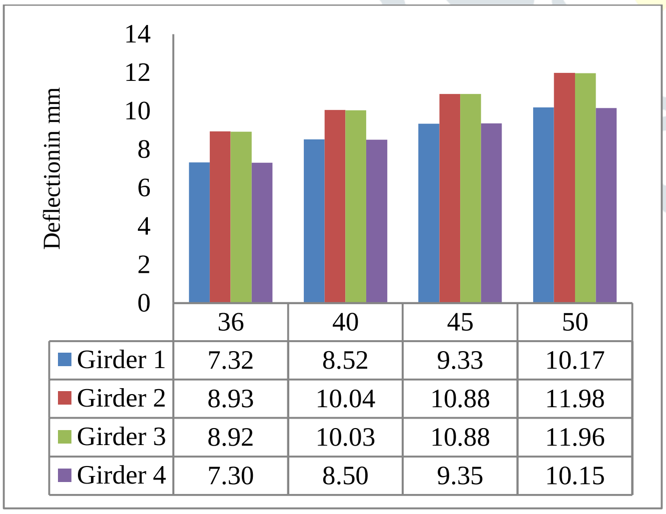
	36	40	45	50
G1	2.62	8.50	15.26	17.45
G2	31.67	35.92	37.29	41.89
G3	31.67	35.56	36.92	41.89
G4	2.62	8.39	14.56	17.45

Figure 11 Maximum Shear force in girder due to live load for each span



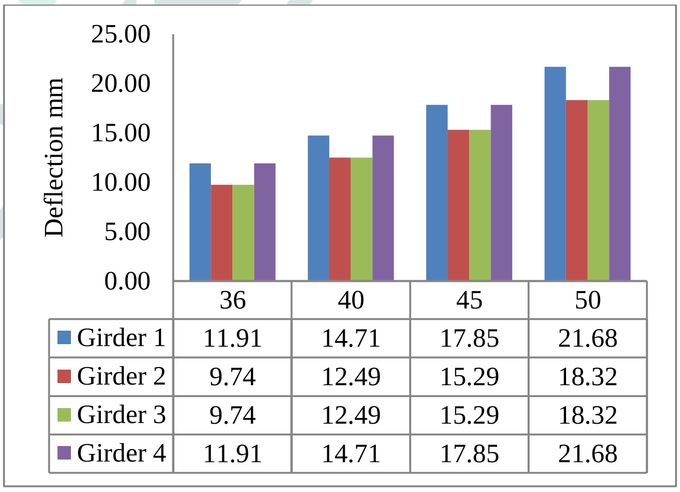
	36	40	45	50
Girder 1	37.54	38.19	42.16	50.24
Girder 2	8.52	11.58	14.06	13.15
Girder 3	8.52	11.58	14.06	13.15
Girder 4	37.54	38.19	42.16	50.24

Figure 12 Maximum Shear force in girder due to Dead load for each span



	36	40	45	50
Girder 1	7.32	8.52	9.33	10.17
Girder 2	8.93	10.04	10.88	11.98
Girder 3	8.92	10.03	10.88	11.96
Girder 4	7.30	8.50	9.35	10.15

Figure 13 Maximum Deflection in girder due to live load for each span



	36	40	45	50
Girder 1	11.91	14.71	17.85	21.68
Girder 2	9.74	12.49	15.29	18.32
Girder 3	9.74	12.49	15.29	18.32
Girder 4	11.91	14.71	17.85	21.68

Figure 14 Maximum Deflection in girder due to Dead load for each span

The figure no 1 and 2 shows that as a span increases the value of Maximum Bending moment in girder due to live load and dead load both goes on increases. The figure no. 3 shows the incremental value of maximum Shear force with respect to each span. As the moving live load passes between inner two girders so the values of max. Shear force seems to be higher at inner two girders e.g. G2 and G3. As per the figure no. 4 the maximum impact of dead load Shear force is on outer girder of the span of bridge due to the dead weight of foot-path, crash barrier, road side curb are governing. This same concept relates to figure no. 5 and 6 respectively.

3.2 Results And Discussion For Five Girder Arrangement

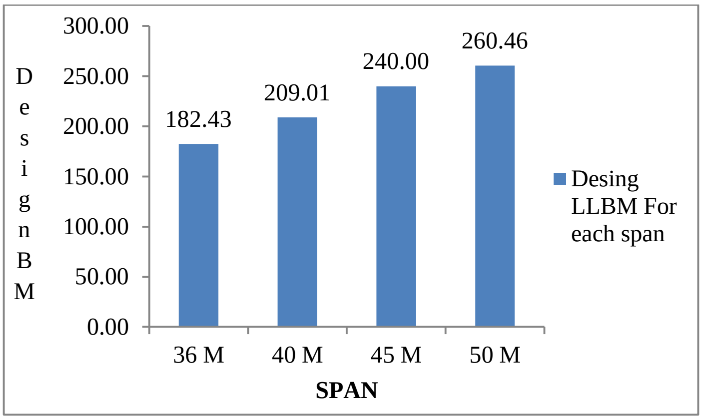


Figure 15 Span vs. Design LL Bending Moment

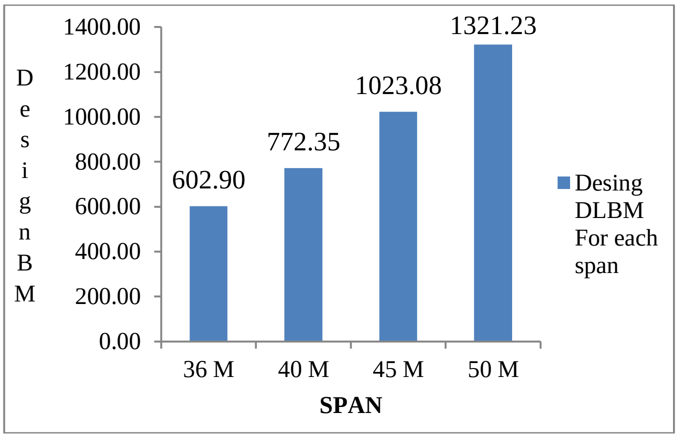
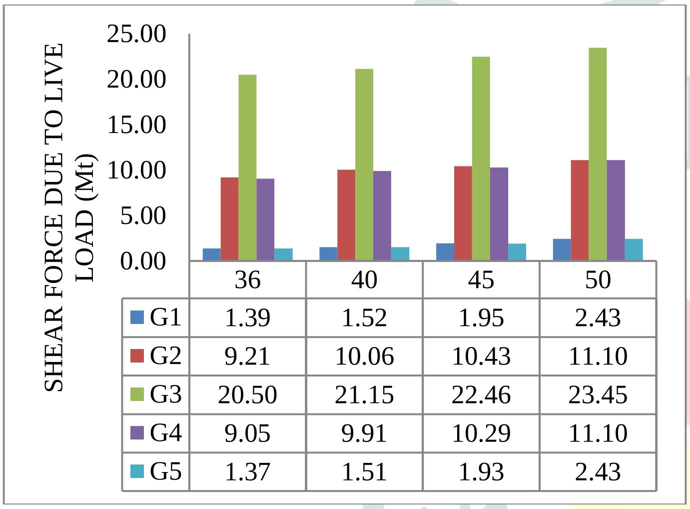
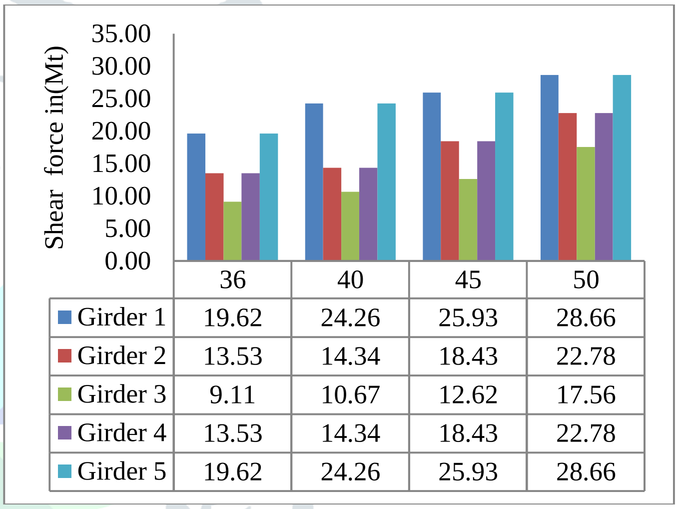


Figure 16 Span vs. Design DL Bending Moment



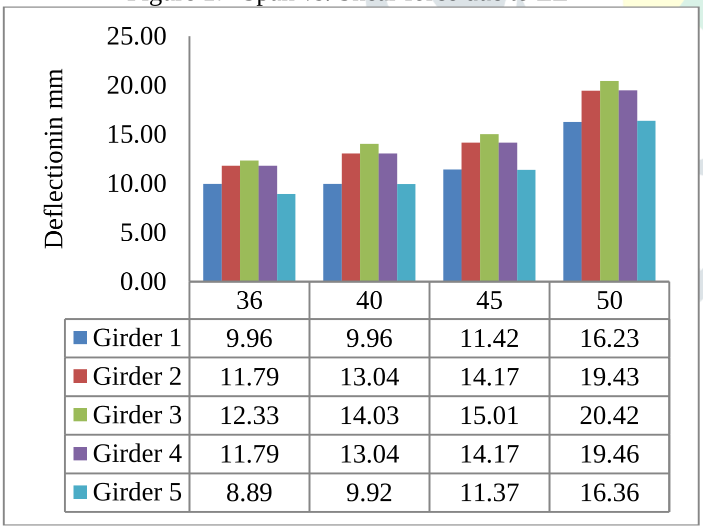
	36	40	45	50
G1	1.39	1.52	1.95	2.43
G2	9.21	10.06	10.43	11.10
G3	20.50	21.15	22.46	23.45
G4	9.05	9.91	10.29	11.10
G5	1.37	1.51	1.93	2.43

Figure 17 Span vs. Shear force due to LL



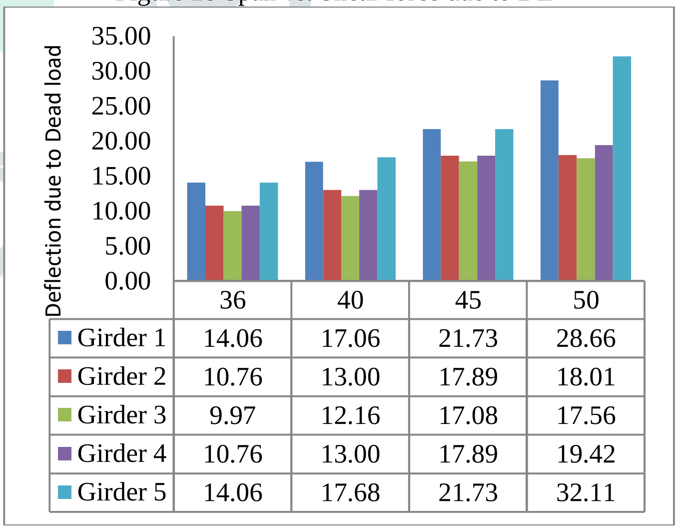
	36	40	45	50
Girder 1	19.62	24.26	25.93	28.66
Girder 2	13.53	14.34	18.43	22.78
Girder 3	9.11	10.67	12.62	17.56
Girder 4	13.53	14.34	18.43	22.78
Girder 5	19.62	24.26	25.93	28.66

Figure 18 Span vs. Shear force due to DL



	36	40	45	50
Girder 1	9.96	9.96	11.42	16.23
Girder 2	11.79	13.04	14.17	19.43
Girder 3	12.33	14.03	15.01	20.42
Girder 4	11.79	13.04	14.17	19.46
Girder 5	8.89	9.92	11.37	16.36

Figure 19 Span vs. Deflection due to LL



	36	40	45	50
Girder 1	14.06	17.06	21.73	28.66
Girder 2	10.76	13.00	17.89	18.01
Girder 3	9.97	12.16	17.08	17.56
Girder 4	10.76	13.00	17.89	19.42
Girder 5	14.06	17.68	21.73	32.11

Figure 20 Span vs. Deflection due to DL

The figure no 7 and 8 shows that as a span increases the value of Maximum Bending moment in girder due to live load and dead load both goes on increases for five girder arrangement also. The figure no. 9 shows the incremental value of maximum Shear force with respect to each span. As the moving live load passes through the girder no G2, G3 and G4 so the values of max. Shear force seems to be higher at central girders i.e. G3. As per the figure no. 10 the maximum impact of dead load Shear force is on outer girder of the span of bridge due to the dead weight of foot-path, crash barrier, road side curb are governing. This same concept relates to figure no.11and12 respectively.

3.3 Comparison Between Four And Five Girder Arrangement

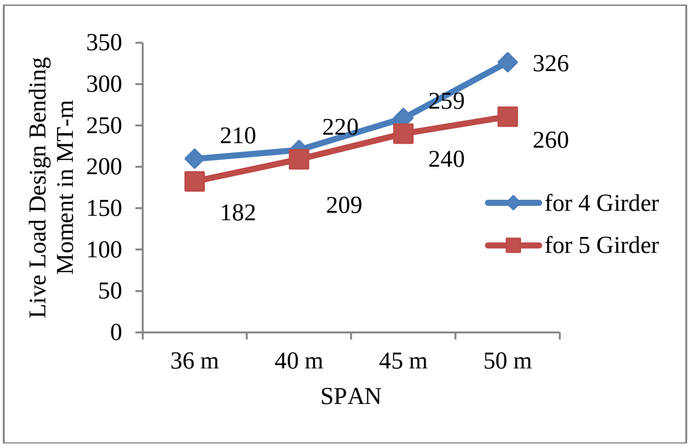


Figure 21 Comparison of Design Bending Moment due to Live load for each span

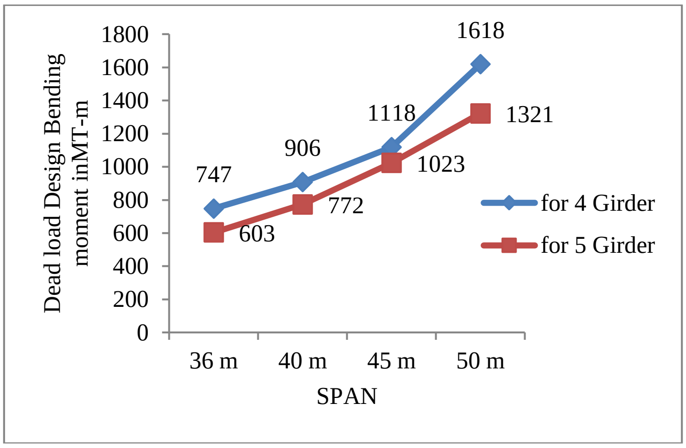
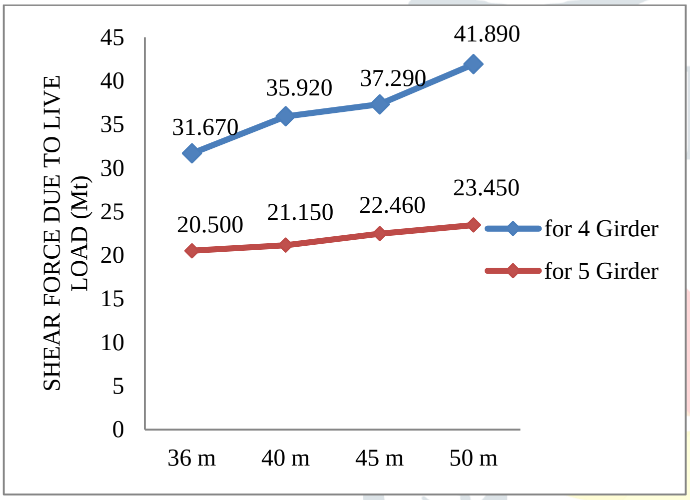


Figure 22 Comparison of Design Bending Moment due to Dead load for each span



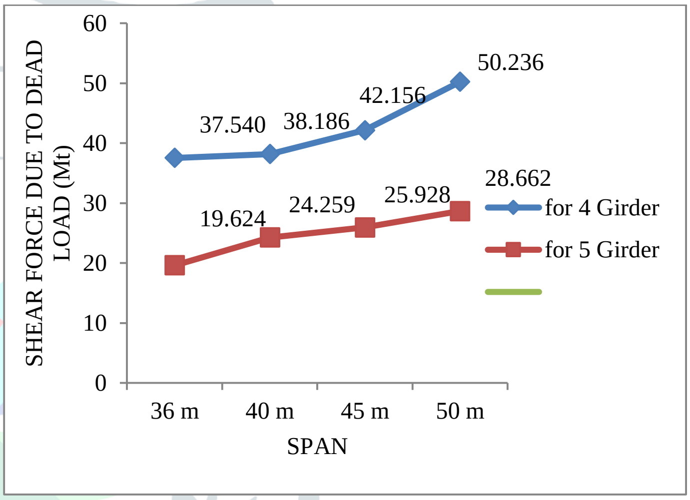


Figure 23 Comparison of Design Shear Force due to Live load for each span

Figure 24 Comparison of Design Shear Force due to Dead load for each span

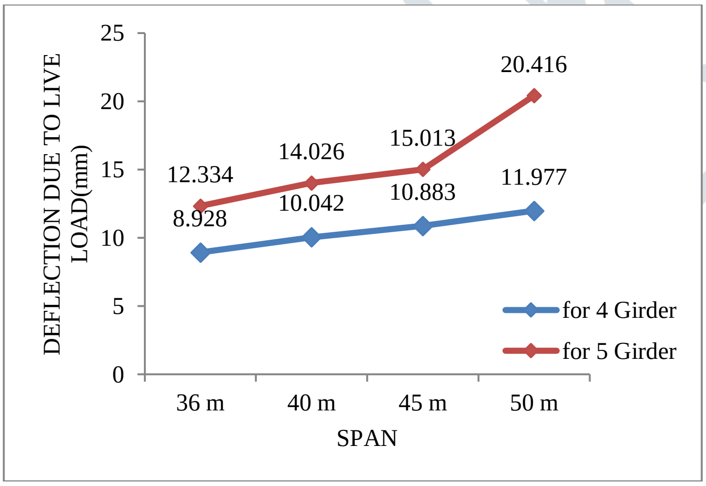


Figure 25 Comparison of Max. Deflection due to Live load for each span

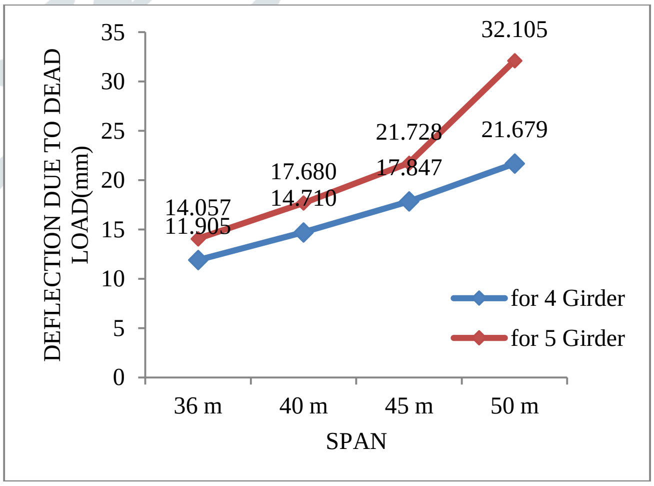


Figure 26 Comparison of Max. Deflection due to Dead load for each span

The figure no 13,14,15 and 16 shows the maximum value of design bending moment and design shear force due to both Live load and dead load for each span of the bridge, on both four girder and five girder arrangements, the values of five girder system seems to be higher than the four girder as the total bending moment splits in to five numbers of girder. The figure no. 17 and 18 shows the deflection value of girders for each span and it results that higher deflection is in five girder system as compared with the four girder system, as the sectional modulus of five girder system is less than four girder system.

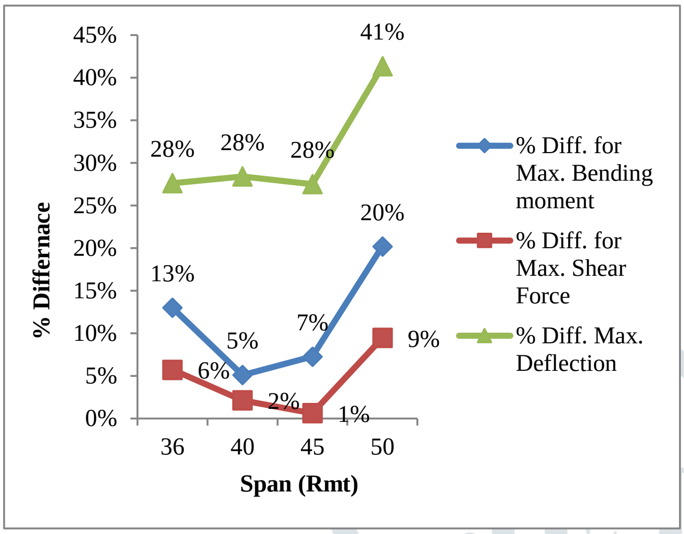


Figure No 27 Percentage difference Bending moment due to Dead load

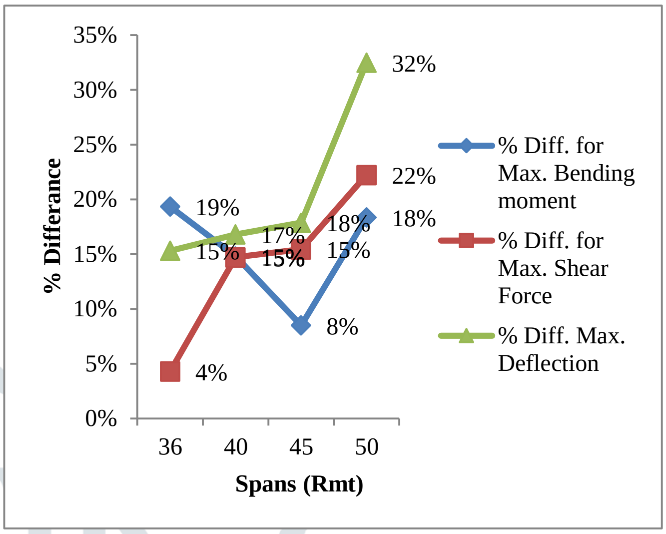


Figure No 28 Percentage difference Bending moment due to Live load

IV. CONCLUSIONS

Based on the analyses described in this paper, the following conclusions are made.

1. The major constituent in any design is the ‘ value of maximum bending moment’, by referring Figure 27 and 28 can conclude that by using five girder arrangement system the values of maximum bending moment and shear force reduces up to 15% and 14% respectively under the influence of live load also 11% and 4% percent respectively under live load. Comparison is made for four and five girder arrangement system, and then it is found that averagely 21% and 31% additional deflection occur due to dead load and live load respectively. Based on this value the conclusion is made that the four girder system is more suitable than the five girder system
2. As the bending moment is governing factor in the design, it results that the 45 m span under influenced by both dead load and live load shows the minimum value of bending moment, which seems to be more economical span as compared with all other spans.

V. REFERENCES

[1] Z. Lounis, M. S. Mirza/ Member, “Segmental And Conventional Precast Pre-stressed Concrete I-Bridge Girders”, Journal Of Bridge Engineering, ASCE-73 -1997

[2] Abdel-Karim, A. and M.K. Tadros . State-of-the-Art of Precast/Prestressed Concrete Spliced I-Girder 7Bridges. Precast/Pre-stressed Concrete Institute, Chicago, IL, 1995

[3] Jones, “Minimum Cost Prestressed Concrete Beam Design” Journal of Strucural Engineering,1985.

[4] Lounis, Ph.D. & M. Z. Cohn, P. Eng. “Optimization of Precast Pre-stressed Concrete Bridge Girder Systems”PCI Journal,1993

[5] Shohel Rana ,” Cost Optimization of Post-Tensioned Prestressed Concrete I-Girder Bridge System” thesis of Master of Science structure 2003.

[6] Shohel Rana, “Cost Optimum Design of Posttensioned I-Girder Bridge Using Global Optimization Algorithm”, Journal of Strucural Engineering,2013

[7] Mast, R F. "Lateral stability of long pre-stressed concrete beams-part 2." PCI J., 38(1),70-88.1993.

[8] Geren, K. L., and Tadros, M. K. . "The NU precast/pre-stressed concrete bridge I-girder series." PCI J., 39(3), 26-39,1994.

[9] By Sami M. Fereig,l Member, ASCE, “Economic Preliminary Design Of Bridges With Pre-stressed I-Girders”, Journal Of Bridge Engineering,18-19

[10] R. G. OESTERLE, J. D. GLIKIN and S. C. LARSON, “Design Of Precast Pre-stressed Bridge Girders Made Continuous” Transportation Research Board,322-1989

[11] By Paul J. Barr,1 Marc O. Eberhard,2 and John F. Stanton3 , “Live-Load Distribution Factors In Pre-stressed Concrete Girder Bridges” J. Bridge Eng 6:298-306.2001

[12] Castrodale, R.W. and C.D. White Extending Span Ranges of Precast Pre-stressed Concrete Girders. Transportation Research Board, National Cooperative Highway Research Program, Report No. 517, 603 pages. 2004.

[13] Bureau of Research Testing & Consultation (BRTC).“Teesta bridge project report.” File No. 1247, Dept. of Civil Engineering Library, Bangladesh Univ. of Engineering and Technology, Dhaka, Bangladesh.2007.
[14] Koch, S. “Pre-stressed PCBT Girders Made Continuous and Composite with a Cast-inPlace Deck and Diaphragm”. Master of Science Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 140 pages,2008.