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Analysis of Pre-Stressed Pseudo Box Bridge using Inverted-T Girder and Splicing Technique

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ANALYSISOFPRESTRESSEDPSEUDOBOXBRIDGEUSINGINVERTEDTGIRDERANDSPLICINGTECHNIQUE

Strictly as per the compliance and regulations of :

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I. Introduction

a) General Concept

Large bridge with long span and vertical clearance for navigation is required in some places. Pre-stressed concrete girder bridge is constructed where river is deep and more navigation clearance is required. Post tensioned box girder is the latest system for long span bridge for which modern construction technologies as well as huge construction fund are required.

The box girder normally comprises either prestressed concrete, structural steel, or a composite of steel and reinforced concrete. The box is typically rectangular or trapezoidal in cross-section. Box girder bridges are commonly used for highway flyovers and for modern elevated structures of light rail transport. Although normally the box girder bridge is a form of beam bridge, box girders may also be used on cable-stayed bridges and other forms. This study is carried out with the intension of finding some other alternating as can be used as compatible to post tensioned box Girder Bridge.

b) Objective of the Study

The objective of the study is to analysis of a pseudo box girder bridge of a 750m long multiple span (50m each span) using on 2 lane highway.

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c) Scope of the Study

To use splicing technique for pre-cast inverted T-girders which are placed very closely and act as pseudo box section as can be used for long span bridge.

d) Approach of the Study

The approach of structural analysis is made by STAAD pro 2006, which is based on numerical finite element grid analysis theory. The study selected suitable section of inverted-T girders of two different lengths of 28m and 22m long which are to be applied for making continuous simply supported 750m long bridge.

II. Modeling and Analysis

a) Introduction

The bridge was analyzed as considering simply supported multi – span RCC deck slab supported on pre-stressed post tensioned concrete inverted-T girder. The bridge length is 750m comprising of 15 number spans (50m each). The bridge is analyzed as continuous multiple spans with pre-stress concrete inverse-T girder. Fixed permanent loading were analyzed to find out the inflection points. The change of inflection point was determined by different live load combinations. STAAD-pro software and AASHTO-2003 were used as design tools for numerical grid analysis and loading criteria respectively.

b) Bridge modeling configuration

Total length: 750 m, 15 span: 15 @ 50m, No. of lane: 2, Type of support: fixed and hinge support analysis purpose only, Girder type: inverse-T girder, No. of girder: 12, Cross beam type: rectangular (two types).

Bridge deck: Total width: 13.543m, Carriage way: 11.033m, Footpath with curb: 0.65 * 2, Parapet: 0.255 * 2.

Type of superstructure: RCC deck slab (150mm thick) supported on simply supported post-tensioned concrete spliced inverted-T girder.

Type of construction: Pre-cast inverted-T girder and spliced cast-in-situ on Conventional Propping System.

Curvature: horizontal: Straight, vertical: 1.0% parabolic (as open to bidder).

c) Member Properties

Inverse-T girder parameter:	Box section of single cell:
Top flange width: 410mm	Top flange thickness: 150mm
Thickness of top flange: 625.1mm	Web thickness: 300mm
Depth of girder: 1510mm	Bottom flange thickness: 256mm
Thickness of web: 210mm	Height of box: 1660mm
Bottom flange width: 990mm	
Thickness of bottom flange: 256mm	

Overall dimensions 990x1510 mm

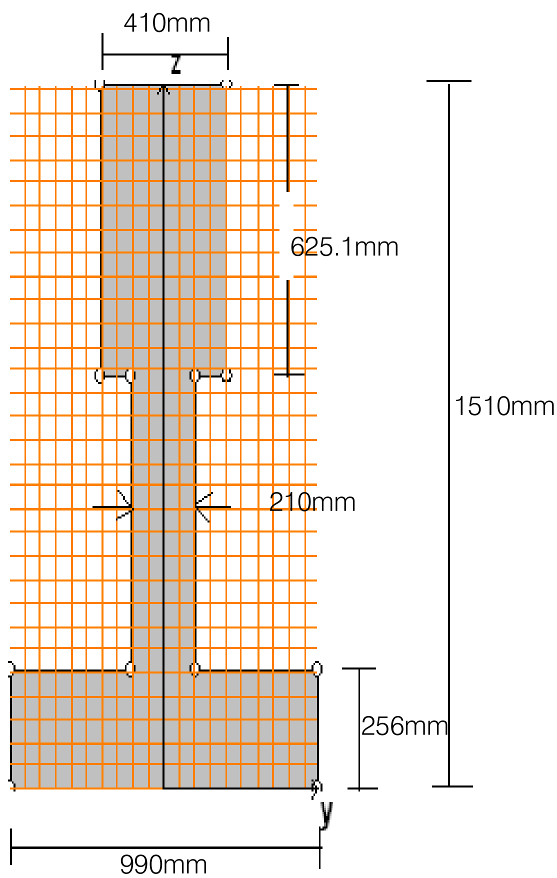

Figure 1 : Section of inverse-T girder

III. Results and Discussion

Structural analysis of 750m continuous girder has been performed by using STAAD pro 2006 to find out inflection points for splicing which deals with the finite element analysis. We have compared the analysis result of single inverted-T girder, transverse box section and longitudinal box section to find out the depth and thickness of box Girder Bridge for different loadings to join the girder successfully at site.

Relation of Permanent Loading and Inflection Points

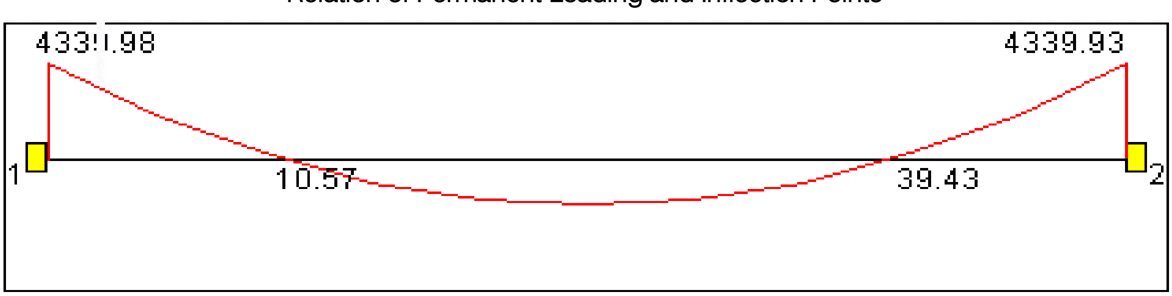

Fig 2 : Typical Inflection Point Diagram *a) Results for Single Inverted-T Girder analysis*

Table 1 : Combination-1 (SW+SDL) for Edge Girder

Beam	Beam results								
	Moments (max) (kN-m)			Shear (kN)			Deflection (Max.) (m)	Inflection point (m) from left support	
	Left support	Mid point	Right support	Left support	Mid	Right support	……..		
G1	4698.32	-2349.149	4698.32	563.796	0.001	563.791	0.102	10.57	39.43
G2	4698.28	-2349.116	4698.36	563.793	-0.002	563.792	0.102	10.57	39.43
G3	4698.27	-2349.139	4698.33	563.794	-0.001	563.795	0.102	10.57	39.43

Table 2 : Combination-1 (SW+SDL) for Interior Girder

Beam	Beam results								
	Moments (max) (kN-m)			Shear (kN)			Deflection (Max.) (m)	Inflection point (m) from left support	
	Left node	Mid point	Right node	Left support	Mid	Right support	……..		
G1	4339.979	-2169.982	4339.951	520.796	0.001	-520.795	0.094	10.57	39.43
G2	4339.949	-2169.952	4339.945	520.793	-0.001	-520.793	0.094	10.57	39.43
G3	4339.938	-2169.972	4339.965	520.794	-0.001	-520.795	0.094	10.57	39.43

Table 3 : Combination-2 self weight (SW) + Superimposed dead load (SDL) + Lane Load (UDL) + Concentrated Load in Mid Support of the Bridge

Beam	Beam results								
	Moments (max) (kN-m)			Shear (kN)			Deflection (Max.) (m)	Inflection point (m) from left support	
	Left node	Mid point	Right node	Left support	Mid	Right support	……..		
G1	5167.067	-2833.522	5167.038	600.046	-39.999	-600.045	0.119	10.78	39.22
G2	5167.031	-2833.485	5167.028	600.043	-40.002	-600.043	0.119	10.70	39.22
G3	5167.020	-2833.509	5167.050	600.044	-40.001	-600.045	0.119	10.78	39.22

Table 4 : Combination-3 self weight (SW) + Superimposed dead load (SDL) + Lane Load (UDL) + Concentrated Load in Edge Support of the Bridge

Beam	Beam results								
	Moments (max) (kN-m)			Shear (kN)			Deflection (Max.) (m)	Inflection point (m) from left support	
	Left node	Mid point	Right node	Left support	Mid	Right support	……..		
G1	4667.065	-2333.522	4667.035	560.046	0.001	560.045	0.104	10.57	39.43
G2	4667.032	-2333.489	4667.030	560.043	-0.002	560.056	0.104	10.57	39.43
G3	4667.021	-2333.512	4667.052	560.044	-0.001	560.062	0.104	10.57	39.43

Table 5 : Combination-4 self weight (SW) + Superimposed dead load (SDL) + Lane load (UDL) + HS 20-44 Truck Loading at Center of the Interior Girder

Beam	Beam results								
	Moments (max) (kN-m)			Shear (kN)			Deflection (max) (m)	Inflection point (m) from left support	
	Left node	Mid point	Right node	Left support	Mid	Right support	……..		
G1	5311.783	- 2154.362	5380.629	538.668	-21.377	642.01	0.088	10.14	37.95
G2	5380.639	- 3639.122	5434.46	643.930	-17.411	583.021	0.170	10.15	40.04
G3	5434.402	- 2140.849	5434.53	583.033	22.988	583.11	0.087	12.16	39.89

Table 6 : Combination-5 Self weight (SW) + Superimposed dead load (SDL) + Lane load (UDL) + HS 20-44 Truck Loading at Center of Left Exterior Span and Interior Span

Beam	Beam results								
	Moments (max) (kN-m)			Shear (kN)			Deflection (max) (m)	Inflection point (m) from left support	
	Left node	Mid point	Right node	Left support	Mid	Right support	……..		
G1	5669.964	-3246.013	5931.432	639.779	-21.562	658.11	0.135	10.97	38.97
G2	5931.422	-3.265	5277.88	658.076	-3.265	578.41	0.152	11.12	40.08
G3	5277.897	-2180.143	5277.900	578.344	18.299	578.52	0.091	11.84	39.79

Table 7 : Combination-6 self weight (SW) + Superimposed dead load (SDL) + Lane load (UDL) + HS 20-44 Truck Loading at Center of All Span

Beam	Beam results								
	Moments (max) (kN-m)			Shear (kN)			Deflection (max) (m)	Inflection point (m) from left support	
	Left node	Mid point	Right node	Left support	Mid	Right support	……..		
G1	5739.010	-3280.833	5792.63	643.933	-17.408	645.451	0.138	11.03	39.20
G2	5792.739	-3267.294	5643.851	645.541	-15.800	643.851	0.137	11.12	39.22
G3	5643.931	-3253.819	5643.92	643.931	-17.410	643.931	0.135	11.10	39.13

Table 8 : Combination-7 self weight (SW) + Superimposed dead load (SDL) + Lane load (UDL) + HS 20-44 truck loading at First Support of Interior Span

Beam	Beam results								
	Moments (max) (kN-m)			Shear (kN)			Deflection (max) (m)	Inflection point (m) from left support	
	Left node	Mid point	Right node	Left support	Mid	Right support	……..		
G1	5395.070	-2385.671	4847.661	708.663	-10.774	633.131	0.108	9.92	39.12
G2	4847.678	-2339.665	4863.512	633.028	-6.713	630.891	0.105	10.24	39.16
G3	4863.617	-2392.653	4863.65	630.798	-2.239	630.992	0.109	10.28	39.52

Table 9 : Maximum and Minimum Inflection Point

Beam	Minimum inflection point from left support of load combination (1st zone)	Maximum inflection point from left support of load combination (1st zone)	Minimum inflection point from left support of load combination (2nd zone)	Maximum inflection point from left support of load combination (2nd zone)	Splicing zone (m)	
					1st	2nd
B1	9.92	11.03	39.12	39.43	1.11	0.31
B2	10.15	11.12	39.16	40.08	0.97	0.92
B3	10.28	12.16	39.22	39.89	1.88	0.67

Table 10 : Exact Girder Length (G) with Splicing Zone (Z) for the Analyzed 150m Continuous Girder

G-1 m	Z-1 m	G-2 m	Z-2 m	G-3 m	Z-3 m	G-4 m	Z-4 m	G-5 m	Z-5 m	G-6 m	Z-6 m	G-7 m	Total m
10.575	1.11	28.95	0.31	21.438	0.97	28.985	0.92	21.66	1.88	28.435	0.67	9.875	150

b) Results for All Inverted-T Girder Analysis

Table 11 : Combination-1 SW+ SDL+ Lane Load (UDL) + Concentrated Load at mid support of the Bridge

Beam	Beam results		
	Moments (max) (kN-m)		
	Left node	Mid point	Right node
G1	4256.560	-2611.447	0.378
G2	0.378	-3884.87	0.372
G3	0.372	-2628.86	4181.164

Table 12 : Combination -2 SW+ SDL+ Lane Load (UDL) + Concentrated Load at Edge Support of the Bridge

Beam	Beam results		
	Moments (max) (kN-m)		
	Left node	Mid point	Right node
G1	4243.470	-1834.78	11.234
G2	11.234	-1863.87	12.976
G3	12.976	-1843.67	4190.456

Table 13 : Combination-3 SW+ SDL + Lane load (UDL) + HS 20-44 truck loading at Interior Girder

Beam	Beam results		
	Moments (max) (kN-m)		
	Left node	Mid point	Right node
G1	4422.370	-2045.236	0.487
G2	0.487	-4308.354	0.479
G3	0.479	-2067.784	4410.657

After analysis using STAAD Pro and checking deflection for different sections, finally we can conclude that different sections can be used for making continuous span by the technique of splicing at the erection site.

The inflection point due to self weight and superimposed dead load was checked by different bridge live load cases. After doing the analysis for different load cases, we found that inflection points were varied due to different loading position. The variation of the position of lane loading and truck loading effectively changed the location of inflection point. From the above findings the bending moment of bridge is reduced gradually by finite element plate analysis. If we use false box technique then we get the reducing bending stress benefit and reduced bending stress can give reduce bending moment which gives the lighter section. For this reason, deflection due to dead load is small and the live load deflection is reduced by pre-stressing of cross girder.

The pseudo box (false box) and splicing technique can be effectively practiced in the world where the box girder is most costly. Considering the socio-economic condition this technique for bridge construction is economic.

c) Merits of Pseudo Box Bridge Using Inverted-T Girder and Spliced Technique

There are two types of benefit using splice and pseudo box girder. These are

i. *Construction Benefit*

Where scaffolding for long time is not permitted then pseudo Box Bridge and splicing technique can be used for construction of bridges which is less time consuming at site work. That's why less number of workers will be required. Spliced girder segments are smaller than a full girder having a length of 50m. Also handling stress of the inverted-T girder is small than the actual box section, which can be transported easily from the factory to site and also easier to erect to their final location. We can reduce traffic hazards during the construction.

ii. *Structural Benefit*

To tell about the structural benefits about splicing technique at first we can highlight about the section of the girder. For false box technique bending stress is reduced, by the reduction of bending stress the bending moment is also reduced. Reduced bending moment can give reduced section which is lighter. For this reason, deflection due to dead load is small and the live load deflection is reduced by pre-stressing of cross girder.

iii. *Demerits of Pseudo Box Bridge Using Inverted-T Girder and Spliced Technique*

Principle demerits of using continuous girder by inverted-T girder and splicing technique are given below-

- We assumed all supports are not allowed to be settled. This is uncertain and need to be researched more about soil settlement.
- Experienced and skilled workers are needed but not available in our country.
- Analysis should be done carefully to detect the inverted-T section and spliced zone.
- As it is post-tensioned pre-stressing method accuracy must be maintained.

IV. Conclusion

The analysis of 750m continuous girder has been performed for two lanes 15 spans of 50m each. Objective is the beneficial using of pre-cast girder for long span bridges by pre-stressed pseudo Box Bridge using inverted-T girder and splicing technique. This analysis is done only for the vertical loadings. Analysis is fully performed by the STAADpro 2006 software to find out the moment, shear, and deflection of the structure specially the inflection zone for joining the inverted-T girders actually. With some limitations pre-stressed pseudo box using inverted-T girder and splicing technique can be applied in practical field. This technique for bridge and flyover construction is more economic and less time consuming. We hope that for our country pseudo box using inverted-T girder and splicing technique will be applied and practiced. To get the benefits both construction and structural this technique will be helpful. Bangladesh is a land of river, agricultural and flood affected country. Navigation clearance and hydraulic criteria (100year flood discharge) must be counted. That's why this technique should be practiced by the engineers.

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