International Journal of Bridge Engineering (IJBE), Vol. 2, No. 2, (2014), pp. 21-30

RESPONSE OF BOX GIRDER BRIDGE SPANS
Influence Based Moving Load Analysis

G. Venkata Siva Reddy[1], P. Chandan Kumar[2]

[1,2] GIT, Gitam University, Dept. Civil Engineering, Visakhapatnam, India
email: sivareddy6263@gmail.com, pckumar20@gmail.com

ABSTRACT: Recent developments in the field of Bridge engineering, Box Girder Bridges have heightened the need for improving the ability to carry the live load and undertaken as a result of code provisions. This paper deals with the response of Reinforced concrete and Prestressed concrete bridges when subjected to standard moving vehicular loads. Currently length of the span and width of the carriage way are kept constant for the models and analysis is carried out using MIDAS CIVIL software. Influence based moving load analysis**:** Influence lines and Influence surfaces are generated to analyze the response of bridge structure subjected to live loading within designated lanes. BM, SF and Displacements are obtained by placing moving tracer at different positions of the designed lanes throughout the span length. This study makes an attempt to develop efficient geometric models for new constructions, and to provide necessary structural configuration against live load bending moments, shear force and displacements. The determination of absolute maximum live shear and bending moment due to moving concentrated loads on the box girders is discussed.

KEYWORDS: Bridges, Box girders, Bending moments, Displacement, Moving tracer, Shear force.

1 INTRODUCTION
Influence based moving load analysis had important application for the design of bridge super-structures that resist large live loads. Influence lines and Influence surfaces are generated to analyse the response of bridge structure subjected to moving vehicle live loading within designated lanes. The theory is applied to the structures subjected to uniformly distributed load, or a series of concentrated forces developed by the vehicle on the span. It was well known that shear and moment diagrams represent the most descriptive methods for displaying the variation of loads in a member. If a structure is subjected to a live

load or moving load, the variation of shear and bending moment in the member is best described using the influence line. An influence line represents the variation of the reaction, shear, moment or deflection at a specific point in a member as a concentrated force moves over the member.

In this context, this paper explains how different types of box girder bridge decks perform under different standard moving load cases. 70 m continuous span length for RCC & PSC box girders with 12.6 m of top flange width, in which 9.6 m of effective carriage way designed for two lanes and footpaths of 1.5 m on either side are adopted for the analysis purpose. Moving load cases are defined as per Indian Roads Congress (IRC: 6-2000) codal provisions i.e., one lane of 70R loading or two lanes of Class A loading, if the effective width of carriage way is up to 9.6 m. Out of two load cases Class A loading is the heavy loading and all the National Highways built in India should design for this heavy loading. Dimensions of box girders are taken with respect from clause 9.3.2 of IRC: 18-2000. Analysis is carried out at different positions on each key element to produce live bending moments, shear forces and Displacements. The design aspects, detailing of reinforcement, sub-structure details like pier cap, pier and foundation details are excluded from the current study.

2 LITERATURE SURVEY

Fushun LIU et al. [1] deals with New Damage-Locating Method for bridges subjected to a moving load by introducing a new moving load damage-locating indicator (MLDI). From his study a vehicle is modeled as a moving load and the damage is simulated by a reduction of stiffness properties of the elements. His conclusion indicates, the method not only can determine a single damage location accurately, but also can determine multiple damages in a simply supported bridge or in a continuous bridge.

C Adam et al. [2] made studies on Reliable Dynamic analysis of an uncertained composite bridge under traffic loads. According to his studies, the main structure is modeled as a two-layer beam consisting of a steel girder connected elastically to the concrete deck. The governing sixth-order partial differential equation of motion of the homogenized beam is extended to include uncertainty in the mechanical property of the interface. He concluded that the above efficient analysis can be performed without reliable knowledge of the uncertainty of the material parameters by considering structural inherent worst case scenarios.

3 NEED FOR THE STUDY

The need for the present study is to develop efficient, economical and reliable box girder super structure bridge spans under moving loads (live loads) with minimum shear force and bending moments. Two types of box girders are modeled and evaluated its structural performance with respect to member strength. The results obtained from MIDAS CIVIL software for two models at different specified points are correlated with each other and selected an efficient structural member for further design purpose. Moving tracer, moving load analysis give accurate live load distribution of the span at a specified points within the designated lanes.

Table 1: Data for analysis of box girders

type of super structure	rcc & psc box girders		grade of concrete	IS(RC) -M60 (PSC) -M40 (RCC)
clear span length	35 m (2 spans)		span type	Continuous
carriage way with	9.6 m		footpaths width on either side	1.5 m
depth of girder	span/25=2.8 m		length of segment along x-direction	5 m
no. of Segments	14 no's (for pre-cast)		shape	rectangle, trapezoidal
standard loading	class A & 70R loading		standard vehicles	as per IRC: 6-2000
no of lanes	2- lanes		eccentricity of lanes	3.5m on either side
modulus of elasticity, E_s	$2x10^8$ KN/m		tendons/ strands	31# of 12.7 mm diameter
prestressing type	post-tensioned		jacking type	both ends
duct diameter	0.07 m		bond type	bonded
prestressing force	1330000 kN/m		age of concrete at the beginning of shrinkage	3 days
time dependent materials	comp. Strength, creep and shrinkage		poisons ratio	0.2
elastic link	rigid type		supports	fixed, roller
wobble friction factor	0.0066		relaxation coefficient	as per IRC: 18-2000 (normal)

Table 1 represents briefly about the data required for the analysis of a 2-lane continuous reinforced and pre-stressed concrete box girder bridge span when subjected to different standard moving load cases. Dimensional parameters and post-tensioned details are included in the tabular form.

4 MODELLING

Modelling of bridge super structure spans is done using MIDAS CIVIL software. Two different types of concrete box girder bridge super structure spans are modeled and check their structural resistance to each other by moving load analysis.

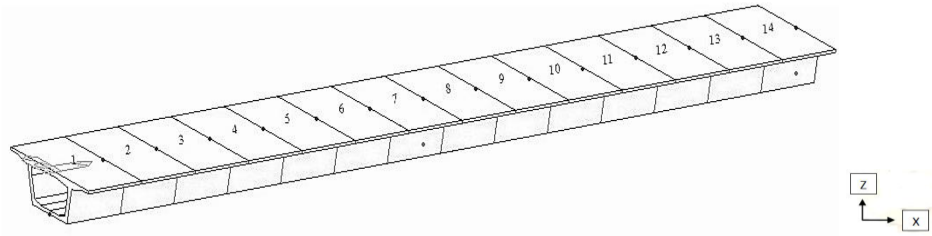


Figure 1. Typical 3D view of 70m continuous single-cell PSC Box Girder Bridge deck

Fig 1 shows typical 3D view of continuous single-cell post-tensioned box girder bridge span with an effective top flange width of 12.6 m and depth 2.8 m. The centre-centre distance between the piers is 35 m (2 spans). The super structure deck consists of 14 individual box segments, each of 5 m along longitudinal direction [x-direction]. The segments are divided into two categories, pier segments and field segments. The segments which directly rest on pier are called pier or anchorage segments which transfer the load centrically through pier and finally to foundation. Anchorage segments had thicker webs when compared to field segments as they carry tendon ducts for post-tensioning. Field segments are the intermediate ones which distribute live load and webs are thinner as they carry only tendons.

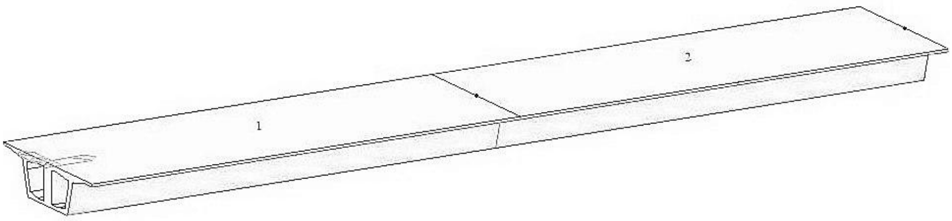


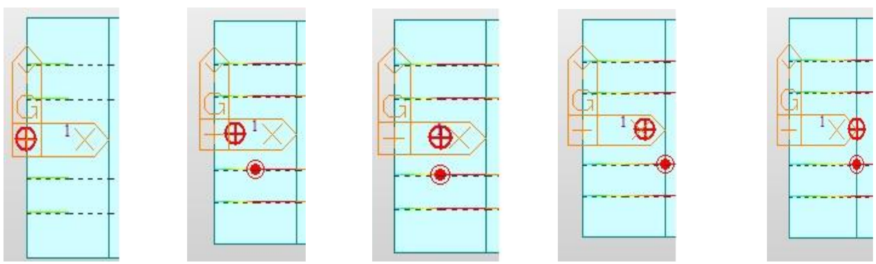
Figure 2. Typical 3D view of 70m continuous RCC Box Girder Bridge deck

Fig 2 shows typical 3D view of continuous RCC girder bridge span with an effective top flange width of 12.6 m and depth 2.8 m. The centre-centre distance between the piers is 35 m (2 spans). The super structure deck consists of 2 box girders, each of 35 m along longitudinal direction [x-direction]. RCC box girder contains an additional web of 0.3m thickness at the centre in order to resist the live loads coming on to the deck. Supports are provided at each end of the girder such that the span is restrained along X and Y-direction and free along Z-direction.

5 ANALYSIS

Fig 1 & 2 Constitute two different types of box girder named as model-A and model-B considered in the analysis purpose. Model (a) is a single-cell trapezoidal PSC box girder. Model (b) is a two-cell trapezoidal RCC box girder bridge deck with an additional intermediate web. Haunches are provided in the inner edges of the cell for smooth distribution of stresses. Model-A explained above is analyzed using influence line method along with the static loads (sw, sidl, prestress and diaphragm loads) using MIDAS CIVIL software. Simultaneously model-B is also analyzed in the same manner expect for pre-stress loads. For each model two moving load cases are developed as case-I & case-II. Case-I indicates that one lane is designed with Class A standard vehicle loading and one lane with 70R loading. Case-II indicates two lanes are designed for Class A loading as per IRC: 6-2000. Design parameters such as bending moment, shear force, reactions are verified as per the values presented in the table 2, 3 & 4.

Analysis is carried out on each model by placing moving tracer at different positions on each key element i.e., at i^{th}, $1/4^{th}$, $1/2^{th}$, $3/4^{th}$ and j^{th} positions.



(a) i^{th} (b) $1/4^{th}$ (c) $1/2^{th}$ (d) $3/4^{th}$ (e) jth

Figure 3. (a), (b), (c), (d) and (e) Different positions of moving tracer for key element-1, model-A

Fig 3 represents different positions of the moving load tracer for key element-1 to generate live shear force, bending moments and displacements. The moving tracer is passed through out the span length from key element 1 to 14. Likewise the same procedure for each key element is repeated for model-B during the analysis.

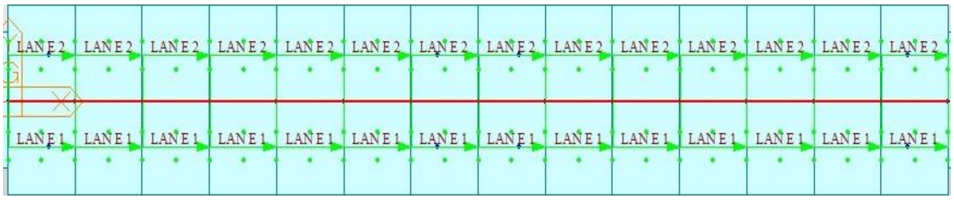


Figure 4. Represents Lane-1 & Lane-2 with an eccentricity of 3.5 m on either side for a 2-lane road bridge

Fig 4: represents lane-1 and lane-2 of the super structure deck with an eccentricity of 3.5m on either side. Each lane is designed for traffic volumes moving in both the directions. Moving load cases are defined for each traffic lane as per the relevant standard codes.

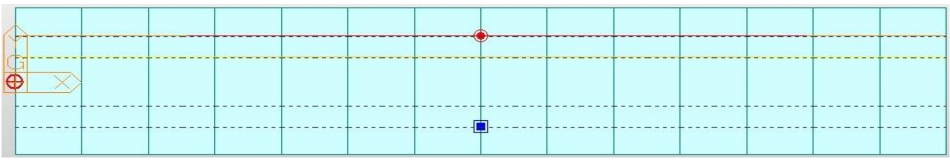


Figure 5. Influence lines for each lane generated for moving load analysis

Fig 5: represents the top view of bridge span showing, two influence lines generated for each designated lane and these lanes are required to generate bending moments, shear forces and displacements under standard moving loads. Influence lines are so for generated to get accurate live load distribution within the lanes.

6 NUMERCAL RESULTS

The results obtained from Midas Civil software for model-A and model-B are defined in the below tabular forms. Maximum bending moments occurred at centre of the span and maximum live shear forces obtained at the supports are taken into account which are further required for the design conditions. Maximum bending moment and shear forces are taken along MZ and FY directions. Maximum displacement is taken along DX, DY and DZ directions and maximum rotational moments along RX, RY and RZ directions.

Table 2. Maximum Bending moments and Shear Forces for different box girder spans

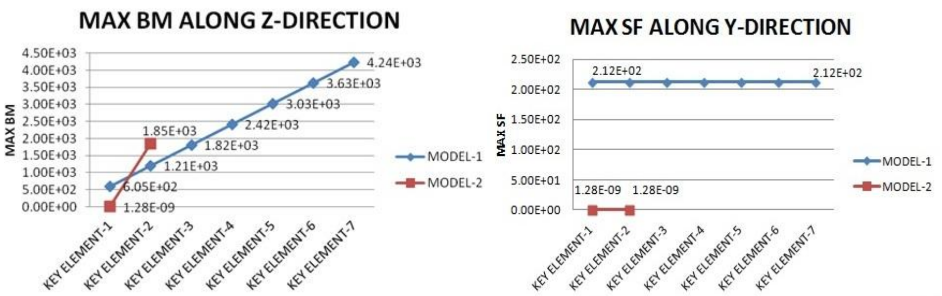
type of model	moving tracer position	direction	max shear force	max bending moment
			KN	KN-M
model-1	end span element-1 (ith)	X	4.3022e-008	2.3423e+002
		Y	1.2100e+002	2.5936e-008
		Z	8.2846e+001	2.8110e-009
	mid span element-7 (jth)	X	4.3004e-008	2.4283e+003
		Y	1.2100e+002	0.0000e+000
		Z	1.0609e+003	4.2351e+003
MODEL-2	end span element-1 (ith)	X	2.5074e-008	4.7536e+001
		Y	2.5458e+001	9.0341e-008
		Z	8.9762e+001	1.2789e-009
	mid span element-2 (ith)	X	7.2267e-010	2.4654e+003
		Y	5.2989e+001	0.0000e+000
		Z	0.0000e+000	1.8546e+003

Table 2 shows maximum bending moments and shear forces along X, Y and Z directions for pre-stressed concrete box girder bridge span and Reinforced concrete bridge span, the forces which are maximum shear forces and maximum bending moments of end span and mid span of different key elements for each model.

Table 3. Maximum Displacements forces and Rotational moments

type of model	moving tracer position	direction	max displacement force	max rotational moment
			KN	KN-M
model-1	end span element-1	X	6.9262e-004	4.5276e-004
		Y	1.3583e-003	1.9537e-004
		Z	1.1835e-011	3.2242e-005
	mid span element-7	X	8.1324e-004	2.9509e-004
		Y	1.8836e-003	6.6040e-005
		Z	3.7576e-004	1.2571e-005
model-2	end span element-1	X	6.5807e-004	2.2107e-004
		Y	1.3396e-003	1.8144e-004
		Z	1.2823e-01	1.0957e-005
	mid span element-2	X	8.3158e-004	5.5312e-005
		Y	3.1212e-004	1.0395e-004
		Z	0.0000e+000	1.4145e-005

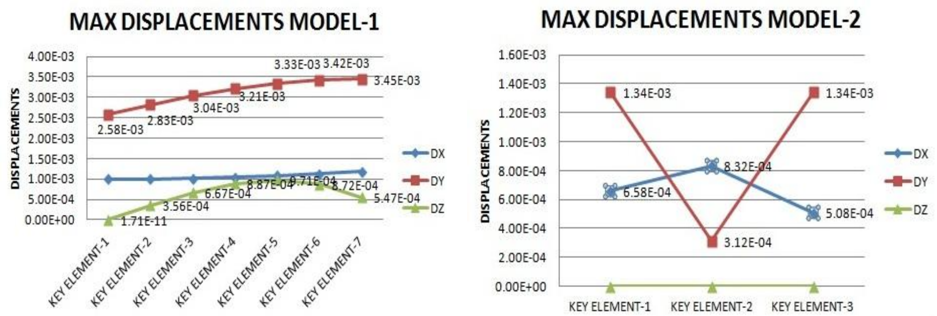
Table 3 shows maximum Displacement forces along DX, DY and DZ and maximum Rotational moments along RX, RY and RZ direction for two different types of box girder bridge spans due to moving tracer. Model-B shows minimum values when compared to model-A.



(a) (b)

Fig 6: (a) represents maximum bending moment along z-direction for key element 1-7 for model-1 and for key elements 1 & 2 for model-2, (b) represents maximum shear force along y-direction for key elements 1-7 for model-1 and for key elements 1 &2 for model-2.

From the above figures we can observe that bending moments and shear forces are minimum for model-2. Hence model-2 is opted in the design point of view.



(a) (b)

Fig 7: (a) represents maximum displacements along DX, DY and DZ direction for model-1 obtained due to moving tracer for key elements 1-7, (b) represents maximum displacements along DX, DY AND DZ direction for model-2 obtained due to moving tracer for key elements 1-3.

From the above figures we observe that displacements are minimum along the three directions for model-2. Hence model-2 is adopted for the following design process.

7 RESULTS AND DISCUSSION

Considering overall bending moments (z-direction), shear forces (y-direction) and displacements (x, y and z directions), model-II is selected from the two models.

In model-II, the vertical load resisting system provided by arrangement of intermediate web (as shown in figure 2) reduces the live shear andbending moments by increasing the structural resistance to the span.

This consideration helps the super structure ability to carry the vehicular live load for particular designated lanes and also increases the safety of the structure in the future traffic volumes.

For model-II the span/depth ratio has been reduced, subsequently decreases the self weight of the super structure and thereby reducing the self weight moments also.

In general considerations, prestressed concrete box girder decks are more economical as the section is reduced when compared to reinforced concrete decks. Selection should be based on the required construction conditions and type of bridge firm.

PSC box girders are preferable when segmental construction is adopted as the total number of the span is divided into independent segments and stressed together.

RCC box girders are preferable when segmental construction is not possible. They are casted by false work construction in the site itself.

8 CONCLUSIONS

Based on the above, the following conclusions can be drawn:

(a) Multiple cell box girders are efficient means to show resisting performance of the structure, and they provide effective means of vehicular live load resisting system.

(b) The overall bending moments, shear forces and displacements can effectively controlled by adopting intermediate webs of required thickness.

(c) The designer has versatility to adopt number of intermediate webs for live load resisting.

(d) Model-II exhibits less bending moments, shear forces and displacements when compared to model-I and is preferable for design considerations.

(e) The comparison shows only the response between the two models under moving loads and how the bending moments and shear forces vary for particular designed lanes.

(f) PSC box girders are mostly designed for light weight transport systems and light rail transport system like metro rails. Whereas RCC structures are designed for heavy loadings.

(g) Moving load analysis gives accurate live load distribution of the spans.

REFERENCES

[1] Fushun LIU, Haujan LI, Guangming YU "New Damage Location for Bridges subjected to a Moving Load", Journal of Ocean University of China, Vol. 6, No. 2, pp. 199-202, 2007.
[2] Adam C, Heuer R, Ziegler F "Reliable Dynamic Analysis of an Uncertain Compound Bridge under Traffic Loads", Springer-verlag, Acta mech 223, pp.1561-1581, 2012.
[3] MIDAS CIVIL "Model Integrated Design and Analysis", a bridge design software 30 days trail version
[4] Freyssinet Prestressing (pre-tensioning and post-tensioning) manual.
[5] IRC: 6-2000, Standard specification and code of practice for road bridges, section-III
[6] IRC: 18-2000, Design criteria for prestressed concrete road bridges.
[7] IRC: 21-2000, Standard specification and code of practice for road bridges, section-III
[8] IRC: SP: 64-2005, Guidelines for design of construction of segmental bridges.
[9] IRC: SP: 67-2005, Guidelines for use of external and unbounded prestressing tendons in bridge structures.
[10] IRC: SP: 71-2006, Guidelines for design and construction of precast pre- tensioned girders for bridges.
[11] IS: 1343-1980, Code of practice for prestressed concrete
[12] IS: 1785-1983, Specification for plain hard-drawn steel wire for prestressed concrete (part 1 cold drawn stress-relieved wire).
[13] IS: 2090-1983 specification for high tensile steel bars used in prestressed concrete.
[14] Oris H. Degenkolb., Concrete Box Girder Bridges, American Concrete Institute
[15] Krishna Raju N., Prestressed Concrete, 3rd Edition, Tata McGraw-Hill Publishing Company Ltd., 1988.
[16] Krishna Raju N., Design of bridges 4th Edition, Oxford & IBH Publishing Co.Pvt.Ltd, New Delhi., 2011.
[17] Johnson Victor D., Essentials of Bridge Engineering 6th Edition, Oxford & IBH Publishing Co.Pvt.Ltd, New Delhi., 2012.
[18] Jagadeesh T R and Jayaram M A., Design of Bridge Structures 2nd Edition, PHI Learning Pvt Ltd., 2004.