Analysis and design of PSC box girder in Bridges using SAP 2000

Kavya S N[1], Rajeshwari B[2], Smithagowda M S[3]

[1]*Assistan Professor, Department of civil Engineering, East West institute of Technology, Bengaluru*
[2]*Assistan Professor, Department of civil Engineering, East West institute of Technology, Bengaluru*
[3]*Assistan Professor, Department of civil Engineering, East West institute of Technology, Bengaluru*

Abstract *Now days the Seismic perfomance of structure very much essential while designing any structure. Analysing the PSC Box girder bridge, staticaly and dynamicaly is the basic aim of this dissertation. Here with and without application of PSC box girder system, the performance of bridge is studied. The study of bridge with bearing between girder and top of pier are included. By applying moving load, vehicle (or) truck load, pre-stress and axial forces, the effects of bridge model is carefully studied. Determining the actual siesmic demand of bridge depends on the behavior of these model and also the importance of bearing between girder and top of pier is taken into consideration. Box girder bridges can have a considerable effect on the behavior of the bridge espcially in the short to medium range of span such as 30m, 45m, 60m. In our project we study the behavior of box girder bridges with respect to support reaction shear force, bending moment, torsion and axial force under standard IRC Class AA loading and the box girder bridges models analysed by finite element method. It is found that the deflection obtained due to various loading conditions and at service condition is well within permissible limits as per IRC. The maximum vertical deflection is found to occur near mid-span location of the girder. The Design of PSC multi-cell box girder performed is found to be an economical design corresponding critical bending moment and shear forces developed due to various load combinations as per IRC specifications in comparison with the design of different span configuration using Box girders with deck slab.*

***Key Words*: Sap-2000, IRC class AA loading, box girder, finite element method**

1. INTRODUCTION

Civil engineers are dealing with bridge engineering from past few centuries in society. For the first time a timber bridge trestle type of crossing over bridges was "Pioneered by a Switz approximately 4000 B.C". A pedestrian stone slab bridge is the oldest stone in working condition it was built across the "Melesee River" 2800 years past. "Rodolphen Perronease he perfected masonry arch bridge with the introduction of slender piers.

"A bridge which the main beams comprise girder is in the form of unoccupied box".

Pre-stressing concrete, Structural Steel (or) a Composite of Steel and Reinforced concrete are the basic building of the box girder bridge. The box girder are usually constructed either in trapezoidal (or) rectangular cross-section used commonly for light rail transport and highway flyover. So as to achieve desired alignment in plan, the box girder is cast in the place of construction. Significant curvature is possible with box girder as it is having high torsional resistance. Internal stress of required magnitude and distribution are introduced in the concrete to counteract external load coming over it. This Pre-stressed concept is exploited use over the world.

The types of pre-stress force apply on concrete are as follows.

(1). Pre-tensioning
(2). Post-tensioning

Pre-tensioning : "Pre-stressed is applied once concrete is toughened". Concrete is cast with the cables with suitable tensile forces required to Pre-stress the cable then is allowed to attain strength.
Post-tensioning : "It is a technique for reinforcing concrete, post-tensioning tendons, that are pre-stressing steel cables inside plastic duct otherwise before the concrete is placed sleeves are located in the form".
Pre-stressed box girder are found not economically for small spans and hence are used for the construction of longer span bridges, the depth of box girder can be reduce effectively comparing to I-girder.

1.1 Categorization of Bridges

Bridges are classified based on form, type of materials used for construction, inter span relationship, so on.

1.1(a) Classification of Bridges Form (or) Type of Superstructure: Slab Bridge, Beam Bridge, Arch Bridge, Truss Bridge, Cable Stayed (or) Suspended Bridge

1.1(b)Categorization of Bridges According to substance of Construction of superstructure: Composite Bridge, Aluminum Bridge,R.C.C Bridge, P.C.C Bridge, Timber Bridge, Concrete Bridgestone Bridge, Steel Bridge

1.1(c) Classification of Bridges According to Inter-Span Relationship: Simply Supported Bridge, Cantilever Bridge, and Continuous Bridge

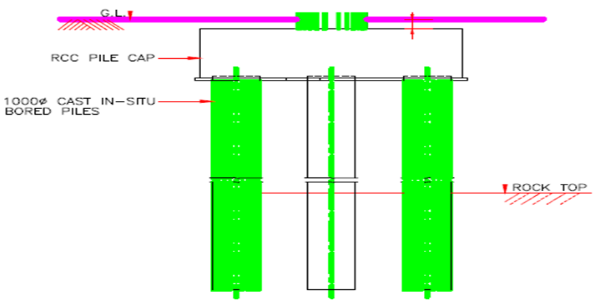
1.1(d) Classification of Bridges According to Function: Aqueduct Bridge, Viaduct Bridge

1.2 Typical Main Parts of Bridge

[1] Substructure

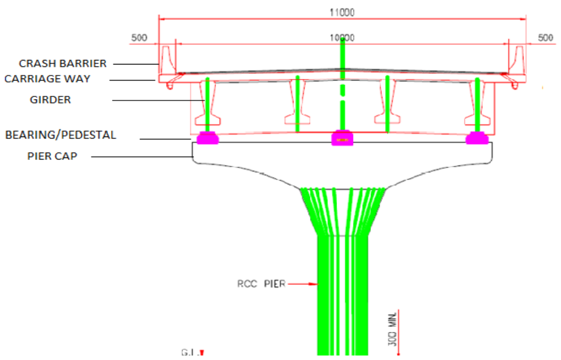
[2] Superstructure

Substructure: The first part is known as substructure, it includes all the work constituting the foundation and the layout on the ground of construction are of a more (or) less vast set of installations, substructure contains two parts Pile Foundation, Pile Cap.



Superstructure: The second part is known as "Superstructure the part of a construction set up above the main construction and that consist of all elements which do not play a part in the mechanical strength of the work". Superstructure contains Pier, Pier Cap, Pedestal/Bearing, Girder, Carriageway and Crash Barrier.

"It is a part of a construction set up above the main construction and consists of all elements which do not play a part in the mechanical strength of the work".



2. LITERATURE REVIEW

Kamel Bezih[1], Alaa Chateauneuf[2], Mahdi Kalla[3], Claude Bacconmet[4] (2015)[1]: Presented the paper regarding the nature of effect of soil-structure-interaction on the reliability of reinforced concrete bridges with the random and non-linear behavior of soil may lead to insufficient reliability level, because it is necessary to take into irregularity of soil properties that can considerably affect the bridge behavior regarding serviceability and ultimate limit states. By the present study investigates the failure probability for existing.

Dr. D. N. Shinde[1] (2015)[3]: In this paper they have analyzed static and dynamic behavior of RC bridges. They have says, we can studied the performance of bridges with and without application of isolation system and it involves the rigid bridge, base-isolated bridge, bridge with bearing between girder and top of pier. They have considered the seismic force carefully on the effect of seismic force on bridges model. They have considered according into behavior of models the actual seismic demand of bridges is find and isolation system is taken into account. In order to reduce the seismic affect the elastomeric bearing and led-rubber isolator is used. They have compared of isolated and without isolated bridge structure is drag it out. They have conducted the response spectrum analysis, time history, moving load analysis, non-linear pushover analysis etc… They conducted for un-isolated bridge structure results the time period is less, frequency is high, inertia force are transmitted only in Z-direction and displacement is less but flexibility is also very less which is not required for bridge structure moments are high, for isolated bridge structure results, the time period is more, frequency is less, beam stresses are low, inertia force are transmitted in all 3-directions and displacement are more compared to un-isolated structure. It's within the limits and structure is flexible and moments are low.

3. METHODOLOGY

Finite Element method is the resourceful method, in which it can contain structures of intricate shapes easily, in boundary condition subdivision of the whole structure into number of small elements can be involved each one of these small elements can be involved each one of these small elements connected to the adjacent element through nodal point. Each element displacement field can be assumed in terms of nodal displacements. The element properties are expressed in terms of matrix, using the application of appropriate variation principle, the governing equation of the structure response can articulated. Thus the final equation which is obtained is purely algebraic and it can also be solved to obtain the response of structure appropriate selection of element. Through finite element method, the suitable subdivision of structure into large number of elements with any desired accuracy can be achieved.

The few methods of analysis of structure these are follows,

1. Analytical method
2. Experimental method
3. Numerical method

Speed results solutions are provided by analytical methods, but here only minor geometries are treated only the ideal structure concept are considered.

Full scale model (or) representatives can be tested by experimental method.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

The analytical method both in term of test facilities, the model, instrumentation and actual test time more cost effective compared to experimental methods.

Numerical approaches require very in adequate restrictive conventions and its give composite geometries, compared to the experimental there are less expensive.

The finite element method is the most resourceful numerical method in the hands of engineers. Analytical method has been adopted for carrying out the analysis of the box girder in the present work. The finite element method to perform the analysis is used basically and the results obtained are more efficient, consistent and effective.

Creating the model using SAP 2000 software,

1). As per IRC codes applying loads to the model.
2).The various stress functions such as bending moment, shear forces, displacement get it from performing the analysis.
3). Extraction of output results from the analysis model.
4). As per IRC standards per forming the design.

4. ANALYSIS RESULTS

4.1. BEHAVIUOR OF BOX GIRDER DUE TO DEAD LOAD

Following are the results which are extracted from the model of box girder of 60m, 80m and 100m span length and effective end to end length of box girder is 65m, 85m and 105m for the dead load combination. Self-weight of the box girder is the dead load and from analysis it is extracted that the maximum moment at center of span which is shown in the table as it is modeled as simply supported case minimum moments will be at support and it is shown in table, for shear force in box girder the maximum shear force will be at support and minimum shear force at middle of span and it is shown in table.

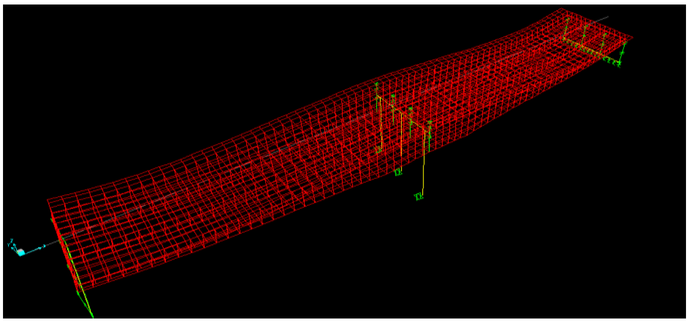


Figure1- Deformation due to DL for 60 m span Bridge

Results for Dead load: Results for axial force (P), Vertical shear (V_2), Horizontal Shear (V_3), Torsion (T), Moment vertical (M_2) and Moment horizontal (M_3) are tabulated for the Dead load in the below Table.

Table 1- Results for Dead load for 60m Span Bridge

Distance	P (Axial force)	V2 (Vertical shear)	V3 (Horizontal Shear)	T (Torsion)	M2 (Moment Vertical)	M3 (Moment Horizontal)
m	KN	KN	KN	KN-m	KN-m	KN-m
0	-1.61E-08	-1851.019	13.13	-838.6827	115.8608	-221.4075
2.77778	-1.61E-08	-1270.075	13.13	-841.7141	79.3892	4011.7799
2.77778	-1.61E-08	-1270.075	13.13	-841.7141	79.3892	4011.7799
5.55556	-1.61E-08	-766.337	13.13	-841.2315	42.9176	6841.9336
5.55556	-1.61E-08	-766.337	13.13	-841.2315	42.9176	6841.9336
8.33333	-1.61E-08	-252.595	13.13	-840.4202	6.4459	8260.1239
8.33333	-1.61E-08	-252.595	13.13	-840.4202	6.4459	8260.1239
11.11111	-1.61E-08	276.151	13.13	-839.271	-30.0257	8231.6174
11.11111	-1.61E-08	276.151	13.13	-839.271	-30.0257	8231.6174
13.88889	-1.62E-08	824.903	13.13	-837.7727	-66.4973	6707.7879

4.2. Deformation due to ML for 60m Bridge

In the live load case we have to also consider the truck load moving on the Bridge deck, for that we have to consider the number of truck vehicles, trend of vehicle and duration of loading on the Bridge deck is as shown in the figure 5.6. For this present work four lane has been provided depending upon the more number of lanes, live load combination has been made as shown in figure.

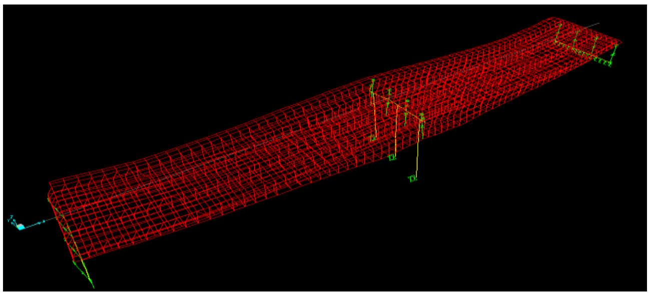


Figure2- Deformation due to ML for 60 m span Bridge

Table 2-Results for Moving load for 60m Span Bridge

Distance	ItemType	P	V2	V3	T	M2	M3
m		KN	KN	KN	KN-m	KN-m	KN-m
0	Max	4.98E-09	50.372	9.054	605.654	-28.4873	162.9858
0	Min	-6.58E-09	-321.183	-8.257	-661.6185	52.9775	-178.1223
2.77778	Max	4.98E-09	50.372	9.054	501.3333	-31.2162	840.6571
2.77778	Min	-6.58E-09	-288.235	-8.257	-631.1835	58.8679	-110.3809
2.77778	Max	4.98E-09	50.372	9.054	477.5305	-31.2162	862.4741
2.77778	Min	-6.58E-09	-272.158	-8.257	-648.1704	58.8679	-110.3809
5.55556	Max	4.97E-09	66.483	9.054	444.9789	-45.9544	1349.0015
5.55556	Min	-6.57E-09	-241.127	-8.257	-674.4129	74.5945	-247.5796
5.55556	Max	4.97E-09	82.668	9.054	439.2015	-45.9544	1366.9039
5.55556	Min	-6.57E-09	-226.271	-8.257	-690.3324	74.5945	-247.5796
8.33333	Max	4.96E-09	113.904	9.054	438.0689	-69.4366	1650.7423
8.33333	Min	-6.55E-09	-198.052	-8.257	-726.9161	90.6772	-387.2911
8.33333	Max	4.96E-09	128.842	9.054	441.9042	-69.4366	1658.8018
8.33333	Min	-6.56E-09	-184.726	-8.257	-741.6276	90.6772	-387.2911
11.11111	Max	4.97E-09	157.194	9.054	455.3562	-94.5859	1775.9727
11.11111	Min	-6.56E-09	-159.672	-8.257	-765.1124	107.0841	-527.113
11.11111	Max	4.97E-09	170.573	9.054	464.7848	-94.5859	1775.1949
11.11111	Min	-6.57E-09	-147.932	-8.257	-773.6854	107.0841	-527.113
13.88889	Max	4.98E-09	195.714	9.054	502.5488	-119.7352	1765.6934
13.88889	Min	-6.59E-09	-125.967	-8.257	-786.5909	123.8269	-667.0346
13.88889	Max	4.99E-09	207.488	9.054	527.9589	-119.7352	1760.7663
13.88889	Min	-6.59E-09	-115.699	-8.257	-790.4136	123.8269	-667.0346
16.66667	Max	5.00E-09	229.514	9.054	573.9281	-144.8845	1637.6927
16.66667	Min	-6.61E-09	-96.491	-8.257	-795.1633	141.5341	-806.9562
16.66667	Max	7.21E-09	239.8	9.054	594.4292	-144.8845	1639.3651
16.66667	Min	-7.87E-09	-87.511	-8.257	-795.2894	141.5341	-806.9562
19.44444	Max	7.21E-09	259.017	9.054	630.8769	-170.0338	1415.2418
19.44444	Min	-7.86E-09	-70.651	-8.257	-793.2343	161.4263	-946.8778
19.44444	Max	7.21E-09	268.009	9.054	646.9298	-170.0338	1425.6321
19.44444	Min	-7.87E-09	-62.722	-8.257	-790.2479	161.4263	-946.8778
22.22222	Max	7.21E-09	284.868	9.054	675.2432	-195.1831	1114.4397
22.22222	Min	-7.86E-09	-47.765	-8.257	-782.4899	183.7596	-1086.7994
22.22222	Max	3.74E-08	292.777	9.054	687.5737	-195.1831	1131.9477
22.22222	Min	-3.22E-08	-40.701	-8.257	-776.6624	183.7596	-1086.7994
25	Max	3.74E-08	307.677	9.054	709.7215	-220.3325	747.3846
25	Min	-3.22E-08	-27.275	-8.257	-763.918	206.6106	-1226.7209
25	Max	3.74E-08	314.734	9.054	719.6299	-220.3325	774.518
25	Min	-3.22E-08	-21.589	-8.257	-756.7402	206.6106	-1226.7209
27.5	Max	3.74E-08	326.829	9.054	736.1846	-242.9668	401.5223
27.5	Min	-3.22E-08	-12.058	-8.257	-743.7748	227.1968	-1352.6504
27.5	Max	3.74E-08	332.589	9.054	743.9872	-242.9668	428.8598
27.5	Min	-3.22E-08	-7.759	-8.257	-737.1789	227.1968	-1352.6504

Results for Moving load: Results for axial force (P), Vertical shear (V_2), Horizontal Shear (V_3), Torsion (T), Moment vertical (M_2) and Moment horizontal (M_3) are tabulated for moving loads in the be

4.3. JOINT DISPLACEMENT OF BOX GIRDER

From the analysis the result obtained for displacement for different load case are tabulated in the table .1 in which the displacement will be always maximum at the center of span so the results are taken at the mid span at length 17.125m where we get maximum deflection and the variation of deflection is represented in the table 5.3 where it shows that the maximum displacement with the blue color and minimum value with the pink color from this color variation we can judge where the maximum displacement is appearing in the box girder in the present model the maximum displacement is at edge of the box girder at the center of span

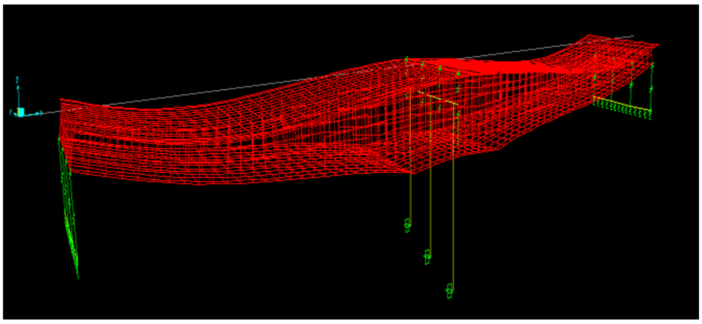


Figure 3-Deformed shape of box girder

4.4 Result comparison for Dynamic load and Truck load:

Moment variation for Dead load:

The below graph shows the variation of bending moment for 30m, 40m and 50m bridge model which shows that the variation of BM is maximum in 50m span bridge and minimum in 30m.

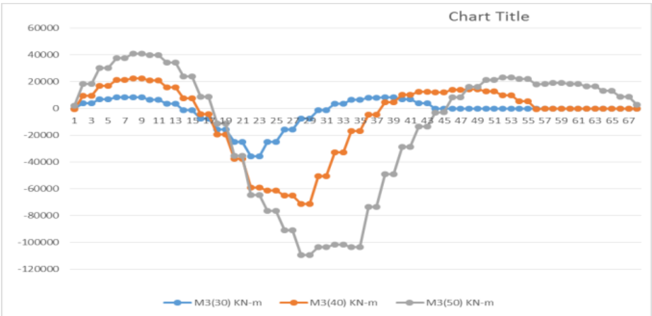


Figure 4-Result comparison for Dynamic load and Truck load

Shear force:

The graph shows shear force variation for different span of bridges. The below graphs include spans of 60m, 80m and 100mbridges. The graphical study of the below graphs shows that the shear force increases linearly with the increase in the span.

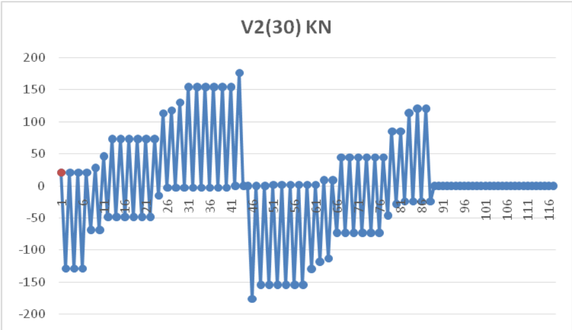


Figure 5- Shear force variation for 60m Bridge

5. CONCLUSIONS

- The Design of PSC multi-cell box girder performed is found to be an economical design corresponding critical bending moment and shear forces developed due to various load combinations as per IRC specifications in comparison with the design of different span configuration using Box girders with deck slab.
- The HDPE pipespipes have been used for cable ducts of PSC box girder modeling. The results obtained in girder with HDPE pipes are found to be more viable since the loss of pre-stress is much less in case of HDPE pipes thereby increasing the stress levels in the concrete sections.
- The stresses that are developed in the box girder at service condition is found to be well within the permissible limits as per IRC specifications and no tension being developed at any cross section in the girder at service condition.
- Finite Element Analysis of Box Girder from SAP-2000 modeler software is found to be more accurate and close to reality in comparison to other analysis methods. The FEA results are in good agreement with the results obtained from other methods.
- It is found that the deflection obtained due to various loading conditions and at service condition is well within permissible limits as per IRC. The maximum vertical deflection is found to occur near mid-span location of the girder.
- The temperature stresses that are developed due to temperature gradient as per IRC have been checked and combined with the final stresses. The maximum final stresses are found to be in good agreement with the allowable values.

- The Model has also been checked for Ultimate moment and Ultimate shear cases separately as per IRC guidelines.

6. REFERENCES

1. *Responses of Oblique Pre-stressed Concrete Box Girder Bridge- Research Journal of Applied Sciences, Engineering and Technology 6(19): 3642-3657- 2013*
2. **Erin Hughs and Rola Idriss -***Live-Load Distribution Factors for Prestressed Concrete,Spread Box-Girder Bridge*- Journal of Bridge Engineering, Vol. 11, No. 5, September 1-2006
3. **Dr. Husain M. Husain and Mohanned I. Mohammed Hussein -** *Finite element analysis of post-tensioned concrete box girders*- **-** Journal of Bridge Engineering (2007)
4. **Ali Fadhil Naser and Wang Zonglin**-*Finite Element and Experimental Analysis and Evaluation of Static and Dynamic* march/April 2005
5. **Dereck J. Hodson, S.M.ASCE, Paul J. Barr, M.ASCE and Marvin W. Halling,** *Live-Load Analysis of Posttensioned Box-Girder Bridges* journal of bridge engineering © asce / july/august 2012 / 651