Parametric Study on Piled-Abutment Post-Tensioned Box Girder Bridge

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Abstract - *A structure built to span any obstacle such a waterbody, valley or road is known as a Bridge. There are many different designs that serve a particular purpose and apply to different situations. Depending on the requirements, the different types of bridges are constructed. We are known to such types like the girder bridges, the slab culverts, the flyovers, the post tensioned deck etc. When it comes to the abutments, maximum of times we plan retaining wall with fixed support at the bottom to hold the earth material from behind it. Exceptional cases arise when the presence of earthen material is under the river or stream. As due to presence of water the soil gets moist and loose, sometimes it may so happen that even with the presence of retaining wall, all the soil may get eroded away causing variation of the strength in superstructure. Therefore, we need to provide piles for the abutment wall support to overcome from such scenarios. Hence this paper deals with the parametric study comprising the difference in the piled abutment and regular abutment. Here the Post-tensioned Box-Girder bridge is modelled and analyzed as per the latest code IRC: 112-2011 in the Csi Bridge Software. The results such as Bending Moments, Shear Forces and Displacements are computed by the software for the two cases. It has been observed that, for the same loading, the piled abutments served the best strength when compared to regular abutment. The Bending Moments are less for piled abutment when compared to the later one. Also, during the flood conditions, piled abutments hold the soil initially by retaining it with the retaining wall, which further are founded by piles deep into the ground, not causing the disturbance or displacements of the superstructure.*

Key Words: Post-Tensioned Box-Girder, Piled Abutment, Bending Moments, Shear Force, Csi Bridge

1.INTRODUCTION

Transportation is a vital factor in the human life today. In order to keep the communication and to satisfy the demands which are not locally available, one has to rely on the transportation to fetch the needs. Hence to overcome the difficulty to travel across the hurdles caused by Rivers, Streams, Valleys etc the construction of Bridge came into the picture. In order to supply safer and larger speed of traffic, the route is made as straight as potential Box girders, have gained wide acceptance in superhighway and bridge systems owing to their structural potency, higher stability, useableness, economy of construction and pleasing aesthetics. A bridge must be suitable for its site and it must be of appropriate scale, it must be designed to be built efficiently and without unnecessary risk of failure, it must be economical and its appearance must be given a high priority. These attributes depend on the quality of the conceptual design. Freyssinet's founder Eugene Freyssinet successfully developed pre-stressed concrete in the 1930s, after recognizing that placing concrete under compression greatly increased its strength. Thereafter, the bridge construction used the Pre-stressed method, giving better strength and efficiency. Cellular box girder bridges decks with multiple cells are being increasingly adopted for urban fly overs & long span bridges in preference to the traditional tee beam & slab bridges decks due to their inherent advantages. Full-height bridge abutments supported on foundations piled through soft clay are frequently exposed to lateral interaction effects associated with soil movement relative to the structure and piles. The study is been done to compare between Piled abutment and Regular Wall abutment for the same application of loads, especially for the river bridges. Here the Modelling of the Bridge is done in Csi Bridge Software.

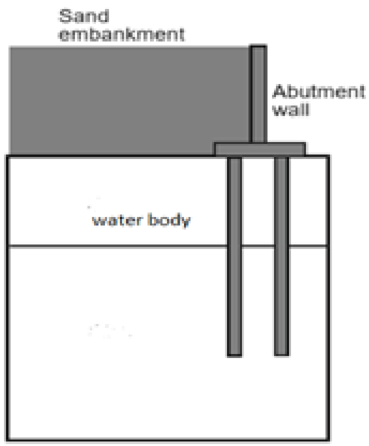

Fig-1: Typical View Of Piled Abutment.

The study carried out by Stewart et.al. [2] concluded that the piles supporting bridge abutments on soft clay may be loaded laterally from horizontal soil movements generated by the approach embankment. Recommendations for the design of pile groups for loading from lateral soil movements were also given. The bridge assessment as suggested by Tasiopoulou et al [3] sheds light to the deformation mechanism, initiated by the riverward displacement of abutment–pile and pier–pile systems along with the spreading ground. An attempt to quantify the contribution of the superstructure (deck–abutment) to the pile–foundation performance is based on the simplified method. Patil Shreyansh and Dr. R. Shreedhar [8] made a comparative study of PSC T-Beam and Box Girder bridge design by both working stress method and limit state method using IRC 18-2000 & IRC 112-2011 respectively. The T-Beam and Box girder were modelled and analyzed using SAP 2000 software. Based on the analysis and results of the analysis they developed efficient L/D ratios for all spans up to 70m designed as per IRC- 112:2000. The work carried out by Ajith R and Dr J.K. Dattatraya [9] on the behavior of Single Celled PSC box girder bridge using SAP 2000. The analysis and design of Prestressed Box Girder Bridges using the code IRC 112-2011 was carried out by Phani Kumar.Ch, S.V. V. K. Babu and D. Aditya Sai Ram [10]. The Limit State design governed by IRC:112 consumes less steel when compared to the Working Stress design prescribed by the older codes, moreover it is desirable change grade of steel rather increasing grade of concrete for more %p steel difference. Rohit M and Dr. J. Jegan[13] worked on the Transverse Analysis of PSC Box Girder Bridge. Here they analyzed the bridge for Moving Load analysis as per IRC: 6 recommendations. The analysis of the PSC Box girder Bridge was performed by Prajwal Raj and Mr. Vasantha. D[14] using CSi Bridge software. Here the comparison was made based on the Indian Standards and American Standards of Loadings. Mayank Chourasia and Dr. Saleem Akhtar[15] worked on the parametric study on two different cross-sections of box-girder for same loading conditions to find the most economical cross-section. The box girder was subjected to IRC Class AA loading. IRC: 18-2000 was used for analysis. The objectives of the present study is to analyze a bridge of 100m total width bridge using CSi Bridge software and to understand the behavior of a piled abutment bridges as compared to a regular bridge. Also, the study of pile bending moments and Shear Forces was made and was observed to be less than for the equivalent prototype.

2. METHODOLOGY

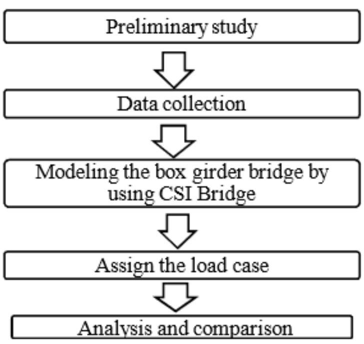

Fig-2: Step by Step Procedure adopted in Software

2.1 Description of the Model

A Box Girder is chosen as the deck of the bridge, reason being that they are more suitable for larger spans and wider decks. They are elegant and slender. Economy and aesthetics further lead to evolution of cantilevers in top flanges and inclined webs in external cells of box girder.

Data:

Type of support:- simply supported
Length:- 50 m
Carriageway width:- 7.5m
Foot path width:- 1.25m
Segmental width :- 10m
Load type :- IRC class AA loading
Concrete grade: M60
Number of Cells: 4 (four)
Bottom & Top Slab thickness = 300 mm
External & Internal wall thickness = 300 mm
Total width = 10m Road
Width of Carriage way = 7.5m
Wearing coat = 80mm
Cross-sectional Area = 1.62 m^2

Tendon Properties:

Pre-stressing Strand: ϕ15.2 mm (0.6"strand)
Yield Strength: f_{py} = 1.56906 X 10^6 kN/m^2
Ultimate Strength: f_{pu} = 1.86326 X 10^6 kN/m^2
Cross Sectional area of each tendon = 0.0037449 m^2
Elastic modulus: Eps = 2 X 10^8 kN/m^2
Jacking Stress: f_{pj} = 0.7fpu = 1330 N/mm^2
Curvature friction factor: μ = 0.3 /rad
Wobble friction factor: k = 0.0066 /m
Slip of anchorage: s = 6 mm

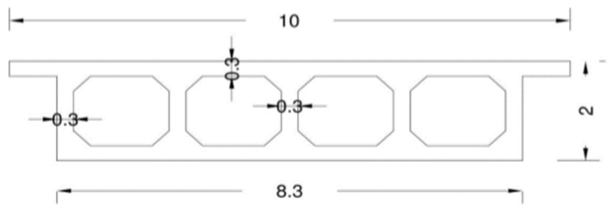

Fig-3: Cross-sectional details of 4 celled Concrete Box Girder (all dimensions in meter)

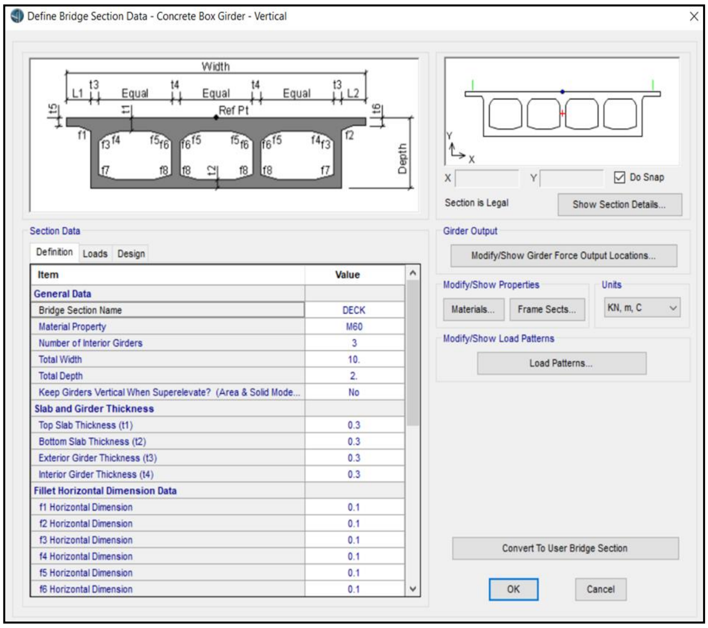

Fig-4: Modelling of Deck in the software

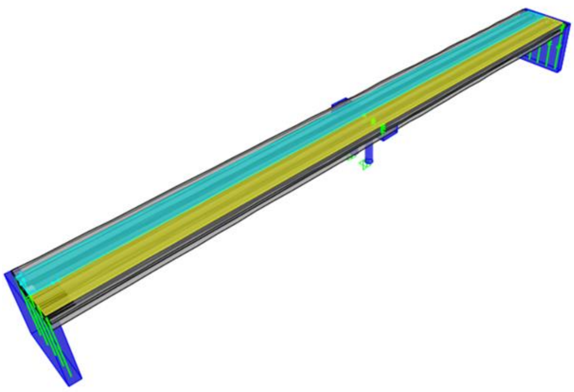

Fig-5: 3D View of the bridge

2.2 Analysis

In this case, as per IRC: 112-2011 loading, class AA tracked or 3 class A whichever is maximum, will govern the live loading, once all loading is done analysis proceeds as per standard practice.

Load Combinations used:

DL+P+ML(A)
DL+P+ML(AA)
DL+P+1.5ML(A)
DL+P+1.5ML(AA)
1.35DL+P+1.5ML(A)
1.3DL+P+1.5ML(AA)

Where DL= Dead Load P= Prestress Load ML= Moving Load

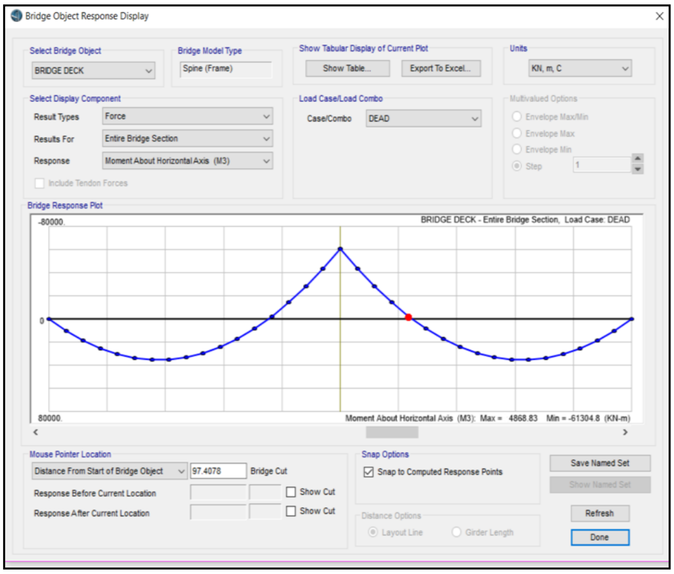

Fig-6: Box Girder Analysis in software

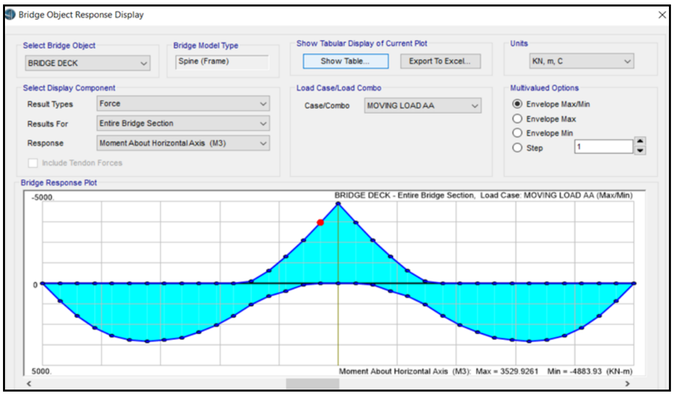

Fig-7: Class AA tracked loading

Table-1: Forces Computed for the Deck

Bending Moments and Shear Forces on the Deck				
Bending Moments (Outer web Girder)			Shear Forces (Inner Girder)	
	At Mid Span Section (kNm)	At Mid Support Section (kNm)	At Mid Support Section (kN)	
D.L	7526	13250	D.L	1314
M.L	4298	1986	M.L	371
Total working	11824	15236	Total working	1685
Ultimate	22035	24840	Ultimate	2898.5

The above values are obtained by calculating the Bending moments and shear forces at the girders by applying the factors of safety for the ultimate case. Ultimate case being as 1.35DL+1.5ML.

The results obtained for the deck for the ultimate load case as shown below:

Table- 2: For load case 1.35DL+P+1.5ML(A)

Distance	P	V2 (max)	V3	T	M2	M3 (max)
m	kN	kN	kN	kNm	kNm	kNm
10	449.68	969.313	3.18	132.94	23.64	0
20	456.71	773.94	12.8	469.72	0.693	4868
30	453.09	691.87	31.6	516.4	56.9	8956.8
40	455.09	453.79	56.2	380.4	85.86	12569.96
50	455057	375.93	12.4	241.37	88.2	-10569.9
60	458039	126.88	37.1	96.95	170.3	8965
70	461.44	55.6	9.88	67.5	183.8	13256
80	463.08	139.16	-29.9	8.4	278.44	14269.2
90	465.49	206.03	-35.6	145.92	341	7296.56
100	471.21	271.17	183.41	116.32	350.66	0

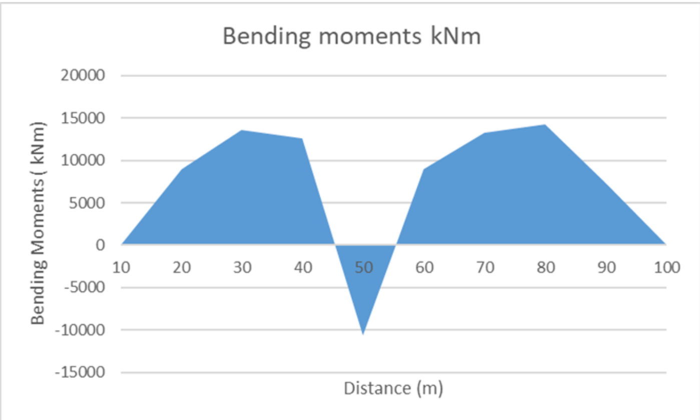

Fig-8 Bending moments along the length of the deck

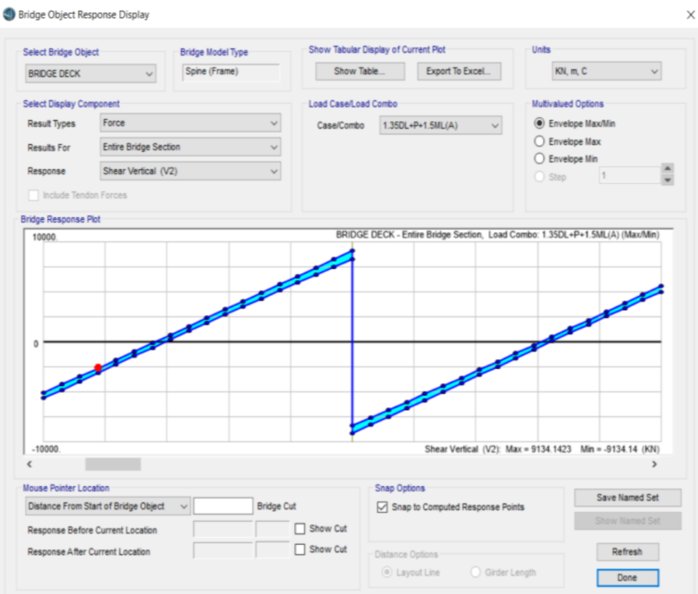

Fig-9 Shear Forces along the length of the deck

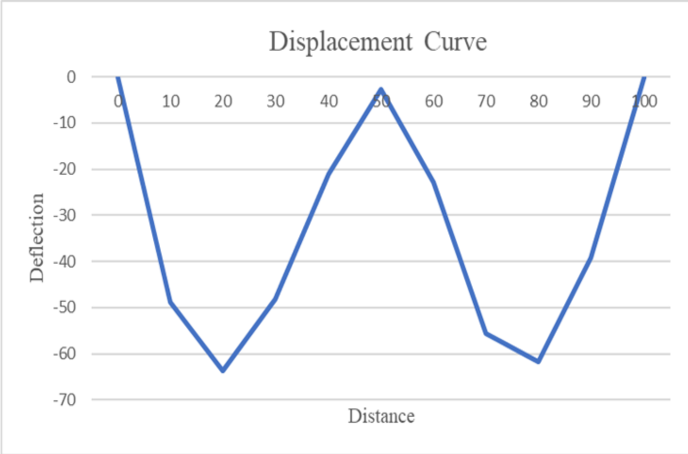

Fig-10: Displacement along the length of deck

The base reactions at the support of abutment wall abstracted from the software are given in the following table:

Table- 2: Base Reactions for the abutment wall

OutputCase	CaseType	StepType	GlobalFZ	GlobalMX	GlobalMY
Text	Text	Text	KN	KN-m	KN-m
1.35DL+P+1.5ML(AA)	Combination	Max	390.2603	-9.606	-1951.27
1.35DL+P+1.5ML(AA)	Combination	Min	390.2603	-9.606	-1951.27
1.35DL+P+1.5ML(A)	Combination	Max	398.8068	1443.923	-1951.27
1.35DL+P+1.5ML(A)	Combination	Min	390.2603	-1537.6	-2024.54
DL+P+1.5ML(AA)	Combination	Max	289.0817	-7.1156	-1445.39
DL+P+1.5ML(AA)	Combination	Min	289.0817	-7.1156	-1445.39
DL+P+1.5ML(A)	Combination	Max	297.6282	1446.414	-1445.39
DL+P+1.5ML(A)	Combination	Min	289.0817	-1535.11	-1518.65
DL+P+ML(AA)	Combination	Max	289.0817	-7.1156	-1445.39
DL+P+ML(AA)	Combination	Min	289.0817	-7.1156	-1445.39
DL+P+ML(A)	Combination	Max	294.7794	961.9041	-1445.39
DL+P+ML(A)	Combination	Min	289.0817	-1025.78	-1494.23
1.35DL+1.5ML(AA)	Combination	Max	390.2603	-9.606	-1951.27
1.35DL+1.5ML(AA)	Combination	Min	390.2603	-9.606	-1951.27
1.35DL+1.5ML(A)	Combination	Max	398.8068	1443.923	-1951.27
1.35DL+1.5ML(A)	Combination	Min	390.2603	-1537.6	-2024.54

2.3 Results for Piled Abutment:

Full-height piled bridge abutments constructed on soft clay are prone to lateral soil structure interaction effects resulting from placement of the retained parallel, and associated deformation of the underlying soil. The interaction increases lateral structural loading and displacement, and hence may result in unserviceable behavior of the abutment or bridge deck.

When the abutment wall was provided with a group of piles of height 10m for the same deck the following results were obtained. The Bending moments and Shear Forces of the pile along its length are as shown in the following graphs:

As the length increases down the ground, it is observed that the bending moment goes on decreasing and finally reaching zero, indicating that the pile is fixed to the ground.

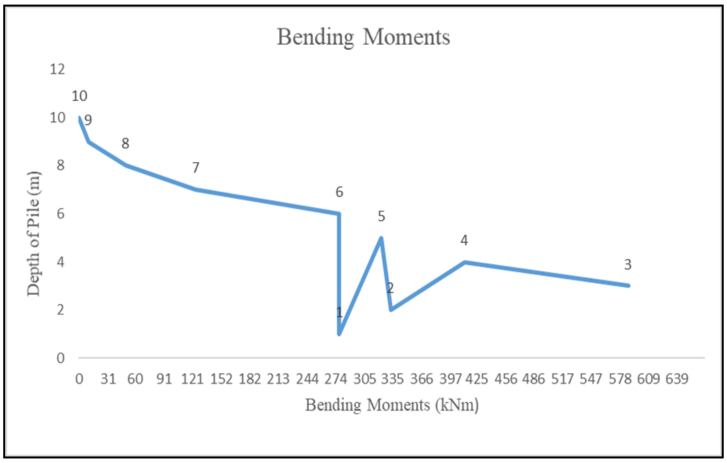

Fig-11: Bending moments of the pile beneath the abutment wall

Shear Forces along the length of pile are as shown below, it is observed that the shear force goes on increasing and becomes maximum at the support.

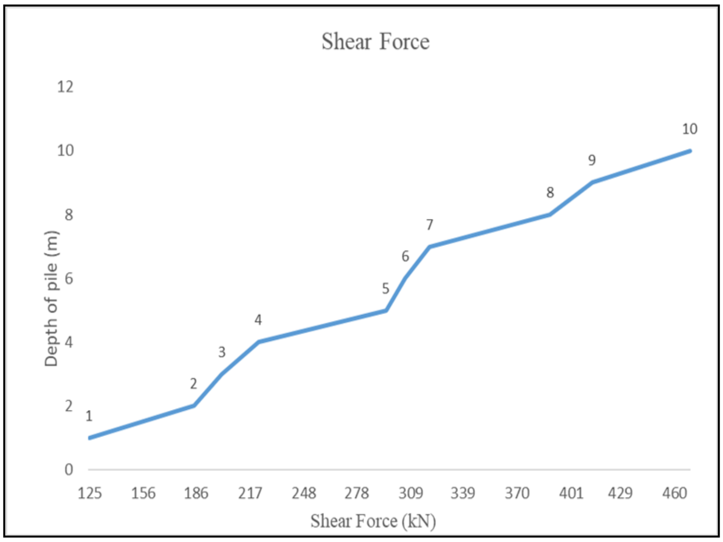

Fig-12: Shear forces along the length of the pile

Now, as per the objective of this paper let us do the comparison between the abutment wall reactions with that of piled abutment. To check the superiority of existing in the river, let us consider the maximum amount of bending moments and shear forces coming on to each.

The following bar graphs plots gives the clear picture as to which produces more bending and which has the maximum shear force.

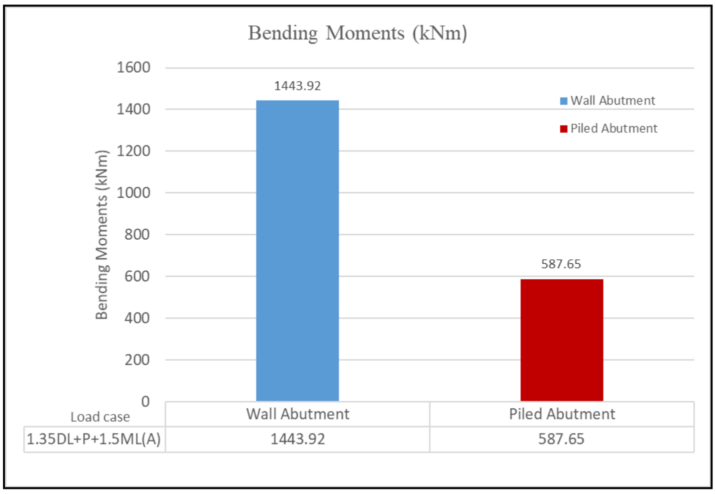

Fig-13: Comparison of Maximum Bending Moments produced by Wall Abutment and Piled Abutment for the Same Deck

It is observed that the bending moment produced due to piled abutment is much less when compared to the regular wall abutment. Lesser risk of deflection wen the piles are been deepened into the soil.

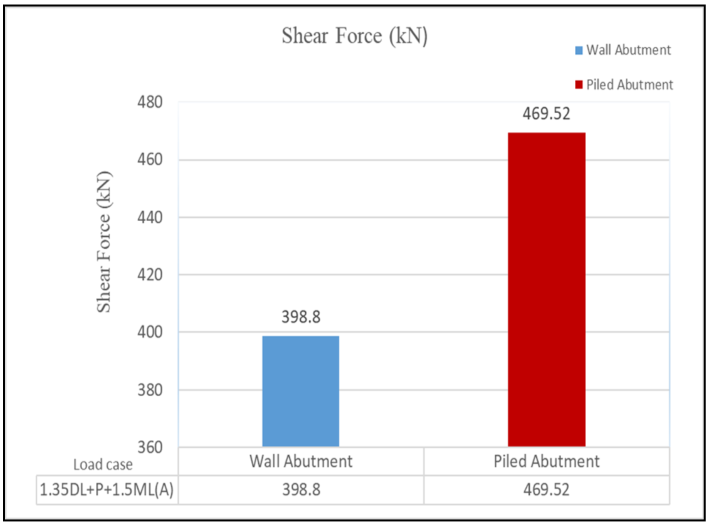

Fig-14: Comparison of Maximum Shear Force produced by Wall Abutment and Piled Abutment for the Same Deck

It is observed that the piled abutment gives more Shear force as compared to the regular Wall Abutment. Hence showing to counter with larger forces by providing greater resistance than the abutment wall.

3. CONCLUSIONS

The following were conclusions drawn from the wok:
It is found that the deflection obtained due to various loading conditions is well within permissible limits as per IRC. The maximum vertical

- deflection is found to occur near mid-span location of the girder around 61.8mm
- New code (IRC:112) requires increased cover for pre tensioned strands as well as post tensioned ducts, which will lead to increased thickness of webs and deck slab / soffit slabs for PSC girders / PSC box girder bridges.
- Under the live load analysis, between IRC Class AA tracked and Class A, Class A is found to be more critical.
- For the same loading, the values obtained for Bending Moments and Shear forces for the two different types of abutments are different.
- The values of Bending moment obtained for piled abutment are much lesser when compared to the values of Bending moments obtained by the abutment wall.
- The values of Shear Forces obtained for piled abutment are more when compared to the values of Shear Forces obtained by the abutment wall, hence providing greater resistance than that of the abutment wall.
- The lateral thrust on the piles, and particularly on the rear row of piles, because the soil had an extra degree of freedom allowing movement of soil vertically upwards under the pile cap. Consequently the pile bending moments and displacements would be less than for the equivalent prototype.
- Piled bridge abutment constructed on soft clay show very good correspondence when compared to the retaining wall with fixed support specially in the case where it has to account for a river bridge where the soil beneath is moist and loose.
- The lateral load pressure of the soil can be also easily sustained by the piles under the bridge and traverse the load to the bottom support of the pile.
- Especially during the flood conditions, the retaining wall with the fixed support may likely be susceptible for the overturning, which can be easily compensated with respect to the piled support below the wall abutments.
- Post tensioned bridges are well known for their better stability and performance.

4. SCOPE FOR FURTHER STUDY

1. The further study can be extended to study the Effect of the additional kinematic constraint at the top of the piles, attributed with the axially stiff deck, to that with lateral spreading of piles and its resistance.
2. It can also be used to study the Pile-Soil Interaction.
3. Construction of piled abutments where it is not possible to construct retaining wall abutment.
4. An attempt to quantify the contribution of the superstructure (deck–abutment) to the pile–foundation performance.

REFERENCES

[1] E. A. ELLIS and S. M. SPRINGMAN, “Full-height piled bridge abutments constructed on soft clay” (2001). Geotechnique 51, No. 1,Journal of Bridge Engineering, 3-14.
[2] Stewart, D. P., Jewell, R. J. & Randolph, M. F., “Design of piled bridge abutments on soft clay for loading from lateral soil movements”, (1994). Geotechnique 44, Journal of Bridge Engineering, No. 2, 277-296
[3] P. Tasiopoulou, E. Smyrou, “Bridge pile abutment deck interaction in laterally spreading ground”, 15 WCEE, Lisboa 2012, pg. 1-9.
[4] J. Bauer, H.-G. Kempfert & O. Reul, “Lateral pressure on piles due to horizontal soil movement - 1g model tests on single piles and pile rows”, the 8th International Conference on Physical Modelling in Geotechnics 2014 (ICPMG 2014), Perth, Australia,14*17 January 2014.
[5] D,P. Stewart, R.J. Jewell and M.F. Randelph, “Numerical Modelling Of Piled Bridge Abutments On Soft Ground”, 1993 Elsevier Science Publishers Ltd, England, Pg. 1-26.
[6] Sami Arsoy, J. M. Duncan, and R. M. Barker, “Performance of Piles Supporting Integral Bridges”, Transportation Research Record 1808 Paper No. 02-2626.
[7] Bo Li, Kaiming Bi, Nawawi Chouw, John W Butterworth, Hong Hao, “Effect of Abutment Excitation on Bridge Pounding”, Engineering Structures 54(2013) pg. no. 57-68.
[8] Patil Shreyansh and Dr. R. Shreedhar, “ Comparative Study of PSC Box Girder Bridge Design using IRC 112-2011 and IRC 18-2000”(2016), i-manager’s Journal on Structural Engineering, Vol 5 No.2 , pg. 1-7.
[9] Ajith R and Dr. J. K. Dattatraya, “Study on the Structural Behavior and Design of a Typical Single Cell Post Tensioned Concrete Box Girder Bridge”, June 2015, Journal of Civil Engineering and Environmental Technology, Volume 2, Number 11, pg. 1 – 6.
[10] Phani Kumar.Ch, S.V. V. K. Babu and D. Aditya Sai Ram, “Analysis and Design of Prestressed Box Girder Bridge by IRC: 112-2011”(2016), International Journal of Constructive Research in Civil Engineering (IJCRCE), Volume 2, Issue 2, ISSN 2454-8693, Pg. 1-10.
[11] Shivanand Tenagi and Dr. R.Shreedhar, “Comparative study of T-beam bridge longitudinal girder design using IRC 112:2011 and IRC 21:2000”(2015), International Journal of Scientific & Engineering Research, Volume 6, Issue 8, ISSN 2229-5518, pg. 1807- 1815.
[12] G. Venkata Siva Reddy and P. Chandan Kumar, “Response Of Box Girder Bridge Spans Influence

Based Moving Load Analysis"(2014), International Journal of Bridge Engineering (IJBE), Vol. 2, No. 2, pg. 21-30.
[13] Rohit M and Dr. J. Jegan, "Transverse Analysis on PSC Box Girder Bridge" (2017), International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 5, ISSN(Online) : 2319-87, pg. 8031-8037.
[14] Prajwal Raj, Mr. Vasantha. D, "Structural Behavior Of Box Girder Bridge Using Csi Bridge" (2015), International Research Journal of Engineering and Technology (IRJET), Vol No. 04 Issue No.04, e-ISSN: 2395 -0056, pg. 2444-2448.
[15] Mayank Chourasia and Dr. Saleem Akhtar, "Design and Analysis of Prestressed Concrete Box Girder by Finite Element Method (4 Cells & 1 Cell), (2015), International Journal of Civil and Structural Engineering Research, Vol. 3, Issue 1, ISSN 2348-7607 (Online), pg. 413-421.
[16] IRC : 112-2011, "standard specifications and code of practice for concrete Road Bridges (pre-stressed concrete and reinforced concrete)," Indian Road Congress, New Delhi, India-2011.

BIOGRAPHIES

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