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

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Abstract - A structure built to span any obstacle such as 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.
2. METHODOLOGY

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 m²

Tendon Properties:

- Pre-stressing Strand: φ15.2 mm (0.6”strand)
- Yield Strength: \( f_{py} = 1.56906 \times 10^6 \text{kN/m}^2 \)
- Ultimate Strength: \( f_{pu} = 1.86326 \times 10^6 \text{kN/m}^2 \)
- Cross Sectional area of each tendon = 0.0037449 m²
- Elastic modulus: \( E_{ps} = 2 \times 10^6 \text{kN/m}^2 \)
- Jacking Stress: \( f_{pj} = 0.7f_{pu} = 1330 \text{N/mm}^2 \)
- Curvature friction factor: \( \mu = 0.3 / \text{rad} \)
- Wobble friction factor: \( k = 0.0066 / \text{m} \)
- Slip of anchorage: \( s = 6 \text{ mm} \)

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

**Fig-2: Step by Step Procedure adopted in Software**
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(AA)

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

<table>
<thead>
<tr>
<th>Bending Moments and Shear Forces on the Deck</th>
<th>Shear Forces (Inner Girder)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At Mid Span Section</strong> (kNm)</td>
<td><strong>At Mid Support Section</strong> (kNm)</td>
</tr>
<tr>
<td>DL</td>
<td>7526</td>
</tr>
<tr>
<td>M.L</td>
<td>4298</td>
</tr>
<tr>
<td>Total working</td>
<td>11824</td>
</tr>
<tr>
<td>Ultimate</td>
<td>22035</td>
</tr>
</tbody>
</table>

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)**

<table>
<thead>
<tr>
<th>Distance</th>
<th>P</th>
<th>V2 (max)</th>
<th>V3</th>
<th>T</th>
<th>M2</th>
<th>M3 (max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>kN</td>
<td>kN</td>
<td>kNm</td>
<td>kNm</td>
<td>kNm</td>
<td>kNm</td>
</tr>
<tr>
<td>10</td>
<td>449.68</td>
<td>969.313</td>
<td>3.18</td>
<td>132.94</td>
<td>23.64</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>456.71</td>
<td>773.94</td>
<td>12.8</td>
<td>469.72</td>
<td>0.93</td>
<td>4868</td>
</tr>
<tr>
<td>30</td>
<td>453.09</td>
<td>691.87</td>
<td>31.6</td>
<td>516.4</td>
<td>56.9</td>
<td>8956.8</td>
</tr>
<tr>
<td>40</td>
<td>455.09</td>
<td>453.79</td>
<td>56.2</td>
<td>380.4</td>
<td>85.8</td>
<td>12569.96</td>
</tr>
<tr>
<td>50</td>
<td>455057</td>
<td>375.93</td>
<td>12.4</td>
<td>241.37</td>
<td>88.2</td>
<td>-10569.9</td>
</tr>
<tr>
<td>60</td>
<td>458039</td>
<td>126.88</td>
<td>37.1</td>
<td>96.95</td>
<td>170.3</td>
<td>8965</td>
</tr>
<tr>
<td>70</td>
<td>461.44</td>
<td>55.6</td>
<td>9.88</td>
<td>67.5</td>
<td>183.8</td>
<td>13256</td>
</tr>
<tr>
<td>80</td>
<td>463.98</td>
<td>139.16</td>
<td>-29.9</td>
<td>8.4</td>
<td>278.44</td>
<td>14629.2</td>
</tr>
<tr>
<td>90</td>
<td>463.49</td>
<td>206.03</td>
<td>-35.6</td>
<td>145.92</td>
<td>341</td>
<td>7296.56</td>
</tr>
<tr>
<td>100</td>
<td>471.21</td>
<td>271.17</td>
<td>183.41</td>
<td>116.32</td>
<td>350.66</td>
<td>0</td>
</tr>
</tbody>
</table>

**Fig-8 Bending moments along the length of the deck**

**Fig-9 Shear Forces along the length of the 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**

<table>
<thead>
<tr>
<th>OutputCase</th>
<th>CaseType</th>
<th>StepType</th>
<th>GlobalFZ</th>
<th>GlobalMX</th>
<th>GlobalMY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.35DL+P+1.5ML(A)</td>
<td>Combination</td>
<td>Max</td>
<td>390.2603</td>
<td>-9.606</td>
<td>-1951.27</td>
</tr>
<tr>
<td>1.35DL+P+1.5ML(A)</td>
<td>Combination</td>
<td>Min</td>
<td>390.2603</td>
<td>-9.606</td>
<td>-1951.27</td>
</tr>
<tr>
<td>1.35DL+P+1.5ML(A)</td>
<td>Combination</td>
<td>Max</td>
<td>398.8068</td>
<td>1443.923</td>
<td>-1951.27</td>
</tr>
<tr>
<td>1.35DL+P+1.5ML(A)</td>
<td>Combination</td>
<td>Min</td>
<td>390.2603</td>
<td>-1537.6</td>
<td>-2024.54</td>
</tr>
<tr>
<td>DL+P1.5ML(A)</td>
<td>Combination</td>
<td>Max</td>
<td>289.0817</td>
<td>-7.1156</td>
<td>-1445.39</td>
</tr>
<tr>
<td>DL+P1.5ML(A)</td>
<td>Combination</td>
<td>Min</td>
<td>289.0817</td>
<td>-7.1156</td>
<td>-1445.39</td>
</tr>
<tr>
<td>DL+P1.5ML(A)</td>
<td>Combination</td>
<td>Max</td>
<td>297.6282</td>
<td>1446.414</td>
<td>-1445.39</td>
</tr>
<tr>
<td>DL+P1.5ML(A)</td>
<td>Combination</td>
<td>Min</td>
<td>289.0817</td>
<td>-1535.11</td>
<td>-1518.65</td>
</tr>
<tr>
<td>DL+P1.5ML(A)</td>
<td>Combination</td>
<td>Max</td>
<td>289.0817</td>
<td>-7.1156</td>
<td>-1445.39</td>
</tr>
<tr>
<td>DL+P1.5ML(A)</td>
<td>Combination</td>
<td>Min</td>
<td>289.0817</td>
<td>-7.1156</td>
<td>-1445.39</td>
</tr>
<tr>
<td>DL+P1.5ML(A)</td>
<td>Combination</td>
<td>Max</td>
<td>294.7794</td>
<td>961.9041</td>
<td>-1445.39</td>
</tr>
<tr>
<td>DL+P1.5ML(A)</td>
<td>Combination</td>
<td>Min</td>
<td>289.0817</td>
<td>-1025.78</td>
<td>-1494.23</td>
</tr>
<tr>
<td>1.35DL+1.5ML(A)</td>
<td>Combination</td>
<td>Max</td>
<td>390.2603</td>
<td>-9.606</td>
<td>-1951.27</td>
</tr>
<tr>
<td>1.35DL+1.5ML(A)</td>
<td>Combination</td>
<td>Min</td>
<td>390.2603</td>
<td>-9.606</td>
<td>-1951.27</td>
</tr>
<tr>
<td>1.35DL+1.5ML(A)</td>
<td>Combination</td>
<td>Max</td>
<td>398.8068</td>
<td>1443.923</td>
<td>-1951.27</td>
</tr>
</tbody>
</table>

**Fig-10: Displacement along the length of deck**

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](image)

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](image)

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](image)

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 when 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](image)

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 work:

- 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 prestressed 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


[12] G. Venkata Siva Reddy and P. Chandan Kumar, "Response Of Box Girder Bridge Spans Influence


BIOGRAPHIES

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