COMPARISON OF HIGH SPEED RAILWAY BRIDGE FOUNDATION DESIGN

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ABSTRACT

This paper discusses the design and analysis of bridge foundation subjected to load of train with three codes, namely AASHTO code, British Standard BS Code 8004 (1986), and Chinese code (TB10002.5-2005).The study focused on the design and analysis of bridge's foundation manually with the three codes and found which code is better for design and controls the problem of high settlement due to the applied loads. The results showed the Chinese codes are costly that the number of reinforcement bars in the pile cap and piles is more than those with AASHTO code and BS code with the same dimensions. Settlement of the bridge was calculated depending on the data collected from the project site. The vertical ultimate bearing capacity of single pile for three codes was also studied. By using the two-dimensional Plaxis program and other programs like SAP2000 14 and PROKON many other parameters were also calculated. The maximum values of the vertical displacement were close to the calculated ones. The results indicate that the AASHTO code was economic and safer in the bearing capacity of single pile.

The other purpose of this project is to study the pier on the basis of the design of the pile foundation. There is a 32m simply supported beam of box section on top of the structure. The pier of bridge is round-type. The main component of the design is to calculate pile foundation and the settlement. According to the related data, we choose 1.0m in diameter bored pile of 48m. The pile is laid in the rectangular pile cap. The dimension of the cap is 12m×9m. Because of the interaction factors of pile groups, we must check the load-bearing capacity of simple pile, the punching resistance of pile cap, the shear strength of pile cap, and the part in bending of pile cap, all of them are very important to the structure stability. Also, checking soft sub-bearing capacity is necessary under the pile foundation. This project provides a deeper analysis and comparison about pile foundation design schemes. First, here are brief instructions of the construction situation about thebridge. With the actual construction geological features and the upper load on thebridge, this project analyzes the bearing capacity and settlement of single pile. In the paper, the Equivalent Pier Method is used to calculate and analyze settlements of the piles.

1. INTRODUCTION

In Iraq,the earthquake situation has not been considered in design of bridge from many years ago. Currently in our code of practice BS 5400, there is no rule on earthquake design consideration for bridge structure. Even though our country does not have earthquake very frequently, we must be aware that our neighboring countries such as Iran is located in an active earthquake prone region. Therefore, we must take into consideration the potential impacts of earthquakes in our neighboring countries in design of our structures, especially bridges. Even though our bridge structure might just get small vibration due to earthquake from our near region country, it may also contribute to some side effect in long term period if it happened for many times. This situation might cause cracking and collapse of our bridge. So,in solving this problem we need a code of practice that considered earthquake loading in design process.

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2. METHODS

In this research, we try to compare two codes of practice AASHTO-ACI and BS 5400 for bridge design to resist against seismic loading. The design of a highway bridge, like most other civil engineering project, is dependent on certain standards and criteria. Naturally, the critical importance of highway bridges in a modern transportation system would imply a set of rigorous design specification to ensure the safety and overall quality of the constructed project**.**

Most bridge engineers in many countries such as Malaysia are using BS 5400 code for guideline in design bridge project. This is because bridge engineers in those countries got their basic knowledge or education from European countries like United Kingdomand others countries that use BS 5400 as a code of practice. Even though they already knew that BS 5400 does not have seismic consideration in their practice calculation design, they just ignore this case because they believe their countries are not seismically active. They forgot countries that are near to their countries still having earthquake risk. Therefore, a need to review our practice design code and also our construction method especially in design of bridge is much needed so as to protect bridge structure from the undesired damaging effect due to this natural disaster.

The aim of this research is to compare our currently code of practice (BS5400) with AASHTO-Seismic Design Code in term of efficiency in design a bridge. It also investigates which two codesare more applicable to be applied in our country. The way to compare these two codes is by trying to redesign our existing bridge structure by using the different code of practices. In our case, we analyze and determine which code is much better for our country in design.

3. RESULTS AND DISCUSSION

The results of the design bending moment resistance of the pile cap for the AASHTO code and BS code are shown in Table 1.

Table 1. The Design Bending Moment resistance in pile cap

The codes	AASHTO		BS
The value (KN.m/m)	Mux	Muy	Mu
	2125.045	1336.745	36200

The results of the design shear resistance of the pile cap for the AASHTO code and BS code are shown in Table 2.

Table 2.The Design Shear Strength in pile cap

The codes	AASHTO		BS
The value (KN)	Vux	Vuy	Vu
	525.705	547.83	9778.8

The results of the design shear resistance analysis in the pile for the AASHTO code and BS code are shown in Table 3.

Table 3. The Design Shear Resistance Analysis in the pile

The codes	AASHTO		
The shear resistance (Vr)	One way shear		Two way shear
	Longitudinalface(x)	Transverse face(y)	
	3467.08	3477.216	207751.32

The results of the settlement in the pile for the AASHTO code and BS code are shown in Table 4 and the calculations are done using the following equation.

$$S_{ci}=(C_{ci}.H_i)/(1+e_0)Log(\sigma_{0i}+\Delta\sigma_i/\sigma_{0i}) \quad (1)$$

Table 4.The results of the settlement in the pile

S_{ci}(mm)	σ_{0i}(KN/m)	$\Delta\sigma_i$KN/m^2	Z_i(m)	σ_i(KN/m^2)
17.6	639	110	0.65	17.7
25.6	632	78.1	2.68	54.6
15.3	738	51.6	5.68	93
8.6	817	33.5	9.55	271
7.09	905	22.7	13.8	444
3.49	986	16.8	17.8	519
1.89	1087	12.1	22.8	595
1.39	1177	9.37	27.3	632
1.02	1224	8.26	29.8	679
0.19	1249	7.77	31	738
1.8	1297	6.94	33.4	817

Results of stress that founded by using SAP program and Bending and displacement that founded by using PLAXIS program are shown in Tables 5 to 8.

Table 5. Pile cap reinforcement due to AASHTO code

Due to	Flexural resistance	
At the	Longitudinal face	Transversal face
NO.bars	90#9	61#9

Table 6.Pile cap reinforcement due to BS code

Due to	Flexural resistance	
At the	Bottom face	Top face
NO.bars	28#9	28#9

Table 7. Results of stress that founded by using SAP program

Stress	Bending moment (KN.m)	**Shear stress(KN)**	Deflection of pile(m)	
Maximum value	506.957	**922.011**	Edge pile value	0.0052
Minimum value	124.824	**4.133**	Mid. pile value	0.0058
			Edge mid. pile value	0.0057

Table 8.Results of Bending and displacement that founded by using PLAXISprogram

Displacement (m)	Vertical displacement	0.1082
	Total displacement	0.0076
Bending moment (KN.m/m)	Exterior pile	40.83
	Interior pile	3.78

The results of the SAP 2000 program are shown in Figures 1 to 6.

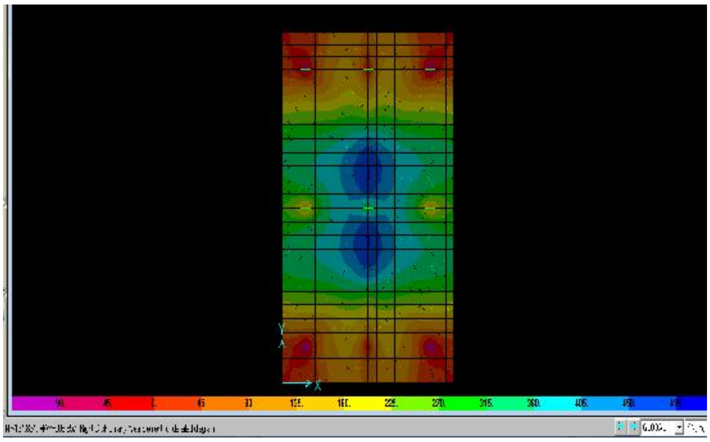

Figure 1.Max.moment (506.957 KN.m), Min. moment (124.824KN.m)

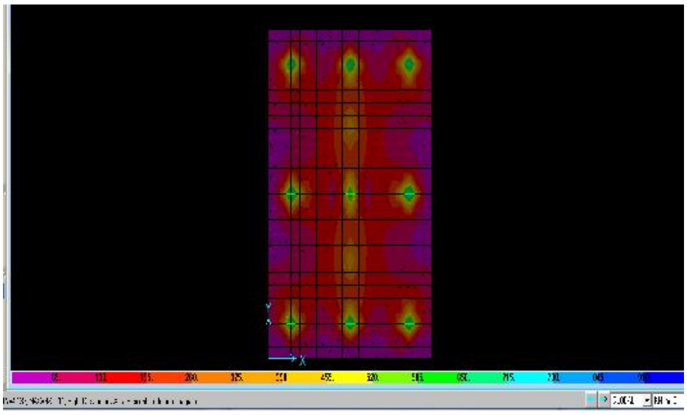

Figure 2.Max.shear (922.011KN), Min. shear (4.133KN)

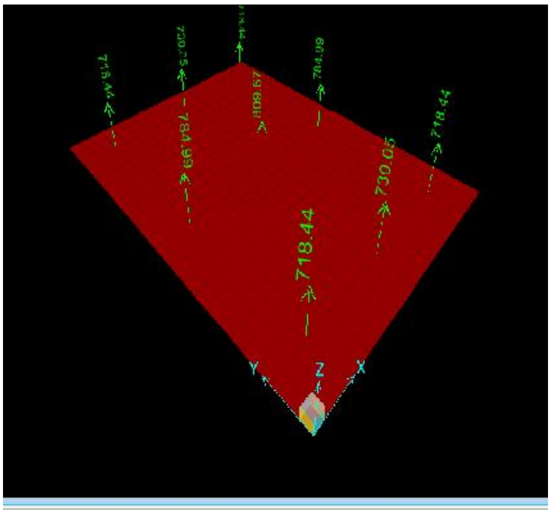

Figure 3. Reaction of pile due to applied load

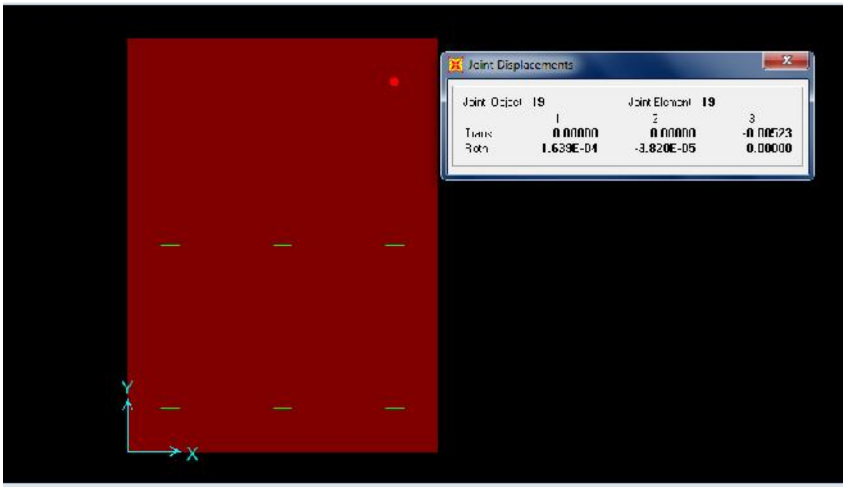

Figure 4. Deflection at edge pile (0.0052 m)

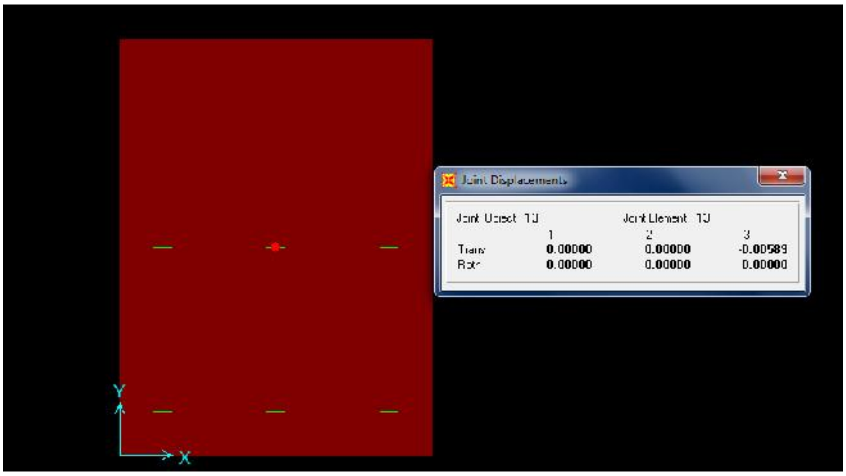

Figure 5. Deflection at mid. pile (0.0058 m)

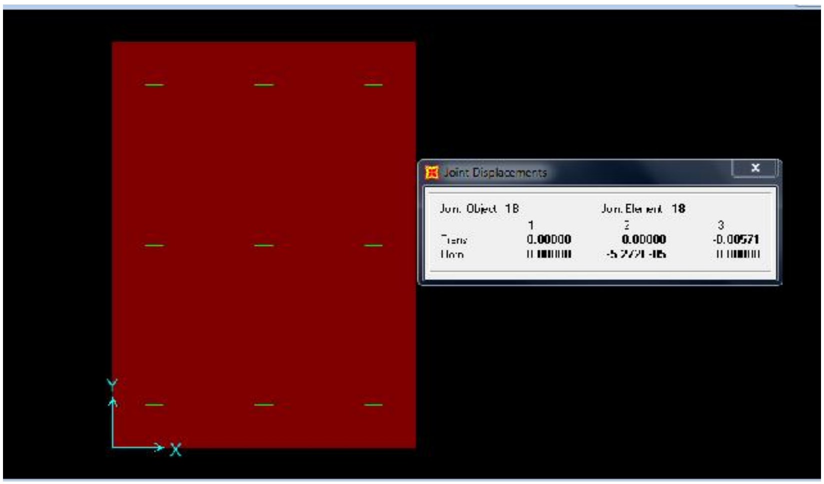

Figure 6. Deflectionat mid. edge pile (0.0057 m)

The results of the Plaxis program are shown in Figures 7 to 11.

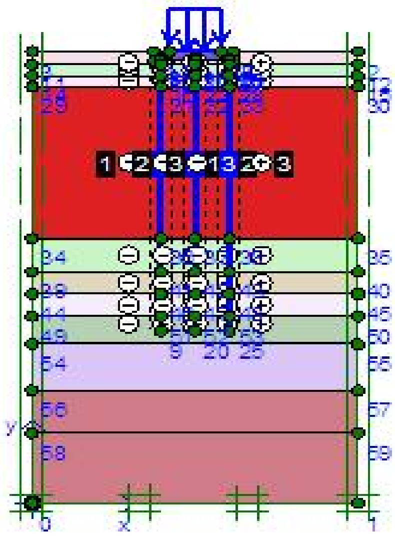

Figure 7. The model of pile cap analyzed by using PLAXIS program

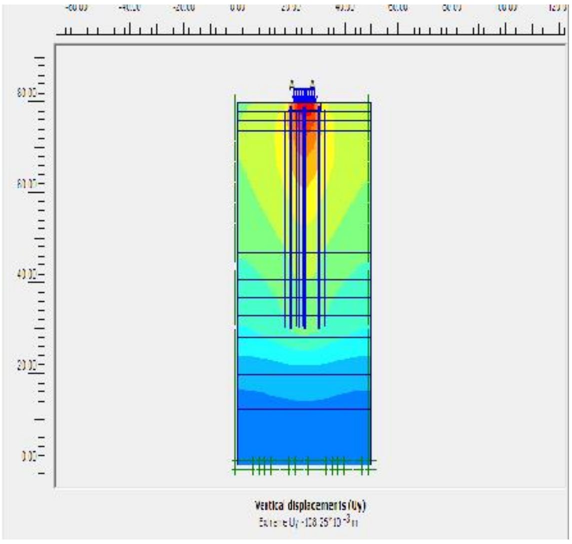

Figure8. Vertical displacement of the model; this figure shows the value of vertical displacement and the value is safe

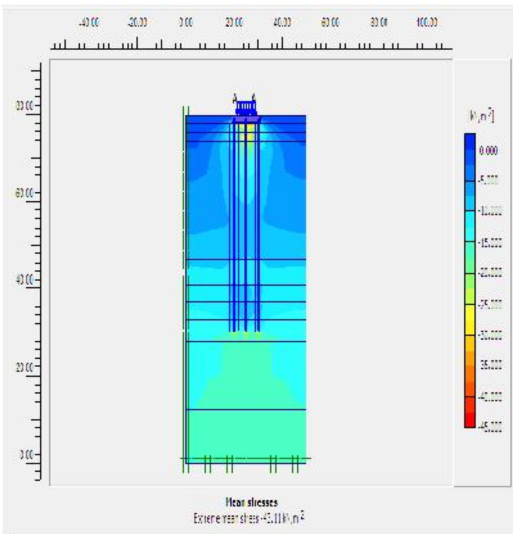

Figure 9. Mean stress

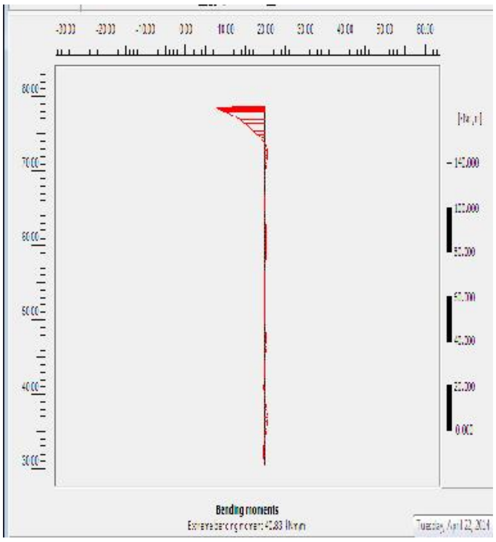

Figure 10.The exterior moment at exterior pile

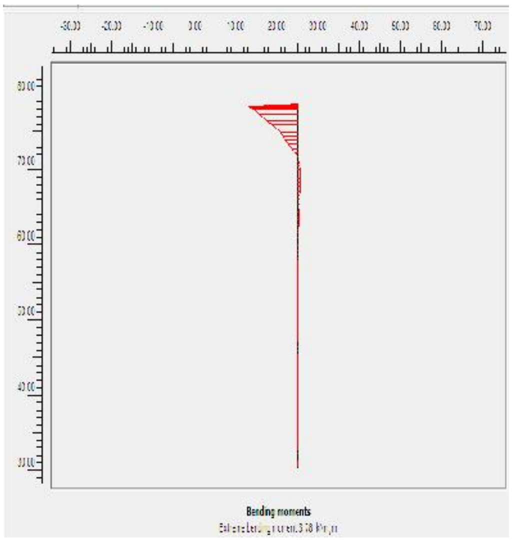

Figure 11. Interior bending moment of piles

4. CONCLUSIONS

The bridge has unchanging cross section with similar supports and a uniform mass and stiffness. The beam weight is equal to 364.215(KN/m).The AASHTO code take the live load =84.158 (Kn/m).The BS code take the live load = 83.6 (Kn/ m).

4.1. CONCLUSIONS

4.1.1. PIER CAP

4.1.1.1. SEISMIC EFFECT

In the AASHTO code, we can see that it take the effect of seismic load, that including all of the dead, buoyancy load, stream flow force, earth pressure, and earthquake effect in its calculation, where this code take 30% as longitudinal motion and 100% as transversal motion effect for this purpose. But in BS code we don't have any calculation for seismic load.

4.1.1.2. DYNAMIC ACTION

In BS code we have the consideration for dynamic action for both shear and bending moment stress but because the dynamic effect for the shear was equal to (1) and also the dynamic effect of bending moment was equal to(1.1) their effect can be neglected. But in the AASHTO code we don't have calculation for dynamic action.

4.1.1.3. TEMPERATURE EFFECT

In the AASHTO code we have the calculation of the minimum temperature and shrinkage steel reinforcement. It is found to be 10#7 near the surfaces of the concrete, but there is no calculation in BS code for this purpose.

4.1.2. PIER COLUMN

4.1.2.1. SLENDERNESS EFFECT

In the AASHTO code we can study the slenderness effect in pier column. This column is un-braced and effecting by the motion of pier cap so this column founded that is slender and it must to be regarded the moment that produced from the slenderness effect. But in BS code we don't have this calculation for this effect.

4.1.2.2. SEISMIC EFFECT

In AASHTO code we have the calculation for this effect for both of longitudinal and transversal motion. Due to earthquake we found that the pier column need for 60#18@10 cmbut does not have this consideration in BS code.

4.1.2.3. TEMPRATURE EFFECT

Both of AASHTO and BS codes studies the temperature effect on pier column but due to symmetry of bridge superstructure no force is developed at intermediatebent due to temperature expansion/shrinkage of the superstructure.

4.1.2.4. SKIN REINFORCEMENT

The AASHTO code has the consideration at the design for the skin reinforcement that needed in the pier column that must to be distributed at (d/2) from the flexural tension reinforcement, but in BS code there is no consideration for this purpose.

4.1.3. PILE CAP

4.1.3.1. TRACTION AND BREAKING LOAD

The BS code has the studies for this effect on the pile cap and suggested the required steel reinforcement that needed for resistance this applied load, but in AASHTO code there no consideration for this applied load.

4.1.3.2. SHEAR EFFECT ANALYSIS

Both codes studied this effect on the footing andthe maximum design shear resistance is found as shown in table (2).

4.1.3.3. FLEXTURAL EFFECT ANALYSIS

Both codes studied the maximum flexural resistance in pile cap design and we note that the AASHTO code suggested more amount of steel reinforcement than BS code suggestion as shown in table (5) and (6).

4.1.4. SOIL BEARING CAPACITY

The soil bearing capacity due to Terzaghi equation found equal to (288.36 kN) that is less than the applied load on the soil. So it is not safe and need to use pile in addition of use of footing. In BS code it is found to use 4 piles but in AASHTO code it found to use 9 piles.

4.1.5. SETTLEMENT

By using the AASHTO code equation, we found the structure is subjected to more than 80 mm settlement that is not logical. By using the Plaxis program 2D we obtained the settlement equal to 108 mm as shown in table (8) that is also un-logical and far from the standard limitations. But by using the SAP program we obtained the deflection under each pile not exceed than (5) mm as shown in table (7). In the same manner we found the total displacement is 29.9mm by the Chinese Code (China National Standards, 2002) which is considered as reasonable value compared with other results obtained from other codes and programs andit can be concluded that the Chinese code is giving good indication in calculating the settlement for pile foundation. The limitations of settlement in the high speed railway according to the Chinese code is 10mm. TB-5001 code limit the settlement for a range between 50-80mm, and CNS code (China National Standards, 2002) limit the settlement about 50mm. So the result of settlement from the CNS code which is about 30mm is accepted according to the above limitations and can be considered in the design of pile foundations.

5. REFERENCES

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