The Pier Foundation Design of the Beijing-shenyang Passenger Line Liaohe Super-large Bridge

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***Abstract*—In recent years, with the rapid economic development of the China, the railway construction also experiences a fast growth. State Department adopts The Twelfth Five-Year Plan of Transportation in 2012, and plans to build a batch of great railway projects. The construction program of Beijing-Shenyang Passenger Line is one of them. The main content of this article is to design the pile foundation of the Liaohe Bridge in Beijing-Shenyang Passenger Line. Using the large diameter bored piles, and design the pile foundation in detail according to the standard, including the settlement of pile, the bearing capacity and the design of the pile caps. Furthermore, it also used FLAC3D to simulate. Through the comparison of simulation results and calculation results, it found that simulation of the ultimate bearing capacity of the pile has little different than the calculation results, the error is 7.1%, settlement rule is also consistent with reality, but the settlement has certain differences, the error is 63.5%. Overall the results of the numerical simulation have played a certain reference role for the design of pile foundation.**

Keywords—bored piles; Pile foundation design; Numerical simulation

I. INTRODUCTION

1.1 Origin and background of the project

Beijing-Shenyang Railway Passenger Dedicated Line is an important part of the main backbone of the Beijing-Harbin Dedicated Passenger Line which belongs "the mid-long term planning for China's railway network". Line since Beijing Xinghuo Railway Station, via Hebei Province Chengde City, Liaoning Province, Chaoyang, Fuxin City, after access Shenyang Station, a total length of 697.626 kilometers, with a total investment of 124.5 billion yuan. The feasibility report of project was approved by the government of China in December 2013. The railway plans to design and construction in accordance with the standards of 350 kilometers per hour. Harbin-Dalian High-speed Railway which has been put into operation and Beijing-Shenyang Passenger Dedicated Line will constitute the second rapid railway channel of Shenyang and northeast China.

Beijing-Shenyang Railway Passenger Dedicated Line as an important part of the "four vertical and four horizontal" Passenger Line Network, The construction of the railway will open up northern Hebei Province, western Liaoning railway corridor, and contribute to the development of those regions. The land acquisition work of Beijing-Shenyang Railway Passenger Dedicated Line project has been completed in the January 31, 2014; then began to enter the stage of construction, and will completed in 2019.

1.2 The development of the bored piles

There are many cross-river and cross-sea bridge in the world, the form of bridge foundation is also more and more. One of the earliest was caisson foundation and open caisson foundation, and next came out all kinds of cylinder pile foundation, and then composite foundation, finally the pile foundation was invented.

In 1893, the manual digging pile came out in United States, now has been 122 years. At that time, because of the development of industrial technology, the height of buildings continues to increase, and then the settlement of high-rise building is too large. In order to improve the bearing capacity of the pile, engineers had to make bearing stratum deeper, and increased pile diameter, but at the time of construction machinery and equipment cannot reach that depth, so the large diameter manual digging pile emerged in this context, and spread to other countries, and it has been use up to now.

About 50 years after manual digging pile appeared, bored pile came out with the successful development of high-power drilling rigs in the United States. With the rapid development of the world economy, a variety of high-rise, super high-rise buildings or important buildings are beginning to use bored pile. After the United States invented the positive circulation drilling method, Japan, Italy, Germany, France have invented a long auger drilling method, Astley method, Benoto method, pump suction reverse circulation method and other new construction processes and equipment, the new technology and more advanced construction equipment has prompted bored pile more widely used.

In the early 1960s, a few large cities in China began to use the bored pile only for the high-rise buildings, but with China's reform and opening up in 1980s, large-diameter bored pile quickly been widely used all over the China. According to statistics, China use about 1 million large-diameter bored piles every year, started late but develop rapidly, which is because of the rapid development of China's economy.

Today, there are many boring methods of bored pile. In addition to the original but the most effective manual hole digging, also there are no circulating fluid drilling method, positive circulation drilling method, reverse circulation drilling method, wire percussive drilling method, grabbing and a full casing drilling method, vibration immersed tube drilling method, large diameter DTH drilling method and so on. No circulating fluid drilling method also includes the length of the helical drilling method, drilling bucket drilling method; reverse circulation drilling method, according to the principle can be divided into the pump suction reverse circulation, the compressed air reverse circulation and jet reverse circulation. To further improve the bearing capacity of bored pile, and then invented belled piles and so on.

II. Design of Bored Pile's Foundation

2.1 Bridge site Introduction

The bridge is located in Xinmin City, across the Liaohe River, the mileage of beginning and end is DK639 + 183.95 ~ DK650 + 410.70, full-length 11226.8m, the mileage of bridge center is DK644 + 797.32, bridge type is 4-16m + 5-20m + 20-24m + 296-32m simply supported beam + 4- (32 + 48 + 32) m + 2- (40 + 56 + 40) m + 1- (40+ 64 + 40) m continuous beams.

The area of this section bridge site is the alluvial plain of Liaohe River, the terrain was generally low in the west to east, the terrain is relatively flat, open, are turned into arable land, the bridge is located in Xinmin City, through the Liaohe River. Liaohe River width 50 ~ 100m, there is water in exploration, depth of about 1.5 ~ 5.0m.

2.2 Design

The bridge is designed with a total of 347 piers, caps are 5 m × 5 m × 1 m, and there are four bored piles under the cap. The upper portion of each pier suffered load of 10000KN, and each cap weight 625 KN. Bearing stratum is dense sand layer which 28 m deep, pile tip into the bearing stratum 2 m, pile length 30 m, diameter 1 m.

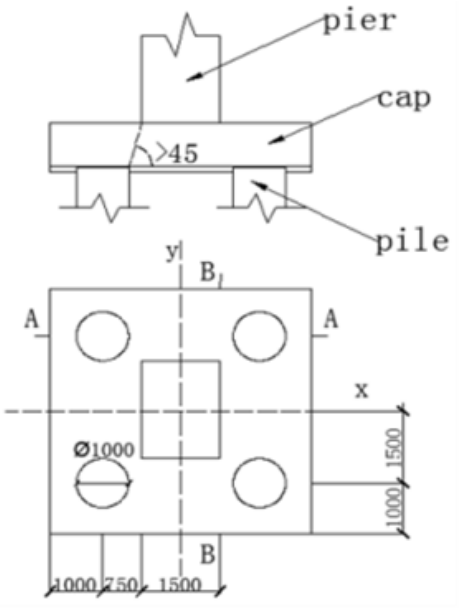

Figure 1: Foundation

According to the Technical Code for Building Pile Foundations (JGJ 94- 2008) and the Code for Design of Ground Base and Foundation of Highway Bridges and Culverts (JTG D63-2007) check the design, Table 1 shows the result.

Table 1: The Results of Design

	JGJ 94- 2008		JTG D63-2007	
	Value of calculation	*value of design*	*value of calculation*	*value of design*
Load(kN)	10000		10000	
Design value of a load(kN)	13500		13500	
ultimate bearing capacity of single pile (kN)	7432.8			
Characteristic value of loading capacity of single pile (kN)	3716.4	2656.25	3597.3	2656.25
Settlement (mm)	28.1	40	28.1	40
Punching capacity of caps from pier(kN)	16778.8	13500	15269.9	13500
Punching capacity of caps from pile (kN)	4759.8	3375	7932.8	3712.5
Shearing capacity of caps (kN)	A:7001 B:8270	6750	9967.1	7425
Flexural capacity of caps(kN)	Mx:3375；My:5062.5			

III. NUMERICAL SIMULATION

3.1 Modeling

Because of symmetrical relationship, only establishes single pile model, Model size is 24m × 12m × 40m, a total of 6907 nodes, 5796 units, pile at the center of the model, length 30m, diameter 1m(Fig.2). Soil use Mohr - Coulomb model, pile use elastic model. Boundary conditions: X = -12; X = 12; Y = 0; Y = 12; Z = -40.

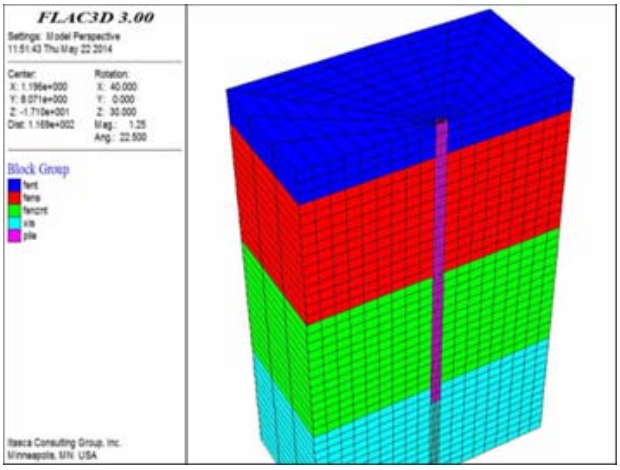

Figure 2: Model

3.2 Settlement simulation

Before the simulation of settlement, it needs balance the initial stress field. Figure3 shows the initial stress nephogram.

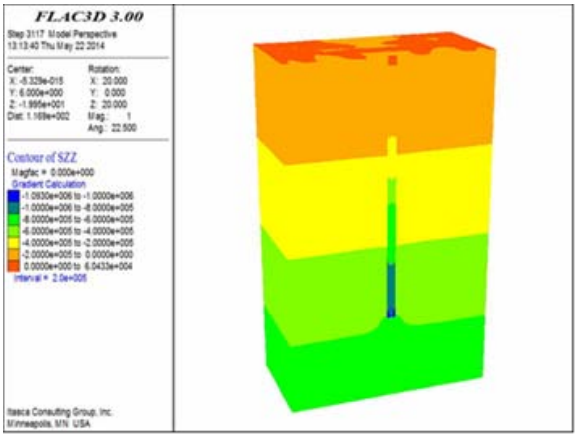

Figure 3: The initial stress nephogram

The load of pile groups is F=10625KN, so single pile is F/4=2656.25KN.When simulation we need uniform force not load, so the uniform force is P=3383.76MPa. Fig. 4 to Fig. 6, shows that the settlement of the pile tip is 10.3mm, which less than the settlement of the pile top is 12.5mm, the reason is that the pile body is compressed, compressed volume is 2.2 mm. Fig.7 shows when the pile under load, pile load decreases with the increase of depth.

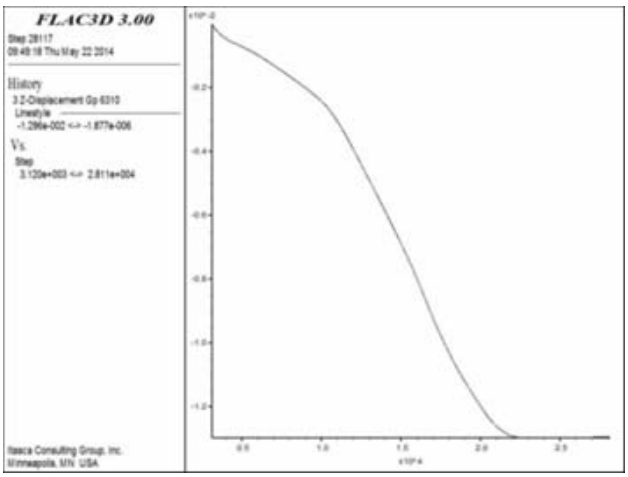

Figure 4: Displacement of pile top

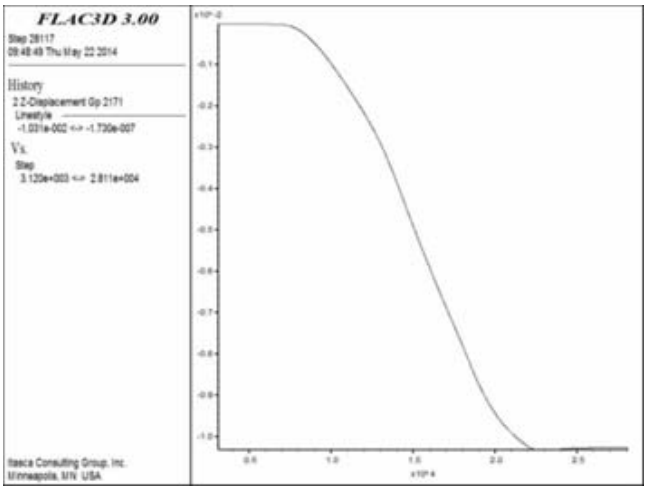

Figure 5: Displacement of pile

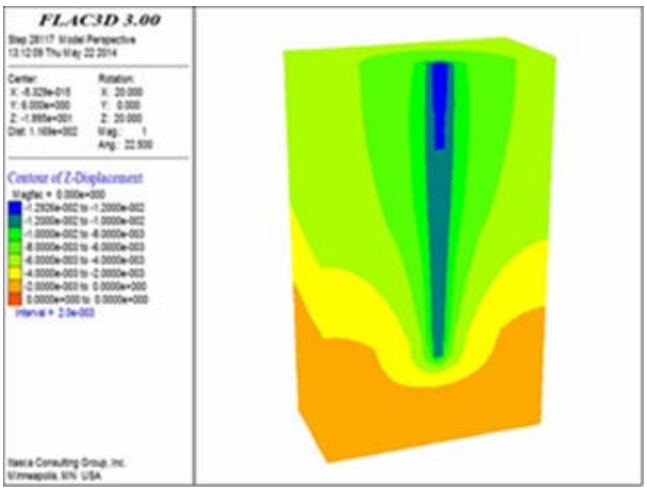

Figure 6: Displacement

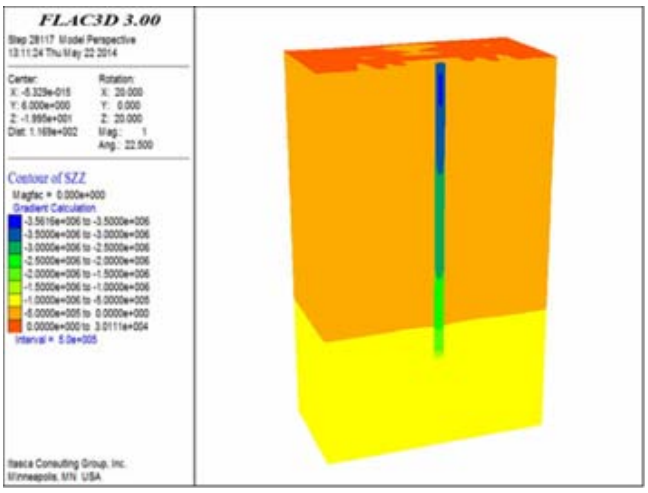

Figure 7: Axial force

3.3 Ultimate bearing capacity of single pile simulation

The simulation of bearing capacity use the way of stress loading, according to the static load test, on top of the pile loading step by step, then generated stress - settlement curve (Fig. 8).

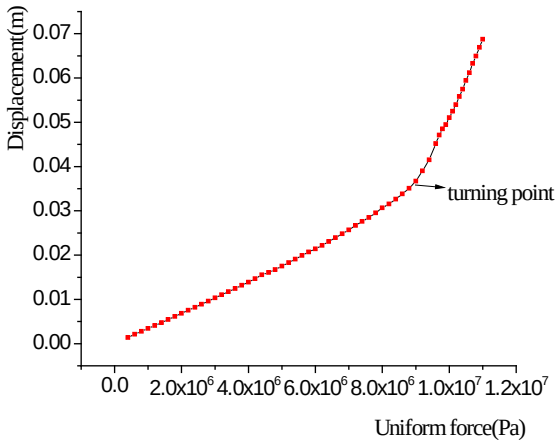

Figure 8: Stress - settlement curve

In the Fig. 8 there is obvious inflection. At the start the displacement increase at a constant speed, when pile bearing capacity limit is reached, Pile body structure damage, displacement increase rapidly. Inflection coordinates roughly (8.8E6, 3.5E-2), Ultimate bearing capacity in which the position of the inflection point for the pile, conversion to load is $Q = p \cdot \pi \cdot D^2 / 4 = 8.8 \times 10^6 \times 1 / 4 = 6908\text{kN}$.

3.4 Simulation and calculation results compared

The settlement of calculation is 28.1mm, the pile tip settlement of simulation is 10.3mm, having the error of 63.5%.The reasons are: When simulation I used single pile, but used pile group to calculate, there is pile group effect, so the settlement of calculation is bigger; Due to complex formation, when modeling I simplified the formation, the settlement of simulation is smaller.

About the ultimate bearing capacity of single pile, the result of calculation is 7432.8kN, the result of simulation is 6908kN. The reasons are: Simplify the stratum, makes the result of simulation is not accurate; there is error when reading Fig. 8, the result is not accurate.

IV. Conclusions

The design of Beijing-shenyang Passenger Line Liaohe Super-large Bridge pier foundation is reasonable. Settlement of calculation is 28.1mm, it is smaller than the biggest settlement 40 mm which Code for Design of Ground Base and Foundation of Highway Bridges and Culverts (JTG D63-2007) ask for. At the same time, the pile foundation bearing capacity meets the design requirements.

Design which according to both specifications are meet requirements, the equations of both specification are same, Just a different factor correction method of the equations. The factor of Ground Base and Foundation of Highway Bridges and Culverts (JTG D63-2007) are bigger, so it requires higher in bearing capacity calculation.

Using the FLAC3D on single pile are analyzed in numerical simulation, it has certain reference function to the design. However, if used pile group as a simulation object, it will be more convincing.

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