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Study on the Jacking Force of Girder Closure for Contimuour Rigid Frame Bridge

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Abstract: The shrinkage and creep of concrete and the temperature change is influence the stress and deformation of the continuous rigid frame bridge greatly. According to Fengtai Huaihe Bridge , using the Finite Element Method, analysis in two closure schemes, cross the bridge girder under dead load and 10 years' shrinkage and creep under the action of deflection, the difference of force and moment of the main pier to verify the continuous rigid frame bridge with across the apical pushed closure of superiority and rationality. The results shows that the push closure stress state can improve the construction of the bridge, and have a significant role in solving the cross deflection.

Keywords: Continuous rigid frame bridge; Closure; Jacking force; Performance after jacked

1. Introduction

Continuous rigid frame bridge structure with good stability, strong spanning capacity, convenient construction and low engineering cost, thus obtained the rapid development of prestressed concrete continuous rigid frame bridge is now gradually to develop in the direction of high pier large across [1]. But the continuous rigid frame bridge under long-term load can lead to loss of prestress, girder down warping, girder and pier horizontal offset. In order to ensure the bridge structure has enough stiffness, because of gravity, concrete shrinkage and creep of large deflection and impact factors such as high speed driving, damage to bridge surfacing and generally adopt the way of setting camber beforehand, provide a camber high late to offset the down warping [2], and in order to eliminate the deviation of bridge piers are harmful to the pier stress, can be like exerted camber, joining in the continuous rigid frame bridge across the exert of a horizontal jacking force, put a reverse displacement of main piers under late joining to offset the difference in temperature, creep and shrinkage caused by factors such as the horizontal displacement.

2. Project Summary

The length of Anhui Fengtai Huaihe Bridge is 4447m, divided into left and right images, each one-way have three-lane decks, the wide of single bridge is 15.95m, include a slow system which wide is 3.25m.Main bridge is three-span continuous rigid frame bridge which length is 97+176+97m, a single dual-chamber box section, box beam using 2.0 times higher parabola from the root to closure section that changed from 10.0m to 4.0m; the main pier double legged high piers the main pier dimensions is 9.95×1.80m; main pier size is 19×14×5m, set on two levels. The main bridge structural arrangement of Fengtai Huaihe River Bridge shown in Figure 1.

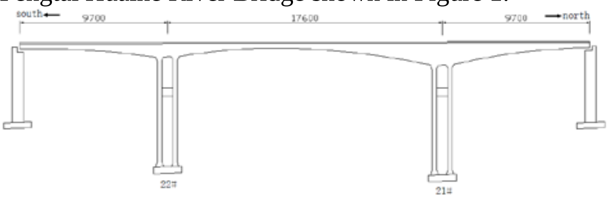

Figure 1. Elevation schematic arrangement of the full-bridge

The main bridge cantilever pouring construction segment, the closure order in the first side span after span, mid-span closure carried out using the Cradle. Closure according to the following steps: 1) establish the template, ordinary steel banding; 2) installation across Stiff Skeleton closure segment and welded at one end, if push the actual construction and design of the temperature difference between the temperature determination; completion after pushing as soon as the stiffness of the frame and the other end welded shut, and then the tension in the span temporary closure beam [3]; 3) Placement span Closure segment concrete, while pouring concrete edge adjust the side closure section of the counterweight, finished pouring time , cross counterweight completely removed [4]; 4) the design strength of concrete to health, according to the design tensioning the corresponding file in the span prestressed beams; 5) demolition cross templates and bracket.

3. Calculation Jacking Force

2.1. Finite element model overview

The bridge uses Midas Civil modeling analysis, the full bridge is divided into 382 units, calculation model shown in Figure 2.

Figure 2. FEM of the full-bridge(Midas Civil)

2.2. Calculation horizontal stiffness

Table 1 shows the Midas Civil model under different top thrust, on the 21st Pier Heart (node 35) and 22 Pier Heart (node 95) and a horizontal cross-section on both sides of the closure of the node (node 64, 66) of displacement.

Table 1. Relationship between the node displacement and jacking-force

Node	Jacking-force /KN		
	300	600	900
35	-1.50×10-3	-3.01×10-3	-4.53×10-3
64	-1.67×10-3	-3.27×10-3	-4.88×10-3
66	-1.67×10-3	-3.27×10-3	-4.88×10-3
95	-1.50×10-3	-3.01×10-3	-4.53×10-3

We can calculated the unit horizontal force horizontal displacement of Pier 21 and Pier 22 in the heart from the Table 1:

$$K=K21=K22=2.0\times105\text{kN/m}$$

2.3. Jacking force determined

Basis jacking force F1 is beam shortening in order to offset the dead load under because of shrinkage and creep caused, according to Midas Civil calculation results in the design closure temperature of 15 ℃ under constant loads after 10 years of shrinkage and creep Cross main beam shortening δ = 22.3mm, the basic thrust F1 is the top girder bridge to shorten the amount of horizontal stiffness of the product. It can be calculated that:

$$F1=22.3\text{mm}\times2.0\times105\text{kN/m}=4460\text{kN}$$

Stiff Skeleton closure section locking closure time temperature is the temperature, the temperature is the starting point for the annual average temperature change, it must consider the temperature difference between the actual closure temperature and impact. By calculating the temperature difference of the beam to shorten the amount of influence, pushing the shift and adjust jacking force to eliminate the adverse effects of the temperature difference between the closure of the bridge. The bridge under the unilateral mechanism T long 87m, according to the concrete linear expansion coefficient shows that temperature change per 1 ℃, its length δ = 0.87mm, the jacking force F2 additional horizontal stiffness of bridge and δ product. According calculated that F2 is 174KN. Whereby the closure when appropriate temperature and design temperature difference Δ T ℃, and ultimately determine the top closure is thrust:

$$F=4460\pm174\Delta T$$

2.4. Pushing verification

The bridge is located area for many years the average temperature of 15.2 ℃, closure section in winter construction, after several days of continuous observation, is expected to book closure period temperature is 0 ℃, day and night temperature at ± 1 ℃, Construction of Closure Segments Stiff Skeleton locking temperature is 0 ℃. Can be calculated jacking force F = 1850KN. In pushing back and forth to work on multiple pre-embedded sensors monitoring, condition monitoring results show that the main beam T configuration block number 0 and the upper and lower edges of the actual stress measured stress pier section is less than the theoretical stress.

Table 2. Stress of some key units under the working condition of jacking construction

Node	32	38	92	98
upper margin	8.47	8.17	7.98	8.24
lower margin	4.75	4.63	4.48	4.57

3. Pushing Force Performance Analysis Before and After the Bridge

For comparison span continuous rigid frame bridge using Cross Pushing rationality closure by finite element numerical simulation comparative analysis of different closure schemes (Scheme 1 to not push closure, program 2 push closure), the full-bridge under constant loads after 10 years of shrinkage and creep, the cumulative difference between the main beam vertical deflection, stress and the lower edge of the upper edge stresses and so on.

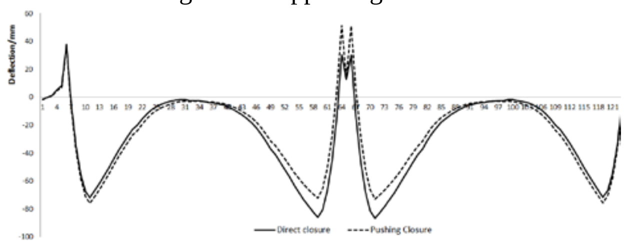

Figure 3. Total flection of this bridge under the effect of dead load and 10 years' shrinkage and creep

Fig 3 shows that in side cross-section of the beam, is greater than Scenario 1 Scenario 2 deflection. The maximum deflection difference in the two programs appear at the node 15, Scheme 1 is 50.3mm, Option 2 is 54.8mm. Cross section of beam deflection program to be significantly greater than 1 Scenario 2, the difference between the two programs appear in the maximum deflection 66 nodes, Scheme 1 is 30.3mm, Option 2 is 51.2mm. The general continuous rigid frame bridge main concern is the midspan problems, thereby pushing the closure of the midspan of the problem according to some improvement can be seen in Fig 3.

Fig. 4 and Fig. 5 for the different closure program, the main beam in the unit after dead load stress state after 10 years. Fig 4 shows that compared with Option 2 program on the edge of a large compressive stress; Fig. 5shows that the side span beam segment, compared with Scenario 1 Scenario 2 lower edge compressive stress is small, the beam cross-section of approximately equal. By comparing these two plans can be seen, the impact of the closure of two ways to stress the difference between the main beam is small, the stress curve is very similar, which is due to force anti-jacking force is generated by the horizontal displacement of the main pier, after long-term shrinkage of concrete creep action, the horizontal displacement will decrease or even disappear, pushing the reaction force will be reduced or disappear [4], so little difference between the two programs in terms of stress.

In contrast to the situation by force aspect pier, Pier Top to define the direction of span offset forward, bending moment produced positive bottom pier. The inside of the pier is pointing double legged high piers near the mid-span of a limb, finger away from the pier across the outside of a limb. Table 3 lists the different closure program, after 10 years in full-bridge shrinkage and creep after the moment at the end of Pier contrast.

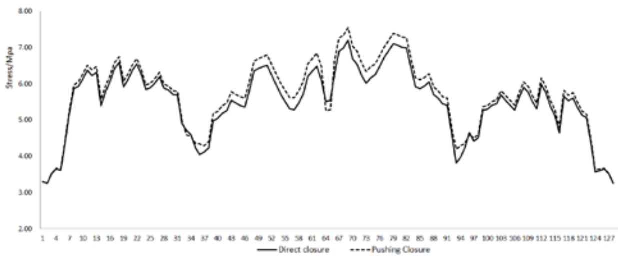

Figure 4. Stress on the top of this bridge under the effect of dead load and 10 years' shrinkage and creep

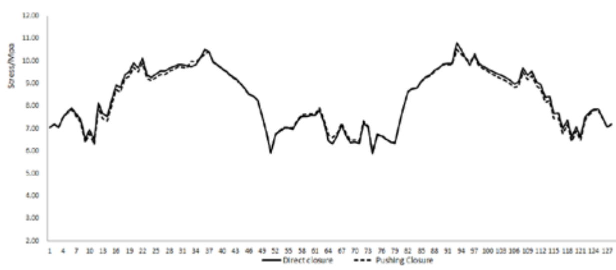

Figure 5. Stress on the bottom of this bridge under the effect of dead load and 10 years' shrinkage and creep

Table 3. Bending moment on the bottom of the pier under the effect dead load and 10 years' shrinkage and creep

Bending torque	Pushing Closure	Direct closure
Inner pier bottom	-5.49×102	-9.79×103
Lateral pier bottom	-2.77×103	-7.30×103

Table 4 under different closure program, after 10 years in full-bridge shrinkage and creep after the stress condition at the end of Pier

Table 4. Stress on the bottom of the pier under the effect dead load and 10 years' shrinkage and creep

Stress	Pushing Closure		Direct closure	
	upper	lower	upper	lower
Innerpier bottom	-3.8	-5.7	-3.9	-10.7
Lateralpier bottom	-1.5	-6.7	-1.0	-10.7

As we can see from the two tables above, without pushing direct closure, only dead load creep and shrinkage effects of lateral Pier moment at the bottom can be reached -7.30×10^{3}kN•m, the compressive stress reached 10.7Mpa, structure security caused problems. The use of push closure, the only negative moment outside of the pier -2.77×10^{3} KN • m, about not pushing the closure of a third of the program, and less stress push closure significantly reduced, the structure is safe.

4. Conclusion

1) Continuous rigid frame bridge at mid-span closure using pushing construction scheme is reasonable. Pushing construction can effectively improve the lower part of the pier stress state, compared to not push direct closure for operators across the bridge in the late Deflection significantly improved.

2) In pushing the construction process, pay attention to work on pushing the temperature changes, pushing to be based on when the actual temperature and the temperature difference between the design of pushing for pushing displacement and top thrust dynamic adjustment.

3) Based on the different closure schemes numerical analysis and calculation, to ensure top thrust exerted to ensure the bridge during the operational phase of the force is in good condition.

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