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An analysis and optimization of partial stress of temporary blocks in the process of bridge construction using long-span PC continuous beams

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SUMMARY

Prestressed concrete bridge, made as rigid-frame-continuous combination beams, has a specific structure and method of construction. Continuous beams, bridge piers and beams in particular need to be consolidated temporarily in the process of construction. The structure system of a bridge transforms after the construction of beams has finished. Based on the example of the West River Bridge, this paper discusses the analysis and simulation method of bridge construction with prestressed concrete continuous beams under temporary consolidation. In the condition of the largest cantilever, we calculated and got three-dimensional stress state and deformation of a temporary concrete block, using a finite element model of continuous beam zero block, which was established by methods described in the paper. Then, we analysed the specific location where the stress exceeded the prescribed value. We tried to adjust it, and finally found out an optimal method of adjustment. By adjusting the vertical prestress and the size of a temporary block, this model can simulate stress/deformation state of a temporary block fairly accurately, ensure the construction of continuous beams bridge to be safe in the condition of the largest cantilever.

KEY WORDS: *continuous-beams, space simulation, local stress, stress analysis, temporary consolidation, optimization.*

1. THE CONSTRUCTION CHARACTERISTICS OF CONTINUOUS BEAMS BRIDGE AND THE MODELLING METHOD OF THE ZERO BLOCK IN THE CONDITION OF TEMPORARY CONSOLIDATION

1.1 ENGINEERING CHARACTERISTICS

The PC rigid-frame-continuous combination beam bridge across the Xijiang river has a total length of *1560.90 m*, the main bridge's length is *808.40 m* (*51.40 m+94 m+4×144 m+87 m*). There are two methods of connection with a zero block and a bridge pier. One method is to install adminicula between the bridge pier and the beam. In that case the bridge pier and the beam have to be temporarily consolidated in the process of construction. The temporary state is completely different from the final state [1], and this paper addresses precisely this phase. The other method is to directly consolidate the pier and the beam. This paper analyses the temporary state in detail, then addresses the local stress of the zero block of the continuous beam in the condition of temporary consolidation. Finally, an optimal adjustment of the stress is suggested.

1.2 THE ELEMENT MODELLING METHOD OF THE MAIN BRIDGE'S ZERO BLOCK

(1) Selecting the element unit

This analysis uses the ANSYS programme, and selects the Solid 187 block unit for simulation, Solid 187 is a three-dimensional, 10-node, isoparametric tetrahedron element. Each node has three degrees of freedom. This type of unit is well suited for simulation of complex structures [2] [4].

(2) The model simplification

According to the Saint Venant's principle, for the zero block of the main beam, the finite element structures just need to be built with blocks from *No. 0* to *3*, which proves precise enough in a space-stress analysis [3]. For the temporary block and bridge pier, the model according to the actual size was simulated in this paper, i.e. we built the pier's model from the top of pile caps. Since the main box girder's upper and lower parts are symmetric, only the upper part was considered in the analysis. In the temporary state, even though the side span and midspan structure are the same, and the accidental load is asymmetric load, both the side span and midspan were taken together for analysis. Further, accidental load was applied to the side span. The model is shown in Figure 1.

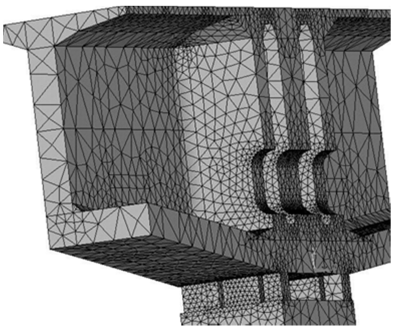

Fig. 1 *The finite element model*

1.3 LOADING METHOD

This paper uses the following way to apply the load. With the method of separation, the effect of prestressed reinforcement was replaced by a replacement load. The overall effect of prestress on the structure can more clearly be shown [3].

At the end sections of *No. 3* block different resultant forces were applied in order to simulate the following two kinds of states:

(1) During the maximum double cantilever, when the *No. 16* concrete block is poured, the bending moment, shear force and axial force is applied to the finite element structure. That is to say, the load was applied to the end section of *No. 3* block in the form of an external force as a dead load.

(2) During the maximum double cantilever, when the *No. 16* concrete block is poured, it was assumed that the one side hanging basket would fall suddenly, which will in turn produce a new resultant force at the end section of *No. 3* block. In this study, it applies to the end of *No. 3* block, as accidental load [3].

2. ANALYSIS AND DISCUSSION OF THE RESULTS OF THE STRESS STATE OF THE TEMPORARY BLOCK LIST

From the form above can be concluded:

(1) The vertical compressive stress of the temporary block is larger, the local vertical compressive stress value is over *15 MPa* and the tensile stress value is over *2 MPa*.

(2) If an accidental load occurs on one side, the vertical compressive stress of the temporary block will pass *25 MPa*, even achieve *39 MPa*. The calculation results are shown in Figure 2.

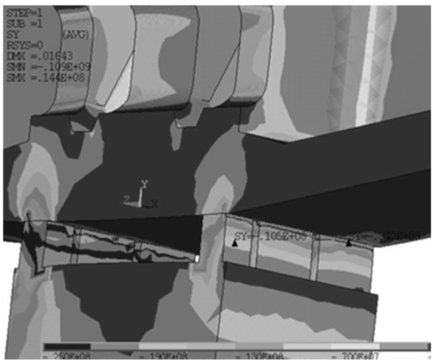

Fig. 2 *Temporary block vertical stress under dead + accidental load*

The concrete of the temporary block will experience the plastic phenomenon if its compressive stress passes *25 MPa*, and it will be crushed if the compressive stress continues to increase [5] [6]. In view of this situation, stress of the temporary block is not reasonable, and the next step is to modify the design of temporary block.

3. THE ADJUSTMENT WAYS OF THE TEMPORARY BLOCK

There are two factors that can influence on the stress of the temporary block. The first factor is: the value of prestress on the temporary block, the second factor is the transverse size of the temporary block. This paper plans to discuss these two factors.

First adjustment relates to the value of the prestress: the adjustment range is *20%* of the original prestress. The loading methods like the following formula:

N% Prestress + Dead load + Accidental load (n=0, 20, 40,60,80,100)

We can get the most reasonable value of the prestress through the first step adjustment, the second step is adjustment of the horizontal size of the temporary block under the most reasonable prestress, with an increase of *0.2 m* at each step.

Table 1 *Stress state of the temporary block list*

direction		*Stress (MPa)*	
vertical		*size*	*location*
Dead load	*overall*	*-17.7*	*most of the parts*
	local	*-25.3*	*The outside of the junction of temporary block and box girder floor* *The inside of the junction of temporary block and pier*
Accidental load	*overall*	*-7.3*	*The temporary block which closed to the sidespan*
		7.3	*The temporary block which closed to the midspan*
	local	*12*	*The top of temporary block which closed to the midspan*
Dead+ Accidental load	*overall*	*-26*	*The temporary block which closed to the sidespan*
		-10.5	*The temporary block which closed to the midspan*
	local	*-39*	*The junction of the temporary block and the box girder floor which close to the sidespan, the inside of the junction of the temporary block and the main pier*
		-34	*The junction of the temporary block and the box girder floor which close to the midspan, the inside of the junction between the temporary block and the main pier*
Longitudinal and transverse		*tension and compression stress is not exceeded*	

Table 2 *The vertical stress in different conditions*

The temporary block	*Stress (MPa)*		*remark*
	the sidespan	*the midspan*	
Dead load	*-9.94*	*-9.94*	
Accident load	*-7.6*	*7.9*	
100% P+D+A	*-27.45*	*-11.95*	*local compressive stress is exceeded near the side span*
80% P+D+A	*-25.468*	*-9.968*	*local compressive stress is exceeded near the side span*
60% P+D+A	*-23.486*	*-7.986*	*local compressive stress is exceeded near the side span*
50% P+D+A	*-22.495*	*-7.322*	*no tensile stress appeared, the value of the compressive stress is not over 25 MPa, this state is the best*
40% P+D+A	*-21.504*	*-6.004*	*local tensile stress occurs near the midspan*
20% P+D+A	*-19.522*	*-4.022*	*local tensile stress occurs near the midspan*
0% P+D+A	*-17.54*	*-2.04*	*local tensile stress occurs near the midspan*

4. THE CONCLUSION AFTER THE PRESTRESS ADJUSTMENT

The vertical stress in different conditions

Above all, in the condition of *50%* Prestress+Dead+Accident load, tensile stress does not occur, the value of the compressive stress is not over *25 MPa*, and this is the best situation. In this paper, only two stress diagrams are shown, Figures 3 and 4.

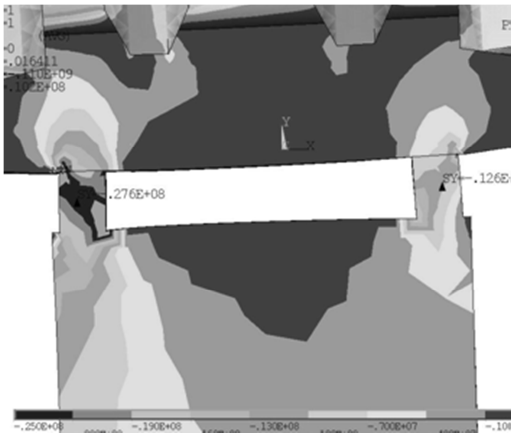

Fig. 3 *Stress (100%P + D+A load)*

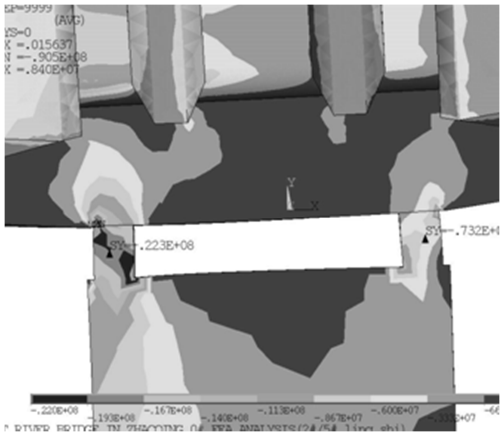

Fig. 4 *Stress (50 %P + D+ A load)*

5. THE CONCLUSION AFTER THE SIZE ADJUSTMENT

The following conclusions have been reached based on the Table 3:.

(1) If the vertical prestress is *50%* of the original prestress, then the compressive stress of the block near the side span is not too big and there is no tensile stress in the block near the middle span. However the stress is still not uniform.

(2) The stress of the block becomes smaller and uniform with the increase of its width, which means that the stress of the block has improved.

(3) The stress of the block significantly improves when the width increases from *0.6 m* to *0.8 m*, the vertical stress of the block near the side span is reduced from - *22.495 MPa* to - *14.92 MPa,* which is shown in Figure 5. The vertical stress of the block near the side span is reduced from - *14.92 MPa* to - *12.01 MPa*, the results shown in Figure 6. In addition, the junction size between the top of the pier and the block *No. 0* is not good enough. From the perspective of economy and convenience, the scheme in which the block's width is *1 m* is not recommended.

Tables 3 *The vertical stress in different conditions*

width = 0.6m	*stress (MPa)*	
	the block near the sidespan	*the block near the midspan*
50%Prestress+Dead+Accidential	*-22.495*	*-6.995*

width = 0.8m	*stress (MPa)*		*Compare with its width of 0.6 m*
	the side span	*the midspan*	
Dead	*-6.65*	*-6.65*	*1. The value significantly smaller* *2. The stress was more uniform* *3. The vertical stress of the block near the side span is not over 18MPa, the stress of the block near the middle span is uniform*
Accidential	*-4.97*	*4.96*	
50%P+D+A	*-14.92*	*-5.04*	

width = 1.0m	*stress (MPa)*		*Compare with its width of 0.8 m*
	the side span	*the midspan*	
Dead	*-5.29*	*-5.29*	*1. The value slightly smaller* *2. The stress was more uniform* *3. The vertical stress of the block Near the side span is not over 16MPa, the stress of the block near the middle span is uniform*
Accidential	*-3.95*	*4.35*	
50%P+D+A	*-12.01*	*-3.71*	

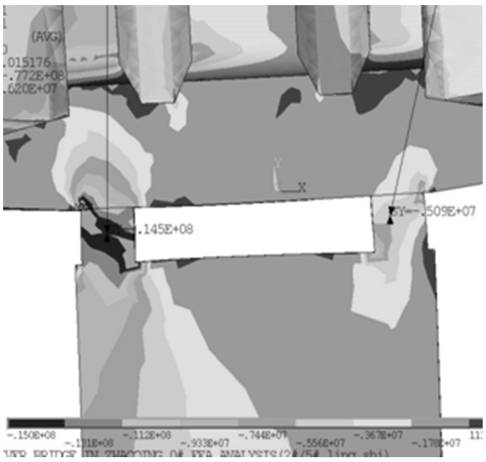

Fig. 5 *Stress (width=0.8 m 50%P+D+A)*

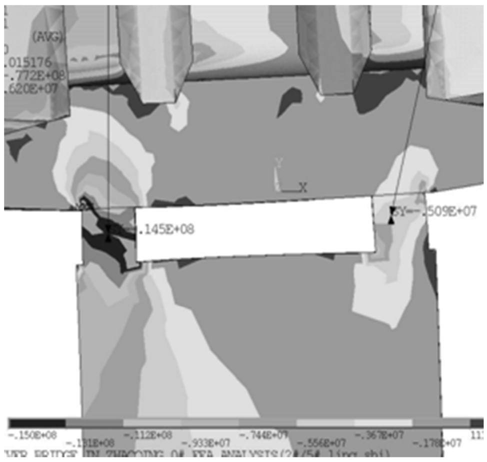

Fig. 6 *Stress (width=1.0 m 50%P+D+A)*

6. CONCLUSIONS

By using the general finite element program to model the long-span, PC rigid-frame-continuous beam bridge and applying the load, we have analysed its construction state, focussing in particular on the stress state of the temporary block, and we have discussed the effects caused by the change of prestress and size. The results have shown that:

(1) The temporary state of construction of a bridge with long-span, PC rigid-frame-continuous beams must be analysed in detail, especially the stress state of the temporary connection block.

(2) The case in which one-side hanging basket falls down suddenly during the analysis of the stress state of the temporary block should also be considered, because it can cause the crushing failure of the temporary block, which can be dangerous.

(3) By adjusting the value of the prestress and the block's size in detail, we can get an optimal state of the temporary block. The effect of the adjustment is fairly obvious.

(4) Except the adjustment of the prestress and size, we also propose the increase in the hoop stirrup in order to avoid crushing failure.

7. REFERENCE

[1] W. Wentao, *Rigid-frame - Continuous Combination Beams Bridge*, China Communications Press, 1993.

[2] H. Wenhua, ANSYS Civil Engineering Application Examples, China Water Power Press, 2005.

[3] W. Weifeng, Space simulation and analysis of Zhaoqing Xijiang bridge 0# block, *Journal of Chinese and Foreign Highway*, 2005.

[4] H. Dajian, Finite Element Simulation Analysis of Zhujiang River Bridge, *Bridge construction*, 2004.

[5] JTGD62—2004, Specification for design of reinforced concrete and prestressed concrete highway bridges and culverts, China Communications Press, 2004.

[6] G. Zhenhai, *The Principle of Reinforced Concrete*, Tsinghua University Press, 1999.

ANALIZA I OPTIMIZACIJA DJELOMIČNIH NAPREZANJA PRIVREMENIH BLOKOVA U PROCESU GRADNJE MOSTA S PREDNAPETIM BETONSKIM KONTINURANIM GREDNIM NOSAČIMA DUGOG RASPONA

Prednapeti most s kontinuiranim grednim nosačima koji je izveden kao okvirni sustav ima ulogu nosive konstrukcije u izvođenju. Dijelovi mosta na mjestima kontinuiteta nosača, stupovi mosta, kao i sami gredni nosači moraju se privremeno konsolidirati u procesu izgradnje. Nosivi sustav mosta se mijenja nakon što se povežu gredni nosači. Na temelju analize mosta West River, u ovom radu se razrađuje metoda simulacije gradnje mosta s kontinuiranim prednapetim grednim nosačima s privremenom konsolidacijom. Na konzolnom dijelu mosta s najvećom duljinom, određeno je trodimenzionalno stanje naprezanja i deformacija u privremenom betonskom bloku primjenom metode konačnih elemenata na modelu kontinuiranog grednog nosača. Nakon toga vrši se analiza područja gdje su naprezanja prekoračena, te se pokušavaju umanjiti predloženom metodom optimizacije. Prilagodbom prednaprezanja i veličine privremenog bloka, predloženom metodom može se odrediti veličina privremenog bloka, te omogućiti sigurna gradnja mosta s kontinuiranim grednim nosačima u slučaju kad je konzola mosta najduža.

KLJUČNE RIJEČI: *kontinuirani gredni nosači, prostorna analiza, lokalna naprezanja, analiza naprezanja, privremena konsolidacija, optimizacija.*