Research of Synchronous Jacking up Construction Monitoring and Control Technologies of Bridge

Jia He[1,a], Xingzan Gao[2,b]

[1]College of civil engineering & architecture, China Three Gorges University, No. 8 University Road in Yichang, China

[2]Hu Bei Expressway Industrial Development CO., LTD, No. 9 Long Yang Road in Han yang District in Wuhan, China

[a]244037253@qq.com, [b]gaoxingzan@qq.com

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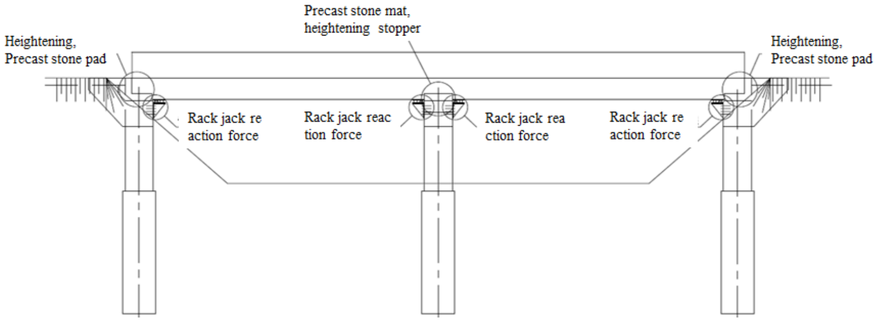
Abstract:This study is to optimize the longitudinal linear of the original route based on the jacking up construction of one bridge in the Xiamen-Chengdu Expressway project, which applied the synch ronous jacking up construction method to raise the beam and consequently achieve the designed lin ear. Through the research of the jacking up technology, the synchronous jacking up construction mo nitoring and control technologies during the whole process of the construction as well as simulate th e limit force of the beam by means of finite element software, the accurate analyzing threshold coul d be offered to the monitoring step.

Introduction

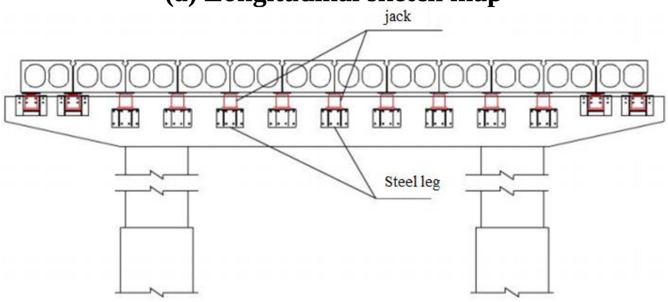
The bridge has a full length of 38 meters, and the superstructure is made up of preset hollow beams under 2 holes (16m), which is simple supported at first and then with continuous deck. The substructure is made up of double-column piers and bored pile foundation. Rectangular laminated rubber bearing is also being applied. In order to optimize the longitudinal linear of the original route, so that the bridge's operational carrying capacity will not be affected, the bridge is heightened. All in all, a Jacking up method will be used on this bridge, and the height of Jacking up method depends on how much the bridge demands to be raised.

Program Design

Jacking up Program. This bridge uses a Steel Corbel staged jacking up program, and the jacking up schematic diagram is like Figure 1 [1]. A jack that can initiate jacking force is installed in every support vertex, and the structure is jacked up by controlling the hydraulic pump drive through the console. When it comes to the projected height in each stage, the beam is fixed by temporary pads or spacers. After the jacks are raised, the jacking up work will move on to stage two. This cycle is repeated until the structure is raised to the designed height.



(a) Longitudinal sketch map



(b) Horizontal sketch map

Fig. 1 bridge type steel bracket lifting diagram

The Calculation of Support Reaction Force. The maximum support reaction force of each bearing is calculated based on the beam's constant load(Weight + Pavement), and the result should take some margin into consideration. The tonnage of the jacks should be deployed no less than 1.5 times of the calculated value [2].

Jacking up Construction Process. The process of Jacking up Construction [3] is shown as the Figure 2.

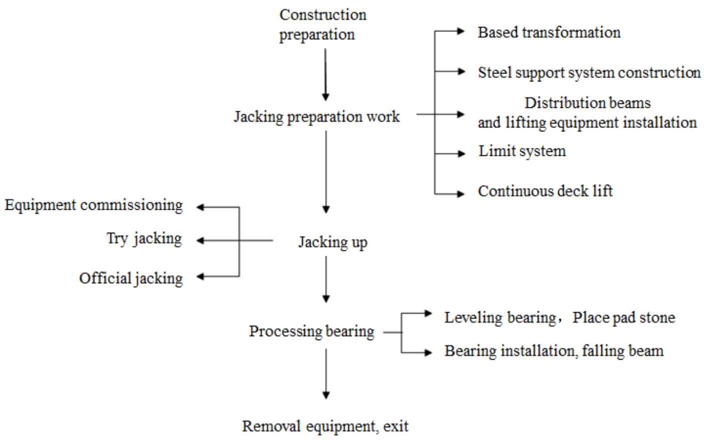


Fig. 2 The construction flow chart of jacking of beam

Jacking up Construction Technology

Placement of the Jack and Temporary Support. Because the designed hollow beam bottom thickness is poor, the jack and temporary support are placed at the beam bottom of the hollow webs, and a 0.30×0.30m2 steel plate is placed to prevent the beam bottom from concentrated force, which is shown as the Figure 3.

Fig.3 Arrangement of jacking of 0# abutment、temporary block and wire drawing sensor

Try jacking

Before the formal jacking, after all of the related constraints are removed, try a 5mm jacking up at first. Through setting different lifting speed, which is increased from 0.1mm / min to 0.5mm / min, and then lock the pilot valve to maintain the cylinder pressure and hold the pressure for 20 minutes.

Formal Jacking. The whole route of 158mm is divided into 2 stages. When the beam is jacked up into the designed height in each stage, keep the jack's oil pressure unchanged and install the temporary support. Then adjust the temporary support height to ensure the temporary support fits the beam bottom [4], and return the oil of hydraulic system and make the beam fixed on the temporary support at the same time. After the jacks are raised, the jacking up work will move on to the next stage, until the projected height is achieved [5]. The Drawing Sensor is used in the jacking system to control the lifting speed and height.

Sustained Load Stage Construction. After the jacking up is done, the whole load from the structure is transmitted to the jacks and temporary support. Scuttle the original pad stone and remove all the cement of the capping beam. Before the pad stone is placed, a 3-5mm layer of cement needs to be paved on the capping beam to level the surface, and ensure the top level. Install the new prefabricated support cushion stone, bearing, etc. to make sure the beam bearing contact closely and prevent void and partial pressure.

Synchronous Falling Beam Construction. After the bearings and pad stone are completely installed, and the hydraulic system oil returns, put down the beam slowly to the newly installed bearings, and transmit the superstructure load to the bearings. Reset the elevation of the beam top after the beam falling.

Monitoring of Synchronous Jacking up Process

Calculation of Safety Threshold during the Jacking Process of Beam. According to the design data, concrete C40 is used for hollow slab beam of bridge, and section design uses 16m span general drawings promulgated by the Ministry of Communications "superstructure of assembled post tensioning prestressed concrete simply supported hollow slab bridge" [6]. Model constraints consider the continuous lifting of the bridge, and one side slide, the other is fixed. Taking the middle beam as an example, a single beam solid mesh model is built by the software FEA Midas, which is shown in Figure 4.

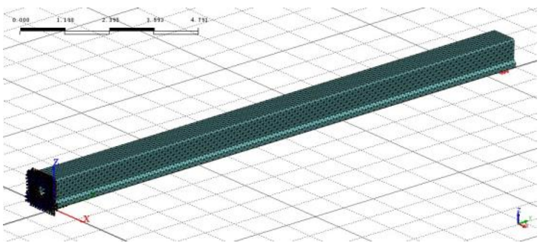


Fig. 4 Single beam solid mesh model

In order to simulate the displacement on both sides of the fulcrum during jacking, sliding end is given a certain amount of forced displacement. Through the comparison of tensile stress value of concrete on the surface of the beam and design value of tensile strength of concrete, two fulcrum maximum displacement difference threshold is determined. The calculation results are shown in Table 1.

Tab. 1 The maximum tensile stress of the beam under different forced displacement of the single beam model

Serial number	Forced displacement /mm	Maximum tensile stress of concrete beam/ MPa	Design value of tensile strength of concrete/ MPa	Cracking or not of concrete
1	1	1.089	1.65	no
2	2	1.200		no
3	3	1.312		no
4	4	1.423		no
5	5	1.535		no
6	6	1.646		yes

Jack monitoring content. Controlling the security of structure is the main goal of jacking process, monitoring early warning should be controlled by a number of indicators. Early warning is needed as long as there is an excessive. Jacking construction monitoring index and monitoring content are gathered in Table 2.

Tab.2 Jacking construction monitoring index and monitoring content table

Serial number	Monitoring index	Frequency of monitoring	Location of monitoring points	Monitoring content	Early warning value	Instrument and equipment
1	Deck elevation	3/pier (abutment)	Upper part of beam end	Elevation difference of fulcrum	5mm	Level
2	Bridge center line	2/set	Upper part of beam end	Deviate from center line	5mm	Steel ruler
3	Longitudinal displacement of beam	4/set	Upper part of beam end	Relative displacement	10mm	Steel ruler
4	Stress and strain at the bottom of the beam	3 pieces of beam/span	Fulcrum of beam bottom	Deformation of beam	33με	Surface mount type strain sensor
5	Cracks in the bottom of the beam	According to the scene	Beam bottom	Width of cracks	Limits of specification	Crack width sensor

Monitoring results of beam body before and after Jacking up. Monitoring results of displacement change:

Before and after jacking up the variety of deck elevation are shown in Table 3.

Tab.3 The elevation change of beam before and after jacking up

Number of measuring point	Position of measuring point	Actual displacement of synchronous jacking /mm	Actual displacement of synchronous falling beam in the first stage /mm	Actual displacement of synchronous falling beam in the second stage /mm	Elevation of beam body after replacement of cushion stone and support /mm	Difference of deck elevation /mm
1	Left side of 0# abutment	158.0	85.4	72.8	158.2	0.2
2	Middle of 0# abutment	158.0	85.7	72.4	158.1	0.1
3	Right side of	158.0	85.9	72.3	158.2	0.2

	0# abutment					
4	Left side of 1# pier	158.0	85.9	72.4	158.3	0.3
5	Middle of 1# pier	158.0	85.5	72.6	158.1	0.1
6	Right side of 1# pier	158.0	85.7	72.5	158.2	0.2
7	Left side of 2# abutment	158.0	85.4	72.8	158.2	0.2
8	Middle of 2# abutment	158.0	85.5	72.7	158.2	0.2
9	Right side of 2# abutment	158.0	85.5	72.7	158.2	0.2

Jacking height of adjacent jacking point of one pier is within 0.5mm and jacking height of one beam is within 0.5mm, which meets the monitoring requirements.

The beam does not appear the situation of deviation of bridge center line during the process of jacking and falling beam.

The beam does not appear the situation of longitudinal displacement during the process of jacking and falling beam.

Monitoring results of stress and strain:

The maximum strain monitoring position is arranged at the jacking point according to the calculation results of finite element software. The same across both sides of the fulcrum jacking difference should be controlled within 5mm, the press should be 33με. The bridge Jacking (falling beam) beam strain Record is shown in Table 4.

Tab.4 Strain record table of the beam during jacking (falling)

stage	0#abutment strain/με			1#pier strain/με			2#abutment strain/με			Temperature/℃
	1#	2#	3#	1#	2#	3#	1#	2#	3#	
Initial Value0mm	0	0	0	0	0	0	0	0	0	32.4
Jacking up5mm	1	2	1	1	1	1	2	1	1	32.6
Jacking up 10mm	2	3	2	3	2	2	2	2	2	33.0
Jacking up 15mm	3	3	4	6	5	7	5	4	4	33.0
Jacking up 20mm	3	4	6	6	5	7	5	4	4	33.0
Jacking up 50mm	3	4	4	6	5	6	4	4	4	33.1
Falling beam of first stage 86mm	4	5	5	4	4	4	3	3	4	32.7
Jacking up 95mm	5	4	4	3	3	2	2	2	3	32.1
Jacking up 110mm	5	4	4	3	2	3	1	2	2	32.0
Jacking up 135mm	6	3	2	2	2	2	1	2	2	32.0
Falling beam of second stage 158mm	4	3	3	3	2	2	1	2	1	32.1

According to the result measured on site, the biggest strain value of the beam during synchronous Jacking up is 7με, which is far smaller than the theoretical limit of the control value, and the structure is safe

Crack change monitoring results:

There is no significant development of the beam crack and no emerge of new crack neither in jacking up process nor after falling.

Conclusions

- The jacking up construction uses a synchronous jacking up system, with each fulcrum position jacking up and falling at the same time. During the whole operation process, the height between to neighbor jacking points in the same abutment is within 0.5mm, and within 5.0mm in the same beam, which meet the monitoring requirements.
- There is no significant development of the beam crack and no emerge of longitudinal and lateral

offset of the beam neither in jacking up process nor after falling.

- The biggest strain value of the beam during synchronous Jacking up is 7με, which is far smaller than the theoretical limit of the control value, and the structure is safe.
- By using fine entity simulation software Midas/FEA to develop single beam entity grid model, we can simulate the limit force of the beam during jacking up precisely, and accurate analyzing threshold could be offered to the monitoring step.

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