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Research on Monitoring Technology of Long-travel Jack Construction Processes of Urban Continuous Girder Bridge

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Abstract

Due to the needs of traffic construction, a flyover bridge in Xiamen is currently undergoing a jack renovation project. The existing overpass bridge is a 3-connection 9-span continuous girder bridge, and the continuous girder bridge is a statically indeterminate structure. During the jack construction process, if the deviation from the displacement attitude to the girder body and the theoretical rigid body displacement will greatly lead to excessive stress in the girder body, resulting in cracking and failure of the beam body, etc. Therefore, the whole process of construction monitoring should be carried out during the jack process. Reasonable and scientific monitoring methods can not only ensure the safety of construction, butalso reflect the technical level of bridge jack construction. In this paper, taking a flyover bridge in Xiamen as an example, combined with the finite element software simulation analysis, the monitoring work during the jack construction process is explained indetail, which can provide a reference for the monitoring work of similar projects.

Keywords

Continuous Girder Bridge; Jacking Transformation; Construction Monitoring; Simulation Analysis.

1. Introduction

Bridge jack is a difficult technique to raise the bridge from the original position to the new position through related equipment, then raise the pier, redo the bearing, and achieve the purpose of increasing the clearance under the bridge. This technology can effectively utilize existing bridge resources, and has the advantages of environmental protection, economy, high efficiency, and little impact on traffic. At present, our country has achieved some successful practices in bridge lifting, such as Tianjin Bei'an Bridge is lifted up by 1.5 meters; Shanghai Wusong Bridge's maximum lifted height of 1.36 meters; The steel box girder of Yuelu is lifted by 5.8 meters as a whole; a viaduct in Chengdu has a maximum lift of 7.42 meters.

Generally speaking, urban continuous girder bridges are quite large regardless of their volume or weight. Various factors need to be considered during the jack process, and errors should be eliminated as much as possible to prevent the bridge from cracking and damage during the jack process and cause economic losses. As we all know, the tensile strength of concrete structure is small, and it is very easy to crack when the stress is too large. Therefore, the key to bridge jack reconstruction is that the bridge beam body does not generate or only generates a small secondary stress during jack, so that the Rigid motion of beam. In order to ensure the safety of the bridge during the jack process, it is necessary to conduct real-time monitoring of the stress, displacement in the beam and the basic

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steel support. In the jack reconstruction project of Shanghai Yangsi flyover bridge, the mode of self-monitoring and third-party monitoring was adopted, and the jack error was setting in advance. by refining the monitoring plan in the early stage and using it accurately in the construction, all the parameters and indicators in the jack construction are controlled within the error range, which ensures the smooth development of the project. During the jacking construction of Zhejiang Zimei Bridge, 4 pull-wire sensors were arranged for displacement monitoring. The construction was adjusted through real-time monitoring data, and the displacement difference between the sensors was controlled within 5 millimeters. A complete detection and monitoring system have been established in the lifting project of Weifang Danhe Bridge. Through displacement sensors and stress sensors, the beam state is sensed in real time, and the lifting parameters are corrected in time. This paper takes a flyover bridge jack reconstruction project in Xiamen as an example, analyzes the monitoring work during the bridge jack process, and provides a reference for similar projects.

2. Engineering Background

A continuous beam bridge in Xiamen was builted and opened to traffic in January 2017, it crossed Guankou Middle Road with Guankou Middle Road in the form of a flyover bridge and then landed. Due to the needs of traffic construction, the bridge needs to be lifted.

There are 9 span bridges existing bridges that need to be reconstructed, and the span arrangement is 3×30+(30+40+30)+3×30 meters, and the total length of the bridge are 286 meters. The total width of the bridge are 25 meters, of which the height of the first and third beams is 2.0 meters, and the height of the second beam is 2.2 meters. Box girders are prestressed reinforced concrete structures. The cantilever length of the box girder is 2.25 meters, and the web slope is 1:2.21. Combined with the actual situation of the bridge, there are many difficulties in the jack construction. First of all, the lifting weight of a single box girder in this jack project can reach 4300t, and the maximum jack height can reach 6.73 meters. Temporary pads need to be replaced multiple times, and the strength, stiffness and stability of the support system have high requirements, and the superstructure of the existing bridge needs to be used after the jack transformation. During the jack process, the bridge deck cannot be cracked or tilted. Due to the large jack area, the precision control requirements for the multi-point synchronous jack system are very high. Therefore, the beam body needs to be monitored in real time during construction.

3. Monitoring

Existing flyover bridges are continuous girder bridges, while continuous girder bridges are statically indeterminate structures of redundant constraints. Therefore, when the displacement of the girder body of the jack process is inconsistent with the theoretical rigid body displacement, the girder body will have secondary stress, when the secondary stress is too large, it will cause the beam to crack. The monitoring of jack construction includes monitoring of stress and displacement. However, since stress is generated with displacement and the causes are complex, displacement is more simple and intuitive. In view of this, the existing flyover mainly uses displacement to guide the construction and prepare to monitor basis. Through real-time monitoring during jack, the stroke of each jack can be adjusted at any time, which can ensure that the secondary stress in the beam body is within a safe level and maintain rigid body displacement.

3.1 Strain Monitoring

Vibrating wire strain gauges and vibrating wire strain collectors were used for real-time collection of beam strains on the jack reconstruction project of the existing flyover bridge. The real-time stress is output by the stress-strain formula, and the actual working state of the beam can be directly understood. The strain monitoring section of the bridge is arranged at the middle pier of each coupling, about 2m away from the jack fulcrum. There are 12 monitoring sections in the whole bridge 3 couplings, and each section is arranged with 4 monitoring points of the bottom of the beam body.

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When the stress is greater than 0.6MPa will warn. The layout of the monitoring points is shown in Figures 1 to 2.

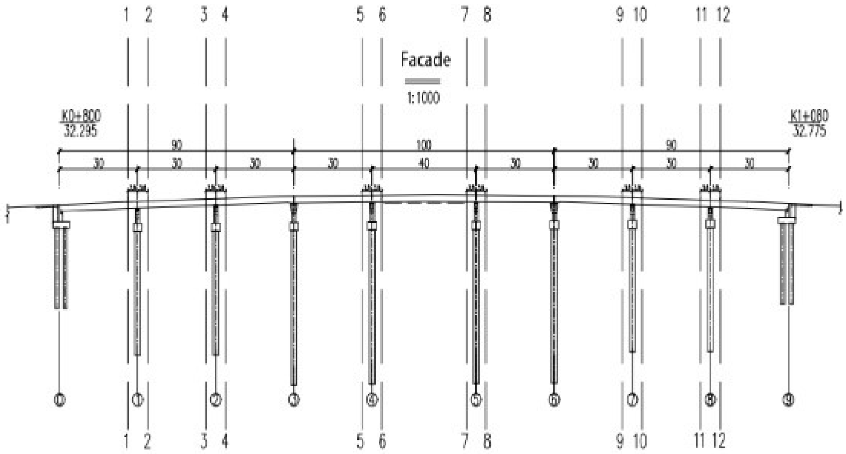

Figure 1. Schematic diagram of the strain monitoring section of the full bridge

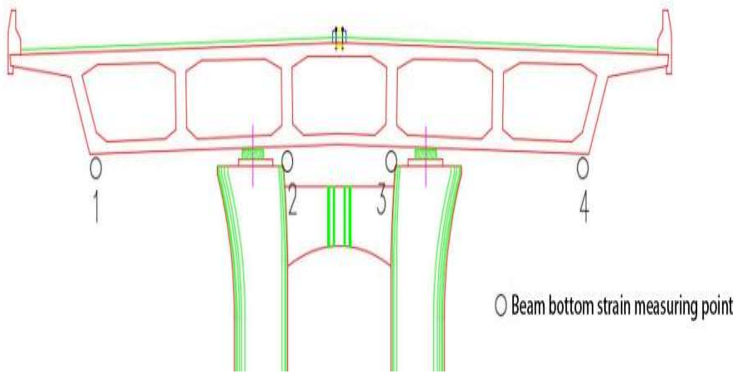

Figure 2. Schematic diagram of the layout of measuring points in each section

3.2 Displacement Monitoring

In order to make the displacement of the beam body of the jack process consistent with the theoretical rigid body displacement, it is necessary to monitor the beam body displacement in real time, especially the vertical displacement. By arranging vertical displacement sensors in the jack beam section to measure the vertical displacement of each measuring point of the key section, the beam body can be controlled evenly and balanced to rise or fall during the jack process, and prevent tilting.

There are many ways to measure vertical displacement, such as dial indicator or grating displacement meter measurement method, water level measurement, level to gauge, etc. When specific to a certain bridge, the optimal method should be selected according to the actual situation of the site. The displacement monitoring of the existing flyover bridge adopts an electronic displacement meter (grating ruler), and two measuring points are arranged at the left and right positions of the main girder of each pier, and four displacement measuring points are arranged at the beam end of the connecting pier. The common pier measuring points is included in the previous one, 8 vertical displacement measuring points are arranged in each connection, and a total of 24 vertical displacements measuring points is arranged in 3 connections with the whole bridge. The arrangement of the vertical displacement side points is shown in Figures 3.

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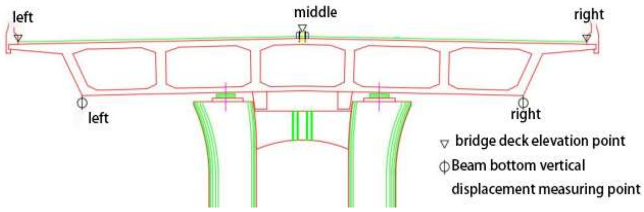

Figure 3. Schematic diagram of the layout of measuring points on the bottom surface of the beam

In fact, when the beam body is jack up, the beam body is in a floating state due to the release of the bearing limit. At this time, although it is only under a small vertical and horizontal component force, a large displacement may occur, and the bridge is in a floating state. During the breaking process, due to the change of the longitudinal slope, the horizontal projection length of the beam changes, resulting in the closing and opening of the expansion joint, which affects the installation of the expansion joint in the later stage. Therefore, a limit device should be installed at the expansion joint and displacement monitoring should be carried out to ensure that the expansion joint installation can be carried out smoothly in the later stage.

Existing bridges usesd a digital dial indicator to monitor the expansion joints, and the displacement monitoring point is installed at the top of the 0# abutment expansion joint when the first joint is jack up; The displacement monitoring points of the second and triple jack is installed on top of the expansion joints on top of the 3# pier and the 6# pier top, and each expansion joint is arranged with two symmetrical measuring points on the left and right. For the lateral displacement of the beam body, monitor the expansion joint of the jack beam body and the beam end of the free beam. The monitoring method of the expansion joint is to draw a lateral displacement observation line of the bridge deck on both sides with the expansion joint in advance, and measure the lateral displacement of the beam with a steel ruler every two strokes during the jack process.

Figure 4. Strain measuring point

Figure 5. Displacement measuring point

4. Simulation Analysis of Jack Process

In the actual lifting process of the bridge, there may be inconsistent jack strokes, resulting in forced displacement of the beam body, and excessive tensile stress resulting in cracking of the beam body. Therefore, the forced displacement of the bridge under various working conditions is calculated, and the corresponding forced displacement value is obtained when the maximum tensile stress of C50

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concrete (1.85MPa) is not exceeded. The calculated data can provide a reference to the jack construction, and can be compared with the real-time monitoring data to determine whether there is forced displacement of the beam during the jack process.

Now take the second link of Xiamen flyover bridge as an example, 8 working conditions are used in the calculation. Condition 1: No. 1 and No. 2 constraints impose a vertical displacement of 10mm upward; Condition 2: Constraints No. 3 and No. 4 impose a vertical displacement of 10mm upward; Condition 3: No. 1, No. 2, No. 5, No. 6 restraint with 10mm upward vertical displacement; Condition 4: No. 3, No. 4, No. 5, No. 6 constraints impose a 10mm upward vertical displacement; Condition 5: No. 3 and No. 5 constraints impose a 5mm upward vertical displacement; Condition 6: No. 1 and No. 6 constraints impose a 5mm upward vertical displacement; Condition 7: Constraint No. 1 applies a vertical displacement of 5mm upward; Condition 8: Constraint No. 3 applies a 5mm upward vertical displacement. The stress cloud diagrams of the beam body along the bridge under each working condition are shown in Figures 7 to 14.

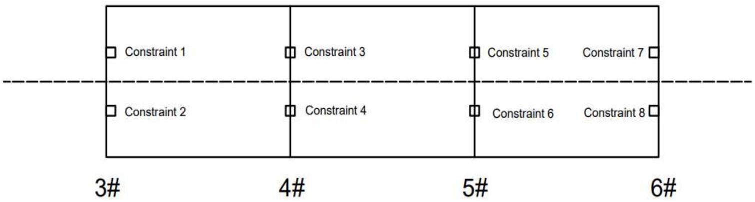

Figure 6. Layout of the support constraints of the computational model

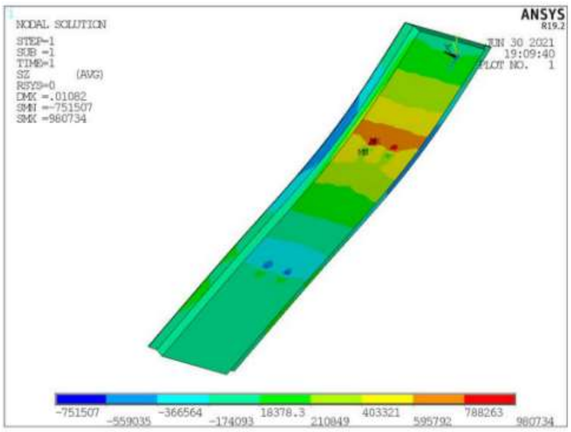

Figure 7. Stress cloud diagram of working condition 1

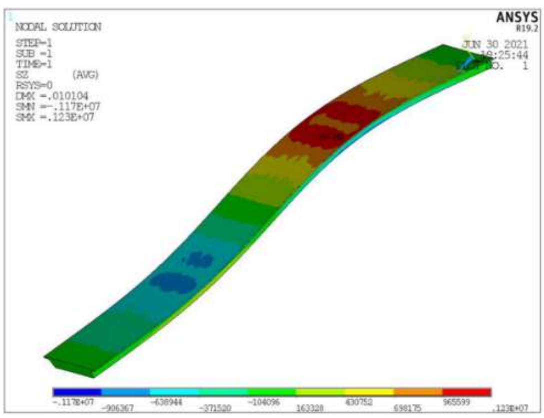

Figure 8. Stress cloud diagram of working condition 2

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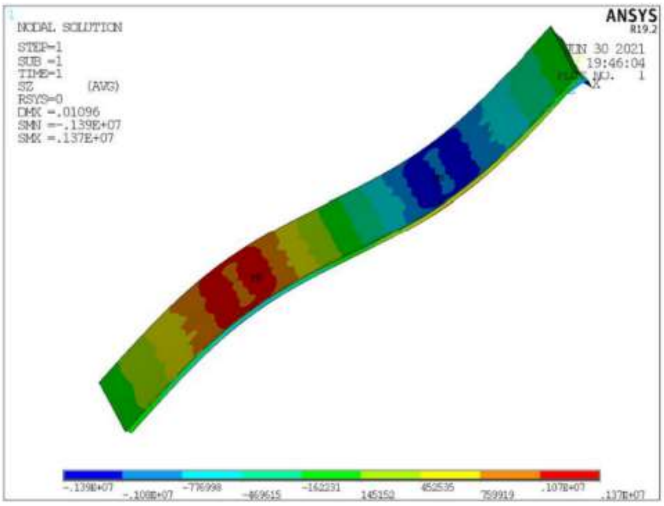

Figure 9. Stress cloud diagram of working condition 3

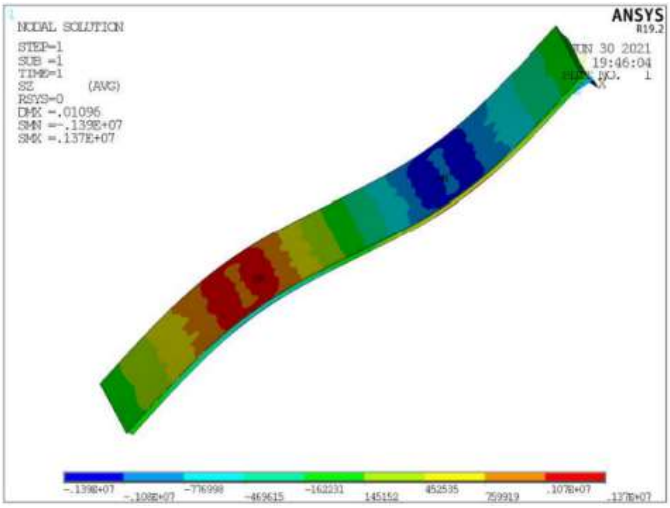

Figure 10. Stress cloud diagram of working condition 4

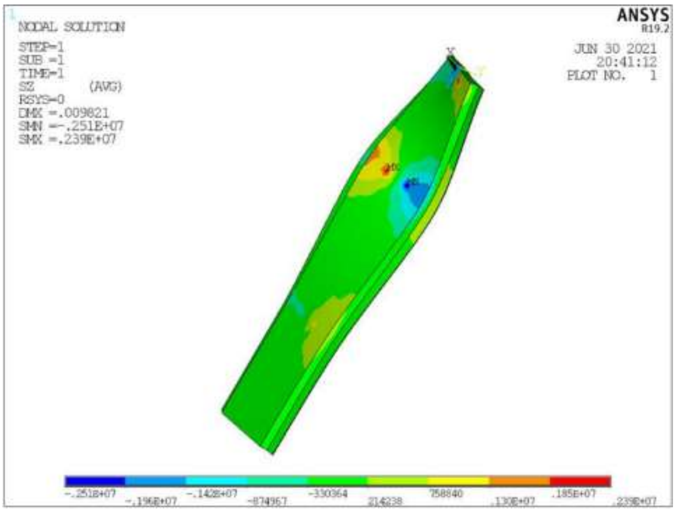

Figure 11. Stress cloud diagram of working condition 5

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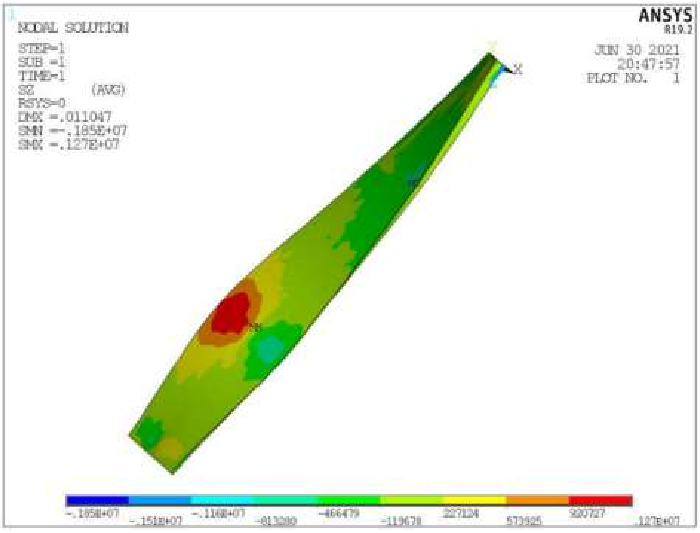

Figure 12. Stress cloud diagram of working condition 6

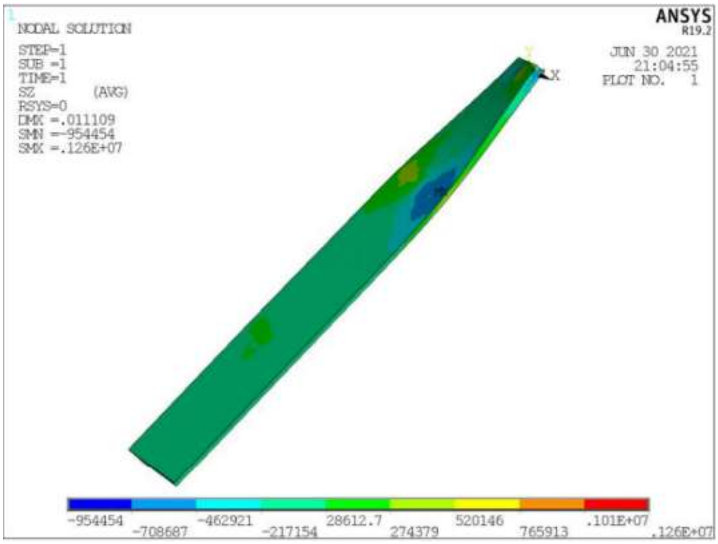

Figure 13. Stress cloud diagram of working condition 7

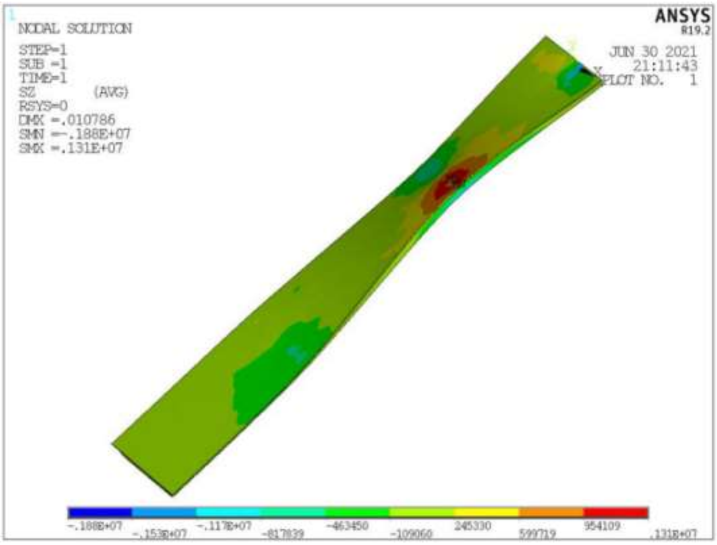

Figure 14. Stress cloud diagram of working condition 8

In the first four conditions, the forced displacements are applied symmetrically to the longitudinal centerline of the bridge, and the displacement values are all 10 millimeters. From the above calculation results, it can be concluded that the maximum tensile stress when the forced displacement occurs at the non-beam end piers is about 25% higher than that when the forced displacement is at the beam end piers, and when there are adjacent non-beam ends when the same forced displacement occurs in the pier, the maximum tensile stress will decrease. The reason for this phenomenon is that the forced displacement at the pier at the non-beam end will cause the weight of the beam on both sides of the constraint to put pressure on it, while the forced displacement at the pier at the beam end only needs to bear the weight of the beam on one side. In the fourth condition, the adjacent piers jointly bear the weight of the middle span and part of the side spans, so the maximum tensile stress value is relatively small. Therefore, during the jack construction, special attention should be paid to the forced displacement in the middle span. In addition, there are stress concentration phenomenon in the above working conditions, but in practical engineering, the stress concentration phenomenon is eliminated by increasing the number of jacks and set up distribution beams between the jacks and the beam body.

In the 5th to 8th conditions, the forced displacement values are all 5 millimeters. The maximum tensile stress of condition 5 is about 88% higher than that of condition 6, indicating that when the forced displacement occurs in the form of a diagonal, the closer the distance, the greater the increment of tensile stress. It can be concluded from conditions 7 and 8 that when a single constraint has forced displacement, a large tensile stress increment will appear in the corresponding bridge deck area. The difference between the maximum tensile stress values of conditions 8 and 9 is about 0.39%. It can be seen that when only a single constraint has forced displacement, the change of its position has no obvious effect on the maximum tensile stress.

Among the above 8 conditions, the forced displacement value of the latter 4 conditions is only half of the former 4 conditions, but the maximum tensile stress is generally larger. It means that if the jacks on the right at the same pier, if the strokes or pressures of the jacks on the left and right sides of the center line of the beam body are inconsistent, it will cause great harm to the beam body. Therefore, in the actual jack construction, it should be strictly ensured that the jacks are evenly distributed, and a distribution beam should be set between the jack and the beam body, and the distribution beam and the beam body should have as large a contact area as possible and closely fit the beam body. During the lifting monitoring, pay close attention to whether the stroke and pressure of each jack are synchronized.

5. Conclusion

A flyover bridge in Xiamen started smoothly in November 2021, and its construction monitoring work was also carried out at the same time. The pre-construction preparations and whether the monitoring system is perfect are the key factors of the smooth progress of the construction. Especially the monitoring work during the whole construction process, which not only escorts the safety of the jack construction, but also reflects the bridge jack construction technical level. In this paper, due to its maximum weight of 4700t and maximum jack height of 6.73 Meter, the flyover bridge in this paper has greatly increased the difficulty of jack construction, and the errors in the construction process also need to be controlled to a smaller extent, which brings great influence to the monitoring of jack construction and it's quite a challenge.

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