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Review Article

The Study of Force and the Mechanical Characteristic of Incremental Launching Construction Method on a Steel-Concrete Continuous Beam Bridge

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Abstract: The usage of steel-mixed composite beams is quite extensive today. During an event of constructing steel-mixed composite bridges, the incremental launching construction method is generally adopted. This paper mainly analyzes the force of incremental launching construction on a steel-concrete continuous beam bridge, the classification of incremental launching construction, the application of incremental launching construction in steel-mixed composite beams, the temporary facilities existing in incremental launching construction as well as their existing problems. Lastly, the analysis of the stress of composite beams in incremental launching construction is described by using the reference for the construction of mixed composite continuous beam bridges provided.

Keywords: Steel-Concrete Composite Beam, Incremental Launching Construction Method, Force, Displacement

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1 Overview of incremental launching construction method

1.1 Classification of incremental launching construction method

There are two categories in the incremental launching construction such as single point launching and multi-point launching. Multi-point launching is divided into drag type launching, wedge type multi-point launching, step type multi-point launching and dragging multi-point launching. The construction progress of drag type multi-point launching is slower, but the cost is lower[1]. While the cost of wedge-type multi-point pushing is high, the construction progress is relatively fast. At the same time, the step type multi-point launching construction progress is also relatively high.

1.1.1 Force calculation for single point launching

The horizontal force of the pier is:

$$H_i = F - R_i(\mu_i + k_i)(i = 1,2.....n)$$

The horizontal force of the slide abutment is:

$$H_i = R_i(\mu_i + k_i)(i = 1,2.....n)$$

H_i : horizontal force;

F : the horizontal force provided by the launch;

R_i : beam body reaction force;

μ_i : friction coefficient;

k_i Resistance coefficient.

1.1.2 Formula for calculating the force of multi-point launching

Longitudinal displacement calculation formula:

$$\left|F_i - R_i(\mu_i + k_i)\right| \le \left[H_{i许}\right](i = 1,2......n)$$

The range of the difference between thrust and resistance:

$$0 \le \sum F_i - \sum R_i(\mu_i + k_i) \le \left[H_{i许}\right](i = 1,2......n)$$

The horizontal thrust formula that the beam body receives when moving is:

$$H = R_i(\mu_i + k_i) - F'(i = 1,2.....n)$$

F_i: the horizontal force provided by the launch;

μ_i: coefficient of friction;

k_i: resistance coefficient;

R_i: beam body reaction force;

$H_{i许}$: withstand horizontal forces allowed;

$\left[H_{许}\right]$: total value;

F' : Malfunction or weak load force at top thrust.

1.2 Application advantages of incremental launching construction in steel-concrete composite beams

The steel beam has a relatively light weight and is widely used in the combined structure. The applicable range is also wide. As an example, in a straight bridge construction or a flat curved bridge construction, the curvature of the flat curved bridge construction is constant, and it be applied in contours as well as in variable height beams. Therefore, it does not matter which beam construction it is, steel beams can be used without temporary piers. This is due to steel beam structure obtaining a light weight and it can be set up to a maximum of 100 meters. In addition to its light weight, the pier and steel beam structure also have strong resistance to compression and are more competitive in comprehensive competitiveness[2].

Next, when the steel beam is under construction, the construction steps and the concrete structure panel are separately carried out. The steel beam structure has a light weight. Therefore, it is possible to first consider whether the steel beam has been installed or not. The steel beam has a light weight and can be lowered during construction. Thus, it can reduce the requirements for construction equipment. At the same time, the position of the steel beam structure can be set first, and then the concrete panel is constructed. Based on the assumed position of the steel beam, the concrete is poured on the panel, or the prefabricated panels are laid. The bridge panels can be cast in place or prefabricated. After the bridge panels are completed, the steel beam structure is constructed.

1.3 Temporary facilities in incremental launching construction

Incremental Launching Construction is necessary to build temporary facilities and assist in the completion of the construction. There are four kinds of temporary facilities in incremental launching construction, which are four temporary devices, such as launching platform, temporary pier, guide beam and sliding device.

1.3.1 Launching platform

Article 1.7.7.7 of the Technical Specification for Construction of Highway Bridges and Culverts (KJTG/TF50-2011) stated: The bottom template of the prefabricated pedestal shall conform to the curvature of the vertical curve of the design. The launching platform can support the lifting of the steel beam in the incremental launching construction, the pre-assembled support and the lifting platform of the steel box girder as well as the starting platform for the incremental launching construction. When the launching platform is set, it needs to meet four requirements. The first requirement is that the platform needs sufficient strength, the second is that the platform needs sufficient rigidity, the third is that the platform needs sufficient elevation and can be adjusted, and the fourth is that the platform also needs a beam sliding system and a guiding installation system. When the launching platform is set, it should be set according to the arc shape[3] to facilitate the processing and construction of the steel beam box.

1.3.2 Temporary pier

When the temporary installation is pushed, the temporary pier has deformation problems during installation and errors in manufacturing, which may cause the effect of the temporary pier to be unobserved. Moreover, when the set height does not meet the requirements, it will cause the beam structure to be faulty. In addition, severe hazard might also occur where by the possibility of beam falling off and partial overhead in the temporary pier setting. Therefore, in order to avoid this, we must first control the quality of the temporary pier to avoid deformation, and secondly control the elevation of the temporary pier, thus reducing the problem of the launching process. Finally, strict monitoring of the set value is the same as the demand value, reducing the cost loss during the launching process. The temporary pier has three functions in the pushing process. Firstly, it can reduce the radius of the main beam during the launching process and reduce the stress on the main beam. Secondly, it can assist the construction of the guiding beam. Finally, it can assist the main beam where rotation with each segment of the beam occurs.

1.3.3 Beam guide

The beam guide is an important temporary back, which plays a key role in the launching process. It mainly ensures that the main beam does not have problems when it is built. It also reduces the displacement change during the pushing process and control the main beam in the construction. The length of the cantilever is such that the main beam does not collapse.

1.3.4 Slide device

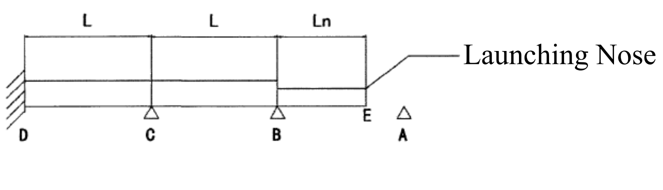
There are two types of sliding devices such as a horizontal-vertical jack-type launching device. This sliding device includes a friction pad, a slider, a sliding plate and a slide. The other sliding device is used for incremental launching method, which it comprises more structures than the jack-type. In addition, the width of the slide is required to be consistent with the direction of the launching manner. There are also many problems in the setting of the sliding device. During the use of the sliding channel, friction will occur with the main beam and the beam guiding, resulting in serious wear of the sliding channel and a rough surface[4] when the main beam and the guiding beam are not in use. Therefore, in order to prevent friction, the surface of the slide is scratched, burrs appear, and the speed of launching is controlled during the launching process.

2 Analysis of force on composite beam during launching process

At begin, before starting to calculate the force analysis, it is assumed that the parameters of the steel-concrete composite beam represent symbols and the self-weight load of the beam guide is q_n, bending resistance is E_nI_n, the length is l_n and the main beams are q, E, l. According to each parameter, the length ratio of the main beam and the guide beam, the self-recovery degree and the stiffness ratio are set respectively as $\alpha = \frac{l_n}{l}$, $\beta = \frac{q_n}{q}$ and $\gamma = \frac{E_nI_n}{E}$. Plus, according to the force parameters of the set steel-concrete composite beam during the launching process, the following is a detailed analysis of the force of the main beam and the beam guide during the launching process.

2.1 Analysis of force on main beam during launching process

The force of the main beam during the launching process can be divided into three stages and the force process of each stage is different. The first support point of the guide main beam in the launching process is A, the second support point is B, and the third support point is C. As shown in Figure 1, the force analysis of the beam guide and the main beam is performed according to the model. Here are three procedures:



2.2 First stage

In the first stage of the force process, the beam guide is also divided into two force processes. The first one is that the force beam is not extended before the B point: $M_{B1} = \frac{q_n a^2 l^2}{2}$. Then, the difference between the beam guide and the main beam is 0; the second is that the beam guide completely protrudes from point A, but still does not extend point B and the force calculation formula at this time is $M_{B1} = -[q_n l_n (0.5l_n + x) + 0.5qx_2]$. When the beam guide reaches point A but does not extend point B, the force process of the main beam and the beam guide currently is the force analysis of the second stage.

2.2.1 Second stage

At the second stage of the force analysis process, the force process can be regarded as the process of repetitive motion. After the completion of the second stage, each subsequent stage is equivalent to repeating the first and second stages of exercise stress. In addition, the parameter variables for setting the displacement of each node in the future are θ_A, θ_F, ΔF, θ_B, θ_C, θ_D, etc. The force process is:

$$A: 4i'\theta_A + 2i'\theta_F + \frac{6i'}{l}\Delta F + (-\frac{1}{2}q_n(l_n + x - l)^2 + \frac{1}{12}q_n(l-x)^2) = 0$$

$$F: (4i' + 4i)\theta_F + 2i'\theta_A + \left(-\frac{6i'}{l} - \frac{6i}{l}\right)\Delta F + 2i\theta_B + \left[-\frac{1}{12}q_n(l-x)^2 + \frac{1}{12}qx^2\right] = 0$$

$$\left(\frac{12i'}{(l-x)^2} + \frac{12i}{l^2}\right)\theta_F + \frac{6i'}{l}\theta_A + \left(\frac{6i'}{l} - \frac{6i}{l}\right)\Delta F + \left(-\frac{6i}{l}\right)\theta_B - \left[\frac{1}{2}q_n(l-x) + \frac{q}{2}x\right] = 0$$

$$B: (4i_1 + 4i)\theta_B + 2i\Delta F + \left(-\frac{6i}{l}\right)\theta_F + 2i_1\theta_C + \frac{1}{12}q(l^2 - x^2) = 0$$

$$C: 8i_1\theta_C + 2i_1\theta_B + 2i_1\theta_D = 0$$

$$D: 4i_1\theta_D + 4i_1\theta_C + \left(-\frac{1}{12}ql^2\right) = 0$$

In the formula: $i' = \frac{E_nI_n}{l-x}$; $i = \frac{EI}{x}$; $i_1 = \frac{EI}{l}$

2.2.2 Third stage

At the third stage of the force process, the force formula is:

$$M^{EOL} = \left(0.134\alpha^2\beta - 0.106\right)ql^2$$

As a summary, according to the analysis of the force process in the first two or three stages, the first stage and the second stage have a greater impact on the launching process. Thus, as long as the parameters of the first stage and the second stage are controlled, the entire process of launching the top can be indirectly controlled.

3 Steel-concrete composite beam launching precautions

3.1 Force and deformation of the beam

Firstly, before an incremental launching construction, the construction process and construction steps need to be determined. The construction basis must be safe and reliable. At the same time, it needs to ensure that the structure of the bridge will not be affected during the construction, which will then affect the steel beam as well. Secondly, when carrying out the launching construction, the steel beam generally only needs to bear its own weight. In the operation of the leave, in addition to its own weight, it will also bear the load caused by the construction. Therefore, in the process of launching up, it is necessary to pay attention to the adaptation process of the beam in the launching process. This is to avoid the damage of the beam structure caused by the uneven force as well as destroy the stability and safety of the steel-concrete composite beam structure. In the design of the incremental launching construction, it is necessary to consider this issue and propose corresponding control measures. Firstly, it is necessary to calculate the force process of the launching process and needs extra monitoring to ensure that the beam will withstand the least damage or damage in the launching construction. In the process of launching, if the span of the bridge is too large, an anemometer[6] needs to be installed at the construction site to control the whole process to control the force and deformation of the beam.

3.2 Height of launching support

During the construction of the bridge, there are generally curves and slopes. In the case of launching construction, there will inevitably be a problem of system height difference. As an example, there is a certain height difference in the process from the initial position of the steel beam to the key position. Therefore, when constructing the launching platform and the temporary pier, it is also necessary to consider the problem of height difference. When designing, you also need to set the preset height and the height of the contour of the bridge. In addition to considering the support height during the push-up process, it is also necessary to consider the number of height adjustments of the launch during the process to avoid frequent adjustment of the support height. This will result in errors and construction errors during the launching process, thereby affecting the safety of the bridge.

3.3 Applicability of the launch method

The launching construction method is a commonly used bridge construction method. The first use is the light weight of the steel structure. Secondly, the combination of the launching construction and the steel structure can reduce the requirements for the construction of temporary equipment. Plus, it does not require a special use. The construction equipment reduces the difficulty of construction and operation. However, when constructing bridges in places with poor environmental conditions, it is not suitable for the application of launching construction. As an example, such as bridge construction in deep valleys and large rivers.

When the steel beam is under construction, the supporting platform is similar to the basic conditions of the factory processing. The platform conditions for the construction are greater and the construction environment is safe. In addition, it is convenient to adjust the position and height of the steel beam, which is beneficial to the welding work on site[7].

There are many additional equipment required for launching construction. At the process of different construction stages, the corresponding construction technology needs to be selected. The slides used in the launch construction are used for lifting and guiding. The interactive devices are also divided into two types. First is a horizontal-vertical jack-type push-type sliding device and the other is a draw-bar pushing-type sliding device. When used, these sliding systems require high operation technology and relatively large difficulty.

4 Conclusion

In the construction of steel concrete composite beams, the temporary facility guide beam is a very important facility. The main method of construction of steel-protected composite beams is the launching construction method. It is crucial to pay attention to the force process of the main beam and the beam guide during the launch construction process. Moreover, it is also necessary to pay attention to the force and deformation of the beam body, the support height of the launch and the type of the bridge to be applied during the launching construction process. In this paper, when the force process of the main beam is analyzed, the assumed parameter method is adapted, and the bridge is calculated according to the specific formula according to the calculation formula. Force analysis of steel-concrete composite beams is beneficial to improve the stability and safety of the bridge structure and improve the performance of the bridge.

References

[1] Pan J. Research on Key Technologies for Manufacturing and Construction of Steel-Concrete Composite Continuous Beam of Hong Kong-Zhuhai-Macao Bridge[D]. Southeast University, 2017.

[2] He Y. Study on Structural Behavior of Continuous Steel Box Girder Bridge during Walking and Launching construction[D]. Chongqing Jiaotong University, 2017.

[3] Yang S. Study on the Thrust Characteristics and Application of Multi-Slide of Concrete Box Girder Bridge[D]. Changsha University of Science and Technology, 2017.

[4] Zhao RD, Zhang SY. Research Status and Development Trend of Bridge Pushing Construction[J]. China Journal of Highway and Transport, 2016, 29(02):32–43.

[5] Liu SY. Application of Incremental Launching Construction Method in Corrugated Steel Web Composite Box Girder[D]. Hunan University, 2014.

[6] Huang HB. Research on Stimulation Analysis and Construction Control of Continuous Girder Roof Demolition and Construction Process[D]. Chang'an University, 2013.

[7] Wang W. Research on the Linear Control and Force Characteristics of the Continuous Composite Box Girder Bridge with Large Pick-up Arm[D]. Changsha University of Science and Technology, 2013.