

# Research on the Precision Control Technology of Short - line Segmental Prefabricated Assembly Bridge

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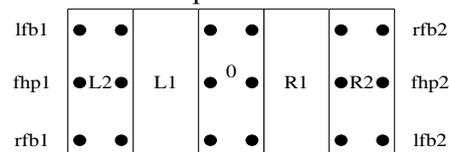
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**Abstract.** Short-line prestressed assembly bridge construction method has been widespread used for more than 10 years in China, unlike the "wysiwyg" cast-in-place beam, prefabrication and assembling construction process control is more important, especially for the virtual segment assembly. Due to the short line method commonly used in the large-scale bridge project, it is necessary to research intensive construction control, and improve the level of short line method. This article studied in two ways: the precast assembling error processing and precision control based on parametric analysis of the structure deformation.

## 1. Introduction

Short line method of precast segmental construction with high efficiency, concrete quality assured, convenient for transportation and hoisting, and many other advantages, Since the widespread use in the Sutong bridge, there are more bridges using this method for bridge construction in China, such as Nanjing fourth bridge, Xiazhang cross-sea bridge, Quanzhou bay cross-sea bridge, Wuhu second bridge and Humen second bridge, etc. Bridges in the process of segmental precast cannot be controlled like cast-in-place beam through simple measurement and calculation, but by the three-dimensional coordinates of measuring points on each segment to build the virtual bridge line shape, while assembly process is the actual reduction of this virtual shape.



**Figure 1.** Schematic diagram of measuring points

Therefore, whether the actual bridge line shape under construction virtual line shape are consistent, determines the comfort of the structure of the bridge and the consistence with design intent. We shall take intensify construction control on the bridge prefabrication and assembling process to make the bridge line shape meets the requirements.



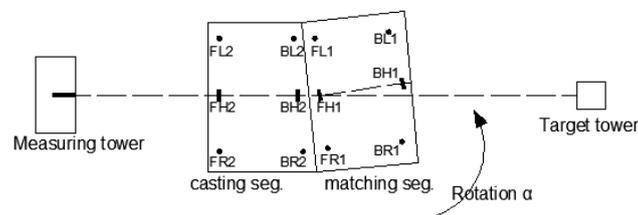
## 2. Prefabrication and assembling process

Bridge short line method of precast concrete construction technology steps as follows:

- (1) Installing templates, prefabricating the first segment, namely the starting block;
- (2) The starting blocks will launch to the matching beam position, with its end as the next casting girder end template, then complete casting of the next segment;
- (3) With  $n - 1$  # block as  $n$  # block matching segment, circulating operation, we can complete all of precast beam segments.

No matter what method is used to control the line shape, the basic principle is to control the relative position between adjacent segments precasted, and carries on the line shape adjustment according to the error situation, therefore it needs measuring points on the beam.

Specific approach is to set up two opposite measuring tower, and the control system is composed of fixed formwork and the center line of the the two measuring tower. After girder casting is completed, using total station to collect 3 d coordinates of measuring points data (including fixed end formwork, casting beam segment and the matching beam segment), and through error analysis to forecast adjustment, to ensure accuracy of the next precast beams.



**Figure.2** measuring point and measuring tower system arrangement

This system can be very intuitive judgment for fixed end and measuring the relative position of the beam segments, matching position of the axis of the beam segment. The time of matching segments and correct fixed end model, measuring tower deviation is shorter, so widely used in China. The measuring tower is necessary facilities, to meet the "high precision, small deformation, no obvious settlement" requirements. Engineers should take regular calibration correction and maintenance.

Assembling process is: firstly completing the installation of the pier-top beam segment, after the bridge installing machine was settled on the pier top block, symmetricly lifting the middle beam segments, finally installing the side span.

Construction control is a "construction - test and measurement error analysis - parameter adjustment - construction prediction and correction" process. To reach the ideal state, as far as possible need to keeping track of calculation and analysis in construction process, constantly adjust and perfect the calculation parameters.

Bridge construction control is a systematic engineering, mainly includes two parts: the part of data acquisition system, namely monitoring the changes of main girder structure during the construction elevation and stress state, the construction site, structure, main section material test results such as the elastic modulus of concrete, bulk density, etc.; Another part is data analysis and processing system. The former is used in the structural arrangement of measuring point or sensors to obtain a large amount of data to be used for site analysis. The latter is the use of special bridge structure analysis software to analyze the field data obtained, adjusting the construction parameters. Through the organic combination of both, control the internal force of the bridge and line shape, achieve the internal force of bridge structure and the line shape designed value at the same time, to ensure the bridge during the construction and normal operation.

## 3. Deviation of the theoretical and the actual situation

For concrete continuous girder or continuous rigid-frame bridge, the cantilever construction process of the structure is statically determinate structure, such as the closure phase is not imposed additional pressure, it will not deviate from the design state too much, so the main target of construction control is geometric line shape control. This article assumes that all of the calculation of of the final closure

would not adopt additional pressure.

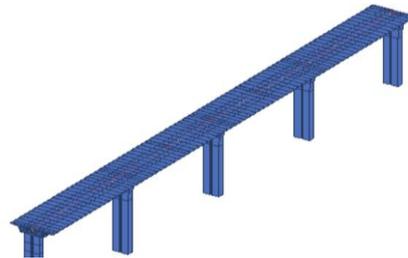
### 3.1. The selection of structure parameters

Main parameters of concrete bridge include concrete density weight (beam), modulus of elasticity, etc. Research mainly focus on girder self-weight, elastic modulus of concrete beams and beam maintenance period, its aim is to estimate the influence of the line shape into a bridge under the changes of the parameters. In this paper, we discuss the specific parameters and range as shown in table 1, "+/-" in table means add, subtract; for example, girder self-weight + / - 5%, means self-weight increase or decrease by 5%.

**Table 1** Structure main parameters

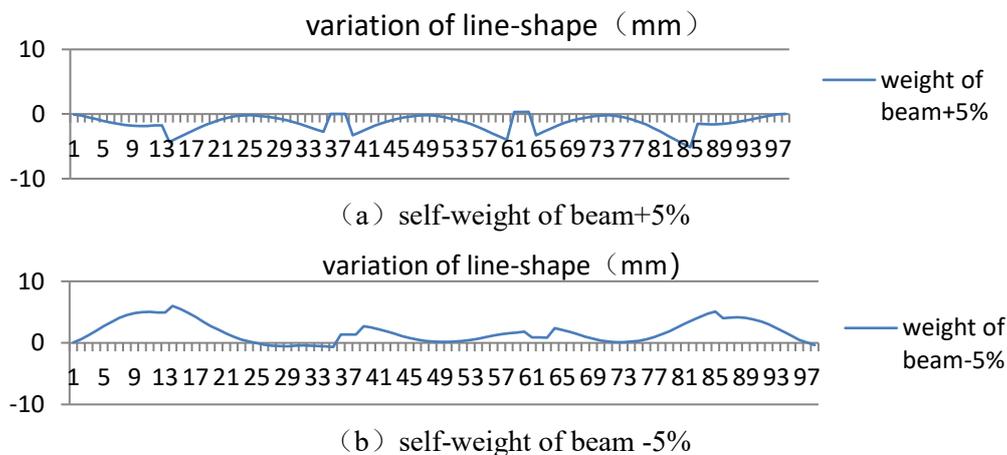
parameter	benchmark status	Change a	Change b
self-weight	design value	+/-5%	-
elastic modulus of RC	3.55E+4(Mpa)	+/-5%	-
maintenance period	3 months	2 months	1 months

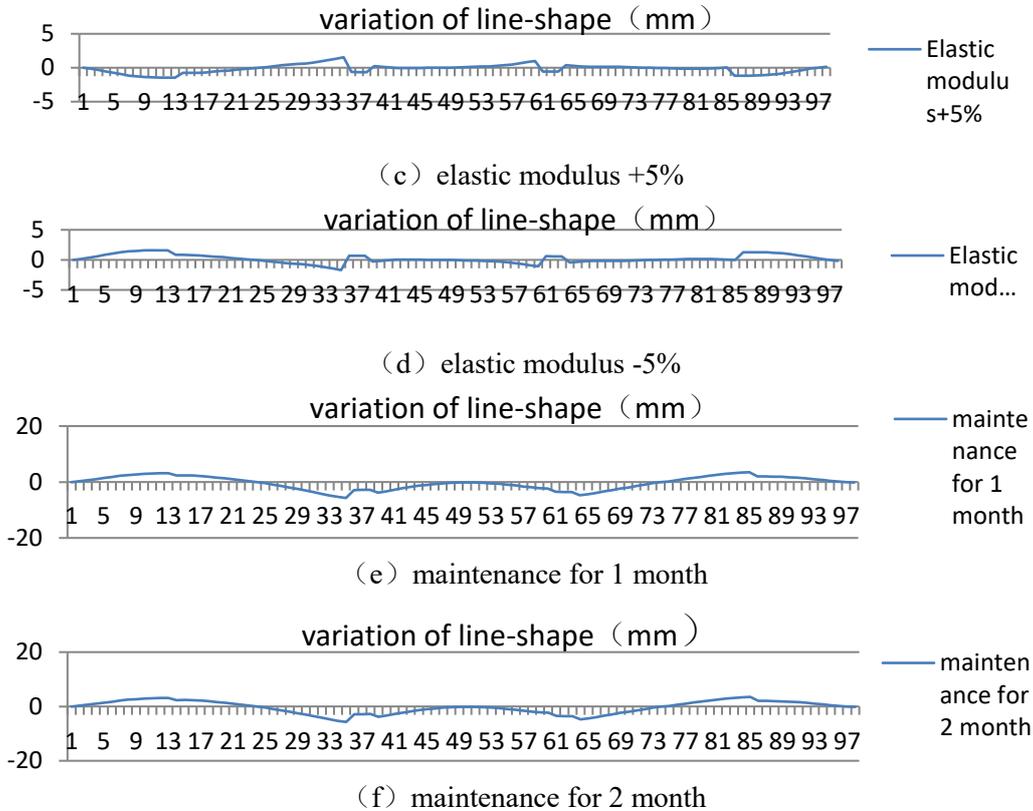
Calculation using the parameters changed that need to explore, and the rest of the parameters are the same with the status of the benchmark. For example, a 5% increase in weight, other structural parameters using benchmark state. Parameter sensitivity analysis using a project which with a 5 x 55 m span bridge as an example, and TDV RM2006 bridge finite element software is adopted to establish the model analysis.



**Figure.3** bridge structure finite element model

After the adjustment of structural parameters, the line shape variation of the structure of the bridge is shown as below(1~97 means points of finite elements).





**Figure.4** variation of line-shape ( mm )

Through calculation and analysis, it can be sure: bridge structure deadweight is most infecting, in the process of construction we should strictly control the beam section to match design value and the deviation of self-weight, and after completion of the precast, weighing and model calibration should be taken to ensure beam segments assembling accuracy.

**4. Precision processing of prefabricating error**

*4.1. Precast control calculation principle*

At the top of each segment the control points with 3d coordinates directly control the relative position between the adjacent segments. In the process of prefabrication, coordinate transformation process is as follows:

- (1) Assume a n# precast segmental block, coordinates of measuring points is known, the matching segment is ( n - 1 ) # block;
- (2) Calculation 3 d coordinates on n - 1 # block as below.

$$\begin{Bmatrix} x_3 \\ y_3 \\ z_3 \end{Bmatrix} = \begin{bmatrix} x_x & x_y & x_z \\ y_x & y_y & y_z \\ z_x & z_y & z_z \end{bmatrix} \begin{Bmatrix} x \\ y \\ z \end{Bmatrix} \tag{1}$$

Where,  $x_3$ 、 $y_3$ 、 $z_3$  for coordinates means 3 d coordinates of n - 1 # block measuring points in the overall system;

x, y, z for coordinate values of n - 1 # block measuring points under local coordinate system;

[ ] for n - 1 # cosine coordinate matrix.

(3)  $n - 1$  # measuring points coordinate values under  $n$ # blocks coordinate system as below.

$$\begin{Bmatrix} x_4 \\ y_4 \\ z_4 \end{Bmatrix} = \begin{bmatrix} x_x' & x_y' & x_z' \\ y_x' & y_y' & y_z' \\ z_x' & z_y' & z_z' \end{bmatrix} \begin{Bmatrix} x_3 \\ y_3 \\ z_3 \end{Bmatrix} \quad (2)$$

where  $x_3$ 、 $y_3$ 、 $z_3$  for coordinates of  $n - 1$  # block measuring points in the overall system;  
 $x$ ,  $y$ ,  $z$  for coordinate values of  $n - 1$  # block measuring points under local coordinate system;  
 $[\ ]$  for  $(n - 1)$  # cosine coordinate matrix.

#### 4.2. precast error analysis

Prefabrication process error will make the virtual assembly deviating from its true line, error mainly includes the following parts:

(1) Measurement error: data of control points on  $n - 1$  # and  $n$ # blocks are obtained by level and total station instrument to measure, in addition to the inherent error of instrument, environment, personnel and other factors will also cause measurement error; That is to say, to reflect the relative position relations between adjacent segment is not absolute precision, and the error in the case of large span Bridges may continue to enlarge;

(2) A single point of maximum error and error data: the data acquisition of all the standard segments are in different working condition of part 2 in this article. Two kinds of working condition of the measurement data in theory by tiny coordinate translation and rotation are essentially coincident, but due to a single point of maximum error or data error, there may be a single point cannot overlap, and other points coincide. If adopted such a single point in the process of calculation data, in the case of difference is bigger, will seriously affect the accuracy of precast.

#### 4.3 The refinement of precast error handling

In type (2), the coordinate transformation matrix based on  $n - 1$  # segmental precast and match the two different conditions, in the absence of error, the transformation matrix is the only exist. If errors is considered, we need reasonable processing of measurement data, to solve the transformation matrix equation.

$$\begin{bmatrix} x_x' & x_y' & x_z' \\ y_x' & y_y' & y_z' \\ z_x' & z_y' & z_z' \end{bmatrix}_{\text{theoretical}} \Rightarrow \begin{bmatrix} x_x' & x_y' & x_z' \\ y_x' & y_y' & y_z' \\ z_x' & z_y' & z_z' \end{bmatrix}_{\text{actual}}$$

Most of error processing adopt nonlinear least square method and least square method based on the simplified model. The former considers all measured data, the coordinate transformation matrix of the nonlinear equations are linearized, calculate the precast and matching phase control point coordinates, to the closest state, then get the actual matrix; The latter on the premise of guarantee enough constraint, then decrease the number of equations, to ensure the convergence of the calculation results, also we can get the actual matrix .

That is to say, the result is obtained by using the nonlinear least squares, there may be no convergence; Considering the existence of single maximum error, blindly use all measurement data in calculation will reduce the precast precision. Therefore, if there's a single point with one largest error, the following process may make sense:

(1) Set a convergence criteria. Matching data generated in theory transformation matrix and the actual transformation matrix matching data generated, and limit the maximum difference value allowed;

(2) To eliminate the error data: There are six points on each of the segments, with  $x$ ,  $y$ ,  $z$  data, a total of 18 data. Cycle calculation with reasonable algorithms, for example least square method, some

of these data is out, when calculating results conform to the step 1. It means the chosen data is reasonable to build the virtual assembly.

## 5. Summary

Short line method of prestressed assembly technology has many technological advantages, recently has been large-scale applicated in China; "prefabricated, assembled at the site", The characteristics also puts forward higher requirements on construction control. Based on the detailed analysis of the structural parameters, and precision precast error eliminating, we shall improve the whole level of construction control in short line method bridges.

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