Walking-Type Bidirectional Incremental Launching and Mid-Span Closure Technology for Steel Box Girders with Long Cantilevers

Kai Wang¹ ² *, Wei Lu¹ ², and Zhongbiao Zhang¹ ²

¹China National Chemical Communications Construction Group Co, LTD, Beijing, China
²The Third Project Co., Ltd of China National Chemical Communications Construction Group, Jinan, China

*Corresponding author e-mail: kaiwang@chemchina.com.cn

Abstract. Unidirectional incremental launching is not applicable for the incremental launching construction of large-span bridges owing to the span capacity of steel box girders is restricted by the cantilever length and the setting of temporary piers. Aiming at the limitation, by taking Qingdao (Shandong Province)–Lanzhou (Gansu Province) expressway bridge crossing over the main canal in the South-to-North Water Diversion Project as the engineering background, a key construction technique, that is, bidirectional incremental launching and mid-span closure of steel box girders with long cantilevers was proposed. On this basis, the walking-type incremental launching device system and the technique of bidirectional incremental launching and mid-span closure were explored and also a finite element analysis model was established to compute the pre-camber. Moreover, the results of the alignment control of structures during the construction were compared and analyzed. The research result showed that during the construction using bidirectional incremental launching and mid-span closure, it was unnecessary to set the steel launching nose and it was able to greatly improve the span capacity of steel box girders and the construction efficiency during incremental launching. The research provides reliable experience in engineering practice for the future similar engineering.

1. Introduction
During the construction of a bridge, traditional construction technologies cannot satisfy the requirements for construction due to the effect of complexity and diversity of surrounding traffic environments, which is especially true when the bridge needs to span existing traffic modes and special areas. However, incremental launching technology for steel box girders can solve the construction difficulty due to its characteristics [1-3]. At present, the common method for incremental launching of steel box girders is described as follows: after precasting segments of upper girders, the precasted segments are erected onto a temporary pier and connected with the steel launching nose to form a whole structure; afterwards, the segmented girder is incrementally launched forwards under forces applied by a horizontal jack until the steel launching nose reaches the next temporary pier;
subsequently, in the rear of the girder, the next segmented girder continues to be welded, assembled and then incrementally launched forwards. By doing this cyclically, the girder segments are progressively launched to the other side [4-7]. The method shows the following advantages, such as simple construction, and stable structure stress and alignment control; in terms of the disadvantages, as it realizes incremental launching and spanning unidirectionally from one direction to the other, the method is not applicable for the construction of large-span bridges owing to the span capacity of steel box girders is restricted by the cantilever length and the setting of temporary piers. Therefore, it is urgent to explore and propose a bidirectional incremental launching and mid-span closure construction and alignment control technology for steel box girders to cross a large span with long cantilevers.

2. Project Overview
The upper structure of the second contract segment K167+527 from Dong’e boundary to Liaocheng sector in Qingdao–Lanzhou expressway bridge crossing over the main canal of the South-to-North Water Diversion project of National Highway consists of continuous steel–concrete composite beams, with the span arranged as 57 + 59 + 57 = 173 m. Two ends of the ridge are connected with abutments. The twin decks are distributed on the bridge, with the total width of the bridge of 38.0 m and the width of a single bridge deck of 18.5 m. The skew angle of the bridge is set as 30°, at a straight line segment, and a cross slope with 2% is set bidirectionally, as shown in Fig. 1. The main girder is composed of the steel–concrete composite box girders, in which three rows of steel box girders are horizontally set in a single deck and connected by using diaphragms there between. The main girder is built into a steel frame by welding the roofs, bottoms, webs, diaphragms and cantilever beams, on which precasted bridge deck with the thickness of 8 cm is paved. The cast-in-place concrete bridge deck slabs with the thickness of 17 cm are integrated with the shear studs on the roofs of the steel girders to form steel–concrete composite box girders, as shown in Fig.2.

The steel box girders were installed and constructed by applying walking-type incremental launching technique. Each main girder in a deck was bidirectionally incrementally launched from two banks to the mid-span separately; after closure at the mid-span, the main girders were connected laterally as a whole. Before the mid-span closure, the maximum length of cantilevers during the incremental launching was up to 29.5m.

Fig. 1 Bridge span layout (Unit: cm)

Fig. 2 Box girder cross-section (Unit: mm)
3. Walking-type incremental launching and closure technique

3.1. Walking-type incremental launching system

The installation of steel box girder adopts step-type multi-point jacking mode\cite{8-10}, and 2 sets of jacking systems are installed on the top of temporary piers of each side span of single width, with the same jacking system, the total length of each set is 2870mm, and its technical parameters are: jacking speed: 25cm/minute; maximum journey of each jacking: 40cm; longitudinal jacking force: 80T; vertical jacking force (each skid steer box): 400T, as shown in Fig. 3 and Fig. 4.

![Walking-type incremental launching system](image)

(a) Planar graph

(b) Lateral view

Fig. 3 Walking-type incremental launching system
3.2. Bidirectional incremental launching and closure process with long cantilevers
A total of two temporary piers for incremental launching were set at side spans in each side, separately at the abutment and main pier. Moreover, temporary supports for assembling steel girders were distributed there between so as to assemble segmental steel girders into a whole. To reduce the number of incremental launching, the temporary supports for assembling steel girders were separately set in the rear of the abutment to increase the length of steel girders equivalent to one time of assembly. A set of incremental launching devices were separately arranged at the top of each temporary pier and all incremental launching devices were uniformly controlled by a computer control system. The bidirectional incremental launching and closure process mainly involved the following steps:

(1) The steel girders were segmentally manufactured in factories; temporary piers, temporary support piers and supports for assembling steel girders were constructed at the bridge site; the incremental launching device and operation systems were installed and debugged to be prepared for installation of steel box girders.

(2) The steel girder segments were transported to the bridge site; steel girders to be installed at the central line of the lane in a row in the single deck (segments 2 ~ 6 in Qingdao side while segments 3 ~ 6 in Lanzhou side) were erected onto the supports for assembling steel girders by using a heavy crane and then welded to form a whole after adjusting the elevation;

(3) The plate fasteners for assembling girders in the side spans were removed and the temporary support piers were lowered to make preparations for the subsequent incremental launching; the first incremental launching for about 14 m was conducted from the abutment to the main pier direction.

(4) The temporary support piers were lifted up to adjust the alignment and residual steel girders of the row were all assembled subsequently; the temporary supports were lowered to perform the second incremental launching of steel girders to the position of final closure; the alignment was adjusted to complete the closure at the middle of the main span.

(5) The incremental launching and closure of the residual two rows of main girders of a single deck were completed according to the aforementioned steps; the lateral connection between three rows of main girders was installed finally.
4. Setting of pre-camber
According to the design requirements, it was necessary to set the pre-camber during the construction of the main girders. The setting of the pre-camber considered two aspects: on the one hand, the deflection of the main girders triggered by deadweight (dead load) of the structure and settling (50 cm) of supports during the incremental launching of steel box girders with cantilevers to complete closure at the middle of the main span; on the other hand, the deflection of the main girders induced by the live load during operation. By applying Midas Civil finite element software, the value of pre-camber was calculated through numerical simulation on construction and finished stages of the bridge, as shown in Fig. 6. Fig. 7 displays the curve concerning the pre-camber.
5. Conclusion

A key construction technique, that is, bidirectional incremental launching and mid-span closure of steel box girders with long cantilevers was put forward. For the technique, it was unnecessary to set the steel launching nose. The maximum length of cantilevers of steel box girders during the incremental launching reached 29.5 m.

The walking-type multi-point incremental launching was employed: a total of two temporary piers for incremental launching were distributed at the side span in each side, separately at the abutment and the main pier; moreover, the temporary supports for assembling steel girders were set therebetween so as to assemble steel girder segments as a whole.

The setting of the pre-camber considered two aspects: on the one hand, the deflection of the main girders triggered by deadweight (dead load) of the structure and settling (50 cm) of supports during the incremental launching of steel box girders with cantilevers to complete closing at the middle of the main span; on the other hand, the deflection of the main girders induced by the live load during operation.

The practice proved that the bidirectional incremental launching and mid-span closure construction technology greatly improves the span capacity of steel box girders and construction efficiency during incremental launching, which is expected to provide reliable experience in engineering practice for future similar engineering.

References

[1] C. Qingqiang. Calculation and Analysis of Incremental Launching Erection of Prefabricated Steel Box Girders Having Complicated Geometry [J]. Bridge Construction, 2009.

[2] M. A. Al-Osta, A. K. Azad, H J Al-Gahtani. Optimization of Continuous Post-Tensioned
Concrete Bridge Girders of Non-Uniform Depth [J]. Arabian Journal for Ence & Engineering, 2012, 37 (2):265-276.

[3] L. Xin-Bin. Research on Technologies control of Incremental Launching Construction of Long-Span Steel-Box Girder on Vertical Curve with Changing Curvature[J]. Construction & Design for Engineering, 2018.

[4] W. Tongmin. Experimental Study on Incremental Launching Friction Pair for the Steel Box Girder of Taohuayu Yellow River Bridge[J]. Construction Technology, 2013.

[5] Y. Zongshan, W. Yufan, F. Wensheng. Study of Construction Technology for Installation of Steel Box Girder of Ji’nan Huanghe River Bridge on Qingdao-Yinchuan Expressway [J]. Bridge Construction, 2008.

[6] C. Kan-Song. Incremental launching construction technology of steel box beam [J]. Shanxi Architecture, 2007.

[7] X. Fujun, Z. Jiasheng. Influence analysis and stability analysis for incremental launching of steel box girder [J]. Journal of Railway Science and Engineering, 2019.