A new Technology for Incremental Launching the Small Curvature Radius Variable Cross-Section Steel Box Girder

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Abstract. This paper mainly introduces a new technology for incremental launching the small curvature radius variable cross-section steel box girder. To solve the difficulties traditional construction method encountered, new incremental launching method, girder curvature adaptation technology and intelligent surveillance system are researched and developed. By using this technology, launching construction of the small curvature radius variable cross-section steel box girder in urban is practically implemented.

Introduction

Small and middle span bridges have taken over 98% of all in China, and there is an increasing demand of green technology for bridge construction [1-5]. Incremental Launching construction technology is the typical one that represents the prospects of the bridge construction [6-8]. The traditional incremental launching technology is generally used for the construction of bridge box girder which has prismatic continuous sections. When launching the variable cross-section box girder, the multiple launching interfaces are unable to be adapted. Therefore, in this paper, we proposed a new incremental launching technology that is capable of realizing the incremental launching construction for the variable cross-section steel box girder. Thereto, this new technology is verified in terms of the successfully engineering construction of a small curvature radius variable cross-section steel box girder.

Project Background

Wuhan Dongfeng avenue freeway viaduct is a typical continuous composite beam-steel bridge. The 89m L7 span of the viaduct is located above an old bridge across the Xinmin River, the construction layout of which is shown in Fig. 1. There is a 2% slope in the transverse direction, and the radius of its bottom surface in vertical plane is 750m with a difference in height from 2.6m to 3.8m. The bearing capacity of the old bridge is limited as 20 tonne so that no other temporary bracket is allowed to erect on the old bridge. Meanwhile, the location of the bridge construction is among the traffic arteries, the construction is required to be green and compliant to the traffic conditions.

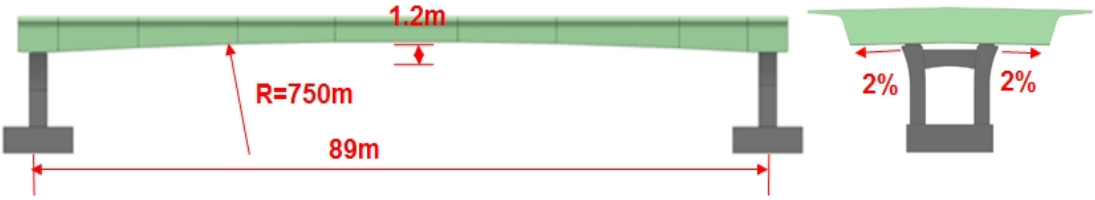

Fig. 1. The construction layout of the L7 span of Dongfeng avenue freeway viaduct

Construction difficulties for traditional construction methods. To construct the steel box girder in urban city, engineers often use mobile cranes lifting method [7] and bracket erecting method. However, considering the bearing capacity of the old bridge, the influence to the traffic conditions and the transportation and manipulation of the pre-made bridge girders, the traditional construction methods [1, 4] are inappropriate for the implementation of this engineering project. Thus, the incremental launching method is adopted. Yet, the general incremental launching method is often used for the construction of box girder, the cross-section of which is even, prismatic and continuous [9, 10]. When launching the variable cross-section girder in terms of using the general incremental launching method, the main difficulties are described as follows:

Height change of launching interface. The height between the bottom surface of the box girder and multiple incremental launching devices are continuously changed. Meanwhile, the heights among all launching interfaces are various at specific launching step. The launching conditions lead to the requirement of height adjustments in a wide range distance (maximum height difference is 1.2m) for all incremental launching devices during the whole construction process that general incremental launching method is unable to fulfill.

Curvature feature of the box girder. In order to prevent the transverse sliding motions of the box girder during launching construction. Fine contacts among box girder and all of the working devices are needed. It requires that all the launching devices are capable of fine adjusting the position and orientation to adapt the local surface features of the girder. The pre-set launching trajectory needs to be updated to ensure the curvature precision of the entire bridge girder is within tolerance at every iterated launching steps.

Considering the difficulties stated above, a new incremental launching technology and related launching system is developed to satisfy the requirements. In the remaining part of paper, we will introduce an innovative incremental launching method specifically used for the construction of the variable cross-section steel box girder. The self-adaptation control, the corresponding surveillance system and the engineering practice are represented, sequentially.

New Incremental Launching method

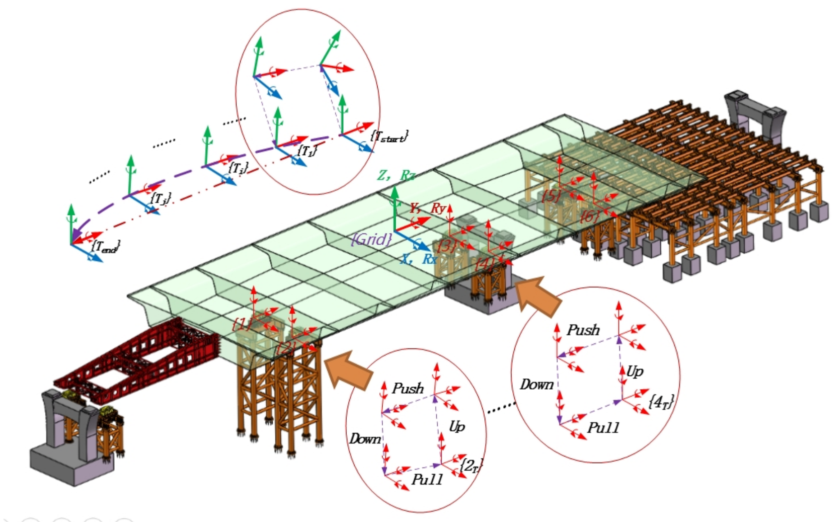

Fig. 2. The launching trajectory planning of the L7 span of Dongfeng avenue freeway viaduct

The new incremental launching method is partially based on the general incremental launching technology [9, 10]. Each incremental launching device executes the 3-dimensional launching movements, which are lifting up, pushing forward, lowering down and resetting, to complete the launching sequence. The bridge girder follows the movements of multiple launching devices correspondingly. As shown in Fig. 2, to launch the variable cross-section steel box girder of L7 span of Dongfeng avenue freeway viaduct, the new incremental launching method has the advantages, which are described as follows:

Adaptation of launching construction. Based on the traditional incremental launching method, the adaptation of the curvature features of the steel box girder is changed. During launching construction, the curvature features of the steel box girder are actively adapted to the positions of all launching devices in terms of its gravity and geometry specifications, instead of changing the nominal heights of all launching devices. By using this method, the times of the height adjustment is largely reduced due to the shrinking of the adjustment range.

Multi-Degrees of Freedom movements of launching device. Based on the design of traditional launching device, the new launching device is capable of implementing fine adjustment of translation and orientation movement in the Cartisian space, simultaneously. It leads to the better contact between the bottom surface of the bridge girder and the working interface of the launching device so that the safety of the launching construction is ensured.

Real-time docking between multi-station hydraulic system and intelligent surveillance system. Based on the distribution features of the launching construction, the intelligent surveillance system is designed to reasonably plan the launching trajectory, compute and analyze the curvature of the bridge girder so that the working heights of all devices are adjusted in time. The bridge girder is continuously launched until its curvature precision is within tolerance.

In terms of using the trajectory planning theory, the new launching device is able to adjust its working interface to better contact with the bridge girder. With the help of the height adjustment device, the launching movements of all devices are safely done by means of changing the working height so that launching failure of the bridge girder is prevented.

Self-adaption Control Strategy

Due to the curvature feature of the bridge girder, the launching heights of every launching device are different. In the meanwhile, the height changes for a single launching device when the bridge girder is at the next launching iteration as well.

Thus, the new launching devices carry the high performance digital sensor to monitor the position, orientation of the bridge girder and all launching devices, the pressure of the each hydraulic branch, etc. In terms of using the robust self-adaption control algorithm, the entire launching process is fully closed-loop controlled.

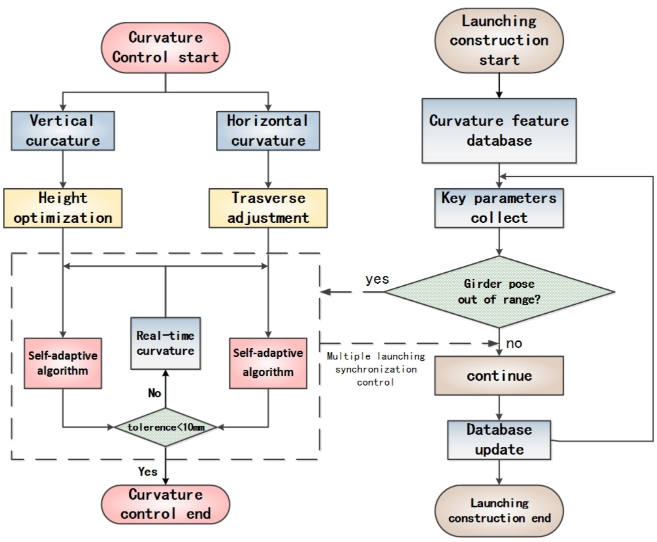

Fig. 3. The incremental launching strategy for the variable cross-section steel box girder

The self-tuning PID control algorithm is applied to maintain the stability of the control performance. Considering the uncertainties of every working device, this control algorithm updates the proportion, integration and differentiation parameters in real time. Together with the *positions* *synchronizing, loads tracking* method, the multi-point launching synchronous performance will not drop, which the traditional launching controlling technology is not capable of ensuring.

As shown in Fig. 3, the distances among bottom surface of the steel box girder and each launching devices are firstly discretized. Then, the padding heights of launching devices and supporting jacks are optimized to ensure the launching movements at specified iteration are within the working range. Thereto, by off-line programming the launching trajectory, the launching curvature center and radius are reasonably computed. Further, the nominal launching heights and adjustment heights are correspondingly feedback to the PLC controller so that the synchronization precision of all launching devices and curvature precision of the bridge girder are guaranteed. Moreover, in terms of using the self-tuning PID control algorithm, the curvature of the bridge girder is segmented for the each iterated launching planning so that the bridge curvature precision at vertical and horizontal directions are fully controlled during the entire launching process.

Intelligent surveillance system

In order to further improve the safety control ability, launching decision-making ability and construction efficiency, the remote communication equipment and distributed monitoring system are established. The monitoring system is configured as the sub-master control units, which is designed to receive continuous key signals from the working stations and bridge girder. The signals are transferred to the remote master control unit in real time. By docking with the modular surveillance software, the signals are analyzed as the construction condition inputs. After computation, the digital launching instructions are send back to the distributed working station. The hydraulic jacks execute the fine launching movements in terms of proportional valves so that the multiple launching devices are adaptively implements the launching construction.

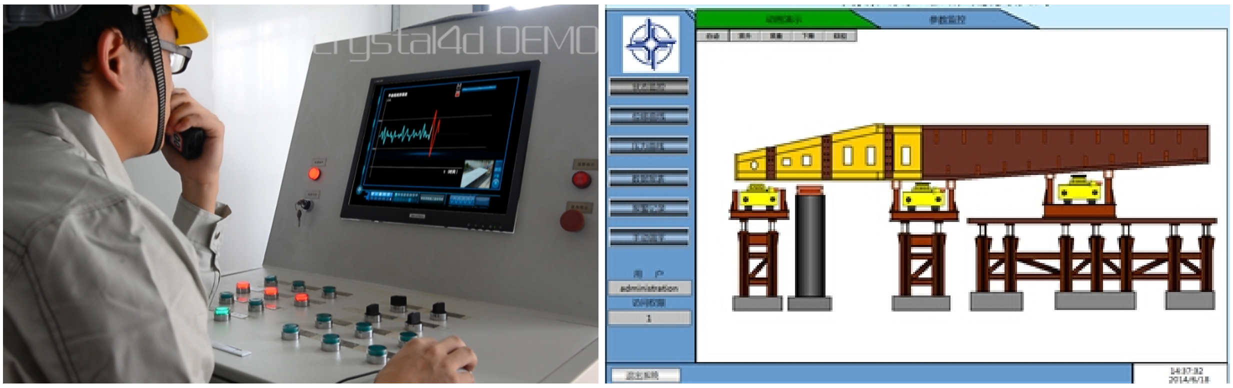

Fig. 4. The remote surveillance platform and the software interface

As shown in Fig. 4, the remote surveillance system includes the auditory and visual alarm system. The surveillance software is capable of abstracting and programming the condition inputs, analyzing and adjusting drop of the synchronization precision, deviation of the bridge construction curvature and the fault of the execution units, etc. Further, human intervention and remote communication functions are available to freely switch the remote/local surveillance level. By using the intelligent surveillance system, the efficiency and quality of the launching construction are improved. Also, the workload of the worker dispatching and the accident rate are evidently declined.

Engineering application and results

In terms of applying the new incremental launching technology and corresponding devices, the 89m L7 span of Dongfeng avenue freeway viaduct is successfully launched, which is shown in Fig.5.

Fig. 5. The launching construction of L7 span of Dongfeng avenue freeway viaduct

The launching construction conditions and the corresponding stress and deformation are listed in Table 1. The stress and deformation of all bearing conditions are verified by FEA analysis, the results of which is partially shown in Fig. 6. The analysis represents the consistency with the launching construction in practice.

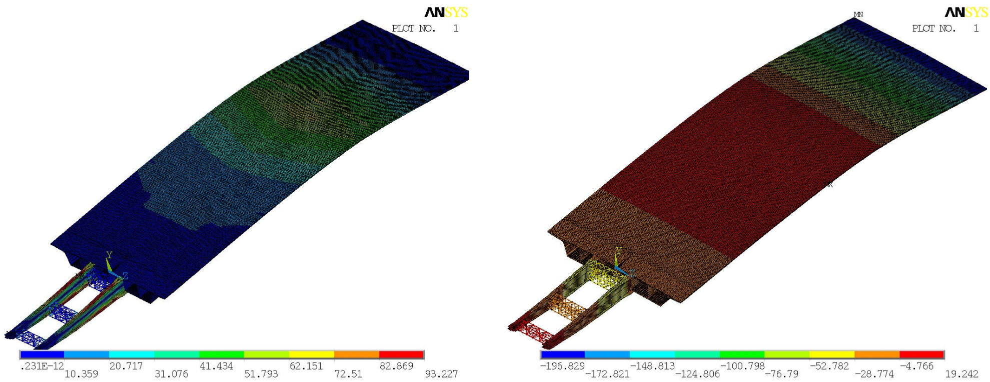

Fig. 6. The stress and deformation analysis of the bridge girder in condition 20

Table 1 Construction conditions and stress and deformation of the steel box girder

CONDITIONS	DESCRIPTION	MAX.STRESS(MPA)	MAX.DEFORMATION(MM)
1	Welding nose and L7-9	14.3	0.8
2	Launching forward 6.5m	16.0	1.2
3	Assembling L7-9	16.7	5.0
4	Launching forward 12m	24.3	6.0
5	Assembling L7-10	24.9	9.6
6	Assembling 15m	62.9	32.1
7	Devices transfer to 3#	72.0	36.8
8	Launching forward 2.5m	97.9	59.2
9	Nose at 3#	72.8	15.3
10	Launching forward 12.5m	87.8	18.4
11	Assembling L7-11	90.5	18.9
12	Launching forward 12m	35.1	8.3
13	Assembling L7-12	36.1	15.6
14	Launching forward 15m	37.5	29.5
15	Devices transfer to 4#	51.5	60.1
16	Assembling L7-13	67.1	168.5
17	Launching forward 2.5m	78.5	126.2
18	Nose at 4#	58.1	118.3
19	Launching forward 5.5m	69.2	66.9
20	Assembling L7-14	93.2	196.8
21	Launching forward 14.45m	55.3	31.7
22	Launching complete	34.5	11.0

Conclusion

This paper proposed a new technology for incremental launching. By using this technology, Wuhan Dongfeng avenue freeway viaduct is successfully launched. This technology solves the difficulties of launching small curvature radius variable cross-section steel box girder. New incremental launching method, girder curvature adaptation technology and intelligent surveillance system are introduced, which would be the benchmark for the similar bridge launching constructions.

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