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Application of Segmental Prefabrication Method in Railway Bridge Construction

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Segmental prefabrication construction method is a bridge construction technology that divides a span bridge into several segments along the axis direction, prefabricated in batch at the beam yard and transported to the construction site for assembly. This method has been gradually popularized for its advantages of rapid construction, green environment protection and strong adaptability. In this paper, the application status of this method at home and abroad, the key points of construction technology are summarized, and the technical characteristics, advantages and disadvantages are summarized, so as to provide a reference for the project using this method.

Keywords: Prestressed concrete; railway bridge; precast; assemble.

1. INTRODUCTION

In recent years, China has vigorously developed infrastructure construction, put forward higher requirements for the speed and quality of construction, and paid attention to the sustainable and healthy development of the construction industry [1]. The segments are prefabricated in batches in the beam field, and multiple segments can be prefabricated at the

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same time. Combined with the building information model (BIM), the standardized production method can improve the construction speed and ensure the construction quality. The template used in the segment prefabrication process can be reused, which improves the utilization rate of materials and reduces waste. Due to the relatively light weight of a single segment, the use of large machinery is reduced in the process of moving segments, which is more energy-saving and environmentally friendly than the traditional cast-in-place method [2]. When the segment is transported to the construction site for assembly, the site occupation is less and the surrounding traffic environment is less affected. Therefore, the segmental precast assembly technology has been valued by the government and various construction units, and has been gradually promoted and applied in the field of bridge construction [3]. This paper summarizes the application and key points of this technology, puts forward the quality control measures in the construction process and summarizes the characteristics of this technology.

2. APPLICATION STATUS OF PRECAST SEGMENTAL ASSEMBLY BRIDGE CONSTRUCTION METHOD AT HOME AND ABROAD

In China, the Jiuzhuanghe No.1 Bridge of Chengdu-Kunming Railway completed in 1966 adopted the construction method of cantilever span-by-span assembly. The cross-section form is variable cross-section single box single room, which is the first railway bridge in China to adopt segmental precast assembly technology [4]; the Zhouhuai Bridge in Henan section of Zhengzhou-Fuyang Railway, which was built in 2017, is the first continuous railway beam bridge in China using prefabricated glue assembly technology. The semi-connected beam section is lifted to the assembly position and then glued and assembled, which can eliminate the influence of eccentric load and accelerate the construction progress. The Hekou Yellow River Bridge built in 2015 was assembled and erected by a bridge erecting machine. The segments were prefabricated in a straight line, and the alignment of the bridge was adjusted through wet joints during assembly to achieve the designed curve alignment. This method realizes the assembly and erection of continuous curved beams on the bridge erecting machine, making the line selection of railway bridges more flexible [5]. The Xuchang section of the Zhengzhou-Xuzhou regional railway completed in 2020 is constructed by segmental precast glue assembly method, which reduces the construction cost and accelerates the construction progress. The formwork used can be flexibly adjusted and is suitable for precasting beam sections with different spans [6]. Examples of segmental precast box girder [7-13] bridges built in China in recent years are listed in Table 1.

In foreign countries, in 1962, the segment prefabrication and assembly technology was first applied to the France 's GuoshuVasillois Bridge, and later promoted worldwide as one of the main technologies for bridge construction [14]. In 1978, the Long Keys Bridge in the United States adopted the prefabricated assembly technology of external prestressed segments, which greatly improved the construction speed and shortened the construction period by 8 months compared with the original plan. The use of the steering block makes the vertical component of the prestressed tendon equal to the size of the dead load shear force at the place, ensuring that the arch is zero during the structural assembly process, making the operation easier [15]. The I-5 Grand Mount to Maytown I/C 2-span Precast Girder Bridge was completed in 2011 [16].

Table 1. Part of the completed segmental precast assembled bridges in China

Completetime	Name of bridge	Longest span	Assembe method
2022	Zhengxu Railway Viaduct	35m	Span by span
2021	Chaobai New River Bridge	80m	Cantilever assemble
2021	Zhengji Railway Bridge	168m	Span by span
2019	Nanchang Hongdu Viaduct	35m	Cantilever assemble
2017	Zhengfu Railway Bridge	412.5m	Span by span
2015	Zhishuigou Bridge	64m	Span by span
2012	Nanjing Changjiang River Bridge	52m	Span by span
2012	Xiazhang Sea-Crossing Bridge	300m	Cantilever assemble

3. BASIC PRINCIPLE OF PRECAST SEGMENTAL ASSEMBLY

The short-line matching method is a segment prefabrication method in which one end adopts a fixed end mold and the other end adopts a movable end mold, or one end uses a prefabricated beam segment as a fixed end mold and the other end uses a movable end mold. When the newly poured beam section is maintained and removed, the previous section is transported to the beam storage area, and the newly poured beam section is used as the matching beam section to start the prefabrication of the next section. Each new pouring beam section is matched with the previous section, which ensures the matching accuracy of adjacent beam sections. After the prefabrication of each segment meets the design requirements, the segments required for the whole span beam are transported directly below the position to be erected, and the segments are lifted to the specified position by using the bridge crane. After adjusting the alignment, daubing epoxy resin glue, tensioning temporary prestress, penetrating permanent prestress beam and tensioning, the assembly is completed, and finally the beam is dropped to the design position to complete the erection of the span beam.

4. TECHNICAL POINTS OF SEGMENTAL PRECAST ASSEMBLY

4.1 Segment Prefabrication

The selection of segment beam precast site should comprehensively consider the distance of beam transportation, the difficulty of site foundation treatment and transportation efficiency. The site is divided into several areas according to the construction process sequence to ensure that the moving line is reasonable and convenient for operation.

The steel bar is processed according to the principle of centralized processing and on-site binding. In the process of binding, it should be noted that each intersection point of the outer edge steel bar should be firmly bound, and the middle part can be separated and interlaced to ensure that the force bar does not move. The outer side of the steel bar is tied with a concrete pad to ensure that the thickness of the concrete protective layer meets the design requirements; the reinforcement joint should be set at a less stressed part, and the joints should be staggered from each other. If the longitudinal reinforcement needs to use a mechanical joint or welding, the lap length should not be less than 35 times the diameter of the reinforcement and not less than 50mm.

The lashed steel bars are integrally lifted into the formwork, and the formwork adopts an integral steel formwork with a large rigidity to ensure the prefabricated alignment. When the concrete is cut, the two sides of the web are symmetrically cut and the cutting speed is controlled to avoid the impact on the embedded parts and change their position. The vibration is supplemented by the attached vibrator, and the plug-in vibrator is mainly used to avoid the vibrating rod touching the bellows, pre-embedded pipes and pre-embedded parts during the vibration process. In summer construction, conventional sprinkling curing is adopted, and steam curing is adopted in winter construction, which can increase the growth rate of concrete strength and shorten the curing time.

4.2 Segment Assembly

The principle of 'four-point lifting and three-point balance' is followed during the lifting of the segment to prevent large stress concentration near the lifting hole and ensure that the stress of each part of the segment beam is within the allowable range. After each segment is hoisted in place, the trial assembly is carried out, and the position of the beam segment is fine-tuned with the help of the bridge erector's own crane to ensure the accurate position of the first segment. During the adjustment process, a wooden pad was placed between the segments to place the beam collision. The preparation of adhesive should be strictly in accordance with the design requirements of the ratio and mixing, coating should be fast and uniform, according to the design thickness of the coating. In order to ensure the accurate position of the segment, the jack is used to temporarily tension each two segments after gluing, and then the double control permanent prestress tension is carried out according to the design requirements. Because the loss of anchor and bell mouth, pipeline friction and pipeline deviation will lead to the loss of prestress, it is necessary to measure the loss of prestress after the tension is completed, so that the tension control force can be adjusted to meet the design requirements. The vacuum grouting of prestressed pipeline is carried out after the completion of permanent prestress tension. The grouting material adopts

micro-expansion cement slurry and adds rust inhibitor to protect the prestressed steel bundle and prevent its corrosion. Finally, the whole span beam is adjusted in place by the bridge erecting machine, and the beam is dropped to the design position, and the grouting material is poured between the bearing bolt hole and the cushion stone.

4.3 Linear Control

Linear control is the key link in the construction of precast segmental bridges, including linear control in the stages of design, prefabrication and assembly [17]. The influence of pre-camber, second-stage dead load, concrete shrinkage and creep should be considered in the design. In the process of segment prefabrication, it is necessary to ensure that the template has sufficient stiffness. In addition, two horizontal control points and four height control points need to be arranged on the segment beam. The spatial position and attitude of the segment to be poured are determined by the three-dimensional coordinates of these six control points [18]. In the process of segment assembly, we must first ensure that the spatial position of the first segment beam is accurate, and take into account the changes in the shape of the prestressed tension and the deformation of the hoisting equipment. In the process of assembly, the position of the beam segment should be calibrated by the three-dimensional coordinates of the control points, and the error should be corrected in time to avoid the accumulation of errors.

5. ADVANTAGES AND DISADVANTAGES OF SEGMENT PRECAST ASSEMBLY TECHNOLOGY

Segmental precast assembly technology is suitable for various span bridges and complex construction environments. It has strong adaptability. The advantages and disadvantages are as follows:

(1) It can be used for bridge construction of different spans, such as small and medium span and large span; it can be used to build different bridge types, such as continuous beams and simply supported beams; different methods can be used for construction, such as span-by-span assembly and cantilever assembly.

(2) It has little influence on the traffic environment around the construction area, and can reduce the land occupation area compared with the whole span prefabrication. Due to the small weight of the section, the difficulty of foundation treatment in the beam storage area is relatively small, which effectively reduces the engineering quantity and land occupation, conforms to the concept of green construction, and has good environmental benefits.

(3) Segmental prefabrication requires fewer types of templates and has high economic benefits. According to the relevant literature [19], compared with the traditional cast-in-place construction, the segmental precast assembly method can save 10% to 20% of the cost.

(4) The superstructure and substructure of the bridge can be constructed in parallel, which can effectively shorten the construction period, reduce the time cost and reduce the project cost.

(5) Segmental beam in the beam field mechanized mass production, reliable quality, production speed. The assembly process can also be mechanized, with good safety, and does not need to set up a bracket on the construction site.

(6) The assembly process is complex and requires high quality. Special instruments and equipment are needed. The linear control and the use of special equipment in the assembly process require workers to have good skills.

6. CONCLUSION

In February 2016, the State Council's "Several Opinions on Further Strengthening Urban Planning Management" put forward the requirement of "vigorously promoting prefabricated buildings, striving to use 10 years or so to make prefabricated buildings account for 30% of new buildings." Segmental prefabricated assembly technology has positive significance for promoting the green and energy-saving development of the construction industry. This paper summarizes the application status of segmental precast assembly technology and expounds the technical points, summarizes the advantages and disadvantages of the technology, in order to provide reference for segmental precast assembly technology in railway bridge construction.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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