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REVIEW ARTICLE

Simply-supported Box Girder Construction Technique of 40 m Movable Formwork Method Cast-in-Situ Railway Passenger Dedicated Line

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ABSTRACT The movable formwork has the characteristics of light self weight, large bearing capacity, small rod type number, rapid assembling, and simplicity to construct. Therefore, when cast-in-situ concrete box girder is constructed, the moveable formwork has great meanings in cost reduction and project time limit shortening. By using this method, the difficulty that brackets cannot be distributed as the ground bearing capacity of bridges. Besides that, bridge sites is low is reasonably solved, cost of material and labor can be reduced, influence to underbridge is minimize, and the construction progress is accelerated. The simply-supported box girder construction technique of 40 m movable formwork method cast-in-situ railway passenger dedicated line is particularly analyzed.

KEYWORDS
Moveable formwork
Simply-supported box girder
Construction technique

1. Introduction

40 m integral beam cast-in-situ simply-supported box girder is a key point of Hengjing especially long span bridge construction. It has the characteristics of large leave tonnage, special structure, aerial working, many and complex quality control points, etc., so that it has great construction difficulties, and from the approach, the 40 m integral beam cast-in-situ simply-supported box girder construction scheme is considered as a significant scheme.

2. Project profile

The railway passenger dedicated line from Shijiazhuang to Jinan starts from Shijiazhuang of Hebei, passes through Hengshui and cangzhou of Hebei, Dezhou of Shandong and ends in Jinan. It is a double-line electric railway, the design time speed of 250 km/h, ballast track is adopted, the line distance is 4.6 m, and the whole line is 323.112 km.

The China Railway 14 Bureau Group contracts to build #147 pillar to #1034 stand of the SJZ-4 bid Hengjing specially long span bridge. There are 887 holes in all, the mileage is DIIK117 + 459.28-D I K147 + 025.19, and the whole length is 29.566 km. The simply-supported box girders of 20 m, 24 m and 32 m are all constructed by using a precast construction method, and simply-supported box girders of 40 m between #300–#337 pillars and #340–#349 were constructed by using a moveable formwork construction method.

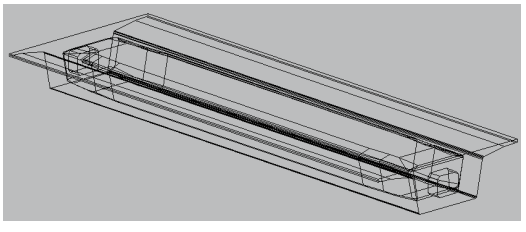

Figure 1. Structure diagram of box girder with the span of 39.1 m.

3. Engineering difficulty and difficulty analysis

The engineering scale is large, there are 46 holes and 40 m of cast-in-situ box girder and 20962 squares of concrete in all in the whole bridge, and how to organize the large-scale production task is the key point to be solved firstly.

The equipment structure is complex and the design difficulty is large. As the box girder is large in cross section

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and self-weight, high in requirement on construction machines, construction schedule is tight, construction quantity is large and construction organization difficulty is large, hence the moveable formwork box girder is the key control project of the tender and shall be particularly arranged and controlled in construction.

The box girder is large in tonnage, plenty in key procedure and complex in process. The railway box girders are all of simply supported structures, as the maximum weight of a single piece can be 1300 tons, and to ensure equipment safety, quality control shall meet the requirements of passenger dedicated lines.

Design speed of the bridge is 250 km/h, ballast tracks are adopted at tracked parts, the line type is highly required, and comprehensive factors such as prestress system, property of concrete, the flatness of casting and rigidity of formwork shall be monitored [1].

4. Moveable formwork method construction process

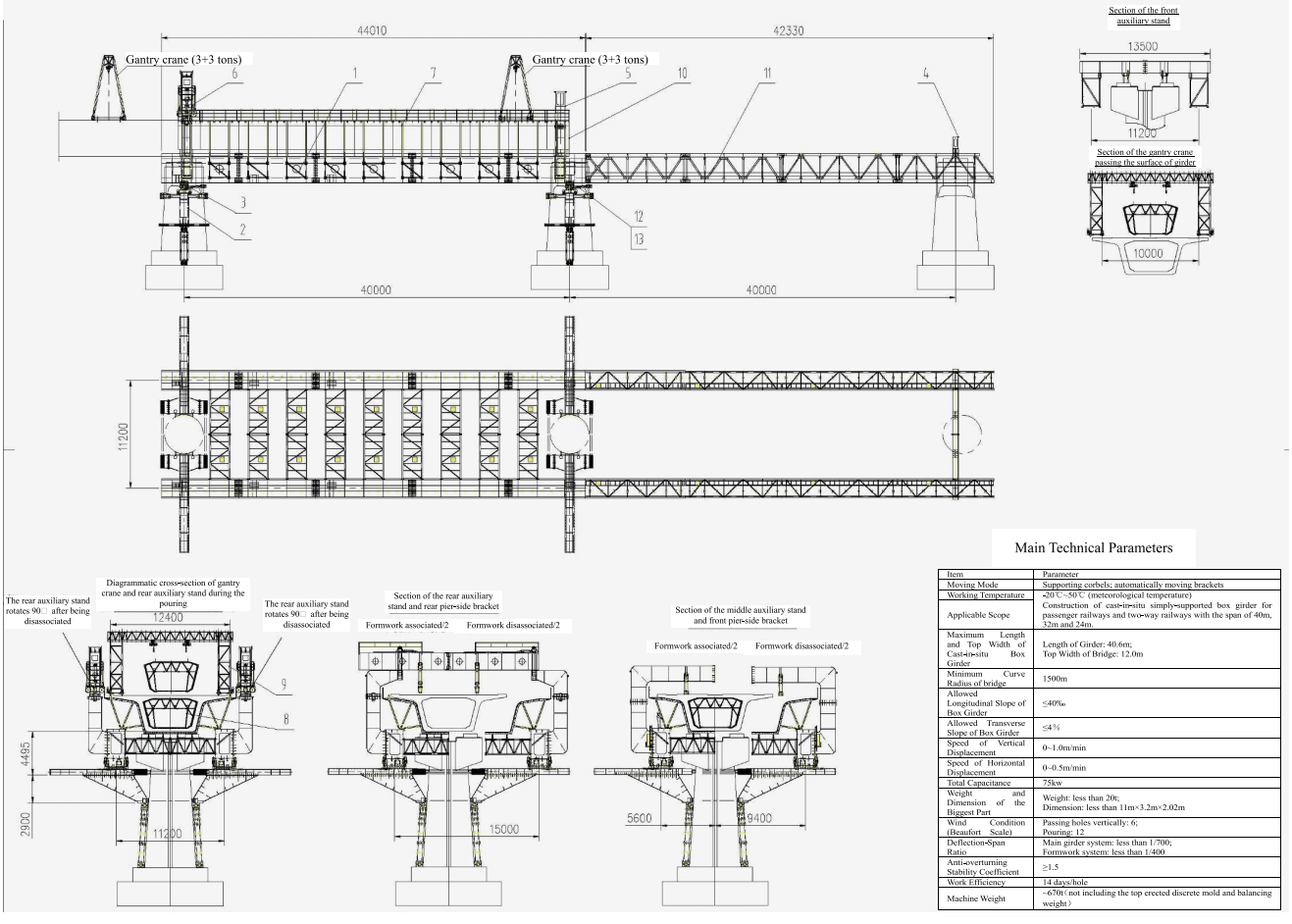
4.1. Construction principle of cast-in-situ simply-supported box girder of moveable formwork

The moveable formwork adopts support platforms as support legs to support the foundation which transverse and longitude moving system of the moveable formwork is mounted. The main girder system comprises three parts, namely, front guide girder, main girder and rear guide girder. The whole length of the three parts is 98 m in all, which is greater than two times of the span of the bridge. Due to the three parts, the whole formwork system can form a bridge manufacturing platform which moves longitudinally, the mold plate system and the main girder are integrally connected and can be associated and disassociated at the bride axis. After the bride was constructed, the moving formwork can be transversely separated and moves forwards longitudinally through the holes to approach to a next construction site. The platform form again after being transversely combined, and thus girder piece casting construction is performed by repeating the operation (Figure 1).

4.2. Cast-in-situ simply-supported girder process of moveable formwork

4.2.1. Manufacturing process of first hole girder

Used mount platform moving mechanism, first mount the main girder in place, then move and prepress the formwork. After that adjust the mold plate system, then mount



Main Technical Parameters

Item	Parameter
Moving Mode	Supporting corbels; automatically moving brackets
Working Temperature	-20℃~50℃ (meteorological temperature)
Applicable Scope	Construction of cast-in-situ simply-supported box girder for passenger railways and two-way railways with the span of 40m, 32m and 24m.
Maximum Length and Top Width of Cast-in-situ Box Girder	Length of Girder: 40.6m; Top Width of Bridge: 12.0m
Minimum Curve Radius of bridge	1500m
Allowed Longitudinal Slope of Box Girder	≤40‰
Allowed Transverse Slope of Box Girder	≤4%
Speed of Vertical Displacement	0~1.0m/min
Speed of Horizontal Displacement	0~0.5m/min
Total Capacitance	75kw
Weight and Dimension of the Biggest Part	Weight: less than 20t; Dimension: less than 11m×3.2m×2.02m
Wind Condition (Beaufort Scale)	Passing holes vertically: 6; Pouring: 12
Deflection-Span Ratio	Main girder system: less than 1/700; Formwork system: less than 1/400
Anti-overturning Stability Coefficient	≥1.5
Work Efficiency	14 days/hole
Machine Weight	~670t（not including the top erected discrete mold and balancing weight）

Figure 1. The girder piece casting construction.

the girder surface gate. After mount the mounting support base, mold the plate web reinforced steel, and laid prestress steel bundles, together with strap top plate reinforced steel on vertical inner mold. Follow by mount girder surface opposite pull reinforced steel and end mold, continue with detect and adjust the mold plate. Report the inspection, and cast concrete in situ. After maintain, demold, stretch or draw, and grout, the mold should move off to arrange fulcrum. Besides that, transversely and longitudinally move the formwork through holes, to combine the formwork. Finally adjust the mold plate, and enter into next operation circulation.

4.2.2. Normal working circulation process

Before the process, clear other things on the moveable formwork, then release vertical and horizontal restrain, and descend the whole moveable formwork for about 120 mm. Initially, release bolt connection in the middle of the bottom mold and finely rolled threaded reinforced steel in the main girder, then generally synchronously transversely move two groups of bottom molds outwards. Detect whether there is obstacle in longitudinal movement, and follow by generally synchronously move the two groups of formworks forwards in place, besides that, move the whole machine longitudinally in place, and generally synchronously transversely move two groups of bottom molds in wards in place [2]. After that, connect the bottom mold and the finely rolled threaded reinforced steel in the main girder, and mount the support, then strap the web reinforced steel. After that lay the prestress steel bundles, strap the vertical inner mold with the top plate reinforced steel, subsequently mount girder surface oppositely pulled reinforced steel and end molds. Detect and adjust the mold plates, inspect, before cast concrete. Maintain is required, after that, demold, stretch and draw, grout, and move off the mold. After that, arrange fulcrum, transversely and longitudinally move the formwork through holes, and combine the formwork. Finally, adjust the mold plate, and enter into next operation circulation.

4.2.3. Standard operation process

Firstly, check the transverse move sliding pad plate of the bearing displacement mechanism, then, mount the pillar top displacement mechanism on the transverse move sliding pad plate, and the main steel box girder is supported by the pillar top displacement mechanism. Bottom and wing molds are mounted on the steel box girders, so that a bridge manufacturing platform which can move longitudinally can be formed, and construction of bridge can be completed [3].

The bottom mold is transversely separated so when pass through the pillars, it longitudinally moved forwards to approach to the next construction place, and can be transversely combined to form the construction platform again to complete construction of a next hole. The method specifically comprises the following steps: (1) Move the formwork and assemble in place, mount the support and construct standard span concrete girders, at the moment, the moveable formwork is supported on the bearing jack at the front and rear end parts of the main girder; (2) After the concrete meets the strength, remove the inner mold and the girder surface oppositely pulled reinforced steel, and expand the prestress reinforced steel. After that, jog the front and rear bearing cylinders, release the mechanically locked screw nuts, and slightly withdraw the front and rear bearing cylinders. Subsequently, demold according to self-weight of the equipment and completely withdraw the front and rear bearing cylinders; (3) Move the gantry crane lifting operation platform in place and mount safety device then release bolts which are longitudinally connected in the middle of the bottom mold. After that, release anchor bolts between the bottom mold and the main girder. Follow with, descend the operation platform to the ground and move backwards to the front span, and fix the gantry crane on cast concrete girder. Start the bottom mold transversely moving cylinder to push the bottom mold to transversely move. At the same time, thread the finely rolled threaded reinforced steel into every one mold plate; (4) Start the longitudinally moving cylinder to push the longitudinal girder to move forwards in place; (5) Remove the bottom mold locking mechanism to start the bottom mold transversely moving cylinder. Next, descend the bottom mold balance girder and pull the bottom mold to combine in place to recover the main girder gantry crane track and the gantry crane lifting operation platform and mount the safety device. Then, mount the bolts between the bottom mold and the main girder and mount the connecting bolts in the middle of the bottom mold; (6) Adjust the front and rear main bearing cylinder supports, to measure the mold plates, and prepare to enter into next operation circulation.

4.2.4. Construction process instruction and measures

When the girders are manufactured, two groups of left and right outer molds are oppositely pulled and combined through the bottom mold truss transverse connecting bolts. The bottom mold is supported on the bottom mold truss through lateral spiral jack, and the side mold is manufactured on the main girder through inclined support rod. When passing through the pillars, the bridge manufacturer moves transversely towards two sides after the bottom mold transverse connecting bolts are released, and finally pass the transverse moving system.

(1) Construction preparation: Clear a field which is 40 m long and 30 m wide between two pillars, and erect a temporary support pillar which is a formwork guide girder standard segment between two pillars. (2) Assembling method: The main girder is assembled by using 2 cranes of 50 t between the pillars and the temporary support pillar in a sectional mode. (3) Load test: Calculate the pre-camber of the mold plate, then simulate cast concrete to perform

load test on the bridge manufacturer to obtain camber set-up test data, and adjust the pre-camber. Calculate the total subsidence value of the bracket (before pre-compression-stable period) by using elevation observation values before pre-compression period. In the pre-compression, stable and after unloading period, calculate the elastic deformation (after unloading-stable period) and non-elastic deformation (before pre-compression-after unloading).

5. Construction notes

The local weather shall be noted when the formwork is mounted. Particularly before the main framework is completely formed, if heavy weather such as torrential rain and gale happens, special measures shall be taken to ensure safety of the formwork.

After being assembled, the moveable formwork shall have pre-compression test before the first hole box girder was constructed.

Support mounting, reinforced steel construction, mold plate engineering, concrete engineering and pre-stress engineering of the moveable formwork shall be carried out according to design and related provisions and instructions.

Corresponding guarantee measures, safety measures and contingency plans shall be made for moveable formwork construction in summer, rainy season and winter.

6. Conclusions

The moveable formwork bridge construction method has features of continuity, stability, reliability, short construction period, reasonable procedure joining, etc. The construction is easy to handle, good in overall property, high in mechanical degree and high in applicability. Due to moveable formwork construction, the overall period effect is very good, and after the formwork assembling and disassembling cost was shared once. Moreover, cost can be reduced, and moreover in span construction, the method has irreplaceable advantages, and once spanning can be achieved with safety and reliability. The practice shows that moveable formwork bridge construction method is feasible.

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