AN AUTOMATIC WALKING-TYPE LAUNCHING SYSTEM AND ITS APPLICATION IN JIUBAO BRIDGE

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SUMMARY

In Long-span bridge construction by incremental launching method (ILM for short), because its complex structural loads, the dragging-type launching equipment commonly used at present no longer applies. Based on Jiubao bridge construction project, a new launching system of the Automatic Walking-type Launching System (AWLS for short) is developed. This paper mainly introduces and describes the operation principle, component, main technical performance and features of the AWLS. The AWLS is a self-balancing launching system that integrates with functions of lifting, pushing and rectifying. It features highly automation, safety and reliability in operation. By using the AWLS, Jiubao Bridge was successfully erected by ILM for the first time as a three-span beam-arch composite bridge in the world. Meanwhile the AWLS can be widely used in construction of bridges with various kinds of structures due to its very wide generality.

Keywords: *Jiubao Bridge, incremental launching method, launching system, automatic, beam-arch composite bridge, girder, walking-type, dragging-type.*

1. INTRODUCTION

Incremental launching method (ILM for short) is widespread used in construction of medium-span bridges. It combines rapidity and high quality of construction, less interference with traffic or navigation, low labour demand, and minimized construction risks. In these projects, usually a dragging-type launching system is adopted, and the launching girder is simple in structure and not heavy. As for construction of long-span bridges with complex structure by ILM, due to heavy launching weight, big reaction force of piers, and complex internal force of the main and temporary structure, the traditional dragging-type launching system is no longer applied, thus new type of launching system should be developed. This paper gives an in-depth study of the technics of the Automatic Walking-type Launching System (AWLS for short) based on Jiubao Bridge construction project.

2. PROJECT BACKGROUND

2.1. Structural design of Jiubao Bridge

Connecting to the satellite cities of Linping, Xiasha and Xiaoshan, Jiubao Bridge composes an indispensable part of the transportation network around Hangzhou, capital city of Zhejiang province in eastern China. It is a three-span continuous beam-arch composite bridge with a total length of 630m and a span arrangement of 3×210m. See Fig. 1. The bridge span structure is supported by V-shape piers. The bridge arch system consists of main arch ribs, assistant arch ribs and the connecting braces between them. The main arch ribs are external slanted with an angle of 12° and a rise of 43.8m. The main girder of the bridge is a uniform steel and concrete composite girder with girder depth 4.5 m, girder width 37.7 m and beam spacing 4.25 m, which is a double main girder grillage structure composed of main longitudinal girders, transverse beams and assistant longitudinal beams. The concrete bridge decks are prefabricated by blocks and are connected by four longitudinal joints cast-in situ. The thickness of the bridge decks is 260mm and the C50 concrete is adopted. The concrete deck and steel girder are connected by cup head shear studs. Fig. 1. shows the general layout of Jiubao Bridge.

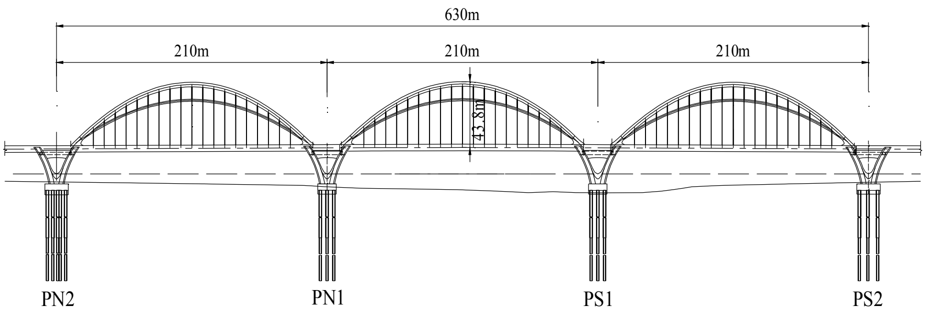

Fig. 1. *General layout of Jiubao Bridge.*

2.2. General Construction Method

When bridge substructure including bridge foundations, pile caps and piers finished, an assembling platform is erected on land, on which the steel beam-arch is segmented assembly. When the first span of steel beam-arch structures is finished assembly as well as the temporary support bars and the front launching nose, they are pushing out of the platform by ILM. Then begin with the next span with the same method. Until finally the third span of beam-arch structures and temporary support bars as well as the back launching nose are finished assembly, they are pushed forward integrally by ILM. Fig. 2 shows General layout of launching construction of Jiubao Bridge, Fig.4 shows two spans of steel beam-arch structures being pushed out of the platform integrally.

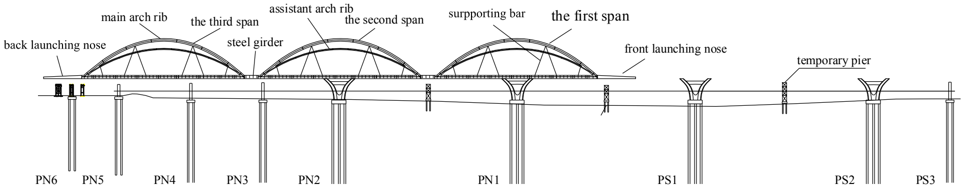

Fig. 2. *General layout of launching construction of Jiubao Bridge.*

Fig. 3. Two spans of steel beam-arch structures.

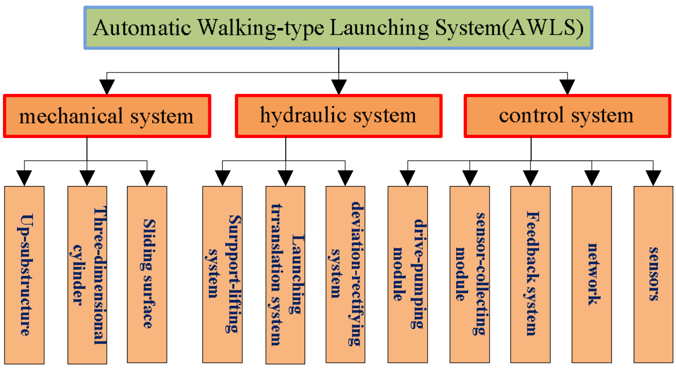

Fig. 4. General layout of the AWLS under construction.

3. PROPOSING OF THE AUTOMATION WALKING-TYPE LAUNCHING SYSTEM

Based on the construction method and project features, there are many difficulties in Jiubao Bridge erection shown as follows.

1) Complicated structural stress and deformation: As the three-span beam-arch composite structure being integrally erected by ILM with the launching span of 210m, only one temporary pier is set between, structural stress and deformation is very complicated and difficult to control.

2) Critical integral stability problem: The total launching weight is near 140000 KN, with a higher gravity center of the main structure. Also the wind load is strong in construction period at the bridge sites. So stability of the beam-arch structure is very critical in Jiubao Bridge construction project.

3) High demands for launching equipment: in the launching process, the reaction of the launching pier is near 14000 KN, and all load forces should be applied on the web plate of the main girder. The launching system should be self-balancing with deviation-rectifying function. The maximum launching points

is nearly 20 under bridge construction, to ensure all the launching points work synchronously is the key factor of safety, thus an advanced control system is also needed for the launching system.

It is for the first time in the world that so complex structure being erected by integral pushing method in Jiubao Bridge construction project, there are no successful experiences to refer to, furthermore there are some other uncertain factors which would make bridge construction practice even more complicated. Because of its low-level automation, and being not able to meet the requirements of the structural force, the dragging-type launching system which is usually adopted in medium-span bridges construction is no longer applicable here, thus a new type of pushing system-the AWLS is developed to ensure Jiubao Bridge construction by ILM successfully.

4. THE MAIN CONSTRUCTION PRINCIPLE OF THE AWLS

4.1. Overall design of the AWLS

The AWLS mainly consists of three part : The launching mechanical system, the launching hydraulic system and the automatic control system. General layout of the AWLS is shown as Fig.5.

4.2. The Launching Mechanical System

The launching mechanical system is mainly composed of the lower and upper structure, sliding surface, three-dimensional hydrocylinder including lifting hydrocylinder, pushing hydrocylinder and deviation-rectifying hydrocylinder. These hydrocylinders are all hydraulically driven and controlled by computer to meet all kinds of construction requirements.

1) The upper structure is mainly made up of a sliding box of 2.7 by 2.5 by 0.3m with a rubber blanket placed on its top to make the launching weight uniformly distributed over it. At the bottom is a 3 mm thick stainless steel plate, together with Teflon of substructure make up a sliding surface. On either side of the box there are two transverse adjustable cylinders which are used for guiding and rectifying deviation of girders. On both ends of the sliding box there is a block acting as reaction support for longitudinally launching.

2) On top of the substructure, there are many mushroom heads, which are able to bear vertical loads and reduce friction effectively. In the middle of the substructure there is a hydraulic cylinder for longitudinal launching. Four lifting cylinders are placed all around, by controlling which the vertical movement of beam-arch composite structures can be achieved. The parameters of the three-dimensional cylinders are given below: 4 jacks of maximum lifting weight 18000 KN and maximum travel distance 30 cm are arranged in vertical direction, 4 jacks of maximum pushing force 1400 KN and maximum travel distance 35 cm are arranged in longitudinal direction, while 2 jacks of maximum pushing force 800 KN and maximum travel distance 5.5 cm are arranged on either side in transverse direction. Fig.5 shows the system diagram of the AWLS, Fig.6 shows the Picture of the AWLS used in Jiubao Bridge project.

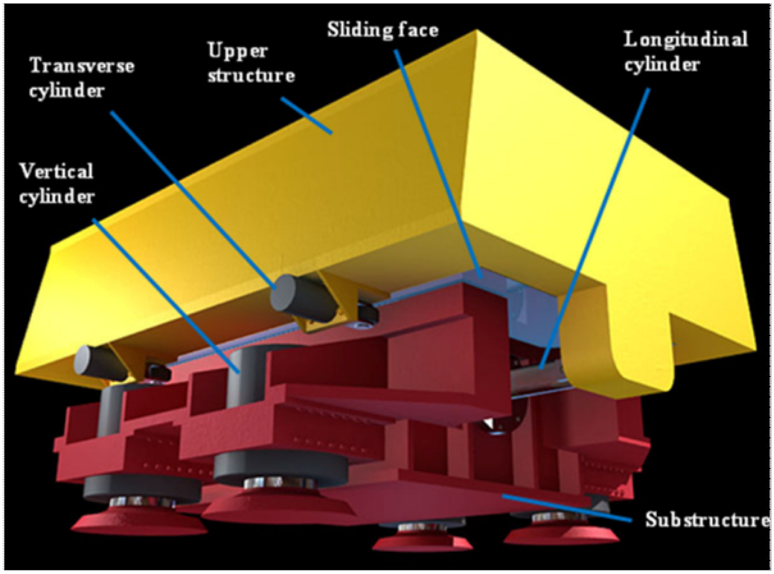

Fig. 5. *System diagram of the AWLS.*

Fig. 6. *the AWLS used in Jiubao Bridge construction.*

4.3. The launching hydraulic system

It is a system for supplying with mechanical power. It mainly includes two parts: The support-lifting system, the push-translation and transverse-adjustment system. The former is mainly composed of frequency motor, quantitative-pumping plunger, directional valves, relief valves, proportional valves, balancing valves, globe valves, hydraulic one-way valves, safety valves. The latter is mainly made up of frequency motor, quantitative-pumping plunger, directional valves, relief valves. As advanced electro-hydraulic proportional control technology is adopted, all the launching point are synchronously controlled with high precision of ±1 mm, and the loading protection for each cylinder is specially designed, which makes dropping down and lifting of launching structures become safer and more reliable. As the hydraulic system is adopted with clear modular design, it combines versatility, reliability and highly automation. The launching hydraulic system is shown as Fig. 7.

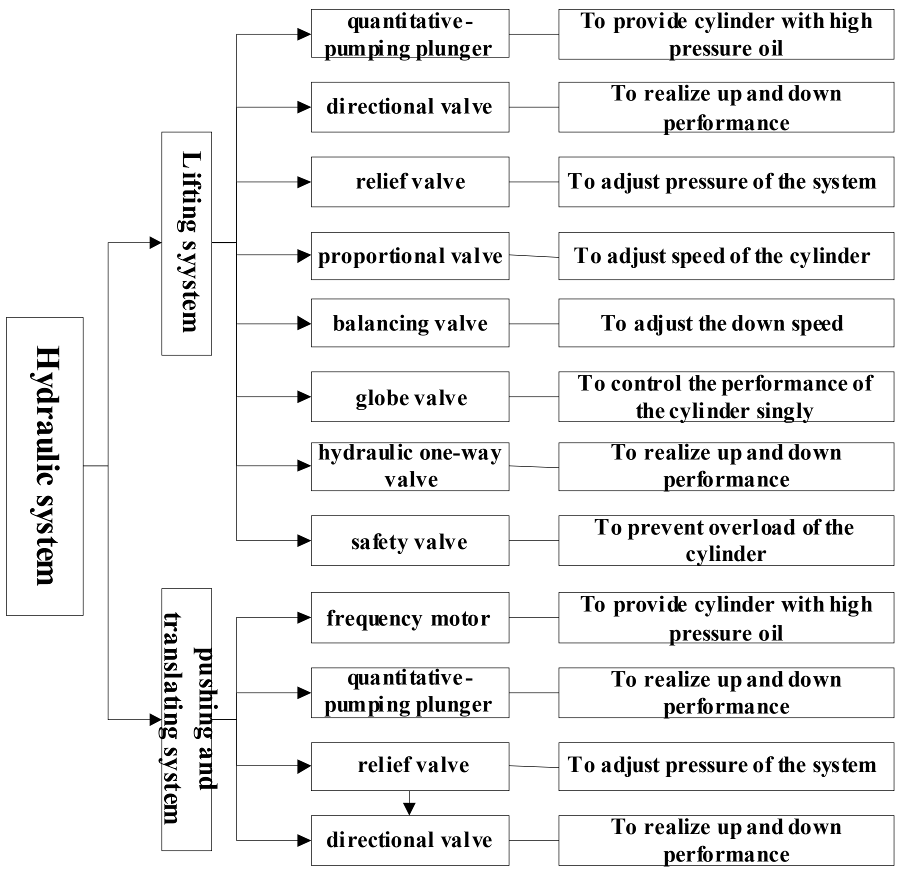

Fig. 7. *Block diagram of the hydraulic system.*

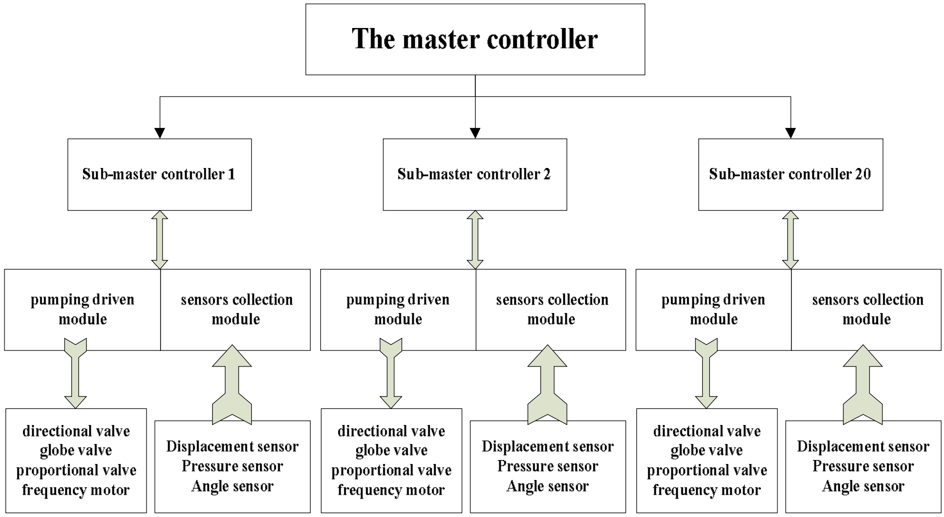

Fig. 8. *Network diagram of the control system.*

4.4. The Automatic Control System

In construction of Jiubao Bridge by ILM with the maximum launching points of 20 and total launching weight of 140000 KN, the controlling performance of all the launching points become more complicated. In order to make all the launching points work synchronously, an automation computer-control system is designed. This control system mainly consists of the real time hardware and software modules control system, real time control network, electronic control unit (ECU), sensor control unit (SCU). The master controller is a standard embedded computer platforms. various signals including structural displacement, stress and so on are sent back from sensors, being processed and analyzed, then change into control signals, which realized centralized control performance of all kinds such as lifting, pushing, deviation-rectifying, pressure and displacement data calculating, fault alarm and so on.

On each launching pier there is a sub-master controller, mainly including pump-driven and sensor-collecting modules, the former mainly deal with signals received from sensors, the latter primary collect current information about cylinders, such as pressure of the cylinders, grade of the beam bottom and so on, then feedback into the master controller. Based on the displacement, lifting and pushing force of the cylinders, the control strategy of "displacement synchronization, load tracking" is adopted, together with two control modes of automatic control and artificial control, ensures that all cylinders works at accurate synchronization. Fig. 8 shows the network diagram of the automatic control system.

4.5. The Operation Principle of the AWLS

The basic procedure of the operation principle of the AWLS is summarized as follows.

Steps 1, lifting: Opening the support-lifting hydrocylinder, lifting the girder as a whole.

Step 2, pushing: Opening the pushing hydrocylinder, pushing the girder forward.

Step 3, dropping: Dropping the support-lifting hydrocylinder, the girder is laying on the temporary support.

Step 4, returning: Returning the pushing hydrocylinder to where it begins, then one incremental launching cycle is completed, ready for the next cycle. see Fig. 9.

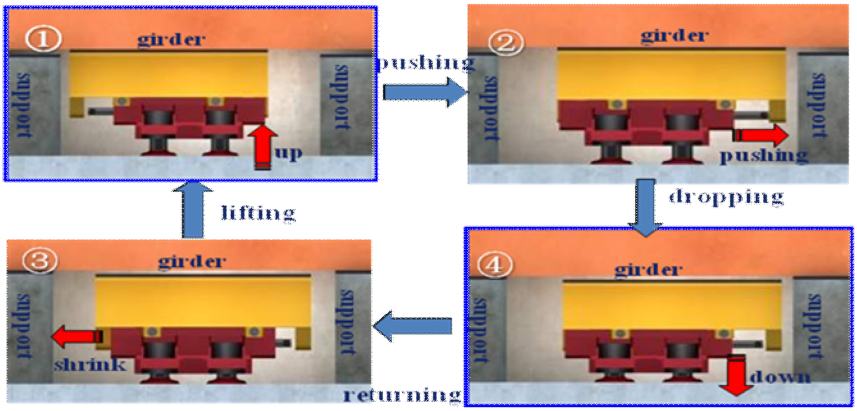

Fig. 9. *Operation principle diagram of the AWLS.*

As is mentioned above, when bridge is under construction by the AWLS, first the whole beam-arch composite structure is integrally lifted over multipoint, then the longitudinal jacks push it forward, finally it drops down on the temporary support, in this cycle of "lifting", "pushing", "dropping", and "returning" the girder is pushed forward.

5. THE ACHIEVEMENT AND PROSPECT OF THE AWLS

5.1. Advantages of the AWLS

In the AWLS, the sliding surface is changed from the bottom of girder to inside the launching equipment, thus greatly decrease the launching friction, avoid injury to the main structure, and reduce the level of internal force of the launching structure, so the AWLS is a truly self-balancing launching system. it combines the functions of lifting, pushing and rectifying into one system. It also features highly automation, safety and reliability in operation.

5.2. The AWLS Successfully Used in Jiubao Bridge

In construction of Jiubao Bridge with ILM by using the AWLS, the launching speed can reach 5m/h, and the AWLS has been in good working condition in the whole process of bridge construction, which also ensured the safety and quality of the bridge construction. It is for the first time to succeed in three-span beam-arch composite bridge erected by ILM in the world. Fig. 10 shows three spans of steel beam-arch structures under construction.

Fig. 10. Three spans of steel beam-arch structures under construction.

5.3. The AWLS Used in Other Bridges Construction

The AWLS is also characterized by wide application range. It is not only applied for beam-arch composite bridge construction such as be mentioned in this paper, but also for bridges with various form of girders, such as bridges with concrete box girder, steel box girder, composite beam, and steel truss girder. Even it can be adopted for girder erection by ILM in suspension bridge and cable-stayed bridge constructions. Here some of the bridges that are constructed by ILM with the AWLS are given following.

Luozhou bridge, which is located in Fujian Province of China, is a three-tower self-anchored suspension bridge with a span arrangement of 80 m + 168 m + 168 m + 80 m. Its main girder which is a 43-meters wide prestressed concrete box girder, is erected by ILM with the AWLS. Fig. 11 shows effect drawing of Luozhou bridge, Fig. 12 shows Luozhou bridge under construction.

Fig. 11. Effect drawing of Luozhou bridge.

Fig. 12. *Luozhou bridge under construction.*

Fuyuan Road Bridge across Xiangjiang River, in Changsha Province of China, mainly consists of three parts: the west approach bridge (55 m + 85 m + 90 m composite beam bridge), the main bridge (3x210 m three-span continuous beam-arch composite bridge), the east approach bridge (90 m + 5×85 m + 60 m + 45 m + 3×77 m + 45 m composite beam bridge). They are all constructed by ILM with the AWLS. Fig. 13 and Fig. 14 refer to the main bridge and the approach bridge of under construction respectively.

Fig. 13. *The main span of Fuyuan Road Bridge under construction.*

Fig. 14. *The side span of Fuyuan Road Bridge under construction.*

6. CONCLUSION

In the erection of large-span bridge with complicated structures by ILM, due to its complicated structural stress and deformation, big launching reaction, and high demanding for launching equipment, a new launching system-the AWLS is developed in this paper instead of the routine dragging-type launching equipment. There are many advantages about the AWLS. It combines the functions of lifting, pushing and rectifying into one system, and has an advanced control system, thus it enjoys highly automation. By changing the sliding surface from the bottom of girder to inside the launching equipment, horizontal thrust on launching piers will be drastically reduced, thus the AWLS turned to be a kind of self-balancing launching system. Compared with the dragging-type launching system, the AWLS would be more safety and reliability. Due to its very wide generality, the AWLS can be widely used in construction of bridges with various kinds of structure. Up to now, the AWLS has been successfully applied in several bridge construction projects. The development of AWLS is a meaningful and valuable innovation of technology of bridge construction by ILM. And it would also promote the development of erection technology of long-span bridges, as well as the development of bridge construction equipment.

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