IOP Conf. Series: Materials Science and Engineering **735** (2020) 012056 doi:10.1088/1757-899X/735/1/012056

Assembling Construction Technology of Prefabricated Box Culvert Components

Yumei Kang[1], Naiyuan Zhang[1], Tao Wang[2] and Yuhang Song[3]

1 School of Resources and Civil Engineering, Northeastern University, No.3-11, Wenhua Road, Heping District, Shenyang, 110819, China
2 China Railway No.7 Bureau Group No.3 Engineering Co, Ltd., Shanxi, 710043, China
3 School of Architecture & Civil Engineering, Shenyang University of Technology, No.111, Shenliao West Road, Economic & Technological Development Zone Shenyang, 110870, China
Corresponding author's e-mail: 451512696@qq.com

Abstract. Box culverts are common small structures in highway engineering. According to domestic and foreign practical experience in recent years, component factory prefabrication combined with on-site assembly can effectively improve production efficiency and construction quality. It will become the main trend in the box culvert structure and gradually replace the traditional cast-in-place process. Based on the project of 03A design section of Daqing to Guangzhou Expressway, this paper expounds in detail the assembly process and key operation points of prefabricated components. It also compared with the traditional culvert construction technique, which demonstrates the superiority of prefabricated box culvert assembly technology.

1. Introduction

Box culverts are widely used on highways. Its main function is to set up a small drainage structure across the roadbed to vent the surface water flow. The flow of water passes under the road, thus avoiding the impact of accumulated water on the road and detracting from its life [1]. At present, prefabricated concrete box culverts have been widely used in highway engineering in many developed countries. However, prefabricated concrete box culverts are less used, so China's fabricated concrete structure system is still not sound enough [2]. Drawing on the advanced experience of foreign countries, we will gradually form a building industrial chain with Chinese characteristics.

Cast-in-place construction technology is often used in the traditional expressway box culvert. Although the construction is simple and the cost is low [3], with the influence of the age of the concrete, the material operation cycle and the external environment, the construction quality is difficult to guarantee, which brings many difficulties to later management [4]. In order to solve the shortcomings of the traditional construction process, the culvert construction will be developed towards standardization, factorization, and industrialization [5]. Nowadays, the culvert components are prefabricated in the factory and transported to the site for assembly. This not only improves the working efficiency but also effectively reduces the construction cost, which embodies the basic requirements of industrialization construction to the greatest extent [6].

This paper based on the project example of 03A design section of Daqing to Guangzhou Expressway, which researched the assembly and construction technology of prefabricated box culvert components, analyzed the main operational points of the assembly process and compared with the

traditional culvert construction. The results show that the centralized operation of the factory has reached the goal of speeding up the project progress and improving labor efficiency.

2. Engineering Situation

The engineering project of the 03A design section of Shuangliao to Taonan section mainly passes through Shuangliao City, Changling County, Tongyu County and Taonan City. The starting point is located at the south side of Hara Road Fortress in Tongyu County, and the stake number is K125+000. The endpoint is located on the southeast side of Changling Village, Tongyu County, the stake number is K150+702.148, the total length is 25.702km, and there are 22 culverts. The project area is located in the Songliao alluvial plain. According to the regional survey geological data, there is no fault structure in the 03A design section, with the thick cover layer, the flat topography, buried depth of water level 1~20m, the better regional stability, and the distribution of saline soil in some paragraphs. The width of the subgrade is 27m, the bearing capacity is 100kPa~150kPa, and the main line of the expressway adopts the standard construction of a four-lane expressway with a design speed of 120km/h.

The project undertakes a total of 60 prefabricated construction tasks for prefabricated reinforced concrete box culverts, including 994 pieces of three structural forms, all of which are made of C40 concrete. Among them, XTI-2×1.5 is prefabricated for the entire section of the whole section, XTI-3×2.2 and XTI-4×3 are a four-component composite structure, which consists of four self-stabilizing members of the roof, floor and two side walls (figure 1). Sizes of prefabricated pipe joints are available in 3m and 1m. The roof of the box culvert is produced by the vertical type, the sidewalls are prefabricated by the inverted type and need to be turned over, the bottom of the floor needs to be pre-embedded, and the hoisting point is cut before assembling. When splicing, the upper roof and sidewall joint are elbow-shaped freely hinged, and then the sling reinforcement and concrete pouring are integrated into one. Taking the four-component composite structure as an example, this paper discusses the construction technology of precast production and assembly of box culvert components.

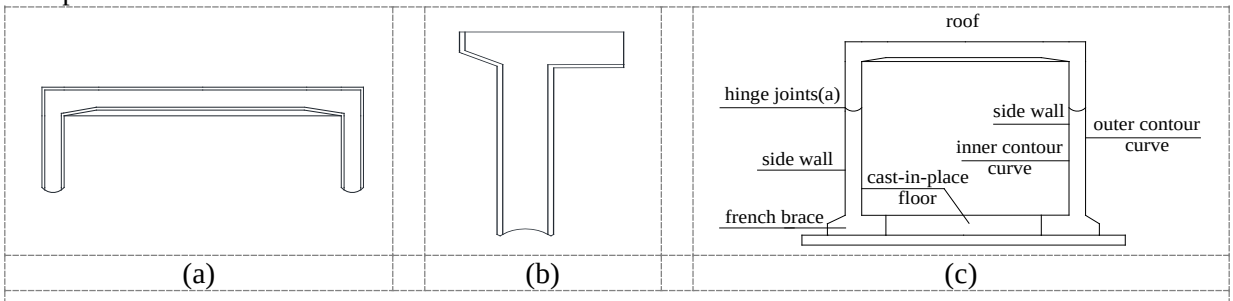

Figure 1. Four-component Composite Structure of Box Culvert

The design principle of the box culvert is based on the comprehensive consideration of the existing culvert structure problem, which changes traditional concrete on-site pouring to factory centralized prefabrication method to realize the specification factory construction and on-site rapid assembly construction [7]. The structure of the box culvert of this engineering is as follows: (1) The space utilization rate of the box-type culvert is large. In order to exert the force characteristics of the box culvert frame, the cross-center bending moment of the side wall and the top is utilized, which has high rigidity and good integrity. (2) Streamlined prefabricated models, with standard sections of 3m and 1m, further reduce the requirements for on-site lifting capacity and the difficulty of factory prefabrication while ensuring structural stress. (3) The requirements for foundation bearing capacity are low, and it can adapt to various geological conditions. The rectangular section type reduces the space requirements for surrounding embankments. (4) The joint between roof and side wall adopts the free articulated type, and the inner side of the joint head is filled with high-viscosity cement mortar, and the structure is as shown in figure 2(a). At the same time, in order to facilitate the integration of the longitudinal segments, chamfers are provided on the inner and outer sides of the longitudinal joint, and the structure is as shown in figure 2(b).

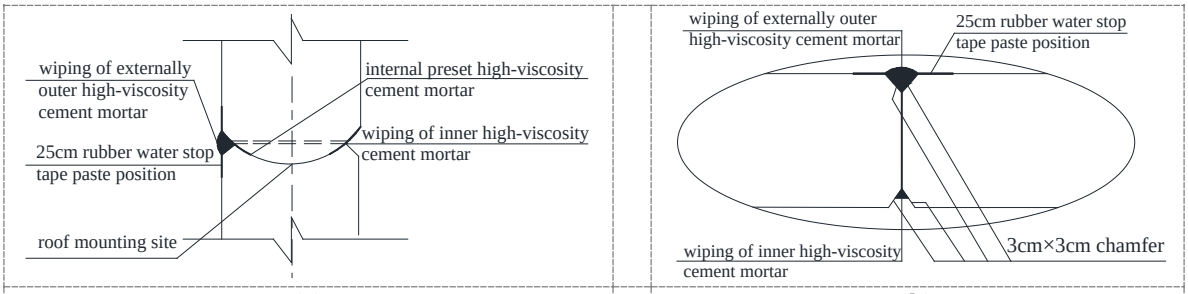

Figure 2. Schematic Diagram of the Construction of the Hinge Joint and the Loop Seam

3. Assembly Technology of Prefabricated Box Culvert

The assembling of the assembled box culvert components shall be carried out through construction preparation, excavation and cushion construction, component assembly, floor and hole cast-in-place, joint and waterproof treatment, backfilling behind abutment and other processes.

3.1. Construction Preparation

The construction preparations are as follows:

(1) Before the construction, comprehensive investigation and verification of culvert location, elevation and geology should be carried out, and geological exploration should be supplemented if necessary. If it is found to be inconsistent with the design, it should be reported to the supervision and design unit immediately and properly resolved as soon as possible.

(2) According to the design requirements, the construction access road is reasonably planned in combination with the terrain characteristics. The prefabricated site selection of the fabricated components is located in the same place as the mixing station and prefabricated beam yard in the S301 provincial highway. The distance between the temporary construction and the station facilities is less than 1km, and the transportation is convenient.

(3) Reasonable arrangement of component prefabrication area, maintenance area, and finished product stacking area is convenient for construction intensive management.

(4) Waterproof and drainage measures shall be taken before excavation of culverts, and construction personnel shall be reasonably arranged and equipped with relevant construction machinery to ensure the continuity of construction.

3.2. Foundation Pit Excavation and Cushion Construction

The foundation pit excavation is the key link of culvert construction. Before excavation, the geological data should be viewed, and the survey personnel should release the four corner piles of the open line of the foundation pit. After the sample is released, it will be reported to the measurement supervision engineer for review. When passing the test, the operator will be arranged to use the white ash to sprinkle the open line in time, and the excavator will enter the site to excavate the foundation pit. The excavation of the foundation pit is shown in figure 3. Excavation is carried out by using 1:1 slope rate for grading and excavation. The foundation pit is excavated according to the working width of the foundation pit width of each structure plus 50cm. Considering the construction of the rainy season and the existence of groundwater, a 50cm×50cm rectangular water collecting well is set at the corner of the foundation pit, the well depth is 60cm, and the water in the collecting well is 50~100m, the head is 2~42m, and the power is 0.75~7.5kW. The submersible sewage pump with a pumping capacity of 7~300m^3/h is collected into the drain and discharged outside the pit.

In order to prevent over-excavation and ensure that the slope is within the reasonable range, when mechanical excavation processed to the design base elevation of 30cm or slope boundary, manual excavation and slope repair should take place. When the foundation pit is excavated to the design elevation, manual leveling is carried out to verify whether the bearing capacity of the foundation meets the design requirements, and the gravel cushion is backfilled after passing the test. Layered and filled

according to design and specification requirements, using crushed stone or sand gravel. The cushion layer needs to meet the design plane size and elevation, and the leveling and tamping treatment.

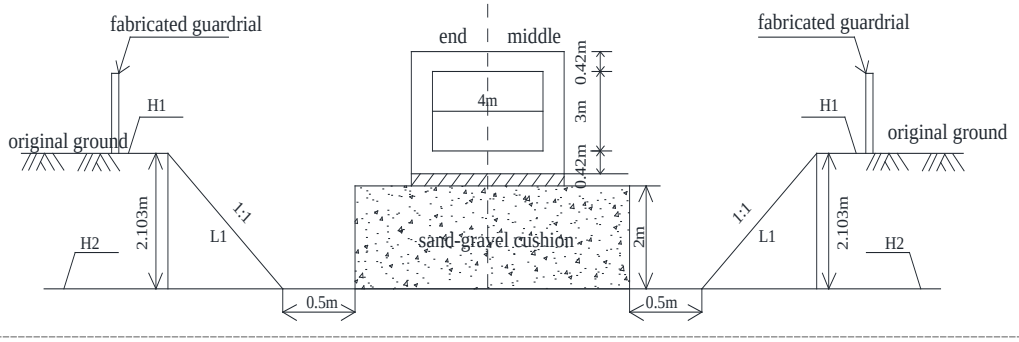

Figure 3. Schematic Diagram of Culvert Foundation Pit Excavation

3.3. Component Assembly

When the prefabricated components are processed in the factory, the concrete strength reaches 90% of the design strength before lifting and transporting. According to the on-site construction access road, two 20t rail flat transport trolleys were used to transport the box and culvert components to the site for assembly. The assembly site is shown in figure 4**.** At the scene, the 50t crane was used to hoist the prefabricated components in place. At the same time, 4 workers, 1 safety technician and 1 technician are arranged to meet the construction needs of the site. Pay attention to the following points when assembling components:

(1) Before assembling the components, the test should be carried out first, and the structural stability and positioning adjustment scheme of the system should be formulated. If necessary, support rods and wire ropes can be used to assist the stability.

(2) When assembling the main body, it should be carried out from the height to the ground, and the same component should be assembled from one end to the other to maintain the stability of the main body.

(3) When assembling the sidewall, ensure the tightness of the base and the cushion, and adjust the lateral position and relative distance at all times.

(4) Before the roof is hoisted, the workers check the position and relative distance of the two walls. Apply viscous M15 cement mortar to sidewall hinge groove to fill it by itself. Use a 3mm chamfer to smooth the cement mortar with an iron trowel.

(5) After sidewall and roof are assembled, the M25 bending bolts are used for connection and fixing, and the assembly should be carried out in an orderly manner according to the design requirements. Finally, check the overall state of the structure to ensure the accurate positioning of the components.

3.4. Floor and Hole Cast-In-Place

When all the components of the box culvert are assembled and accepted, the cast-in-place of floor and hole are made. The transverse steel bars of floor are connected by welding with HRB400 model. The welding quality is strictly implemented in the relevant technical provisions of Technical Specifications for Construction of Highway Bridges and Culverts (JTG/T F50-2011) [8]. Before the concrete is poured, the sidewall and floor joint surface shall be subjected to the brushing treatment, and the height shall be poured into the ground in order. Effective coverage during pouring prevents contamination of side walls. The orthogonal structure models XTI-2×1.5, XTI-3×2.2 and XTI-4×3 hole end segments shall be provided with a splayed wall, and the front view of the entrance hole is shown in figure 5. The eight-character wall and the foundation are cast-in-place, using M15 cement mortar, C30 concrete, 25cm rubber water stop. The four-component structure wing wall needs to be provided with anchor plates.

Figure 4. Box Culvert Roof and Side Wall Assembled Complete

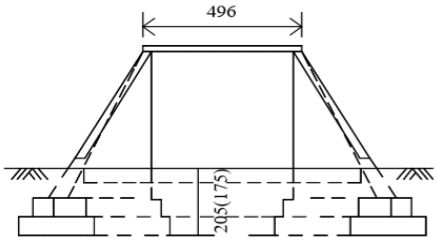

Figure 5. Front View of the Entrance Hole (unit: cm)

3.5. Joint and Waterproof Treatment

The 4cm×6cm groove of the culvert deformation joint is located above roof and floor, and the structure is shown in figure 6 the deformation joint is made of 2cm thick board coated with asphalt paste, and the side is filled with asphalt oakum, which is required to be filled compactness and meet the waterproof requirements [9]. Three layers of asphalt with a width of 50cm and three layers of asphalt and two layers linoleum are set on the outside. The contact part with backfill is coated with three layers of SBS modified emulsified asphalt. The waterproof asphalt is made of No.30 petroleum asphalt. Before the asphalt enters the field, the factory certificate should be inspected and sampled by the tester and sent to the central laboratory for retesting.

When the prefabricated section is waterproofed, the settlement joint and the connection joint shall be set in turn. The settlement joint range shall be set every 4m to 6m, and the inner side shall be attached with 1cm thick asphalt hemp as shown in figure 7. After the seam is fixed, the wire brush is used. The rag will be cleaned, and then coated with a 25cm wide 911 polyurethane waterproof coating. Finally, the special glue will be used to paste the 25cm wide back-mounted rubber water stop. The concrete base surface to which the water stop belt is attached shall be flat and free of cracks, and the allowable deviation of the flatness shall be 3mm. In order to ensure the tightness of the joint section of the joint, the high-strength steel nail may be fixed every 1m.

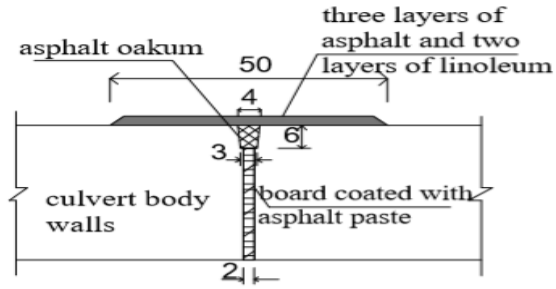

Figure 6. The Structure Diagram of the Deformation Joint of Culvert Body (unit: cm)

Figure 7. Construction of Asphalt Oakum

3.6. Back Filling

The backfilling of box culvert structure shall be carried out after the strength of cast-in-place concrete and mortar reaches 90% of the design strength. The filling shall be compacted in symmetrical layers. The quality of the filling on both sides and top of the box culvert shall be strictly guaranteed to ensure the restraint effect of the soil layer on the box culvert structure [10].

(1) When the culvert is backfilled, the improvement material of cement-soil with good performance should be selected for filling. The compaction thickness of each layer should be less than 20cm and the compaction degree should be less than 96%. When the structure support area is backfilled, the high-density sand can be used for water injection and compaction.

(2) When two side walls are backfilled, it shall be carried out by symmetrical and balanced horizontal layered rolling construction on both sides of the culvert. Manual and small-sized

mechanical compaction shall be used on the side within 1m, so that the backfilling can meet the design requirements of compactness.

(3) When backfilling on the structure roof, the thickness of less than 0.5m should be controlled to use compaction equipment. It is strictly forbidden to use heavy equipment and pile heavy objects, and the operation direction of compaction equipment should always be perpendicular to the structure axis.

3.7. Inspection and Acceptance

In the process of component assembly, the whole assembly process should be inspected and the following basic requirements should be met:

(1) Prefabricated box culvert components must pass the quality inspection of the system and enter the assembly site after passing the quality inspection. The site shall confirm and accept the dimensions, models and quantities of prefabricated components.

(2) During the whole process of component assembly, backfilling construction until completion, the section shape and structural position of the box culvert shall be inspected in three or more different positions.

(3) The construction shall be stopped if the inspection result exceeds the allowable deviation of component installation. The construction shall be continued after the reasons are identified and corresponding measures are taken to confirm the safety and stability of the structure.

4. Conclusion

(1) Relying on the engineering project of 03A design section of Shuangliao to Taonan highway, this paper systematically analyzes the process flow and operational points of assembling prefabricated box culverts components. In the whole assembling process of prefabricated components, the construction requirements of each procedure should be clarified, and accurate connection and coordination should be carried out to ensure assembly efficiency and accuracy.

(2) Compared with the traditional cast-in-place technology, the box culvert of this project adopts the factory centralized operation, which has higher construction efficiency, effectively guaranteed construction quality and enhanced structural durability. At the same time, it can reduce the maintenance cost of the later maintenance, and maximize the superiority of the prefabricated component assembly technology.

5. References

[1] Shi L G, Zhang Y and Li H L. 2017 Construction of precast utility tunnel with upper and lower assembly (Construction Technology) vol 46 18-21
[2] Yang X G. 2013 Design and construction key technology research of the precast reinforced concrete culverts (Central South University)
[3] Wang X X, Liang X L. 2016 Construction technology of factory centralized prefabricated culvert (Journal of Highway and Transportation Research and Development) vol 12 23-5
[4] Zhou W M. 2015 Construction technology of two-component fabricated reinforced concrete culvert (Railway Engineering) vol 02 36-8
[5] Lin Z H, Ma S. 2016 Prefabricated box culvert construction and principle research (Construction Technology) vol 45 329-31
[6] Guo R. 2014 Research on shallow buried soil super-long box culvert jacking key technology of highway (Chang'an University)
[7] Wu X F. 2012 Application of construction technology of fabricated large span arched concrete culvert (Bridge Engineering) vol 30 43-6
[8] CCCC First Highway Engineering Group Co., Ltd, Sichuan Road & Bridge Group Co., Ltd, Hunan Road & Bridge Construction Group Co., Ltd. 2011 (Technical Specification for Construction of Highway Bridge and Culvert)
[9] Xia K, Hu G and Hou Z G. 2012 Prefabricated integrated pipe gallery joint waterproof construction technology (China Concrete and Cement Products) 58-70
[10] Tong X K. 2012 Feasibility analysis of precast box culvert replacing cast-in-place box culvert (China Concrete) vol 38 58-70