Asymmetric demolition technology of large span variable cross-section continuous girder bridge

Cixiang Zhu, Wei Wang, Shaofang Li & Chuangang Jiang
CCCC Road and Bridge Special Engineering Co. Ltd., China

ABSTRACT: An asymmetric demolition construction scheme for the long-span variable cross-section continuous girder bridge was designed to settle the demolition problems of old Nanfeihe bridge in consideration of the Demolition Project Boundary. Based on the key technologies of “The method and device of preloading large-tonnage steel pipe support to jack-up Beam bottom tightly ","a bridge deck crane for the demolition of large and medium-sized concrete bridge "," The anti-impact method for the demolition continuous beam during the process of system transformation" and "the dragging method and device of landing the large tonnage", the construction technological process and main point of asymmetric demolition for long-span variable cross-section continuous girder bridge were described. The application of the complete set of technology assure the safety about structure, construction, traffic and environmental in the process of demolition, achieve the good social and economic benefits, and provides a new technical ideas for bridge demolition under complicated conditions.

1 PROJECT SUMMARY

The old Nanfeihe Bridge was a grand bridge across Nanfeihe river that also part of Hening Highway from Shushan to Longxi. The bridge was constructed by variable cross-section continuous box girder with pre-stressed concrete, into bidirectional three lanes. The length of main span was 45 + 75 + 45 in meters, with the 12.5m deck width and 7.5m beam bottom width. The height of the beam section changed from 2.0 m to 4.1 m, and the thickness of bottom slab changed from 0.3 m to 0.45 m, with 0.25m thickness of top slab. In order to stop the deflection of mid-span, the main bridge had been reinforced by pasting oblique steel plate on the web and applying the external pre-stress to the bottom slab, which didn’t work very well at last. In 2009, the bridge was going to be demolished and rebuilt besides the piers [1], to comply with the requirements of project "four -lane to eight" to Hening highway

Figure 1. The old Nanfeihe Bridge

Figure 2. The old Nanfeihe Bridge

2 PROJECT BOUNDARY CONDITION

The project boundary condition for demolition of the Nanfeihe bridge was identified as follows.

Table 1. the Major project boundary condition of demolition

No.	Factor	Describes of Items					
		1	2	3	4	5	6
1	Current situation	Double three-way prestressed concrete variable cross-section continuous box beam,Single deck width 12.5 m, the bottom of the beam width 7.5 m	The bottom flange thickness changed from 0.3 m to 0.45 m, top flange thickness was 0.25m ,the web thickness was 0.4m	Beam cracking seriously, span Deflection , multiple reinforcement was not completed, continuing Deflection	It is difficult to identify the initial state of the structure, the force is complex	Although in short term condition traffic is able to meet the requirement, satety and serviceability can not meet the requirement in long term conditon.	There is no domestic engineering examples and research results about similar demolition
2	Goal	The superstructure of the bridge was demolished and rebuilt , substructure was reserved to	Maximize the use of the lower part of the original structure, to achieve energy saving and	Eliminate security risks , improve traffic levels			
3	Object	superstructure	bearing	auxiliary facilities			
4	Background	the beam is a typical three-span continuous beam which has no prestressed in the thick roof in cross section of closure	there are prestressed steel in top flange and bottom flange,but there are not in web	The bridge has been operated for 10 years with lag Management and conservation	the main bridge has been reinforced by pasting oblique plate and the external prestressing and carbon fibre sheet,but all are not thorough	The bridge is a grand bridge on the highway , so it attracts a great social concern	The bridge was constructed by two companies with symmetrical parallel cast-in place cantilever method
5	Environment	The bridge is on the main highway ,which is coated with pipelines, and has heavy traffic .	The mid-span crosses over a busy III level channel , and both side-spans cross over the urban village roads .	New bridges has been built on both sides of the bridge; the gas pipelines , communication lines and dedicated lines cross through the bridge	The river was shallow and V-shaped. The condition of the side span foundations was poor and 3 meters mud pools in the local	For urban neighborhoods around the bridge, the personnel flow is larger; and the demolition was constructed during winter and plum rain season	Clear height of side spans is more than 10m, Clear height of mid-spans is more than 15m
6	Demand	Protective removed, piers and pile foundation can not be damaged	Construction safety , construction safety, traffic safety	Traffic on the bridge can be closed, navigation under the bridge can not be interrupted completely can be short-term intermittent closures 4 hours a day	In urban areas, to ensure that there are no noise, water and soil pollution , etc.	Energy saving and environmental protection , higher economic indicators requirements, reduce the negative impact on social	Short duration, must meet the highway " four - lane to eight " expansion time requirements

3 DIFFICULTIES IN DEMOLITION

Base on the project boundary conditions of Nanfeihe Bridge, the demolition was very complex in background, environmental and structural, with big difficulty in construction and organization. The details were described as follows:

(1) Base on the plan of quickly demolishing the middle span to lower the effect to shipping and traffic, the key boundary condition was the technical design for safety during the demolition, and the key difficult was to make a scientific and reasonable construction technology.

(2) In order to ensure the safety of structure, construction, and traffic, static cutting method was adopted rather than blasting method, to protect the piers and pile foundation, which was a mature but costly method[2]. In view of the uselessness of demolition concrete beam, it is extremely necessary to dismantle the beam into large sections, which would bring a technical problem in the increased weight of lifting and transportation.

(3) The erection of a security bracket is another technical problem in consider of the complex terrain, poor bearing capacity of the foundation, and the small clearance of construction.

4 DESIGN OF DEMOLITION

Four schemes (see Fig.3) were proposed based on static cutting method:

Scheme 1-little supports: seven rows of brackets will be set under side span. The main span will be removed early by 1-2 section than the side spans.0# block will be removed in several blocks.

Scheme 2-more supports: same as scheme 1 basically. Differences: 13 rows of supports will be set under the side spans. The side spans will be removed after the completely demolition of main span.

Scheme 3-full supports: same as scheme 2 basically. Differences: full supports for side spans. The side spans will be chiseled directly.

Scheme 4- reverse order: completely reverse with the procedure of new construction. And the pier will be consolidated with the beam.

In consider the advantages and disadvantages of the four schemes, scheme 2 was adopted.

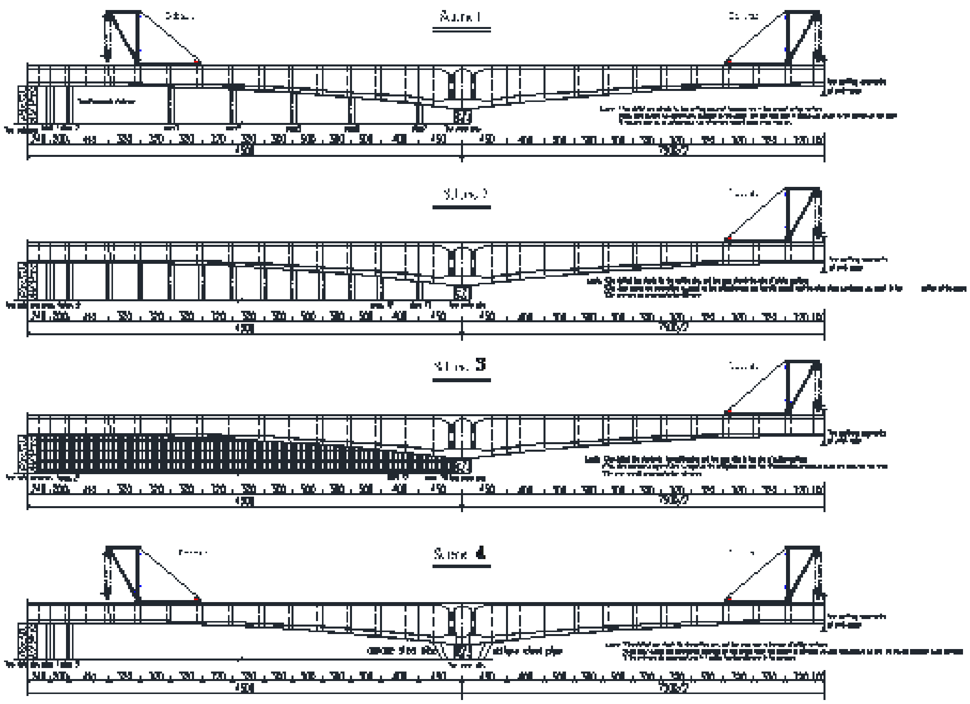

Figure 3. Four schemes of the old Nanfeihe bridge demolition

According to scheme 2, the order of the asymmetric demolition was the south half range first, then the north half range. The construction method of single range beam demolition as follows: 13 rows of steel tube supports [3] was built under both side spans, then the external pre-stressing and necessary restraints were relieved, and set security and anti-shock measures, then dismantled the mid-span by sections with static cutting device (Fig.4). Each sections were hanged by the bridge crane [4] (Fig.5) and hauled ashore [5](Fig.6) after transferred to wharf by the flat barge. Last the side spans and 0# section were removed. The shipping lane was broken off 4 hours each time when the main span was hanging to protect the safety of shipping. The sections could be pre-cut before be lifted, the remains were lifted after the shipping lane was broken off. At the end the sections were crushed after it were put in the ship and transported to the temporary wharf. The safe passage was set under the bridge to ensure the safety of person and vehicles when the side spans were removed.

Figure 4. Concrete being cut by chain-cutter

Figure 5. The deck crane

Figure 6. Drag ashore

5 THE PROCESS OF CONSTRUCTION

The process of the elected scheme of demolition construction is as shown in Figure 7.

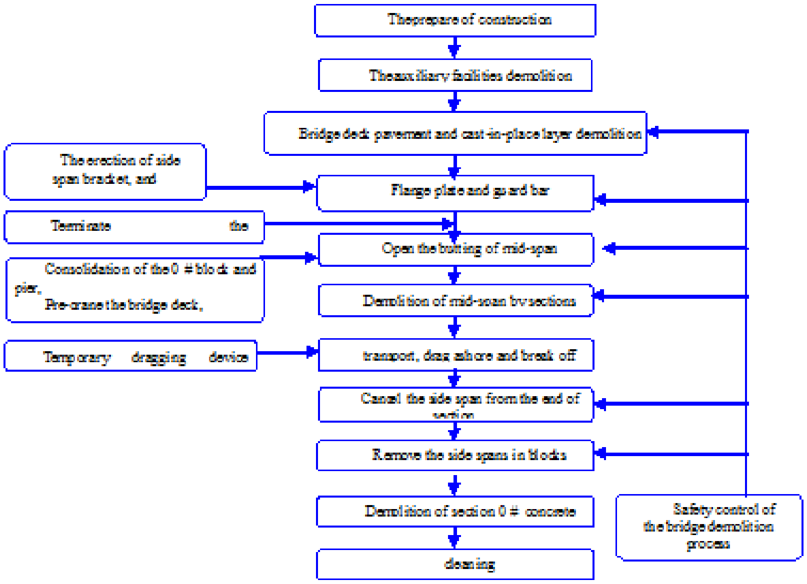

Figure 7. Overall construction process flow diagram of the bridge demolition

6 MAIN POINTS OF THE IMPLEMENTATION

6.1 *Bridge Deck Pavement and Cast-In-Place Layer Demolition*

The asphalt bridge deck pavement were removed directly by a forklift or a bucket, the concrete bridge deck pavement and cast-in-place concrete were cut in blocks by a small road cutting machine, then they were crushed by artificial wind draft, electric drill and hammer. Demolition was in the order from the mid-span to the side spans.

6.2 *Building and Preloading of the Side Spans Support System*

The structural systems were the side spans supporting steel tubes and spread foundation. The plan view size and reinforcement location of the spread foundation is according to the support counter-force and the bearing capacity of foundation soil. Channel steel or steel pipe diagonal bridging were longitudinal welding with 45 ° Angle between the adjacent steel pipe columns after they were erected. And steel pipe lateral bracings were transverse welding on each row, the diagonal bridging and lateral bracings were welding every 5m which is according to the height of the steel tube column. The support were pre-pressing with the 1.2 times of the steel pipe support counter-force and last not less than 30 minutes, and wedged it with miscellaneous wood wedge after it was stable (as shown in Figure 8 and Figure 9, can be found in the references [3]). They were protected and settlement monitored after the pre-pressing, and set the water-proof channels and drainage channels. The acceptance inspection should be completed before using steel pipe support system (Figure 10) in formal.

6.3 *Demolition of the Guardrail and Part of the Flange Plate*

After the demolition of the affiliated facilities, we began to dismantle barriers and part of the flange plate. We should use the combination of a chain cutter and disc cutting machine to decompose, and the 16 t or 25 t lifting capacity cranes to lift, and the large rock drill to achieve secondary crushing. For the cantilever flange that is about 2.5m of box girder, we should cut the beam into sections according to the distance which was around 1.5m for the transverse bridge along with concrete parapet, and which was 3m along the bridge longitudinal. Demolition should be completed from the mid-span to the side spans. Cutting block should be numbered and be tagged by the cutting line for facilitate of the metrology management. The fence and part of the flange plate which was cut down should be lifted by the truck then transported to concentrate broken.

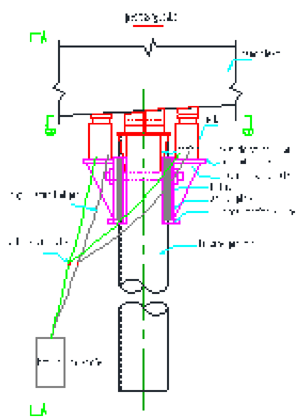

Figure 8. Elevation of the steel pipe support prepressing device

Figure 9. Scene of the steel pipe support prepressing

Figure 10. After the steel pipe support prepressing

6.4 *Relieve the External Pre-Stressing*

The side mid-span of the beam had been symmetric reinforced by the externally pre-stressing (as shown in Figure 11, Z1 to Z5). So the externally pre-stressing should be relieved with the procedure of “middle span after side span” before open the butting segments of mid-span. First numbered the external cable from the longitudinal axis to sides of the bridge and determine the implementing safe cutting position. Before relieving, the anti-jumping steel hoops (Fig.12) should been installed on the external cable which is between the bunk in the box girder. Meanwhile cut the steel stand by roots with the long handle oxyacetylene metal-cutting in the side of the deflecting plate. Make construction command, to ensure that the external cable of the whole bridge could be basic symmetric synchronization relieved.

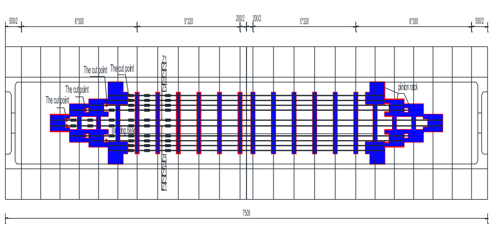

Figure 11.Cutting position arrangement of the steel cable in mid-span

Figure 12. Installation of the anti-jumping steel hoops

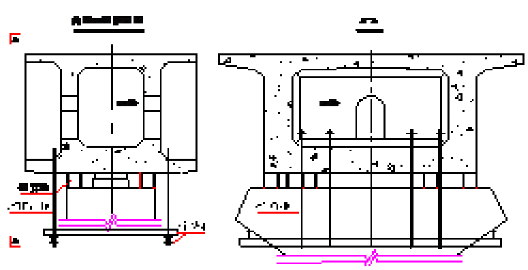

Figure 13. Temporary fixed construction of the pier beam

Figure 14. Steel drums between the main pier and the beam

6.5 *Consolidation of the 0 # Block*

In order to guarantee the stability of the whole structure during the process of demolition, 0 # block must be connected with the main piers to be a structure which can resist rotation from the original piers to ensure that the rotational resistance is no less than any unbalanced bending moment acting on the top of the piers from gravity of one box girder section. The bottom plate of 0# block were locked with hoops on the bent cap with 8φ 32 finished deformed bar. And tensed the fining twisted steel bar by jack to a certain tonnage, last underlying all around the bearing with steel drums(Fig.14) which was made by the steel pipe of φ530 * 10.

6.6 *Demolition of the Butting Segments in Mid-Span and Inverted Dismantled by Sections*

The size of the demolition butting segments in mid-span is 1.0m. Cut off the other sections in the same way after the butting segments in mid-span was cut off. For the convenience of dropping the pieces of the cutting, the cutting surface was cut into "eight" shape in Chinese, and 15cm width of straight slot was cut off from top plate. After the sections were completely cut off they were dropped on the transport ship (Fig.15). Wire ropes on the same lifting point should be tightened to the same degree. And the wire ropes in the snap ring were forbidden to overlying each other, in order to prevent excessive force. In order to prevent the wire rope from breaking, rubber pad were stuffed in the contact site between the wire ropes and the hole for hoist.

Before the butting segments in the mid-span were officially cut off, it was necessary to symmetric capture the butting segments with 2 bridge cranes (references [4]) and install anti-impact outrigger (Fig.16). Jacks were installed on the front of the anti-impact outrigger when the official cutting was beginning. Sudden uneven subsidence and impact of the box girder were prevented because of the capacity of the jack oil cylinder. The other sections were removed in the same manner with the butting sections in the inversion sequence. Also they were dropped (Fig.17) on the transport ship by deck crane, and then transferred to the temporary wharf for breaking.

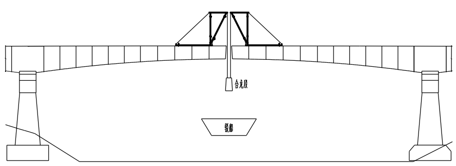

Figure 15. Drop the cutting segments in mid-span by deck crane

Figure 16. Anti-impact outrigger

Figure 17. Drop the mid-span of box girder

6.7 *The Cutting Segments Be Dragged Ashore*

The cutting segments were dragged ashore by the drag and ashore device of large tonnage (Fig.18, references [5]) which is composed of 2 structural steel rail in the wharf and teflon slide on the steel rail. First the steel railways abutted with the pathway on the ship, then the cutting segments were crushed on the crushing point after they were hauled ashore by winch hauling system (Fig.19).The structural steel of the rail on the bank should be poured on the concrete foundation. The pathway on the ship was arranged transverse direction of ship. The pathway and the ship should be welded by adequate stiffening plate. The size of the pathway depends on the tonnage of the box girder sections. The space between the pathways is about 1m smaller than the width of box girder bottom.

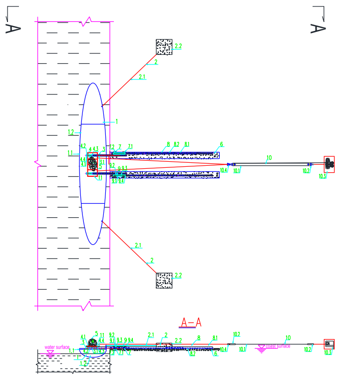

Figure 18. The schematic diagram of the large tonnage dragging ashore

Figure 19. Dragging the section of box girder by winch hauling system

6.8 *Side Spans Removed in Small Blocks*

The overall section number of side spans of box girder is as shown in Figure 20. The long of the longitudinal section is difference from 1 m to 3.2 m. According to the cutting area, cutting force, cutting way of the section and hoisting way, each section was divided crosswise into 2 ~ 7 units. Whose sections had deflecting plate and anchorage tooth plate in box girder will consider 1~2 blocks more. Considering the actual operation feasibility and the degree of safety in the demolition process, the side spans were static cutting removed (Figure 21) 1.2m far away from the center of the side pier top. Which the sign of removed is the support of the transitional pier out of work (reaction is zero). The box girder was broken into sections and then blocks then removed with the lorry-mounted crane, after the side spans were relieved. The sections were cut on the principle of longitudinal before horizontal, upside before downside, and middle before side. To avoid the longitudinal pre-stressing anchor head in the top plate, the cutting line was 50cm far away from the original construction segmental line. The middle blocks of top plate were cut by 2 to 3 segments continuously to make sure that the bottom plate of the last section can be the operating platform (Fig.22) of the next section.

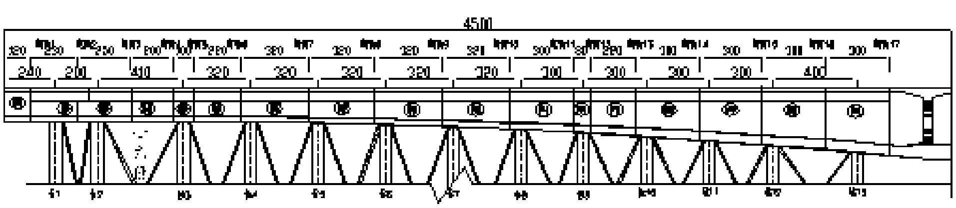

Figure 20. The side spans of box girder divided into sections and small blocks

6.9 *0 # Block Removed*

0 # block should be synchronously removed combining with the 1# block, 0 # block were divided into small blocks about 10t, and then hanged by lorry-mounted crane, at last secondary decomposed on the spot or at other designated places. 0 # block demolition construction steps as shown in Figure 24.

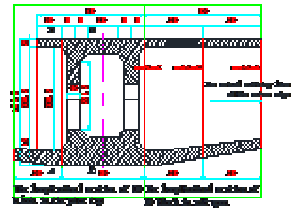

Figure 21. Cut at 1.2m far away from the center

Figure 22. Sections of the side spans hanged in blocks

Figure 23. The longitudinal section of 0# block

Figure 24. The process of the 0# block demolition

7 CONCLUSIONS

On the background of the demolition for typical 3 spans variable cross-section continuous girder bridge - the old Nanfeihe Bridge - an asymmetric demolition scheme of the long-span variable cross-section continuous girder bridge was designed. In this scheme, based the static cutting and the special anti-shock and system conversion technology, the affiliated facilities, the deck pavement and the guard bar were removed first, then removed the mid-span box girder by sections with the double deck crane and drag device. At last side spans and 0#blocks were removed in blocks with the less support system and crane. "The method of the long span continuous static beam cutting construction" was formed. And "a bridge crane used in demolition of large and medium-sized concrete bridge "," preventing impact method and measures in the process of system transformation of continuous beam demolition" and "the drag and ashore method and device of large tonnage", “preloading and jack-up tight methods and devices of large-tonnage steel pipe support under Beam bottom" and other key techniques were proposed. This key tech had applied to the demolition of 2 concrete variable cross-section continuous bridges whose main spans exceed 75m.In those demolition constructions, the safety of structure, construction, traffic and environment were done well. And we had achieved good economic and social benefits. In the condition of doing the minimum compact on the highway and navigation under the bridge, the demolition construction had completed about 60days early, which provided favorable conditions for the construction of Hening highway extension. And new technical ideas were provided for the demolition construction of similar variable cross-section continuous beam and continuous rigid frame bridge.

REFERENCES

[1] Cixiang Zhu, Zhifei Zhou. “discussions about the methods and techniques of long span concrete girder bridge demolition”[J]. Highway traffic science and technology. 2010.6(70),72-77.

[2] Cixiang Zhu,Chuanggang Jiang. “The research about the construction method of concrete box girder un-blasting demolition” [J]. Road. 2013.1.

[3] Cixiang Zhu, Wei Wang, Zhongfu Xiang, et al. “The method and device about preloading and jack-up tight methods and devices of large-tonnage steel pipe support under Beam bottom”[P]. Chinese patent: 201210326296，2013-03-28.

[4] Chuanggang Jiang, Wei Wu, Cixiang Zhu.” Bridge deck crane used for the demolition of large and medium-sized concrete girder” [P]. Chinese patent:20102015138.3，2010-11-17.

[5] Cixiang Zhu, Chuanggang Jiang, Wei Wu.”the drag and ashore method and device of large tonnage". Chinese patent:201010608649.3，2013-06-12.

[6] Chuanggang Jiang, Wei Wu, Cixiang Zhu.”Construction methodof static cutting method about Long-span variable cross-section continuous girder bridgeDemolition construction”. The number of construction method: GGG C1-2011.