Application examples of steel-concrete composite bridges that can be quickly replaced

Bingbin Wang[1], Junyan Wu[2], Laiyong Wang[2, *], Xu Zong[3] and Wenpeng Xu[3]

[1]Fuzhou Minqin Highway Bureau, Fuzhou 350000, China

[2]China Academy of Transportation Sciences, Beijing 100088, China

[3]School of Transportation and Civil Engineering, Shandong Jiaotong University, Jinan 250357, China

*Corresponding author e-mail: Laiy.wang@163.com

Abstract. Compared with concrete bridges, steel-concrete composite structure bridges have lighter dead load and lower beam height, which can better adapt to the longitudinal alignment of the route. Therefore, it has great application and promotion value in bridge reinforcement, reconstruction or expansion projects in which the upper structure is removed and the original lower structure is retained. This article introduces the application examples of fast-replaceable steel-concrete composite structure bridges in engineering, and introduces in detail the key contents of the bridge structure, such as structural dimensions, construction methods, and construction periods, which can provide references for the implementation of such projects.

Keywords: steel-concrete composite structure, simply supported box girder bridge; statistical analysis; design parameters.

1. Bridge Overview

G534-Fuqing-Changting-Songkou Bridge, the bridge center pile number is (K134+110), the total length is 182.45m. The bridge has a total of 8 spans, the span layout is: 8×22.16m; the full width of the bridge is 8.8m, the bridge deck horizontal layout is: 1.0m (sidewalk, railing) + 6.8m (carriageway) + 1.0m (sidewalk, railing) . The upper structure is reinforced concrete T-beam, plate rubber bearing; the lower structure is reinforced concrete embedded bridge abutment, pile foundation; mortar-masonry gravity bridge pier, enlarged foundation; bridge deck is cement concrete pavement, comb-shaped expansion and contraction Sew. Design load: Car -15 grade.

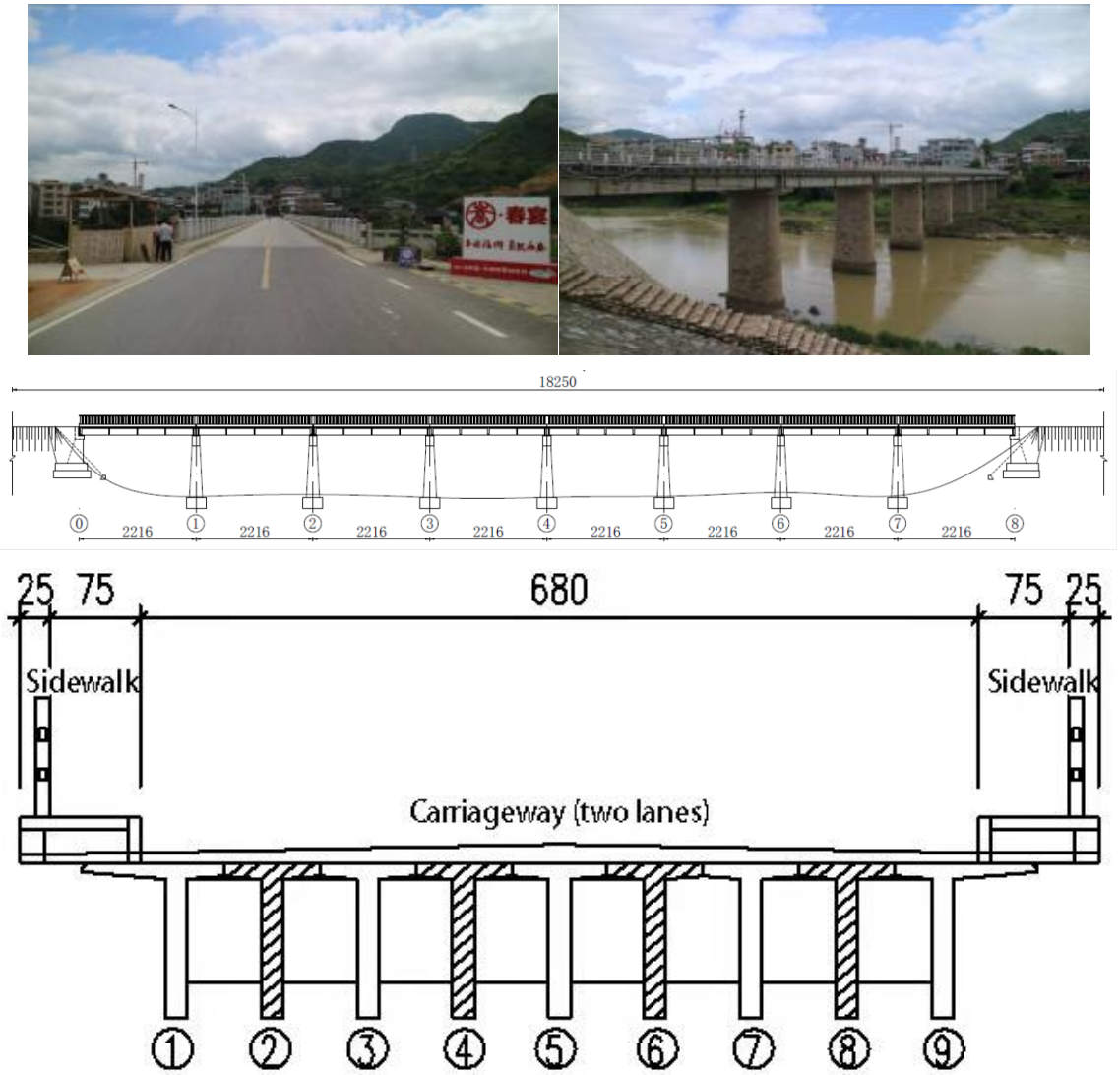


Figure 1. Among them, beams 1, 3, 5, 7, and 9 are the original T beams, and beams 2, 4, 6, and 8 are newly built T beams when they were reinforced in 2009.

2. Design scheme of bridge superstructure

2.1. Reconstruction design content

In this design, the upper structure is demolished and reconstructed, and the lower part is reinforced and used. The upper part of the bridge adopts 4×22.16+4×22.16m steel-concrete composite beams, and the length of the bridge remains unchanged. The upper structure has four horizontal steel main beams, the main beam height is 1.10m, the prefabricated beam bottom width is 1.3m, the center beam prefabricated width is 2.60m; the side beam prefabricated width is 3.40m, and the side beam cantilever is 1.45m. The bridge deck pavement is 20～27.5cm C40 cast-in-place concrete layer, and the bridge deck cross slope is adjusted by the pavement layer. After the transformation, the width of the bridge deck is 12m, and the horizontal layout is 2.25m (sidewalk, railing and guardrail) + 7.5m (carriageway) + 2.25m (sidewalk, railing and guardrail). Type 40 expansion device and polypropylene fiber concrete are used at the bridge abutment, and Type 80 expansion device is used at the connection of the 4# pier.

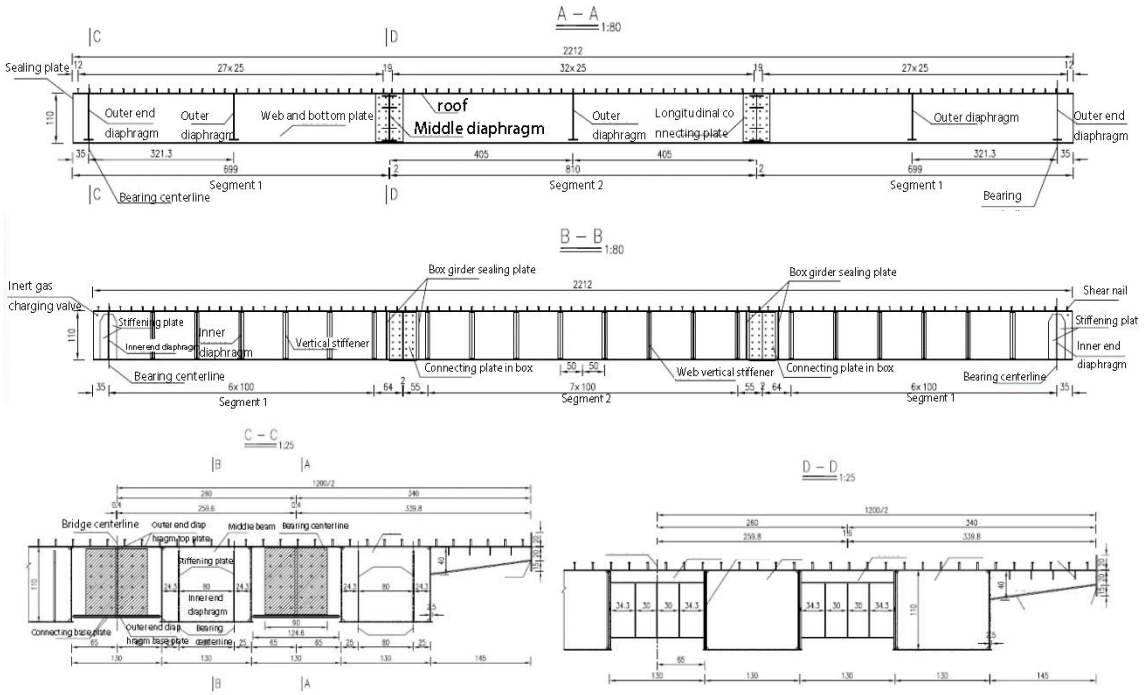


Figure 2. Schematic diagram of steel-concrete composite beam

Through this transformation, the width of the bridge deck has increased by 3.2m, and the dead load of the upper structure is 1.16 times that of the original upper structure, which has little impact on the lower structure; and the dead load per square meter on the upper part of the bridge is 0.88 times that of the original bridge. The design load level is upgraded to highway-II level, which greatly improves the traffic capacity of the bridge.

2.2. Superstructure calculation results

Structural design calculations comply with "Code for Design of Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts" JTG 3362-2018, "Code for Design of Highway Steel Structure Bridges" (JTG D64-2015), "Code for Design and Construction of Highway Steel-Concrete Composite Bridges" (JTGT D64) -01-2015) requirements. The upper structure of the steel-concrete composite beam adopts the MIDAS space link program to calculate the internal force of the structure. The transverse distribution coefficient of the main beam is calculated according to the rigid connection beam method. The bridge deck is calculated according to the one-way plate and the cantilever plate.

The main girder is welded and fabricated in the factory, and the bridge construction adopts the temporary support method. After the construction of the lower pier cap beam reaches the strength, the steel box temporary support is installed, and the steel box structure is installed, and then high-strength bolts are used to connect at the interface. For the beam between the boxes, the steel box bears its own gravity at this time, then the steel bars are tied, the bridge deck pavement is poured and the bridge deck is continuous. At this time, the steel box serves as a temporary support to bear its own weight and concrete weight, and then construct anti-collision guardrails. In the final stage of bridge completion, the steel-concrete composite structure jointly bears the second stage of dead load and live load.

Through calculations, under short-term conditions, the maximum compressive stress of steel beams in the construction phase is 90.3Mpa, and the maximum tensile stress is 81.3 Mpa, and the flexural bearing capacity meets the requirements; under permanent conditions, the maximum compressive stress of steel beams in the operation phase is 110.4Mpa, and the maximum tensile stress is It is 185.4Mpa, and the flexural load-bearing capacity meets the requirements; In the enduring condition, the maximum vertical deflection of the steel beam is 8.4mm, which is less than

l/500=42.84mm, which meets the requirements of the specification. The actual pre-camber is 3.0cm. Under the basic combination of bearing capacity limit state, the maximum compressive stress of the upper flange of the concrete bridge deck is $\gamma_{0\sigma}$=6.09Mpa, which is less than the design compressive strength of C40 concretef_{cd}=18.4Mpa and less than 0.5f_{ck}=13.4Mpa.

The compression flange of the concrete bridge deck and the steel beam are connected by shear connectors. The two have been firmly combined and can prevent the lateral displacement of the compression flange of the steel beam, and the overall stability meets the requirements.

Under the action of fatigue load, $\sigma_{pmax} = 2.737\text{MPa}, \sigma_{pmin} = -0.158\text{MPa}$, $\gamma_{Ff} * \Delta\sigma_p = 2.895\text{MPa} < \frac{k_s \Delta\sigma_D}{\gamma_{Mf}} = 54.5\text{MPa}$, the overall fatigue calculation of the normal stress of the steel beam meets the requirements of the specification; $\tau_{pmax} = 4.811\text{MPa}$, $\tau_{pmin} = -0.222\text{MPa}, \gamma_{Ff} * \Delta\tau_p = 6.455\text{MPa} < \frac{\Delta\tau_L}{\gamma_{Mf}} = 33.9\text{MPa}$, the overall fatigue calculation of steel beam shear stress meets the requirements of the specification.

3. Bridge superstructure construction

3.1. Design to keep routes accessible during construction

The access road is located on the upstream (west side) of the Songkou Bridge, with a total length of 240.2 meters. The two sides are connected to the parking lot and the current village road respectively. Adopt filling subgrade and bury water-passing pipe culvert. The width of bridge deck and road surface is: 7.5m = 0.5m guardrail (road shoulder) + 2×3.25m motor vehicle lane + 0.5m guardrail (road shoulder).

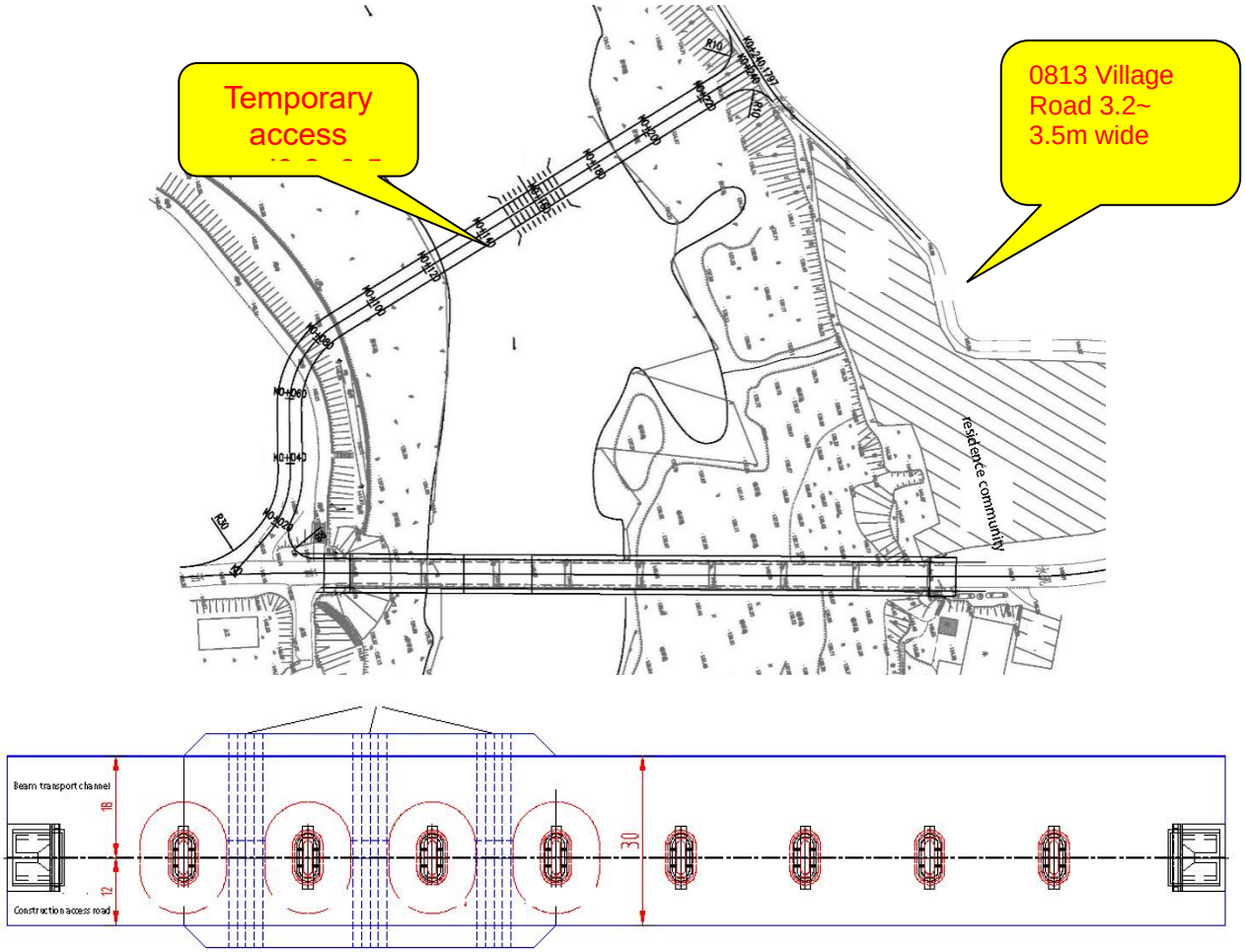


Figure 3. Schematic diagram of the layout of the construction access road (m)

3.2. Structural demolition plan and steps

The demolition of the bridge deck system and ancillary facilities includes bridge sidewalks, guardrails, etc., the deck pavement is removed, and the demolition is demolished with a 25t truck crane and a 220 excavator with a breaker hammer.

T-beam removal is carried out hole by hole from No. 0 abutment to No. 8 abutment. The demolition adopts static cutting. The method is to use a diamond-encrusted chain saw to aim at the part of the concrete member that needs to be dismantled and repeatedly cut, and use the ultra-high strength of the diamond to cut the reinforced concrete until the part is cut through. At the same time, water cooling is used, which is not only required for cooling the cutting equipment, but also an effective measure for dust prevention and noise reduction.

The static cutting first cuts horizontally along the center line of the pier top, and then cuts longitudinally along the wet joint between the T beams. Before longitudinal cutting, a wooden wedge must be used to tighten the diaphragm at each T beam end. The cutting line layout and sequence are shown in the figure below.

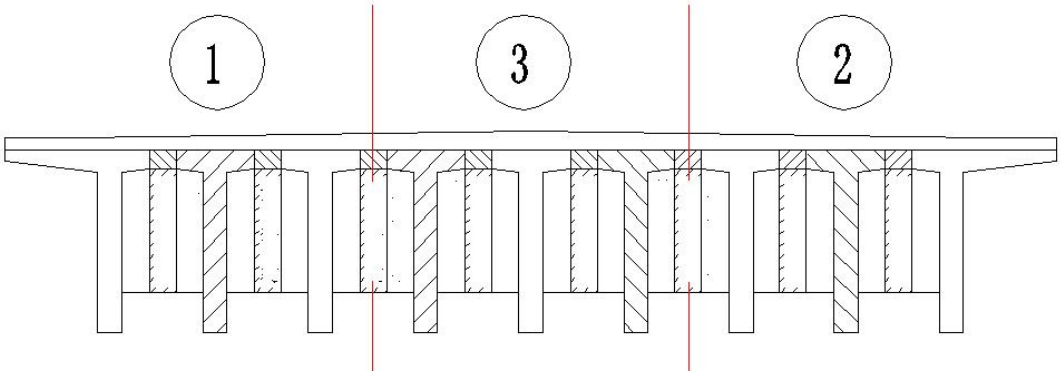


Figure 4. Schematic diagram of longitudinal cutting of T beam

After the longitudinal cutting is completed, use a 160mm diameter rhinestone to drill a hole 1m away from the beam end for the wire rope to pass through. Before the old beam is hoisted, a shoulder pole beam needs to be processed. The pole beam is 3m long and has a load-bearing capacity of 70t.

After the old beam is cut, each span is divided into two parts. The maximum lifting weight is about 100t. Two 180t truck cranes and 200t beam trucks are used for lifting to the crushing site, and two 80t gantry cranes are used for unloading, and then crushed by breaking hammers. , The excavator is shipped to the dump truck and transported to the designated spoil ground.

3.3. Superstructure installation plan and steps

The steel-concrete composite beam is processed in sections by the factory, transported by land to the construction site, and assembled into a whole span using two 80t gantry cranes.

The steel-concrete beam installation adopts two 180t truck cranes and a 200t beam truck to hoist the entire span to the designed position, and then cast the roof concrete on site. The steel-concrete beam hoisting across the entire span requires a shoulder pole beam. The beam is 10m long and has a load-bearing capacity of 50t.

3.4. Mechanical equipment configuration

Table 1. Mechanical equipment configuration table

Serial number	Equipment name	Model specification	unit	quantity	Remark
1	Car crane	180t	set	4	
1	Car crane	25t	set	1	
2	Beam truck	200t	set	2	
3	Gantry crane	80t	set	2	Prefabrication plant, crushing plant
4	Excavator (including breaker)	Carter 220	set	2	
5	Forklift	Lonking 50	set	1	
6	self-discharging truck	Shaanxi Automobile Delong	set	3	
7	Diamond wire saw		set	3	

The construction machinery and equipment are mainly 180-ton truck cranes. There is no need for on-site assembly and assembly of large-scale equipment. The construction is on-the-go. The requirements for the route are low, which is convenient for construction organization, and is especially suitable for emergency rescue of low-grade highways in mountainous areas.

3.5. Schedule

Table 2. Assuming that the construction start date is January 1, 2020 and the total construction period is 65 days, the specific construction plan is as follows:

Serial number	Construction content	Construction period	Work surface/team	Starting time	End Time	Remark
1	Construction preparation	15	1	January 1	January 15	
2	Foundation and pier reinforcement	6	2	January 16	February 3	
3	Steel concrete beam production	/	/	January 16	February 16	
4	Reinforcement of cap and cover beam	6	2	January 23	February 19	
5	Demolition of bridge deck system and ancillary	2	1	February 20	March 7	
6	Static cutting of the old bridge	1	1	February 22	February 29	
7	Remove old beams	1	1	February 23	March 1	Closed traffic
8	Steel concrete beam hoisting	1	1	February 24	March 2	Closed traffic
9	Bridge deck system and ancillary construction	2	2	February 25	March 5	

According to the construction schedule, it can be seen that the use of steel-concrete beams for integral hoisting can be used for dismantling, hoisting, and bridge deck construction flow operations. The total construction period from the removal of the old beams to the bridge deck construction is 15 days, which greatly reduces the closed traffic Time, the social benefits are obvious.

4. Conclusion

(1) In the design of the reconstruction and expansion of the bridge where the upper structure is dismantled and the lower structure is repaired, the structural form of steel box composite beams is adopted, and the beam height is low. Under the condition of keeping the road surface unchanged, the space under the bridge can be guaranteed.

(2) Steel box composite beams can be manufactured in the factory and assembled on site. The quality of the components is guaranteed and the long-term durability is good;

(3) Steel box girder sections can be made into standard parts, which are convenient for road transportation, and have lower requirements on site sites, which can reduce the need for zero-hour land occupation; steel box composite girder transportation and construction do not require large-scale equipment, which can be used in emergency repairs on low-grade mountain roads.

References

[1] Chen Baochun, Mou Tingmin, Chen Yiyan, Huang Jizhuo Research progress and engineering application of steel-concrete composite structure bridges in China [J] Journal of building structures, 2013,34 (S1): 1-10

[2] GB 50917-2013, code for design of steel-concrete composite bridges [S]

[3] Code for design of highway steel structure bridges: JTG d64-2015 [S], 2015

[4] Zhang Xianrong, Hu jia'an Wuhan Erqi Yangtze River Bridge 6 × Design of 90m steel-concrete composite continuous beam [J] World bridge, 2012,40:11-14

[5] Feng Jiangang, Qin Zhijun, Zhao Xiuwen Design and construction of steel-concrete composite box girder bridge [J] Highway Traffic Technology Application Technology Edition, 2010,06:6-8

[6] Ye Jianshu, Li Guoping Structural design principle [M] Beijing: People's Communications Press, 2008.193-194