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Advantage Analysis of Composite Girder with Corrugated Steel Web Compared with Concrete Girder in Continuous Rigid Frame Bridge

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***Abstract*—This paper focuses on the application, characteristics and advantages of composite girder with corrugated steel webs at home and aboard. The comparison between concrete girder and composite girder includes material quantity, intensity and stiffness. The results show that composite beam has saving on the material quantity and the use of composite beam would avoid burdensome procedure and speed the construction period. Composite beam would also have a larger bearing capacity and a smaller stiffness.**

Keywords-composite girder; corrugated steel web; rigid frame bridge

I. INTRODUCTION

With the increasing span of the prestressed concrete bridge, the dead-weight of bridge has become a constraint to its span capacity. The French put forward a new type of steel-concrete composite box-girder to solve this problem, and they decided to replace the traditional concrete web with corrugated steel web. Cognac Bridge is the first steel-concrete composite box-girder bridge.

Since then, many other countries have built the same type bridges and made the steel-concrete composite box-girder available all the world, especially in Japan [1]. Japanese bridge engineers have done a lot of research on this type and built more than 200 similar bridges. Also, the corrugated steel web bridge norms in design and construction are sophisticated and standardized and including beam bridge, arch bridge, cable-stayed bridge and so on.

In recent years, composite box-girder bridges with the corrugated steel webs have developed rapidly in China, Table 1 shows some examples.

II. CHARACTERISTICS OF COMPOSITE BOX-GIRDER BRIDGES WITH THE CORRUGATED STEEL WEBS

Composite box-girder bridges with the corrugated steel webs consist of top-and-bottom concrete board, pre-stressed tendons and corrugated steel webs. Figure 1 shows the normal form of this type.

Compared with the concrete girder bridges, composite girder bridges with the corrugated steel webs has the following advantages:(a) the dead-weight of girder is reduced by 20%~30% because of the use of corrugated steel webs; (b) the efficiency of pre-stressing is improved and the influence of temperature and concrete shrinkage and creep on the top-and-bottom board is reduced; (c) the shear strength of corrugated steel web is relatively high; (d) the adoption of external pre-stressed tendons could avoid the difficulties of the construction and is beneficial to the maintenance of the bridge; (e) corrugated steel webs have a high degree of standardization and could be made in the factories, which means the quick speed of construction.

TABLE I. SOME CHINESE COMPOSITE BOX-GIRDER BRIDGES WITH THE CORRUGATED STEEL WEBS

Bridge Name	Construction Type	Span[m]	Girder Type
Henan Guangpo	Continuous girder bridge	4×30	Small box girder
Jiangsu Huaian Changzheng	Continuous girder bridge	18.5+30+18.5	—
Chongqing Yongchuan Dayan River	Simply supported girder bridge	23.7	Single box single-cell
Qinghai Sandao River	Simply supported girder bridge	50	Simple-box double-cell
Ningbo Yongxin River	Continuous girder bridge	24+40+24	Single box single-cell
Shandong Dongying Yingzuo	Simply supported girder bridge	38	Single box single-cell
Pudong Jiyang Road Overpass	Continuous girder bridge	45+45	—
Miluo Lijia River	Continuous girder bridge	20+30+20	Single box single-cell
Henan Weihe	Continuous girder bridge	47+52+47	Single box triple-cell
Juancheng Huanghe	Continuous rigid frame bridge	70+11×120+7	Single box single-cell
Nanjing Changjiang 4#	Continuous girder bridge	56+96+56	Single box single-cell
Yingyugou 2#	Continuous girder bridge	25+65+25	Single box single-cell
Xinmi Zhengshui	Cable-stayed bridge	30+70+30	Discrete simple-box double-cell
Shenzheng Nanshan	Continuous girder bridge	80+130+80	Simple-box double-cell
Shenzheng Pingti	Continuous girder bridge	80+130+80	Simple-box double-cell
Taohuayu Huanghe	Continuous girder bridge	75+135+72	Single box single-cell
Xingtai Qili River	Continuous girder bridge	88+156+88	Single box single-cell

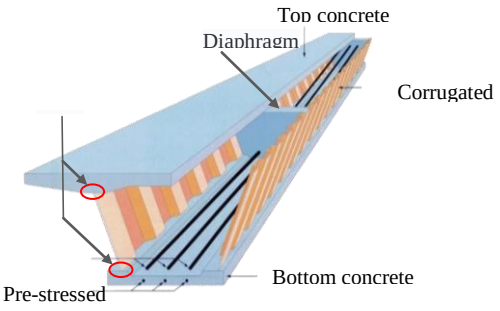

Figure 1. Normal form of composite box-girder bridges with the corrugated steel webs.

III. Comparison of The Same Span Between Concrete Girder and Composite Girder With The Corrugated Steel Webs

A. General Situation of the Engineering

1) Continuous rigid frame bridge with concrete girder

The span of continuous rigid frame bridge with concrete girder is 65+2×120+65m and the main beam adopts single cell and single box section. The root height of box is 7.2m, the top board width of box is 15.9m and the bottom board width is 8.4m. The height of the box and the thickness of the bottom board are all changed from the mid-span to the root in the form of 1.8 parabola, which is 3.0m high on the mid-span and 7.20m on the support. The main beam adopts thee-direction prestressed system.

2) Continuous rigid frame bridge with composite girder with the corrugated steel webs

The span of continuous rigid frame bridge with composite girder with the corrugated steel webs is 65+5×120+65m and the main beam adopts single cell and single box section. The top board width of box is 15.9m and the bottom board width is 8.4m. The height of the box and the thickness of the bottom board are all changed from the mid-span to the root in the form of 1.8 parabola, which is 3.0m high on the mid-span and 7.50m on the support.

B. Material Quantity Variance

The quantity of C50 of composite girder with the corrugated steel webs saves 9.2% per meter compared with concrete girder, and the dead load of girder is reduced; the quantity of steel strand also saves 14.5% because of the replacement of the concrete web with corrugated steel web and tendons in webs with external pre-stressed tendons; the quantity of vertical fining twisted steel also saves 84.9%. These savings mean that the use of corrugated steel web could effectively avoid burdensome procedure and speed the construction period. Table 2 shows the result of comparison of material quantity.

TABLE II. Comparison of Material Quantity

Material qunatity	Concrete girder①	Composite girder with the corrugated steel webs②	Saving percent (①-②)/①
C50[kg/m^2]	1.152	1.046	9.2%
Steel strand[kg/m^2]	73.426	62.753	14.5%
JL32 fining twisted steel[kg/m^2]	14.042	2.115	84.9%
HRB400[kg/m^2]	194.041	176.212	9.2%
Q345D corrugated steel web[kg/m^2]	/	56.722	/
Q345D steel plate[kg/m^2]	/	25.240	/

TABLE III. Comparison of Intensity and Stiffness

Items			Concrete girder	Composite girder with the corrugated steel webs
			Span:65+2×120+65 [m]	Span:65+5×120+65 [m]
Dead Load	Midspan of mid-span	Moment[kN•m]	-122	-15133
		Axial force[kN]	-75290	-82221
		Upper stress[MPa]	-6.0	-6.6
		Lower stress[MPa]	-6.6	-9.4
	Midspan of side-span	Moment[kN•m]	20272	-42102
		Axial force[kN]	-97533	-89020
		Upper stress[MPa]	-8.5	-6.4
		Lower stress[MPa]	-5.8	-9.4
	Support of side-span	Moment[kN•m]	-140249	-34497
		Axial force[kN]	-220379	-191193
		Upper stress[MPa]	-9.7	-10.7
		Lower stress[MPa]	-10.8	-11.4
Live Load	Midspan of mid-span	Deflection[mm]	-23	-39
	Midspan of side-span	Deflection[mm]	-7	-11

C. Comparison of Intensity and Stiffness

The moments in midspan of mid-span and side-span under dead load are both hogging moment, which means the girder would show arch phenomenon under the permanent loads; and the upper and lower compressive stress is less than the allowable compressive stress. Therefore, the composite beam will have a larger bearing capacity compared with concrete beam. The deflection of composite beam in midspan of mid-span and side-span is larger than that of concrete beam, which means that the stiffness of composite beam is smaller and the aseismic capacity is larger. Table 3 shows the result of comparison of intensity and stiffness.

IV. CONCLUSIONS

In this study, the comparison of material and intensity and stiffness between concrete beam and composite beam with corrugated steel webs was studied.

(1) The composite beam has saving on the material quantity of concrete, steel strand, fining twisted steel and steel bar. Also, the use of composite beam would avoid burdensome procedure and speed the construction period.

(2) Considering the intensity and stiffness, composite beam would have a larger bearing capacity compared with concrete beam, and the stiffness of composite beam is smaller and the aseismic capacity is larger.

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The author declares that they have no conflict of interest.

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