Research Journal of Applied Sciences, Engineering and Technology 4(5): 475-480, 2012
ISSN: 2040-7467

Submitted: October 15, 2011 Accepted: October 10, 2011 Published: March 01, 2012

Field Tests of Anchor Beams during Strengthening of Jiamusi Prestressed Concrete Highway Bridge

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Abstract: Jiamusi prestressed concrete highway bridge is located in the Jiamusi City within Heilongjiang Province in the north east of China. The application of external prestressing tendons for strengthening of existing bridges has been used in many countries since the 1950s and has been found to provide an efficient and economic solution in a wide range of the bridge types and conditions. The objectives of this study are to explain the strengthening process by using external prestressing tendons, test and analyze the anchor beams of Jiamusi prestressed concrete highway bridge. Three field tests are adopted in this study. These tests are concrete compressive strength test of anchor beams, tensile test of anchor beam re-bars, and tensile test of anchor beams structure and external prestressting tendons. The results of field tests and analysis of anchor beams and external prestressing tendons show that the value of longitudinal deformation is equal to 0.02 mm and the value of lateral strain ranges from 5 to 1 0 $\mu\varepsilon$. This indicates that the anchor beams have sufficient bending stiffness and the bending capacity of anchor beam is good. The measured and theoretical values of elongation of external prestressing tendons are consistent and the values of tensile force of external tendons are less than the design tensile force (1250 kN).

Key words: Deformation, elongation, external prestressing tendons, strain, strengthening, tensile tests

INTRODUCTION

The prestressing systems can be defined as the preloading of a structure before the application of the service loads, and consist of two types of pre-stressing. The first type is known as pre-tensioning pres-stressing and the second type is known post-tensioning prestressing. Post-tensioning is a method of strengthening of concrete structure with high strength steel strand or bars referred to as tendons. (Arthur, 1987).

The wide use of external prestresting system to strengthen reinforced and prestressed concrete members requires the full understanding of the behavior of the strengthened members. At ultimate the stress in the external prestressing tendons need to be known in order to calculate the ultimate strength of the strengthened member (Hugenschrnidt, 1982; Ahmed and Beeby, 2005).

External prestressing is defined as a system in which the pre-stressing tendons or bars are located outside the concrete section. The pre-stressing force is transferred to the member section through end anchorages, deviators or saddles. The use of external post-tensioning became popular in the last two decades, after the improvement for corrosion protection of external tendons by methods such as epoxy and grease coating. (Thiru and Tim, 2005; Nihal and Amin, 2002; Hakan, 2005).

The main aim of the bridge structure strengthening by using additional external pre-stressing tendons is to fulfill all necessary serviceability criteria and not to extend its ultimate limit state. The use of external post-tensioning for the strengthening of existing bridges has been used in many countries since the 1950s and has been found to provide an efficient and economic solution for a wide range of bridge types and conditions (Ivanyi and Buschmeger, 1996; Daly and Witarnawan, 1997)

In this study, three field tests are adopted in this study. These tests are compressive strength test of anchor beams concrete, tensile test of anchor beam re-bars, and tensile test of anchor beams structure and external prestressting tendons. The objectives of this study are to explain the strengthening process by using external prestressing tendons, test and analyze the anchor beams of Jiamusi prestressed concrete highway bridge.

DESCRIPTION OF THE BRIDGE STRUCTURE

Jiamusi prestressed concrete highway bridge is located in the Jiamusi City within Heilongjiang province in the north east of China. The total length of the bridge is 1396.2 m and the width is 17 m. The bridge was open to traffic in 1989. The type of a bridge is a T-shape rigid frame. Figure 1 shows the layout of the bridge structure and Fig. 2 shows the pier and span prestressed box girder layout.

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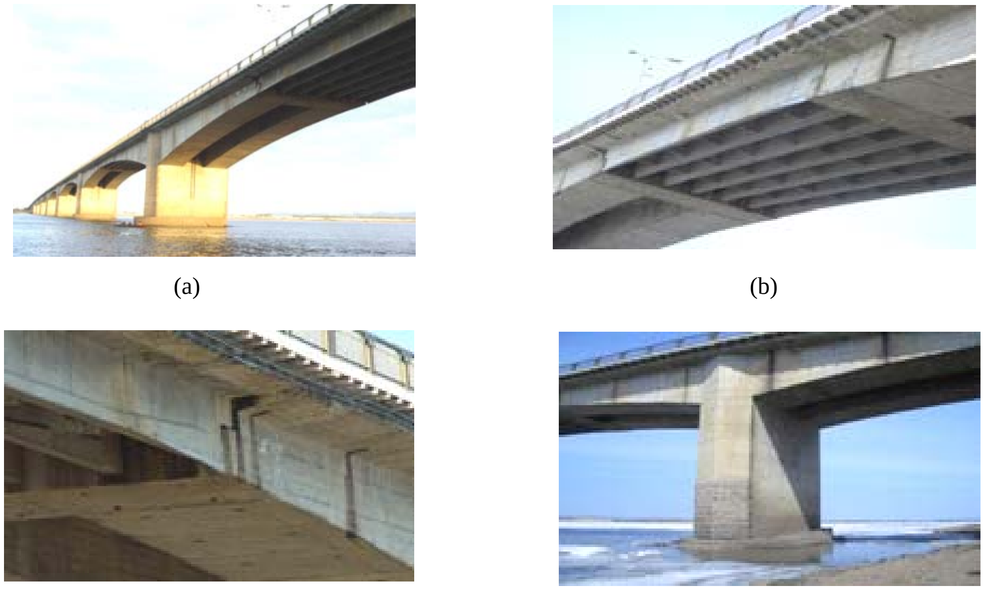
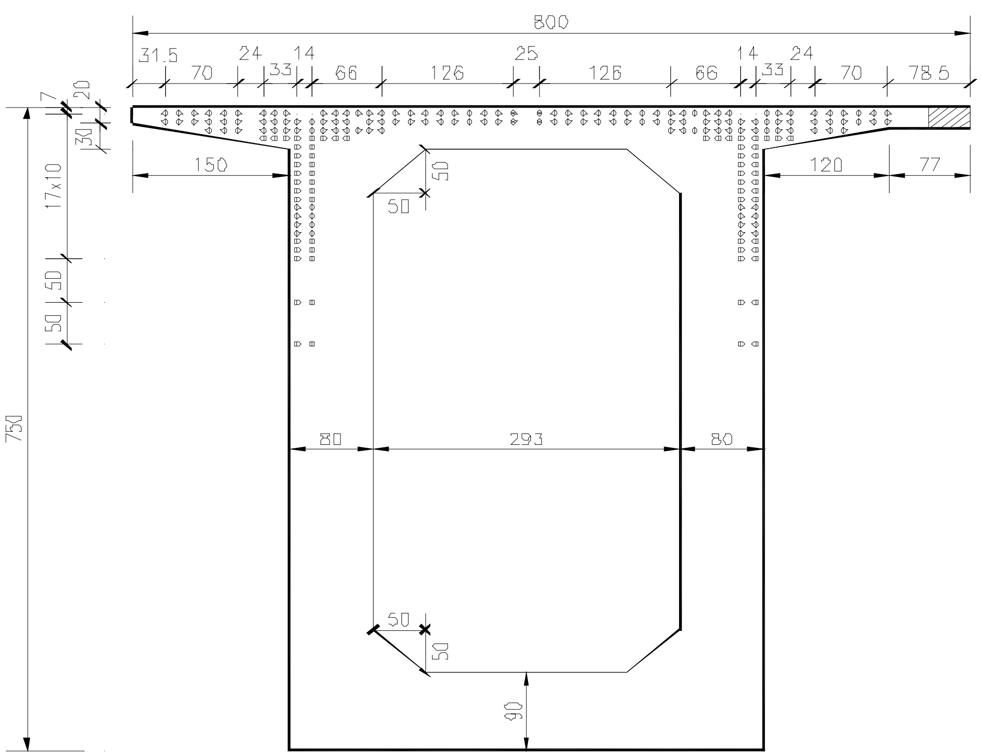


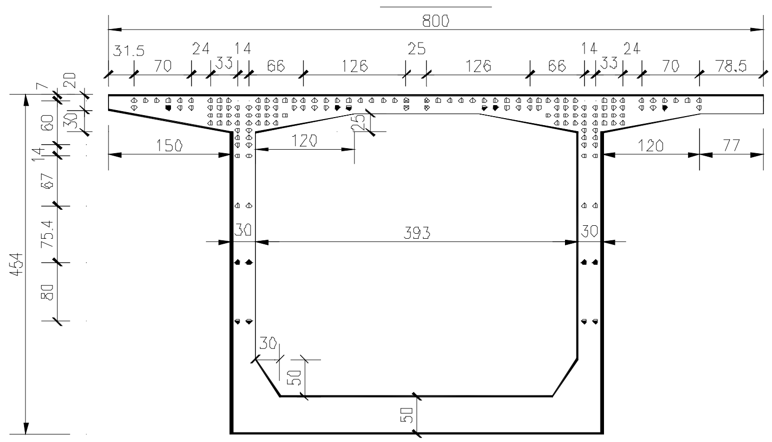
(a) (b)

(c) (d)

Fig. 1: Layout of the bridge (a) view of bridge spans, (b) view of T-beams and box birders, (c) view of corbel between T-beams and box girder, (d) view of pier



(a)



(b)

Fig. 2: Box girder layouts, (a) pier box girder, (b) span box girder

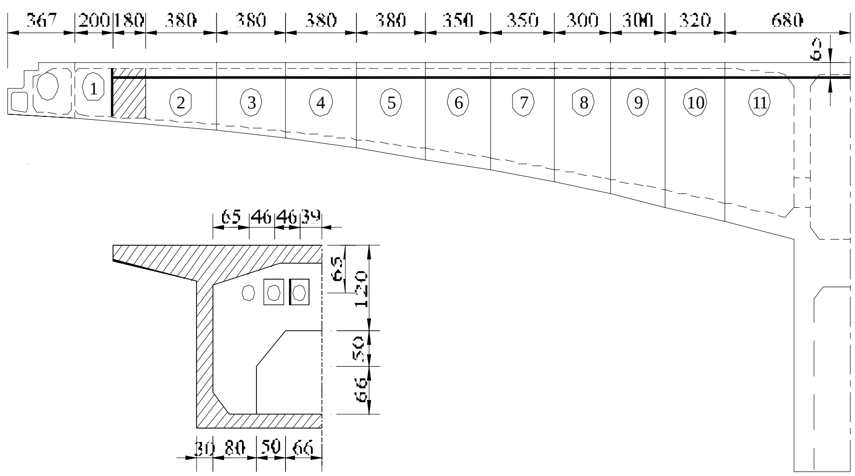


Fig. 3: Layout of external prestressing tendons

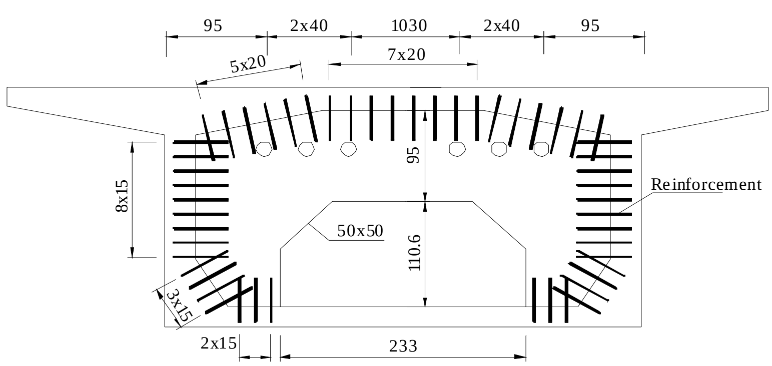


Fig. 4: Anchor beam rebars

Table 1: Values of compressive strength of anchor beam concrete

Samples group no.	Test location	Age of concrete (day)	Average Load (kN)	Average compressive strength (MPa)[a]	Design strength ratio (A/50)
First	Laboratory	3	906	40.1	0.802
Second	Laboratory	3	842	31.3	0.748
Third	Laboratory	7	1310.1	58.2	1.164
First	Field	7	1268.4	56.4	1.128
Second	Field	7	1177.4	52.3	1.046
Third	field	7	1354.8	60.2	1.204
Fourth	field	7	1411.4	62.7	1.254

Strengthening of the bridge using external prestressing tendons: The location of the bridge is important in Jiamusi City to develop the regional economy in the Heilongjiang province and it is always subjected to the heavy traffic load. According to the damages inspection by the team of inspection in School of Transportation Science and Engineering/ Bridge and Tunnel Engineering/ Harbin Institute of Technology (HIT), the corbel in the part of cantilever end suffers from down deflection. This deflection is about 10.3 cm, and meanwhile, when the vehicles is passing on the bridge structure, the vibration of the bridge is large and the duration of vibration is long, which effects the safety and the normal using of the bridge structure. The effects of creep and shrinkage of concrete related to cause the deflection in bridge structure, resulting the losing in the stiffness, resistance, and prestress in the main girder. Therefore, there are needs to strengthen the bridge structure. The strengthening process includes two stages. The first stage is the laying of the leveling layer for bridge deck pavement, and the thickness of leveling layer range between 10 cm in the part of corbel and zero in the part of pier. The second stage includes the strengthening of box girders by using external prestressing tendons. The design and construction of external prestressing system includes the design and construction of anchor beam which includes the design of re-bars and the design of damper devices, and the layout of external post-tensioning tendons along the bridge deck. Figure 3 shows the layout of external prestressing tendons in the top of box girders.

Field tests:

Compressive strength test of anchor beam concrete: Self-compacted concrete is applied in the construction of the anchor beam due to its high durability, shrinkage don occur in the hardening process, and there is not need to vibrator in the casting process. C50 dense concrete is used in the concrete mixture. In this test, three groups of samples are casted and tested in the laboratory at ages of 3 days and 7 days. And four groups are casted and tested in the field at age of 7 days. The results of the test are listed in Table 1. As shown from this table, the average values of concrete strength in the laboratory test at age of 3 days are equal to 37.4 and 40.1 Mpa for group No. 1 and 2, respectively. These values are less than the design strength (50 MPa). At the age of 7 days, the average value of concrete strength in the laboratory test is 58.2 Mpa for group No.3, exceeding the design value (50 Mpa). In the field test, the average values of concrete strength are 56.4, 52.3, 60.2 and 62.7 MPa for group No. 1, 2, 3 and 4, respectively. All these values exceeded the design strength (50 MPa), indicating that the strength of concrete is good.

Table 2: Values of tensile force

Hole no.	Anchoring depth(cm)	Tensile force (kN)
1	20	115.1
2	20	110.3
3	20	100
4	15	98.9
5	10	73.4
6	10	75.7
7	10	80
8	15	104
9	15	99.2

Tensile strength test of anchor beam rebars: Figure 4 shows the anchor beam re-bars. HRB335-re-bars are adopted, and the diameter and length of which is 16mm and 1m, respectively, as implanted rebars between anchor beam and box girder structure. Pier top box girder is selected to test. After implanting re-bars, tensile strength test is adopted by using ZY-20 anchor type. Three anchoring depths are used in this test, 20, 15 and 10 cm. The results of test are listed in Table 2. From Table 2 it can be noted that the anchor rebar with 10 cm anchoring depth has smallest values of tensile force. Therefore, the tensile force increases with the increasing of anchoring depths.

Tensile test of anchor beams and external prestressting tendons: In this test, two anchor beams are selected to test. The first beam located within length of 90 m T-shaped structure of bridge and the second beam located within length of 120 m T-shaped structure. The tensile force is applied to external prestressing tendons by using five levels of tensile. These levels are:

$0\text{--}20\%\sigma_k$, $20\%\sigma_k\text{--}40\%\sigma_k$, $40\%\sigma_k\text{--}60\%\sigma_k$, $60\%\sigma_k\text{--}80\%\sigma_k$, $80\%\sigma_k\text{--}100\%\sigma_k$

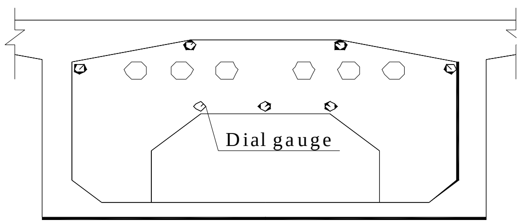


Fig. 5: Location of longitudinal deformation dials gauges

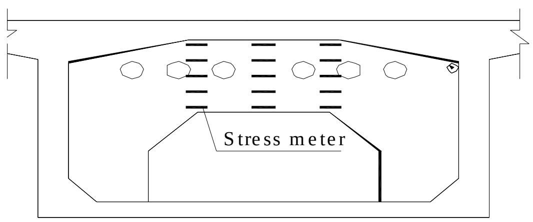


Fig. 6: Location of vibrating wires stress meter

Table 3: Measured and theoretical values of external tendons elongation for 9th box girder

Tensile leve	l20%	40%	60%	80%	100%
Tensile force (kN)	248.2	496.4	744.6	992.8	1241
Theoretical elongation of tendon (mm)	31.6	63.2	94.8	126.4	158
Measured elongation of left box tendon (mm)	29	70	108	138	170
Measured elongation of Right box tendon (mm)	25	56	86	121	153

The time of each tensile level is not less than 10min and within each level is required to measure and monitor the elongation of external tendons, the longitudinal deformation and stresses in anchor beam, the tensile values of external tendons, and the development of cracks. But before the starting of tensile test, the appearance of anchor beams is inspected by marking the location, width, and length of cracks. When the cracks are developed after starting of tensile test, the test must be stopped immediately.

Instruments of measuring: To measure the longitudinal deformation of anchor beams, 7-dial gauge are used. Figure 5 shows the location of dial gauges within anchor beam. 15-Vibrating wires stress meter are used to measure the lateral strain and located in the center of anchor beams. Figure 6 shows the location of vibrating wires stress meter.

Analyses of tensile test results: The period of tensile test takes about 4hr, and the final tensile force is 1100 kN. The results of test show that the original cracks do not develop and there is not new cracks observed. The longitudinal deformation between anchor beam and the top of box girder is very small, only about 0.02 mm. Therefore, the connection between anchor beam and the top of box girder is good, and this satisfies the requirements of the shear capacity. The longitudinal deformation of upper edge of anchor beam hole is also very small, about 0.1 mm. This indicates that the anchor beams have sufficient bending stiffness. The values of lateral strain of anchor beam range from 5 to 10 $\mu\epsilon$. These values are small. Therefore, the bending capacity of anchor beam is good. The measured and theoretical values of tensile elongation of external tendons for 9th box girder are listed in Table 3. The tensile forces also are listed in this table. This table represents a sample for analysis. From this table it can be noted that the measured and theoretical values of elongation of external prestressing tendons are consistent and the values of tensile force of external tendons are less than the design tensile force (1250 kN).

CONCLUSION

- The main conclusions that can be drawn from this study are:
- Damages inspection results of the bridge structure show that the corbel in the end of cantilever suffers from down deflection. This deflection is about 10.3 cm, and meanwhile, when the vehicles is passing on the bridge structure, the vibration of the bridge is large and the duration of vibration is long, which effect the safety and the normal using of the bridge structure.
- The strengthening process includes two stages. The first stage is the laying of the leveling layer for bridge deck pavement, and the thickness of leveling layer range between 10 cm in the part of corbel and zero in the part of pier. The second stage includes the strengthening of box girders by using external prestressing tendons.
- Three field tests are adopted in this study during the strengthening process. These tests are compressive strength test of anchor beams concrete, tensile test of anchor beam re-bars, and tensile test of anchor beams structure and external prestressting tendons.
- The results of field tests of anchor beams show that the connection between anchor beam and the top of box girder is good, and this satisfies the requirements of the shear capacity. Anchor beams have sufficient bending stiffness and the measured and theoretical values of elongation of external prestressing tendons are consistent and the values of tensile force of external tendons are less than the design tensile force (1250 kN).

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