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Experimental Analysis and Performance Evaluation of Fu Feng Highway Prestressed Concrete Bridge After Strengthening in China

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Abstract. Fu Feng highway prestressed concrete bridge is located in Changchun City which is the capital and largest city of Jilin province and it located in the northeast of China. The strengthening of the bridge structural members can be attempted by replacing poor quality or defective materials by better quality materials, attaching additional load-bearing materials, and re-distribution of the loading actions through imposed deformation on the structure system. The objectives of this study are to explain the strengthening process of damaged structural members of Fu Feng bridge, and to evaluate the performance of the bridge structure by adopting static load test. The strengthening process of damaged structural members includes three stages. These stages include the strengthening of box girders floor by casting of 10cm of reinforced concrete in the floor of box girder within the location of positive bending moment in the mid-span and edge span, the strengthening of box girders web by pasting steel plates in the inside of the right and left of box girders, and the strengthening of the transverse beam of piers No. 18 and No. 19 by using carbon fiber sheet. The results of static load test show that the values of testing coefficient (λ) of stress range from 0.83 to 0.92 are less than allowable value 1.05. Therefore, these values satisfy the allowable value of standard, indicating that the structural member has a certain strength reserve and the working state of the bridge structure in good state. the ratio between the measured and theoretical deflection is 1.41 and 1.68 for condition 3 more than allowable value 0.8, indicating that the state of stiffness is not good and there are still a serious shortage in stiffness of structure. Therefore, this study recommended that the bridge structural members need to re-strengthen by using other effective technical and materials to increase the stiffness of structural members of the bridge.

Introduction

Prestressed concrete (PC) bridges are the most widely used type of the bridges in the world, because of reduced construction time, savings in life-cycle cost and excellent performance. The failures of prestressing concrete structures due to poor design, bad workmanship or faulty prestressing steel, and not to deterioration of well designed concrete structures [1].

The strengthening of concrete structure involves upgrading of the strength and stiffness of a structure members and, the repair process involves re-establishing the strength and function of the damaged members. The strengthening of the bridge structural members can be attempted by replacing poor quality or defective materials by better quality materials, attaching additional load-bearing materials, and re-distribution of the loading actions through imposed deformation on the structure system. [2, 3]

The selection of an appropriate method for the strengthening and repair of the bridge structure members depends on a number of factors. The factors include the type and age of structure, the importance of structure, the magnitude of the strength required which is need to increase, the type and degree of damage, available materials, cost and feasibility, and aesthetics. The strengthening and repairing of the bridge structure can be provided an effective and economic solution in appropriate situation. [4, 5]

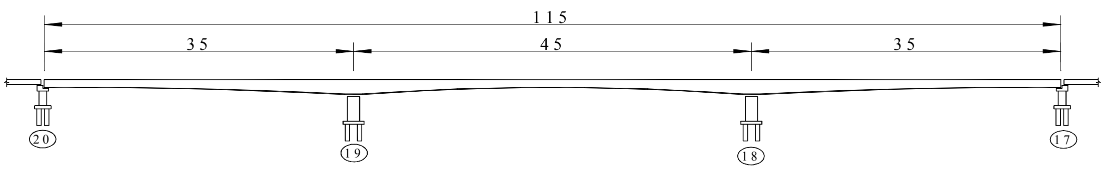
In recent year, many studies have been published to evaluate the performance of different types of the bridges by adopting static and dynamic load tests in either a controlled or when the bridge was opened to traffic. Experimental data was taken from static and dynamic load tests of the bridge were used to regulate finite element model. The main purposes of experimental and theoretical analysis of the bridge structure are to check normal service stage, fatigue, and ultimate loads; development of theoretical models to calculate the performance of the bridge structural members; and verifying the analytical results by comparing them with the obtained results from experimental tests. [6, 7, 8]

If a bridge is not defined as structurally deficient or functionally obsolete, it is rated satisfactory. A satisfactory rating indicates that the bridge meets agency standards for condition, load capacity, waterway adequacy, and geometry. [9]

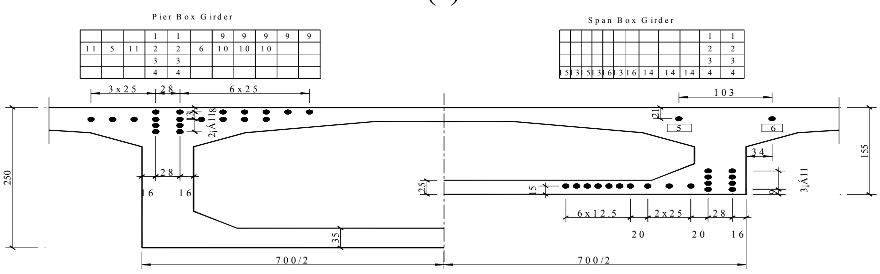
The objectives of this study are to explain the strengthening process of damaged structural members of Fu Feng Bridge, and to evaluate the performance of the bridge structure by adopting static load test.

Description of the Bridge

Fu Feng highway prestressed concrete bridge is located in Changchun City which is the capital and largest city of Jilin province and it located in the northeast of China. The bridge was constructed in October 1997 and was opened to traffic in 1999. This bridge consists of three spans. The spans arrangement is 35m+45m+35m. The total length of the bridge is 115m and the total width is 26m. The type of the bridge is a continuous box girder prestressed concrete. The continuous spans are made by two separated box girders and the width of every box girder is 12.5m. The height of box girder ranges from 1.35m to 2.50m. Fig. 1 shows the bridge structure and transverse section of box girder.



(a)



(b)

Fig. 1 Bridge structure: (a) layout of the bridge spans, (b) transverse sections of box girder

Strengthening of Damaged Structural Members of the Bridge

During the operation life of the bridge, the mid-span deflection of the main span (L=45 m) was increased obviously. The stiffness of the structural members is small because of there are many cracks in the box girders of the main span. Therefore, there is a need to strengthen the damaged structural members of the bridge to improve the stiffness of the bridge structure.

Strengthening of the Box Girder Floor. The strengthening of box girders floor include casting of 10cm of reinforced concrete in the floor of box girder within the location of positive bending moment in the mid-span and edge span. Fig. 2 shows the elevation of box girders floor strengthening.

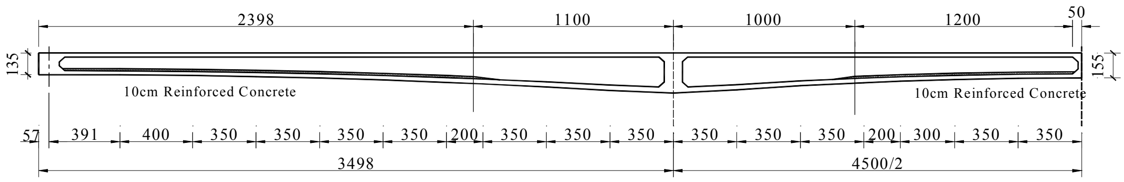


Fig. 2 Elevation of box girders floor strengthening

Strengthening of the Box Girder Web. Steel plates are used in the strengthening of box girders web. Steel plates are pasted in the inside of the right and left of box girders. The steel plates are a kind of A3 steel and have thickness of 8mm. Fig. 3 shows the strengthening of box girders web by using steel plates.

(a) (b)

Fig. 3 Strengthening of box girders web: (a) right web of box girder, (b) left web of box girder

Strengthening of transverse beams of Y-shaped pier. Carbon fiber sheet is used to strengthen the transverse beam of piers No. 18 and No. 19. Fig. 4 shows the strengthening of the transverse beam of Y-shaped piers.

(a) (b)

Fig. 4 Strengthening of the transverse beam of Y-shaped piers: (a) front view, (b) side view

Static Load test

The purposes of static load test are to measure strain, stress, and deflection; to monitor the development of cracks after application of load test; and to evaluate the performance of the structural members of the bridge. In this study, the tested sections are selected as shown in Fig. 5. These sections are mid-span section of the middle span of 45m (section A-A), middle fulcrum (section B-B), mid-span section of edge span (section C-C), and transverse beam of pier No. 19.

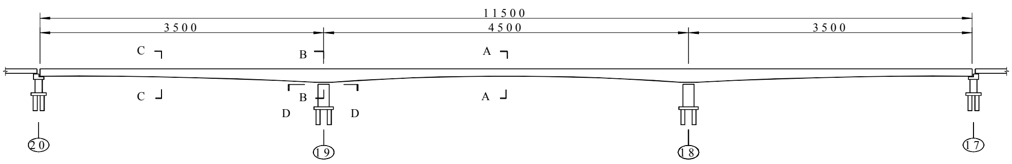


Fig. 5 Tested sections

Loading of Vehicles. The characteristic parameters of the vehicles for static load test are listed in Table. In this study, the load test is determined by using method of equivalent load. The efficiency coefficient (η) of load test >0.8 [10, 11], and there are four automobiles FAW produced by the heavy-duty factory in Changchun city in China.

Table 1 Characteristic parameters of the vehicles for static load test

Model	Axle load(kN)				Wheel distance(cm)	
	Front axle load	Middle axle	Rear axle	Total weight	Between front and middle axles	Between middle and rear axle
FAW	58.6	117.2	135	393	325	125

Loads Conditions Layout of Vehicles Loads. The loads conditions of static load test are listed in Table 2 and the layout of vehicles load are shown in Fig. 6.

Table 2 loads conditions of static load test

Condition No.	Tested section	Test content	Vehicles No.
1	A-A	Stress and deflection	6
2	D-D	Fulcrum reactions	10
3	C-C	Stress and deflection	6
4	B-B	Fulcrum negative moment	8

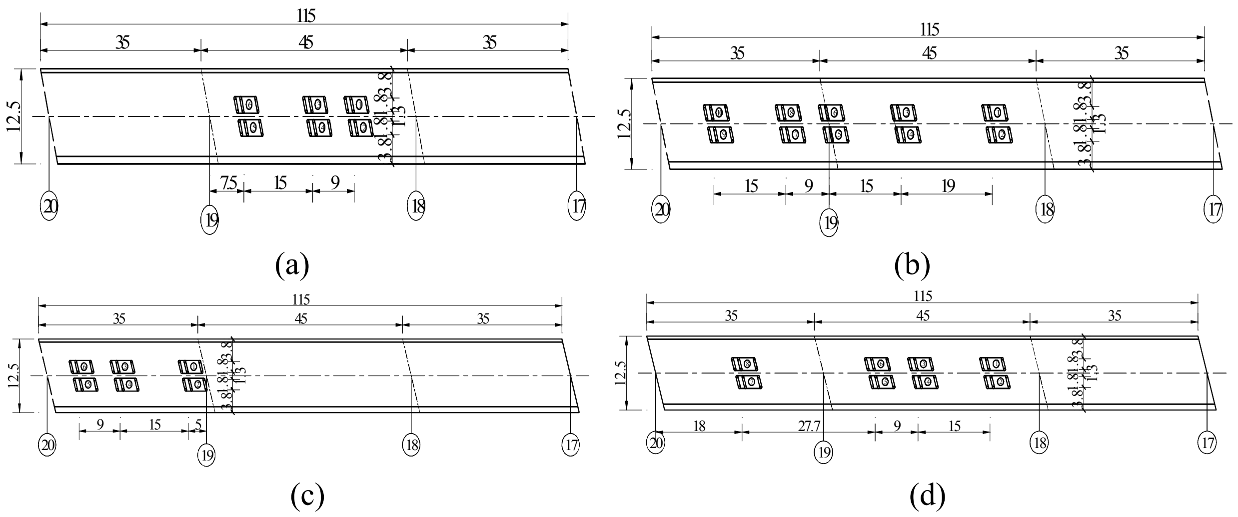


Fig. 6 Layout of vehicles load: (a) condition 1, (b) condition 2, (c) condition 3, (d) condition 4

Layout of Measuring Points. Fig. 7 shows the layout of measuring points to measure the strain in the sections (A-A), (B-B), (C-C), and (D-D). There are three strain gauges on the floor of mid-span section (A-A) of the main span (L=45m), two strain gauges in the lower edge of fulcrum section top (B-B), three strain gauges on the floor of mid-span section (C-C) of edge span, and two strain gauges in the transverse section (D-D) of Y-shaped pier No. 19. For deflection, there are 36 measuring points, 18 points in every side. Fig. 8 shows the layout of measuring points of deflection.

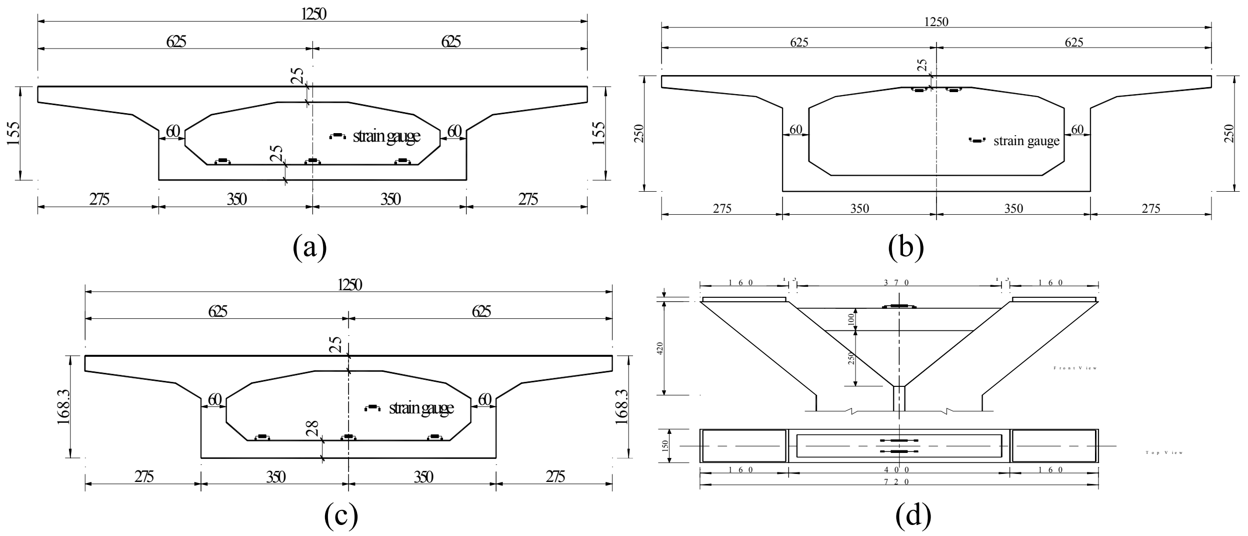


Fig. 7 Layout of strain measuring points: (a) section (A-A), (b) section (B-B), (c) section (C-C), (d) section (D-D)

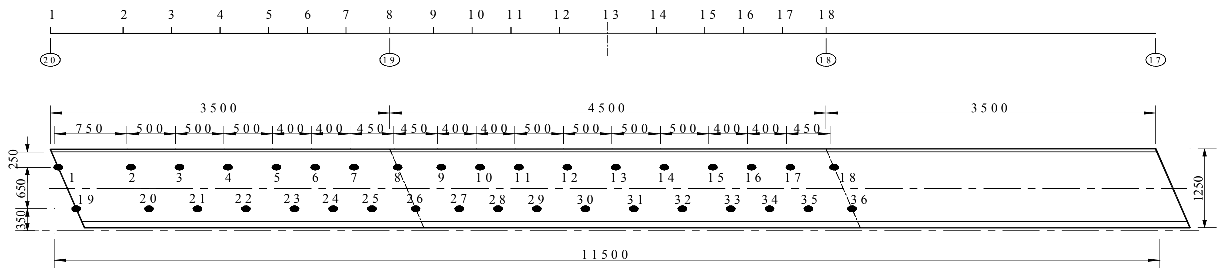


Fig. 8 Layout of deflection measuring points

Results of Static Load Test

Results of Strain and Stress. The results of measured strain after applied load test are listed in Table 3 and the comparison results between measured and theoretical stress are listed in Table 4. From this table it can be noted that the values of testing coefficient (λ) range from 0.83 to 0.92 are less than 1.05 [12]. Therefore, these values satisfy the allowable value of standard, indicating that the structural member has a certain strength reserve and the working state of the bridge structure in good state.

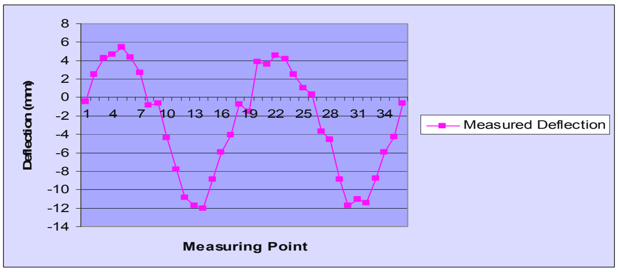
Results of deflection. Figs. 9 and 10 show the results of measured and theoretical deflections for conditions 1 and 2. From these Figures it can be noted that the maximum average measured deflection is 11.73mm and theoretical deflection is 8.34mm for condition 1 and the ratio between the measured and theoretical deflection is 1.41 more than allowable value in standard (0.8). For condition 3, the maximum average measured deflection is 10.13mm and the theoretical deflection is 6.05mm, and the ratio is 1.68 also more than 0.8, indicating that the state of stiffness is not good and there are still a serious shortage in stiffness of structure.

Table 3 Results of measured strain after applied load test ($\times 10^{-6}$)

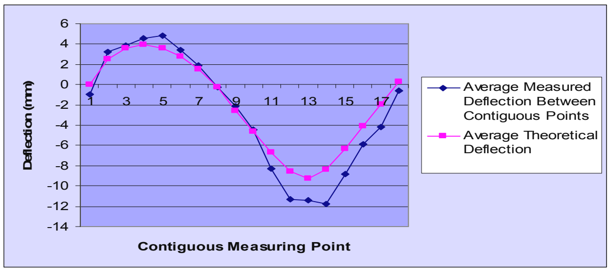
Condition No.	Tested section	Average measured strain($\mu\varepsilon$)	Measured stress(Mpa)
1	A-A	-37.2	-1.3
2	D-D	14.3	0.5
3	C-C	-24.6	-0.86
4	B-B	22	0.77

Table 4 Comparison results between measured and theoretical stress of concrete (negative is compressive Mpa)

Condition No.	Tested section	Average measured stress	Average theoretical stress	Ratio
1	A-A	-1.3	-1.49	0.87
2	D-D	0.5	0.6	0.83
3	C-C	-0.86	-0.95	0.91
4	B-B	0.77	0.84	0.92



(a)



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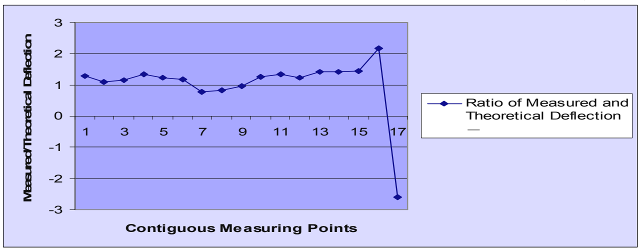
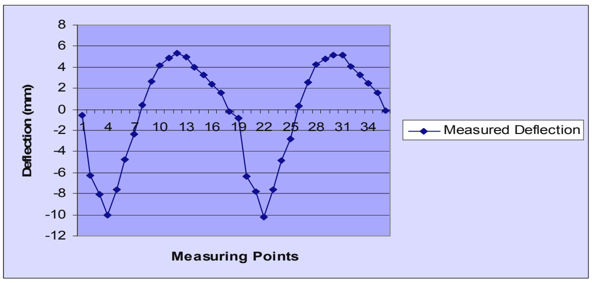


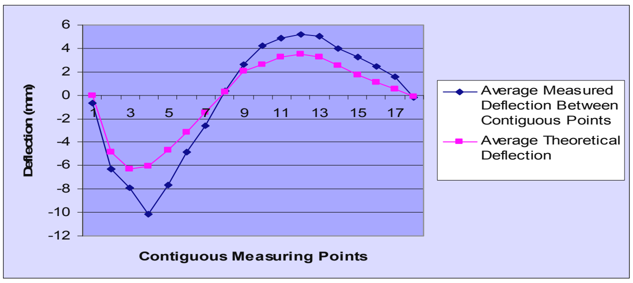
(c)

*Contiguous points mean that point 1 with point 19

Fig. 9 Results of Deflection for condtion1: (a) Measured Deflection for 36 measuring points, (b) Average measured and theoretical deflection, (c) measured to theoretical ratio of deflection



(a)



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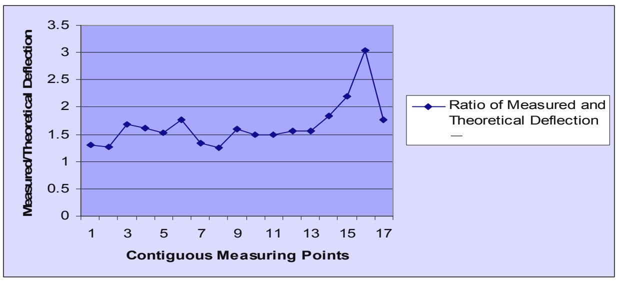

(c)

*Contiguous points mean that takes average deflections of point 1 with point 19 and for all other points

Fig. 10 Results of Deflection for condtion3: (a) Measured Deflection for 36 measuring points, (b) Average measured and theoretical deflection, (c) measured to theoretical ratio of deflection

Conclusions

The main conclusions of this study are:

1- The strengthening process of damaged structural members includes three stages. The first stage includes the strengthening of box girders floor by casting of 10cm of reinforced concrete in the floor of box girder within the location of positive bending moment in the mid-span and edge span. The second stage includes strengthening of box girders web by pasting steel plates in the inside of the right and left of box girders. The third stage includes strengthening of the transverse beam of piers No. 18 and No. 19 by using carbon fiber sheet.

2- Static load test is adopted to evaluate the performance of the bridge structure. The results of static load test show that the values of testing coefficient (λ) of stress range from 0.83 to 0.92 are less than allowable value 1.05. Therefore, these values satisfy the allowable value of standard, indicating that the structural member has a certain strength reserve and the working state of the bridge structure in good state. the ratio between the measured and theoretical deflection is 1.41 and 1.68 for condition 3 more than allowable value 0.8, indicating that the state of stiffness is not good and there are still a serious shortage in stiffness of structure. Therefore, this study recommended that the bridge structural members need to re-strengthen by using other effective technical and materials to increase the stiffness of structural members of the bridge.

References

[1] C. Nathalie, and L. Zoubir, *Field Performance of prestressed Concrete Bridge Girder Protected by Cathodic Protection and Concrete Surface Treatment*, 7th International Conference on Short and Medium Span Bridges, pp. 1-10, Montreal, (2006).

[2] E. Naser, *Repair and Strengthening of Reinforced Concrete Structure,* R. V. Anderson Associated Limited, Toronto, Canada. (2005).

[3] F. Hugenschmidt, *Strengthening of Existing Concrete Structures with Bonded Reinforcements,* EMPA, Switzerland, (1981).

[4] A. W. Daly, *Strengthening of Bridges Using External Post-Tensioning,* The 2nd Conference of Eastern Asia Society for Transportation Studies ,P.P. 29-31, Seoul, Korea, , (1997).

[5] L. Hai, L. Wei, J. Daved, and H. Ai, *Strengthening an in-Service Concrete with CFRP Bars*, Journal of Zhejiang University SCIENCE A 10(5), p. p 635-644, China, (2009).

[6] J. James, E. Issam, and C. Ching, *Performance Evaluation of Bridges with Structural Bridge Deck Overlays (SBDO)*, Technical Report No. KTC-06-05/FRT 81-82-97F, Kentucky Transportation Center, University of Kentucky (2006).

[7] A. Aktan, R. Miller, B. Shahrooz, M. Zwick, M. Heckenmcreller, , I. Ho, W. Hrinko, and T. Toksoy, *Nondestructive and destructive Testing of a Reinforced Concrete Slab Bridge and Associated Analytical Studies*, Report FHWA/OH-93/017, U. S. Department of Transportation, Washington, D. C. (1992).

[8] R. Cook, F. Fagundo, A. Rozer, and H. Muyer, *Service, Fatigue, and Ultimate Load Evaluation of a Continuous Prestressed Flat-Slab Bridge System*, TRR, No. 1393, Washington, D. C.-104-111. (1993).

[9] A. Cherilyn, and S. Kim, *Performance of Steel, Concrete, Prestressed Concrete, and Timber Bridges*, Proceedings of 4th International conference on short and medium span bridges, The Canadian Society for Civil Engineering, 341-354. Halifax, Nova Scotia, Canada. Montreal, P.Q., Canada. (1994).

[10] JTJ021-89, *Design Code for Highway Bridge and Culverts*, People's Republic of China, (1989).

[11] JTJ023-85, *Design Code for Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts*, People's Republic of China, (1985).

[12] Traffic Highway Research Institute, *Experimental Method for Long Span Concrete Bridge*, People's Republic of China, (1982).