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Site Inspection and Evaluation Behavior of Qing Shang Concrete Bridge

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***Abstract*—**It is necessary to evaluate the bridges conditions and strengthen bridges or parts of them. The reinforcement necessary due to some reasons can be summarized as: First, a changing in use of bridge could produce internal forces in a part of structural which exceed the existing cross-sectional capacity. Second, bridges may also need reinforcement because damage due to external factors which reduced the cross-sectional resistance to external loads. One of other factors could listed here its misdesign in some details, like safety of bridge or part of its.This article identify the design demands of Qing Shan bridge located in is in Heilongjiang Province He gang - Nen Jiang Road 303 provincial highway, Wudalianchi area, China, is an important bridge in the urban areas. The investigation program was include the observation and evaluate the damage in T- section concrete beams , prestressed concrete box girder bridges section in additional evaluate the whole state of bridge includes the pier , abutments , bridge decks, wings , bearing and capping beam, joints, ……..etc. The test results show that the bridges in general structural condition are good. T beam span No 10 were observed, crack extended upward along the ribbed T beam, and continue to the T beam flange. Crack width varying between 0.1mm to 0.4mm, the maximum about 0.4mm. The bridge needs to be improved flexural bending strength especially at for T beam section.

***Keywords*—**Field investigation, prestressed concrete box girder, maintenance, Qing Shan Bridge

INTRODUCTION

BRIDES owners today must make decisions pertaining to maintenance and improvements that take into account both funding constraints and the overall needs of the highway system. Bridge management systems represent a unique convergence of the disciplines of structural engineering, operations research, economics, planning, and information technology. [1] On-site investigation of concrete bridges may be necessary for a wide range of reasons which will generally be associated with assessment of specification compliance, maintenance requirements or structural adequacy.

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Establishing the precise aims of inspection and testing is an essential requirement to all test programs planning including fundamental aspects such as selection of methods, location of test points and interpretation of results. On-site inspection and testing, other than superficial visual inspection, is seldom cheap as complex access arrangements are frequently necessary and procedures may be time-consuming. Furthermore, individual observations or test results are often inconclusive, and back-up testing coupled with considerable engineering judgment and experience are then required. [2]Prior to starting repair of concrete structures, it is always advisable to investigate the possible causes of this deterioration [3]. Nothing will be gained by carrying out a repair if the deterioration is likely to commence immediately. Causes of deterioration may be divided into recurring and non-recurring. If the recurrence of deterioration is acceptably low, then it is normally acceptable to restore the structure as nearly as possible to its original state. If, however, there is an unacceptable risk of recurrence, the structure should be repaired and the fundamental cause of deterioration should be controlled to acceptable limits [4]. Once the cause of deterioration is known, a decision of the extent of repair is required. This includes the parameters of durability, strength, function, and appearance of the structure after the repair process is completed. After the above decision is made, the choice of repair material and repair technique could be investigated.

BRIDGE DESCRIPTION

Qing Shan Bridge shown Fig. (1.1) is located in He Gang – Nenjiang 303 provincial highway lane, Heilongjiang Province, China; an important bridge in the urban areas of Wu Dalian Chi. The bridge has been operating for more than 29 years since August 1982.Bridge length is 314.0 meters, including 13 Span; the bridge consists of the left approach, right approach and the main bridge span. among them, the left approach abutment no. 1- Pier no. 2 (A1 ~ P2) has two span, 20 meter of reinforced concrete simply supported T beam; the main bridge pier no. 2 – pier no. 5 (P2 - P5) has three-span in total, overall prestressed concrete box girder, spans arrangement are (30m +50 m +30 m); the right (P5 ~ A2) Approach has eight spans, 20 meter of reinforced concrete simply supported T beam, the horizontal section consists of five simply supported T beam, jointed together.

Fig.1 is located in He Gang – Nenjiang 303 provincial highway lane, Heilongjiang Province, China

A. Span Combination

Full-bridge span arrangement for the 2 × 20m (simply supported T beam left side) and (24m +50 m +24 m prestressed concrete box girder in the middle part) and 8 × 20m (simply supported T beam right hand side), a total of 13 span, full bridge length is 314. m. Bridge structure is shown in Fig. (1).

The bridge deck slab lanes are paved 9 cm thick concrete pavement. Construction methods for the superstructure: simply supported T beam was prefabricated installation and prestressed box girder was constructing by cantilever casting method. Fig. (2) (a, and b) shows the main parts of bridges (dimensions in cm).

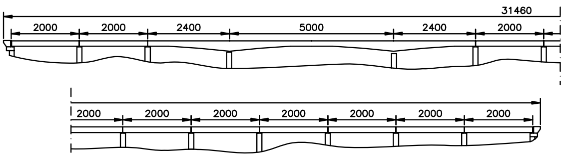

Fig. (2). (a) General layout of bridge

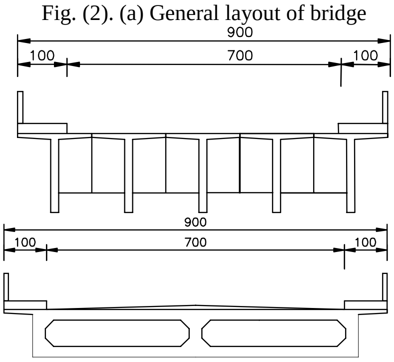

Fig. 2 (b) Bridge superstructure sections. (simply supported T beam and prestressed continuous box girder

B. Bridge Inspection Details

1 Inspection program:

To evaluate the functionality of the bridge , should providing basic data for the plans of management and development, making a comprehensive inspection for the whole main structure of the bridge and its sub-sections bridge for using of functional assessment, to collect technical data of construction conditions for the regular inspections which mainly including the followings:

1. Visual inspection for the main beam (including whether there is cracks in the cross section, water leaking, exposed tendons ,……..etc);
2. The main beam transverse connection components.
3. Inspection for the pier and foundation.
4. The visual inspection of floor system: bridge line, bridge deck, railings..…. etc.
5. Concrete strength measurement of main beams and piers.
6. Inspections of steel corrosion. Also inspection of other facilities (such as the side wall, cone slope……etc.).

Inspection the status of the bridge component defects on the surface of bridge structural was done according to the specification of (Highway Bridge Maintenance Specifications) (JIG H11-2004) [5] which issued by Ministry of Communications.

C. .Abutment and Foundation

There are some damage in concrete wall of abutment #14, especially the parts corresponding with the main beam rib ,most of the surface is cracked or collapsed or exposed tendons and steel corrosion ,which the positions are shown in Fig. (3).

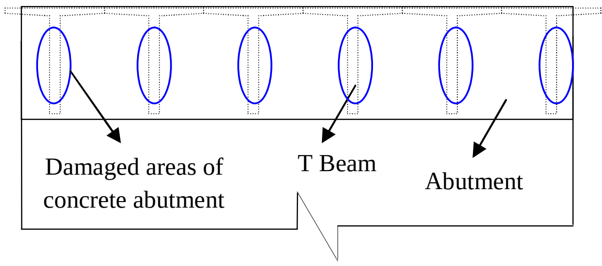

Fig. 3 Concrete bridge abutment #14 wall indicate the damaged area

Fig. 4 Damage of concrete bridge abutment #14 and pier No. 5

After checking the abutment joints, the joints were filled with sand and small stones and other debris; the result will be the abutment expansion joints lose functionality. The beams were close to the abutment wall, and the reasons for these

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defects include the following :(1) elongation due to heated up beam contract the concrete of back wall. (2). soil pressure behind the abutment makes the abutment move or tilt forward. In other word, the pressure between the beam and the back wall directly causes the damage and defect of concrete as shown in Fig. (4).

The cracked part of the back wall, affecting the durability of the bridge, also if the abutment is damaged to certain degree, the stability of the bridge will be worse.

D. Bridge pier and foundation

There are 12 bridge piers; all have different defects in certain degree, detailed as followings: first : Pier overall had a good condition, there is no damage of concrete bridge surface, no apparently cracks, only in the center of the piers, at upper part that has a micro-crack, width about 0.2mm, length about 2m. Reason for cracking was degradation of temperature or mass concrete dried, rather than structural joints. Second : the piers # 5 have the most seriously damaged, it's the transition pier between main bridge and approach bridge span , which have a large cracks, described as follows:(1) large crack with maximum width of about (1mm - 2mm) as shown in Fig. (5). There is a crack located in the middle area of the pier had not extended to the top of pier. The inside crack width about 5mm, the depth was more than 60mm.The vertical crack about 3mm, all were beyond the bridge regulatory require, were overtake the bridge specifications. The main reasons caused the cracks was temperature or big concentrate during construction. There was no doubt about that, during the recent years, the cracks lost their function, leading to the rain or the melt ice flew onto the pier surface, and the course of melt and freeze had accelerated the speed of the crack expending. (2) The horizontal crack in the pier root was caused by temperature (heat) produced, in the winter as it is also subject to the freeze-thaw cycle. (3) There are many different reasons for cracks of the pier #5, mainly includes the melted ice lead penetrated through concrete to the aggregate lead to improper reaction and negative affection, as a result, the water flew directly pier surface. Winter freeze-thaw cycles are aggravated by the net crack growth.

Fig. 5 5 Pier # 5 crack depth

Pier #5 conditions is worse, badly influence on carrying capacity and the durability of the bridge. Some cracks there have white lime precipitation, crack width about 0.6mm, as shown in Fig. (6).

Fig. 6 South side of the pier # 5 surface cracks whitening

Pier #11 at bottom have more horizontal cracks appeared in the north side of pier, and in opposite side has small cracks, the maximum of 1.2mm width, crack distribution as shown below in Fig.(7).

Fig. 7 Transverse cracks Pier #11

Piers # 11 have main vertical and horizontal cracks due to cooling and thawing, respectively, when the temperature stress is too large. Over the years of using the bridge deck expansion joint lost its function because the water and the melt snow flew directly into the pier surface, winter freeze-thaw increase the speed of the vertical crack expending.

E. Bearing and capping beam

Simply supported reinforced concrete T beam was used steel bearing, bearing dose not showing damage reduction activities, Capping beam have no any obvious damage.

Fig. 8 Bearing steel plate

F. T beam crack case

The T beam of all 10 spans were investigated, the occurrence of most T beams have cracking phenomenon occurred. T Beam crack region appears at the bottom under bent beam, crack extended upward along the ribbed T beam, the individual extends to the T beam flange crack, crack width distributed over 0.1mm to 0.4mm, the maximum was about 0.4mm, and crack spacing was about 10 to 15cm. The bridge needs to be improved the flexural bending strength. T beam support region have shear cracks, diagonal cracks were found there, but does not covered large area, crack width about 0.2mm. Cracks generated by the structural force and that reflect the possible consequences of inadequate carrying capacity of the bridge, which effect on bridge safety and durability. Fig. (9) show the cracks types.

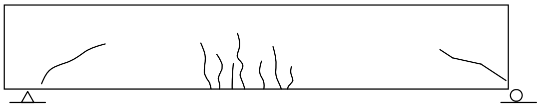

Fig. 9 (a) T beam crack distribution

Fig. 9 (b) T beam cross-cracks in the region

Fig. 9 (c) T beam cross-cracks in the region

G.T Beam connections

All lateral connections on the bridge observed in detail, simply supported T beam horizontal connections in good condition and the occurrence of cracking was apparent, diaphragm locally have crack, but crack width was small, about 0.1mm.

Fig. 9 (d) T Beam connections is good, no obvious damage (diaphragm)

I. The Bearing Elements of Continuous Beam

The continuous beam span for the whole box girder and the concrete surface was in a good condition, no obvious damage and cracks. Climb from the box at pier 2 internal inspection of the box found within the surface of structural cracks, top of the local area (especially the original hanging holes of hanging span) the concrete take off, tendons exposed and leaking.

Bridge deck waterproofing was in bad condition, box leakage, closed hole wasn't dense construction which effect on the durability of the bridge

Fig. 9 (a) the internal box water drainage damage

II. Bridge Deck

Cement concrete pavement deck with less smoothness, spots potholes, and cracks. Cracking phenomenon effect on carrying capacity of the bridge, functionality, durability, ……..etc, as shown in Fig. (10)

Fig. 10 Deck Damage

III. Expansion Joints

There are severely damaged expansion joints shown in Fig. (11), basically loss of functionality, overloading rolling, improper maintenance witch effect on durability.

Fig. 11 Serious damaged bridge deck expansion joint

IV. Strength Material Testing OF Bridge Component

A. Detection of Concrete Carbonation Depth

The concrete cover is the basic protection of steel in concrete, once the carbonation depth has reached steel, steel will lose protection, under certain conditions, steel will rust, this will increase the hardness of concrete carbonation, but the strength will decreased, and cross-section of structure decrease. The test use site drilling, then spray phenolphthalein. Results are shown in Table (I).

TABLE I
STATISTICS OF CONCRETE CARBONATION DEPTH MEASUREMENT POINTS

Point No.	Carbonation (mm)
1	3.8
2	4.7
3	4.3
Average	4.27

Test results showed that, the average carbonation depth of concrete is 4.27 mm, protective layer of concrete carbonation to a lesser extent.

V. Rebound Concrete Strength Testing

Concrete strength testing of structure can be directly reflected the quality of concrete, according to (Assessment of concrete compressive strength Rebound Technical Specification) (JGJ/T23-92), the detection of components by bulk sampling, rebound test, data processing were carried out respectively, considering the strength of concrete carbonation revised test results in Table (II).

TABLE II
REBOUND ESTIMATE VALUE OF THE MAIN GIRDER CONCRETE STRENGTH (UNIT: MPA)

Member		Conversion value of concrete compressive strength (Mpa)			Estimate strength (MPa)
No.	Name	Average	Standard Deviation	Min.	
1	T Beam	36.04	2.021925	28	32.7
2	Box girder	47.3	2.399432	54.7	43.4
3	Bridge Pier	27.1	3.134401	43.2	21.9

B. Bar position detection

Detection device was using to testify the simply supported T beam concrete cover. The measured bottom concrete cover layer average thick is 27 mm, and the side average is 31mm thick.

C. Detection of rebar corrosion

The presences of harmful substances in concrete will affect the durability of concrete .Surface erosion by the CO2; reduce the alkalinity of reinforced concrete around, or erosion by the chloride. The chloride intensity is high; this can cause damage to the steel surface oxide film. The steel embedded in the concrete with intrusion of oxygen and water reflects the occurrence of corrosion, so that effect reduced the cross-section area, and the expansion of force generation on the surrounding concrete. This eventually could leading to structural damage and this done by using sampling and testing procedure on the site, through measuring the bar potential state of the steel reinforcement corrosion to determine steel corrosion situation. The main beam over the abutments and piers, respectively, arranged four test areas, test results are listed as following in Table (III):

TABLE III
REBAR CORROSION POTENTIAL MEASUREMENTS.

Survey area	Potential values (mv)	Criteria of corrosion
Beam (a)	-375	300 - 500mv, the probability of steel corrosion 95%;
Beam (b)	-178	200 -350mv, probability of steel corrosion 50%
Bridge pier	-125	
Abutment	-163	200 mv or less, probability of steel corrosion 5%

Note: beam (a) represent the damage covered layer; beam (b) the layer having no any damage.

Test results showed that: According to the relationship between steel potential values and the steel corrosion, that the main reinforced concrete cover layer has serious damage, the other side layers had no visual cracks. The damage of concrete layer shows the seriously steel corrosion as shown in Fig. (12).

Fig. (12) Steel corrosion detectors

VI. Comprehensive Assessments of Technical Conditions of the Bridge

A "Highway Bridge Maintenance Standards" for the assessment of the status of the bridge defect, as shown in Table IV.

TABLE (IV)
BRIDGE TECHNOLOGY COMPREHENSIVE ASSESSMENT STATUS

No	Part Name	Weight (Wi)	Component defects Degree of scale		Defect on the use of Function		Defects in the development of Status Fixed		Scale assessment of the components Ri	Wi· Ri
i	a	b	c		d		e		f=c+d+e	g=b×f
1	Wing Wall, Side wall	1	moderate	1	small	1	Slow development	0	2	2
2	Cone slop , Slop	1	moderate	1	small	1	Slow development	0	2	2
3	Abutment and foundation	23	moderate	1	Big	2	Slow development	0	3	69
4	Pier and foundation	24	serious	2	Big	2	Slow development	0	4	96
5	Foundation scour	8	moderate	1	Big	2	Slow development	0	3	24
6	Bearing	3	moderate	1	small	1	Slow development	0	2	6
7	*Top main bearing components	20	moderate	1	Big	2	Slow development	0	3	60
8	Top main bearing components	5	moderate	1	Big	2	Slow development	0	3	15
9	Deck	1	serious	2	Big	2	Slow development	1	5	5
10	Bump	3	moderate	1	small	1	Slow development	0	2	6
11	Expansion Joint	3	serious	2	Big	2	Slow development	1	5	15
12	Side walk	1	moderate	1	small	1	Slow development	0	2	2
13	Railing, fence	1	moderate	1	small	1	Slow development	0	2	2
14	Lighting, signs	1	moderate	1	Non	0	Slow development	0	1	1
15	Drainage	1	serious	2	Big	2	Slow development	0	4	4
16	Modulating structures	3	Mild	0	small	1	Slow development	0	0	0
17	Other	1	Mild	0	Non	0	Slow development	0	0	0
18	Full-Bridge technology comprehensive evaluation status									38
19	Technical condition of full-bridge rating									Class 4

Comprehensive evaluation using the following formula:

$$D_r = 100 - \sum_{i=1}^{5} R_i W_i / 5$$

Where:

Ri:- Determine by "Highway Bridge Maintenance Standards" Table 3.5.2-1 method of assessing the various components of the scale (0 to 5).

Wi :- The weight of each component ΣWi = 100,

Dr: - Full-Bridge technical conditions score (0 to 100) score high that was better and fewer defects.

A. Limits Assessment of classification.

$D_r \geq 88$: Class I need normal maintenance.
$66 \leq D_r < 88$: Class II need minor repairs.
$40 \leq D_r < 66$: Class III need repair, as appropriate. traffic control.
$D_r < 40$: Class IV and V.

For the class four of bridges, repair or reconstruction should be carried out in time of traffic control (such as limit load, speed); for serious defects should be closed the traffic. Class five for reconstruction of the bridge the traffic should be promptly closed.

B. Assessment Results:

According to assessment of boundaries, the bridge rating of class four, and according to the importance of components (such as piers) which is rated as class four; need to repair and reinforcement.

VII. CUNCLUSION

From review of the above results, indicating that the Qing Shan Bridge has not reached the active duty, less than the original design of the technical requirements. In addition, the bridge is located in Heilongjiang Province Hegang - Nen River 303 provincial highway lane, an important bridge in Wu Da Lian Chi, the current traffic is busy, and also there are often overloaded vehicles. In order to ensure the safe operation of the Qing Shan Bridge and extend its service life, recommended as the followings: Superstructure:

(1) The active implementation of the Qing Shan Bridge, detailed investigation, the static load test, designed must be carried out to provide the necessary technical basis for the maintenance.
(2) Approach spans of reinforced concrete T-beam should provide design of the implementation reinforcement to increase the carrying capacity of the bridge.
(3) Replacement of expansion joints. However, in order to improve driving conditions and improve the bridge level of service, while reducing the workload

of the daily maintenance and management, proposed a continuous deck structure, to minimize the number of joints.

(4) Provide appropriate repairs for steel corrosion, concrete cracking and falling concrete parts.

(5) Completely replace the waterproof layer, re-set the road vent pipe (vent pipe should be guaranteed about 20cm below the main beam);

(6) Re-laying of pavement, to resolve technical issues such as Bump;

Substructure:

(7) The extent of serious damages in piers #5 and # 11 the maintenance and reinforcement must be carrying out for piers. The extent of other minor damage should also apply maintenance process.

Temporary security measures:

(8) To ensure the safety of the bridge during the maintenance and reinforcement of the Qing Shan Bridge, load and speed must be limited.

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