Front. Struct. Civ. Eng. 2013, 7(2): 164–177
DOI 10.1007/s11709-013-0196-8

RESEARCH ARTICLE

Evaluation of the static and dynamic structural performance of segmental pre-stressed concrete box girder bridge after repairing and strengthening

Ali Fadhil NASER*, Zonglin WANG

School of Transportation Science and Engineering, Bridge and Tunnel Engineering, Harbin Institute of Technology, Harbin 150090, China

Corresponding author. Foundation of Technical Education-Al-Mussaib Technical Collage-Iraq. E-mail: ali_hu73@yahoo.com

ABSTRACT The objectives of this study are to explain the repairing and strengthening methods which are used to improve the structural performance of the bridge structure, to analyze the static and dynamic responses after strengthening, and to evaluate the performance of the bridge structure after repairing and strengthening. The methods of repairing and strengthening include reconstruction the deck of the bridge by casting 10 cm layer of concrete, strengthening the web and bottom floor of box girders of middle spans and side spans by sticking the steel plates, strengthening the whole bridge structure by using external pre-stressing tendons, and treatment the cracks. The results of theoretical analysis show that the values of tensile stress and vertical deflection are decreased and the compressive stress is increased after strengthening. There are not tensile stresses are appeared in the sections of the bridge structure. The modal analysis results show that the value of natural frequency is equal to 2.09 Hz which is more than the values before strengthening which is equal to 1.64 Hz, indicating that the stiffness of the bridge structure is improved and the strengthening process is effective to improve the cracks resistance and bearing capacity of the bridge structure.

KEYWORDS structural performance, steel plates, external pre-stressing, cracks, grouting method, static

1 Introduction

The strengthening of concrete structure includes improvement of the strength and stiffness of structural members, and the repairing process involves re-establishing the strength and function of the damaged members. The strengthening of the bridge structural members can be carried out by replacing poor quality or defective materials by using better quality materials, attaching additional load-bearing materials, and re-distribution of the loading actions through imposed deformation on the structure system [1–3].

The repairing process includes materials selection, method selection, support design, safety precaution, costs, and logistics. The performance requirements of concrete repair involve protection of re-bars, aesthetics, integrity and computability, carry loads, and waterproofing. Concrete structure repair can be classified either as cosmetic-repairs or rehabilitation-repair [4–6].

The selection of the suitable method for the repairing and strengthening of the bridge structural members depends on many factors. These 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 [3,7].

External post-tensioning 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 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. Strengthening by using external post-tensioning is simply to apply axial load combined

Article history: Received Nov. 8, 2012; Accepted Dec. 25, 2012

with bending moment to improve the flexural and shear capacity of the bridge structural members [8–11].

The objectives of this study are to explain the repairing and strengthening methods which are used to improve the structural performance of the bridge structure, to analyze the static and dynamic responses after strengthening, and to evaluate the performance of the bridge structure after repairing and strengthening.

2 Description of the bridge structure

Sanguxian viaduct pre-stressed concrete bridge is type of a continuous segmental box girder T-shape rigid frame bridge and it was located in the Mudanjiang-Harbin Highway within Heilongjiang province in the east north of China. The total length of the bridge is 280 m and the width is 12 m. The spans of bridge are arranged as 35 m + 60 m + 90 m + 60 m + 35 m. The transverse section of the bridge consists of 10.5 m as a deck and 2×0.75 as sidewalk. It has slop 2.2% along the length of the spans. The bridge is constructed by using the cast-in-place cantilever method. There are two separate T-shaped cantilever beams. Each separate T structure is consisted of 10 segments for each side .The length of segment No. 0 is 7.0 m which is located on the top of pier. The segments number one and two are cast-in situ segments. The others eight segments are cast-in-place cantilever segments. The height of the box girder on the top of piers is 5.0 m, and the height of the mid-span box girder is 2.0 m. The height of girder varies according to two parabolas along the length of the bridge. Bridge deck pavement has is 1 thickness which is equal to 10 cm. The bridge was open to traffic in 1997. Figure 1 shows the view of the bridge structure. Figure 2 shows the pier and span pre-stressed box girder layout.

(a)

(b)

Fig. 1 The Sanguxian bridge. (a) Longitudinal view; (b) transverse view

3 Repairing and strengthening of the bridge structure

The results of damage inspection, static and dynamic load test show that the bridge structure has large downward deflection in the center of the bridge. The values of measured downward deflection under static load test are more than the theoretical values. The load test coefficients are more than the allowable values, indicating that the stiffness and elastic working state of the bridge structure is not good. The bridge structure suffers from serious cracks in the parts of middle span and side spans. Therefore, the bridge structure needs to repair and strengthen to improve the rigidity and structural performance. The methods of repairing and strengthening include reconstruction the deck of the bridge by casting 10 cm layer, strengthening the web and bottom floor of box girders of middle span and side spans by sticking the steel plates, strengthening the whole bridge structure by using external pre-stressing tendons, strengthening the lower edge of bottom closure end segment of middle span by using high strength composite fiber, and treatment the cracks.

3.1 Reconstruction the deck of the bridge structure

The thickness of original box girders deck is increased by casting reinforcement concrete layer which is equal to 10 cm to enhance the bearing capacity and overall rigidity of the original box girders of the bridge spans. The construction process of new layer includes:

1) Remove the entire old deck pavement.

2) Roughening the exposed top of the box girders and chisel away some of concrete surface of box girders about 2 cm in order to make the surface rough and into the dentate shaped, make stirrup expose. Some appropriate treatments to the bonding surface, such as cleaning and drying are carried out.

3) To make the connection of old and new reinforced concrete is better, epoxy adhesive is applied as a layer on the surface of box girders concrete which has been roughened and implanted ϕ12 steel bars which is 20 cm in length. The implanted depth is equal to 10 cm. The spacing between steel bars is equal to 20 cm in a plum-shaped on the top of the original box girders to strengthen