Replacement of Health Monitoring System and Health Evaluation for Jinan Yellow River Cable-stayed Bridge

Ze-Ying YANG, Ting-Ting TAN, Yang-Yudong LIU, Ming-Hao SUN
School of Civil and Hydraulic Engineering, Shandong University, Jinan, Shandong, 250061, China

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Abstract. In order to understand the behavior of Jinan Yellow River Bridge more accurately and evaluate the bridge health, we change the sensors of the health monitoring system so that the data collected are more detailed and comprehensive. The monitoring data are analyzed synthetically. And then, based on this, the health condition of the Jinan Yellow River cable-stayed Bridge was evaluated.

Background of Project
Jinan Yellow River Highway Bridge is located in the northern suburb of Jinan City, Shandong Province. Bridge span 2023.44 m, its main span is 488 m and approach bridge is 1535.44m. The main bridge is 5 holes’ continuous prestressed concrete cable-stayed bridge, whose towers and cable plane are both double. Figure 1 shows the overall layout of the Jinan Yellow River Highway Bridge.

The Yellow River Bridge Health Monitoring System’s Replacement
By 2014, the fiber grating modulation demodulator (containing IPC) had completely paralyzed and it was beyond repair, so we replaced the new demodulation instrument and IPC. In July 2015, we replaced the strain and acceleration sensors with fiber grating sensors. The installation position of sensor and replacement is the same as before.

Main Beam’s Strain Monitoring Subsystem
Figure 2 shows the measuring position of the main girder stress monitoring point. The monitoring section is near the mid-span and the expansion joints of the main bridge’s south side. In the mid-span and southern side span, the sensor’s arrangement and numbers are shown in Figure 3, including the temperature compensation sensor of 2 #, 6 #, 9 # and 12 #. These sensors are used to eliminate the effects caused by temperature factors.

Fig.1 The overall layout of the Jinan Yellow River Highway Bridge

Fig.2. The measuring position of the main girder stress monitoring point
When the strain sensor is installed, we need to connect sensors in series. Strain sensors and temperature sensors are mounted on the base and the metal plate respectively, as shown in Figure 4.

**Main Beam's Vibration Monitoring Subsystem**

Main beam's dynamic stress monitoring uses fiber grating vibration sensor, which has no zero drift, good dynamic characteristics and immune to electromagnetic interference effects. Five vibration measurement sections of the main beam are arranged in the min-span of side span, min-span and quarter-span. The southern min-span is also arranged in a longitudinal vibration sensor. There are a total of 16 vibration sensors and 5 temperature compensation sensor, as shown in Figure 5 and 6.

To avoid vibration sensor from accidental damage, the vibration sensor needs adding an external housing protection, that must be marked with the direction of sensor test to check and replace in late period, as shown in Figure 7 and 8.
Arrange the Total Cable

When the strain and vibration sensors are installed, we start to connect and arranged the bus. We need to locate each fiber corresponds to the channel in the collective line box of monitoring room, and then through the jumpers connect the fiber's jack to the demodulator's socket accordingly, as shown in Figure 9. Finally, debug the data conversion software of demodulation instrument on the computer that is connected to the demodulator, and display real-time strain and acceleration values monitored on the computer screen, as shown in Figure 10 and 11. Then store the data in the corresponding database for analysis and processing.
The Analysis of the Monitoring Results

Since the strain of mid-span is the largest in the cable-stayed bridge, so is the vibration and displacement, the mid-span is regarded as the main reference point therefore. The monitoring data by software in November 2015 are analyzed as follows.

The Analysis of the Vibration Monitoring

From Figure 12 to 15, we can see if the noise (the acceleration increases abruptly in the figure) is ignored, the maximum of longitudinal acceleration does not exceed 0.0003g (g is the gravitational
acceleration 9.8m/s², the same below). Longitudinal stiffness of the bridge is still very large, able to meet the needs of normal use. The western side’s maximum acceleration of western box girder does not exceed 0.0005g and eastern side’s does not exceed 0.01g. The eastern and western sides of box beam are quite different in the acceleration, indicating box girder damaged and concrete used in the bridge changed to some degree after a long period of operation, causing torsional stiffness decreased. The maximum of horizontal acceleration is at most 0.00002g, declaring that the bridge tower and bearing work in good condition. Overall, due to the longer time of use, there have been some changes in the bridge structure and the overall stiffness has declined, but it’s still in normal use. And the bridge still needs to strengthen the periodic maintenance.

The Analysis of the Strain Monitoring

![Fig. 16 Strain in the mid-span](image)

Since the strain of mid-span is the largest in cable-stayed bridge’s box girder, we just analyze mid-span’ strain. Figure 16 shows that the maximum strain is 230 times micro-strain, indicating that main beam has produced some deformation, due to the impact of external load and concrete’s own shrinkage and creep, as well as the loss of box beam’s prestress. But the main beam can still meet the needs of normal use.

The Analysis of the Displacement Monitoring

![Fig.17. The longitudinal coordinates of the cable tower top](image)

![Fig.18 The transverse coordinates of the cable tower top](image)

![Fig.19. The coordinates of the cable tower top](image)
As can be seen from Figure 17 to 22, the tower and mid-span of box girder locate basically steadily with no major displacement amplitude. This indicates that the stiffness of cable tower is pretty large and the tower works in good condition. What’s more, the intensity of stay cables can be required to meet current conditions without replacement.

On the whole, because of the reasonable structure, regular maintenance and cable timely replaced, the health condition is still good even after a long period of work. However, as a result of the fatigue of reinforced and the loss of prestress increasing with time, the bridge needs to increase the frequency of maintenance and strengthen efforts to maintenance at the later stage.

Conclusion

(1) The health monitoring system is very important for the large-scale bridge working in a long time, so the bridge can be easily and timely monitored. Besides, we can be able to find out the operational status of the bridge in time, providing accurate analysis and forecast of injury and disease. This can effectively prevent serious collapse accident of the bridge.

(2) Based on the monitoring data of Jinan Yellow River Bridge in research, we can find that the bridge is currently in good health. It’s structure is stable and it can basically meet the current needs of normal use, although the bridge was built in an earlier time and traffic is heavy. This is mainly due to the addition of limit carrier on both bridge heads, cable replacement and routine maintenance properly. Moreover, paste carbon cloth can strengthen the girder.

Acknowledgments

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