Prestressed Continuous Bridge Evaluation using Structural Health Monitoring System

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Abstract. Dorim Goh is a prestressed concrete (PSC) continuous bridge in Seoul, Korea. The structural health monitoring is used to assess the behavior of this bridge. 12 strain, 6 displacement and two accelerometer sensors are used to collect the behavior of the bridge under static and dynamic loads. The low-pass filter is used to estimate the static behavior of bridge and extract the accurate values for the bridge performances. Six’s cases of static loads and truck’s speeds from 10 to 60 Km/h are evaluated. The maximum strain and deflection collect during static loads are 60 $\mu$e and 1.8 mm, respectively. Moreover, the distribution of stress on the bridge deck is assessed, and we find that the bridge status is safe under static loads. The dynamic factor (DF) is calculated during dynamic test, and the results show that the maximum DF is 0.228. In addition, Fast Fourier Transformation (FFT) is used to estimate the dominant frequency of bridge. The dominant frequency is estimated from acceleration measurements after filtering the collection data; the results show that the dominant frequency of bridge girder is 4.94 Hz. The results are compared with the design simulation model results and we find that the bridge is safe under applied loads.

1. Introduction
The structural health monitoring (SHM) nowadays has been become one of good tools utilized to assess the bridges in Korea. The SHM is applied using different sensors that used to measure the behavior of structures. The one of important sensors that measured the stress, deflection and accelerometer are used in this study. Sohn et al. [1] summarized the SHM methods, sensors and evaluations systems. The semi-static and dynamic of sensors measurements are used to estimate the full behavior of bridges. Therefore, the previous studies are used strain to detect the fatigue behavior of bridges; as well as the acceleration is measured to estimate the frequencies contents and modes of structures; and the deflection of bridge is observed using displacement sensors [2-4].

Many bridges in Korea are constructed in Korea over Han river to connect the two sides of Seoul city [5]. Dorim Goh bridge is one of these bridges that are constructed using prestressed concrete (PSC). A continuous SHM is used to measure the performance of this bridge from it is constructed. In this study the short-period monitoring system is used to measure the performance of bridge. This system is used frequently to assess the bridge while no continuous monitoring system was designed on the bridge.

The time and frequency domains are used to assess the full behavior of bridges [1, 6-8]. The time series under static and dynamic traffic loads are used to assess the behavior of the bridge. Previously, the statistical analysis was used to estimate the behavior of building using acceleration measurements [9]. Moreover, the strain measurements with statistical analyses are used to assess highway steel bridges [1, 10, 11]. In this study the statistical analysis and signal processing is used to evaluate the bridge in time
domain; and Fast Fourier Transformation (FFT) is applied to assess the frequency domain. More details for the analyses methods can be found in [1,6].

2. Measurements

Figure 1 show the bridge section, SHM system and case of bridge load. 12 strain, 6 displacement and two accelerometer sensors are used to collect the behavior of the bridge under static and dynamic loads. Static and six’s cases of static loads and truck’s speeds from 10 to 60 Km/h are evaluated.

![Figure 1](image1.png)

**Figure 1.** (a) Bridge section and monitoring system, (b) case of field-test (D is displacement, S is strain, ACC is accelerometer).

SHM system of the bridge is composed (figure 2). Sensors are connected to a data acquisition device by wire. Measured data are digitized in AD converter and delivered through Bluetooth module and Access Point (AP) by wireless. The collected data are stored in SD memory and PC. A data acquisition device used in this research has one channel; each device was time synchronized by signal sender from PC each time. PC stores data in real time and controls the sensor nodes (data acquisition devices).

![Figure 2](image2.png)

**Figure 2.** Structural Health Monitoring system composition.

3. Evaluation and Conclusion

The statistical analysis is used to evaluate the static behavior of bridge. The maximum strain and deflection collect during static loads are 60 με and 1.8 mm, respectively. Moreover, the distribution of stress on the bridge deck is assessed, and we find that the bridge status is safe under static loads, as presented in figure 3. From figure 3, it can be observed that the positive stress is 58.76 and 35.47 MPa for the girders G1 and G2, respectively. Moreover, the negative stress is approximately equally. These results mean that the stress is within the design value of stress.

![Figure 3](image3.png)

**Figure 3.** Stress distribution along bridge girder G1 and G2.

In addition, the low-pass filter is used to estimate semi-static performance for the strain measurement and calculate the dynamic factor (DF) for the measurements. The DF can be calculated using the following formula (DF=(Ddyn/Dstat)-1); while, the Ddyn is the maximum strain dynamic behavior
observed, and Dstat is the maximum semi-static strain measurements which are smoothed using the filter applied. Figure 4 presents the strain measurements and DF of strain girder. The strain performances exhibit that the range of strain is 60 με (see figure 4.a); this means that the bridge behavior is small under affecting loads. In addition, from figure 4.b, it can be seen that the maximum DF is 0.228, while the design DF value is 0.23; it means that the bridge is safe.

Moreover, the FFT is used to determine the bridge dominant frequency. Figure 5 illustrates the acceleration and FFT results. From this analysis, it can be shown that the first mode of frequency is 4.94 Hz. The comparison between the observed and simulated bending frequency (2.34 Hz), it can be summary that the measurement can measure the second frequency mode; and to measure the first mode frequency the traffic load should be redesign with low speed of traffic.

These results are compared with the design simulation model results and we find that the bridge is safe under applied loads. In conclusion, it can be summarized that the bridge is very safe under affected load.

**Acknowledgments**

This research was supported by a grant (18TBIP-C144315-01) from Technology Business Innovation Program (TBIP) Program funded by Ministry of Land, Infrastructure and Transport of Korean government.
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