Application of FBG Sensors to Strain and temperature Monitoring of Full Scale Prestressed Concrete Bridges

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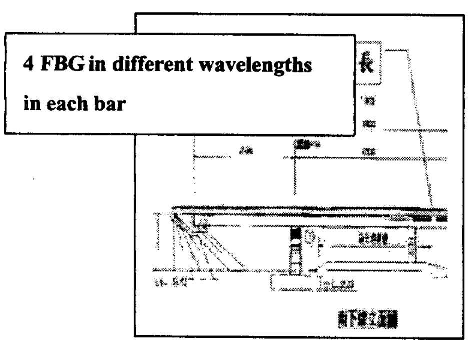
This paper presents the results of applying the FBG sensors to monitor the strain and temperature of a full scale pre-stressed concrete bridge made with high performance concrete during the construction process. The advantages and disadvantages of FBG as compared with other types of sensors are also discussed.

INTRODUCTION

In order to study the performance of pre-stressed concrete bridges, one made of regular concrete and the other of high performance concrete, two bridges with different materials were constructed as U-Zi bridges in the Tai-Chung County. Since the north-bound one is the first HPC bridge in Taiwan, the behavior of the bridge is strictly monitored by various FBG sensors.

INSTALLATION

The distribution of the FBG sensors is shown in Figure 1 where four FBG sensors were installed in each reinforcement bar. In order to make sure that the FBG sensors will survive during the process of instrumentation and construction, a special protection system, including plastic pipe and special tape, was used to prevent the bare fiber directly exposed in the concrete, as shown in Figure 2.



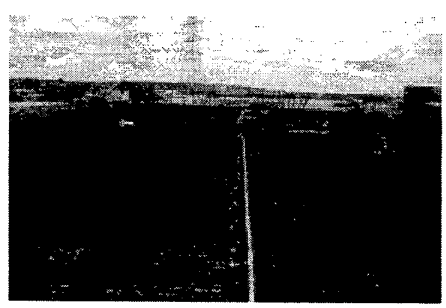


Figure 1 the distribution of the FBG sensors

Figure 2 the final protection system

The distribution of the FBG sensors was designed in advance so that the strain

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distribution along the longitudinal direction of the bridge can be measured. The reinforcing bars each with four pre-installed FGB sensors were placed in the left-hand side of the bridge. Figure 3 shows the distribution of the reinforcing bars along the bridge. Because the bridge is symmetric in the longitudinal direction, the instrumentation layout will be able to obtain the moment distribution of whole bridge. Meanwhile, in order to compensate the temperature effect of the FBG, two FBG sensors were designed in the state of free-strain condition. The working theory is illustrated in Figure 4. Therefore, the strain variation due to grouting, curing and demolding of the bridge can be measured and analyzed.

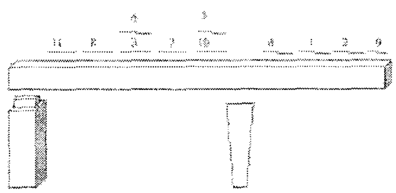

Figure 3 the detailed distribution of the reinforce bars

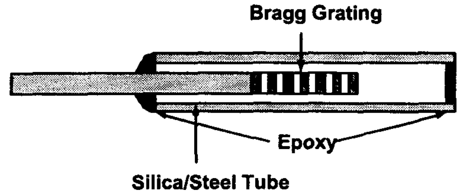

Figure 4 the working theory of temperature FBG sensors

GROUTING STAGE

The north-bound HPC bridge was grouted on July, 3rd, 2001 and the recording of FBG sensors lasted six days. Two FBG data within the same reinforcement (No.2) with one meter apart are used to compare with the RSG sensors. The variation of wavelength in both FBG sensors is shown in Figure 5 which shows that the trend is quite similar. The data of FBG2 was broken due to the damage in the connection in the second day but was immediately repaired after discovered. It is found that there seems to be some noise signals every 24 hours. After checking with the field construction condition, the "noise signal"is found to be the excitation due to the maintenance truck. The "noise signal" occurred when the truck sprayed water on the surface of the bridge deck. Therefore, when there is no maintenance on the fifth day, the "noise signal" disappeared. After compensating the temperature effect on the FBG sensors, the strain due to grouting is then compared with the RSG sensors. The data of FBG1 with the corresponding RSG sensor at the same location is shown in Figure 6. Although the trend is still quite the same, the annoying noise problem in the RSG makes the reliability of RSG doubtful. On the contrast, the FBG data is smoother and closer to the reasonable range during grouting and the advantage of using FBG sensors can be demonstrated easily.

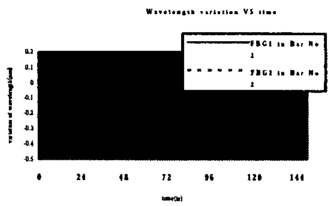

Figure 5 the variation of wavelength

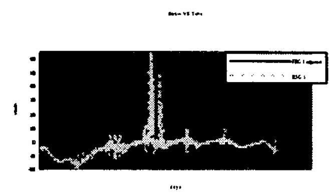

Figure 6 Comparison of FBG&RSG after temperature compensation

PRESTRSSING & DEMOLDING

The bridge was prestressed in August, 3rd, 2001 and demolded the side support in August 4th, 2001. Four FBG sensors in reinforcement bar No.2 were chosen to explain the strain variation in the prestressing process. The detailed record before temperature compensation is shown in Figure 7 and the prestressing influence can be seen obviously in the first quarter of the record. The practical strain data during the prestressing step differs from the periodic trend caused by the temperature change between day and night and is quite compatible with the theoretical analysis. Meanwhile, the prestressing loss can be estimated from the Figure and is approximately 100 μ. The data after temperature compensation is shown in Figure 8 and the corresponding temperature is shown in Figure 9.

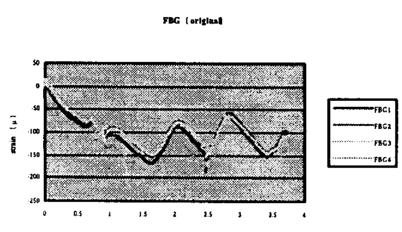

Figure 7 the prestressing process of the bridge

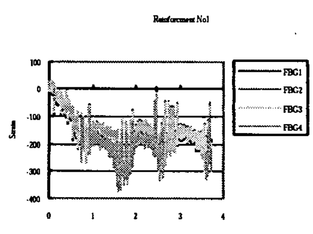

Figure 8 the data after temperature compensation

The temperature data in the first half day seems to contain some error and make the temperature compensation void during this period. Even under this situation, the prestressing process can still be seen in Figure 8 and the gap cause by prestressing is almost 100 μ. Finally, the comparison between RSG and FBG sensors was shown in Figure 10. The data measured by RSG sensor is interfered by some noise and the distribution of the data becomes unstable and unsmooth. On the other hand, the data collected from FBG can depict the trend successfully. The advantage of using FBG sensors is demonstrated once again.

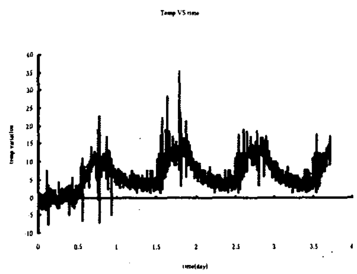

Figure 9 the temperature data

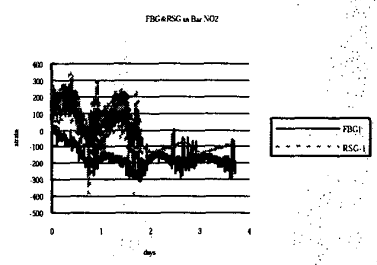

Figure 10 the comparison between RSG and FBG sensors

SUMMARY & CONCLUSION

The whole construction process of the first HPC bridge in Taiwan is monitored by FBG sensors. Since FBG sensor has better sensitivity and may get rid of the conventional noise problems, the goal of this research is to prove its feasibility in practice. The processes including grouting, prestressing and demolding were recorded by various FBG sensors and the results were compared with the RSG sensors. Under the same working environment, the result has shown that the FBG sensors could give a more reliable and precise readings than the RSG sensors. The result has demonstrated the superior characteristic of FBG sensors in structure monitoring. Under the fast growth of optical fiber industry, the characteristics of low transmission loss, light weight could make the FBG sensor a good candidate in structure instrumentation and may replace the conventional sensors in the near future.

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