DEVELOPING A BIM-SHM INTEGRATED SYSTEM FOR DISASTER RISK MANAGEMENT USING AUTO-REGRESSIVE MODEL

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Nowadays, one of the most prominent and global discussed topics is presenting scientific methods to evaluate potential structural damages to improve infrastructure disaster risk management. The most strategic infrastructure, including buildings, bridges, dams, and oil platforms, typically has high total cost throughout its life-cycle (Lynch & Loh, 2006). Hence, any damage and interruption in its on-going operation will impose prohibitive implications. Structural Health Monitoring (SHM) systems have been developed in recent years to aptly determine the damage contingency, level, and location before the structural collapse. These systems can provide decision-makers the required information about the level of structural damage immediately after an earthquake. The current challenge in structural safety management, however, is to find algorithms to process the invaluable data obtained from sensors and to define practical criteria to assess the ongoing structural health states.

This study aims to provide a proper assessment of the structural health immediately after an earthquake and to determine building serviceability through approximating the damage level and its location. This will effectively contribute to the safety decision-making such as immediate building evacuation and timely rehabilitation of damaged elements. This study entails two steps. First, it defines a structural health monitoring system for a 5-story building and estimates the level and location of the damages caused by a specific earthquake. Second, it forms a connection between the information obtained from the SHM system and the structure's BIM model. The story accelerations induced by the earthquake is recorded by accelerators to provide an appropriate SHM system, as stated by Rytter (1993). Following acquiring the accelerations, damage sensitive features are chosen. These features are indicators of structural characteristics. Therefore, any change in these features represents a change in the state of the structure. Auto-regression (AR) coefficients are employed to determine the damage occurrence and its time-period. This study also utilizes the natural frequencies and mode shapes as the damage sensitive features to ascertain damage level and its location (Brockwell et al., 2002). Subsequent to detecting the damages, it is time to build a connection between the SHM system and BIM models. The connection is enabled through the Application Programming Interface (API) coding in Visual Basic. In this study, the BIM model is defined by modeling a 5-storey structure in Autodesk NavisWorks.

Furthermore, four stages of damage thresholds are defined in the BIM model to assist in early decision making after the earthquake (Table 1). Finally, the damage stages will be demonstrated in the model by the means of color-coding.

Table 1. Damage-related alerts.

Warning	Level of damage
Emergency Evacuation	50% <
Major Repair-Crisis	30% _ 50%
Minor Repair-safe	10% _ 30%
Safe	10% >

Conclusion

In this study, a SHM system was developed by employing AR coefficients, natural frequencies, and mode shapes as sensitive damage features. Then, a connection is made between the health monitoring system and the pre-defined BIM model to enable visualization of the system outputs. This integrated BIM-SHM system was implemented in a 5-storey building. SHM system detected the occurrence of damage during the time from 110 to 135 seconds after the start of earthquake. The results indicated that maximum damage has occurred on the second floor. The damaged story is colored blue in the 3D model of the building as depicted in Figure 1. The proposed integrated system will significantly enhance safety decision-making by allowing visualization of SHM-based information through a convenient user interface shortly after an earthquake.

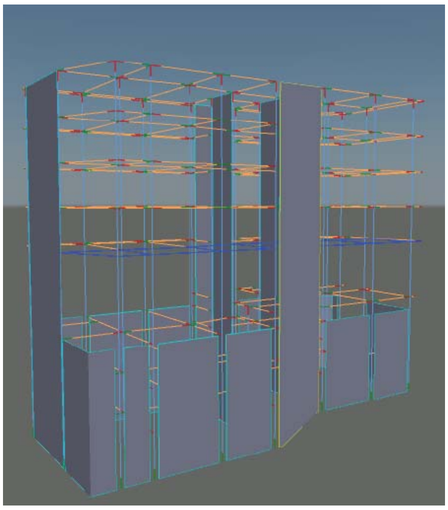

Figure 1. View of the 5-story building studied in the present research (picture by authors).

REFERENCES

Lynch, J.P. and Loh, K.J. (2006). A summary review of wireless sensors and sensor networks for structural health monitoring. *Shock and Vibration Digest, 38*, 91-130.

Rytter, A. (1993). *Vibration-Based Inspection of Civil Engineering*. University of Aalborg, Aalborg, Denmark.

Brockwell, P.J., Davis, R.A., and Calder, M.V. (2002). *Introduction to Time Series and Forecasting*, vol. 2: Springer.