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Convergence IT Technology in Connection with Concrete Filled Steel Tube Development of Building Safety System

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Abstract:

The recent massive earthquake causes a lot of damage. To reduce earthquake damage, improved seismic retrofit techniques and maintenance systems are needed. In this study, a seismic reinforcement maintenance system that combines an advanced seismic reinforcement technology, CFT(Concrete Filled Steel Tube) and IoT(Internet of Things), is proposed. The proposed system collects information about seismic waves in real time and uses it to determine the seismic performance level of buildings. Secondary casualties can be reduced by alarming through an alarm system according to the seismic performance level during an earthquake.

Keywords: *IoT Remote measurement system, Seismic Strengthening Technology, Seismic Performance Evaluation Disaster Preparedness, Convergence technology, Maintenance technology, Concrete Filled Steel Tube*

I. INTRODUCTION

In China, a magnitude 8.0 earthquake occurred on May 12, 2008 in Sichuan province, and in Japan, the magnitude 9.0 earthquake on March 11, 2011 hit the northeastern region, making it the largest earthquake in Japan's history. Due to the impact of the earthquake, the media in China and Japan reported unprecedented deaths and property damage every day, and in Korea, there was a lot of concern and concern about the earthquake [1].

◦ Improved seismic reinforcement technology is needed to reduce earthquake damage.

◦ There is a need for a rapid damage recovery method to prevent secondary damage of damaged buildings after an earthquake, and a real-time safety management system that can predict and alert the real-time damage situation and collapse risk of the damaged buildings.

The existing seismic reinforcement method did not have a clear maintenance method for safety management after construction. This study introduces the concept of constant safety management monitoring that can check the safety status of reinforced structures in real time using the CFT(Concrete Filled Steel Tube) seismic reinforcement method that is fused with recently developed information and communication technology. This ensures the reliability of seismic reinforcement and prevents secondary damages from disasters [2.3].

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Fig 1. Earthquake Damage

II. CFT Seismic Reinfrocement Method

2.1. OVERVIEW

In addition to safety and economics, seismic reinforcement technology requires various performances, such as simplifying the reinforcement procedure and reducing construction period and facilitating the use of existing structures. CFT is a structure that filled concrete inside a steel pipe and is a recently developed method having excellent structural performance. The seismic reinforcement method using concrete filled steel pipe is shown in Fig. As shown in 2, it is installed in the outer frame of existing reinforced concrete buildings, and it was designed for the purpose of completing reinforcement within a short period of time by minimizing the demolition of existing structures. In addition, there is an effect of increasing the strength and ductility of the internal concrete due to the restraint of the steel tube, and increasing the rigidity due to the increase of the cross section. High strength anchored bolt and epoxy are used to integrate the existing column with the CFT column. Non-shrink mortar was installed inside the CFT so that there was no gap in the internal space. Reinforcing bars for fixing in existing foundations were installed inside the CFT to integrate with the foundation [4,5].

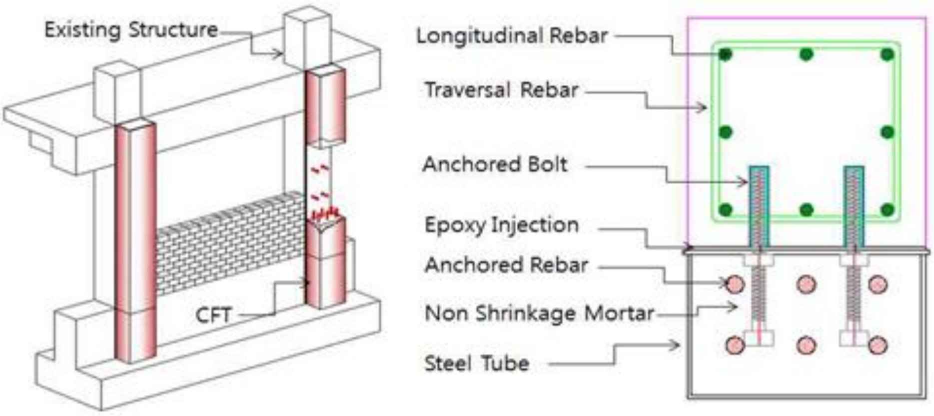

Fig 2. CFT Column Seismic Reinforcement Concept

2.2. CONSTRUCTION PROCEDURE

Seismic reinforcement method of CFT column is installed by installing CFT joining device on the surface of existing reinforced concrete pillar member and welding the c-type CFT pillar to the joining device. And it is a method of improving the seismic performance of existing reinforced concrete structures by injecting concrete or high-performance mortar (non-shrink mortar). The construction procedure of CFT column seismic reinforcement method is as follows: 1) Remove the existing column and arrange the ground surface, 2) Install the CFT bonding device, 3) Install the type CFT column, 4) Non-shrink mortar, 5) Epoxy injection, 6) Finishing material Construction is done in order of installation.

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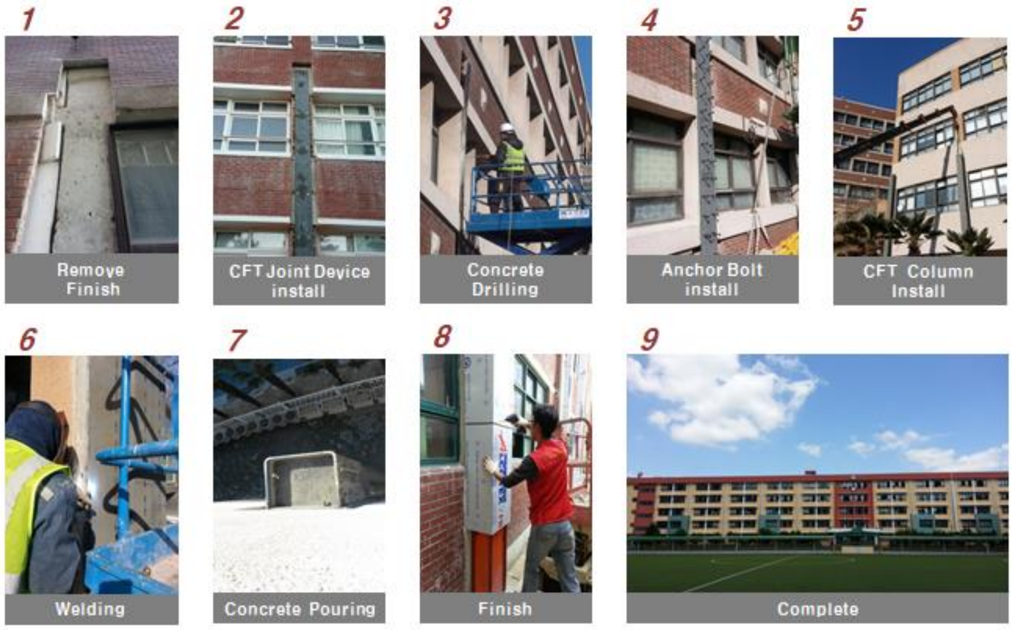

Fig 3. CFT Column Construction Sequence

III. IoT Based Real-Time Remote Measurement System

IoT(Internet of Things) based real-time wireless remote safety management system that can check the safety status of structures in real time after seismic reinforcement is shown in Figure 4 below. Through this, it is possible to secure the reliability of applying the earthquake-resistant reinforcement method and to secure safety in emergency situations from the inspection and response system to the preemptive response system [6].

Real-time remote measurement system connects sensor to Slave RTU(Remote Terminal Unit) to measure and store the structural load change state value at a fixed time (cycle). The RTU collects that data. After that, the data is transmitted to the communication base station using IoT communication, and it is composed of NETWORK which transmits the data to the computer in the control room through the Internet [7].

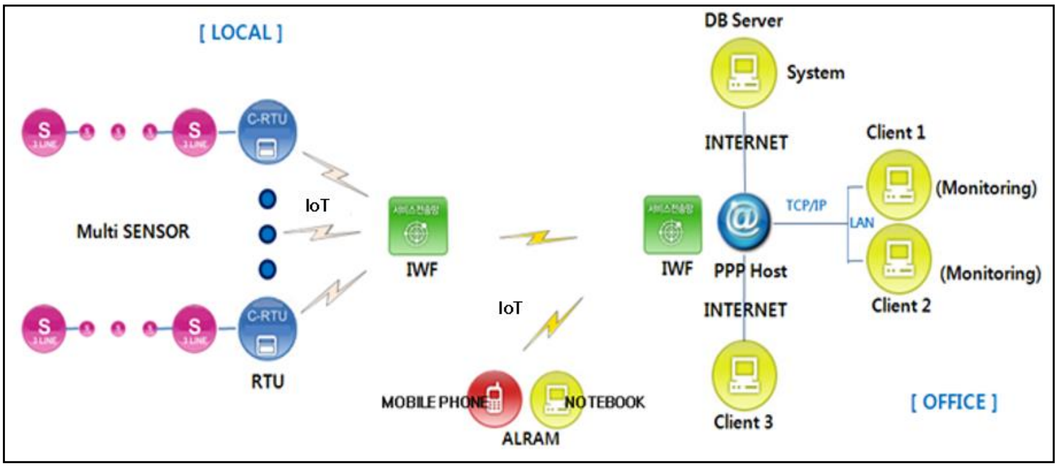

Fig 4. Conceptual diagram of real-time remote measuring system based on IoT

An example of the application of a real-time telemetry system is a film center located in Busan, Korea. Deformation sensors and displacement(inclinometer) sensors are installed on

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the main members of the structure, and the W(wireless)-RTU is connected to continuously measure the stress and displacement of the structure continuously. In addition, by measuring the change of the external environment of the structure through the wind direction anemometer and transmitting it to the structural safety monitoring computer through wireless communication, it monitors the change of the state of the structure.

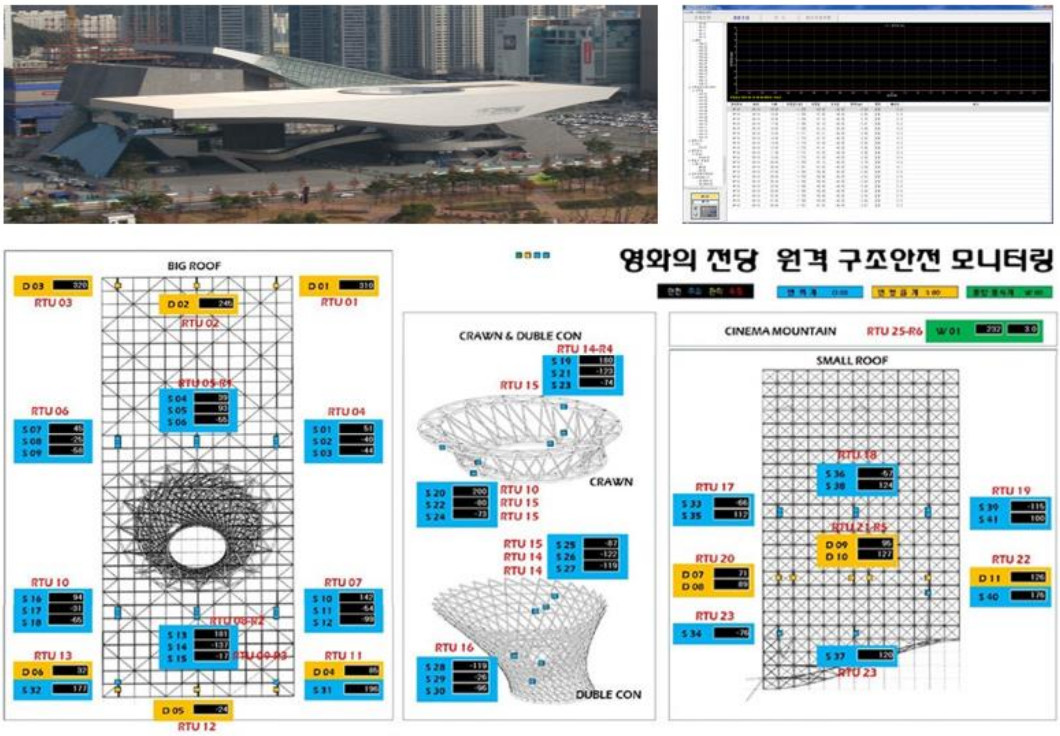

Fig 5. Real-Time Remote Measurement Case

IV. CFT Seismic Reinforcement Maintenance System

4.1. SYSTEM CONCEPT

The conceptual diagram of the CFT seismic retrofit maintenance system proposed in this study is shown in Figure 6 below.

After securing the seismic performance of existing buildings through CFT seismic reinforcement technology, which is an improved seismic reinforcement technology, real-time remote measurement system is installed. In the event of an actual earthquake, accelerations and strains are measured from sensors installed in the reinforcement. Data measured by the instrument is transmitted to the Internet through IoT technology, and transmitted to the measurement and analysis computer from the Internet. Nonlinear analysis is performed by applying the received acceleration data to a previously prepared analysis model. The measured strain data is compared with the analysis results to determine the accuracy of the analysis. Seismic performance evaluation is performed with the result of analysis corrected from the strain, and the state of the current building is judged. If the condition of the building is outside the level of life safety, an alarm system will trigger an evacuation alarm.

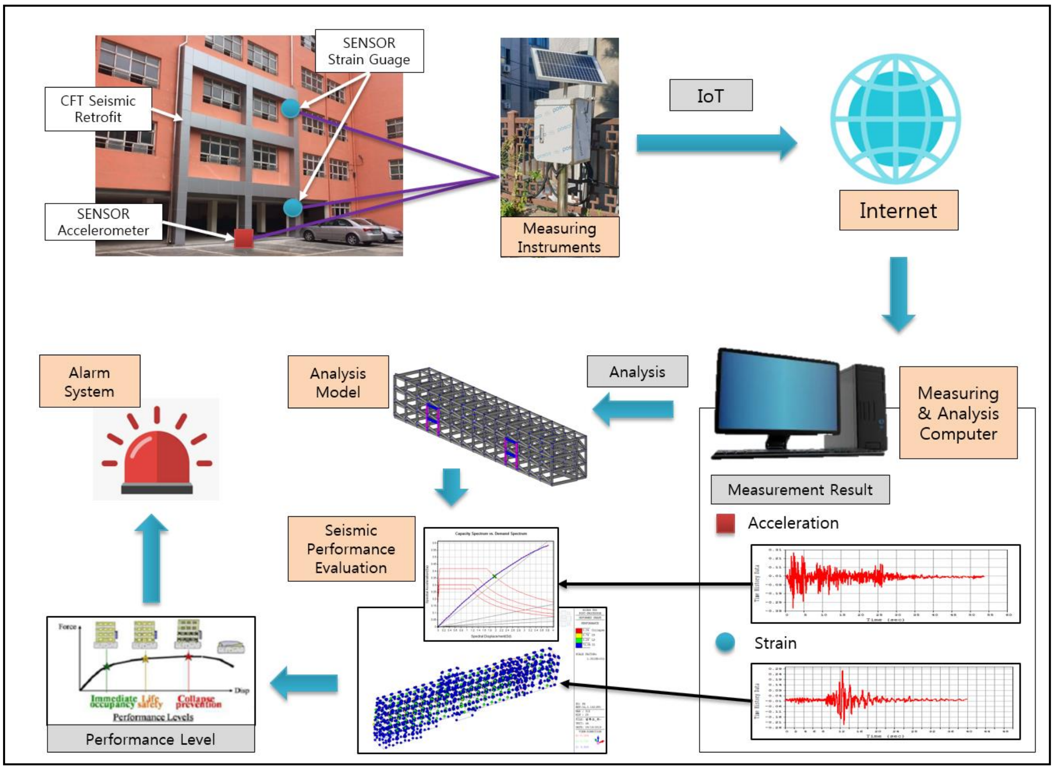

Fig 6. Conceptual diagram of CFT Column Seismic Retrofit Maintenance System

4.2. REAL-TIME TELEMETRY

The wireless remote measuring terminal receives the sensor signal, converts it into measurement data, stores it, transmits the data to a remote server computer using a wireless modem, receives control commands sent from the computer, and performs control functions according to the commands. It is a two-way wireless remote device consisting of Slave RTU for short range communication and Repeater-RTU for long range communication.

Remote measuring device function

Packet-based bidirectional communication function using TCP / IP communication (multiple simultaneous access to multiple RTUs)

RTU remote control using SMS (DB server IP change, RTU transmission cycle change)

RTU's own storage function and remote RECOVER function after system recovery in case of server computer failure

Automatic reset and self-diagnosis using WATCHDOG (operating power and communication status information)

Measurement time synchronization function using WCDMA

SENSOR SIGNAL High speed sampling and noise filtering function

Multi-sensor processing function (electric, vibration expression, pulse type)

Preserves the current setting even when the power is off, and operates the previous setting when the power is on.

On-site processing function for on-site information checking and function upgrade (built-in connection port)

4.3. ANALYSIS

For seismic performance evaluation, nonlinear static analysis or nonlinear dynamic analysis was performed to obtain the closest result. For the analysis model, seismic performance evaluation was made in real time by using the data base as the analysis model created when performing the seismic performance evaluation of existing buildings.

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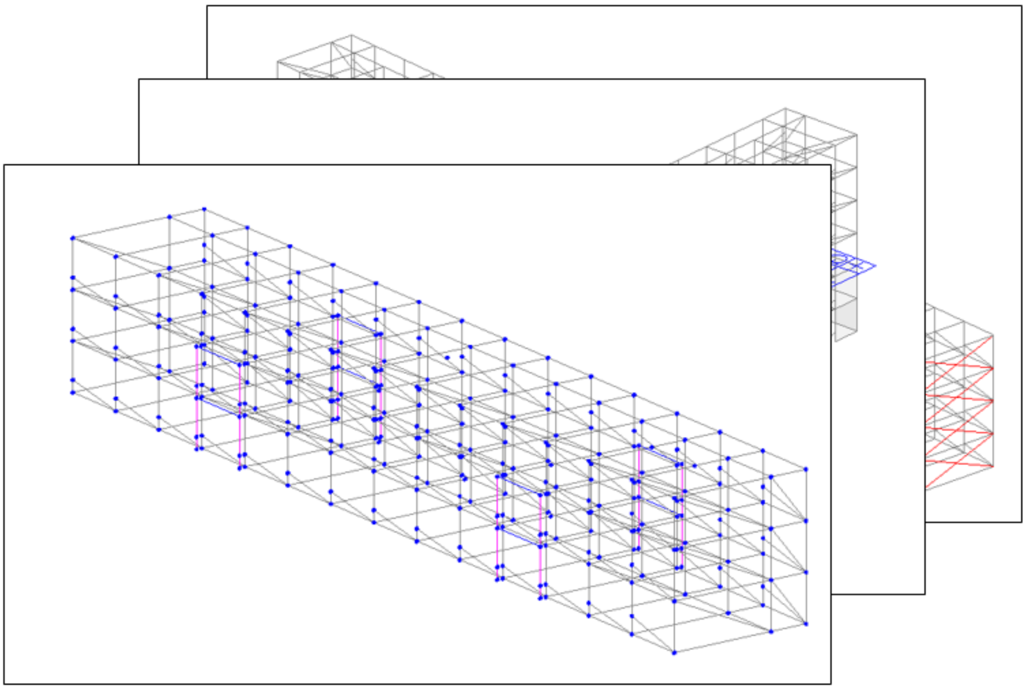

Fig 7. Data Base of Analysis Model

4.4. SEISMIC PERFORMANCE EVALUATION

Seismic performance evaluation is performed using ATC40's Capacity Spectrum Method (CSM) when performing nonlinear static analysis. The seismic performance evaluation method of ATC40 is shown in Fig. 8 below. The capacity spectrum method is a method of estimating the performance point of a structure by comparing the structure's demand performance determined by the structure's capacity and seismic load. The performance point is defined as the intersection of the capacity curve and the demand curve and defines the performance level from the state of the building at the performance point.

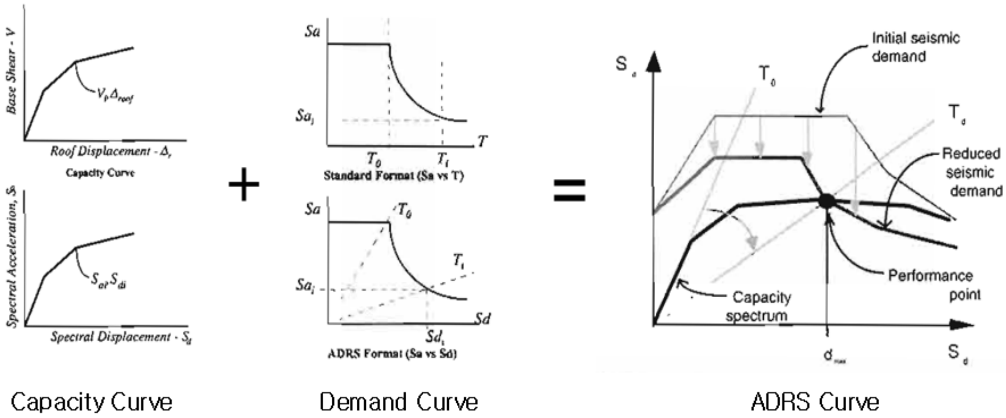

Fig 8. CSM Conceptual Diagram of ATC40

4.4.1. Demand Curve

The design response spectrum shows the target response to an elastic structure with 5% viscous damping. The vertical axis of the graph represents the spectral acceleration and the horizontal axis represents the natural period of the structure. In

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order to compare this design response spectrum with the capability spectrum of the structure, it needs to be converted into the required spectrum in the form of Acceleration Displacement Response Spectrum(ADRS). The required curve used in the seismic performance evaluation of this study is calculated from the real-time maximum acceleration measured from the sensor installed in the field.

$$S_{DS} \quad S \times 2.5 \times F_a \times 2/3$$

$$S_{D1} = S \times F_v \times 2/3$$

$$S_a = 0.6 \frac{S_{DS}}{T_0} T + 0.4 S_{DS}$$

$$S_a = \frac{S_{D1}}{T}$$

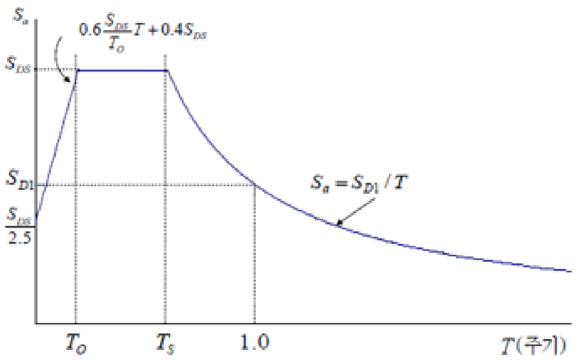

Fig 9. Design Spectrum Acceleration (KBC2016)

S = Effective Ground Acceleration of the 2,400 Regeneration Cycle Earthquake
SDS = Short Cycle Design Spectrum Acceleration
SD1 = 1 second cycle design spectrum acceleration
Fa = Short Cycle Ground Amplification Factor
Fv = 1 second cycle design spectrum acceleration

4.4.2. Seismic Performance Evaluation

In seismic performance evaluation, the measured earthquake uses the measured seismic wave. The seismic performance evaluation results are performed through the capacity curve, performance point estimation, individual member evaluation, and inter-layer deformation angle evaluation as follows.

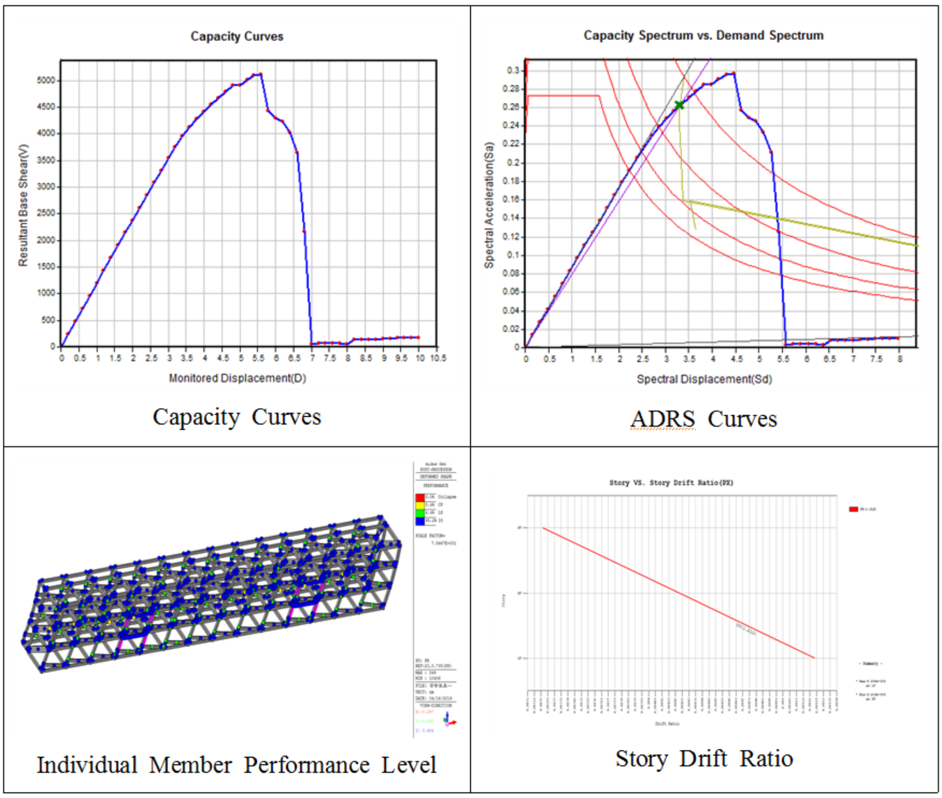

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Fig 10. Seismic Performance Evaluation Result

4.4.3. Determination of seismic performance level

The seismic performance level is calculated according to the standard of FEMA356 and based on the Basic Safety Objective. The Basic Safety Objective (BSO) is a Rehabilitation Objective that achieves the dual rehabilitation goals of Life Safety Building Performance Level (3-C) for the BSE-1 Earthquake Hazard Level and Collapse Prevention Building Performance Level (5-E) for the BSE-2 Earthquake Hazard Level. The BSO is intended to approximate the earthquake risk to life safety traditionally considered acceptable in the United States. Buildings meeting the BSO are expected to experience little damage from relatively frequent, moderate earthquakes, but significantly more damage and potential economic loss from the most severe and infrequent earthquakes that could affect them. The level of damage and potential economic loss experienced by buildings rehabilitated to the BSO may be greater than that expected in properly designed and constructed new buildings.

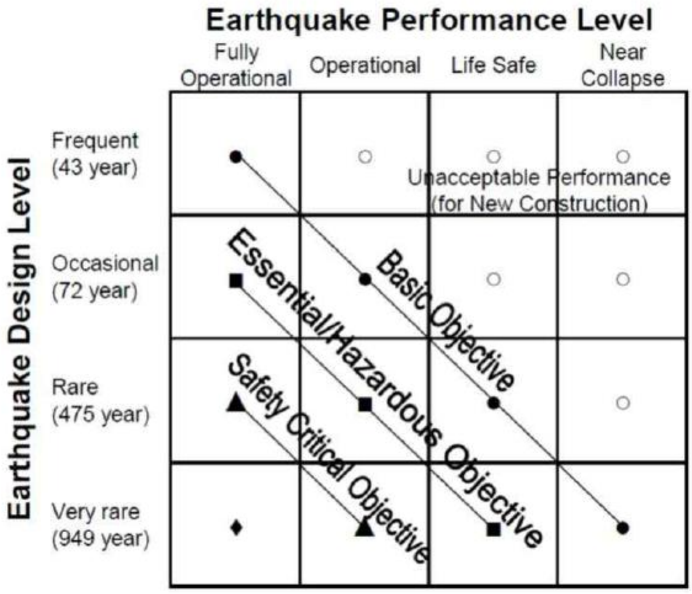

Fig11. SEAOC Vision 2000 recommended seismic performance objectives for buildings

4.4. Verification of analysis results

Figure 12 shows the conceptual diagram for verifying the analysis result. The reliability of the analysis results is verified by comparing the member forces of individual members and the real-time strain measured from sensors installed in the field. If there is a big difference in the member force after comparative analysis, correct the analysis result and perform the seismic performance evaluation again.

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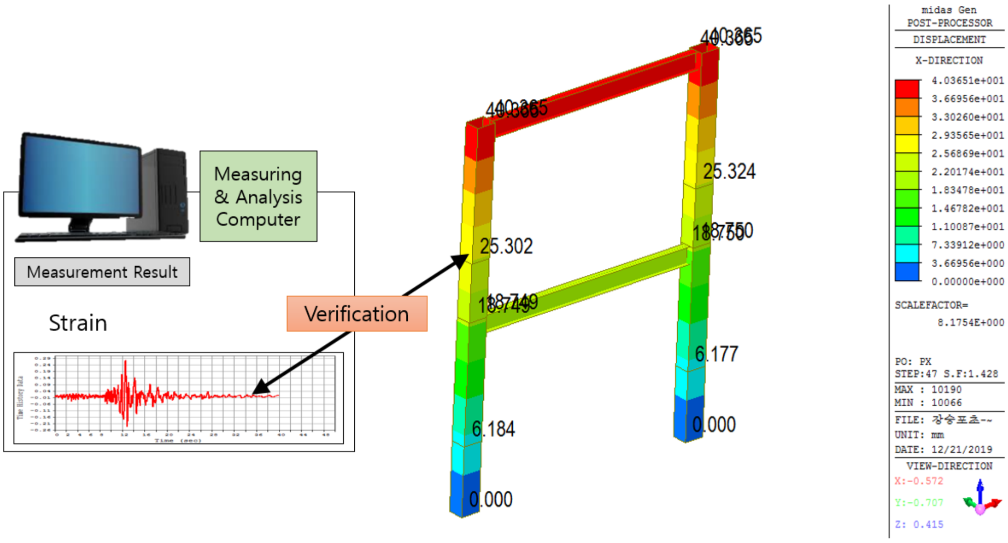

Fig12. Analysis result verification concept

V. Conclusion

In this study, we proposed a maintenance system that combines seismic reinforcement technology and IoT technology to cope with large earthquakes.

Conceptually, seismic reinforcement and maintenance technology that can respond to real-time disasters is presented. More reliable real-time building status checks can prevent secondary damage from disasters.

An experimental study is needed to grasp the hardware problem that may occur when transmitting data wirelessly.

An analytical study is needed to analyze the difference between the measured and measured strains.

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