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Structure Earthquake Analysis Program using Computer-Aided IT Sensor

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Abstract: The purpose of this study is to develop a complex test and analysis technique to improve the reliability of seismic performance evaluation of buildings, and to establish a seismic performance evaluation system using shear damper as an earthquake preparation technology. In this study, validated examples of viscoelasticity provided by OpenSees were selected for verification of hybrid experimental results data and compared with hybrid experimental techniques. By applying the analysis program and the developed Labplugin, the hybrid experimental system built through the connection between the equipment was verified. As a result, the behavior of the cyclic loading test showed the general behavior of the damper, but in the hybrid test, the behavior of the damper with respect to the ground acceleration and the decrease in stiffness caused by fracture were found. From the above comparison experiment, it can be seen that the hybrid technique developed in this study shows excellent seismic behavior compared to the cyclic loading experiment, dynamic experiment, and analytical technique. With the system built in this study, it is judged that it is possible to design a structure damper in the future. In addition hybrid experimental system will help to conduct more economical and reliable research on seismic control by applying partial experimental data to structures with nonlinear behavior in the future.

Keywords: analysis program; IT sensors; hybrid experiment system; seismic analysis; steel damper

1 INTRODUCTION

In recent years, there have been earthquakes in the Nepal earthquake in 2015, and even in Korea, earthquakes such as Gyeong-ju Earthquake (2016) and Pohang Earthquake (2017), which occurred within the Korean Peninsula's influence zone, have been reported in Korea. It also proves that it is not an earthquake safe zone. There are still earthquakes in many places, but there is still a shortage of response technologies. The hybrid experimental analysis system was applied as an experiment and analysis system that more accurately reflects the behavior of dampers caused by earthquakes [1].

Hybrid experimental technique development has been actively carried out since the early 2000s, and in the United States and Canada, through hybrid experiments, the advantages of each laboratory device are linked with the program, and experiments and interpretations are carried out at the same time, making more precise experiments[2]. In this study, the algorithm for seismic characteristics analysis through hybrid experiments, and the shear pulsation damper applied with the actual hydraulic actuator through Labplugin developed to apply the actual damper values. In addition, the seismic characteristics were analyzed by the hybrid test on the building with shear damper. The hybrid analysis program used UI-SIMCOR2) developed by NEES, and the validity of the data results of the hybrid system was verified by comparing them with the OpenSees analysis results.

In addition, the building to which the shear-type steel damper was applied was modeled according to the hybrid experiment and the behavior was analyzed to evaluate the verification of the system construction and the validity of the results [3]. Tab. 1 summarizes the advantages and disadvantages of hybrid experiments for quasi-static experiments and vibrating table experiments, which are the existing experimental methods.

The purpose of this study is to construct a hybrid experimental system for reliable analysis by analyzing the overall behavior of the building through the interlocking of the experimental data of the damper and the analysis data of the building. The goal of this experimental technique is to design and develop a damper in the future, and to establish a seismic analysis process for a complex analysis structure to which the damper is applied.

Table 1 Advantages and disadvantages of experimental techniques

Division	Quasi-static experiment	Hybrid experiment. (Similar experiment)	Vibration test.
Experiment method	Experiment and analysis of the previously analyzed displacement history in the absence.	Experiments and analysis in which the step is numerically analyzed in every step of the hour to emphasize displacement, and then the response is exchanged and calculated in real time	Experiment and analysis through the behavior of the diaphragm similar to the actual ground motion
Strengths	Simple structure The cost of the experiment is low	It can mimic the destructive behavior relatively accurately. There's little limit on the size of the test subject. Small improvements make deployment less expensive	Responses, collapse procedures, and residual deformation of structures close to reality can be identified.
Weakness	Dynamic stiffness change cannot be considered	Since the experiment is conducted by dividing the time into stages, the dynamic effect of the actual earthquake history cannot be considered because there is no concept of time	The deployment cost is high. Limit of capacity. Error due to reduction

Therefore this study is to construct a hybrid experimental technique system that simultaneously conducts experiments and analyzes by connecting the experimental values of the steel dampers with the whole building analysis to analyze the damper-installed buildings.

2 METHODOLOGY
2.1 Substructure Analysis

In the partial structure quasi-dynamic seismic response test, the members or households that are considered to have a great influence on the response properties, especially in the structure under review, are replaced by mathematical models. It is one of the experimental techniques to simulate the earthquake response of the whole structure by performing numerical analysis [4].

2.2 Hybrid Test

As shown in Fig. 1, hybrid test is an experimental method that introduces partial structure technique to Pseudo-Dynamic Test in order to evaluate the seismic behavior of structures efficiently and more realistically. Simultaneously analyze the earthquake response of the structure as a local partial test of the structural element or substructure in parallel with the loading test and analysis.

Simultaneously analyze the earthquake response of the structure as a local partial test of the structural element or substructure in parallel with the loading test and analysis. The advantages of the hybrid experimental technique are that it avoids the problem of scale, which requires the specimen of the shaking table to fit the size of the shaking table, can reasonably handle the seismic response of the structure as well as the scaled specimen, and can observe the destruction process in detail [5].

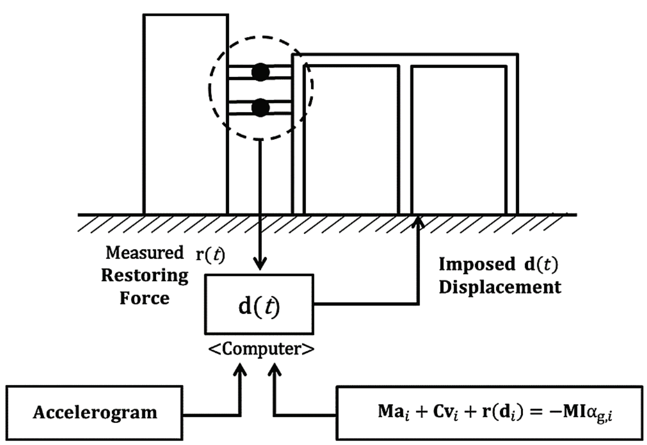


Figure 1 The pseudo-dynamic testing method

And many structural analysis programs developed in recent years have their own advantages. If you can take advantage of the inherent analysis capabilities of these various analysis programs, you can create more realistic structural analysis models for more complex structures. After dividing the target structure into analysis modules and experimental modules, the results obtained through experiments or analysis of each module are fed back at every hour increments, and then the behavior of the whole structure is obtained through dynamic motion equations [6].

2.3 Shear Type Damper

Shear type damper is a shear yield type vibration damping device that can be installed in the center of connecting beam where the bending moment is hardly generated in the connecting beam and the maximum shear deformation occurs and can increase the damping efficiency of horizontal load [7]. By installing one energy dissipation device in the center of the beam, it is possible to dissipate more energy in the beam that takes much shear force.

Fig. 2 shows the installation position of the sheared pulverized beam. The beam is subjected to the bending moment and shear force according to the relative displacement of the shear wall, and it is possible to minimize the damage of the existing structure by dissipating energy by applying the damper, an energy dissipation device, by using the deformation of the shear wall and the cross-sectional force generated in the shear beam. Fig. 3 is a diagram explaining the shear force of a pulley beam on the behavior of buildings during an earthquake [7].

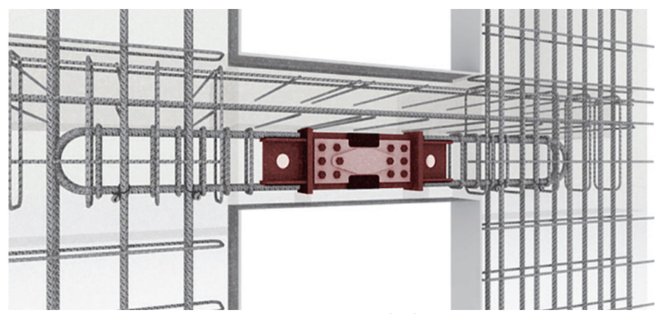


Figure 2 An example of a figure

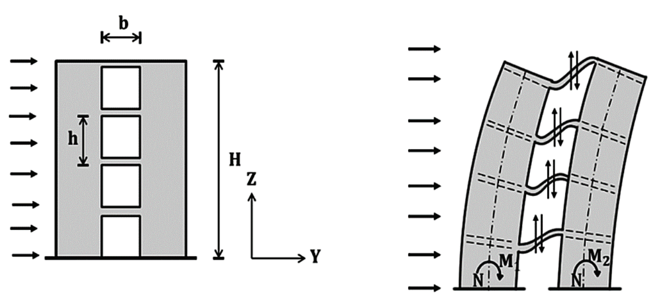


Figure 3 The principle of relative deformation of the shear wall under lateral force

3 HYBRID EXPERIMENTAL CONFIGURATION
3.1 Experiment Algorithm

The purpose of the hybrid experiment is to perform the complex analysis of the structure where the damper is installed because the experimental data of the damper is analyzed in conjunction with the analysis data of the structure in order to increase the reliability of the structure analysis in the seismic performance evaluation [8].

3.2 Composition of Ui-SIMCOR

UI-SIMCOR can distribute and control pseudo-dynamic analysis in several sites, and the number of control is not limited. With a variety of communication protocols, you can test from a single degree of freedom system to highly complex structures. Simulation can be any experiment, any combination of experiment and analysis, any analysis, and UI-SIMCOR applies a static force that is not time-dependent. Figure 4 is a program form of UI-SIMCOR, and figure 5 shows the execution order and description of the UI-SIMCOR.

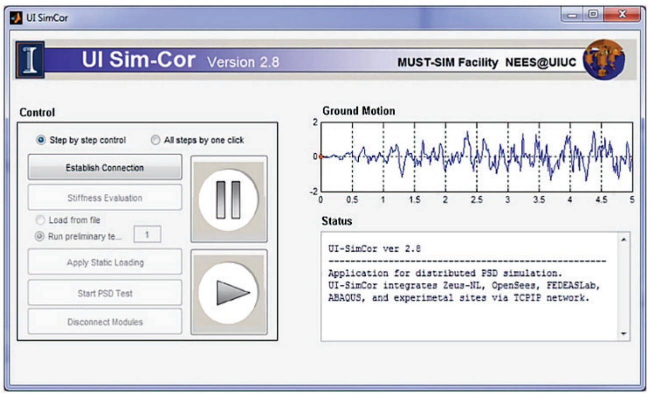


Figure 4 UI-SIMCOR

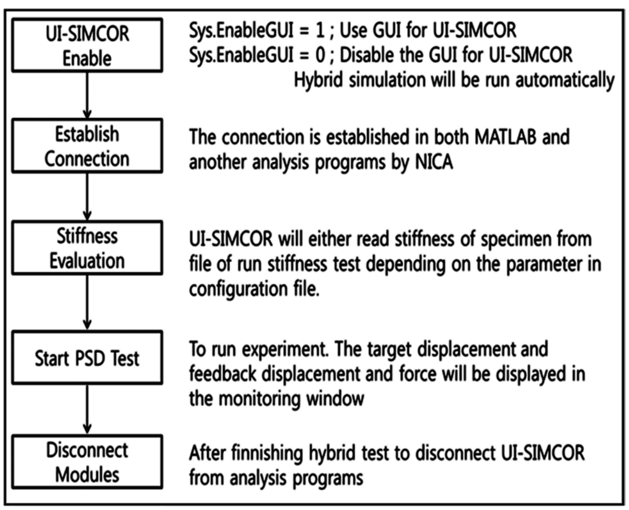


Figure 5 UI-SIMCOR progress

In this hybrid experiment, in order to see the dynamic force exerted on the structure in more detail by integrating the seismic acceleration, the velocity and displacement are made by integrating the seismic acceleration, and the displacement value is divided into 500 steps. When one displacement is applied, one restoring force is measured by static analysis and the pseudo-dynamic analysis is performed. Construct the building to be analyzed as a model using the finite element method, divide the building model into parts by applying the partial structural analysis method, and build the individual analysis program or the test object and collect the results of the experiment and analysis again in Matlab to analyze the results of the entire model.

In this experiment, the actual actuator displacement value transmitted through Labplugin is transmitted to the third substructure of MDL3, and the damper's experimental result is transmitted as an analysis value through LabPlugin. Since we proceed to displacement control, we move the actuator by sending displacement of MDL3 node to Labplugin. After that, due to the displacement of the actuator, the restoring force value is extracted from the load cell connected to the shear damper, and then returned to the program analysis [9].

4 LABPLUGIN

In the hybrid experiment, the displacement of each node is transmitted to the modular substructure in UI-SIMCOR, and the reaction force is measured by the analysis program or the experiment and put into the overall structure matrix for analysis. At this time, the experimental data can be transmitted only to the program with communication system such as TCPIP. So, if there is no communication system in the program that handles devices, Labplugin should be developed and connected. When performing the hybrid experiment, Labplugin receives the displacement data from UI-SIMCOR through TCP / IP, moves the actuator by the corresponding displacement, measures the displacement and load value of the actuator, and transmits it to UI-SIMCOR to interpret the experimental data.

The part setting for the instrument reading the load cell and displacement meter, the manual operation part, the graph indicating the target displacement of the actuator including the hybrid, the position graph of the actuator, and the reaction force graph that adjusted the measurement result value, UI-Consists of displacement and reaction force graph when transmitting to SIMCOR. In addition, the displacement shape transformation coefficient applied in the non-x direction makes it possible to analyze brace-like structures. As a limitation, it is not currently available if it is not in one direction, and there is an error due to time difference between analysis and experiment [10].

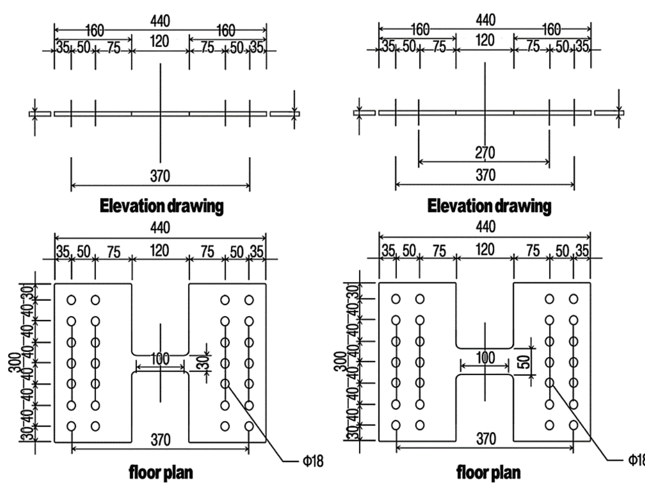


Figure 6 Steel damper drawing

4.1 Specimen

Tab. 2 defines test steel dampers applied to this study. For steel dampers with 30 × 5 mm shear area, 30 steel dampers are designated as symbols and 50 steel dampers for 50 × 5 mm shear area.

Table 2 Specimen number

No	Specimen	Design Variables
1	30 Steel Damper	Shear area 30 × 5 mm
2	50 Steel Damper	Shear area 50 × 5 mm

Fig. 6 is a drawing of test damper steel damper. Fig. 7 is a picture of the steel damper set up.

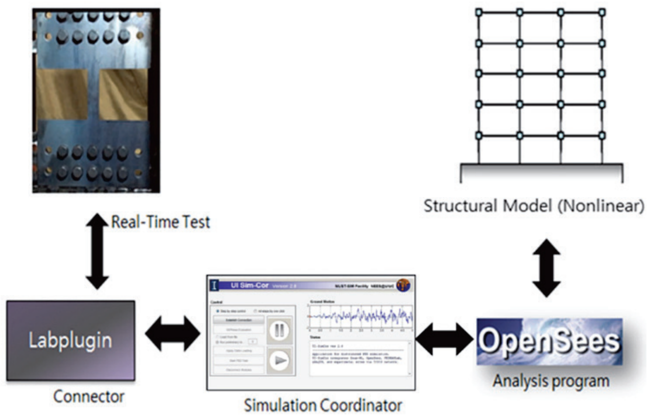


Figure 7 Hybrid experimental diagram

5 EXPERIMENT CONFIGURATION

In order to verify the hybrid experimental technique, the frequency design test, the fault structure analysis, and the terminal induction test were carried out. These are summarized in Tab. 3. Example Structure 2 of Multi-Stie Online Simulation Test (MOST) is a sample structure provided by UI-SIMCOR, the main program of hybrid experiments made by NEES, and the result data is verified by comparing with other programs.

Table 3 Experiment plan

Test Name	Specimen Type	Analysis
MOST (2Bay 1Story) Structure Hybrid Experiment	None	OpenSees
	30 Steel Damper	Hybrid Test
	50 Steel Damper	50 Steel Damper

5.1 Experiment Setup

This experiment is to evaluate the seismic performance of the actual shear type damper using the actuator. The 100t hydraulic actuator was used and the test damper was installed. Figs. 8 and 9 is the experimental setup. In order to transmit only the shear force, four longitudinal H-beams were installed and horizontal bars were placed in the middle to install horizontal bars. And to prevent eccentricity, rollers and rails were installed to move only on the *x*-axis. The results of the experiment were applied to the hybrid system, and the experiment was carried out by constructing the experiment analysis through interworking between programs. The measurement was performed using an Agilent 34972A meter. Fig. 10 and Fig. 11 are actual setup photos and damper installation photos.

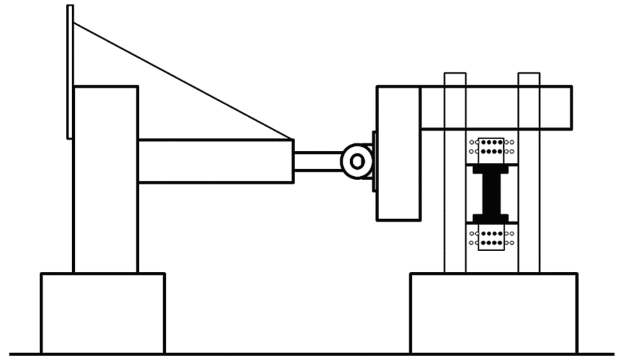


Figure 8 Experiment setup no. 1

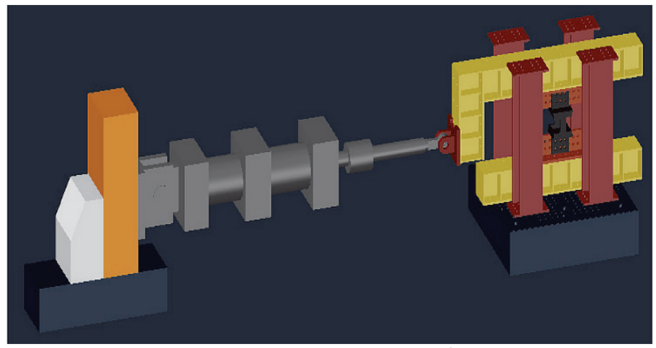


Figure 9 Experiment setup no. 2

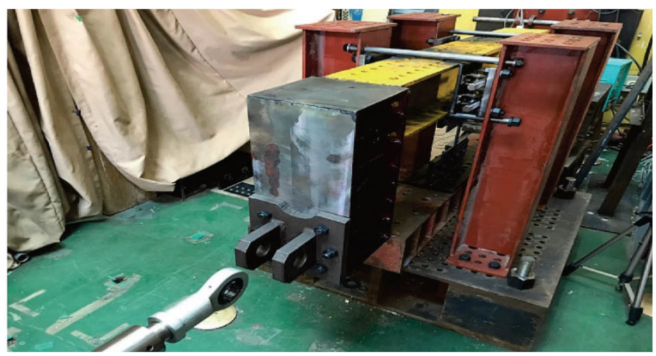


Figure 10 Actuator and Experimental setup connection part

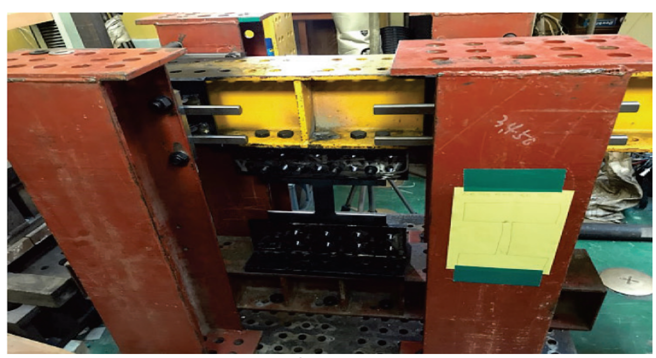


Figure 11 Steel damper setup

5.2 Hybrid Test System

The hybrid experiment is constructed by applying the finite element method to the building to be analyzed, and by applying the partial structural analysis method, the building model is appropriately divided, the individual analysis program or the test object is constructed, and the results of the experiment and analysis are gathered back to the UI-SIMCOR.

6 STRUCTURE HYBRID TEST EXAMPLE

6.1 Example Model

The Multi-Stie Online Simulation Test (MOST) example structure is an example structure provided by UI-SIMCOR, the main program of the hybrid experiment made by NEES, and the result data is verified by comparing with other programs. Fig. 12 shows the application of steel dampers to modeling. Fig. 13 is a modeling diagram for hybrid experiments. When shear dampers are installed in the central column of MOST structure, the behavior of damper is analyzed and the effect on the whole structure is analyzed.

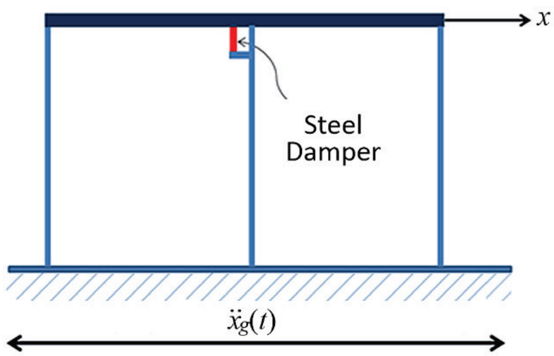


Figure 12 MOST structure with shear damper

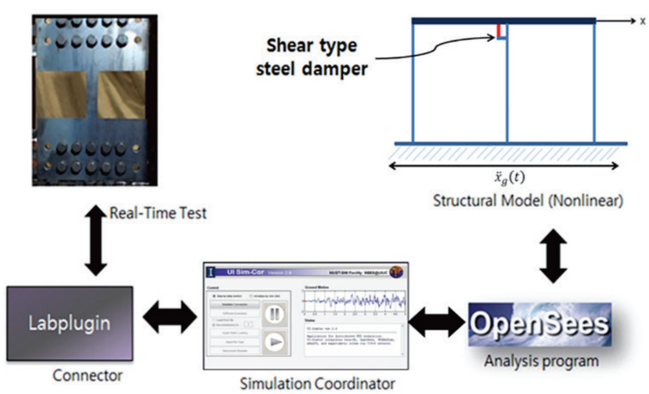


Figure 13 Hybrid experimental diagram

6.2 Acceleration Graph

The structure consisted of 3 parts and analyzed. The seismic wave was Acc475C seismic wave. Fig. 14 is a graph for Acc475C, the ground acceleration applied to the analysis.

6.3 Experiment Result

Fig. 15 shows the force displacement of the structure with ground acceleration, and Fig. 16 shows the force-displacement graph for the nodes.

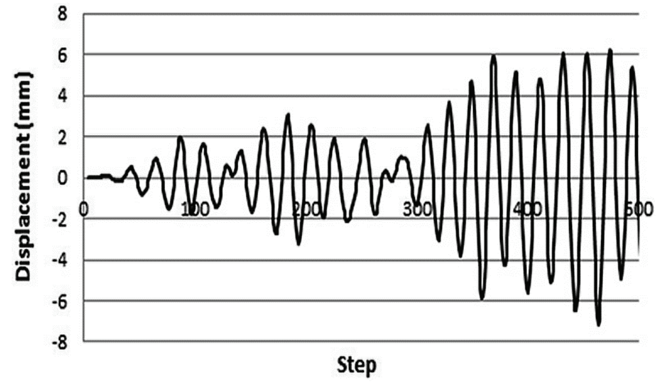


Figure 14 Acc475C acceleration graph

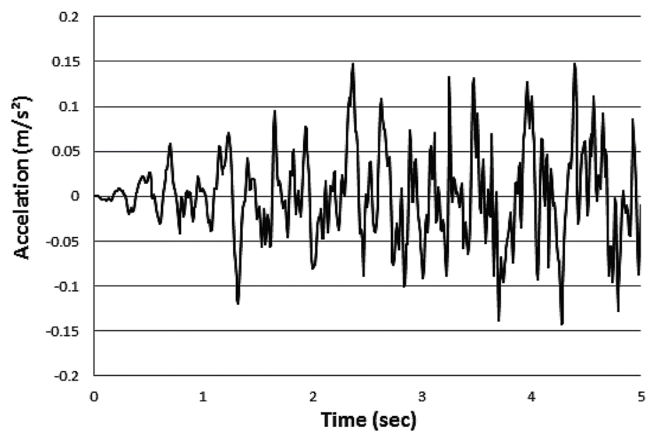
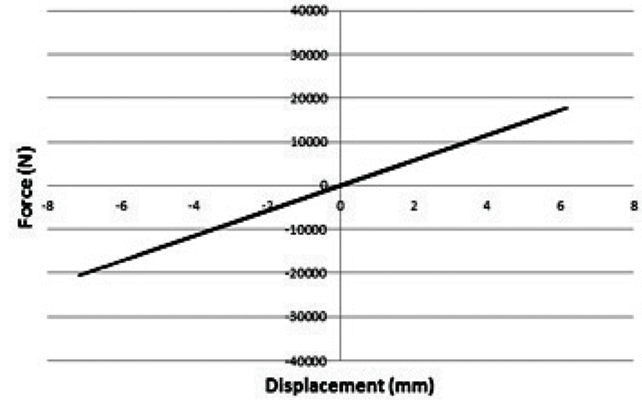


Figure 15 Applied displacement

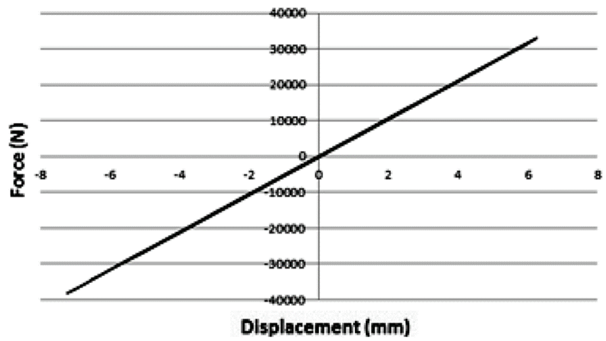
In Fig. 15, 500 quasi-dynamic analyzes at 0.01 second intervals showed that the displacement of the structure moved 6mm and –7 mm at the origin, so the maximum width of 13 mm had the greatest effect on the structure. For this displacement, the structure is shown in Fig. 16. This is a force-displacement graph for the left, center, and right columns of the MOST structure, respectively. The graph shows a linear graph of 30000 N (3 Tons) for 6 mm. The reason why the linear graph appears is that the yield point of the modeled structure has not been reached.

Fig. 17 shows the force displacement of a damper-mounted structure and Fig. 18 shows the force-displacement graph for a node.

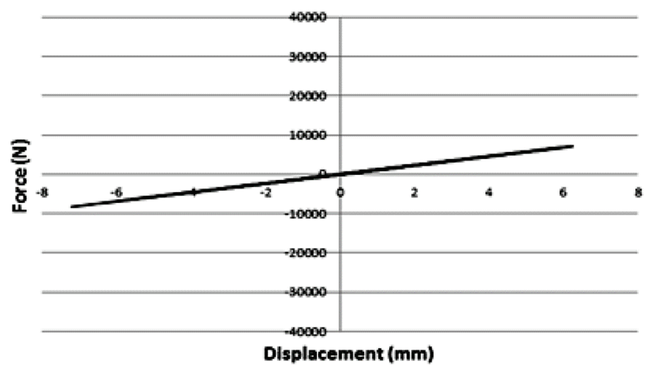
In the model where the shear type steel damper is installed on the two-node central column by applying the hybrid system, the displacement is similar to the displacement applied in the OpenSees analysis. At the nodes for each column, however, the force-displacement graph changed slightly under the influence of the damper, unlike the linear graph in the OpenSees analysis. Fig. 19 shows the force-displacement graph of the damper experimental data when the structure is analyzed by the quasi-dynamic analysis.



(a) Left column Force-Displacement Graph

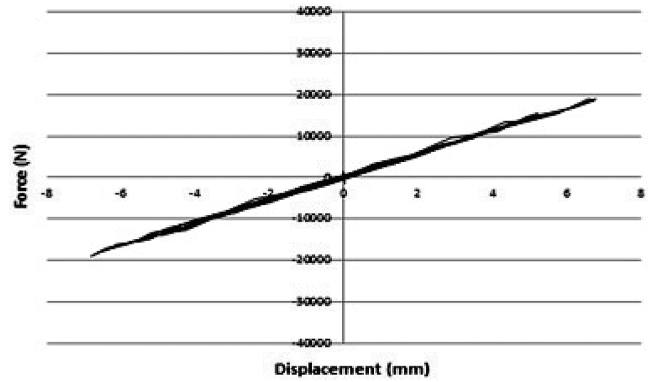


(b) Middle column Force-Displacement Graph

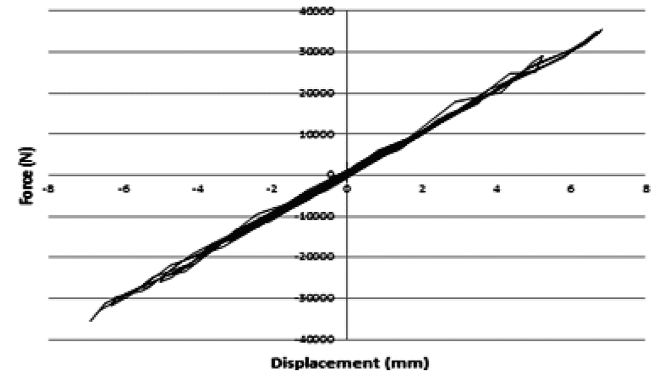


(c) Right column Force-Displacement Graph

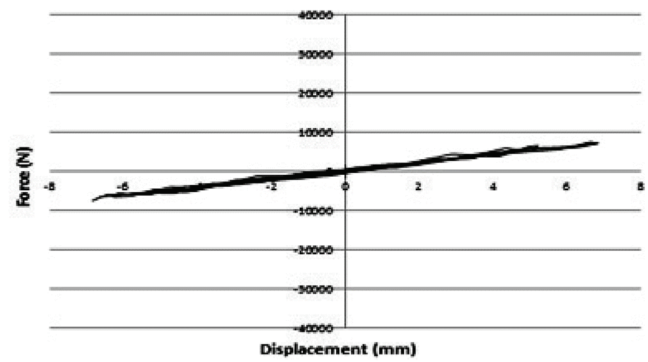
Figure 16 Force-displacement graph of the MOST example



(a) Left column Force-Displacement Graph



(b) Middle column Force-Displacement Graph



(c) Right column Force-Displacement Graph

Figure 18 Displacement graph of MOST hybrid test

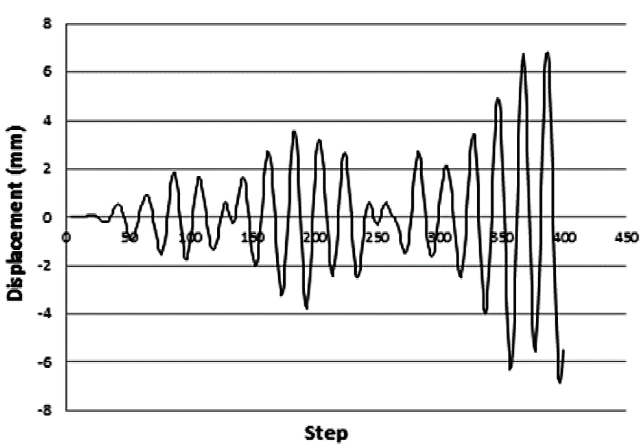


Figure 17 Applied displacement

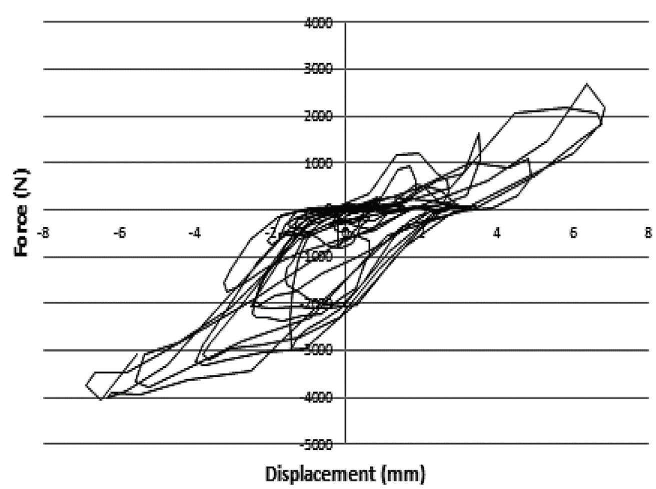


Figure 19 Force-displacement graph of 50 steel damper

7 CONCLUSIONS

In this study, a hybrid test system was constructed to analyze the complex structure due to the application of dampers. Hybrid test system is an experimental technique that analyzes the whole structure by dividing the whole structure into substructures, combining the experimental results of the damper with the analysis results of other parts through the analysis program. The structure of the damper against the earthquake of nonlinear structure controlled by shear type damper was analyzed by testing the structure of steel damper which is the test body of shear type breaker damper. In future research, it is necessary to reduce the errors caused by time difference, instrument error, and understanding of the model due to systemic errors.

In this study, the structural analysis was performed by applying the steel damper, which was made arbitrarily for the purpose of building a hybrid test system. In addition, it is expected that the constructed hybrid test system will be more economical and reliable for the study of seismic control applying partial experimental data on nonlinear behavior structures in the future. In addition, hybrid experimental system will help to conduct more economical and reliable research on seismic control by applying partial experimental data to structures with nonlinear behavior in the future.

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Notice

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