Structural performance identification of the existing SRC building with seismic observation results

by

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ABSTRACT

In this paper, the results of the analytical studies are shown as the first step to develop the health-monitoring technique for the real existing buildings. One of the purposes of the first step is to make the analytical models for evaluating the performance. The target building is the annex of Building Research Institute, of SRC building with 8 stories. Three-dimensional model was made and compared with the records against earthquake. As the results of the comparison, the models tend to show longer period than the real building records for the effects of walls, slab stiffness, rigid zone. The model is changed including the effect of walls, finishing elements, and analyzed dynamically with measured ground motions. Then good agreement is obtained. The static elasto-plastic analysis is also carried out to predict the collapse mechanism under severe earthquakes. Base on the results of the analytical study, the peak strain sensors will be installed at the members in which damages are expected to occur.

KEYWORDS: Health Monitoring
Existing building
Seismic Observation
FEM analysis

1. INTRODUCTION

The ultimate goal of structural health monitoring is to detect and locate damage and degradation of the performance in structural components and to provide this information quickly and in a form easily understood by the operator or occupants of the structure. Considering detecting the damages such as aging, damages for external forces, and evaluating the current residual structural performance, main research items in health monitoring are the damage detection technology and the performance evaluation technology. Only damage detection technology apt to be focused on as a structural health monitoring, but to evaluate the structural performance is indispensable for reasonable structural rehabilitation.

The basic concept of structural health monitoring shows in Figure 1. Here, evaluating performance means estimating residual restoring force characteristic of structure. For the complicated building structure, it may be impossible to converge vast data and analyze them. Furthermore it is not practical to install quite a number of expensive sensors into all over the building components. In another way, it should be important to develop the system, what is called scenario, for the structural health monitoring.

In this paper, a scenario for buildings is shown as a case study. The target building stands at

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Figure 1 Relationship of performance evaluation, damage detection and repair

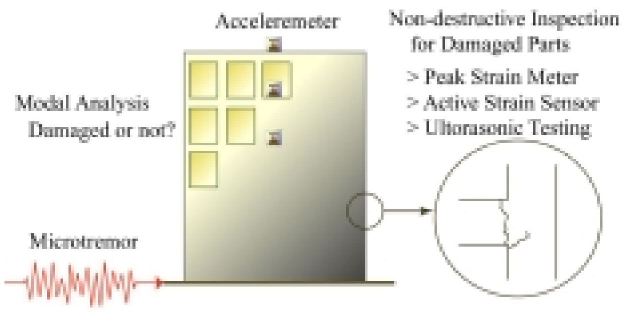
the site of the Building Research Institute. It is expected that buildings be regarded as the most complicated one among other infrastructures, because of the resisting mechanism, such as the distributions of the stress against external force. Structural performance is difficult to evaluate and then discussions are being carried on. If the sampling tests, damage detection, and initial structural design are integrated, it will be evaluated more accurately.

As the first step of the utilization of initial structural design to evaluate structural performance, a numerical model including non-structural elements was made and damage points of the structural elements were clarified analytically for verifying the scenario of our structural health monitoring technology.

2. SCENARIO OF HEALTH MORNITORING TECHNOLOGIES

In our scenario for utilizing the structural health monitoring, as shown in figure2, two quite different approaches are used. One is the global damage detection stage. It means whether damages occur or not, and that damaged components are roughly predicted using modal analysis. Generally, for the global damage detection, micro tremor is utilized with acceleration meter. Then the detail inspection will be performed for the expected the damaged components in the next stage, that is called the local damage detection. Nondestructive inspection such as ultrasonic testing, strain meter and new smart sensors are utilized. In general these kinds of sensors are expensive. To install quite a number of sensors for all parts of structure is not reasonable and practical. Therefore making a correct numerical model and analyzing will reduce number of sensors.

In the global damage detection, nonstructural elements have to be considered as structural elements because in range of micro tremor, we cannot ignore the effect of nonstructural element. Data before damage is also needed for comparing those after event. If you don't have the data before damages, you have to make its data based on the structural design. As mentioned above, for appropriate repair and reinforcement, a performance evaluation is regarded as important as damage detection. When the global vibration data is used for a performance evaluation, you have to evaluate non-structural element appropriately. It is taken for granted that structural performances depend on structural method, main materials, and so on. For real buildings, you need the consideration for an accurate numerical model including effects of non-structural element.



1) Global Damage Detection --> 2)Local Damege Detection

Figure 2 Scenario of structural health monitoring technology

Based on these backgrounds, this report has been composed. The implementation in this paper consists of three items. The first is to make an accurate model including nonstructural elements. The necessity of consideration of nonstructural element will be made clear. The second is pushover analysis. It is to identify the location of damages. Last one is to define the next step after the global damage detection.

3. ANALITICAL STUDY

3.1 Target building

The structure for a case study is a real building in the site of the Building Research Institute as shown in Photo 1. The building has eight stories and one basement. In this building, several acceleration meters on basement, top, and so on have been installed. Structural outlines are shown in Table 1 and figure 3. Main structures consist of steel encased reinforced concrete(SRC).

Photo. 1 Taget building

Table 1 Outline of structure

Name	Building Research Institute Annex Building
Stories	Eight Story + One Penthouse
Total floor area	5,050m^2
Height	30.9m
Main structure	Steel encased reinforced concrete (+ steel frame)
Foundation structure	Spread foundation

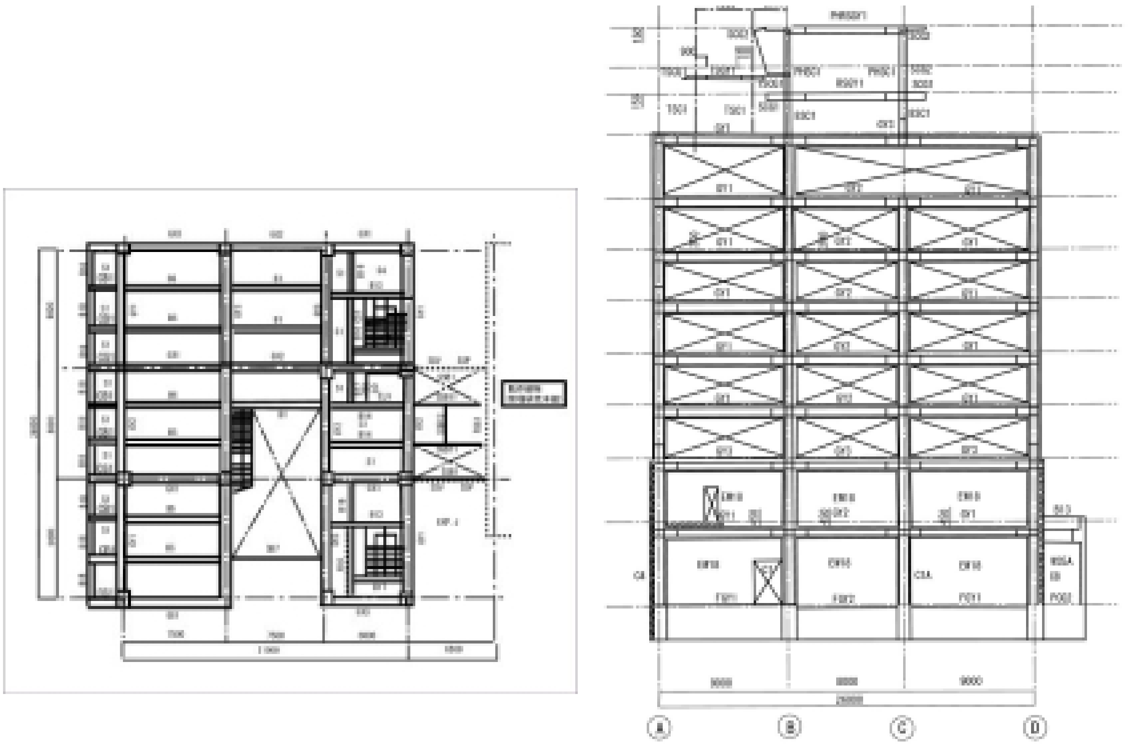


Figure 3 Elevation and plan of target building

3.2 Flow of analysis

Figure 4 shows the flow of analysis. At first, the finite element model including non-structural elements is prepared, and then the frame model for tracing the result of finite elements model is made. Some response records during earthquakes have been obtained. These data are analyzed. In the concrete, response spectrum is computed. These data are input into the frame model, and the response is also computed. Based on the comparison between records and the results of analysis, finite element model is modified. This effort is continued until analysis corresponds to records. The pushover analysis is conducted to this final model.

Earthquake records are shown in Table 2. Maximum accelerations on the basement were less than 30 gal. It is expected that the structure still remain in linear range.

4. DISCUSSIONS

4.1 Effect of non-structural element

The numerical model corresponding with records was the three-dimensional model including non-structural element like finishing and walls that were connected by expansion joint. Two-dimensional waves were input into this model. Figure 5 shows the example of response spectrum compared with records and analysis.

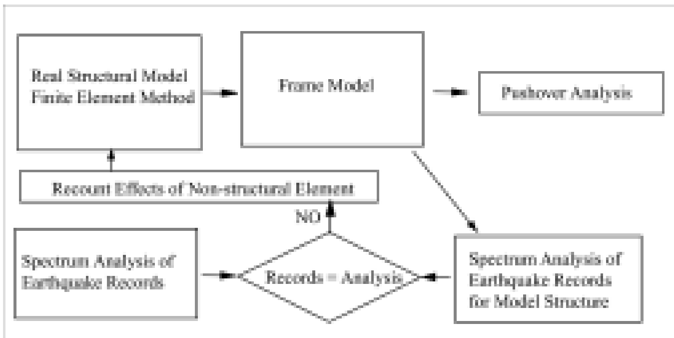


Figure 4 Flow of analysis

Table 2 Earthquake records

No.	Date	Magnitude	Depth [km]	Distance [km]	Max. Acc. [gal]
1	06/24/98	4.6	73	2.2	14.3
2	08/29/98	5.1	67	58.4	6.4
3	11/08/98	4.6	78	57.7	3.2
4	03/26/99	4.9	58	60.4	27.7
5	04/25/99	5.1	58	62.4	25.1
6	07/15/99	4.9	56	42.1	4.2
7	08/09/99	4.4	116	34.3	3.6

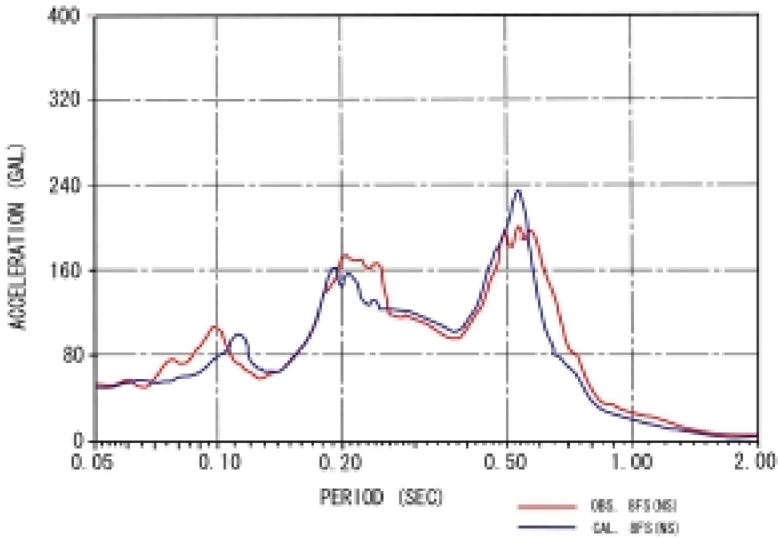


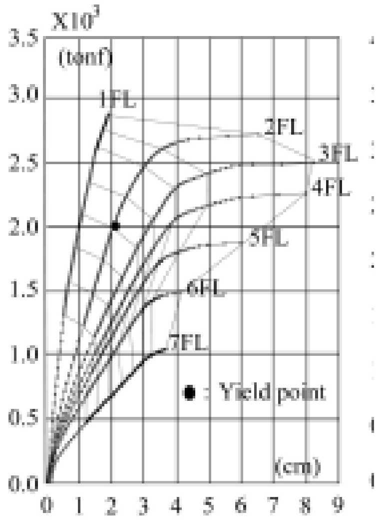
Figure 5 Comparison of earthquake records and analytical results

4.2 Expected damage parts by push-over analysis

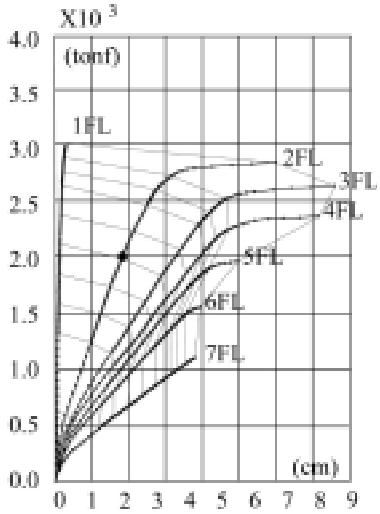
It is expected that damaged components are different in accordance with distributions of external forces. Here the distribution that has been widely used as structural design is adopted, which is called "Ai distribution." In case of analysis for estimating effects of non-structural elements, walls that are connected to main structure by sliding connecter were considered. But in push-over analysis they were ignored.

Figure 6 shows the result of the push-over analysis. The capacity of shear force is shown in figure 7 as a result of analysis. In the X direciton, plastic hinges are made at first in the column bases of second floor. Then, beam edges on from the third to sixth floors become plastic. The collapse mechanism are made of them at the base shear coefficient of 0.52. In Y direction, similar mechanism are made at the base shear coefficient of 0.57.

Figure 8 shows the expected first yield points. It will be effective to install smart sensers around these vulnerable components.

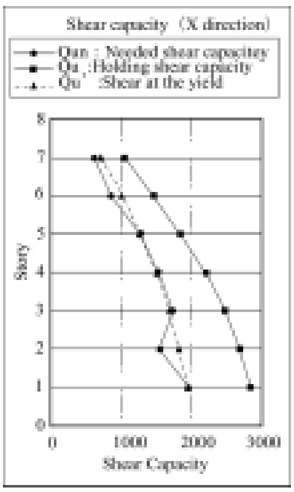


a) X-direction

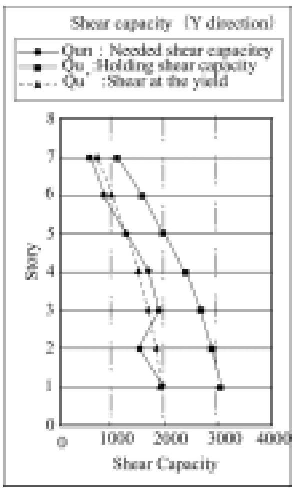


b) Y-direction

Figure 6 Results of push-over analysis

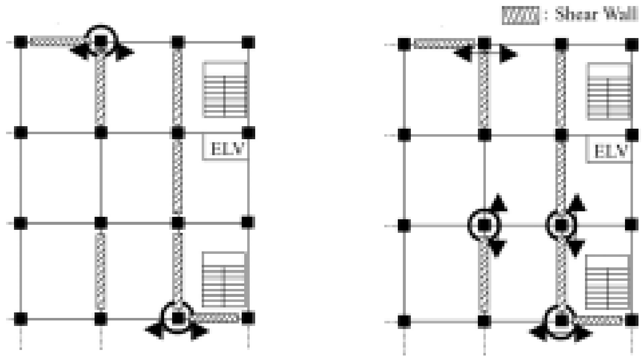


a) X-direction



b) Y-direction

Figure 7 Shear capacity



a) X-direction b) Y-direction

Figure 8 Vulnerable components

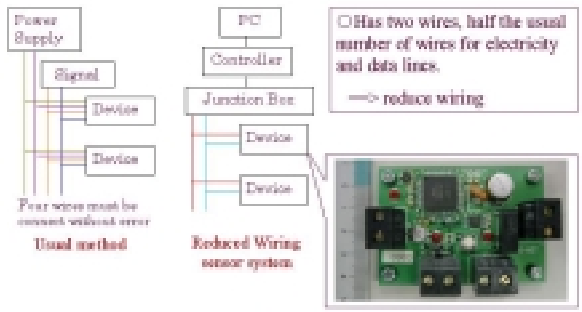


Figure 9 Reduced wiring sensor system

5. FUTURE STRATEGIES

Base on the results of the analytical study, peak strain sensors will be installed at the members in which damages are expected to occur. As the measurement system, reduced wiring sensor system, as shown in Figure 9, will be installed. Of course wireless sensor system is desirable, but for solving the problems of power supply and data collection, wiring sensor is practical. Additionally, real time data collection system is not rational because huge memory space to save data is needed. For detecting damage and evaluating residual performance, maximum strain meter is worth trying to use. The examination of the durability and reliability of sensors, and of data collection and power-supplying system will be required. Some peak strain sensors will be installed in the most sensitive parts, if there are any ideas about sensors to install, we would like to consider them. We will wait for next earthquakes.

6. CONCLUSION

The numerical model to trace the real behavior during earthquakes was made. The vulnerable component was predicted under push-over analysis. And then the sensor that will be install for local damage detection was decided. The numerical model and these sensors will help us to detect the damages for future earthquakes and to evaluate structural performance.

ACKNOWLEDGMENTS

This study is being carried out under the US-Japan collaborative Research Program" Smart Structural System (also called as Auto-Adaptive Media"). The authors wish to thank members of the Structural Health Monitoring working group in the Sensor Sub-Committee for their fruitful discussions.