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SEISMIC PERFORMANCE OF REINFORCED CONCRETE SCHOOL BUILDING IN FUKUSHIMA UNDER THE GREAT EAST JAPAN EARTHQUAKE

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ABSTRACT: On March 11 of 2011, a great earthquake occurred in Tohoku region, which caused severe damages and collapses of buildings. That is why, it is necessary the study of the seismic performance of buildings to understand the causes of their damages, especially, if these buildings are important facilities which ensuring the life safety. In this sense, this study attempts to evaluate the seismic performance by the standard evaluation of seismic capacity and the static elastoplastic analysis method on the 3D model of the school building.

Key words: Great East Japan Earthquake, nonlinear static analysis, school building

INTRODUCTION

This study analysis the seismic performance of RC School Building under the Great East Japan Earthquake which performs a nonlinear static analysis in order to study the earthquake resistant capacity.

OUTLINE OF THE BUILDING AND DAMAGES

Outline of the building

This school is located in Fukushima prefecture, which is conformed by 4 RC buildings, the layout plan of buildings is shown in Fig.1. Buildings for classrooms (Building “A” and Building “B”) are located on the north and south. Two connecting corridor buildings (Building “C” and Building “D”) are connected to A Building and B Building with gap.
Building “A” is 4-story Reinforced Concrete (referred to as RC, hereafter) building with total floor space of 2,962m^2. Building “B” is 3-story RC building with total floor space of 2,059m^2. Building “C”

is 2-story RC building for connecting corridor and class rooms with total floor space of 459m^2. Building “D” is also 2-story connecting corridor with class rooms building of which 1st story is RC and 2nd story is steel structure with total floor space of 382m^2.
East portion of Building “A” and 1st floor of Building “D” was constructed at 2973, East portion of Building “B” and Building “C” was constructed at 1974, and west portions of Building “A” and “B”, and 2nd floor of Building “D” was constructed at 1975.

Outline of damage

Overview of Building “A” is shown on Fig.1, and 1st floor plan with damage indexes of columns and walls is shown in Fig.2.
The north frame of the building was severely damaged, and the columns of the special classroom at the west end of the building on the 1st floor failed in shear with its damage index of V. Window frames by the sides of the column deformed due to its vertical shortening as shown in Fig.2
On the other hand, the shear wall at the west end of the building suffered no serious damage as shown in Photo 3. Some girders with standing wall in the north frame failed in shear. Floor level of Building “A” was 15cm lower than building “C”.
The minimum residual seismic capacity index “R” according to Japanese Guidelines for Damage Classification was 33.3% for the longitudinal direction of the 1st floor. The building was evaluated as “severely damaged” according to the index.

The school is on a small hill, and all four buildings suffered moderate or severe damages. The damage level is much higher than another school buildings located just at the foot of the hill. Further research such as pushover analysis is needed to investigate seismic capacity of the buildings. The JMA seismic intensity measured around the school was 5-.

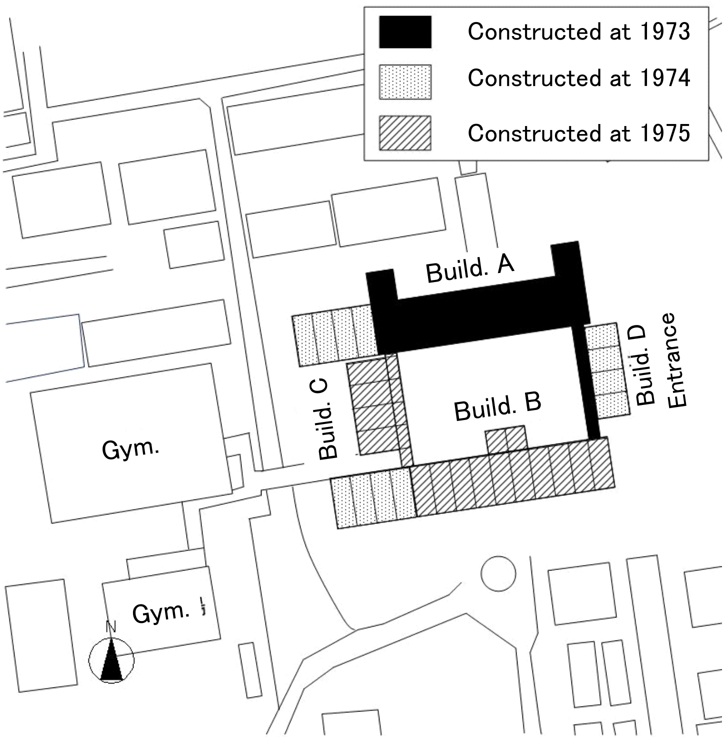


Fig. 1 Location of buildings

Fig. 2 Overview of Building “A”

Fig. 3 Shear failure of the first story column at north frame of Building “A”

Fig. 4 West side view of Building “A”

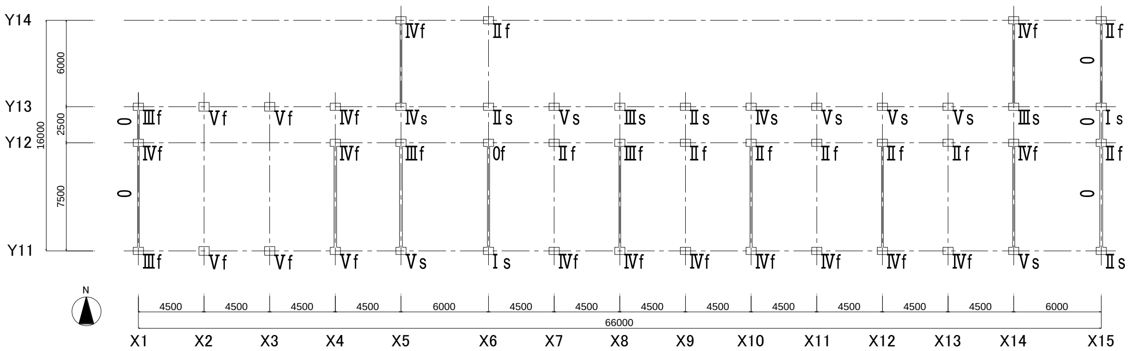


Fig. 5 Plan and damage grade of structural members of Building “A”

ANALYSIS OF THE BUILDING

Outline building model

This structure has columns, beams and shear walls as earthquake resistant elements. In longitudinal direction (X axis), the earthquake resistant structure is conformed by moment-resisting frames, while in transversal direction (Y axis), the earthquake resistant structure is conformed by a combination of shear walls and moment-resisting frames, shown in Fig.6 and Fig.7.

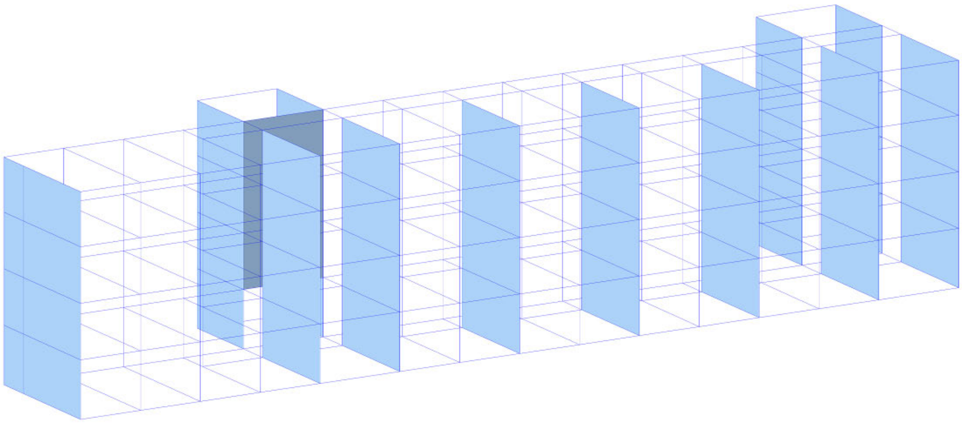


Fig. 6 Frame model of the Building A

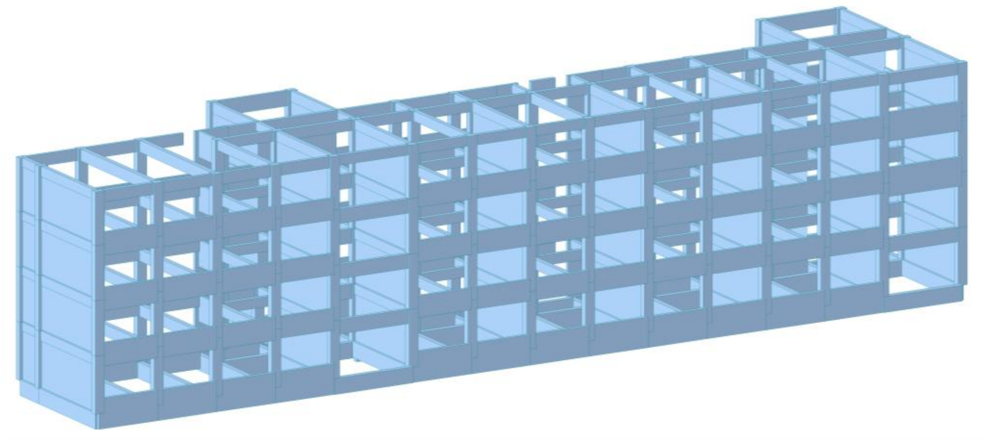


Fig. 7 Section model of the Building A

Elements of this structure are replaced by models, shown in Fig.8 and Fig. 9, and their plastic hinges are located at 1/4 of length from the end of each member. Each wall plane is connected by rigid beams, and the last to the adjacent floor, therefore it is considered as a rigid diaphragm. Bending moment and shear force are considered in frames and shear walls to provide the nonlinearity.

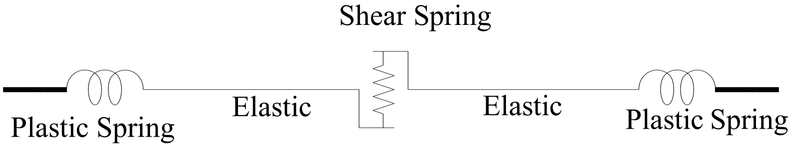


Fig. 8 Line model of the column and beam

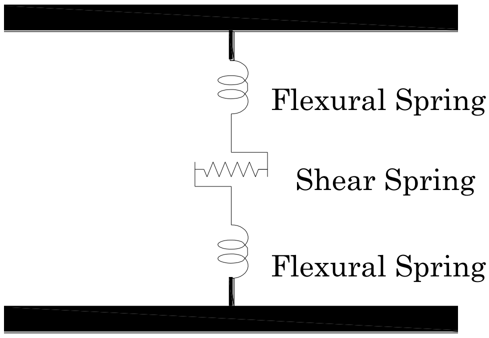
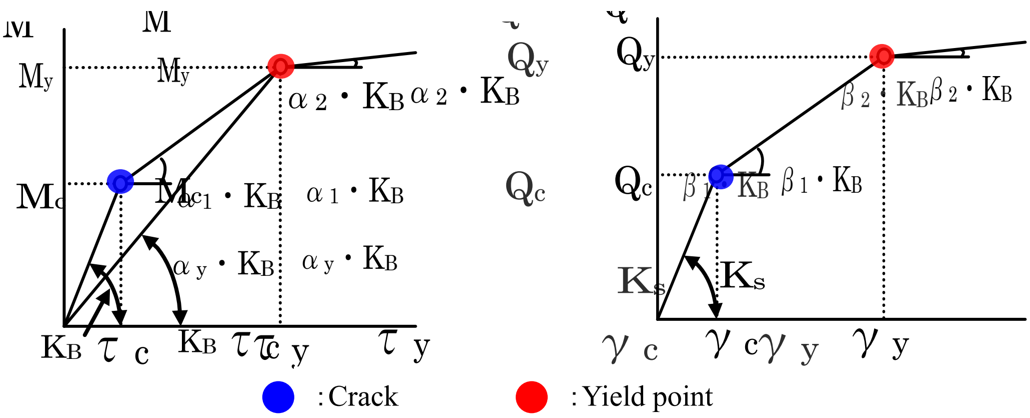


Fig. 9 Line model of the shear walls

The external force distribution to conduct the static analysis (pushover) has the triangular shape.

Restoring Force Characteristics
Trilinear model is assumed as the restoring force model for the flexural spring model and shear spring model, shown in Fig. 10.



Fi   : model

RESULTS (ATIC ANALYSIS

Fig. 15 shows the shear damage pattern in the Building A by observation after the Great East Japan Earthquake, which is described in Fig. 11.

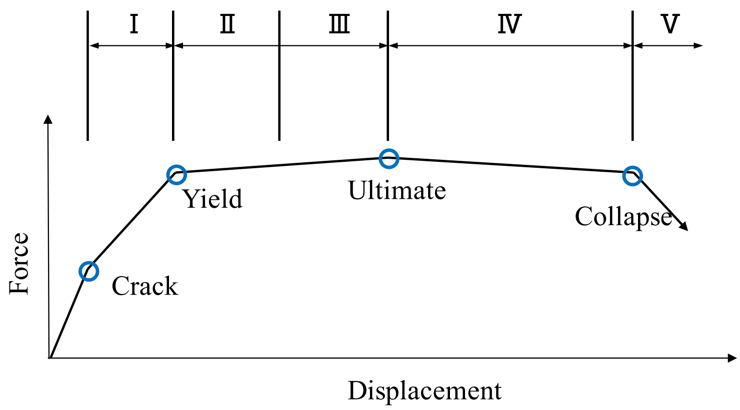


Fig. 11 Seismic performance level

The inverted triangular external force distribution along the building height conducts the nonlinear static analysis of the structure. The purpose of this study is to analyze the most affected structure (Building A) in the weakest direction (X axis). The shear force and relative story displacement of the Building A is show in Fig, 12.

Furthermore, damage state of the drift angle 1/50 is show in the Fig.14, the damage pattern in the Building A by mean of observation is shown in the figure.15, collapse mechanism of the Building A by the shear force is shown in Fig. 16.

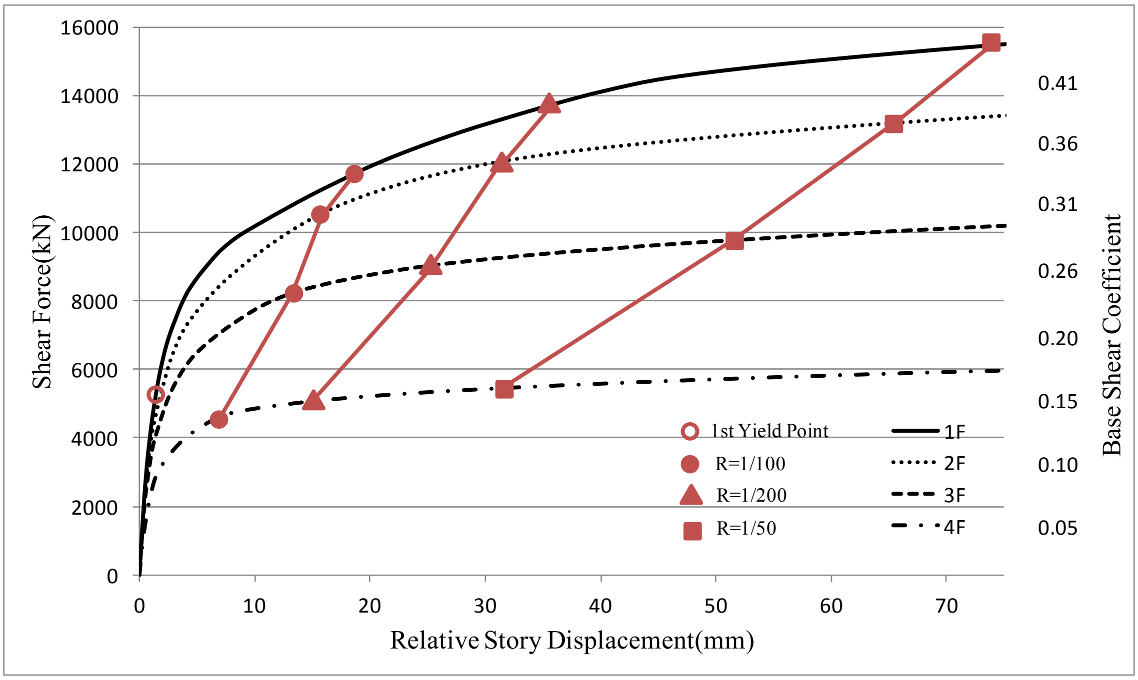


Fig. 12 Capacity curve of the Building A

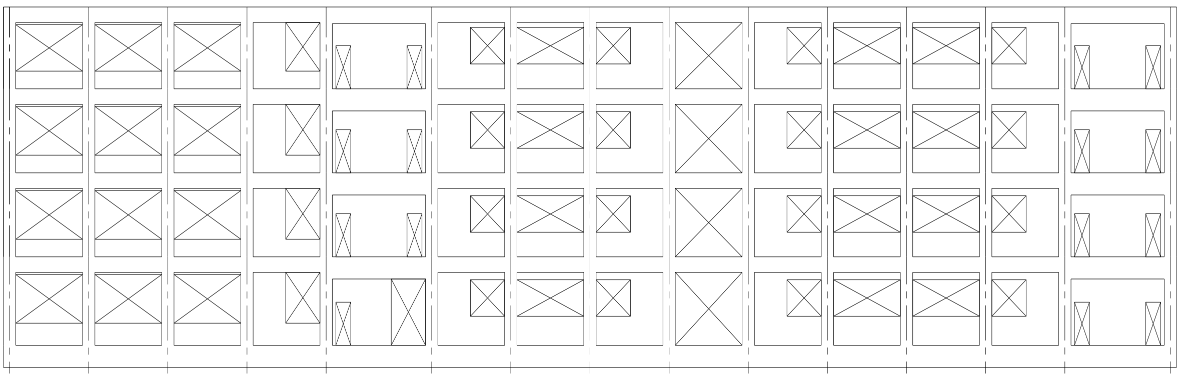


Fig. 13 Framing elevation of the Building A (Y13-Frame)

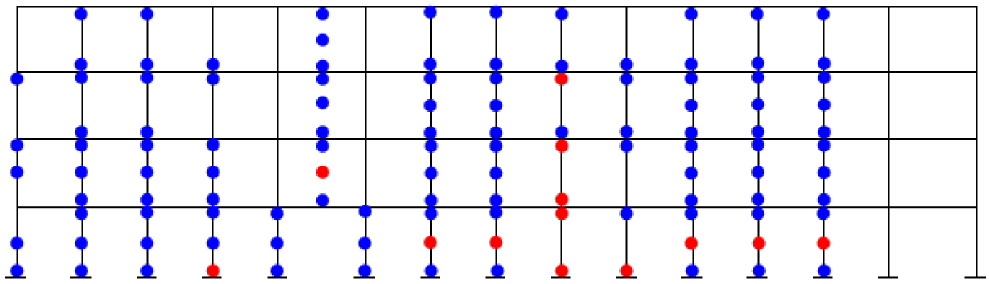


Fig. 14 Hinges pattern in the Building A by analysis (Y13-Frame; R_1=1/50)

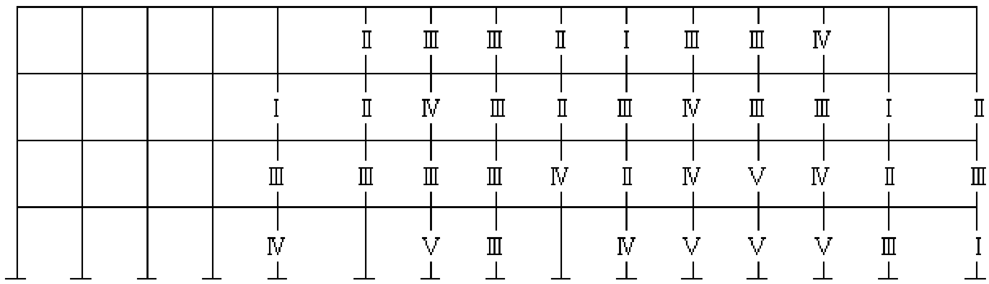


Fig. 15 Shear damage pattern in the building A by observation

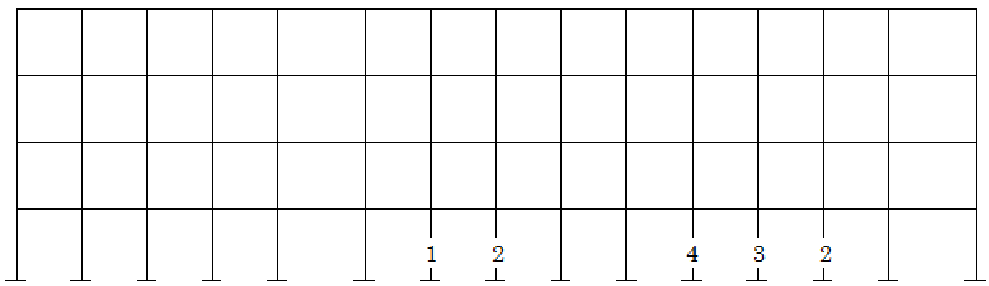


Fig. 16 Collapse mechanism in the Building A by shear force

CONCLUSIONS

This study conducted a nonlinear static analysis in an existing RC school building in Fukushima, which was damaged by the Great East Japan Earthquake.
Results show a slightly difference between collapse stage of structure (R=1/50) and the actual damages pattern obtain by observation.
Time-history analysis is needed in order to acutely study the dynamic behavior of this type of structures under strong ground motions.

REFERENCES

Technical Manual for Seismic Evaluation and Seismic Retrofit of Existing Reinforced Concrete Buildings, 2001. Translate by Building Research Institute, and published by The Japan Building Disaster Prevention Association.