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DYNAMIC ANALYSIS OF BASE ISOLATED STRUCTURE USING VARIOUS NUMERICAL MODELS

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SUMMARY

Because of the lack of actual data on the behavior of base isolated structures during severe earthquakes, as opposed to the wealth of data available for structures on the conventional foundation, it is necessary that the results of experiments, earthquake observations and analysis be comprehensively judged and effectively used in the seismic design of structures such as high-rise buildings. Also, it is necessary to consider the habitability of the buildings. In this paper, an examination is made of how complicated model should be depending on the purpose of analysis in order to obtain sufficiently accurate results.

INTRODUCTION

To fully understand the dynamic behavior of a building suffered an earthquake motion, the use of a three-dimensional analysis model is required. With a high-rise building having a height greater than a plan area, it may be treated as a one-dimensional multiple mass and spring model in the vertical direction.

When considering the dynamic behavior of a base-isolated building, the size of its plan, in many cases, is greater than the height, and since the foundation is not supported directly on the ground, it is necessary to consider a certain extent of the vertical independent displacement of the columns. For this reason, the response analysis by means of a three-dimensional model will be necessary.

BUILDING OUTLINE

The building analyzed here is fully equipped with all the facilities required in a conventional house with specifications to allow actual habitation. This building is located on Chiba prefecture closed to Tokyo district. Six isolators were inserted between the foundation and the superstructure. Since the building is a 2 stories house of reinforced concrete construction having a enough strong structure of columns, girders and shear walls, the superstructure itself is sufficiently aseismatic, even though it is constructed directly on the foundation without a base isolation system. Fig.1 and 2 shows the outline of the building.

BASE ISOLATION SYSTEM

The isolator used was 30 cm in diameter, 8.2 cm in height and was made of stainless steel and rubber, vulcanized under high temperature and pressure. The horizontal spring constant in the displacement range of between 100 and 150 mm was 0.533t/cm. The vertical spring constant was 380t/cm and the vertical to horizontal spring ratio was about 710. The precast concrete plates are used as a vibration damper. A damping effect is caused of friction force between the dry area shielding precast concrete plate and top of the side wall.

INPUT EARTHQUAKE MOTION

The earthquake motions were observed on the ground and recorded on two occasions. Earthquake A was observed on October 4, 1985, and its maximum acceleration was 102 cm/sec^2, while Earthquake B was observed on December 17, 1987, and its maximum acceleration was 131 cm/sec^2.

VARIOUS STRUCTURAL IDEALIZATIONS OF SUPERSTRUCTURE

In examination of the behavior of base-isolated buildings during an earthquake, the following four types of model are assumed:

(1) One Mass Model (Fig.3)
This is the simplest model with the superstructure assumed as a single mass.

(2) Multiple Mass Model (Fig.4)
This is a shear type model with the mass concentrated at each floor. In this model, each mass considers only a horizontal movement. Input earthquake motion is inputted in one direction.

(3) Multiple Mass considering two horizontal movements and Rotation of each Floor (Fig.5)
This is a model with the mass concentrated at each floor and with each column replaced with shear spring. In this model, each mass is provided with horizontal plane three degrees of freedom at x, y, and Θ_Z, and input earthquake motion is inputted simultaneously in two direction of x and y.

(4) 3-Dimensional Frame Model (Fig.6)
This is a model to catch a phenomenon as an actual superstructure. The superstructure is of three-dimensional frame. The floor slab is rigid in its horizontal plane. Each floor considers displacement of three components; x, y, and Θ_Z. In consideration of a high-dimensional mode due to vertical vibration , each mass at column position having inertial force against vertical vibration is provided.

VARIOUS STRUCTURAL IDEALIZATION OF BASE ISOLATION SYSTEM

a. Isolator: assumed as an elastic shear spring in every model. In Model (4), this isolator has an elastic spring in the vertical direction.

b. Damper: assumed as a elasto-plastic spring in Model(1) and (2). In Model(3) and (4), an MSS model considering the effects of two directional interaction is used (Fig.7)

RESULT OF DYNAMIC ANALYSIS

a. Comparison of Accelerations of observed and analyzed by Model(4)

Fig.8 and 9 show three-dimensional analysis and observed results, with regard to Earthquakes A and B, respectively. The graph indicates the analysis and observed results of the roof, proving that the analysis results can explain with the observed results.

b. Comparison of Analysis Results through Model(1) and (2)

Fig.10 shows the analysis results of Earthquake B through Model(1) and (2), arranged in a row. (1) is a one mass model while (2) is a three masses model, and although both results were nearly close, but Model(2) shows the effect of high-frequency.

c. Effect of Vertical Motion

Fig.11 compares Model(3) and (4). In Model(4), the vertical motion of each column is considered, but not in Model(3). This wave form is the Time axis enlarged, Model(4) could be one to which the effect of high-frequency on Model(3) is added.

d. Model(4) Response Results

Fig.12 compares the response results of the first floor, second floor and the roof obtained through the analysis of Model(4). Because high-dimensional mode is represented by the roof and the first floor witch vibrate with the second floor being the center node, the high-dimensional mode in the second floor is small.

RESPONSE SPECTRA

Fig.13 shows response spectra which was calculated from the acceleration wave of observation and analysis of the EW component of 1.FL. From the figure, it can be seen that the response of 1.FL in short period domain decreased as compared with the response of basement.

CONCLUSION

Since the seismological observation has not yet encountered a large scale earthquake, the evaluation of the observation data cannot necessarily be high. However, we consider that sufficiently effective data were obtained for the studies of the behavior of the base isolation system during medium to small scale earthquakes.

We were able to establish that the dynamic analysis is effective in the evaluation of the base isolation system and that the roles played by the simplified model and the elaborate model were well defined. Model(1) is optimal for the examination of the deformation while model(4) is required for the consideration of habitability.

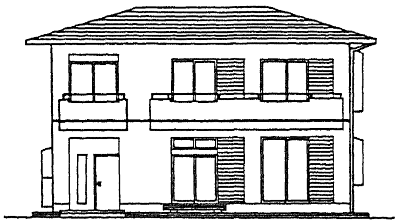

Fig.1 Elevation

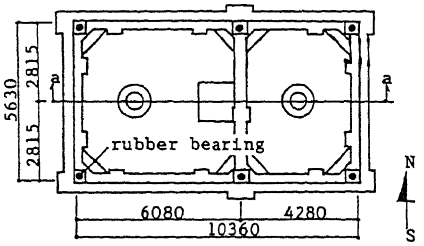

Fig.2 Foundation Plan

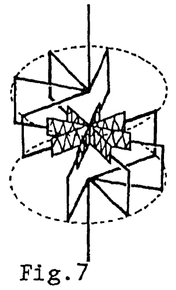

Fig.7 MSS model

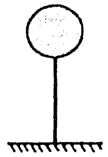

Fig.3 model ①

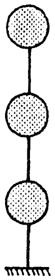

Fig.4 model ②

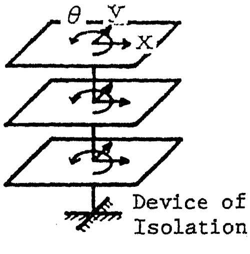

Fig.5 model ③

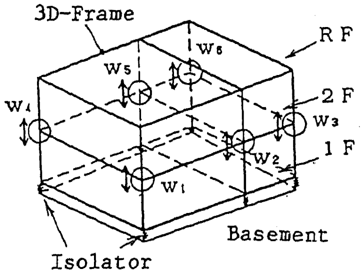

Fig.6 model ④

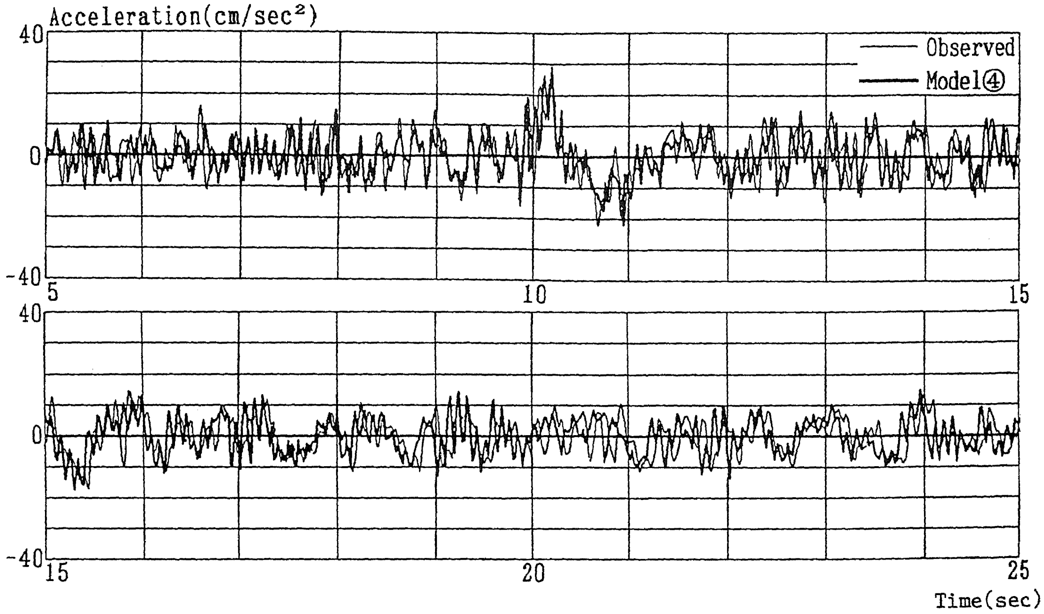

Fig.8 Observed & Calculated Acceleration at Roof(EW) due to Earthquake A

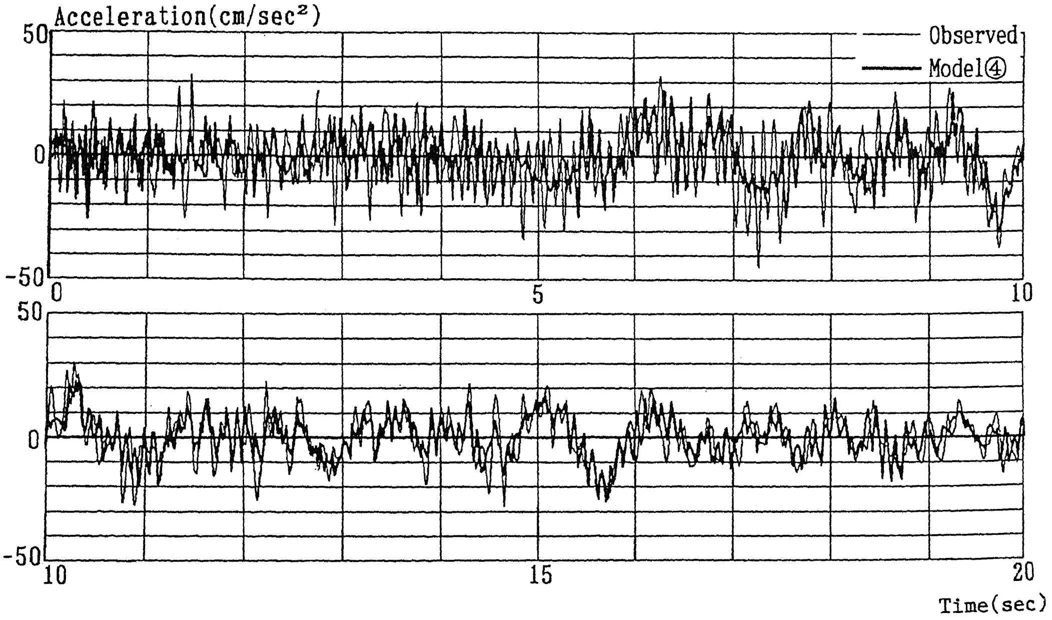

Fig.9 Observed & Calculated Acceleration at Roof(EW) due to Earthquake B

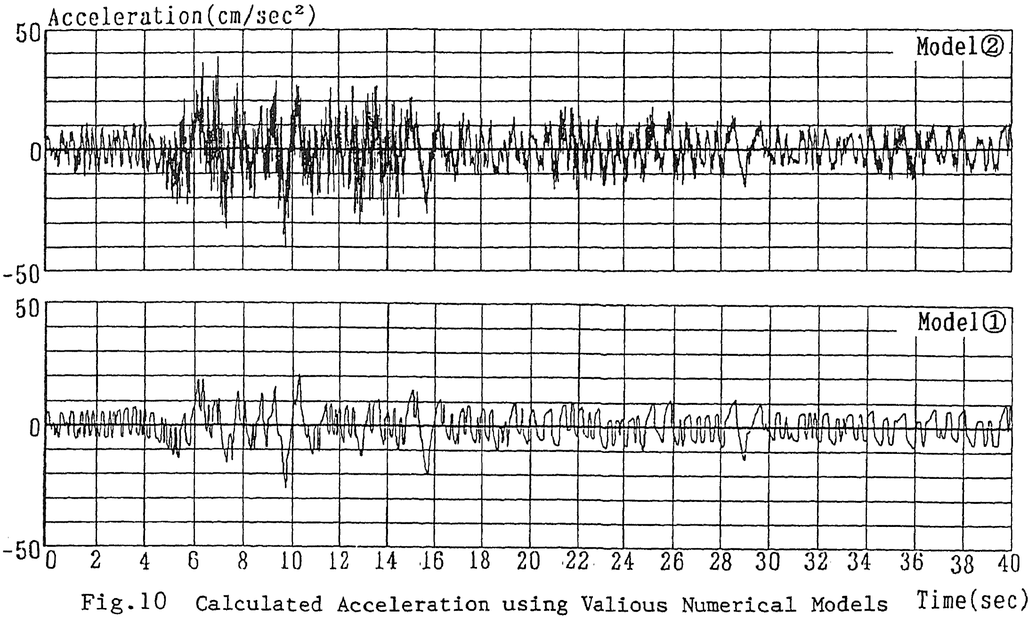

Fig.10 Calculated Acceleration using Valious Numerical Models at Roof(EW) due to Earthquake B

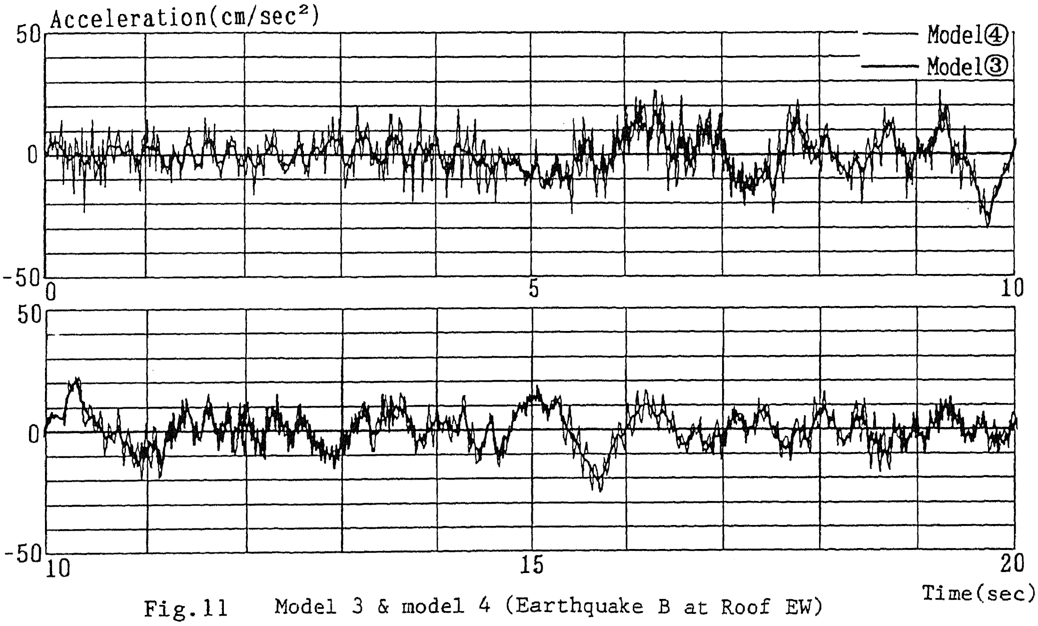

Fig.11 Model 3 & model 4 (Earthquake B at Roof EW)

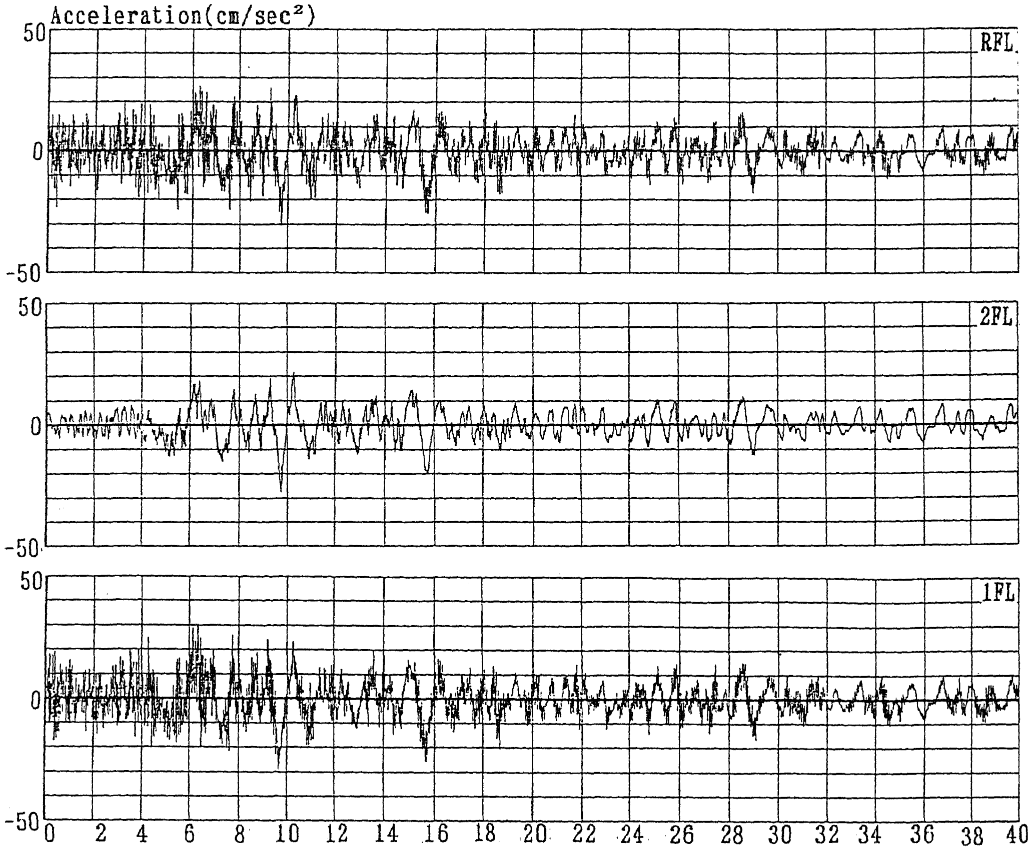

Fig.12 Calculated Acceleration of Each Floor using model 4 due to Earthquake B

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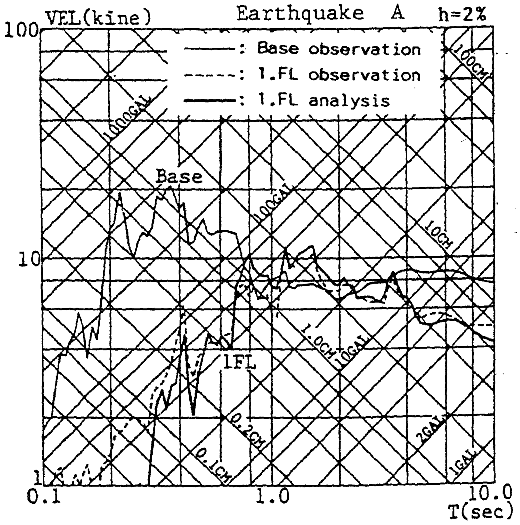

Fig.13 Response spectra