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A STUDY ON EARTHQUAKE RESISTANCE OF REACTOR BUILDINGS WITH HORIZONTALLY AND VERTICALLY IRREGULAR SHAPE

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ABSTRACT

So as to to determine the effect of a specific irregular shape on the earthquake resistance of a building, the behavior of the building under the earthquake loads in the elastoplastic range needs to be determined accurately. In consideration of these factors, a research plan was drawn up for the evaluation of the earthquake resistance of a reactor buildings that have horizontally and vertically irregular shapes.

INTRODUCTION

It has traditionally been a common practice to design reactor buildings so that they have regular and simple shapes in the horizontal plane. Most of the existing reactor buildings, therefore, are dynamically simple.

However, if equipment and piping systems are to be arranged reasonably and economically, it may be necessary to explore the possibilities of irregularly shaped buildings instead of regularly shaped ones.

In order to determine the effect of a specific irregular shape on the earthquake resistance of a building, the behavior of the building under earthquake loads in the elastoplastic range needs to be determined accurately. This necessitates the development of a reliable three-dimensional elastoplastic analysis program. Experimentation is necessary, too. Irregularity in the shape of a building could cause stress concentration in members of the building due to torsional vibration, thereby making design conditions extremely tight. Introduction of seismically isolated structure provides a possible solution to this problem. In consideration of these factors, a research plan was drawn up for the evaluation of the earthquake resistance of reactor buildings that have horizontally and vertically irregular shapes.

Further, This study aims to determine proper input levels, ground motion characteristics in the long period range, and earthquake motion as three-dimensional movement, including the vertical movement of seismic isolation systems, for reactor buildings. Vibration characteristics of reactor buildings that have horizontally and vertically irregular shapes are also to be considered using the earthquake motion determined.

Research Plan

The research plan outlines the experiment on and the analysis of the behavior of reactor buildings that have horizontally and vertically irregular shapes, and the evaluation of the earthquake resistance of those buildings. The plan also deals with the behavior of seismically isolated buildings.

The content of the plan is as follows:

1 Earthquake Motion Used in Analysis/Experiment
   a) Three-Dimensional Earthquake Motion
   b) Generation of Artificial Earthquake Motion

2 Three-Dimensional Elastoplastic Response Analysis
   a) Preceding analysis programs
   b) Development of a reliable analysis program
   c) Response analysis of irregularly shaped buildings

3 Experiment
   a) Experiment using a vibrating table
   b) Experiment on seismically isolated buildings
   c) Static loading test for members

A flowchart for the planned research is shown in Fig.1.

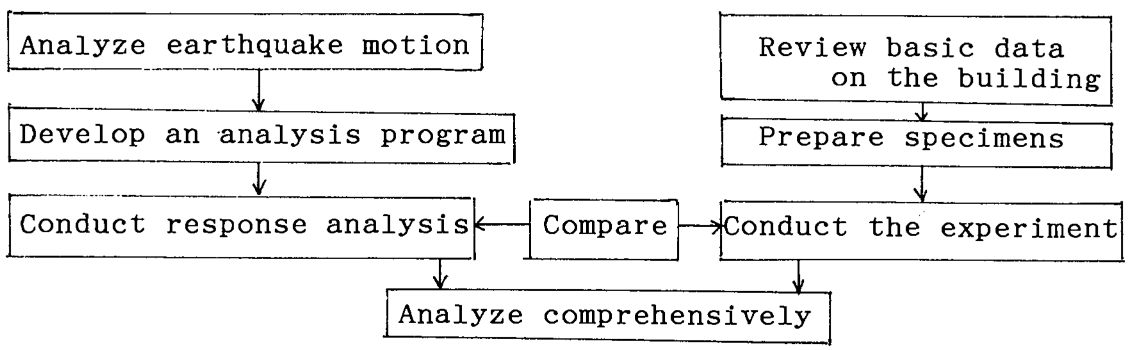


Fig.1 A flowchart for the planned research

Defining Input Earthquake Motion

Evaluation of expected values by the stochastic method, as well as seismotectonic data and data on the magnitude of the maximum probable earthquake as shown in Fig.2, indicate that earthquakes that occur in Japan will never exceed 8.75 on the Richter scale. According to previous studies of the response spectrum level which is shown in Fig.3, values of the velocity response spectrum in the constant velocity range for body waves propagating through media equivalent to hard ground range from 31 cm/s to 87 cm/s. Examination of three-dimensional earthquake motions including vertical movement indicated that the vertical-to-horizontal spectrum ratio averages about 0.5 as shown in Fig.4. From these results, a target spectrum of S2 earthquake motion corresponding to certain earthquakes was assumed, and an artificial earthquake motion simulating the S2 earthquake motion was defined. The phase of seismic motion is used La Union 1985 Mexico.The target spectrum of S2 earthquake and the artificial earthquake acceleration is described in Fig.5 and Fig.6, respectively.

Earthquake Response Analysis Considering Geometric Irregularity

Analytical Model

An earthquake response analysis of a seismically isolated reactor building that has horizontally and vertically irregular shapes was conducted using the earthquake motion defined in the preceding chapter in order to investigate the effect of a seismic isolation system on the vibration characteristics. The analysis was conducted for two cases: eccentricity due to weight and eccentricity due to stiffness. The case of eccentricity due to weight was used two story analytical model and the eccentricity due to stiffness was used three story analytical model. The analytical models are shown in Fig.7. Table 1 summarizes the properties used in the analytical models. The following three parameters are taken into consideraton in this study. These parameters are taken to be close correlated with the earthquake response.

1.Eccentricity due to weight : 0, 0.15, 0.3
 (Center of Weight/Center of stiff. in case of 2-story model)
2.Eccentricity due to stiffness : 0.25, 0.41, 0.56
 (Location of a wall in case of 3-story model)
3.Isolated system : withut or with

Table 1(a) Properties of the analytical moel(Column and wall)

Member	Dimension	Shear-Area (cm)	Area-Moment of Intia	1st-Yield Point(t cm)	2nd-Yield Point(t cm)
Column	3	9025	6.79x10	4.67x10	2.29x10
Wall (t=15cm)	2	22625	7.71x10	1.93x10	--
Wall (t=30cm)	2	27200	8.07x10	2.29x10	--

Table 1(b) Properties of the analytical moel(Isolate system)

Dimension	1st-stiffness	2nd-stiffness	1st-Yield Point
3	2.39 t/cm	0.15 t/cm	47.52 t cm

Results of the earthquake response analysis

When there is no eccentricity and the stiffness distribution factor for the upper structure is 0.53-1.22 as shown in Fig.8 , the seismic isolation system reduces seismic force acting on the upper structure and dramatically reduces relative story displacement.

When the eccentricity of each story in the upper structure is 0.07-0.56 and the stiffness distribution factor is 0.48-1.36 as shown in Fig.9, responses in the input direction show a tendency similar to one shown by the concentric model.

Conclusion

Results of the earthquake response analysiscan be summarized as follows.

Deformation perpendicular to the input direction observed in the model without the seismic isolation system can be reduced to almost none by correcting the eccentricity of the seismically isolated story.

Referrence

1)Yamanouchi, H et al. 1992,"Earthquqke resistance of reactor building with horizontally and vertically irregular shape" Trans. of Archi. Inst. Japan(in Japanese)

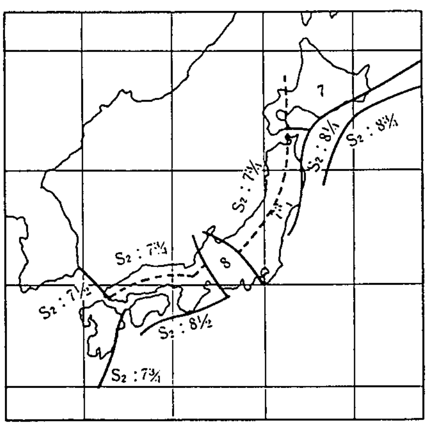


Fig. 2 The magnitude of tne maximum probable earthquake in Japan

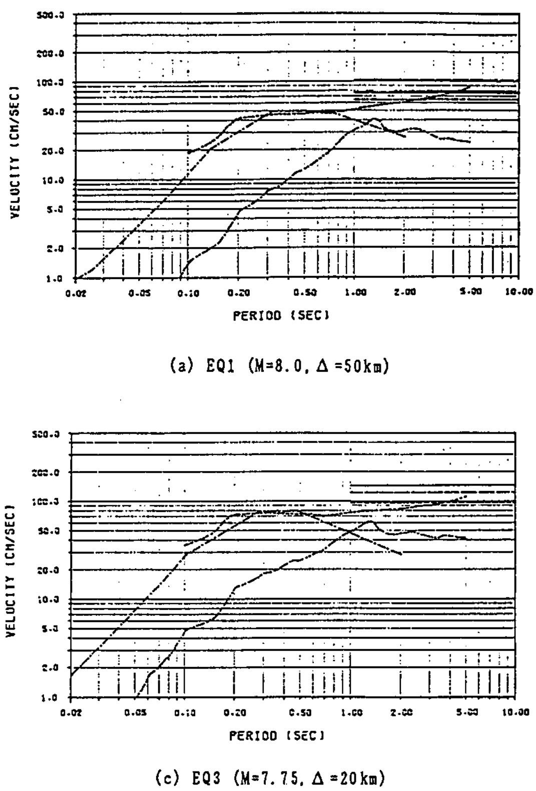


Fig. 3 Response spectrum level by previous stdies

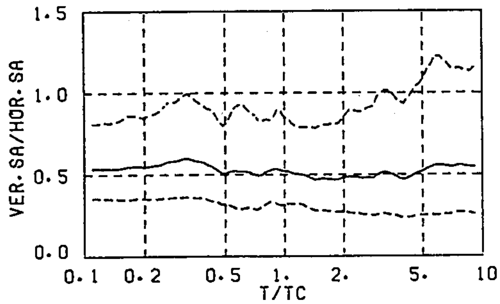


Fig. 4 The vertical-to-horizontal spectrum ratio

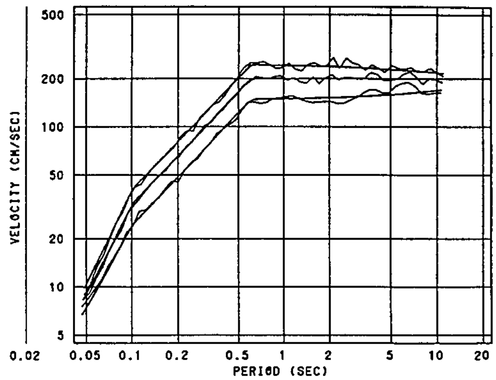


Fig. 5 The target spectrum of S2 earthquake

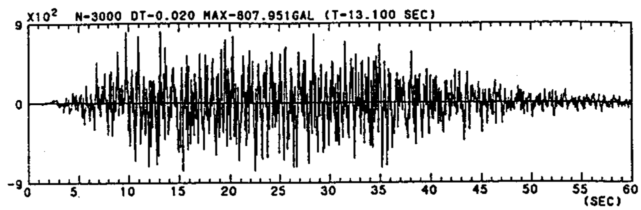


Fig. 6 The artificial earthquake acceleration

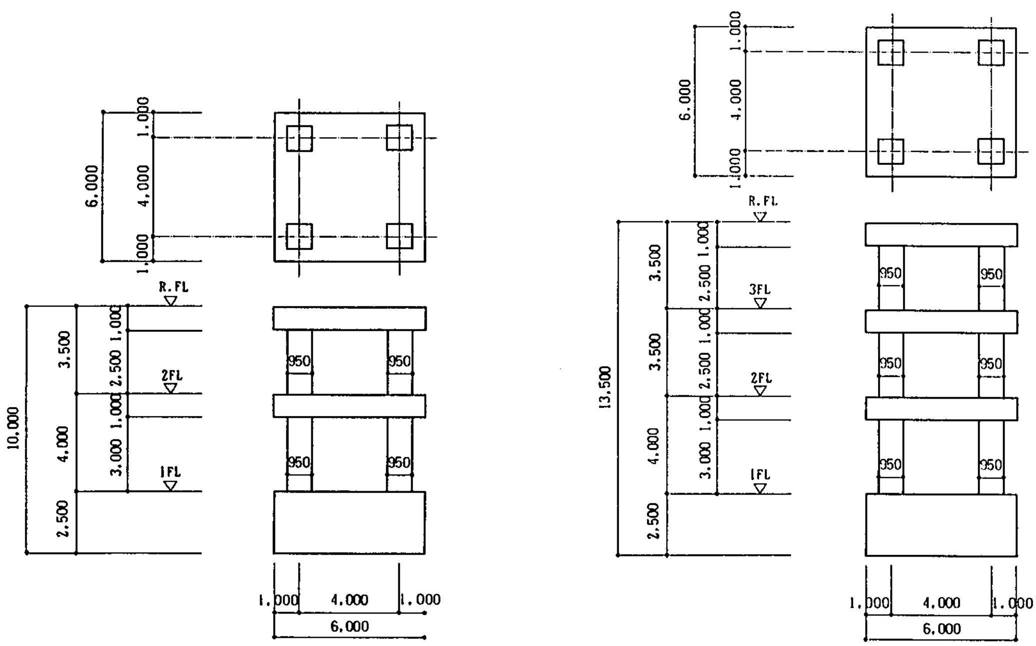


Fig. 7 The analytical model

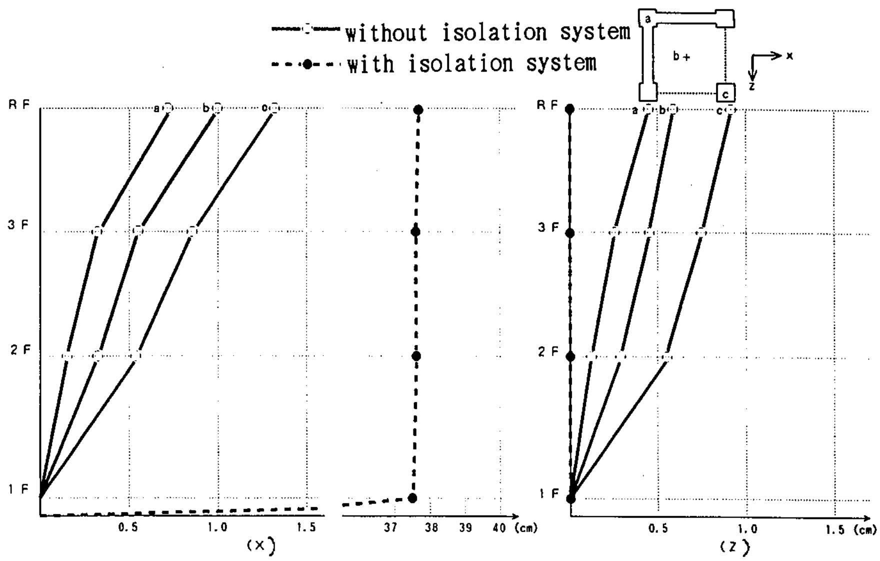
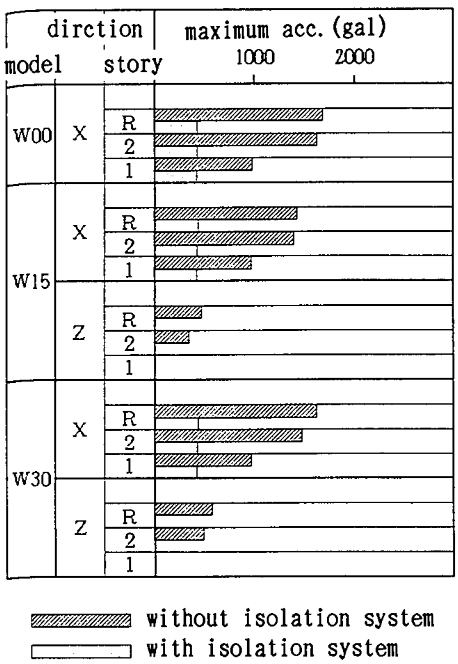


Fig. 8 The distribution of maximum displacement response of the 3-story model



W00 : R=0.0 W15 : R=0.15 W30 : R=0.30

** R ; (Center of weight)/(Center of steffness) **

X : Direction of earthquake acceleration

Z : Right-angle direction of earthquake acc.

Fig. 9 The maximum displacement response of the 2-story model