An Experimental Study on Responses of Base Isolated Shell Structure

TARO NIKI*
KIYOSHI SHINGU**
TAKAYUKI KAWASHIMA***

* Department of Computer Science, Nihon University
7-24-1,Narashinodai,Funabashi-shi,Chiba 274-8501, JAPAN
TEL&FAX +81-474-69-5426
E-mail niki@shinguu2.cs.cst.nihon-u.ac.jp

** Department of Oceanic Architecture & Engineering
Department of Computer Science, Nihon University
7-24-1,Narashinodai,Funabashi-shi,Chiba 274-8501, JAPAN
TEL&FAX +81-474-69-5426
E-mail kshingu@shinguu2.cs.cst.nihon-u.ac.jp

*** Department of Aerospace Engineering, Nihon University
7-24-1,Narashinodai,Funabashi-shi,Chiba 274-8501, JAPAN
TEL +81-474-69-5412
FAX +81-474-67-9569

Abstract

Damage of structures by Hyogoken-nanbu earthquake were extremely huge. Recently, research of base isolated structures are developing successfully. However they are mainly about rigid-connection frame structures. A study of vibration control on a shell structure has performed using fuzzy theory by Shingu et al. at first. Furthermore, a shell structure which has springs and dampers between the shell and the ground, was carried out. The system is called a base isolated shell structure. It has been suggested by Shingu that a base isolated shell structure is useful for vertical seismic forces by use of computer simulation. In this study, the usefulness of a base isolated shell structure was established. Two types of shell models made of silicon rubber were vibrated. One model (base isolated shell structure) is supported by springs on a thick plate and the other (non-isolated shell structure) is hinged on the plate. The results of the experiment show that strains and accelerations on the base isolated shell structure are very small in comparison to those of the non-isolated shell structure.

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1. Introduction

Damage of structures by Hyogoken-nanbu earthquake (Jan. 17, 1995) was extremely huge. Recently, research on base isolated structures is However they are mainly about rigid-connection frame structures. A study of vibration control on a shell structure was performed using fuzzy theory by Shingu et al[1]. Furthermore, a shell structure which has springs and dampers between the shell and the ground was carried out by Shingu et al. The system is called a base isolated shell structure[2), 3)]. It was established that the responses of strains and stresses were extremely reduced by computer simulation[2), 3), 4)].

2. Purpose

One of the authors has suggested that a base isolated shell structure is able to reduce strains and accelerations by use of computer simulation. The purpose of this study is to show that the base isolated shell structure is able to reduce strains and accelerations markedly. For this purpose, small shell models were vibrated, and responses in the base isolated shell were compared with those in the non-isolated shell.

3. Experimental method and experimental device

The shell models are made of silicon rubber. The base isolated shell is supported by springs on a thick plate and the non-isolated shell is hinged on the plate. Strain gauges and accelerometers are pasted up on the shells (Fig.1, Fig.2). The two types of shells are vibrated sinusoidally in the vertical direction by a vibrator, then the input acceleration is 0.2G. Because shallow rotational shell structures are subjected to greater influence in the case of the vertical than horizontal earthquake motion[5)], we examined the vertical motion. Strains in the meridional direction and accelerations are measured with frequencies ranging from 10 to 200Hz at 10Hz intervals. In this model, a damper is not equipped to the shells.

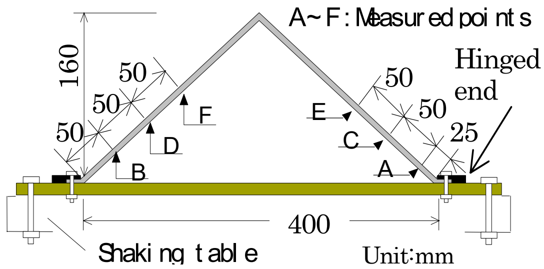


Fig. 1 non-isolated shell

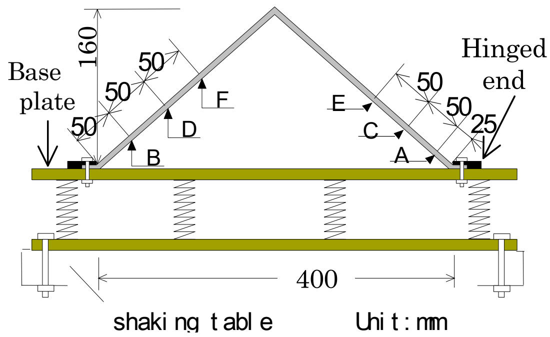


Fig. 2 Base isolated shell

The material and geometrical properties are as follows:

Shell:

Span: 0.4m, Rise: 0.16m
Thickness: 0.058m, Mass: 1.606kg,
Mass density: 1629kg/m^3
Young's modulus: 68.04MN/m^2
Poisson's ratio: 0.6458

Springs:

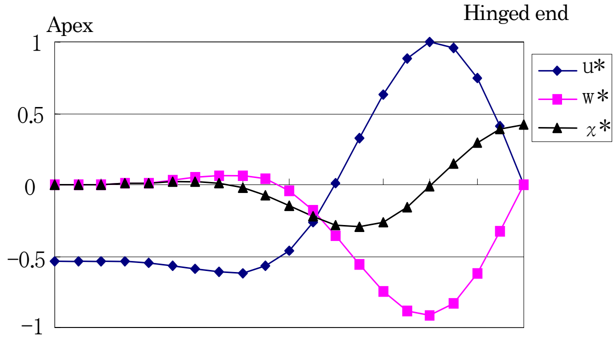
Total springs coefficient: 5.347KN/m
Total mass of shell including springs and base plate: 5.411kg
Natural frequency as one-degree-of-freedom system: 5.04Hz

Base plate:

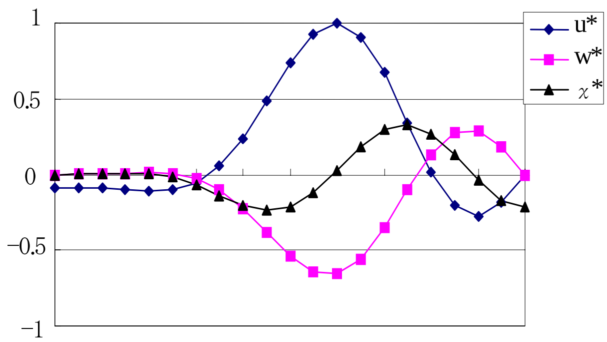
Mass: 3.805 kg

Natural frequency of base plate: 771Hz (Experiment)

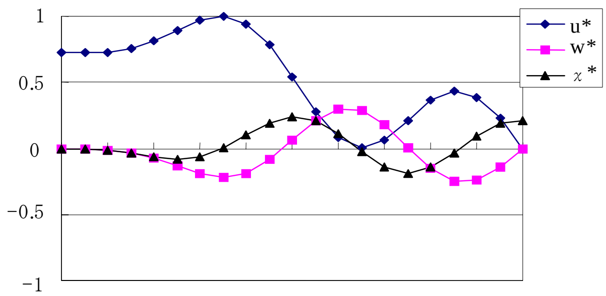
Some of the natural vibration modes and the corresponding natural frequencies of the non-isolated shell are shown in Fig.3 and Table1. u*, w*, and χ* in Fig.3 are the vertical and horizontal displacements, and the angle of rotation, respectively.



(a) First



(b) Second



(c) Third

Fig.3 Natural vibration modes

Table1 Natural frequencies (Analysis)

Order	Frequency (Hz)
1st	153.7
2nd	203.3
3rd	253.6

Some of the experimental equipments are shown in Photo1 and Photo2.

Photo1 Vibration generator

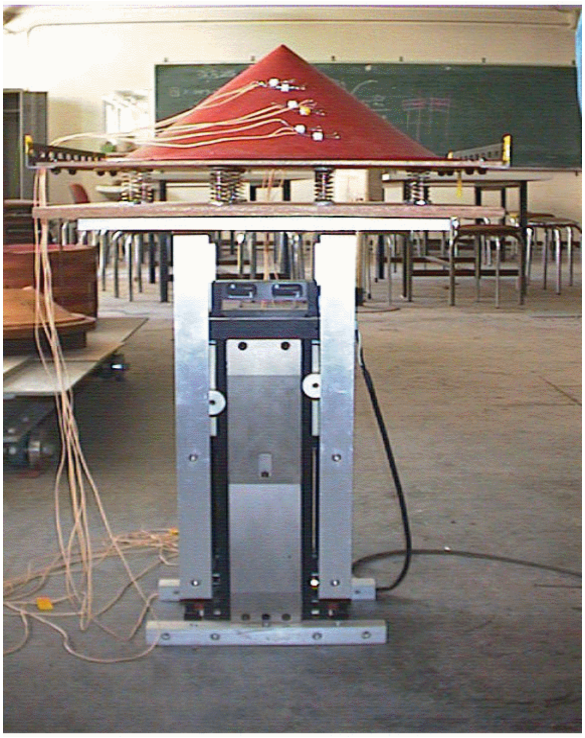


Photo2 Vibrator and shell

Axial and bending strains ε_n, ε_b obtained from measured strains in the shell are as follows.

$$\left.\begin{aligned} \varepsilon &= \varepsilon_n + \varepsilon_b \\ \varepsilon' &= \varepsilon_n - \varepsilon_b \end{aligned}\right\} \qquad (1)$$

Where ε and ε' are strains of the face and back of the shell.

As it turned out.

$$\left.\begin{aligned} \varepsilon_n &= (\varepsilon + \varepsilon')/2 \\ \varepsilon_b &= (\varepsilon - \varepsilon')/2 \end{aligned}\right\} \qquad (2)$$

4. Results

The experimental results are shown in Figs.4-11. Figs.4-9 show maximum absolute strains in the meridional directions on the face, maximum absolute axial strains, and maximum absolute bending strain in the non-isolated and base isolated shell at the points of A, B, C, D, E, and F, respectively.

We see from Fig.4 and Fig.5 that the strains in the non-isolated shell are very large, in contrast, those in the base isolated shell are very small. Additionally, the maximum strain in the non-isolated shell occurs when the input frequency is at 100Hz. Fig.6 and Fig.7 show that the maximum absolute axial strains in the base isolated shell are much smaller than those in the non-isolated shell. Furthermore, we see from Fig .8 and Fig.9 that the maximum absolute bending strains in the base isolated shell are lower than those in the non-isolated shell.

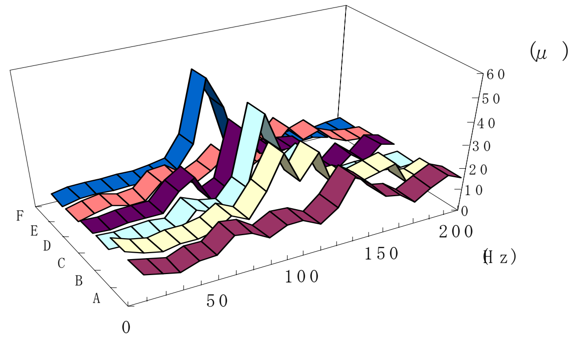


Fig.4 Maximum absolute meridional strains on the Face (Non-isolated shell)

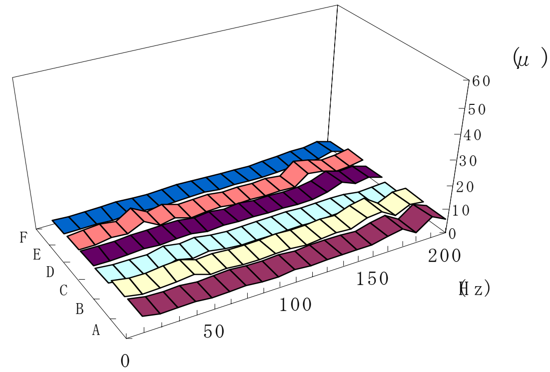


Fig.5 Maximum absolute meridional

strains on the Face (Base isolated shell)

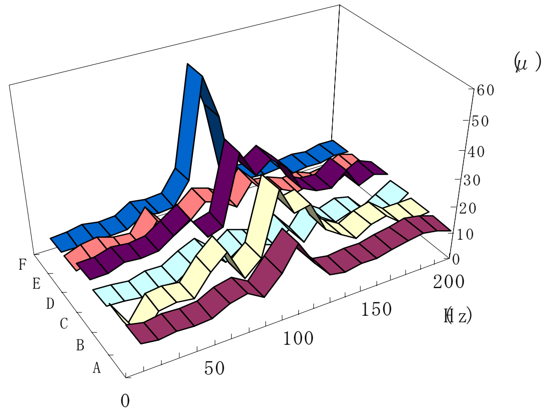


Fig.6 Maximum absolute axial strains (Non-isolated shell)

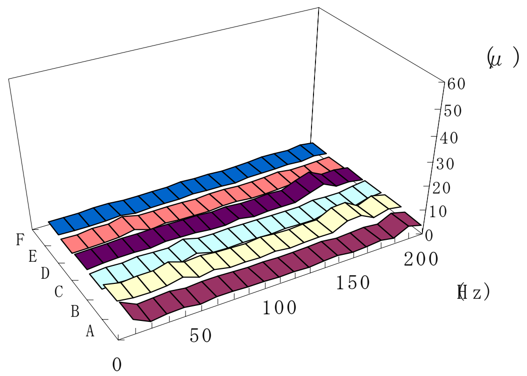


Fig.7 Maximum absolute axial strains (Base isolated shell)

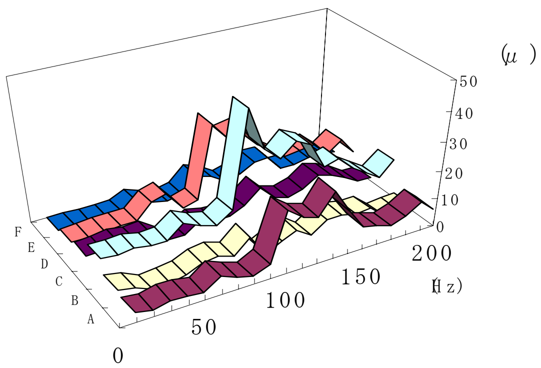


Fig.8 Maximum absolute bending strains (Non-isolated shell)

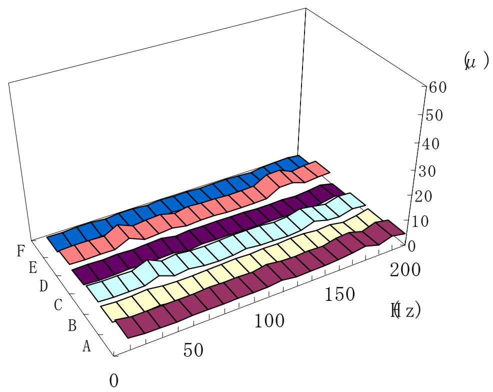


Fig.9 Maximum absolute bending strains (Base isolated shell)

We see from Fig.10, which shows acceleration response magnifications at points A, C, and E, that the acceleration response magnifications on the base isolated shell are a lot smaller than those on the non-isolated shell. Fig.11 shows acceleration response magnifications at 4 - 5Hz which include natural frequency of the base isolated shell. Acceleration response magnifications of the base isolated shell are much the same as the non-isolated one. But those are smaller than maximum values of the non-isolated shell at 10 - 200Hz.

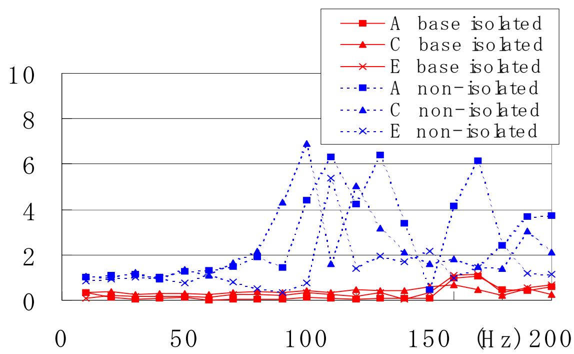


Fig.10 Acceleration response magnifications at A,C and E (10-200Hz)

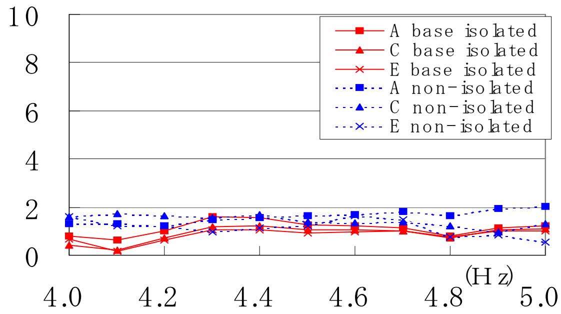


Fig. 11 Acceleration response magnifications at A,C and E (4-5Hz)

5. Conclusions

It was experimentally proved that, as suggested previously, the base isolated shell is able to reduce strain and acceleration responses markedly in comparison to the non-isolated shell, so it is useful for vertical seismic forces.

Hereafter we are going to perform additional experiments using a base isolated shell model with springs and dampers, then strains, accelerations, and displacements will be measured.

References

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