EXPERIMENTAL STUDY ON BASE ISOLATED SHELL

Taro NIKI[1] And Kiyoshi SHINGU[2]

SUMMARY

It has been suggested by Shingu that a base isolated shell structure is effective for vertical seismic forces by use of computer simulation. In the series of research, the validity of a base isolated shell structure has been established. Two types of shell models made of silicon rubber were vibrated in the vertical and horizontal directions, respectively. The base isolated shell model is supported by springs on a thick plate and the non-isolated shell is hinged on the plate. The results of the experiments show that strains in the base isolated shell are very small in comparison to those of the non-isolated shell.

INTRODUCTION

Damage of structures by Hyogoken-nanbu earthquake was extremely huge. Recently, research on base isolated structures is developing successfully. However they are mainly about rigid-connected frame structures. A study of vibration control of a shell structure was performed using fuzzy theory [Shingu, Kawanishi and Harumoto, 1990]. 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” or “a base isolated shell” [Shingu, 1993, Shingu and Fukushima, 1994]. It was established by computer simulation that the responses of strains and stresses were extremely reduced [Shingu, 1993, Shingu and Fukushima, 1994, Shingu, Fukushima and Niki, 1996].Furthermore, it was carried out that a base isolated shell is able to reduce strains and accelerations by experiments when shell is vibrated in vertical direction[Niki and Shingu, 1998].

PURPOSE

Shingu 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. In order to demonstrate the validity of the analytical results of a base isolated shell, small conical shell models were vibrated in the vertical and horizontal directions, respectively. Responses of the base isolated shell were compared with those of the non-isolated shell.

EXPERIMENTAL METHOD AND EXPERIMENTAL DEVICE

The conical 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 acceleration censors are pasted up at six locations on the shells (Fig.1, Fig.2). The two types of shells are vibrated sinusoidally in the vertical and horizontal direction by a vibrator (Photo 1, Photo 2), then the input maximum acceleration are 0.2G(vertical) and 0.4G(horizontal). Strains in the meridional direction and accelerations in the vertical/ vertical and horizontal direction(s) are measured with frequencies ranging from 10 to 200Hz at 10Hz intervals. In this model, a damper is not equipped to the shells.

[1] *Shingu Laboratory, Graduate School, Nihon Univ., Funabashi 274-8501, Japan, niki@shinguu2.cs.cst.nihon-u.ac.jp*

[2] *Dept. of Oceanic Architecture and Engineering, Nihon Univ., Funabashi 274-8501, Japan, kshingu@shinguu2.cs.cst.nihon-u.a*

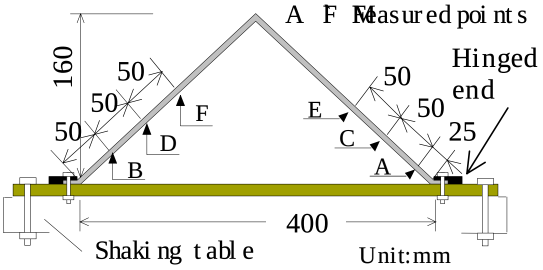


Fig. 1 Non-isolated shell

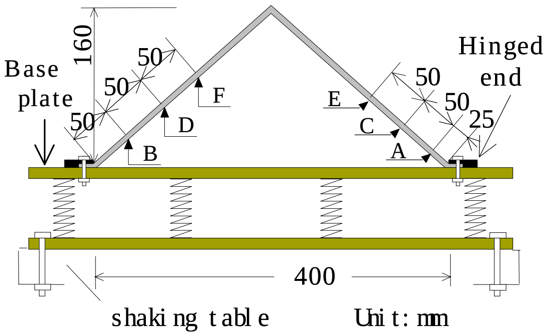


Fig. 2 Base isolated shell

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: 0.428
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)

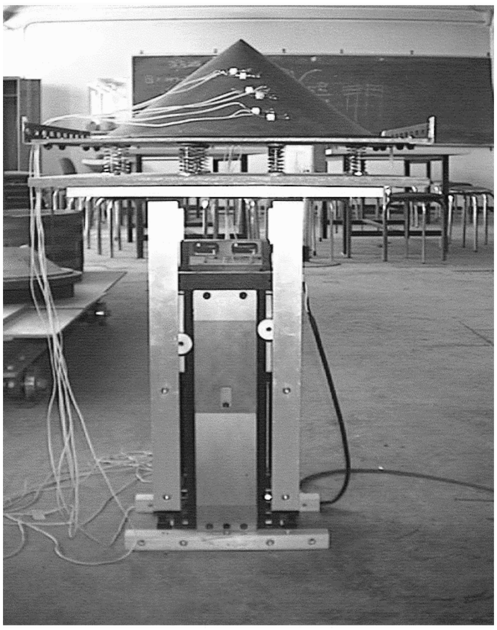


Photo1 Vibrator and conical shell model (Vibrated vertically)

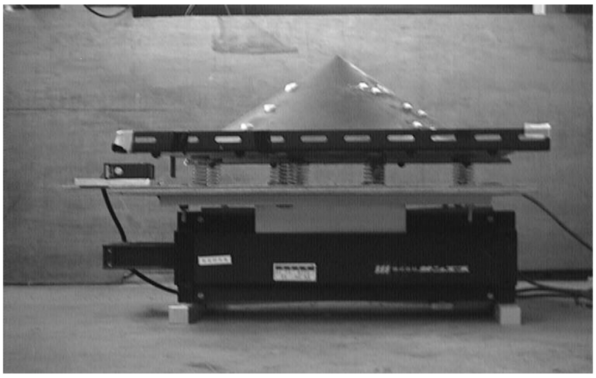
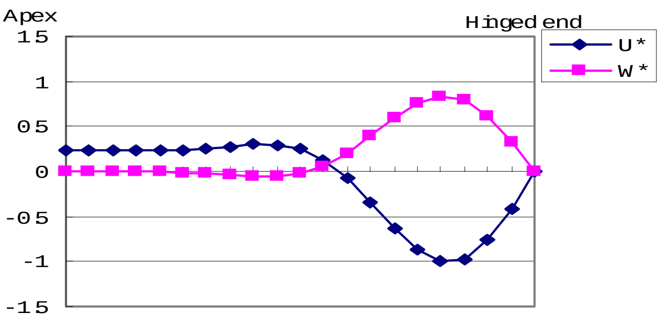


Photo2 Vibrator and conical shell model (Vibrated horizontally)

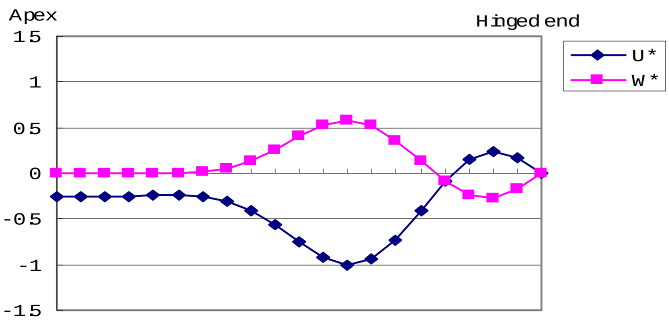
Some of the natural frequencies and the corresponding natural vibration modes of the non-isolated shell are shown in Table1 and Fig.3. Displacement components u* and w* in Fig.3 are vertical and horizontal one's, respectively.

Table 1 Natural frequencies (Analysis)

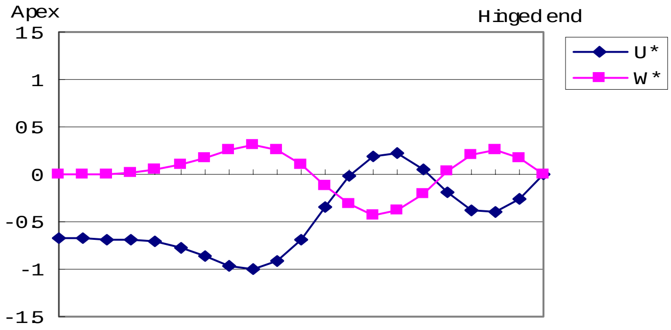
Order	Frequency (Hz)
1st	141.6
2nd	175.0
3rd	210.7



(a) First



(b) Second



(c) Third

Fig.3 Natural vibration modes

Axial and bending strains ε_n ,ε_b obtained from measured strains on 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 outer and inner surface of the shell.

As it turned out.

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

EXPEIMENTAL RESULTS

The experimental results are shown in Figs.4-10. Figs.4-6 show maximum absolute strains in the meridional direction on the outer surface of the shell, maximum absolute axial strains, and maximum absolute bending strains in the non-isolated and base isolated shell at the locations of A, C, and E when the shell is vibrated in the vertical direction, respectively.Fig.7 shows maximum absolute meridional strains when the shell is vibrated in the horizontal direction.

Fig.4 shows that the strains in the non-isolated shell are very large, in contrast, those in the base isolated shell are decreased 90% for the former. Additionally, the maximum strain in the non-isolated shell occurs when the input frequency is at 100Hz. The maximum absolute axial strains in the base isolated shell are much smaller than those in the non-isolated shell as shown in Fig.5. Furthermore, we see from Fig .6 that the maximum absolute bending strains in the base isolated shell are much smaller than those in the non-isolated shell.

Fig.7 shows that the strains in the non-isolated shell are very large, in contrast, those in the base isolated shell are decreased 75% for the former. Additionally, the maximum strain in the non-isolated shell occurs when the input frequency is at 40Hz.

Therefore, we examined that the base isolated shell is able to reduce strains when the shell vibrated vertical and horizontal directions.

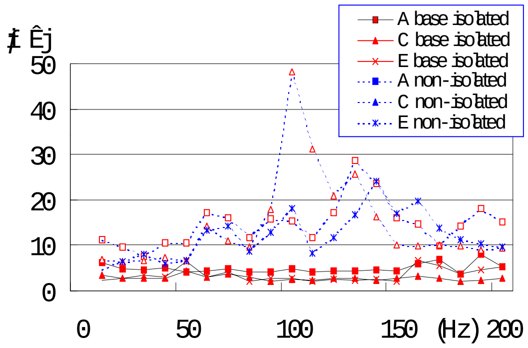


Fig.4 Maximum absolute meridional strains on the outer surface at A,C and E (Vibrated vertically)

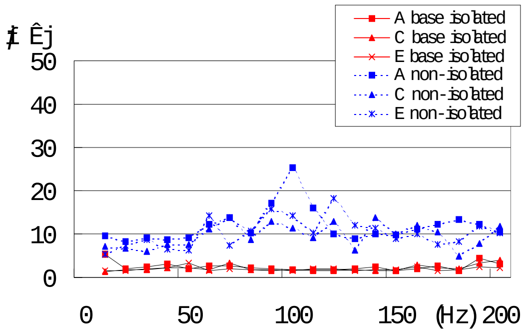


Fig.5 Maximum absolute axial strains at A,C and E (Vibrated vertically)

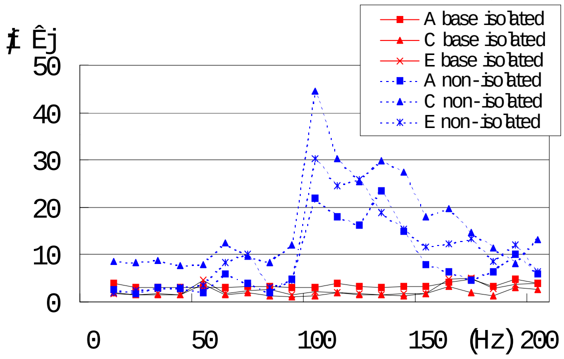


Fig.6 Maximum absolute bending strains at A,C and E (Vibrated vertically)

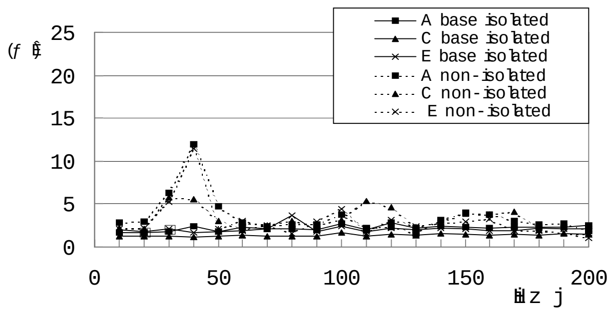


Fig.7 Maximum absolute meridional strains on the outer surface

at A,C and E (Vibrated horizontally)

Fig.8-10 show acceleration response magnifications. Fig.8 shows acceleration response magnifications when the shell is vibrated in vertical direction, and Figs.9 and 10 show those when the shell is vibrated in the horizontal direction. We see from Fig.8, which shows acceleration response magnifications at the locations of A, C, and E, that the acceleration response magnifications on the base isolated shell are much smaller than those on the non-isolated shell. Furthermore, we see from Fig .9 and Fig.10 that the maximum acceleration response magnifications on the base isolated shell are smaller than those on the non-isolated shell.

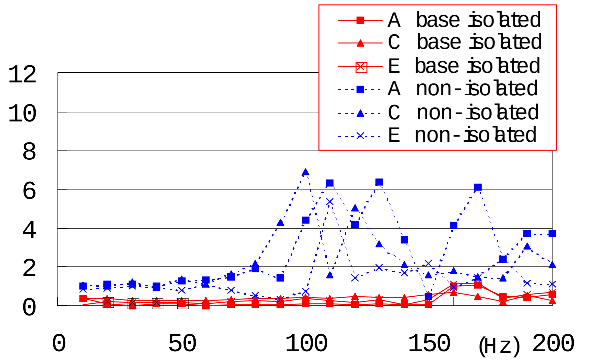


Fig.8 Maximum acceleration response magnifications at A,C and E (Vibrated vertically)

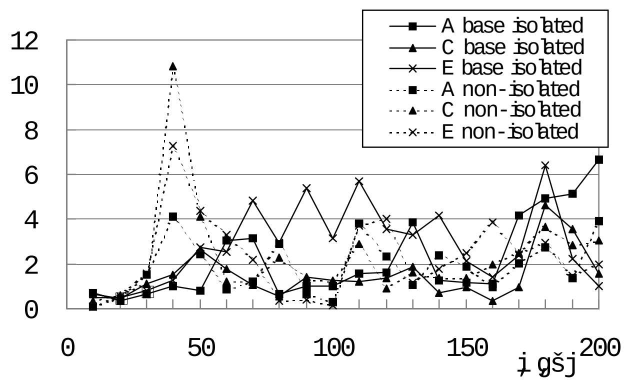


Fig.9 Maximum vertical acceleration response magnifications

at A,C and E (Vibrated horizontally)

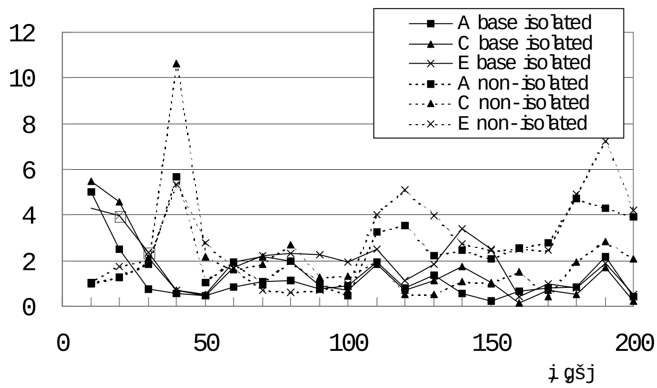


Fig.10 Maximum horizontal acceleration response

magnifications at A,C and E (Vibrated horizontally)

CONCLUSIONS

It is concluded that 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 and horizontal 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.

ACKNOWLEDGMENT

This study was supported in part by the Nihon University Joint Research Grant for 1999 (Representative :K. Shingu).

REFERENCES

Niki,T. and Shingu, K. 1998, “A Fundamental Experiments on Strain Responses of Base Isolated Shell Structures”, *Theoretical and Applied Mechanics,* Vol.47, Science Conical of Japan, pp305-312

Shingu,K., Kawanishi,T. and Harumoto,M., 1990, ”A Study on Active Control of a Conical Shell Subjected to Seismic Forces”, *Proc. of International Association for Shell and Spatial Structures*, Dresden and Cottbus, pp32-42

Shingu,K., 1993, ”Seismic Isolation and Fuzzy Vibration Control of a Shell Subjected to Vertical Seismic Forces” *2nd Seminar on Shells and Spatial Structures, Architectural Institute of Japan,* pp15-22 (in Japanese)

Shingu,K. and Fukushima,K.,1994, ”Seismic Isolation and Fuzzy Vibration Control of Shell Structures Subjected to Vertical Seismic Forces” *Transactions of the Japan Society of Mechanical Engineers,* (C), Vol.60, No.577, pp2999-3005 (in Japanese)

Shingu,K., Fukushima,K. and Niki,T., 1996, ”Dynamic Response of Seismic Isolation Conical Shell with Edge Beam Subjected to Vertical Seismic Forces”, *Proc. of 4th International Conference on Civil Engineering,* Manila, pp583-590