Study of Base-Isolated Structures of Nuclear Power Plants (A Study on the Arrangement of Bearings and Stresses in the Basemat)

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1. INTRODUCTION

The buildings of a nuclear power plant are much heavier than ordinary buildings. For example, the weight of the reactor building for a 4 loops PWR in Japan is about 200,000 tons. Many bearings are needed to support it and it is therefore important to study how to arrange the bearings. The characteristics of the three types of bearings arrangements considered in this study are as follows:

a) an arrangement of 500 ton bearings under walls (Fig. 1)

Since the weight of the superstructure is transmitted to the base isolation layer through the walls, it is effective to arrange the bearings under the walls so that the bearings can support the weight directly. The variation in the bearing loads can be reduced by spacing the bearings under walls according to the weight of the superstructure.

b) a unformly distributed arrangement of 500 ton bearings (Fig. 2)

If we can arrange the bearings without any relation to the wall layout of the superstructure, many advantages can be expected. This arrangement makes use of the characteristics that the shear stiffness of laminated rubber is not very sensitive to the supported load.

c) an arrangement of 1000 ton bearings under walls (Fig. 3)

There are advantages in using large capacity bearings such as simpler construction and maintenance, etc.

2. CONDITIONS and CASES ANALYSED

(1) Reference building --- reactor building for a 4 loops PWR
(2) Loads --- dead load + live load (D+L)
(3) Thickness of the basemats
    Type 1 upper basemat 2.5m, lower basemat 1.5m
    Type 2 upper basemat under PCCV 2.5m, other places 1.5m
    lower basemat 1.0m
(4) Soil Conditions --- Vs=2200m/s, Vs=1000m/s, Vs=500m/s
(5) Bearing Arrangements --- 3 types mentioned above
(6) Cases of Analysed

Table 1 Cases Analysed

Models	bearings			basemat thickness		velocity of shear wave (m/s)
	standard load	arrange- ment	pieces	upper (m)	lower (m)	
Model 1	500t	under wall	95	2.5	1.5	2200
Model 2	500t	under wall	95	2.5	1.5	1000
Model 3	500t	under wall	95	2.5	1.5	500
Model 4	500t	under wall	95	under PCCV 2.5 other places 1.5	1.0	2200
Model 5	500t	uniformly distributed	95		1.0	2200
Model 6	1000t	under wall	47		1.0	2200

(7) Analytical model

A quarter of the reactor building is modeled by F.E.M. Basemat are modeled by plate elements. PCCV, internal concrete and the reactor external building are modeled by beam elements. Pedestals are modeled by beams, bearings by springs and soil by winkler springs. The plan of the arrangement of the 500 ton bearings under walls is shown Fig. 1 and the conceptual model is shown in Fig. 4.

3. RESULTS

(1) Fig. 5 shows the variations in bearing loads. Models 1, 2, 3 show the changes in these variations due to soil conditions. The ratios of max. load to avg. load are 1.28 for model 1, 1.74 for model 2 and 2.33 for model 3. If the bearings must be designed to withstand the max. load, the bearings of model 3 will be the most expensive. Models 4, 5, 6 show the changes in the variation cased by bearing arrangements. The ratios of max. to avg. are 1.33 for model 4, 1.34 for model 5 and 1.28 for model 6. The difference between model 4 and model 5 is not important from the point of view of designing bearings. However, attention must be paid to the fact that there are a few bearings with extremely small loads in model 6. Fig. 6 shows the variations in bearing loads diagram- matically in plan view.

(2) Fig. 7 shows the changes in the displacements and deformations of the basemats due to soil conditions. Fig. 9 shows the corresponding changes in the stresses. The displacements and also the local deformations and stresses are smaller for hard soil than for soft soil.

(3) Fig. 8 shows the changes in the displacements and deformations of the basemats caused by the arrangements of the bearings. Local deformations in the upper basemat are smaller when bearings are located under the walls than those for when uniformly distributed, but the opposite applies to local deformations in the lower basemat. Fig. 10 shows a disgrammatical representation of a deformed basemat.

4. CONCLUSIONS

(1) Stiffness of soil

- As the stiffness of the soil increases, the variation in the bearing loads decreases.

- As the stiffness of the soil increases, the vertical displacements, local deformations and stresses in the basemat become smaller.

- The reactor building may be satisfactorily designed with an upper basemat 2.5m thick and the lower basemat 1.0m thick for all the cases in the study.

(2) Thickness of the basemat

- For hard soil (Vs=2200m/sec), the basemat thickness does not have any effect on the deformation of the total system.

(3) Bearing arrangements

- Arrangement of 500 ton bearings under walls

  Because the weight of the upper building is transferred through the walls directly to the lower basemat, the deformation of the upper basemat is small and the variation of the bearing loads is small.

- Uniformly distributed arrangement of 500 ton bearings

  The stresses in the lower basemat are smaller than in the case of bearings arranged under the walls, but the stresses in the upper basemat are greater. There is a large variation in the bearing loads.

- Arrangement of 1000 ton bearings under walls

  There are a few bearings which have extremely small loads because the distance between bearings is limited by the design of the upper slab. Therefore, it is recommended that a combination of 500 ton and 1000 ton bearings should be used.

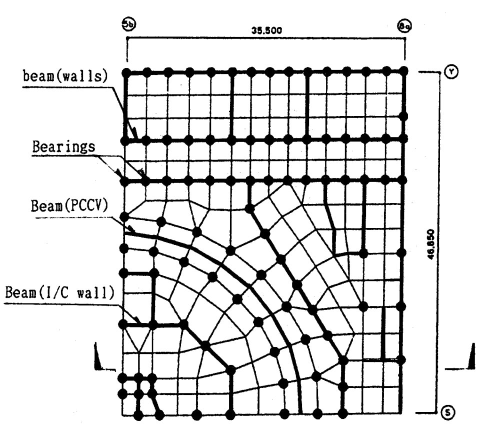

Fig. 1 500t bearings arranged under walls

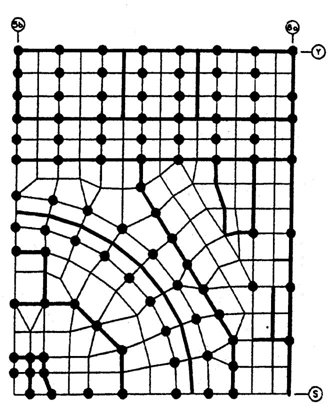

Fig. 2 Uniformly distributed arrangement of 500t bearings

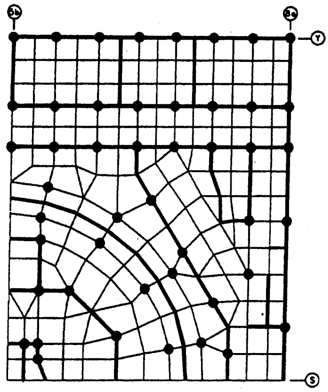

Fig. 3 1000t bearings arranged under walls

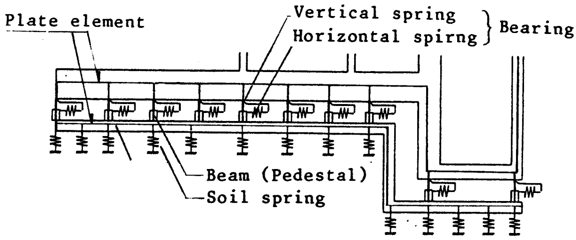

Fig. 4 Conceptual model

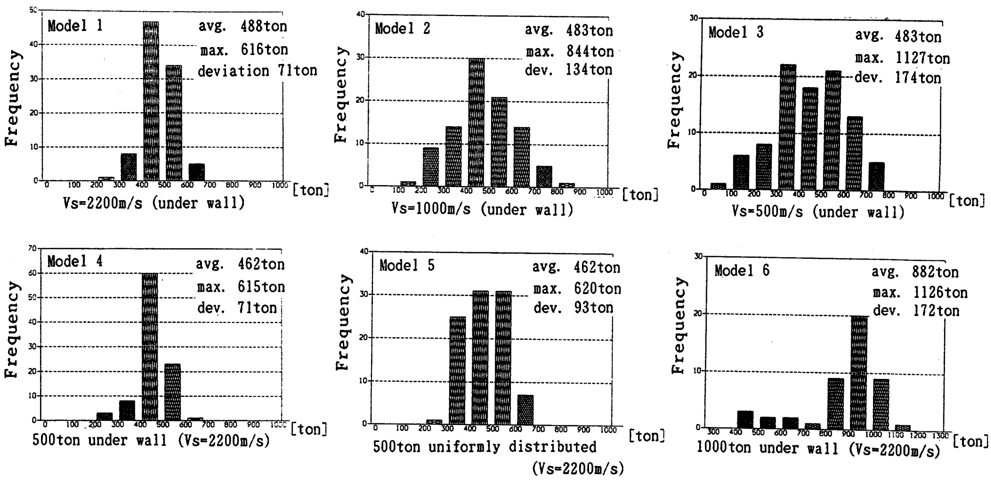

Fig.5 Variations in bearing loads

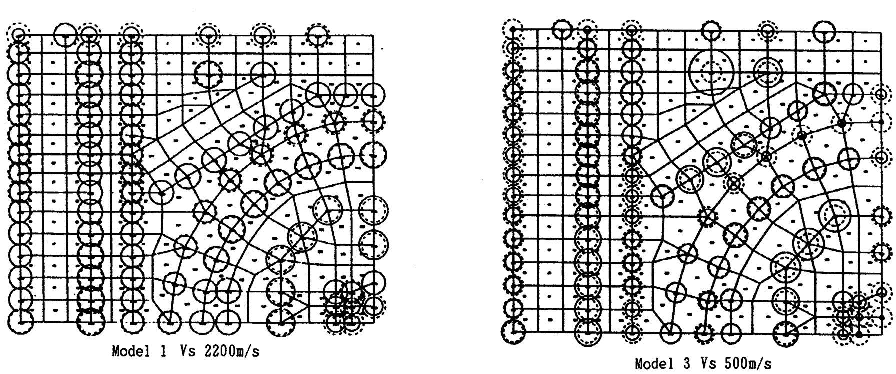

Fig. 6 Bearing loads due to soil conditions

(Diameter represeuts the bearing load. existing load 500t load)

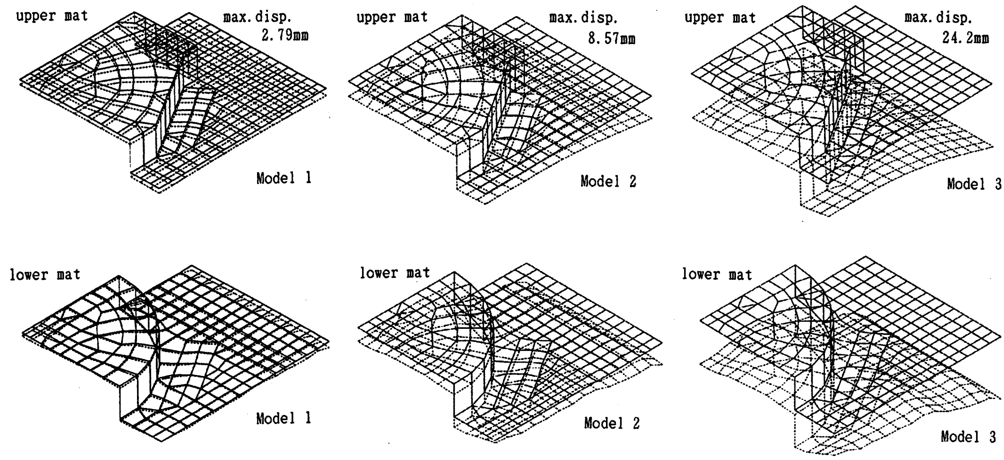

Fig. 7 Changes in the displacements and deformations of the basemats due to soil conditions

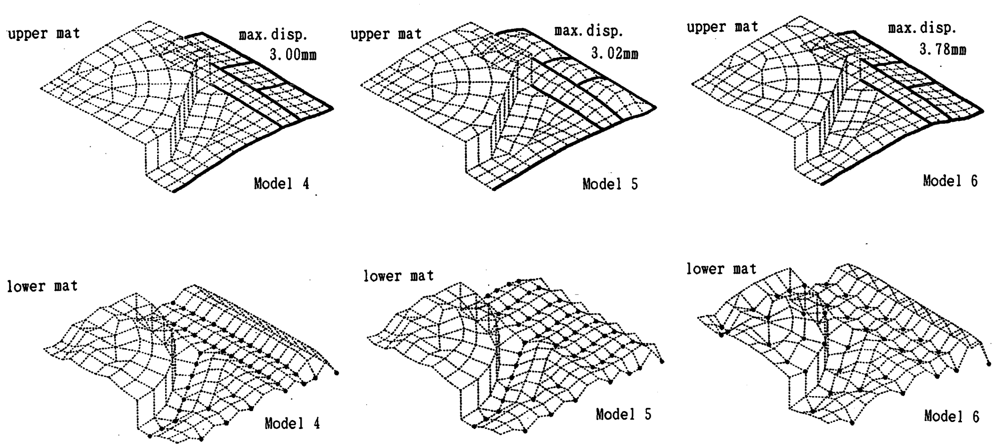

Fig. 8 Changes in the displacements and deformations of the basemats due to the arrangement of the bearings

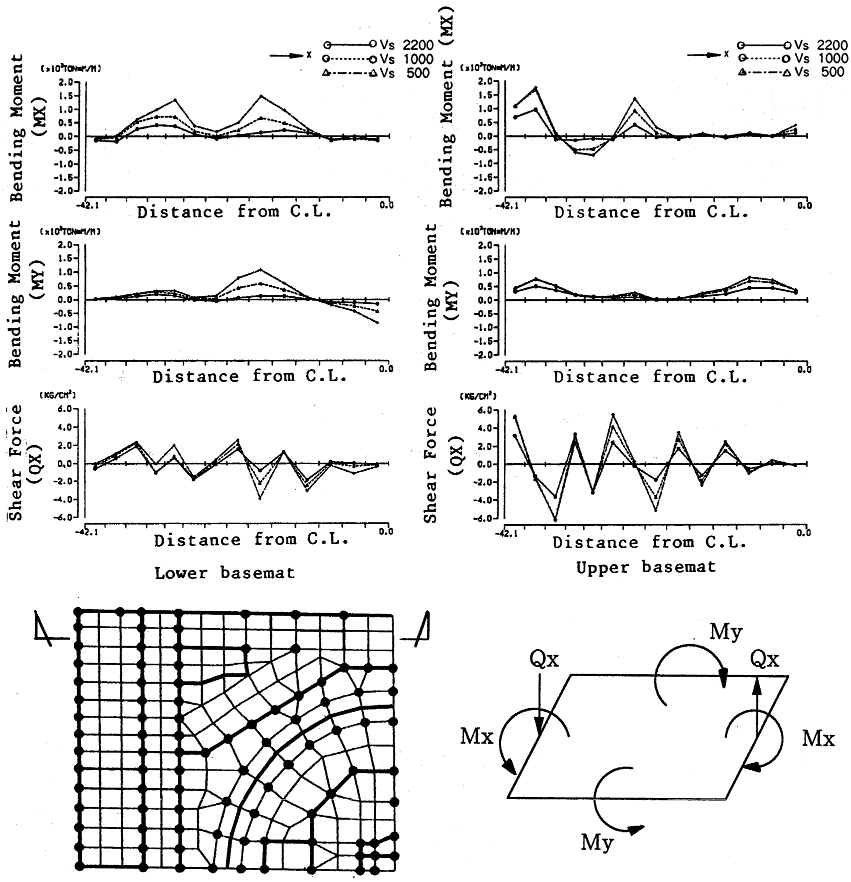

Fig. 9 Stresses in the basemats for different soil conditions

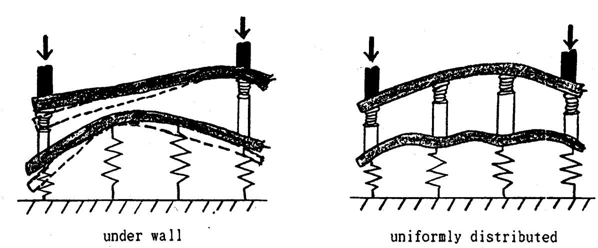

Fig.10 Diagramatic representation of a deformed basement