Study on Ultimate Strength of Base Mat to Seismic Load for PWR Type Reactor Building

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1. Objectives

Since the base mat of the reactor building performs the important function of supporting the superstructures, it is generally designed more conservatively than the superstructures. Although a lot of studies have been undertaken on the ultimate strength of the walls of the superstructures (Cylindrical walls, box walls, etc.), studies on the ultimate strength of the base mat have been few. However, when examining the ultimate strength of the building as a whole, it is necessary to evaluate the ultimate strength of the base mat.

In this study, the base mat of a PWR type reactor building which is applied the seismic force (maximum acceleration=400gal) to the elastic design, is analysed using the 3-dimensional finite element method (FEM), and its ultimate strength and yield lines are calculated. A flow chart of analysis is shown in Fig. 1, and a vertical cross section of a PWR type reactor building is shown in Fig. 2.

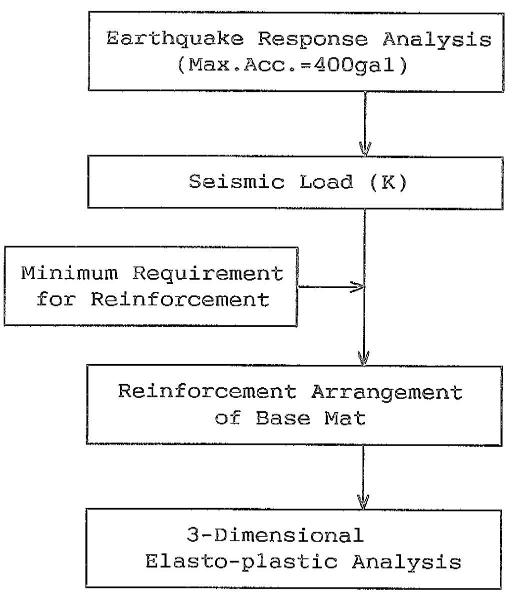

Fig. 1 Flow Chart of Analysis

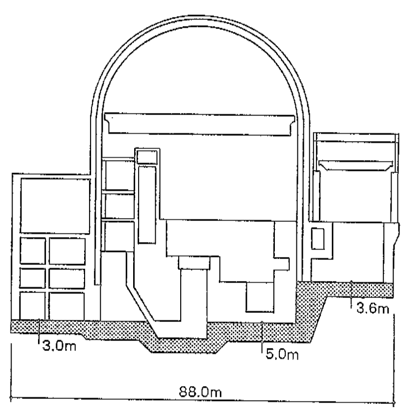

Fig. 2 Vertical Cross Section of a PWR Type Reactor Building

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2. Analysis Conditions

2.1 Analysis Methods

Static incremental load analysis is carried out using the 3-dimensional elasto-plastic finite element method. The applied load is a combination of the vertical load (D+L) and the horizontal seismic load (K), that is, $1.24 \cdot (D+L) + \alpha \cdot (K)$, where the value of α is gradually increased and 1.24 is the effect adding the vertical seismic motion. The seismic load is applied to the superstructures to match the shear force and the overturn moment for the bottom face of the base mat obtained from earthquake response analysis on the lumped mass model.

2.2 Analysis Model

The analysis model is a half model of a PWR type reactor building which has a stepped base mat. Fig. 3 shows the analysis model, and Fig. 4 shows the reinforcing bars' arrangement of the base mat. The elasto-plastic plate elements are used in the base mat and lower part of the superstructure's shear walls, and the elastic plate elements are used in the upper portion of them and slabs in the superstructure.

The elasto-plastic plate elements are modeled on the layered shell elements. Fig. 5 shows the layered shell element. It consists of 9 concrete layers modeled on the isotropic membrane elements and 2 steel reinforcing bar's layers modeled on the orthotropic membrane elements set in position. Fig. 6 shows the stress-strain characteristics of the concrete and steel reinforcing bar.

The soil condition is 1500m/s of shear wave velocity and the soil stiffness is modeled on the 3 directional winkler springs. The horizontal springs are elastic while the vertical springs are not left to tension. Tension cut off is operating to the uplift. Fig. 7 shows the characteristics of vertical springs.

3. Analysis Results

3.1 Base Mat Deformation

Fig. 8 shows base mat deformations. As the seismic load increases, the plastic zone also increases and the amount of uplift of the base mat grows, with about half area of the uplift occuring when the horizontal load is 1.6 times K load. At 3.2 times K load, the uplift is 90% of the area. In this case, the maximum soil pressure is around $1100t/m^2$. For the ultimate bearing capacity of the soil (Vs=1500m/s), this is enough for it to bear.

3.2 The Yield Line on the Base Mat and Its Ultimate Strength

The reinforcing bars begin to yield (tensile strain at yield strength above 1900μ) when the horizontal load is 2.1 times K load. It is believed the yield line will be changed by the shear wall arrangement of superstructures, however in this wall arrangement, the zones of yielding are under the O/S and I/C portions of the top of base mat which is forced upwards by the seismic load and the bottom of base mat which is forced downwards by the seismic load. Under 3.2 times K loading, the yield line penetrates the portion of the base mat which is forced downwards. Thus, if the ultimate strength of the base mat is defined by the load when the yield line penetrates, that is 3.2 times K load. At the load, the maximum transverse shear stress of the base mat which occurs under O/S, is about $35kg/cm^2$. About 1 % of the transverse shear reinforcement will be needed for the zone. In the case of the elastic superstructures, even at 3.8 times K load, there is no penetration of the yield line,[1] and it is found that the means of modeling the superstructures has a large effect on the results of the analysis.

3.3 Yielding in the Superstructure's Shaer Walls

The yielded elements in the superstructure's shear walls can be seen in Fig. 9. The yield of reinforcing bars in the shear walls starts at 2.2 times K load, after which the yield elements increase in the same manner of the base mat. By the load which yield line penetrates the base mat, many shear walls already yield and are about at their ultimate stage.

4. Conclusions

- Position of yield line : In this wall arrangement, yield line appears under O/S and I/C portion of the base mat which is forced downwards by the seismic force.
- Ultimate strength : The object of this study is the base mat of a PWR type reactor building designed by seismic load (K), and it is found that the base mat has the ultimate strength to bear a load of about 3 times K load. Also, when the base mat reaches its ultimate stage, the shear walls of thesuperstructures are also about in their ultimate stage.

REFERENCES

1) Yoshida,S. et al. (1990) Study on Ultimate Strength of Base Mat of PWR type Reactor Building, Summaries of technical papers of anual meeting AIJ.

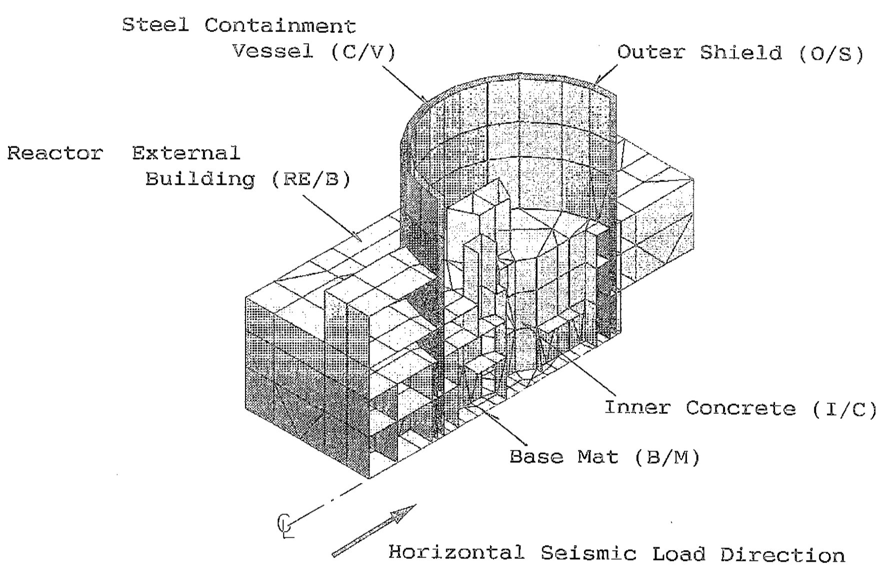

Fig. 3 Analysis Model

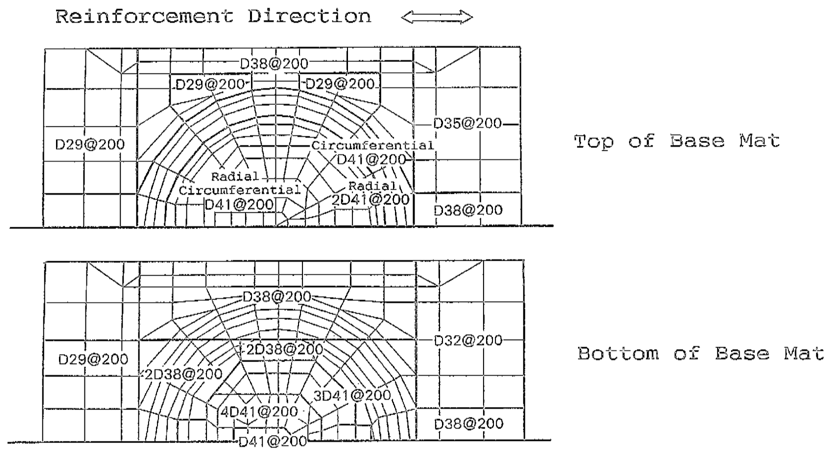

Fig. 4 Reinforcing Bars' Arrangement of Base Mat

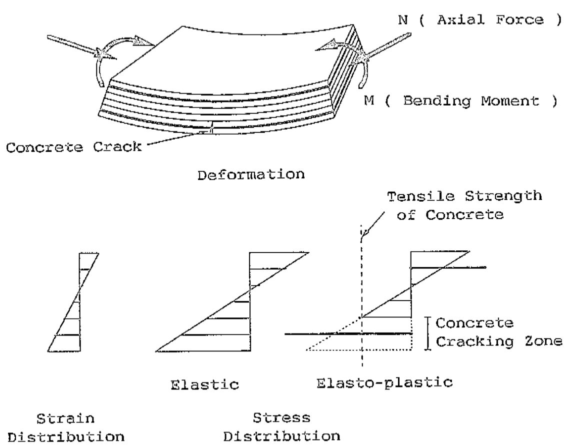

Fig. 5 Layered Shell Element

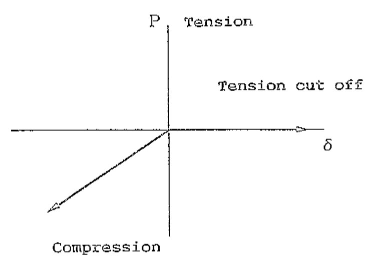

Fig. 7 Characteristics of Vertical Soil Springs

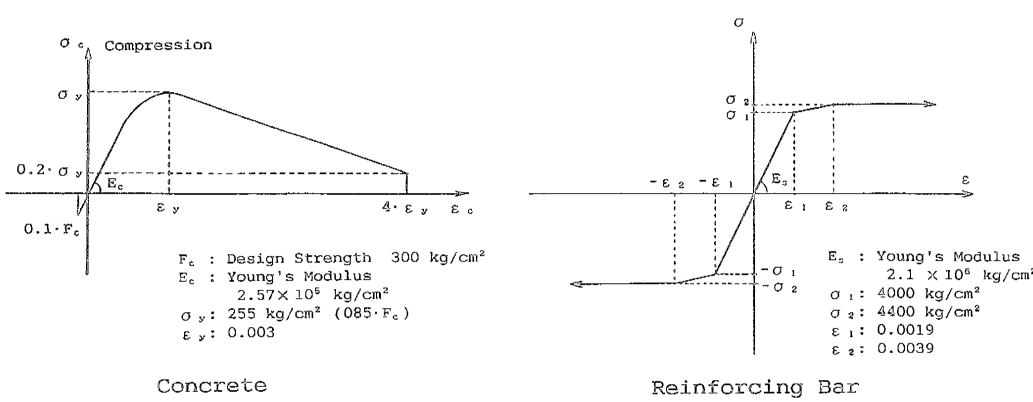

Fig. 6 Stress-Strain Characteristics

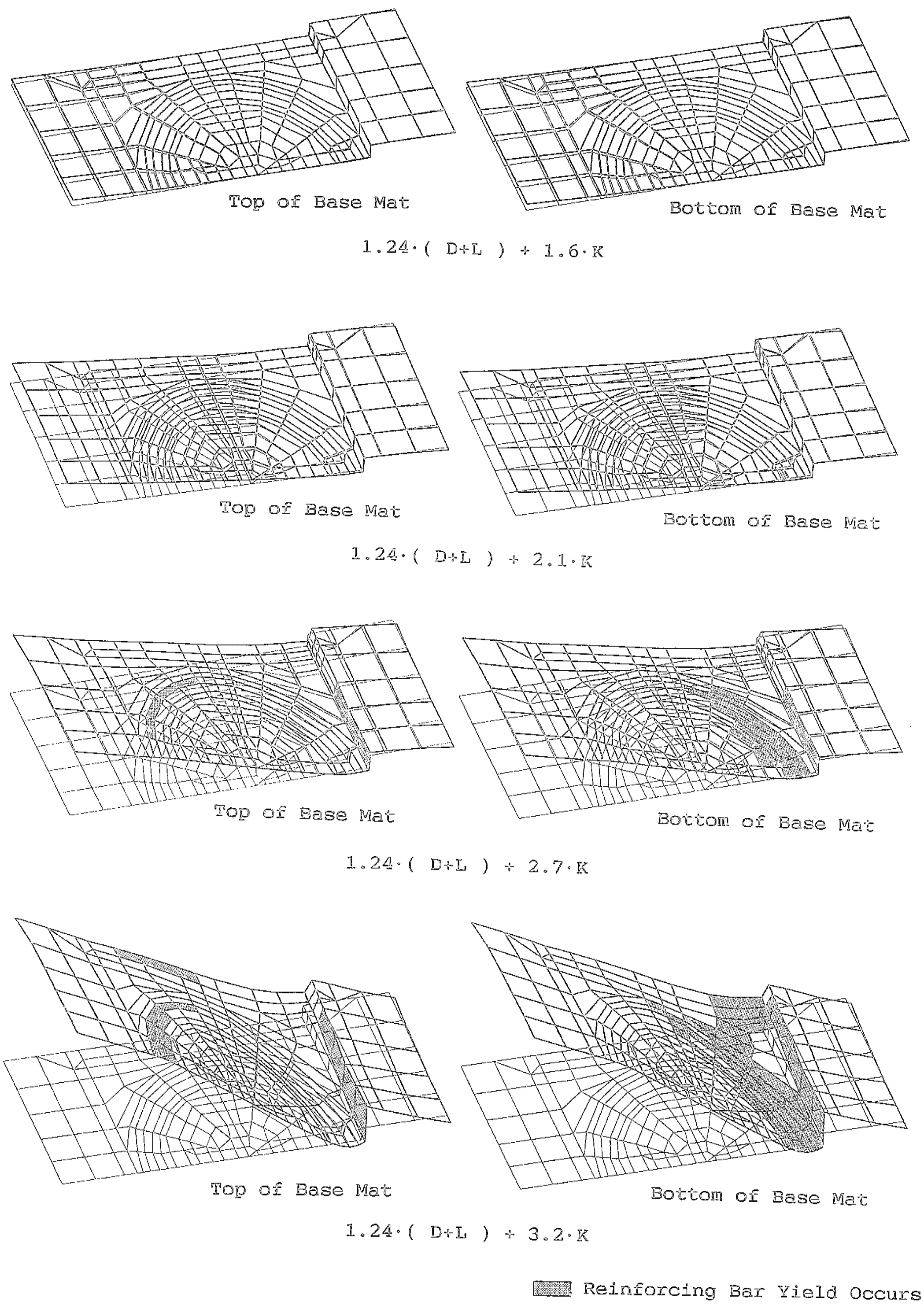

Fig. 8 Base Mat Deformation and Yielded Elements

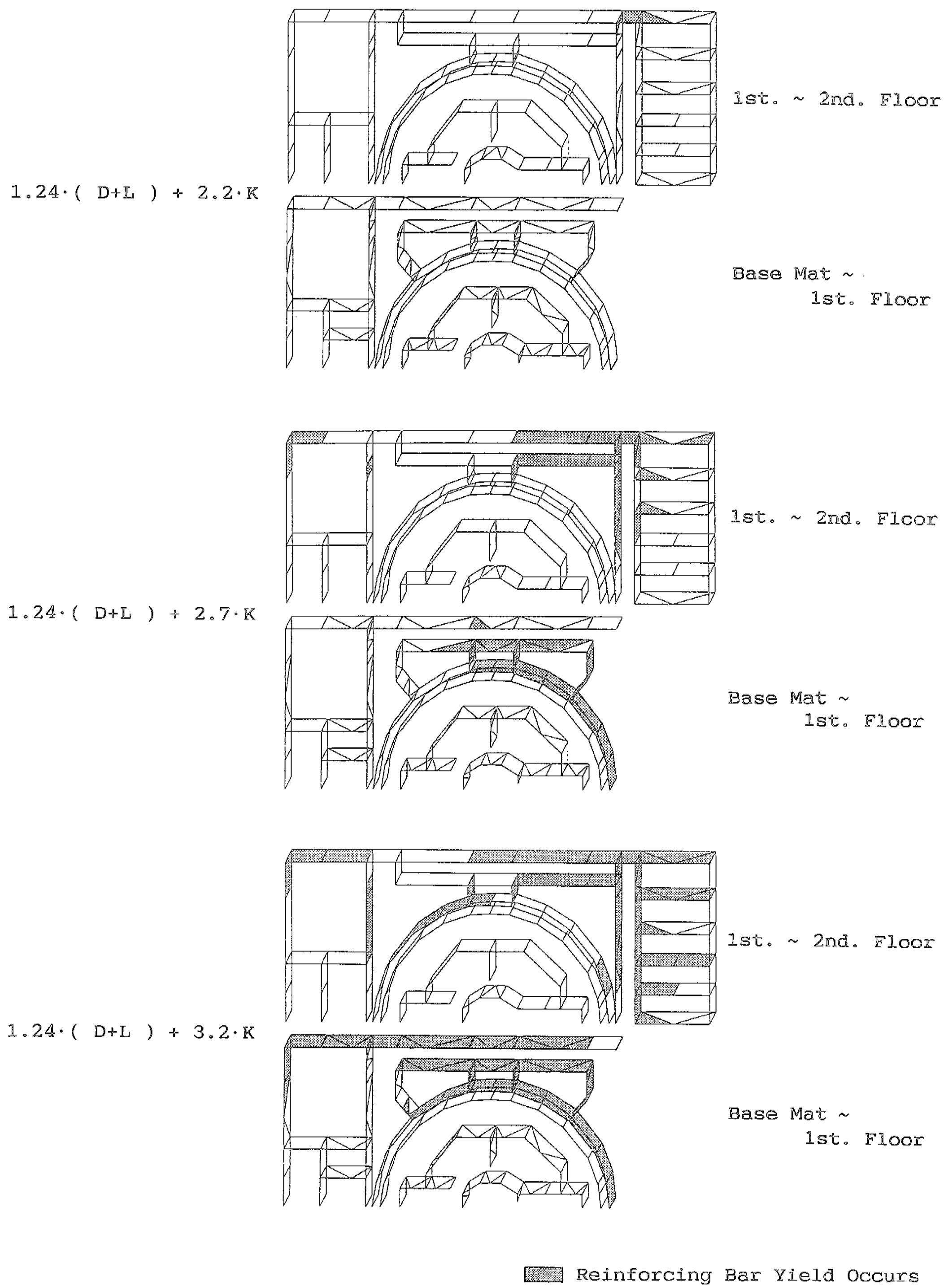

Fig. 9 Yielded Elements in the Superstructere