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Development of Simple Modal Analysis Model for KALIMER-600 Reactor Building

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1. Introduction

This paper develops a simple structure model which consists of several beams and concentrated masses to simulate the dynamic behavior of the KALIMER-600 reactor building [1,2,3]. There are two methods for obtaining the natural frequencies of a structural system. The first one is the well known 3D solid modeling method for a FE analysis. The second one is the structural modeling method represented by several beams with concentrated masses at nodal points for the structures and components. The second technique reduces the order of the model size, and it converts a complex system to a simple structural element model with several degrees-of-freedom. The merit of the lumped mass technique is its simplicity. The 3D-model FEA method has a computationally complex, and requires considerable computing time. Therefore the 3D solid FEA method is not employed in a preliminary design. The use of the lumped mass technique is more convenient for the performance and behavior analyses because it is cost effective for a time history analysis for a seismic load with a long period when compared to the 3D solid model.

2. Methods and Results

Modal characteristics of the reactor building were firstly obtained by a detail 3D FEA model using the ABAQUS. Owing to the fact that the fundamental mode of a vibration mainly contributes to the response of a structural system, the system can be approximated by several beam elements for the first few modes. The model has several beams with a mass for its each discrete section of a building. The dynamic modal characteristics are subsequently compared to the corresponding modal properties calculated by the lumped mass model analysis. The first few modes are compared to each other. The modal characteristics of the lumped mass model and the 3D-model are obtained by the ABAQUS program.

2.1 3D Model

The reactor building is modeled by using a shell type 3D element of the ABAQUS program as shown in Fig.1. This shell element model was applied to both isolated and non-isolated systems. The structural property values used are the elastic modulus of 33GPa, the density of 2400kg/m^3, the height of the building is about 57m, the area of the building is 49m×36m, and an average mass is used for the uniform 3D-model. The reactor support wall has the same elastic modulus and density. The dynamic characteristic analysis was performed for two types of buildings. One is for the isolated system, and the other is for the non-isolated system, where the basement is fixed to the ground. The frequency analyses are performed to obtain the dynamic properties of the building. The 3D FEA is a useful tool in a dynamic structural analysis. But the 3D solid model requires an enormous amount of computing work in the time history analysis for a seismic load.

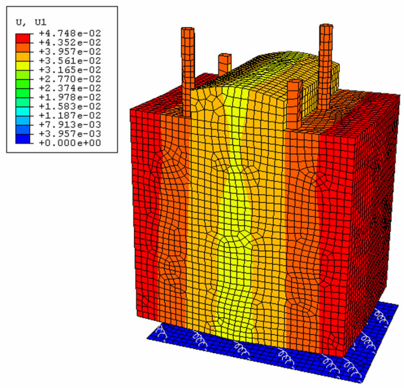
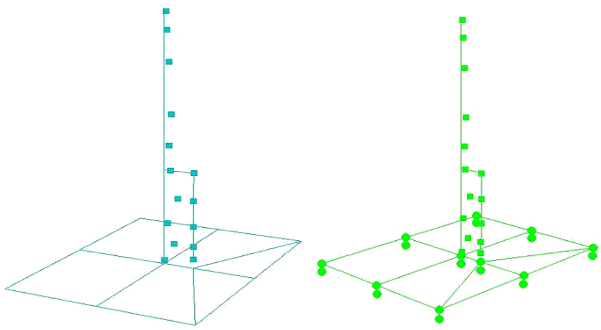


Fig.1 Isolated 3D-model of KALIMER-600

2.2 Lumped Mass model

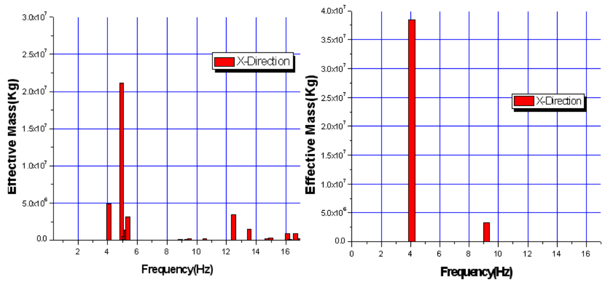


(a) non-isolated (b)isolated
Fig.2 Lumped mass model

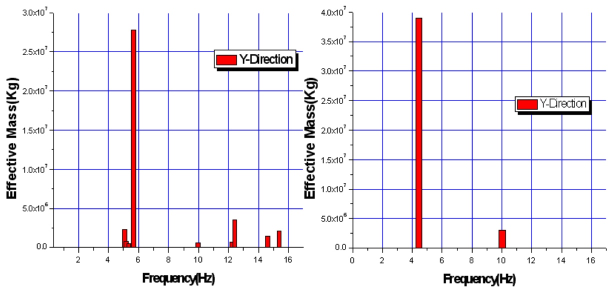
The lumped mass model for the reactor building is shown in Fig. 2(a) for the non-isolated system, and Fig. 2(b) is for the isolated system. The lumped masses, locations and the beam properties were calculated for several divided sections of the reactor building[3].

2.3 FE Analysis Results and Discussions

Two analyses were carried out for the lumped mass model and the 3D-shell model (Models 1 and 2) of the reactor building. The reactor building has two basement conditions of the non-isolated and the isolated systems. The frequency analyses for the lumped mass model and the detail 3D model are carried out using the ABAQUS program. The results are presented in Fig.3 and Fig.4. The left side of each figure presents the results of the 3-D solid model, and the right side is the results of the lumped-mass model.



(a) X-direction (3D model and lumped-mass model)



(b) Y-direction (3D model and lumped-mass model)

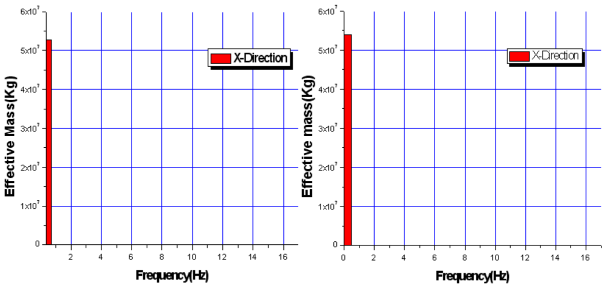
Fig. 3 Frequency and Effective mass for Non-Isolated Condition

The analysis results for the lumped mass model and the 3D shell model give very similar values for the lower frequencies and the corresponding effective masses. As shown in Figs.3 & 4, the important frequencies and corresponding effective masses in the x and y directions of the lumped-mass and 3D analysis models are represented for both the isolated and non-isolated buildings.

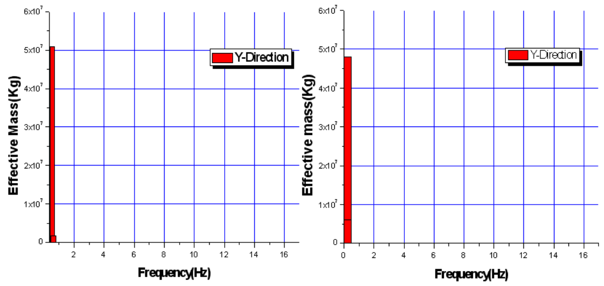
As for the analysis condition of the non-isolated reactor building and the 3D FE modeling method, the x-direction natural frequency as shown in Fig.3 is 4.94Hz, the y-direction is 5.66Hz, and the z-direction is 14.68Hz. As for the non-isolated reactor building and the lumped mass model, the x-direction natural frequency is 4.51Hz and the y-direction is 4.95Hz, and the z-direction is 14.15Hz.

The dynamic characteristics of the developed lumped-mass model agree well with the results of the 3D shell element model. So, the lumped-mass model is successfully fitted to the detail 3D model.

Because the lumped-mass model properties of the fixed based condition give a good result, the lumped-mass model using the same building model properties for an isolated condition has a good dynamic feature of the 3D solid model. As shown in Fig.4, the modal properties of the lumped-mass model agree well with the 3D FE model for this isolated system.



(a) X-direction (3D model and lumped-mass model)



(b) Y-direction (3D model and lumped-mass model)

Fig. 4 Frequency and Effective mass for Isolated Condition

3. Conclusions

It may be concluded that the lumped mass approximate method yields an accurate estimation for the natural frequencies and mode shapes when compared to the 3D shell model in the KALIMER-600 reactor building. The developed simple lumped-mass model can be used to analyze the seismic response of a reactor building.

Acknowledgement

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