Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2018

Seismic Analyses of a Nuclear Power Block Considering Structure-Soil-Structure Interaction

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1. Introduction

The United States Nuclear Regulatory Commission (USNRC) revised the 2007 Standard Review Plan (SRP) 3.7.2 to recommend the seismic design for the structure with seismic category-I reflecting the structure-soil-structure interaction (SSSI) effect [1]. Such a demand arises from a study that the seismic response may change because structures are influenced and exchanged when the structures are adjacent to each other. Particularly, nuclear power plants(NPPs) are disposed to adjacent building complex with reactor containment building (RCB), auxiliary building (AB), turbine building (TB), complex building (CPB), emergency diesel generator building (EDGB) each other. The reactor building and the auxiliary building are constructed on a single mat foundation while the surrounding structures are separated considering the minimum earthquake clearance. The emergency diesel generator building may be also constructed by the side of AB for the operation of the system. Considering the disposed characteristics of the NPP, SSSI effect in the power block surrounding the safety related structures need to be evaluated according to SRP 3.7.2.

In the APR1400 NRC DC project, which is being pursued by domestic nuclear industry, SSSI analysis is performed and applied to the structural design. The seismic response between the SSI response of each building and the emergency diesel generator building adjacent to the entire power block was directly compared and analyzed considering the SSSI effect. The analysis is performed by applying a three-dimensional finite element model. It is a result of the inevitable assumption that the structures are placed on the surface due to a problem of a large analysis time, and thus the buying effect, which is an important variable related to the SSSI effect, is not reflected. After that, additional complementary analysis was performed, but there still existed a problem of a large analysis time and limitation of the analytical model.

HITACHI in Japan conducted SSSI analysis between a compound building and a fire water service complex, and used the input motion dependent to construction site and site characteristics. The SSI and SSSI analyzes are performed considering the embedded effect of the building, and the results are compared. It is clear that there are differences in the SSSI analysis results depending on whether or not they are embedded under ground [2].

Recent research trends in the US are accompanied by an experimental study of the nonlinear numerical analysis and the reduced model of the SSSI effect. The numerical analysis was proposed to a direct comparison of linear analysis in frequency domain and nonlinear analysis in time domain. The validity of SSSI analysis was verified through centripetal fuse experiment [3].

Currently, the research project related with SSSI is being carried out by the industry-academy cooperation, in Korea. We are developing user convenience for CNU-KIESSI analysis program and also installing the high-speed solver engine for the large-capacity input data, and are performing various analytical verification and validation works through the centrifuge experiment for the reduced NPP model.

2. SSSI Analyses of power block

In this paper, a nuclear power block (reactor containment building, auxiliary building, turbine building, complex building, emergency diesel generator building) is constructed and SSSI analysis is also performed reflecting several parameters. As shown in Fig. 1, an analytical model was constructed with three nuclear buildings adjacent to NI consisting of a reactor building and an auxiliary building, where the foundation of the building is embedded under the ground or on surface. The purpose of this analysis is to evaluate the influence of parameters such as building gap size, number of building, and whether they are embedded or not, which are important parameters of the SSSI analysis.

The site property of the analysis example is assumed to be a homogeneous halfspace corresponding to a shear wave velocity of 2,000 and 20,000 ft/sec for the fixed condition. The gap size between buildings is 6.0ft. The analysis was performed with CNU-KIESSI and SASSI2010 [4, 5] respectively.

Figure 2 shows the SSSI analysis model of CNU-KIESSI for the fixed condition. The number of finite element is about 210,000. Figure 3 also shows the SSI analysis models using CNU-KIESSI program of five buildings respectively. The control motion generated based on NRC 1.60 is applied in the east-west direction and the maximum peak ground acceleration is 0.3g shown in Figure 4. Lastly we carried out SSSI analysis works considering various parametric conditions on embedded conditions, gap sizes, control motions etc.

3. Conclusions

In this study, we examined the research trends of SSSI in domestic and overseas and found that SSSI effect should be reflected according to SRP 3.7.2. Also there are limitations on the analysis of the SSSI due to the problems of the vast analysis data and the analysis time.

Also, the simplified analysis model of the nuclear structure was discretized and the parametric analysis was performed. Since the influence of the various parameters on the SSSI analysis was examined, and the future research will develop a finite three - dimensional finite element model of the nuclear power block and carry out further studies considering various ground conditions.

REFERENCES

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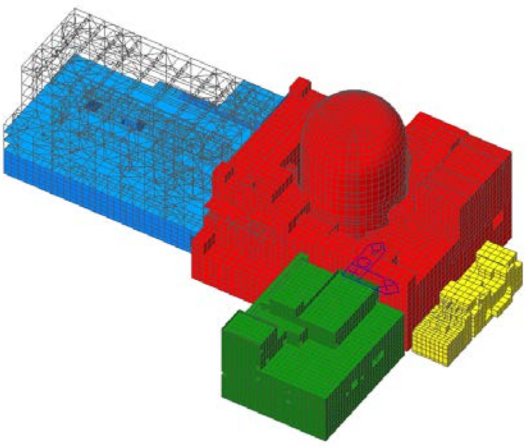


Fig. 1. Numerical models of nuclear power block

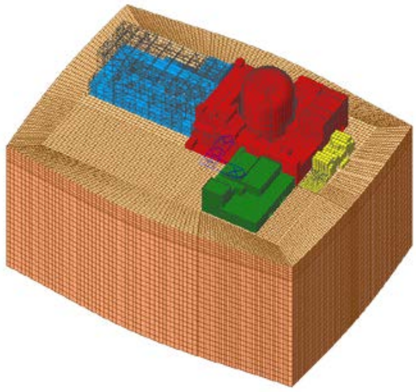


Fig. 2. SSSI analysis model for CNU-KIESSI

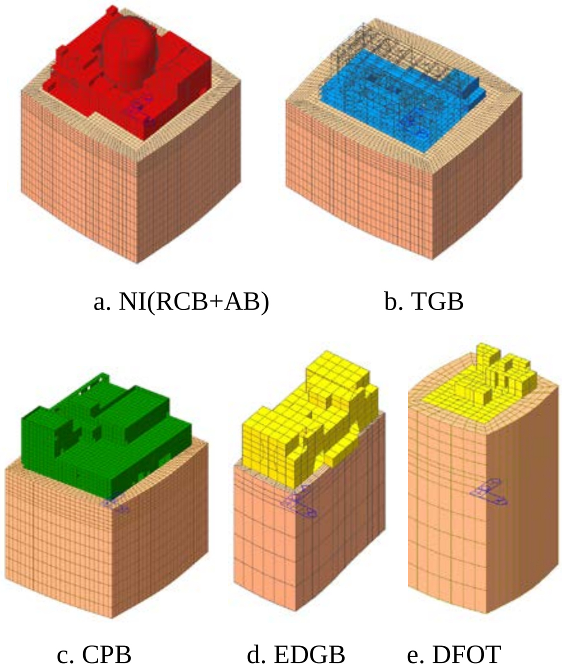
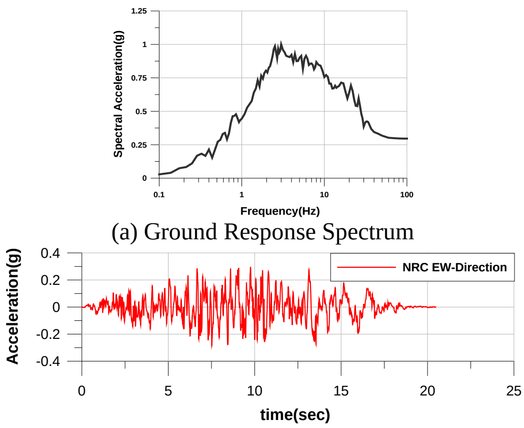


Fig. 3. SSI analysis model for five individual buildings



(a) Ground Response Spectrum

(b) Acceleration Time History (PGA = 0.3g)

Fig. 4. Control Motion based on NRC 1.60 on outcrop