SMiRT26 - 26th International Conference on Structural Mechanics in Reactor Technology

【開催要項】

開催時期：2022 年 7 月 10 日 - 15 日

開催地：ベルリン/ポツダム

Special Session:

Nonlinear Seismic SSI Analysis Based on Best Engineering Practices in US and Japan

〇はじめに：Special Session の目的と座長挨拶

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1- SEISMIC NONLINEAR SSI APPROACH BASED ON BEST PRACTICES IN US AND JAPAN. PART 1: MODELING

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The paper introduces an efficient nonlinear seismic SSI approach for evaluating the reinforced concrete (RC) shearwall structures behavior under severe earthquakes in accordance with the engineering practices and regulatory requirements in US and Japan. The nonlinear SSI approach is based on a hybrid approach that uses an iterative scheme which couples the equivalent-linear complex frequency SSI analysis with the nonlinear time-domain structure analysis. The iterative approach is fast converging in only few SSI restart iterations. The SSI approach implementation follows the Japanese seismic nonlinear analysis engineering practice extended to detailed 3DFEM SSI models. The implementation is compliant with the RC wall structure modeling standard requirements in US and Japan. Independent verifications and validation studies confirmed that the iterative SSI approach is reasonably accurate and extremely numerically efficient. There are two companion papers, Part 1 and Part 2, related to the iterative SSI approach: The Part 1 paper focuses on the key modeling aspects for capturing nonlinear hysteretic behavior of RC structure walls, while the Part 2 paper focuses on its application using the ACS SASSI Option NON software.

2- SEISMIC NONLINEAR SSI APPROACH BASED ON BEST PRACTICES IN US AND JAPAN. PART 2: APPLICATION

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3- COMPARATIVE STUDY USING STICK AND 3DFEM NONLINEAR SSI MODELS PER JEAC 4601-2015 RECOMMENDATIONS

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The paper illustrates the nonlinear SSI analysis under a severe earthquake motion, based on the Japan JEAC 4601-2015 recommendations (JEA 2015). The JEAC 4601 approaches were implemented in the ACS SASSI Option NON software (GP Technologies, 2021), which is based on a hybrid complex frequency-time domain approach that uses a local iterative equivalent-linearization procedure for modelling the hysteretic behavior of the RC walls (Ghiocel, et. al, 2022a and 2022b). To validate this newly implemented nonlinear analysis methodology, a simple test buildings with fixed base are modelled with a 3DFEM model and a stick model by using ACS SASSI Option NON. The results were compared with those obtained by the stick model using the program DYNA2E (CTC Itochu, 2019), which is the nonlinear time-domain analysis program broadly used for the nonlinear SSI analysis of nuclear facilities in Japan.

The both results obtained by the ACS SASSI Option NON and DYNA2E software show good agreement in the nonlinear hysteresis loops, the maximum responses and the response spectra. The results also show some different characteristics between the hybrid complex frequency-time domain approach and the conventional time-domain direct integration approach and between 3DFEM model and stick model.

4- APPLICABILITY OF EQUIVALENT LINEAR THREE-DIMENSIONAL FEM ANALYSIS FOR REACTOR BUILDING TO SEISMIC RESPONSE OF SOIL-STRUCTURE INTERACTION SYSTEM

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This paper aims to evaluate the applicability of the equivalent linear analysis method for reinforced concrete, which uses frequency-independent hysteretic damping with a small computational load, to the seismic design of reactor building of the nuclear power plant. To achieve this, we performed three-dimensional FEM analyses of the soil-structure interaction system, focusing on the nonlinear and equivalent linear seismic behavior of a reactor building under an ideal soil condition. From these results, the method of equivalent analysis showed generally good correspondence with the method of the nonlinear analysis, confirming the effectiveness. Moreover, the method tended to lower the structural stiffness compared to the nonlinear analysis model. Therefore, in the evaluation of the maximum shear strain, we consider that the results were more likely to be higher than the results of nonlinear analysis.

5- SEISMIC SSI ANALYSIS OF REACTOR BUILDING COMPLEX INCLUDING FOUNDATION UPLIFT BASED ON JEAC 4601-2015 RECOMMENDATIONS

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The paper illustrates the nonlinear SSI uplift analysis of a building foundation under a severe earthquake motion. The paper describes the uplift SSI analysis methodology based on the Japan JEAC 4601-2015 standard recommendations (JEA, 2015). The JEAC 4601 standard recommends nonlinear uplift approaches applicable to SR (Sway-Rocking) models based on the base uplift severity.

The JEAC 4601 foundation uplift approaches were implemented in the ACS SASSI Option UPLIFT software (GP Technologies, 2021) by combining the equivalent-linearization for the overall SSI analysis in complex frequency with the nonlinear uplift time-domain analysis occurring at the foundation-soil interface. The multi-step analysis procedure applied for the uplift SSI analysis is described in this paper.

In order to check the applicability of the new Option UPLIFT function, a comparison analysis study was performed for the simple building foundation located on the uniform soil condition subject to various levels of input motion. The response obtained by the ACS SASSI 3D FEM model and Stick with basemat shell model were compared with those obtained by the program DYNA2E (CTC Itochu, 2019) which is the nonlinear uplift time-domain analysis program broadly used for the uplift SSI analysis of nuclear facilities in Japan. According to the comparison results, it was confirmed that the new Option UPLIFT function can provide good agreement with the seismic response results obtained by the conventional time-domain analysis program DYNA2E.

○発表を受けてのディスカッション