UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

November 23, 2020

Ms. Margaret M. Doane
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: NUSCALE TOPICAL REPORT, TR-0118-58005, REVISION 1, "IMPROVEMENTS IN FREQUENCY DOMAIN SOIL-STRUCTURE-FLUID INTERACTION ANALYSIS"

Dear Ms. Doane:

During the 679th meeting of the Advisory Committee on Reactor Safeguards, October 8 - 9, 2020, we reviewed the NuScale Topical Report (TR) entitled, "Improvements in Frequency Domain Soil-Structure-Fluid Interaction Analysis," and the NRC staff's associated Safety Evaluation (SE). Our NuScale Subcommittee also reviewed this matter during a meeting on September 22, 2020. During these meetings we had the benefit of discussions with representatives of the NRC staff and NuScale. We also had the benefit of the referenced documents.

CONCLUSION AND RECOMMENDATION

1. NuScale has developed a new seismic analysis approach that addresses soil-structure interaction (SSI) and fluid-structure interaction (FSI) that improves the analysis process and its accuracy.

2. The SE approves the methodology with conditions and limitations. It should be issued.

BACKGROUND

Regulations require that Structures, Systems and Components (SCCs) important to safety be designed to withstand earthquakes. The analyses must address SSI. Seismic analysis of the NuScale plant is more complex than conventional pressurized water reactors (PWRs) and boiling water reactors (BWRs) because of the large reactor building (RXB) pool in which up to twelve NuScale Power Modules (NPMs) may be immersed and which is also interconnected with the refueling bay and the spent fuel pool. The combined mass of the RXB, NPMs and pool are sufficient to potentially feed back into the SSI analysis, creating a combined SSI/FSI analysis problem.

The conventional approach to nuclear power plant (NPP) seismic analysis is a multi-step process that uses simplified stick models of SSCs in conjunction with an industry-standard SSI code (SASSI) to determine the soil-structure response to earthquake ground motion response

spectra specific to the reactor site. The resulting seismic loads for the building are then input to more sophisticated, general purpose finite element analysis (FEA) code models of the SSCs. The results from the detailed FEA models are used to determine seismic load demands for the seismic qualification of the SSCs.

NuScale has developed a novel approach in which SASSI is used to develop dynamic soil impedances and seismic load vectors for a site and include them directly in a large-scale ANSYS FEA model of the plant. This permits an integrated single-step analysis that addresses SSI/FSI with more accurate modelling of the SSCs, including the RXB pool, in the analysis, without iterating between the SASSI and ANSYS codes.

The TR includes four sample problems ranging from a simplified PWR model that was an original SASSI code demonstration problem, to a small-scale model of a reactor building, with and without a large water pool, and ultimately to a detailed model of a 12-module NuScale reactor building. In each case, the analysis was performed using both the conventional, multi-step process and the integrated single-step process described in the TR. The results were compared and showed excellent agreement between the two methods.

DISCUSSION

The NuScale approach incorporates the following assumptions:

1. Material properties are linear elastic during the analysis.
2. The behavior of boundary conditions and constraints is linear.
3. The seismic load is represented by vertically propagating shear and compression waves.

The staff reviewed the NuScale approach, observing that it conforms to established mathematical principles of the dynamics of structures and fluids and that its validity is demonstrated through the example problems presented in the TR. The SE concludes that the methodology is acceptable for seismic analysis of complex NPP structures involving soil-structure-fluid interactive behaviors, such as the NuScale reactor building, in accordance with the applicable regulations. The SE imposed conditions and limitations that basically consist of demonstrating the applicability of the above three assumptions.

We note that these assumptions are not specific to the analytical improvements described in the TR. They are general assumptions that apply to any linear-elastic, frequency or time-domain seismic analysis, whether performed using the conventional, multi-step approach or the integrated, one-step process. Nonetheless, they remain a necessary condition on the use of the TR methodology. For extreme magnitude earthquakes and/or certain soil conditions, non-linear effects such as foundation slippage, uplift and soil separation may occur. Since there are no general criteria to predict in advance when such non-linear effects will become significant for a particular analysis, the results of a linear analysis must be examined in sufficient detail to evaluate the potential for such effects.

The SE specifies that the staff will verify that each of the limitations and conditions has been satisfied in its review of a site-specific application of the methodology. “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” NUREG-0800, Section 3.7.2 provides guidance on acceptable approaches and methods for implementing the SSI methodology with nonlinearities. This guidance can also be applied to the new proposed methodology in the TR.

SUMMARY

NuScale has developed a new seismic analysis approach that addresses soil-structure-fluid interaction that improves both the analysis process and its accuracy. The SE approves the methodology with conditions and limitations and should be issued.

We are not requesting a formal response from the staff to this letter report.

Sincerely,

Matthew W. Sunseri Digitally signed by Matthew W. Sunseri
Date: 2020.11.23 17:18:12 -05'00'

Matthew W. Sunseri
Chairman

REFERENCES

1. NuScale Power, LLC, Topical Report TR-0118-58005, "Improvements in Frequency Domain Soil-Structure-Fluid Interaction Analysis," Revision 2, September 2, 2020 (ML20126G848).

2. U.S. Nuclear Regulatory Commission, "Safety Evaluation for NuScale Power, LLC, Licensing Topical Report, TR-0118-58005, Revision 2, Improvements in Frequency Domain Soil-structure-fluid Interaction Analysis," October 5, 2020 (ML20024F139).

3. U.S. Nuclear Regulatory Commission, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800, Section 3.7.2, "Seismic System Analysis," Revision 4, September 9, 2014 (ML13198A223).

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