Response to SDAA Audit Question

Question Number: A-3.7.2-28

Receipt Date: 10/09/2023

Question:

(Follow-on from A-3.7.2-08). In response to A-3.7.2-08, the applicant provided additional documents on the audit portal including US460 Double Building Model Revision 2 (EC-103862). In Section 4.3.1.1 of EC-103862, the applicant discusses settlement analysis of the double building model under static loads and indicates that the model has dimensions of 4000' in east-west, 4000' in north-south, and 521' in vertical directions. However, FSAR Section 3.7.2.1.1.2.1 indicates that the double building static analysis model used to obtain differential displacements has the length of 2005.5 ft, the width of 768.5 ft, and the depth of 360 ft. Clarify whether the static analysis models discussed in EC-103862 and FSAR Section 3.7.2.1.1.2.1 refer to the same model and, if so, explain the difference in dimensions of the two models. If not, provide the source materials and correct the dimensions for the static analysis model discussed in FSAR Section 3.7.2.1.1.2.1, as appropriate.

Response:

The US460 Standard Design Approval Application (SDAA) Section 3.7.2.1.1.2.1 dimensions for the static model were carried over from the US600 Design Certification Application (DCA). The dimensions of the half-space model for the US460 SDAA are 4000 ft x 4000 ft x 521 ft, as discussed in EC-103862. NuScale revises US460 SDAA Section 3.7.2.1.1.2.1 to reflect the dimensions of the model.

Markups of the affected changes, as described in the response, are provided below:

Audit Question A-3.7.2-28

The use of the soil impedance libraries in the SSI analysis means that the free-field boundaries extend to the elastic half-space implicitly. However, for the static analyses performed to obtain results due to static loads and differential displacements, the free-field soil is modeled explicitly beyond the backfill soil boundaries. ~~For the double-building RXB-RWB static model, the overall length is 2005.5 ft, the width is 768.5 ft and the depth is 360 ft.~~For the model, the overall length is 4000 ft, the width is 4000 ft, and the depth is 521 ft. The vertical depth is deeper than the SSI model. At this depth, the vertical displacement becomes insignificant due to soil stiffness. The horizontal free-field boundaries are extended far enough away so that fixing them has a negligible effect on the static response of the buildings. Similarly, for the CRB static model, the overall length is 1319.7 ft, the width is 1351.1 ft, and the depth is 300 ft.

3.7.2.1.1.2.2 Cut-Off Frequency

For the frequency-domain SSI analysis with Soil Types 7 and 9 the cut-off frequency is established at 100 Hz, the maximum frequency that can be analyzed with a time step of 0.005 seconds.

For Soil Type 11 the cut-off frequency is established at 35.2 Hz. This value is higher than the wave passing frequency of Soil Type 11 calculated as minimum (Vs/(5T)) = 371 fps/(5x6.25') = 12 Hz.

The building models have element sizes that are less than the 6.25 ft layers that are used to determine the wave passing frequency of the soil. Therefore, the wave passing frequencies of the buildings are greater than the wave passing frequencies of the soil.

3.7.2.1.1.2.3 Cracked Model Stiffness

The Building Design Analysis Methodology Topical Report TR-0920-71621-P-A (Reference 3.7.2-9) describes the methodology for modeling the stiffness of cracked concrete elements.

3.7.2.1.2 Finite Element Models

The finite element model of the RXB, crane, and pool water is developed, in general, using solid shell (SOLSH190), shell (SHELL181), beam (BEAM188), and fluid (FLUID30) elements. Surface (SURF154) and mass elements (MASS21) are used to apply the appropriate distributed and concentrated masses to the structure. The finite element models of the CRB and RWB are similar to the RXB except that models use structural shell elements to represent the slabs and walls instead of solid shell elements.

3.7.2.4 Soil-Structure Interaction

Soil-structure interaction analysis follows the methodology in TR-0118-58005-P-A-R2 (Reference 3.7.2-1). In this methodology, the SSI is performed in the frequency domain using a multi-step approach. For each soil type, soil impedances and seismic load vectors are calculated using SASSI to form a soil library. These soil impedances and seismic load vectors are then imported into an ANSYS model for the SSI analysis. If applicable, the ANSYS model contains fluid elements for modeling fluid-structure interaction.

The CSDRS, CSDRS-HF, and associated time histories sets are developed in Section 3.7.1.1. The soil types are developed in Section 3.7.1.3.

Figure 3.7.2-2 shows the SASSI model of the excavated soil for the DB model. The deepest portion, under the RXB, consists of 12 layers. Each layer is 7 ft thick, except layer 3 is 6 ft thick and layer 12 is 8 ft thick.

Figure 3.7.2-3 shows the SASSI model of the excavated soil under the CRB.The excavated soil model consists of two 75-inch-thick layers. Because the CRB is modeled as surface founded, a soil model with identical properties and meshing as the excavated soil is put back into the excavation.

Audit Question A-3.7.2-29

Figure 3.7.2-4 shows the combined CRB plus soil model. The non-SC-I portion of the CRB is not included in the model, and the soil region is enlarged to include the surcharge effects of the non-SC-I portion. However, the surcharge effects are not incorporated as it is shown that the seismic response with only the SC-I portion envelopes the response with both SC-I and non-SC-I portions.

3.7.2.4.1 Methodology for Combining Seismic Response Results

Seismic responses are obtained due to input motion in each global direction. The combined seismic responses are obtained by algebraic summation of the responses due to each particular input motion direction, as shown below.

$$Out_j(t) = (\sum_{u=X,Y,Z}) Out_{j,u}(t) \qquad \text{Eq. 3.7-1}$$

where, $Out_{j,u}(t)$ is the time domain response due to input motion in u direction, and $Out_j(t)$ is the combined time domain response for structural response component j (Table 3.7.2-9).

As an example, the combined acceleration responses in the time domain are obtained as: