Response to SDAA Audit Question

Question Number: A-3.8.5-9

Receipt Date: 08/07/2023

Question:

It is noted that 8.0’ thick mat foundation is modeled for the RXB with single layer of solidshell (SOLSH190) elements. The staff is seeking to understand the following modeling topics related to the RXB foundation in order to complete its safety review:

1. Given the variation of material types (concrete and steel) and material properties (concrete compression and tension) through mat thickness, explain in detail why using single layer of SOLSH190 elements is adequate to account for the linear and non-linear behaviors of steel reinforced concrete mat. Discuss whether the simplification of using single-layer SOLSH190 elements for a 8-foot-thick reinforced concrete mat foundation might affect the RXB superstructural analysis.
2. It is noted that there are many SC walls on the RXB mat foundation (Figure 3B-30), which divide the foundation mat into several smaller areas, resulting in lower span-to-thickness ratios. Discuss how an 8' thick concrete mat, with its bottom surface supported by soil and top surface separated by a wall, can react like a shell and is therefore modeled as a shell, and explain why the assumption of a thin structure using shell elements is reasonable.
3. From the literature (Biswajit Banerjee et al.) it appears that a plate modeled with single layer of SOLSH190 elements is very stiff in bending, and a plate requires at least three elements through the thickness of the plate to obtain reasonable results. Please indicate if a verification or sensitive study have been performed by NuScale for this, if so please provide details. Discuss the effect of modeling with single-layer SOLSH190 elements on the calculation of total and differential settlement.

Reference:

Biswajit Banerjee, Jeremy Chen, Anjukan Kathirgamanathan, Comparison of ANSYS elements SHELL181 and SOLSH190, July 2011

4. From the literature (Biswajit Banerjee et al.,) it appears that boundary conditions must be applied to all nodes of the SOLSH190 element in order to achieve correct midsurface deformation behavior. Provides information on how to model the contact between SOLSH190 elements and soil elements, or how the nodes of SOLSH190 element are linked to the nodes of

soil element, if applicable. Justify how reasonable deformation behavior for the basemat can be achieved with a single layer of SOLSH190 elements and model boundaries.

Response:

Item 1:
In agreement with reinforced concrete design practice and the corresponding design codes (i.e. ACI 349-13), the foundation basemat is modeled as a shell structure with gross section properties corresponding to the concrete only. ANSYS solid-shell elements (SOLSH190) are used to simulate shell behavior. For simplicity, only one layer through the thickness is considered since ANSYS SOLSH190 elements behave similarly to traditional shell elements. The advantage of using SOLSH190 is its compatibility with general three-dimensional constitutive relations; that is, it can be connected directly with other continuum elements. The plane of the element is defined by the use of a normal vector (i.e., the normal vector is perpendicular to the plane of the element). For the basemat, the element plane is horizontal.

To support this audit response, a mesh-density evaluation was performed to test the impact of multi-layered solid shell elements in the Reactor Building (RXB) basemat deformation. The double building (DB) differential settlement model with half-space is used in this evaluation.
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}}2(a),(c)

Item 2:
In comparison to legacy shell elements that used classical Kirchhoff plate theory, modern shell finite element technologies in ANSYS (e.g, SHELL181 and SOLSH190) follow the higher order Reissner-Mindlin plate theory which takes into account transverse shear strains. Thus, modern shell elements can be used in either thin or moderately thick-plate applications.

Further, ACI Committee 336 (Footings, Mats, and Drilled Piers) developed a guide for the analysis and design of mat foundations, ACI 336.2R-19. Section 6.11 and 6.12 of the ACI guide discuss basemat thickness and two versus three-dimensional analysis and concludes that thin plate analysis is generally used and is adequate. Thus, the assumption of a thin plate structure using shell elements is reasonable. However, the SOLSH190 elements used for the RXB basemat model have better capabilities to model thick members as indicated above.

Item 3:

As explained in the response to item 1 of this question, a sensitivity study was performed to verify the impact of multi-layered solid shell elements in the RXB basemat deformation, EC-151256. {{

}}[2(a),(c)]

Item 4:

RXB settlement analysis uses conformal mesh between the basemat and soil, i.e. they share common nodes. {{

}}[2(a),(c)]

No changes to the SDAA are necessary.