17. ABSORBING BOUNDARY CONDITION FOR SEISMIC SIMULATIONS IN PANAMA CANAL 3RD SET OF LOCKS DESIGN

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SUMMARY

One of the key challenges for seismic analysis of heavy civil structures is the proper modeling of boundary conditions that allow the earthquake loading input and prevent the wave reflection due to the Soil-Structure-Interaction (SSI). Traditionally, the earthquake loading, in the form of acceleration, is applied to the structure while the foundation is considered massless. This typical approach has the drawback of trapping the seismic wave energy inside the finite structure domain, due to the fact that the boundary conditions themselves will reflect the seismic wave, which will result in an overestimation of the seismic response. For the design of the Third Set of Locks for the Panama Canal expansion project, a proper boundary condition was needed to achieve a more realistic and optimum design. To accurately accomplish this analysis, an Absorbing Boundary Condition (ABC) was developed using Abaqus User Elements (UEL) to prescribe the deconvoluted seismic wave conditions at the bottom of the structure. The developed technique also considers the upward convolution of the seismic wave along the sides of the structure to represent the free seismic field solution to the structure. In the meantime, unlike typical enforced acceleration boundary conditions, the ABC technique is able to absorb the seismic waves deflected from the structure, realistically simulating seismic wave propagation in a semi-infinite domain.

The absorbing boundary condition herein is a further development of well-known techniques, like a twosolution approach proposed by Zienkiewicz: one for the free field motion at the boundaries, and the other for the wave absorption. The current technique combines both into Abaqus UEL for both 2D and 3D problems. The ABC technique effectively addresses two key aspects: the seismic conditions are prescribed at the bottom and calculated around a finite structure domain, and the reflected waves from the structure are absorbed by the user elements, extending the infinite element technique in Abaqus. The ABC technique includes three key ingredients: damping forces around the structure for seismic wave absorption based on the relative velocity, a virtual column concept for the free field P-wave and Swave upward propagation, and elastic forces around the structure due to the virtual column P-wave and S-wave propagation. In the meantime, the user elements for the ABC are able to accommodate different material regions within the model to represent common foundation layers found in the real world. The developed technique was validated through benchmark tests and comparisons with several examples.