Assessing and Increasing Resilience of Nuclear Energy Soil-Structure Systems for Dynamic/Seismic Loads

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Earthquake mechanical waves carry dynamic/seismic energy and excite soil-structure systems (buildings, bridges, tunnels, dams, power plants...). The Earthquake-Soil-Structure-Interaction (ESSI), the propagation of dynamic/seismic energy in time and space, through nonlinear soil-structure system, determines the extent of damage, possible collapse and casualties. Controlling, directing propagation of dynamic/seismic energy through the soil-structure interacting (SSI) system can be used to improve safety and economy of SSI systems. If dynamic/seismic energy can be deflected from and/or dissipated outside of structure or dissipated within structures using designated dissipation devices, earthquake damage can be reduced and even completely alleviated.

Presented is analysis methodology, modeling and simulation tools, used to better understand dynamic/seismic energy propagation and practical design recommendations to control and direct propagation of dynamic/seismic energy within Nuclear Energy (NE) SSI systems. Analysis methodology, including modeling and simulation tools are based on recent work [1; 2; 3; 4] that is implemented and available in a public domain program Real-ESSI Simulator [5]. Proposed methodology to control and direct propagation of dynamic/seismic energy encompasses:

1. Plasticity of soil, hard and/or soft, adjacent to and beneath the structure, and the soil-foundation interface zone [6; 7],

2. Energy dissipators, energy sinks, within structure, for example buckling restrained braces (BRBs), frictional pendulum, lead core elastomers, etc. [8; 9; 7],

3. Viscous dampers and viscous coupling between fluid and structure [10; 8; 11],

4. External trenches surrounding the structure [12; 13],

5. Meta-materials/meta-devices, for example resonant unit cells, negative stiffness meta-materials, etc., adjacent to or within the structure [14; 15],
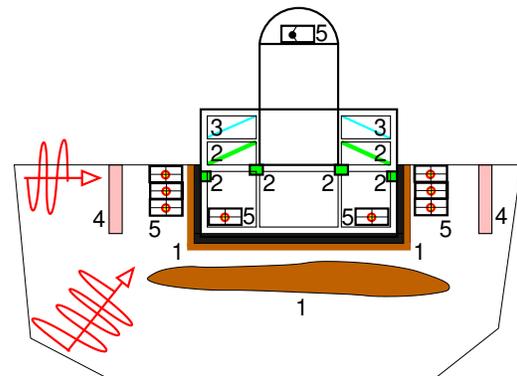

Figure 1: Dynamic/Seismic energy management methods for a typical Nuclear Energy soil-structure system.

Of particular interest is investigation of relative contribution of each of the above noted measures for dynamic/seismic energy dissipation, dynamic/seismic energy deflection and dynamic/seismic energy conversion. Presented will be details about and design guidance for relative efficiency of dynamic/seismic protection approaches. In addition, presented will be analysis methods, simulation tools and models that are available in public domain and that are used by the engineering community for design, assessment and upgrades of NE SSI systems.

High fidelity models of Nuclear Energy and standard building SSI systems [16; 7; 17] will be used to illustrate and asses dynamic/seismic energy control approaches, as noted above. Presented analysis methodology and tools are used to improve safety and economy in designing new objects, as well as improving safety and economy of existing NE SSI systems through upgrades.

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