Seismic response characteristics of graphite fuel-block assemblies in a HTGR core: Experiments, theory, and finite element simulations

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ABSTRACT

A comprehensive study is conducted at the University at Buffalo to characterize the seismic response of graphite fuel-block assemblies in a horizontal, compact high temperature gas reactor (HC-HTGR), as part of the DOE funded Advanced Reactor Concept (ARC-20) project. The HC-HTGR core comprises of prismatic blocks of graphite forming the reflector and fuel elements, as illustrated in Figure 1. The blocks are vertically stacked in columns by means of horizontal shear keys, which provide some degree of interlocking. In the transverse direction (i.e., perpendicular to the longitudinal axis of the reactor), several columns of blocks of varying heights, are placed adjacent to each other forming a 2D wall. Identical walls of blocks are installed along the longitudinal axis of the reactor, completing the 3D assembly. The columns of blocks are separated from others by finite gaps (both in the transversal and longitudinal directions) to accommodate fabrication and installation tolerances, thermal expansion, and swelling of graphite. The seismic response of the columns of blocks is affected by multiple factors, including the rigid-body dynamics of the blocks, friction and clearances within the shear key, kinematic constraints, design and manufacturing tolerances, uplift, disengagement of blocks from the shear key, and impact of blocks in adjacent columns. These effects were characterized through coordinated experimental, analytical, and finite element simulations (see Figure 2, Parsi *et al.* (2024)). The presentation at the 2024 DOE-NRC NPH Workshop will discuss 1) the design of the earthquake-simulator experiments and key results, and 2) validation of the analytical models and finite element simulations that were developed to support the advancement of design.

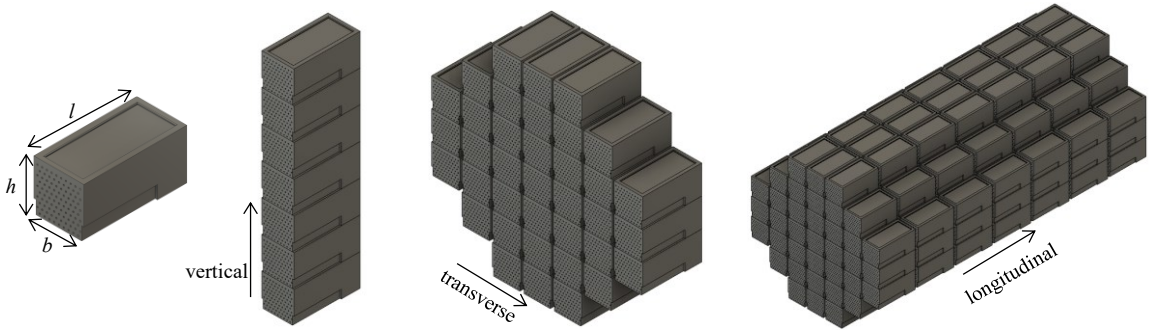
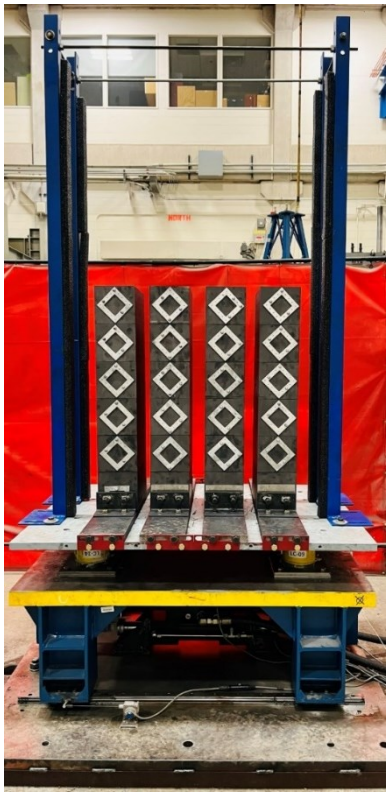
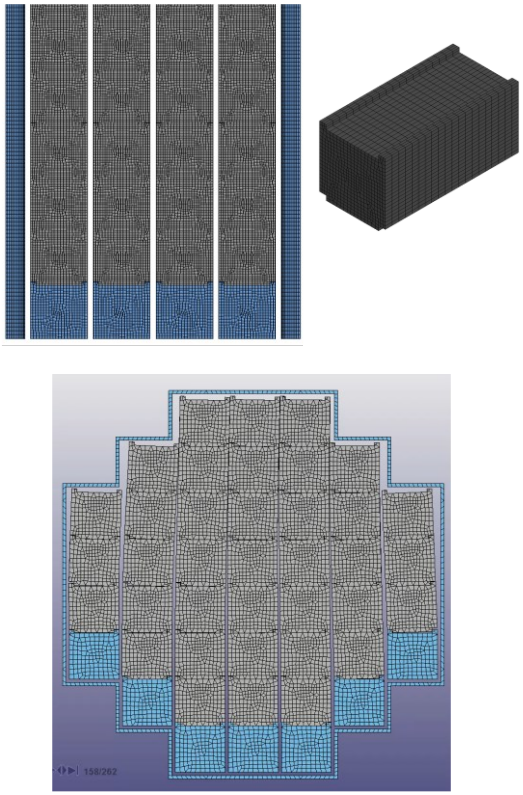


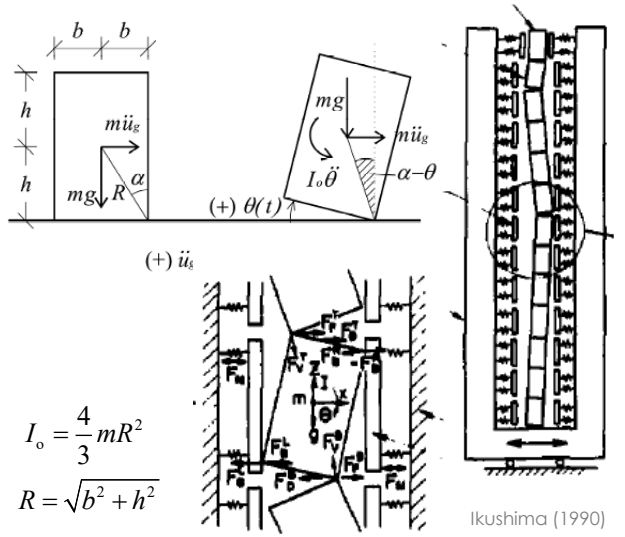
Figure 1. Graphite fuel-block assemblies in a HC-HTGR reactor core



a) earthquake-simulator experiments



b) finite element simulations in LS-DYNA



$$I_o = \frac{4}{3}mR^2 \qquad R = \sqrt{b^2 + h^2}$$

$$I_o\ddot{\theta} + mgR\sin(\alpha - \theta) = m\ddot{u}_g R\cos(\alpha - \theta), \qquad \theta(t) > 0$$

$$I_o\ddot{\theta} - mgR\sin(\alpha + \theta) = m\ddot{u}_g R\cos(\alpha + \theta), \qquad \theta(t) < 0$$

for both θ and α small $\rightarrow$ $\ddot{\theta} - p^2\theta = p^2\left(\frac{\ddot{u}_g}{g} - \alpha\,\mathrm{sign}(\theta)\right)$

c) analytical solutions based on rigid-body rocking dynamics

Figure 2. Characterizing seismic response of graphite fuel-block assemblies in a HC-HTGR reactor core

Reference

Parsi, S. S., Velez-Lopez, E., Stewart, R. W., Shirvan, K., Sivaselvan, M. V., and Whittaker, A. S. (2024). "Dynamic response characteristics of fuel-block assemblies in a horizontal, compact HTGR." *Proceedings: International Congress on Advances in Nuclear Power Plants (ICAPP-24)*, Las Vegas, NV (doi.org/10.13182/T130-44101).