Seismic acceleration demands on nonstructural components attached to elastic and inelastic structures

By Ricardo A. Medina[1] and Ragunath Sankaranarayanan[2]

[1]Assistant Professor, Department of Civil Engineering Department, University of New Hampshire, Durham, NH 03824 U.S.A. ricardo.a.medina@unh.edu

[2] Structural Engineer, New Plants Engineering, AREVA NP Inc., Charlotte, NC 28262. ragu.sankara@areva.com

The seismic design and evaluation of nonstructural components (NSCs) in nonhazardous facilities have received increased attention during the last two decades. Practitioners and researchers have recognized the importance of mitigating damages to NSCs and systems to reduce economic losses and maintain functionality after an earthquake. Failure of NSCs during earthquakes may also pose additional life-threatening hazards to building occupants. The elastic floor response spectrum (FRS) is used in seismic analysis and design to represent the peak acceleration demands exhibited by acceleration-sensitive components. Resonance caused by tuning of the frequency of vibration of the component with the natural frequencies of the primary structures is represented by broadening of the peaks of the FRS to account for uncertainties in the determination of frequencies of vibration and develop design FRS. However, when the frequency of vibration of the equipment is, for example, between the two initial modal frequencies of vibration of the primary structure, inelastic behavior of the primary structure may increase the peak component acceleration demands. If the primary structure is designed to exhibit inelastic behavior, FRS based on elastic analysis may underestimate the strength demands for attachments and connections between equipment and primary structures. This paper summarizes work conducted by the authors on the quantification of a proposed acceleration-response modification factor (R_{acc}) useful to estimate the seismic demands imposed on acceleration-sensitive NSCs attached to inelastic moment-resisting frames and structural wall systems exposed to far-field and near-field ground motions. The proposed R_{acc} factor could be used similar to response modification factors for primary structures to scale elastic FRS to obtain estimates of inelastic FRS. In this context, the terms ‘elastic’ and ‘inelastic’ refer to the primary structure, for linear elastic acceleration-sensitive NSCs are used.

Results obtained by the authors demonstrate that FRS amplification due to inelasticity in the primary structure is more predominant for: (1) NSCs located at the bottom stories with fundamental periods of vibration, T_C, smaller than half the fundamental period of the primary structure, T_{B1}, $T_C / T_{B1} < 0.5$; (2) NSCs with small damping ratios (less than 5%); and (3) primary structures with concentrated inelasticity, as opposed to those that exhibit spread of inelasticity along the height. This latter observation is particularly relevant in the context of structures designed such that inelastic action is confined at the bottom of the structure only. It was also observed that the magnitude of FRS amplification reduces with an increase in the fundamental period of the building. In the region $T_C / T_{B1} \geq 1$, R_{acc} is typically greater than unity and is primarily dependent on the level of inelasticity of the supporting structure. Thus, the proposed R_{acc} factor is a function of the location of the NSC, its damping ratio and period of vibration, as well as the fundamental period of vibration of the primary structure and its level of inelastic behavior. Statistical models for R_{acc} are evaluated and proposed herein and the potential application of these models to seismic design and evaluation of NSCs is discussed.