Determination of the response modification factor for precast RC moment-resisting frames

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Abstract
In the process of designing a typical structure, due to the concept of overstrength, it is assumed that the structure is able to dissipate the seismic energy through inelastic behavior. So as not to overestimate the seismic loads, which results in overdesigned members, the applied loads should be divided by a factor named as “response modification factor” or “R factor.” With respect to precast structures, most of the design codes have not proposed a specific response modification factor and much more research must be conducted. In this paper, three different types of structures are designed in the common way and also modeled by the use of a simplified model (including beams, columns, and springs) in the software Abaqus. Several nonlinear static (pushover) and nonlinear dynamic time-history analyses are performed using the horizontal components of real earthquakes. Afterwards, the seismic behavior of precast reinforced concrete (RC) moment-resisting frames are investigated. The response modification factors of the designed structures are calculated from the results of the nonlinear static analyses. The results of the nonlinear dynamic time-history analyses are also used to determine the R factors. Finally, a comparison is drawn between both of these methods. Eventually a response modification factor of 6 is suggested for these kinds of structures.

Keywords: Precast connections, Reinforced concrete frames, Pushover analysis, Nonlinear time-history analysis, Response modification factor.

1. INTRODUCTION

Precast concrete saves time and money as well as providing for higher quality of structural members. In recent earthquakes, concrete structures have suffered major damages and this has proved the low efficiency of connections in these structures (PCI, 1992; PPCI, 2007).

In fact, connections are the weakness points in precast structures’ behavior when subject to bending moments, axial loads, and shear stresses. During the construction operation, the connection points of precast members create weakness points that lower the stiffness of the connection and this causes substantial local deformations in these points when major earthquakes occur (Khoo, Li, & Yip, 2006). Due to the precast connections’ weakness in absorbing and distributing energy and their inadequate resistance, precast structures are rarely built in regions with high probability of seismic events. Furthermore, some design codes prohibit their construction in such regions (Korkmaz & Tankut, 2005).

Precast concrete structures have many advantages including fastness of construction, better control quality, and less on-site construction (Ochs & Ehsani, 1993). Field studies on earthquakes in Northridge (1994), Kobe (1995) and Wenchuan (2008) and their effect on precast concrete structures showed that these structures fail in such devastative events (Korkmaz & Tankut, 2005). Therefore it is necessary to evaluate the seismic behavior of precast concrete frames that are built in places with high probability of seismic events (Xue & Yang, 2010).

In order to investigate the dynamic behavior of beam-column connections, researchers firstly categorize the connection in terms of dimensions. In peripheral frames the complexity of design and construction of connections is less than in middle frames. For this reason the majority of studies consider connections in peripheral frames (Ertas, Ozden, & Ozturan, 2006).

With the onset of powerful computers and the possibility of solving numerous heavy and complicated mathematical equations, researchers began to write computer programmes that enabled computers to solve complicated mathematical equations for various physical phenomena. Among these phenomena are the structures’ behavior when subject to various loadings. Although laboratory methods give us exact answers there are problems such as the concrete members’ volume, size, and shape, remaking and controlling exact