Three-Dimensional Non-Linear Analyses of Special Reinforced Concrete Moment Frames

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Abstract

The design of special reinforced concrete moment frames (SMFs) requires the consideration of both strength and stiffness. SMFs are proportioned and detailed to allow for extensive inelastic deformations, but most frames are designed using elastic (or modified elastic) two-dimensional models. Two concepts not included in design are the increased lateral stiffness of axially loaded compressive columns (and by contrast, the loss of stiffness of columns in tension) and the increased displacement of leeward columns due to concrete beam elongations. In this paper, shear-force distribution between columns and corresponding beam elongations will be presented using three-dimensional non-linear finite element analyses (3DFEAs). Analyses include load-to-displacement results and associated changes in beam stiffnesses from the 3D-FEA and compare those results to two-dimensional finite element analyses.

Keywords: bridge; building; column; ductility; earthquake-resistant; flexural strength; shear strength.

1 Introduction

As engineers move to performance-based design, there is a need to more closely replicate the state of damage that would occur at higher levels of ductility. When special reinforced concrete moment frames (SMFs) are designed the significance of both strength and stiffness must be taken into consideration. While SMFs are proportioned and detailed to allow for extensive inelastic deformations, most SMF are designed using elastic (or modified elastic) two-dimensional models. Two concepts that should be included in design are the increased lateral stiffness of axially loaded compressive columns (which conversely involves a significant loss of stiffness for columns in tension) and increased displacements of leeward columns (the columns farthest in the direction of the applied load) due to concrete beam elongations.

While it is widely known that columns loaded in axial compression are stronger than columns in axial tension, the compressive columns also have an increased stiffness, which changes the proportionality of the shear-force distribution within the concrete frame. In the case of moment frames, the increase in stiffness in compressive columns exceeds the augmentation in column strength, so that the net effect is that columns under higher compression are the most vulnerable to shear forces.

To characterize the shear-force distribution between columns, a quasi-static concrete frame simulation was reviewed using a three-dimensional non-linear finite element analyses (3D-FEA). The simulation indicates that at higher drift levels, the shear-force distribution among the columns changes and strain hardening of the steel reinforcement takes place. Similar to a weak storey (where a large share of the building drift

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