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Discussion: Analysis of reinforced concrete frames subjected to column loss

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Kim and Yu (2012) used fibre-based beam elements to analyse reinforced concrete (RC) frames subjected to column loss and assumed that beam–column connections had adequate strength to sustain the catenary force induced in beams at large deformations. Accordingly, fracture of longitudinal bars was not considered. Therefore, adequate strength or rotation capacity of beam–column connections is the critical assumption to obtain the conclusion that catenary action is proportional to the amount of reinforcement.

The frames in the parametric studies were designed with and without seismic loads in accordance with ACI 318-02 (ACI, 2002). With seismic loads, the beams were designed with larger cross-sections, greater reinforcement ratios and continuous top and bottom bars throughout the entire beam spans. Without seismic loads, the beams were designed with smaller cross-sections and discontinuous bottom bars in the beam–column joints. In fact, this non-seismic design violated the integrity requirements for reinforcement in section 7.13 of ACI 318-02 (ACI, 2002), but can be regarded as old-fashioned non-seismic detailing. Under the same gravity loads, the performance of non-seismic-designed frames is definitely inferior to that of seismic-designed frames against progressive collapse. Therefore, in earthquake-prone regions, the design against seismic loads will benefit structural resistance against progressive collapse. However, in non-seismic regions, it may not be economic to design a building by artificially introducing seismic loads since progressive collapse is a rare event. Therefore, it is necessary to seek other alternatives.

A high volume ratio of stirrups is one of the features of seismic detailing. In the parametric analysis considered, the authors converted the effect of stirrups into the confinement to concrete. That is, a higher volume ratio of stirrups results in greater compressive strength and ductility of concrete in the compressive arch phase. In this way, the reduced amount of stirrups corresponds to earlier mobilisation of catenary action or earlier termination of compressive arch action. However, severe cracking and very small compression zones at the joint interfaces have been observed in sub-assemblage tests (Yu and Tan, 2011), in particular for fewer tension bars than compression bars at beam–column joint interfaces, so the confinement from stirrups may not work effectively. The author of this contribution also found that, with similar longitudinal reinforcement and geometric dimensions of specimens, the structural responses of specimens (i.e. load–deflection history) with and without seismic detailing were very close. This indicates that the confinement from stirrups was not so effective.

In summary, seismic design that introduces seismic loads will enhance structural resistance against progressive collapse. However, seismic detailing in terms of a high volume ratio of stirrups may not be so effective for RC beams resisting progressive collapse provided that the structural resistance governed by shear failure is greater than that by flexural failure. If catenary action is expected to mitigate progressive collapse, the rotation capacity of beam–column connections should be considered.

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