Effect of Axial Load Redistribution in Progressive Collapse of Existing R/C Structures

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Extended Abstract

Loss of axial load capacity of vertical reinforced concrete (R/C) elements, through disintegration of their poorly confined concrete core, has been shown through post-earthquake reconnaissance to be one of the most common reasons of vertical progressive collapse of older R/C frame buildings (Ghannoum et al. 2008). The vertical loads previously carried by a failing member are subsequently redistributed to neighbouring vertical elements. Therefore, the ability of a framing system to resist progressive collapse in such a scenario hinges on both the ability of horizontal elements to transfer the loads being redistributed to adjacent vertical elements and the latter's ability to resist them without considerably losing their strength and deformability (Lodhi 2012).

Existing research work has looked extensively into the adjacent horizontal elements' capacity to redistribute the vertical loads, but not so much into the neighbouring vertical elements. Even when vertical elements were of concern, these were taken into account as undamaged structural members; this is appropriate for blast-induced or similar collapse scenarios, where damage can be largely assumed localised on one or a small set of structural elements. Nevertheless, earthquake-induced collapse scenarios pose a further difficulty in that there is global damage in a large part of, if not the entire, building even before the loss of a column's vertical load-bearing capacity. Therefore, the neighbouring columns' damaged state has to be appropriately taken into account in a realistic progressive collapse assessment.

Previous studies looking into the non-linear response of substandard R/C columns have looked extensively into the response under constant vertical load or variable axial load corresponding to a corner column's case (e.g. Moehle's and Yoshimura's experiments just around the turn of the millennium, Lynn et al. 1996; Yoshimura & Yamanaka 2000; Yoshimura & Nakamura 2002; Yoshimura et al. 2004; Sezen & Moehle 2006). Recently, Nakamura & Yoshimura (2014) investigated the effect that decreasing axial load has on the lateral non-linear response of substandard columns, thus simulating the response of a column that starts failing axially and its axial load starts decreasing correspondingly. Nonetheless, the effect of the vertical load redistribution on the neighbouring R/C columns has not been investigated at all, thus far (Figure 1).

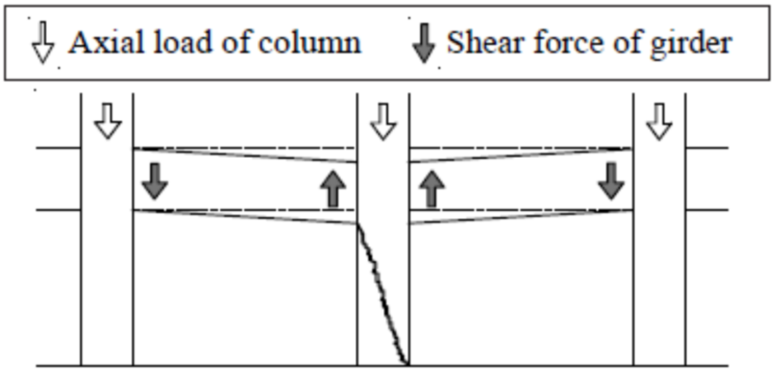

Figure 1: Mechanism of axial load increase of columns neighbouring an axially failing column. (taken from Nakamura & Yoshimura, 2014)

A series of tests was carried out in the frame of the present study, wherein the effect that increasing axial load has on the non-linear (and especially on the post-peak) lateral response of substandard R/C columns is investigated. Two sets of three geometrically and materially identical columns with different reinforcement characteristics were designed, constructed and subsequently tested in cyclic unidirectional quasi-static loading; the experimental set-up can be seen in Figure 2. The specimens are short columns with an aspect ratio of around 3.0, representative of older construction. The axial load is increased by 50% shortly before or just after the onset of shear failure, with a view to investigating the impact on the overall deformability and dissipation capacity of these columns. A base-line specimen for each set is tested with constant axial load.

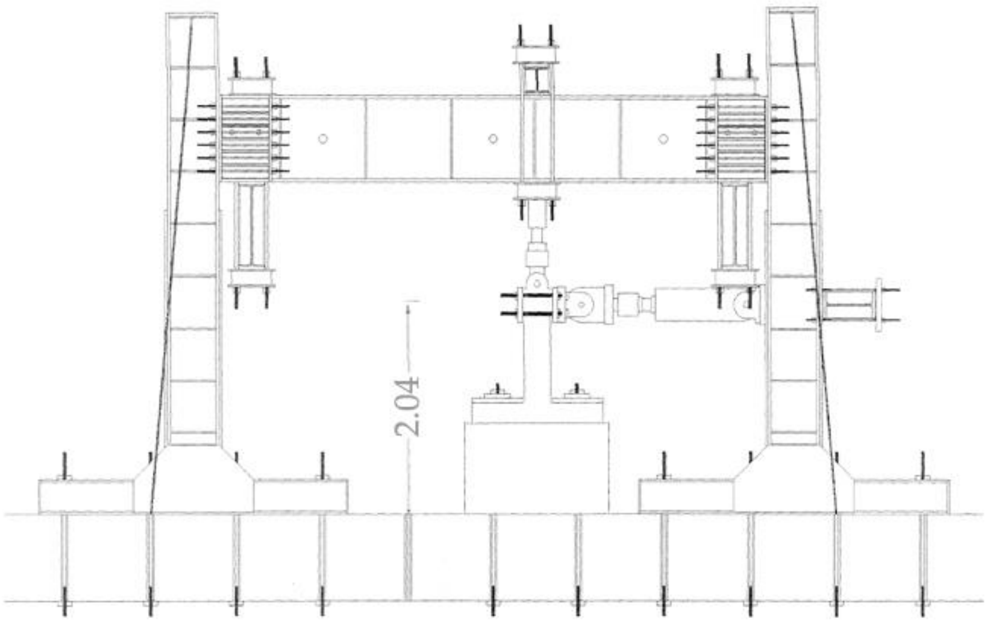

Figure 2: Experimental set-up shown schematically.

To supplement the conceptual and actual design of the experiments that is laid out herein, comparative predictive analyses are performed, to approximate the expected behaviour of the specimens. One of them is carried out using a spread-inelasticity line element previously proposed by the authors using the software IDARC2D. The other one is a 3D finite element analysis performed using the ATENA 3D software. Their results are compared and seem to be close up to the peak point, but differences are found in the remainder of the response.

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