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FUTURE DIRECTIONS FOR REINFORCED CONCRETE BUILDINGS IN EUROCODE 8

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The current Eurocode 8 (EC8) was largely driven by considerations on reinforced concrete (RC) construction (Fardis, 2013). This is reflected in the number of pages dedicated to the guidelines for RC buildings in EC8-Part 1 (CEN, 2004) as well as in EC8-Part 3 (CEN, 2005), which are significantly larger than for any other structural type. From all structural types, the RC guidelines of EC8-Part 1 and 3 are therefore probably the most complete and contain many approaches that are internationally leading (Booth and Lubkowski, 2012). Future directions should focus on keeping this cutting edge approach. At the same time the code should become as user friendly as possible (Booth and Lubkowski, 2012). It is the author's opinion that this is best achieved by finding a good balance between simplicity and accuracy and by making underlying engineering models transparent. The following points outline some aspects that from the author's point of view might call for some thoughts in future revisions of the code. The list is certainly not complete and input on further points is sought from the reader.

It is expected that in future versions of Eurocode 8 displacement-based assessment approaches will be reinforced and displacement-based design approaches introduced. For an effective and robust implementation, limits on engineering demand parameters are required that allow to describe the different limit states in terms of displacement demands for all configurations of RC elements. EC8-Part 3 contains already displacement capacity equations for a large range of element configurations such as elements with and without lap splices in the plastic zone and smooth or deformed bars. Such equations need to be continuously refined and validated against new research; a first revision of these equations is already available (CEN, 2013). The further development of these equations should aim at (i) developing limits for engineering demand parameters for new limit states that are introduced in future versions of the code; (ii) reducing the variability of the predicted to observed displacement capacity and quantifying this variability while maintaining at the same time a good balance between simplicity and robustness, (iii) reinforcing mechanical approaches for the prediction of the displacement capacity as they can be extrapolated to element configurations where the data basis is very thin, such as core walls, (iv) addressing the displacement capacity of degrading systems considering realistic cumulative damage demands. Many quasi-static cyclic tests on RC elements applied significantly more cycles than elements in regions of low to moderate seismicity might undergo (Mergos and Beyer, 2014).

EC8-Part 3 opted for the chord rotation as engineering demand parameter for the displacement demand, which is in particular suitable for nonlinear static analysis of equivalent frame models. As nonlinear time history analysis and more complex membrane, shell or solid element models might become common in seismic analyses, future codes might reconsider the application of other, more local engineering demand parameters as, for example, strains knowing, however, that such engineering demand parameters call for advanced regularisation techniques before they can be used for seismic assessment (Bazant, 1976).

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One of the most successful concepts in improving the robustness and collapse prevention of structures is the capacity design principle (Park and Paulay, 1976). It is also the basis of ductile design provisions in EC8-Part 1. Crucial elements of this approach are the flexural strength evaluation of plastic zones and the effect of higher modes on shear demands. Future research needs to strengthen this successful concept by addressing the following points: (i) evaluation of higher mode effects in wall structures other than cantilever walls on which current shear amplification factors are based (Sullivan, 2010; Fox et al., 2014; Rejec et al., 2014), (ii) capacity design rules for core walls (Reynouard and Fardis, 2001), (iii) effect of the out-of-plane strength of slabs on the flexural strength of coupling beams as well as on the axial force in columns and walls, (iv) capacity design of flat slab systems (Fardis, 2013) including prediction of design forces in slabs and slab-wall interfaces; (iv) capacity design actions in RC frames in regions of low to moderate seismicity where typically a full sway mechanism does not form.

The recent earthquakes in Chile and New Zealand revealed unexpected failure modes that relate to compression and out-of-plane failure of RC walls (Wallace et al., 2012; Kam et al., 2011). Some of these failure modes might have surfaced as other—more disastrous failure modes—such as shear failure of RC walls were avoided through the implementation of capacity design rules in previous versions of codes (Sritharan et al., 2014). Research needs to judge whether the design provisions of EC8-Part 1 can avoid such failure modes and whether EC8-Part 3 can predict these failure modes—the larger challenge being clearly related to the latter. Such critical evaluations of the capabilities of the design and assessment codes are required whenever new failure modes surface in seismic events.

Furthermore, the code should include provisions for new structural systems constructed from RC elements that have the potential to reduce damage and therefore costs, in particular also during small and frequent events. Such systems can be, for example, post-tensioned rocking systems (e.g. Priestley, 2000) or fibre reinforced concrete elements (e.g. Parra-Montesinos et al., 2012) but also the design practice of classical RC elements can be re-evaluated aiming at reinforcement details that limit, for example, crack widths in small events (Sritharan et al., 2014). New versions of the code should also account for the fact that real construction might result in mixed structures, such as the classical RC wall-frame structure but also across building materials, such as RC walls combined with steel frames or load-bearing masonry walls (e.g. Paparo and Beyer, 2014). It is expected that the portion of such mixed structures within the entire building stock will increase in the future (i) due to seismic retrofit interventions, and (ii) because structures might be altered or extended rather than completely new structures built. Such mixed structures are more complex to assess than structures with a single structural system and guidelines of the latter cannot simply be extrapolated to mixed systems.

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