Discussion Forum

Development length of reinforcing bars — Need to revise Indian codal provisions

This has reference to the paper titled "Development length of reinforcing bars — Need to revise Indian codal provisions" by Dr N. Subramanian published in the recent issue[1]. I would like to comment on the following aspects.

It is stated, among many things, that the absence of adequate development lengths of reinforcing bars often results in failures especially in cantilever supports, lap splices and beam column joints.

In case there is an unexpected high-magnitude earthquake, may I presume that the beam-column joint will fail totally? In such cases, if more development length is provided at the joint, as per the current BIS codes, this sort of failure may not be likely to take place due to higher rigidity of the beam at the beam-column junction.

Hence as such, I feel that the existing provisions of Indian code need not be revised for the development length of reinforcing bars.

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The author replies:

I would like to thank Mr. Lakshmanan for his interest in this paper. The main aim of the paper was to show that a number of parameters that affect the development length are not considered in the Indian Code and the provisions have remained unchanged for the past 27 years! Hence, these provisions were compared with those of the American Code, which is revised every three years to reflect the current research undertaken. One more important observation is that the best fit of experiment result is provided by $f_{ck}^{0.25}$ and not $f_{ck}^{0.5}$ as given in both ACI and IS codes. Hence, a formula was suggested to be included in the Indian Code, based on the above observation. This formula could also be modified suitably to take into account the emerging concretes such as high strength, high performance concrete, self consolidating concrete and fibre reinforced concrete. Moreover, the suggested formula is applicable to concretes having strengths up to 100 MPa, whereas the Indian Code provisions are applicable for strength up to 40 MPa only.

Since the discusser has raised a point about anchorage requirements in beam-column joints a brief review is given below about the same. Development length requirements of the flexural reinforcement within a joint of a reinforced concrete moment resistant frame are particularly important. Many structural failures under seismic loading are attributed to poor detailing of beam-column joints[2]. Frequently, joints are the weak links in a frame due to lack of adequate anchorage of bars extending into the joints from the columns and beams. Moreover, when a plastic hinge develops adjacent to a joint, with the beam bars entering the strain hardening range, yield penetration into the joint core and simultaneous bond deterioration is inevitable[3]. Bond loss along a straight bar anchored in an exterior joint would result in complete failure. Therefore, beam bars at exterior joints, which can be subjected to yield in tension during earthquake, should be anchored with a hook or with other means of positive anchorage[4]. Also, anchorage of beam bars should be assumed to begin only at a distance (10 times the bar diameter or half the column depth, whichever is lesser) from the inner column face, well inside the joint core[3,5]. More details about anchorage requirements in beam-column joints subjected to seismic forces are given elsewhere[3-6].

From the above, it is clear that development length requirements in beam-column joints, which are subjected to seismic forces, are more stringent. Moreover, inadequate development length will result in slip and pull-out of the bars, which is not desirable. In any design, the first requirement is safety and hence we should not allow any beam to fail. Failure of beams or partial collapse may lead to deaths or injury. Hence, if proper detailing is adopted, the collapse of building as witnessed in the recent earthquakes in India and Pakistan could be avoided. (It may be of interest to note that similar earthquakes in Japan and USA do not result in huge loss of human life). In a recent paper, Darwin *et al* have shown that the proposed formulae (Equation 9 of the paper) provides better match with the test results than those of ACI 318-05 (that is, more reliable results with less scatter)[7].

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Reference

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5. Key, D. *Earthquake Design Practice for Buildings*, Thomas Telford, London, 1989, pp. 218.
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