Starting from August 2004, *Resonance* is publishing in the Classroom section, a series of short articles, 'Earthquake Tips', related to earthquakes, their effects on civil structures, and design and construction of earthquake resistant buildings. The concepts are clearly explained with sketches and analogies. We hope the *Resonance* readers will benefit from this series of articles.

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Learning Earthquake Design and Construction
19. How do Columns in RC Buildings Resist Earthquakes?

Keywords
Earthquakes, RC buildings.

Possible Earthquake Damage

Columns, the vertical members in RC buildings, contain two types of steel reinforcement, namely: (a) long straight bars (called *longitudinal bars*) placed vertically along the length, and (b) closed loops of smaller diameter steel bars (called transverse ties) placed horizontally at regular intervals along its full length (*Figure* 1). Columns can sustain two types of damage, namely *axial-flexural (or combined compression-bending) failure* and *shear failure*. Shear damage is brittle and must be avoided in columns by providing transverse ties at close spacing (*Figure* 2b).

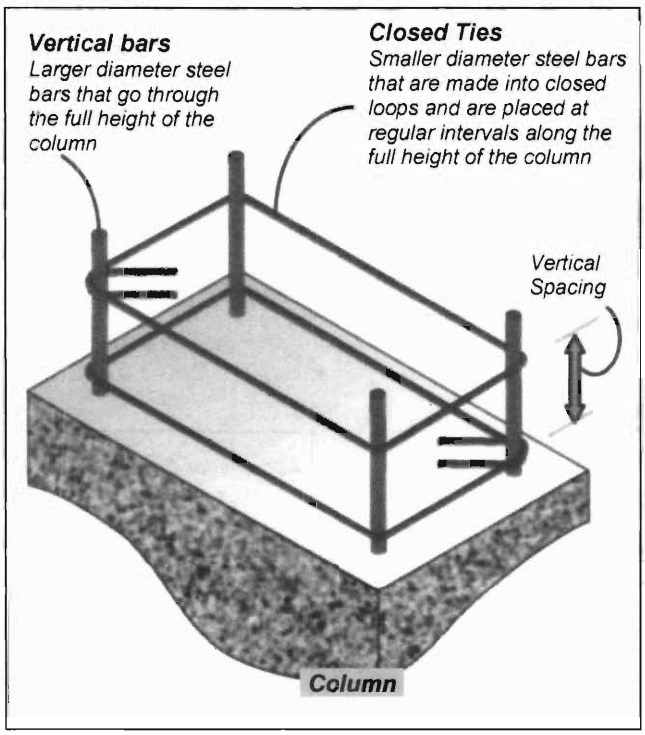

Figure 1. Steel reinforcement in columns – closed ties at close spacing improve the performance of columns under strong earthquake shaking.

Design Strategy

Designing a column involves selection of *materials to be used* (i.e, grades of concrete and steel bars), choosing *shape and size of the cross-section*, and calculating *amount and distribution of steel reinforcement*. The first two aspects are part of the overall design strategy of the whole building. The Indian Ductile Detailing Code IS:13920-1993 requires columns to be at least 300mm wide. A column width of up to 200mm is allowed if unsupported length is less than *4m* and beam length is less than *5m*. Columns that are required to resist earthquake forces must be designed to prevent *shear* failure by a skillful selection of reinforcement.

Vertical Bars tied together with Closed Ties

Closely spaced horizontal closed ties help in three ways, namely (i) they carry the horizontal shear forces induced by earthquakes, and thereby resist diagonal shear cracks, (ii) they hold together the vertical bars and prevent them from excessively bending outwards (in technical terms, this bending phenomenon is called *buckling*), and (iii) they contain the concrete in the column within the closed loops. The ends of the ties must be bent as 135° hooks (*Figure* 2). Such hook ends prevent opening of loops and consequently buckling of concrete and buckling of vertical bars.

The Indian Standard IS13920-1993 prescribes following details for earthquake-resistant columns:

(a) Closely spaced ties must be provided at the two ends of the column

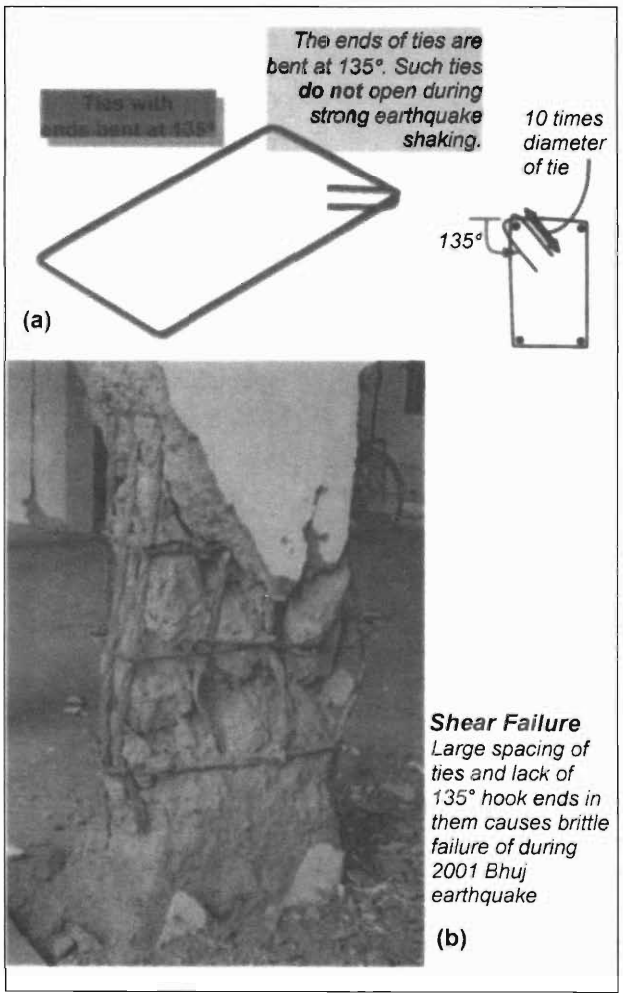

Figure 2. Steel reinforcement in seismic beams – closed ties with 135° hooks are required as per Indian Ductile Detailing Code IS:13920-1993.

over a length not less than larger dimension of the column, one-*sixth* the column height or *450mm*.

(b) Over the distance specified in item (a) above and below a beam-column junction, the vertical spacing of ties in columns should not exceed $D/4$ for where D is the smallest dimension of the column (e.g., in a rectangular column, D is the length of the small side). This spacing need not be less than *75mm* nor more than *100mm*. At other locations, ties are spaced as per calculations but not more than $D/2$.

(c) The length of tie beyond the 135° bends must be at least 10 times diameter of steel bar used to make the closed tie; this extension beyond the bend should not be less than *75mm*.

Construction drawings with clear details of closed ties are helpful in the effective implementation at construction site. In columns where the spacing between the corner bars exceeds 300mm, the Indian Standard prescribes *additional* links with *180°* hook ends for ties to be effective in holding the concrete in its place and to prevent the buckling of vertical bars. These links need to go around both vertical bars and horizontal closed ties (*Figure* 3); special care is required to implement this properly at site.

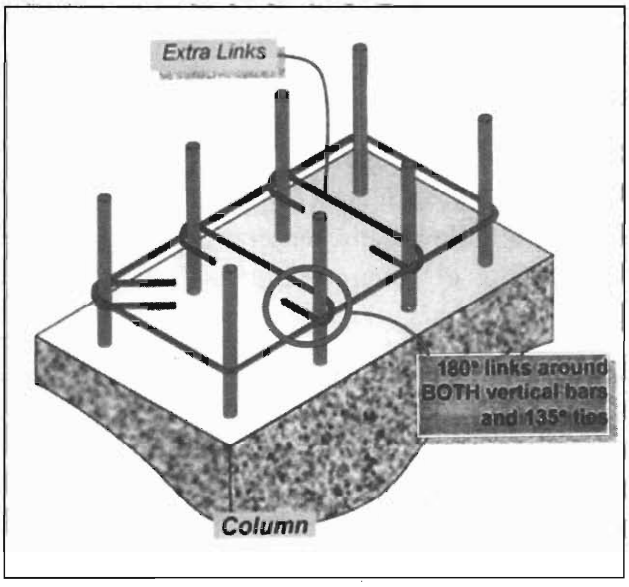

Figure 3. Extra links are required to keep the concrete in place – 180° links are necessary to prevent the 135° tie from bulging outwards.

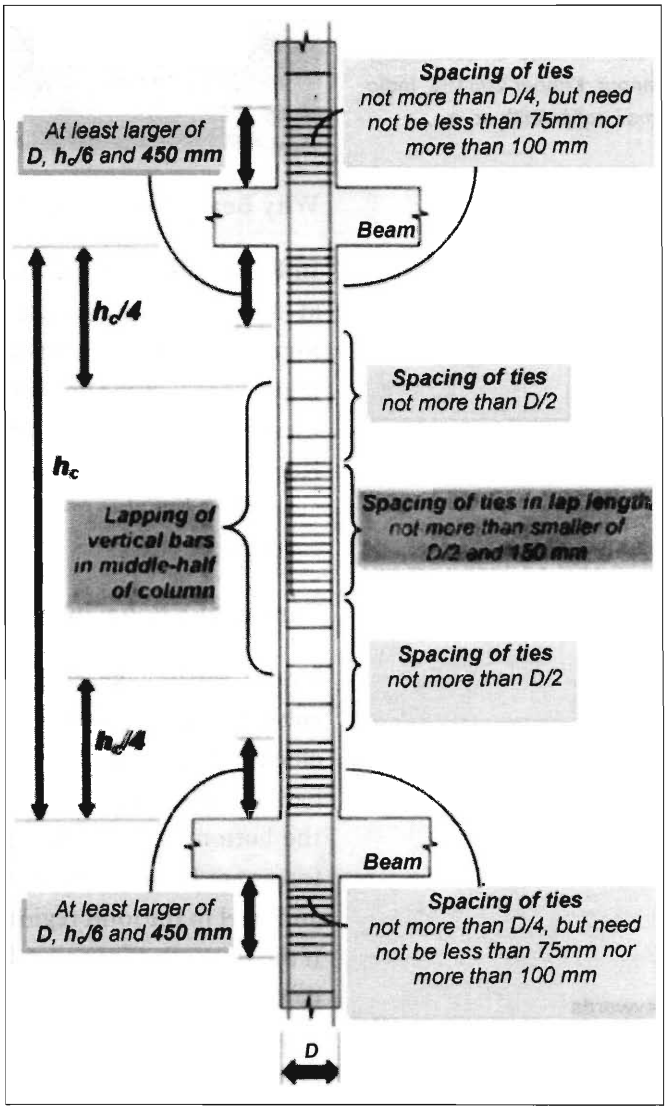

Figure 4. Placing vertical bars and closed ties in columns – column ends and lap lengths are to be protected with closely spaced ties.

Lapping Vertical Bars

In the construction of RC buildings, due to the limitations in available length of bars and due to constraints in construction, there are numerous occasions when column bars have to be joined. A simple way of achieving this is by overlapping the two bars over *at least* a minimum specified length, called *lap length*. The lap length depends on types of reinforcement and concrete. For ordinary situations, it is about 50 times bar diameter. Further, IS:13920-1993 prescribes that the lap length be provided ONLY in the middle half of column and not near its top or bottom ends (*Figure* 4). Also, only half the vertical bars in the column are to be lapped at a time in any storey. Further, when laps are provided, ties must be provided along the length of the lap at a spacing not more than *150mm*.

Suggested Reading

[1] **IS 13920, *Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces*, Bureau of Indian Standards, New Delhi, 1993.**

[2] **T Paulay and M J N Priestley, *Seismic Design of Masonry and Reinforced Concrete Buildings*, John Wiley & Sons, USA, 1992.**

Related IITK-BMTPC Earthquake Tip:

Tip17: How do Earthquakes Affect Reinforced Concrete Buildings?

Tip18: How do Beams in RC Buildings Resist Earthquakes?

Suggestions/comments may be sent to: eqtips@iitk.ac.in.