REINFORCEMENT PLACEMENT

Clear Cover to Main R.I.

S.No.	Member	Cover to Main Reinforcement UOS in mm
1	Foundation/Raft	50
2	Columns	40
3	Retaining wall	25
4	Face of Retaining wall in contact with Earth	40
5	Roof/floor beam	25
6	Shear wall of 230mm thick	40
7	Slab	20
8	Rcc walls of Liquid reatining structure liquid side	40

COLUMNS IN RCC BUILDINGS

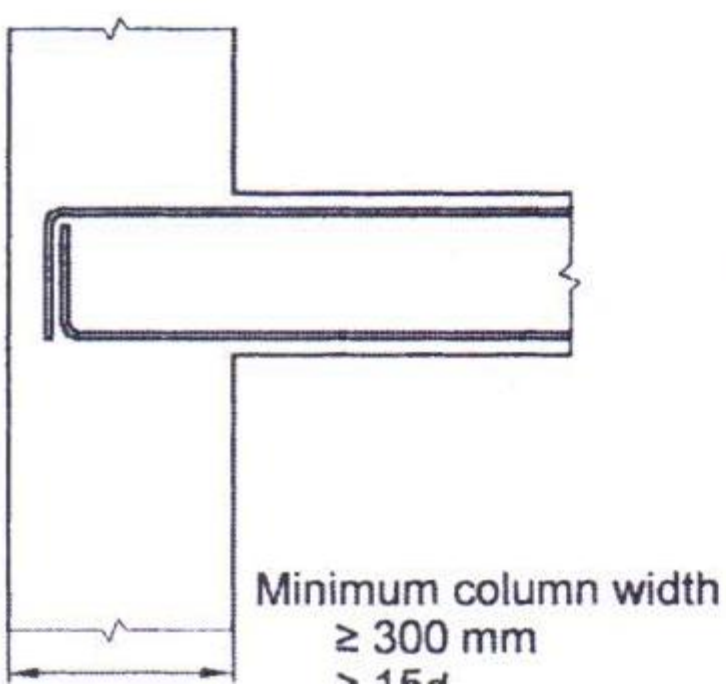
IS 13920:2016

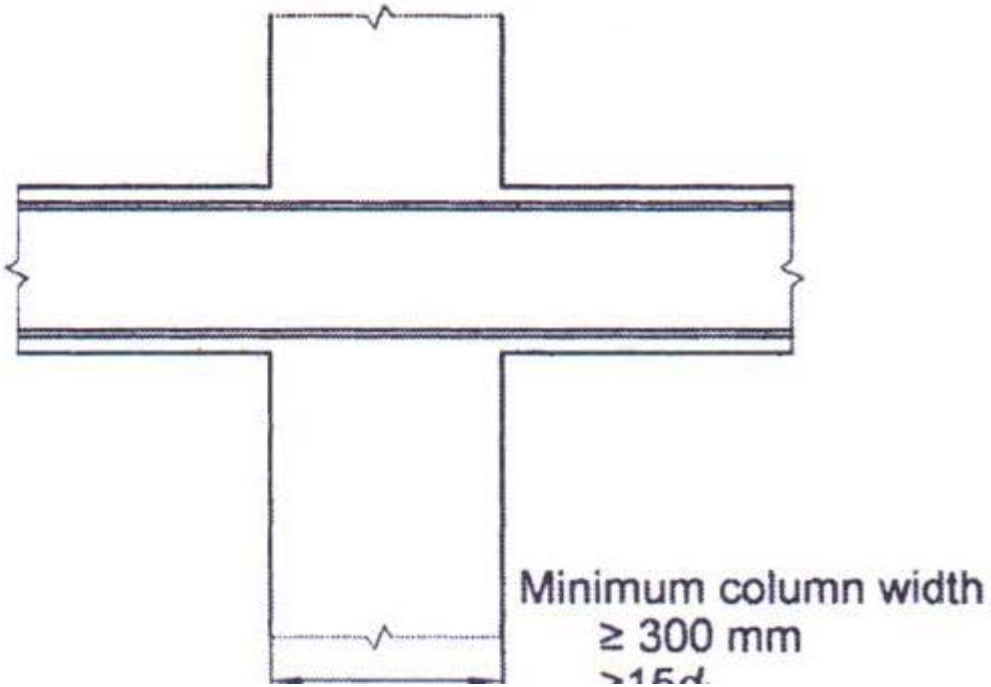
7.1.1 The minimum dimension of a column shall not be less than,

a) 20 d_b, where d_b is diameter of the largest diameter longitudinal reinforcement bar in the beam passing through or anchoring into the column at the joint, or

b) 300 mm (*see* Fig. 7).

COLUMNS IN RCC BUILDINGS





COLUMNS IN RCC BUILDINGS

The Indian Standard IS13920-1993/2016 prescribes following details for earthquake-resistant columns:

- (a) Closely spaced ties must be provided at the two ends of the column over a length not less than larger dimension of the column, one-sixth the column height or 450mm.
- (b) 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.

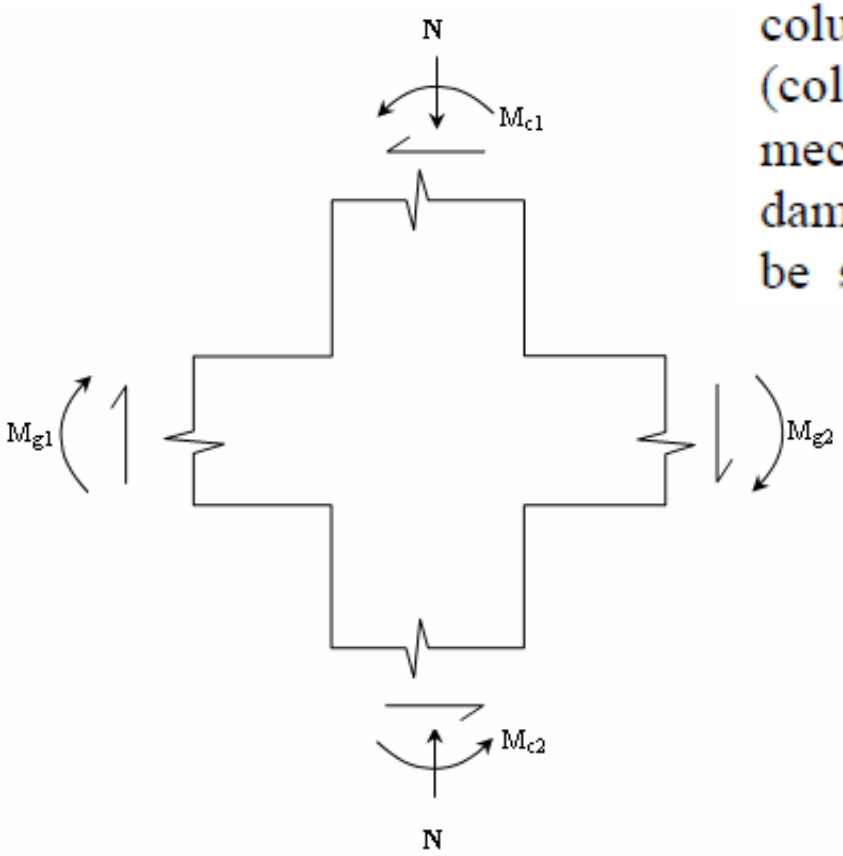
- Minimum grade of concrete shall preferably be M25 > 4 storey or >15m height building in Zone-IV or V (clause 5.2).
- Steel reinforcement of grade Fe 415 or less only shall be used, TMT bar of Fe 500 and 550 can also be used if % elongation is > 14.5% (clause 5.3)
- The minimum dimension of column member shall not be less than 200mm .

➢ For frame which have beam with C/C Span more than 5m or columns whose unsupported length exceeds 4m, the shortest dimension of column shall not be less than 300mm.(clause 7.1.2).

Longitudinal Reinforcement

Weak Beam Strong Column Concept

This clause is based on strong-column weak-beam theory. It is meant to make the building fail in beam-hinge mechanism (beams yield before columns do) and not in the storey mechanism (columns yield before the beams). Storey mechanism must be avoided as it causes greater damage to the building. Therefore, column should be stronger than the beams meeting at a joint.



At least one intermediate bar shall be provided between corner bars along each column face.

$$\sum M_c = M_{c1} + M_{c2}$$

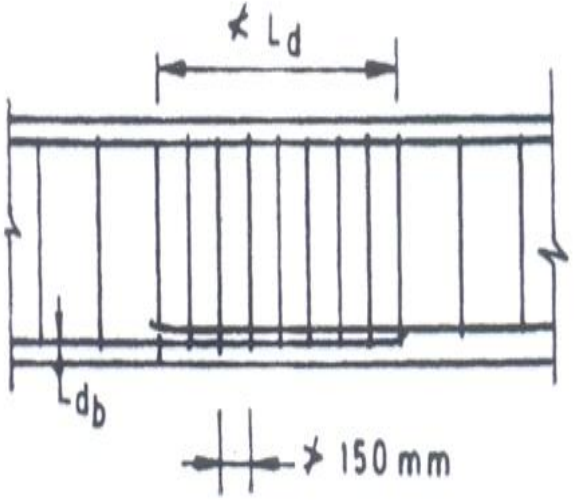
$$\sum M_g = M_{g1} + M_{g2}$$

$$\sum M_c \geq 1.1 \sum M_g$$

R.I. Splicing

- Reinforcement splicing- Splicing is required to transfer force form one bar to another. Methods of splicing include lapping, Welding, mechenical means.
- Splicing should be away from the Section of Maximum Stressed and be staggered.
- Splicing should be avoided in the section where B.M is more than 50% of M.R of the section and not more than 50% of the bar spliced at a section.

Lap splicing

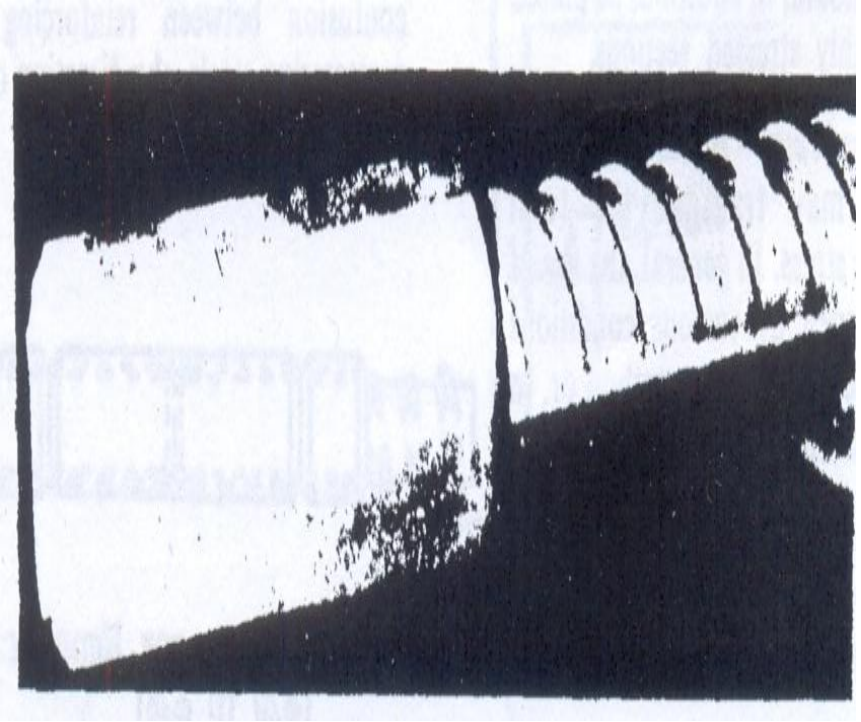


L_d = DEVELOPMENT LENGTH IN TENSION

d_b = BAR DIAMETER

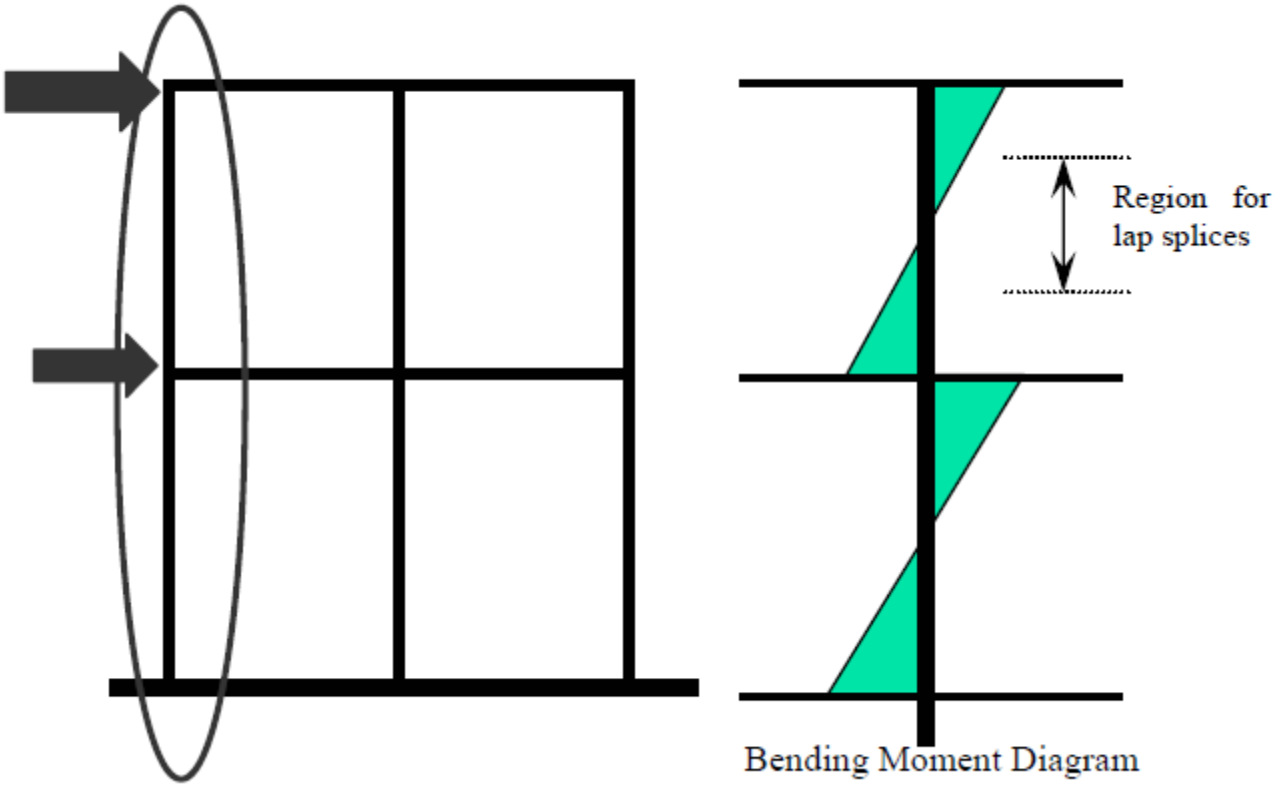
Splice in beam/ column

Splicing by Threaded Couplers (Mechenical Couplers)



Splice in column

Region for Lap Splice



Region for Lap Splice

7.3.2.1 *Lap splices*

When adopted, closed links shall be provided over the entire length over which the longitudinal bars are spliced. Further,

a) the spacing of these links shall not exceed 100 mm.

b) the lap length shall not be less than the development length of the largest longitudinal reinforcement bar in tension.

c) lap splices shall be provided only in the central half of clear column height, and not

   1) within a joint, or

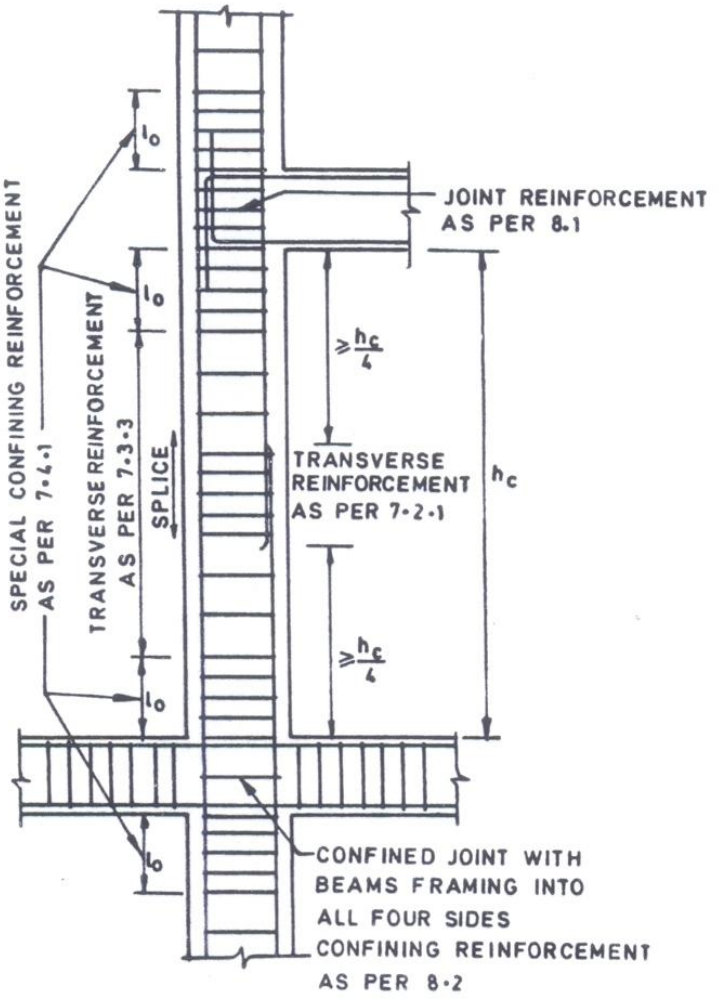
   2) within a distance of $2d$ from face of the beam.

d) not more than 50 percent of area of steel bars shall be spliced at any one section.

e) lap splices shall not be used for bars of diameter larger than 32 mm for which mechanical splicing shall be adopted.

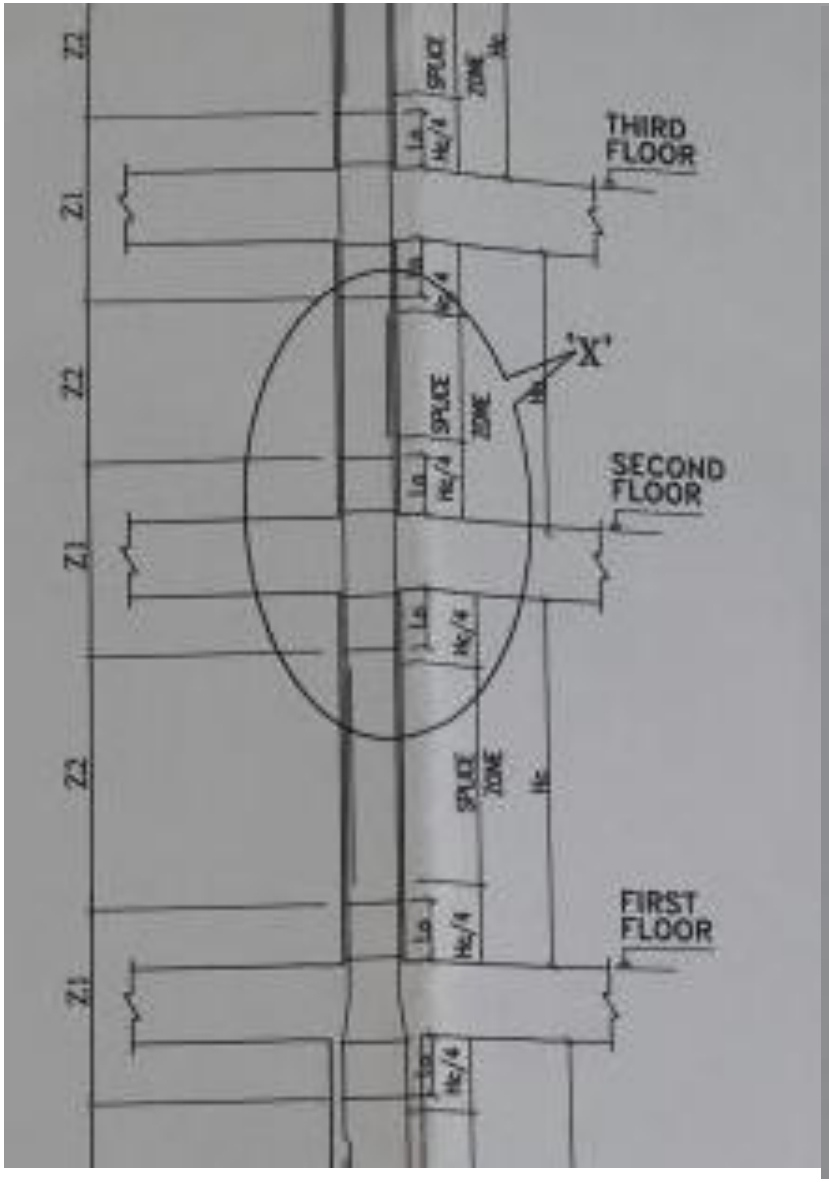
Detailing at Lap Splice

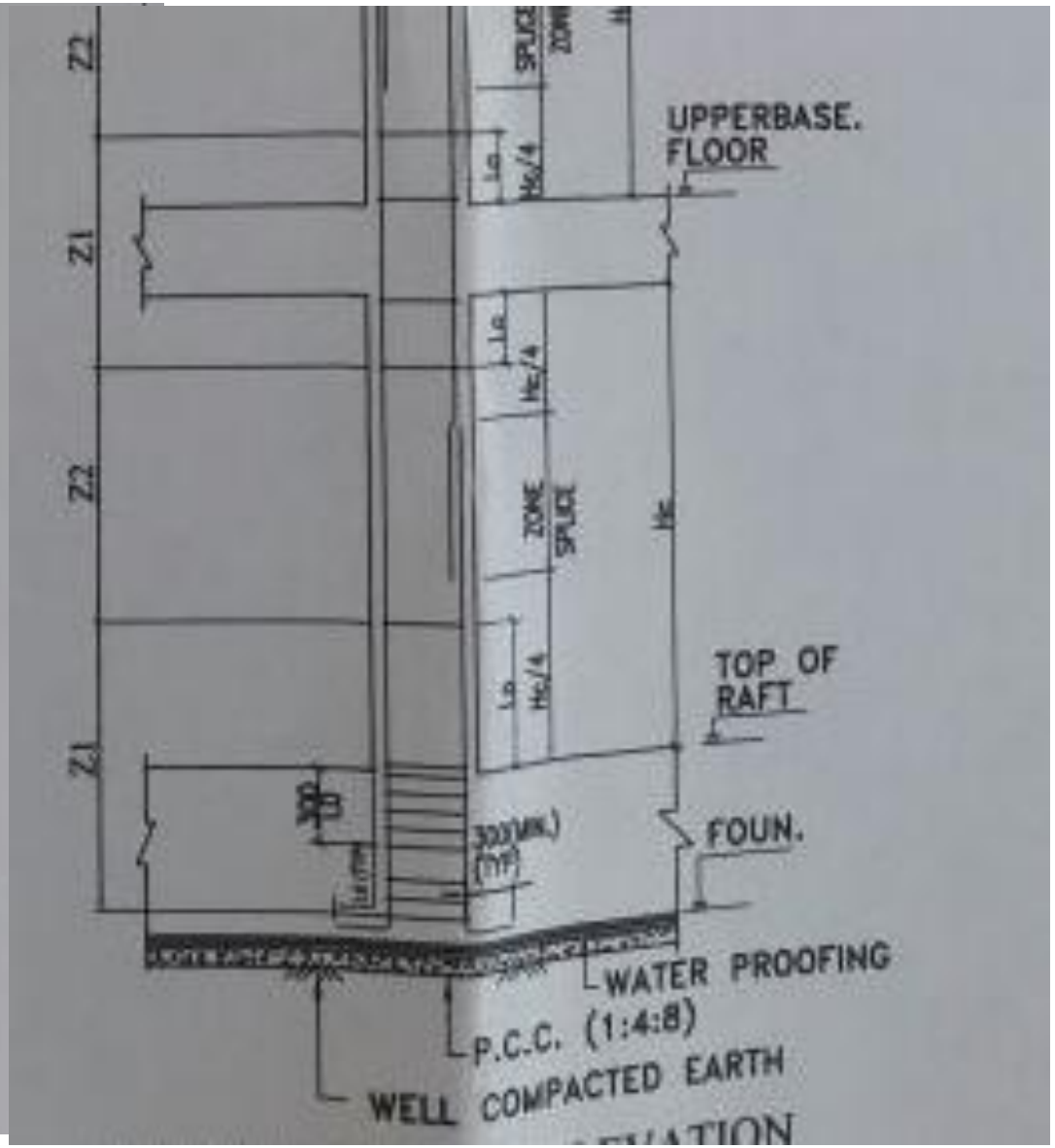
- Lap splice must be provided in central half of the member length.
- Not more than 50 % of bar shall be spliced at one section.
- Lap splices shall be considered as staggered if the centre to centre distance of the splices is> than 1.3 Ld.(IS 456:2000, page 45)
- Iplay is of I IN 6.
- Lap binding @ 2ϕ

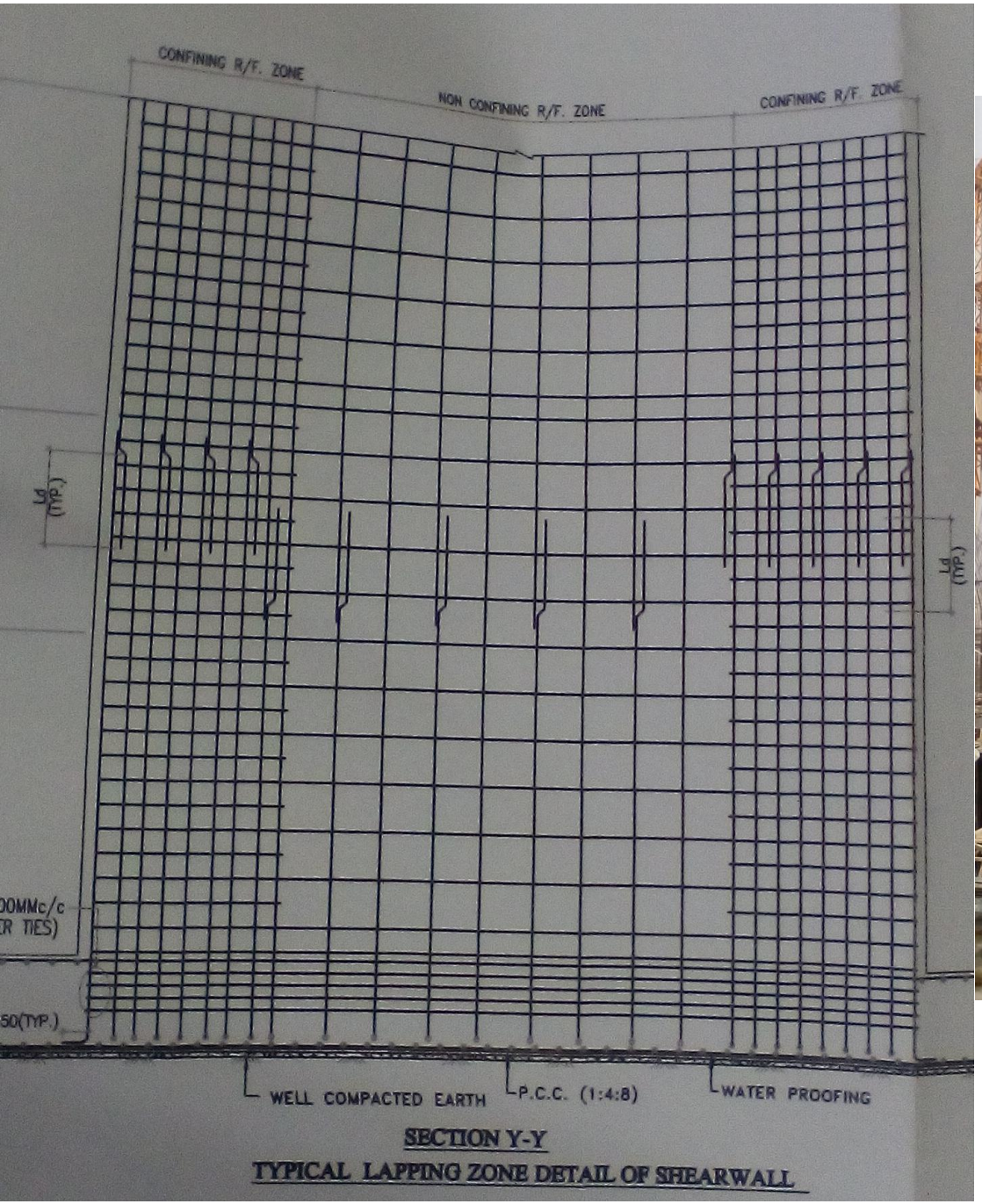


➢When bars of two different diameters are to be spliced, the lap length shall be calculated on the basis of diameter of the largest bar.(IS 1392045:2016

COLUMN ELEVATION







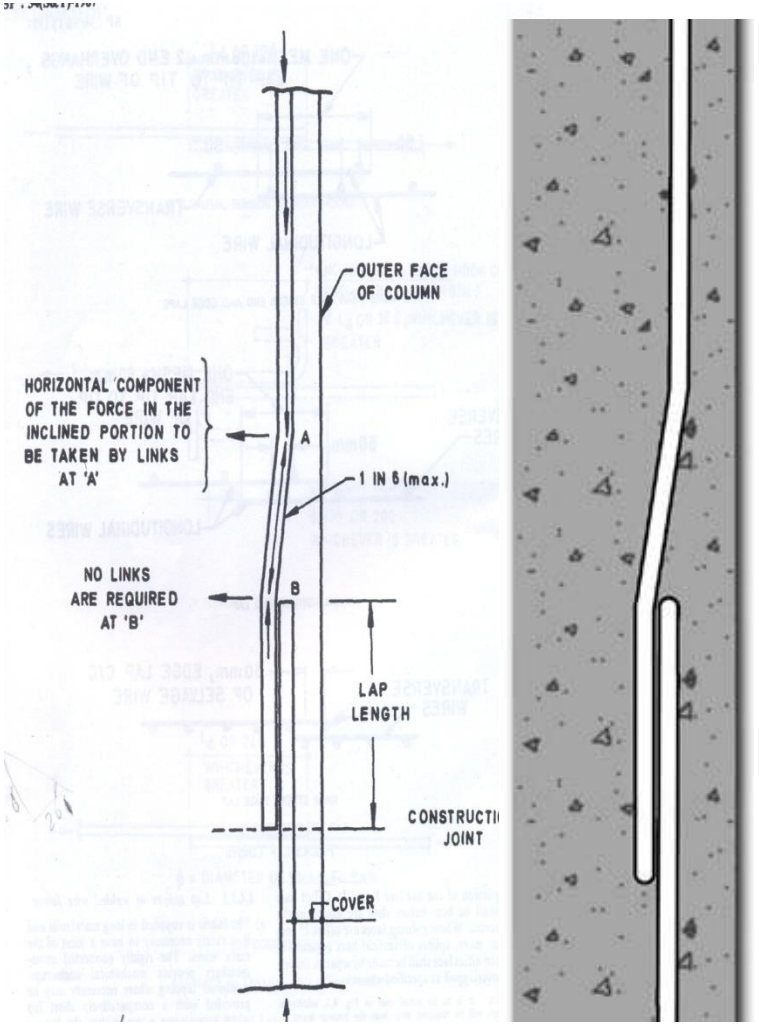
SECTION Y-Y

TYPICAL LAPPING ZONE DETAIL OF SHEARWALL

Lap In Column

Spacing of lateral ties at Lap should not be more than

1. 100mm. (IS 13920: 2016) in 1993 it was 150mm
2. Half least lateral dimension of the column

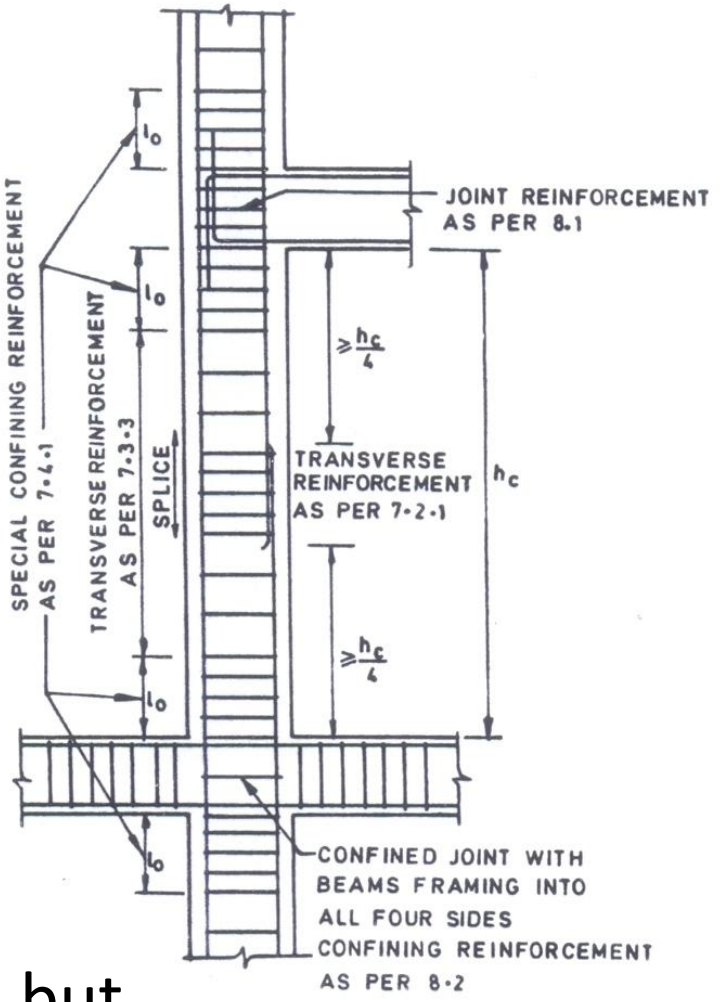


Spliced with offset cranked bar in column

Column Lateral Ties Detailing

Special Confining R.I.

- Closely spaced ties must be provided at the two ends of the column or any section where flexure yielding takes place for a length (Lo)
- Which should be grater of:
  - larger dimension of the column,
  - one-sixth the column height
  - 450mm.



Minimum dia of lateral ties 8mm, but column with longitudinal R.I. dia more than 32 mm it is 10mm (IS 13920:2016 cl 7.4.2)

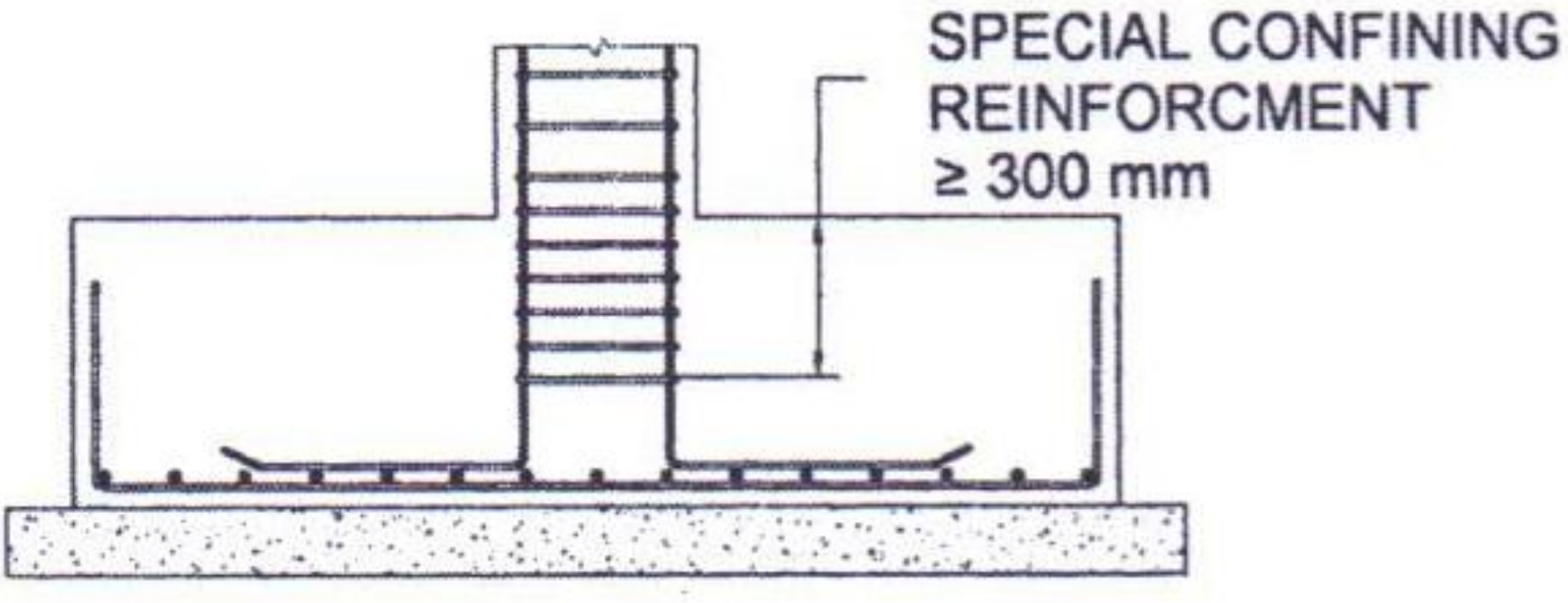
Column Lateral Ties Detailing

b) have a spacing not more than,
   1) 1/4 of minimum member dimension of the beam or column;
   2) 6 times diameter of the smallest longitudinal reinforcement bars; and
   3) 100 mm link.

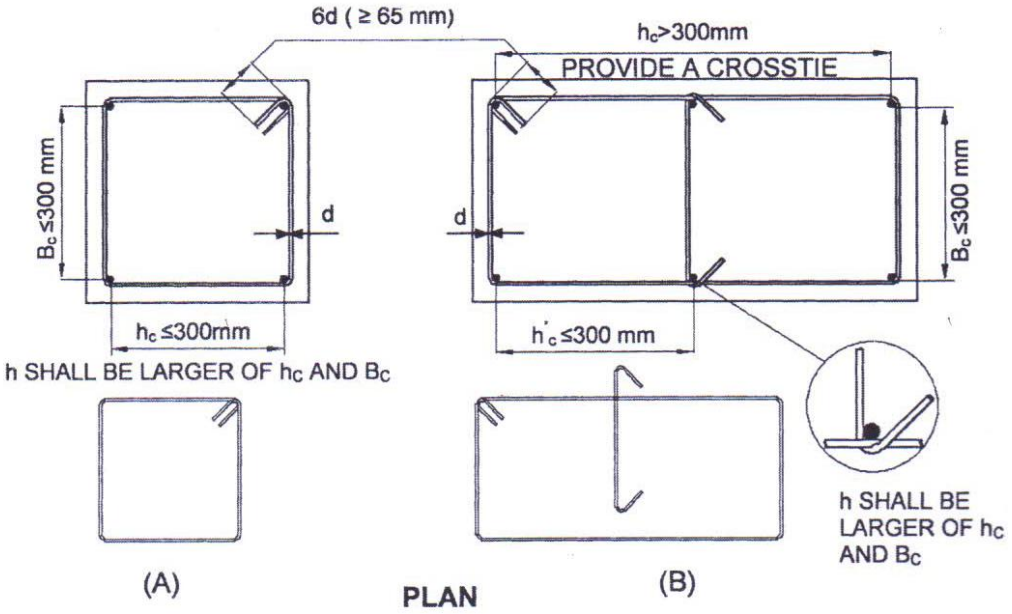
Column Lateral Ties Detailing

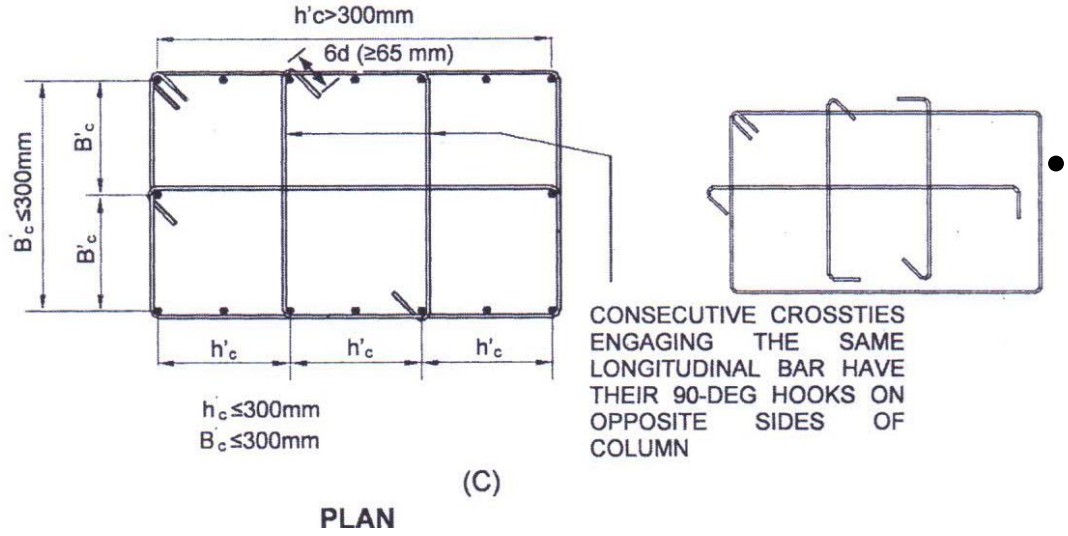
Special Confining R.I.

8.2 When a column terminates into a footing or mat, special confining reinforcement shall extend at least 300 mm into the footing or mat (*see* Fig. 13).



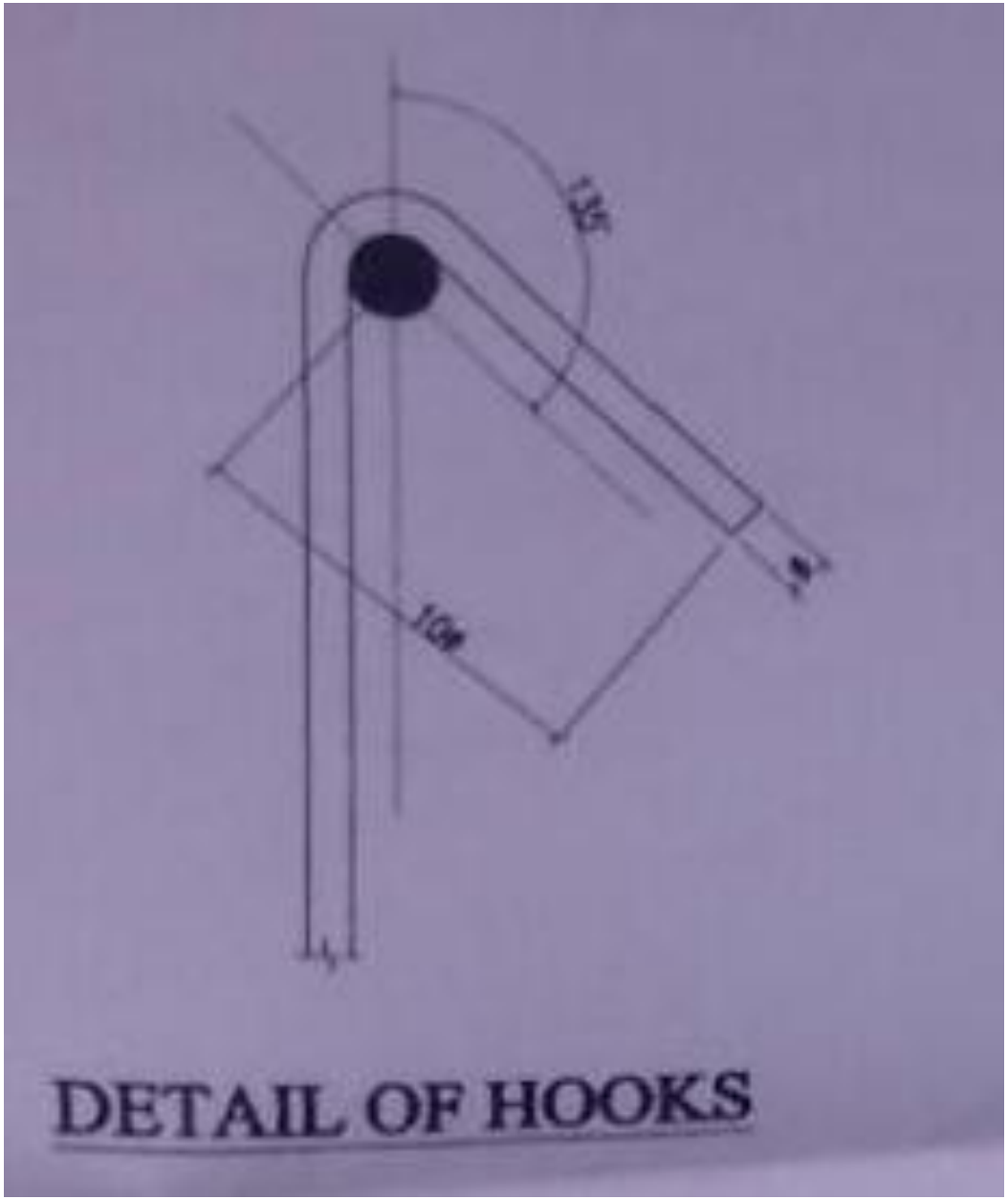
Transverse/ Lateral R.I. in column



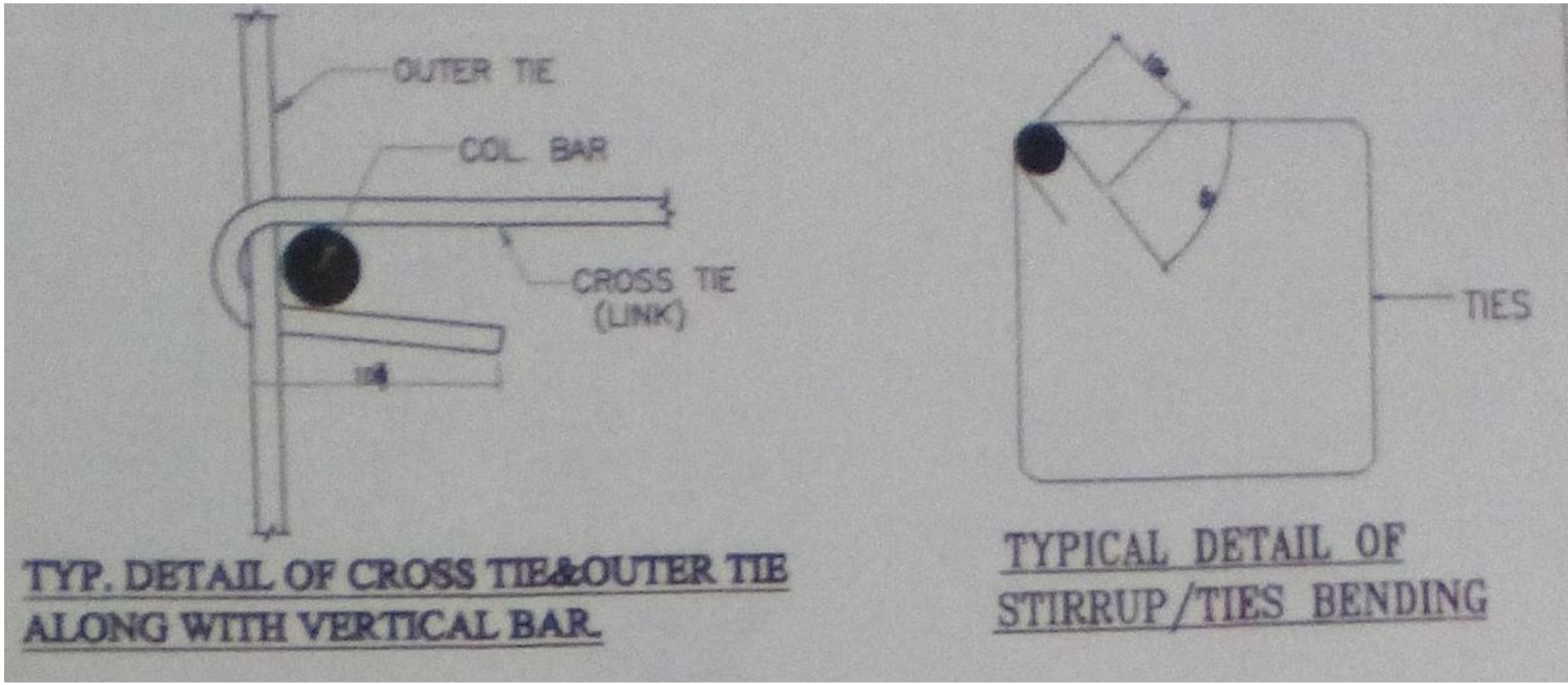


- Hook must be bent at 135^0 with 10 dia extension (but not < 80mm). 6d (13920:2016)
- The c/c distance b/w parallel legs of rectangular ties should not be more than 300mm.
- If it exceeds provide cross ties as shown in fig

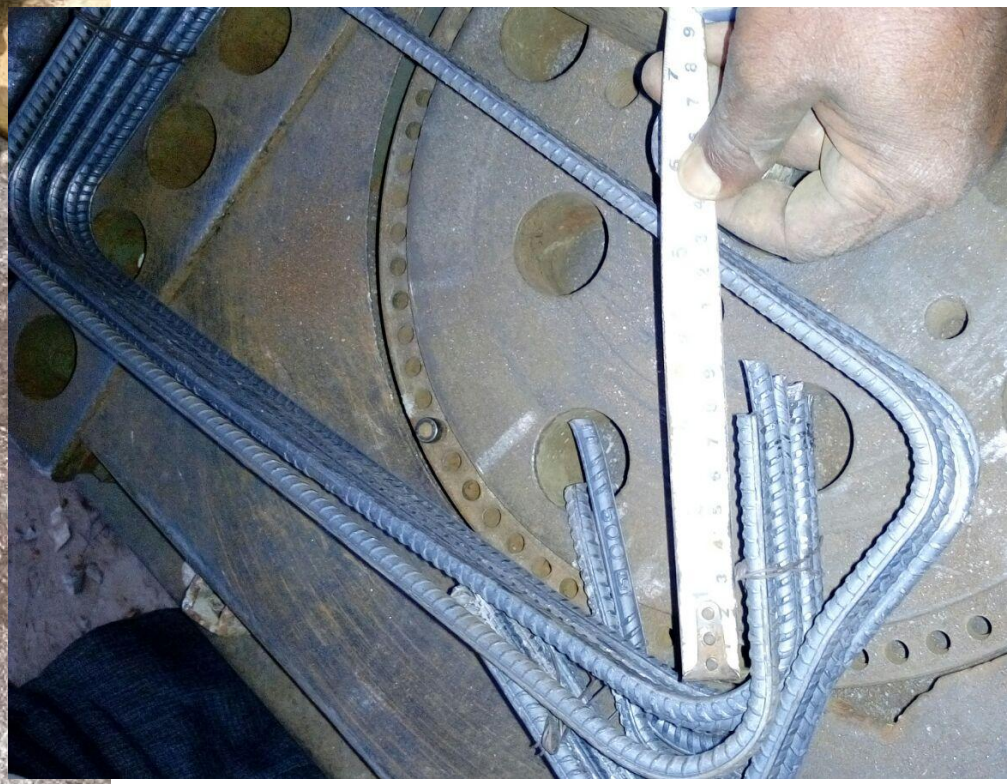
Details of Hooks



Details of Hooks



Details of Hooks



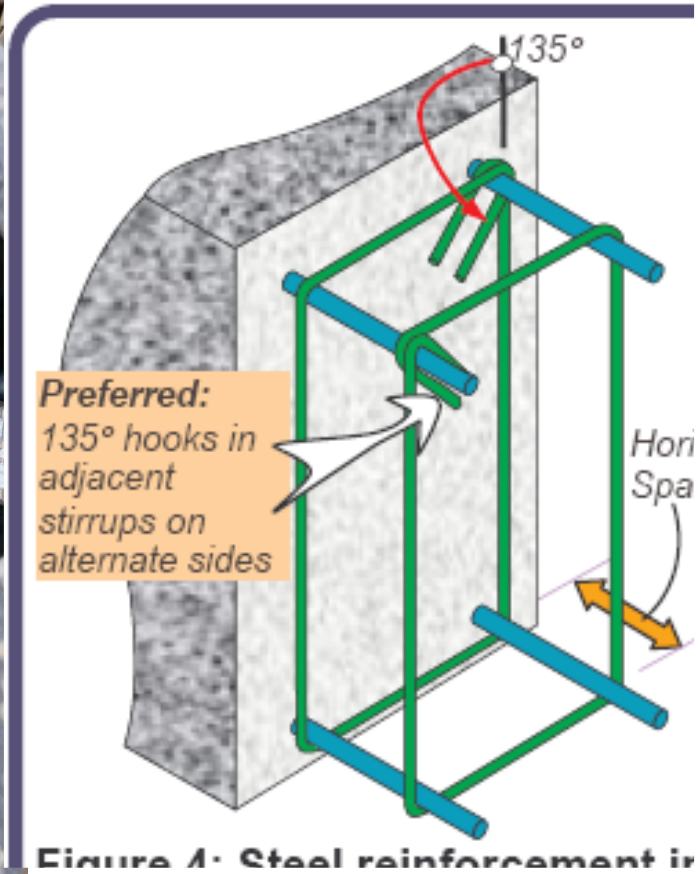


Figure 4: Steel reinforcement ir

Maximum Mandrel diameter for different grade of steel for Bend Test

Sl No.	Nominal Size mm	Maximum Mandrel Diameter for Different Grades								
		Fe 415	Fe 415D	Fe 415S	Fe 500	Fe 500D	Fe 500S	Fe 550	Fe 550D	Fe 600
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	Up to and including 20	3 ϕ	2 ϕ	2 ϕ	4 ϕ	3 ϕ	3 ϕ	5 ϕ	4 ϕ	5 ϕ
ii)	Over 20	4 ϕ	3 ϕ	3 ϕ	5 ϕ	4 ϕ	4 ϕ	6 ϕ	5 ϕ	6 ϕ

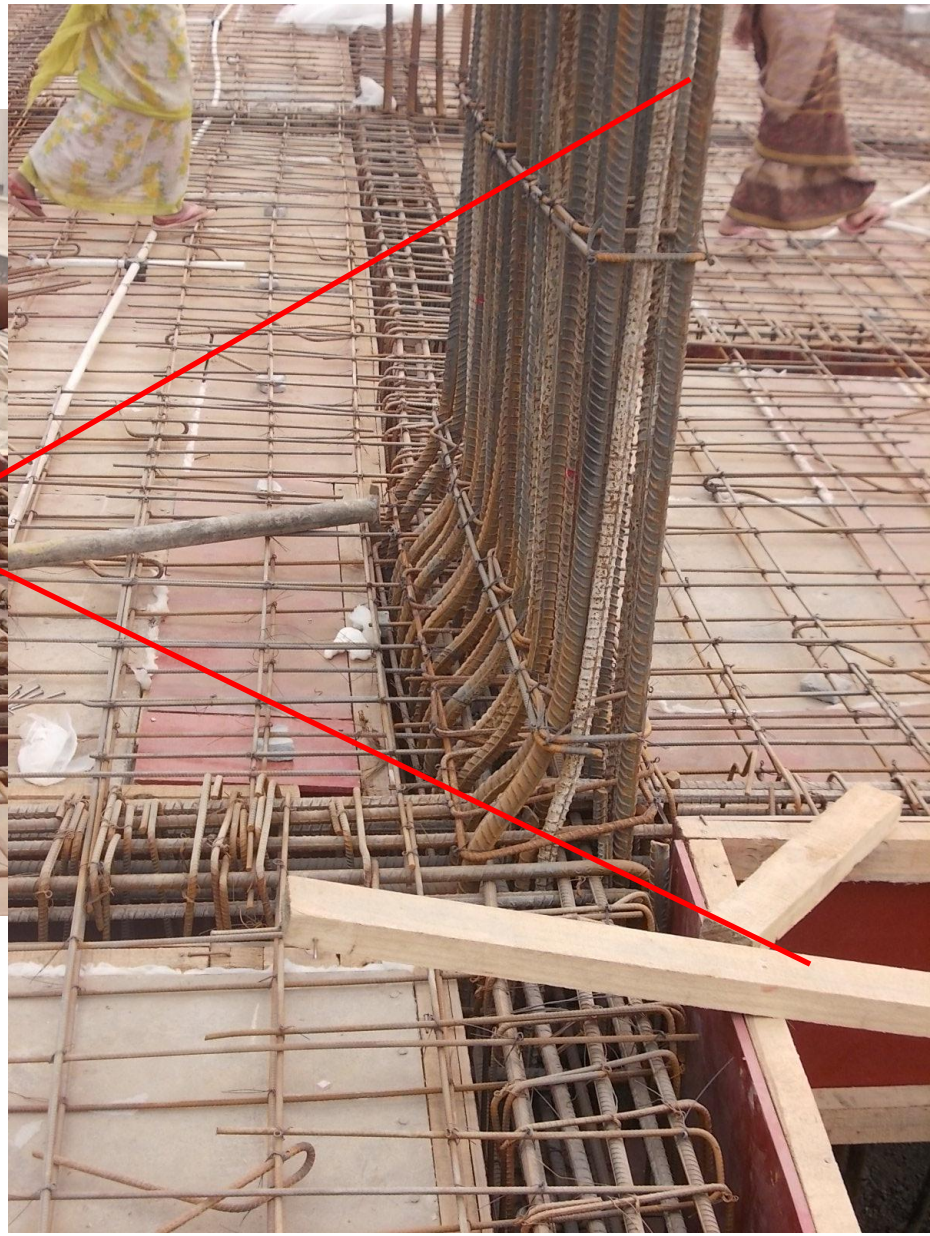
NOTE — ϕ is the nominal size of the test piece, in mm.

Most RC buildings with open ground storey that collapsed showed a very common practice of poor detailing; 6mm diameter lateral ties in the columns with 90^{o} hooks and longitudinal spacing as large as 30cm. This did not provide the required confinement to the core concrete.

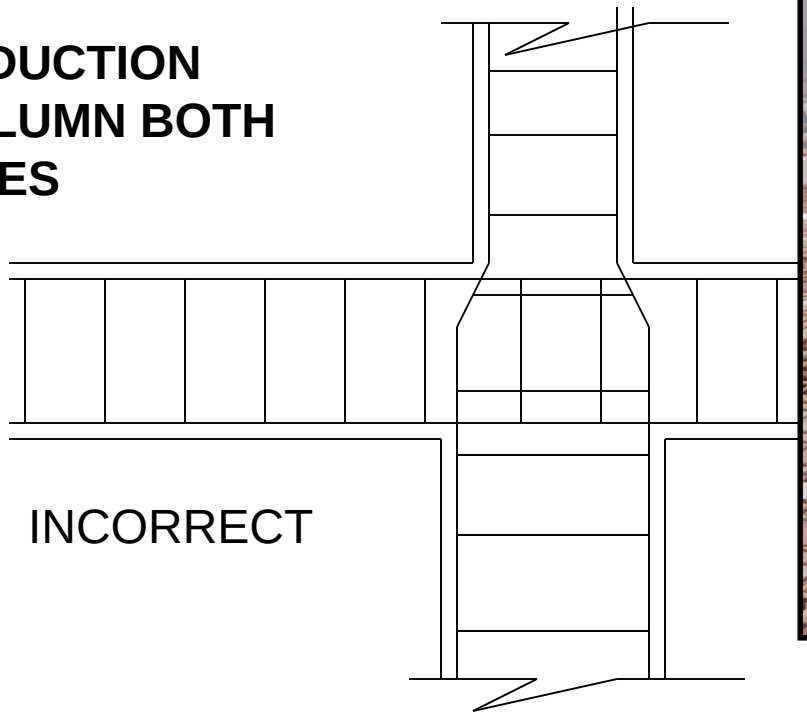
Hooks open up because **hooks at 90^{o}**

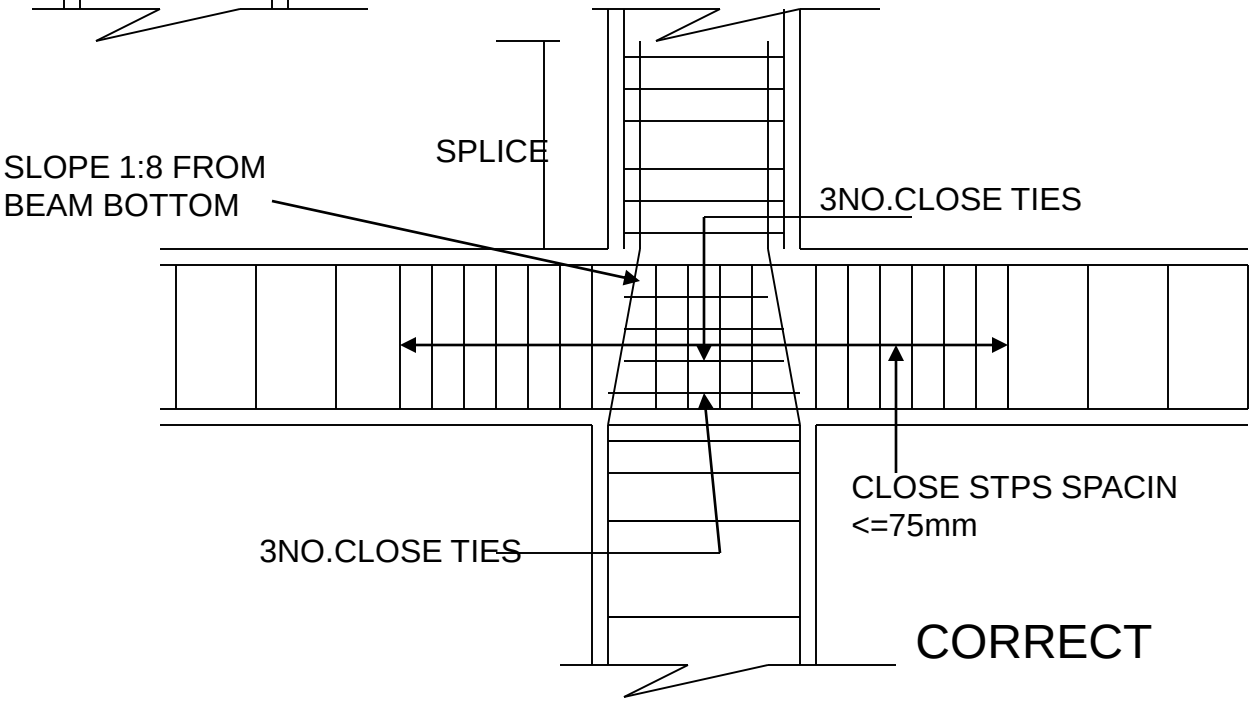
No lateral ties

Reduction of Column Size



REDUCTION COLUMN BOTH SIDES



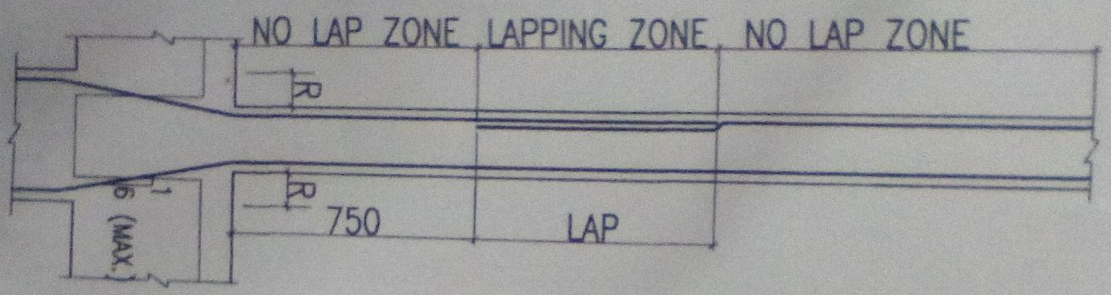


SPLICING OF COLUMN / SHEAR WALL BARS AND REDUCTION OF SIZE

(TIES NOT SHOWN FOR CLARITY)

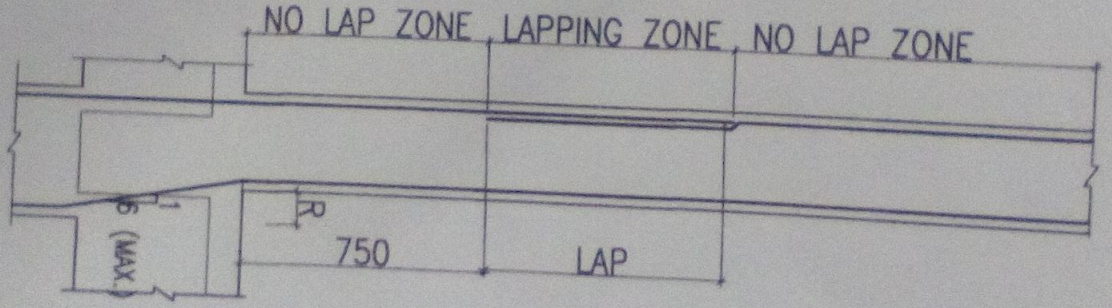
DETAIL : I

(WHERE R <75mm)



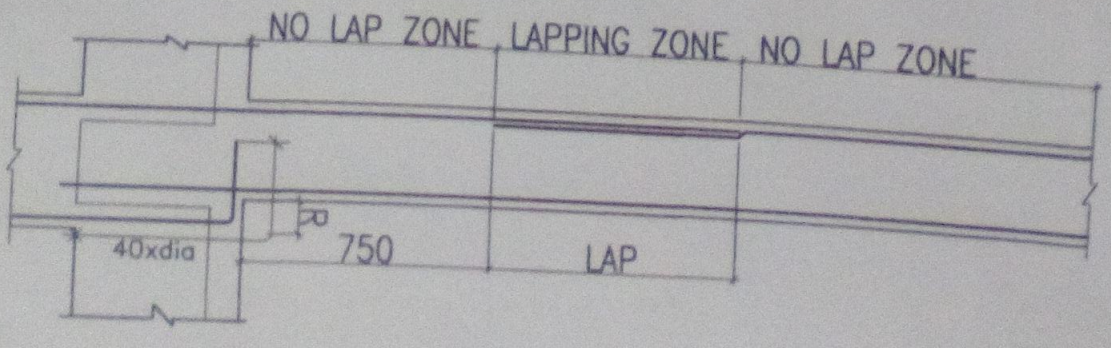
DETAIL : II

(WHERE R <75mm)



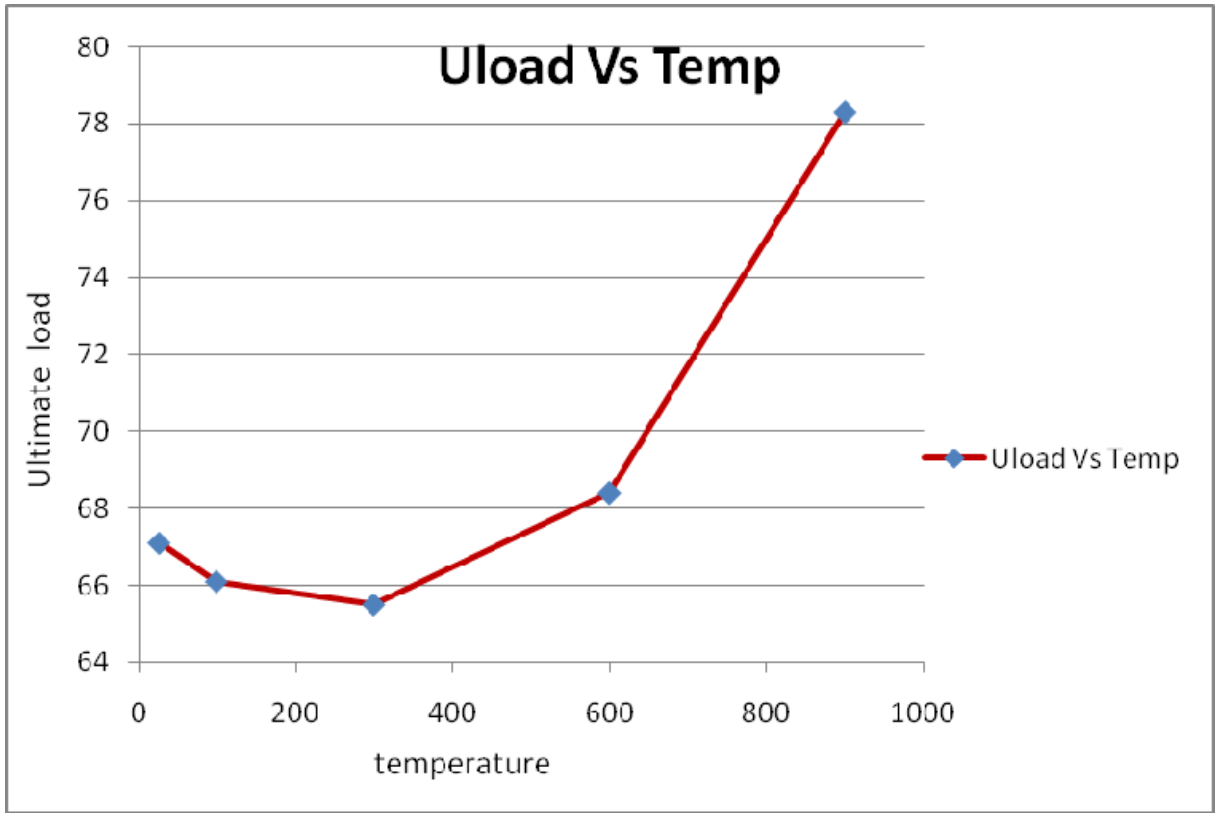
DETAIL : III

(WHERE R >75mm)



Effect of temperature on ultimate load carrying capacity of steel

(A) For rapid cooling condition

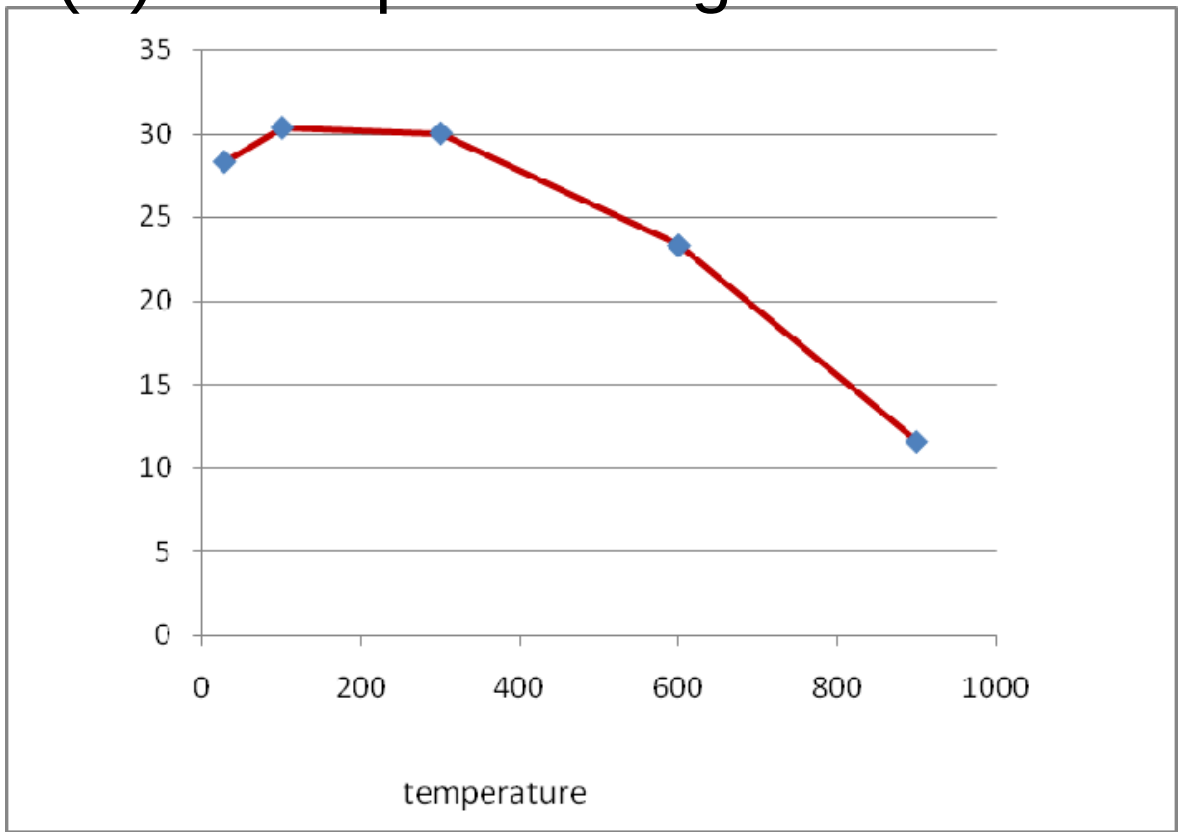


ultimate load initially decreases upto 300 C temp and after that increases, this happens due to the microstructure of the bar.

For high temperatures the grain size decreases.

Effect of temperature on elongation of steel

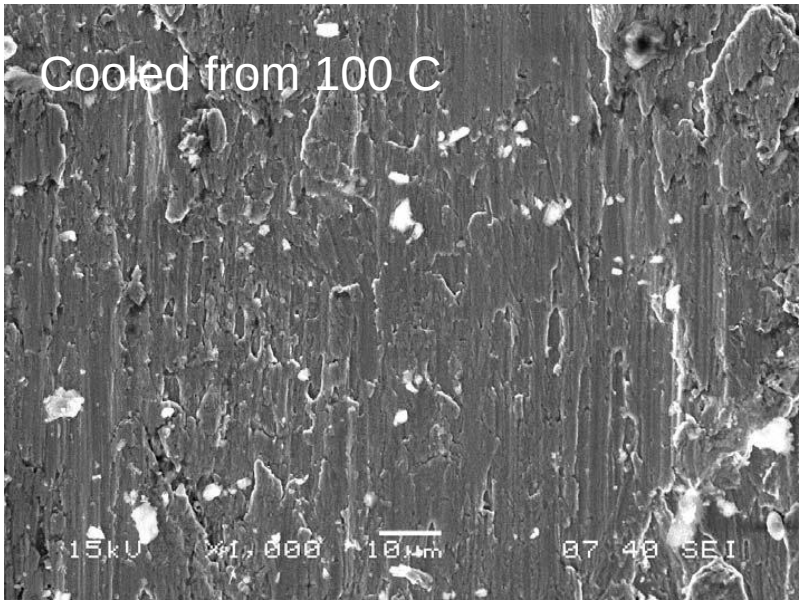
(A) For rapid cooling condition

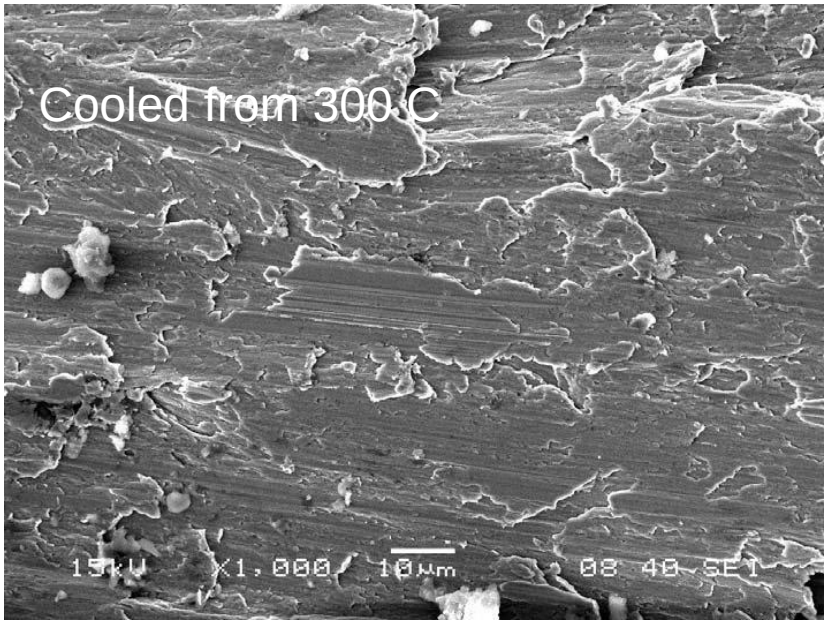


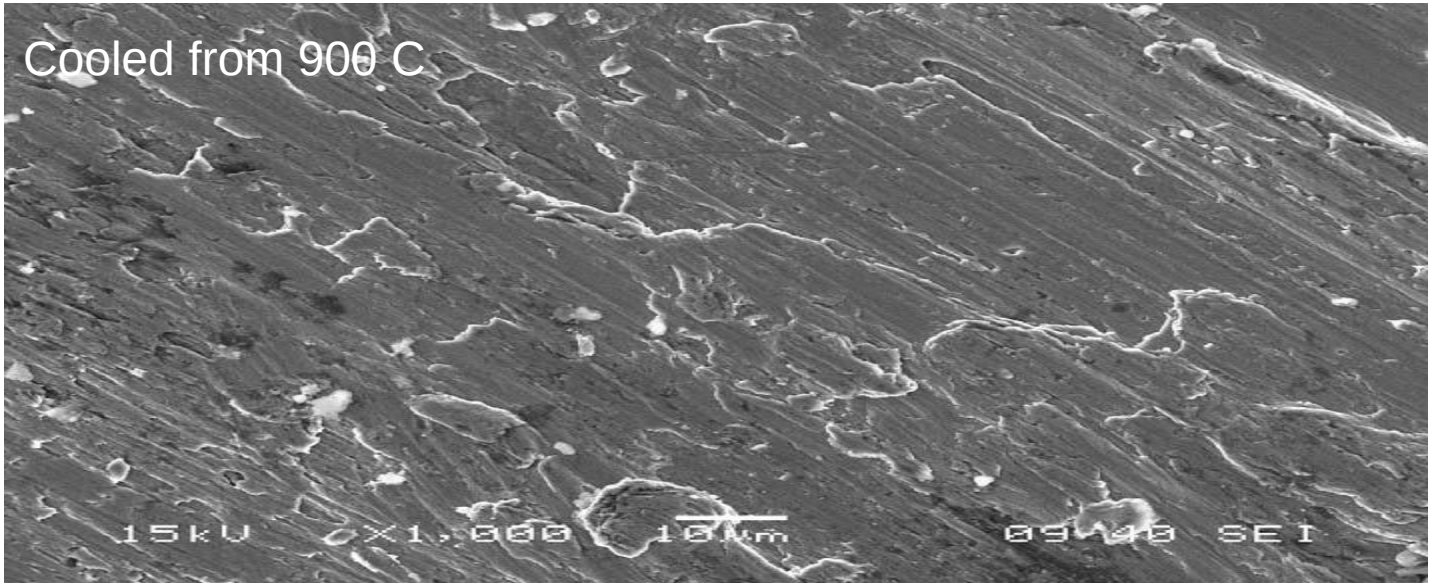
Decrease in elongation indicate significant reduction in ductility of the structure.

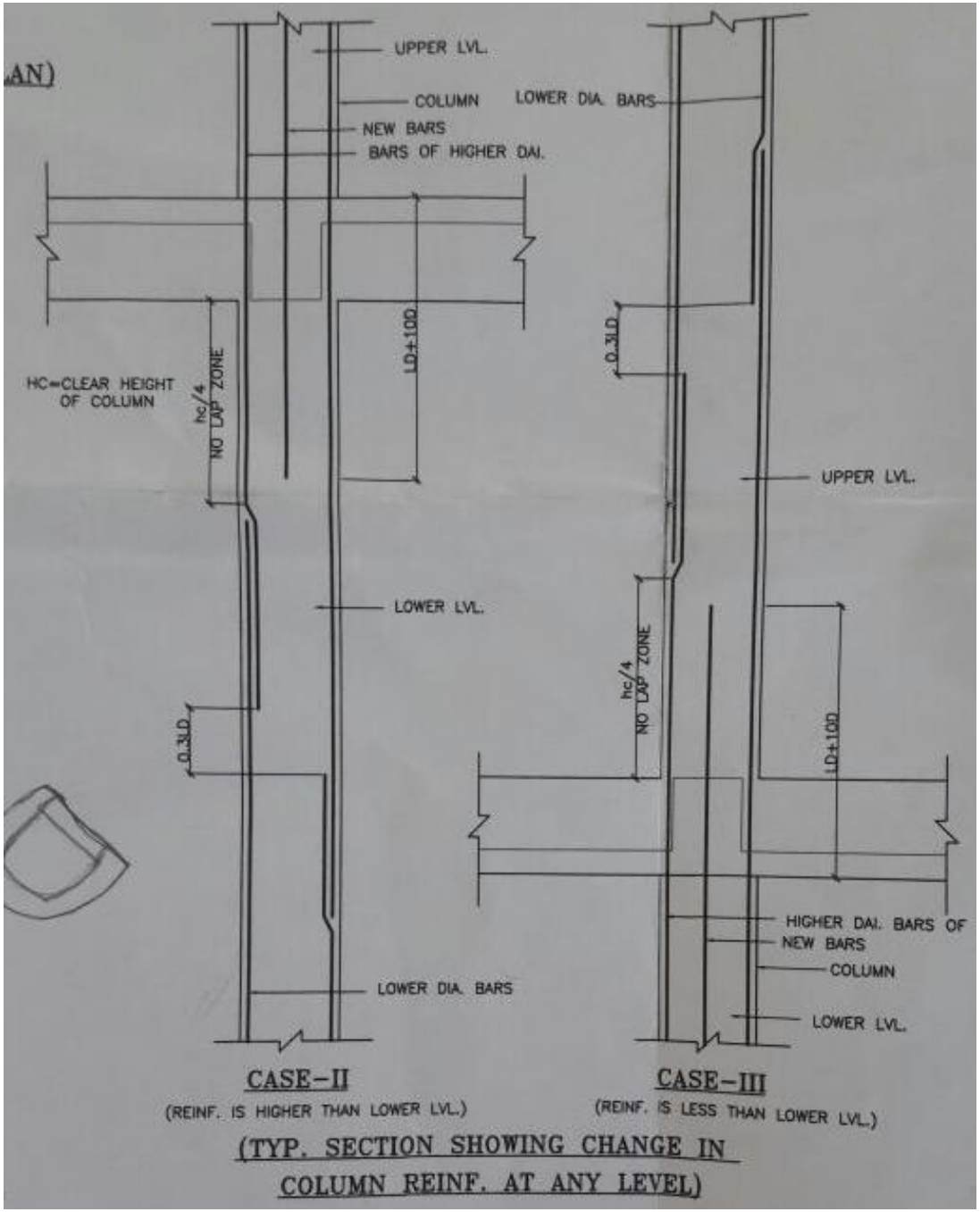
(B) Ordinary cooling it has been observed that reduction in strength and ductility Is more than rapid cooling.

Microstructure of steel after cooling from raised temperature



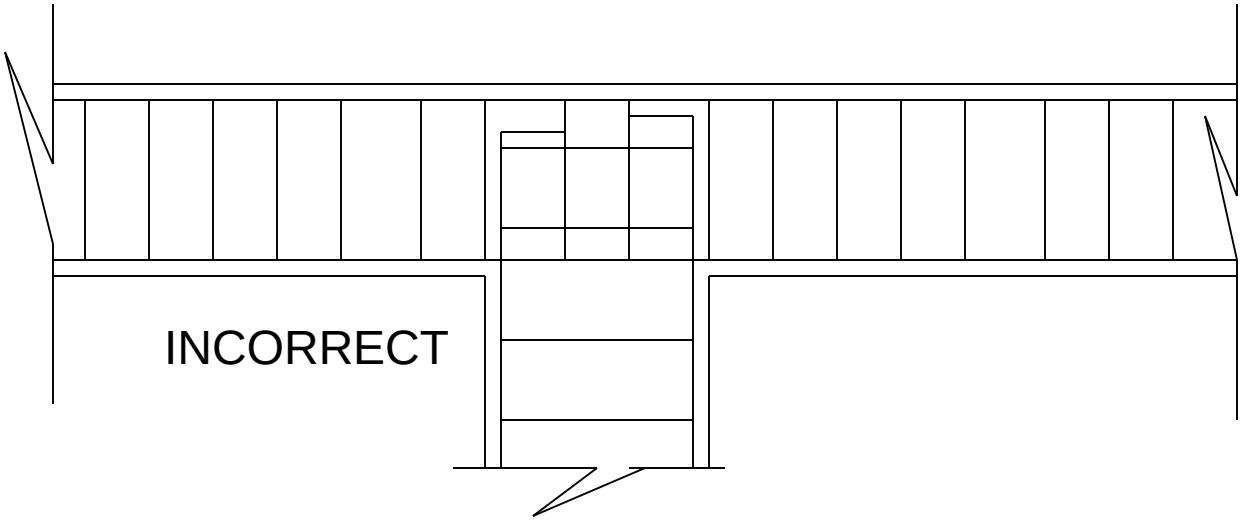


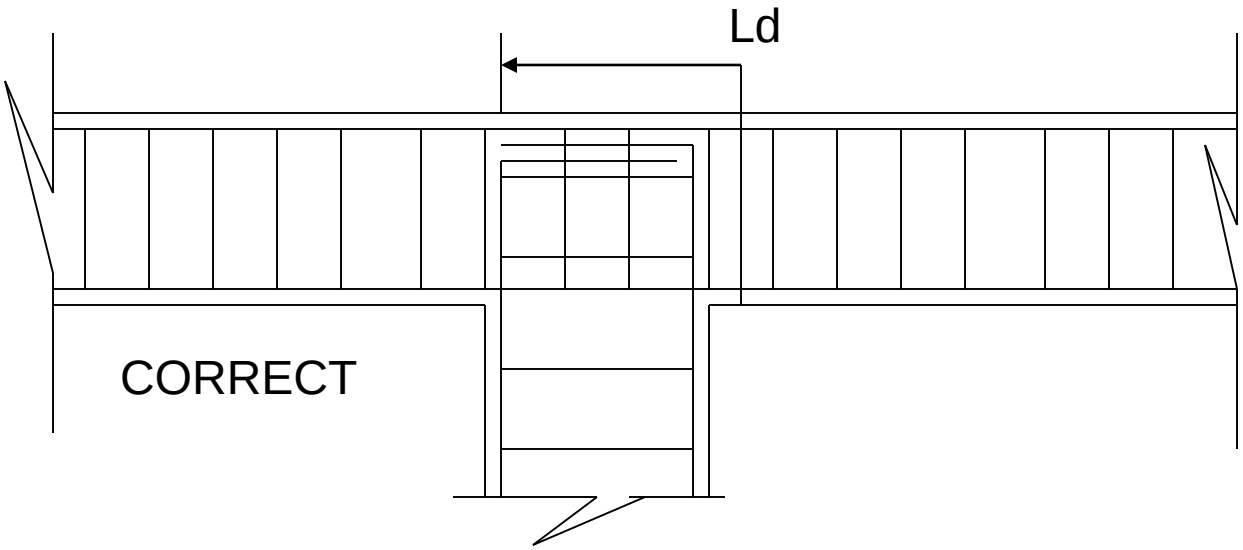




CHANGE IN COLUMN REINFORCEMENT AT ANY LEVEL

TERMINATION OF COLUMN BARS INSIDE BEAM





5.10.3 *Do's—Columns*

a) A reinforced column shall have at least six bars of longitudinal reinforcement for using in transverse helical reinforcement.

b) Spacing of longitudinal bars in column shall be along the periphery of the column, as far as practicable.

c) Column bars of diameters larger than 36 mm in compression can be spliced with dowels at the footing with bars of smaller sizes and of necessary area.

d) A dowel shall extend into a column, a distance equal to the development length of the column bar and into footing a distance equal to development length of the dowel.

e) Keep outer dimensions of column constant, as far as possible, for re-use of forms.

f) Preferably avoid use of two grades of vertical bars in the same element.

5.10.4 *Dont's—General*

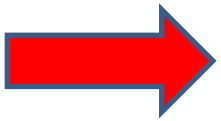
a) Reinforcement shall not extend across an expansion joint and the break between the sections shall be complete.

c) Lap splices shall not be used for bars larger than 36 mm diameter except where welded.

d) Bars larger than 36 mm diameter shall not be bundled.

e) Where dowels are provided their diameter shall not exceed the diameter of the column bars by more than 3 mm.

f) Where bent bars are provided, their contribution towards shear resistance shall not be more than half that of the total shear reinforcement.



Under no circumstances should the bending of bars at welds be permitted.

Figure: Damage to Ground Floor Columns Due to Inadequate Lateral Confinement of Reinforcement bar

On June 28, 2014, an eleven story under-construction building at Moulivakkam in the suburb of Chennai, Tamil Nadu collapsed, killing 61 people, mostly construction workers

The **Lalita Park building collapse** 15 November 2010 in the Indian capital of New **Delhi**. 66 dead and 80 injured

OPENING IN WALLS

10.6.1 Shear strength of a wall with openings should be checked at critical horizontal planes passing through openings.

10.6.2 Additional steel reinforcement shall be provided along all four edges of openings in walls. Further,

a) the area of these vertical and horizontal steel should be equal to that of the respective interrupted bars, provided half on either side of the wall in each direction.

b) these vertical bars should extend for full height of the storey in which this opening is present.

c) the horizontal bars should be provided with development length in tension beyond the edge of the opening.

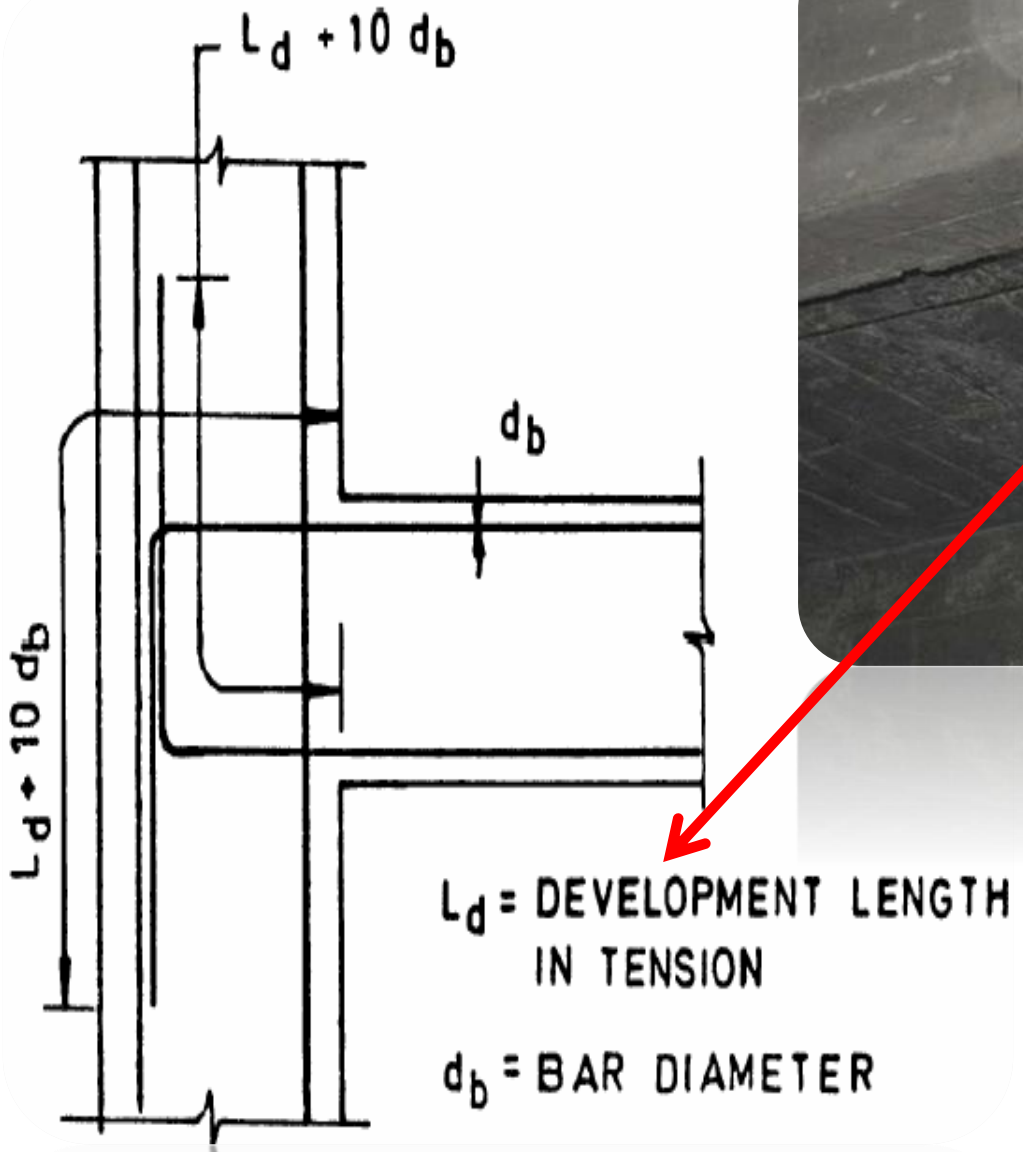
BEAM COLUMN JOINT

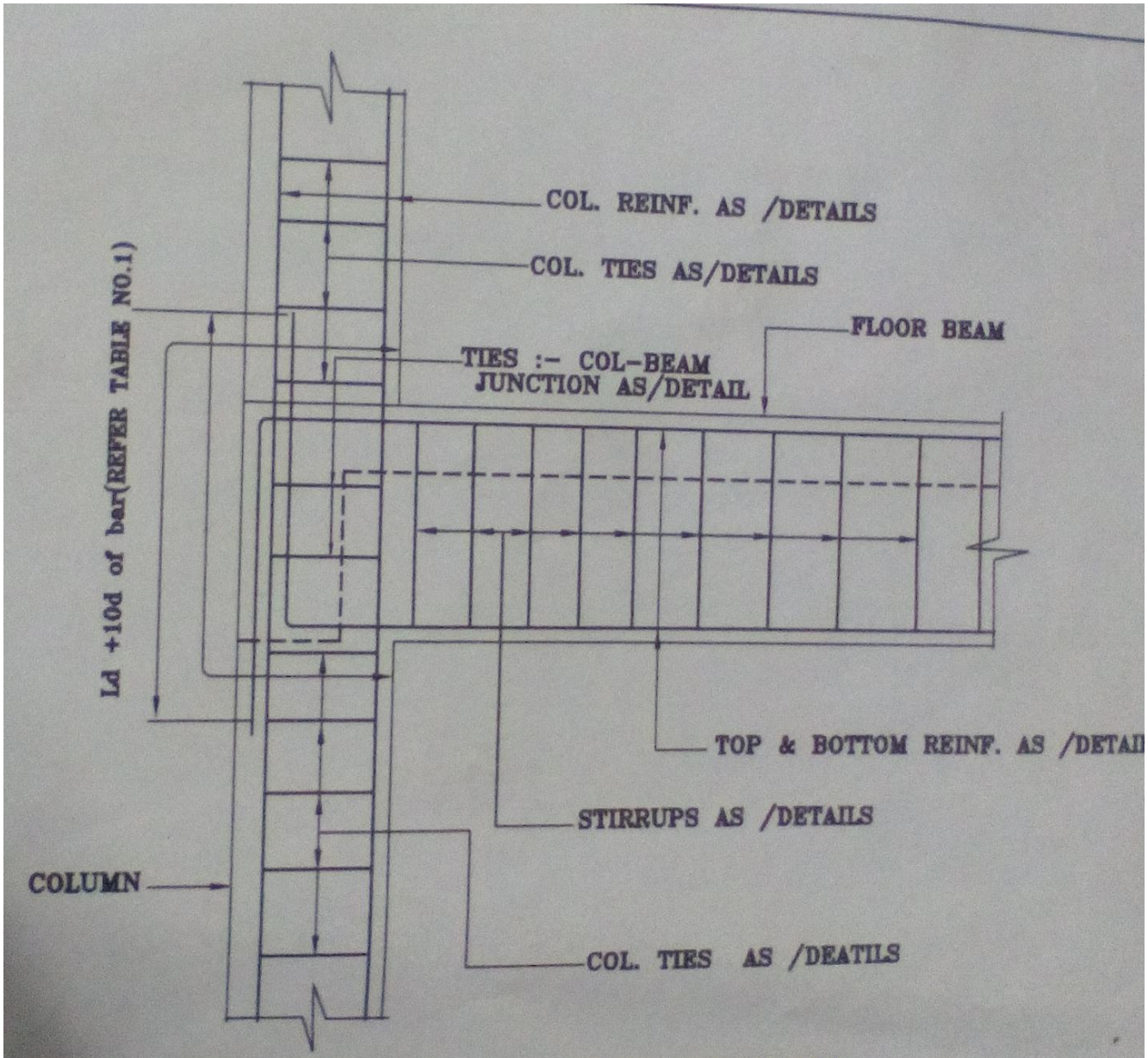
- The minimum dimension of column shall not be less than
  a) 20 times the largest beam bar diameter of the longitudinal reinforcement in the beam passing through or anchoring into the column joint, and
  b) 300 mm.
- A small column width may lead to following two problems :
  a) the moment capacity of column section is very low since the lever arm between the compression steel and tension steel is very small, and
  b) beam bars do not get enough anchorage in the column (both at exterior and interior joints).

BEAM COLUMN JOINT

- $B/D > 0.3$
- $B \geq 200mm$
- $D \leq 1/4$ of clear span

ANCHORAGE OF BEAM BARS IN AN EXTERNAL JOINT

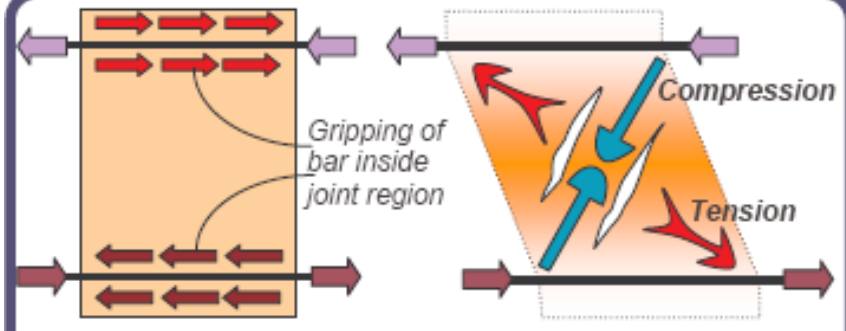




TYP. DETAILS OF A BEAM-COLUMN JUNCTION AT EXTERIOR COLUMN

COLUMN-BEAM JOINTS IN RC BUILDINGS

Beam-column joints shall have ties spaced at or less than 150 mm



(a) **Loss of grip on beam bars in joint region:** *Large column width and good concrete help in holding the beam bars*

(b) **Distortion of joint:** causes *diagonal cracking and crushing of concrete*

Figure 2: Pull-push forces on joints cause two problems – these result in irreparable *damage in joints under strong seismic shaking.*

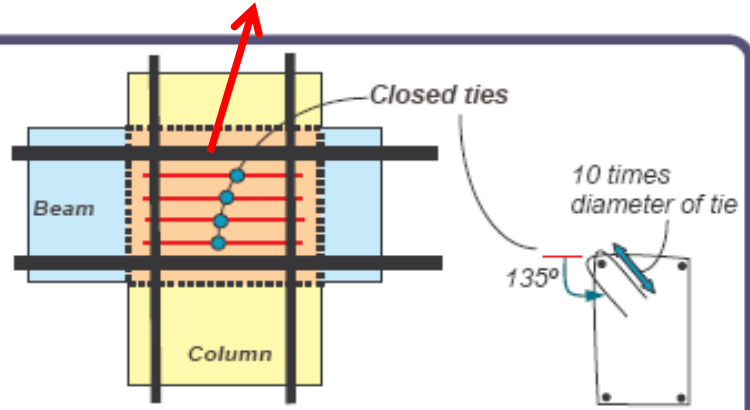


Figure 3: Closed loop steel ties in beam-column joints – *such ties with 135° hooks resist the ill effects of distortion of joints.*

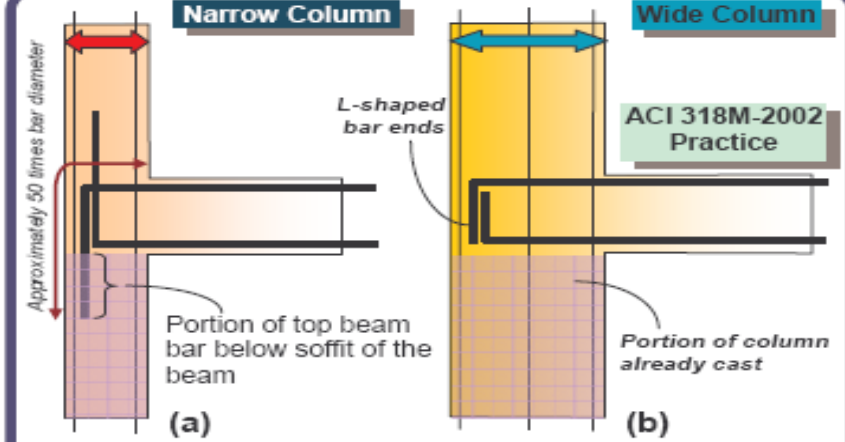


Figure 5: Anchorage of beam bars in exterior joints – *diagrams show elevation of joint region.*

COLUMN-BEAM JOINTS IN RC BUILDINGS

9.2 Transverse Reinforcement

9.2.1 *Confining Reinforcement in Joints*

a) When all four vertical faces of the joint are having beams framing into them covering at least 75 percent of the width on each face,

1) At least half the special confining reinforcement required as per **8** at the two ends of columns, shall be provided through the joint within the depth of the shallowest beam framing into it; and

2) Spacing of these transverse links shall not exceed 150 mm.

COLUMN-BEAM JOINTS IN RC BUILDINGS

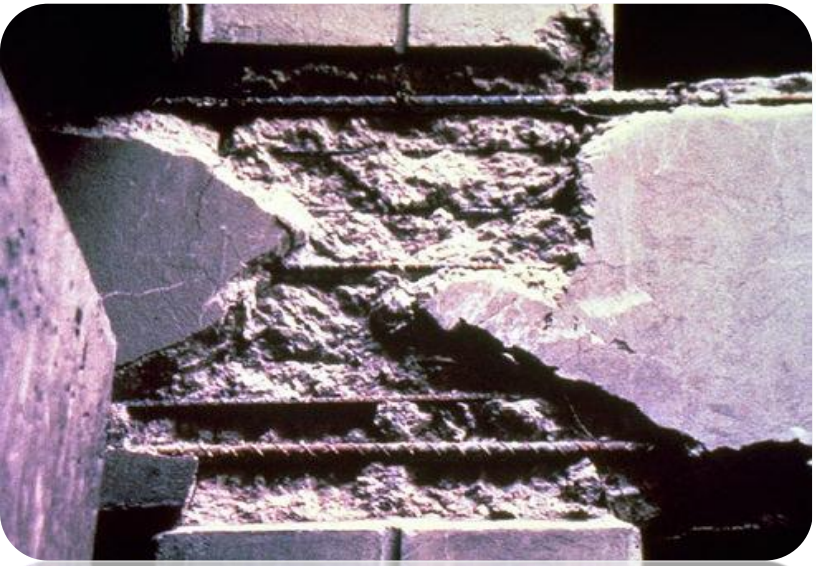
b) When all four vertical faces of the joint are not having beams framing into them or when all four vertical faces have beams framing into them but do not cover at least 75 percent of the width on any face,

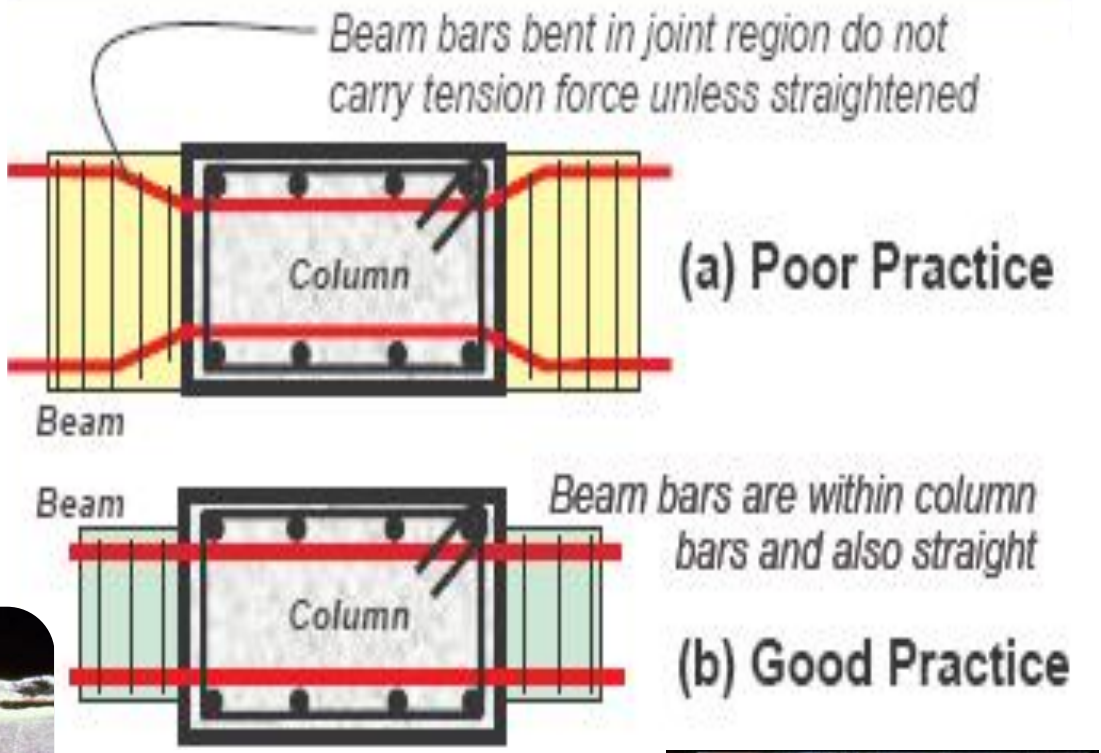
1) special confining reinforcement required as per **8** at the two ends of columns shall be provided through the joint within the depth of the shallowest beam framing into it, and

2) spacing of these transverse links shall not exceed 150 mm.

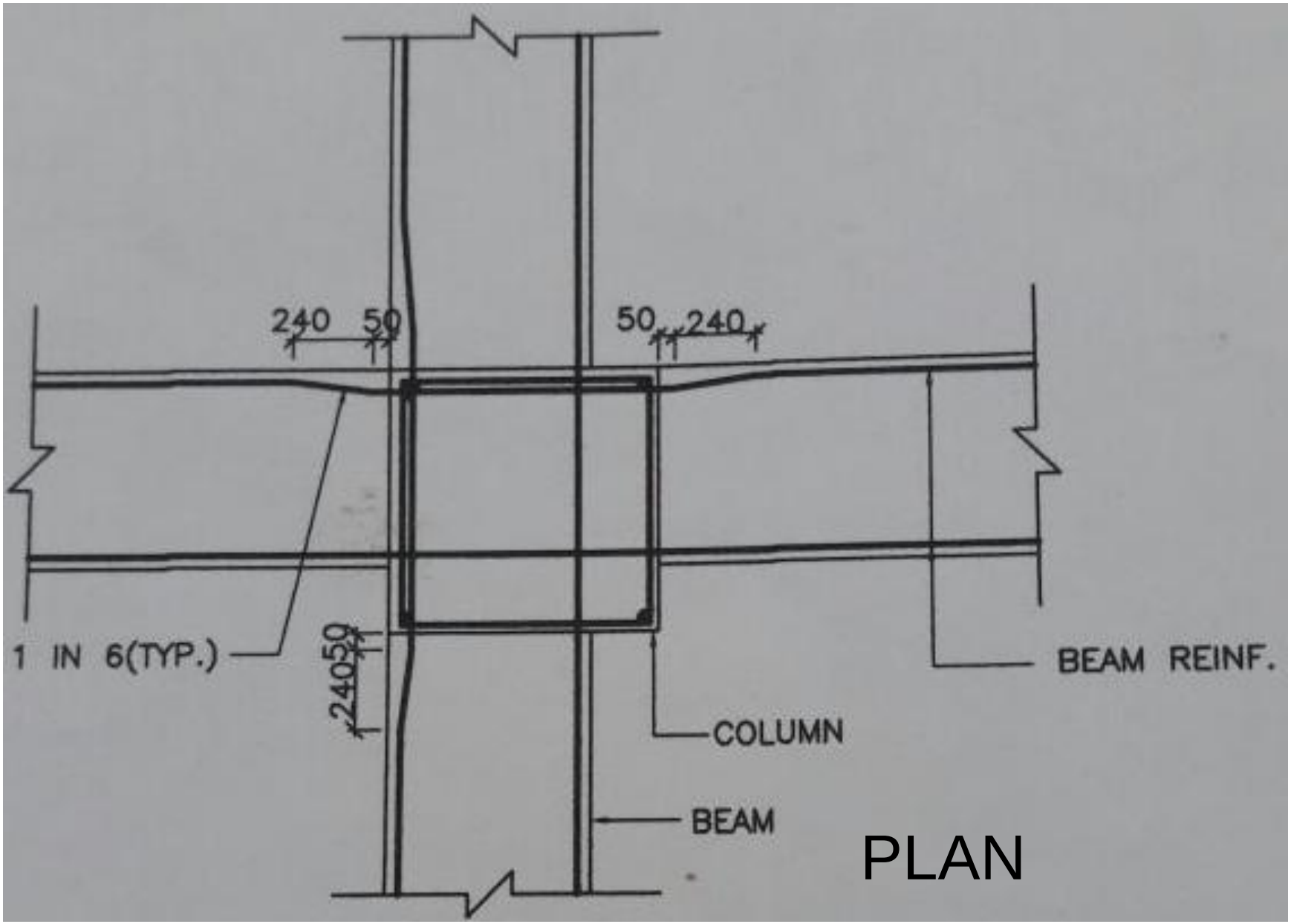
9.2.2 In the exterior and corner joints, all 135° hooks of cross-ties should be along the outer face of columns.

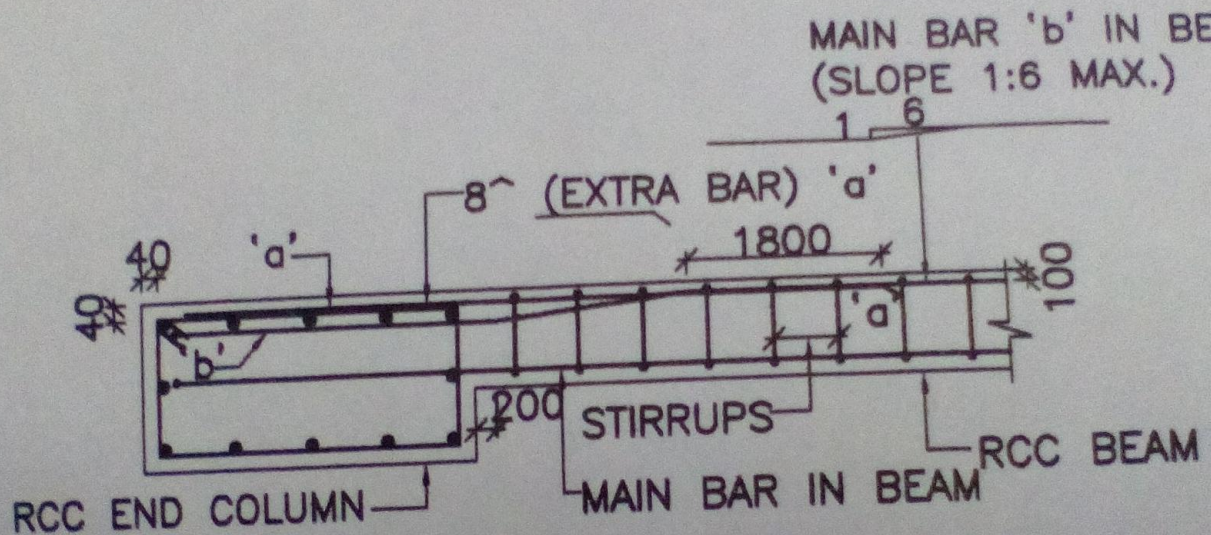
Placement of the Beam R.I. at Column – Beam Joint





COLUMN BEAM JUNCTION





TYP.SECTIONAL PLAN AT

RCC BEAM & END COLUMN JUNCTION

Failure of Beam – Column Joint

Failure of Beam – Column Joint

Beam – Column Joint 13920:2016

9.1 Design of Beam-Column Joint for Distortional Shear

9.1.1 *Shear Strength of Concrete in a Joint*

The nominal shear strength τ_{jc} of concrete in a beam-column joint shall be taken as

$$\tau_{jc} = \begin{cases} 1.5 \; A_{ej}\sqrt{f_{ck}} & \text{for joints confined by beams on all four faces} \\ 1.2 \; A_{ej}\sqrt{f_{ck}} & \text{for joints confined by beams on three faces} \\ 1.0 \; A_{ej}\sqrt{f_{ck}} & \text{for other joints} \end{cases}$$

where A_{ej} is effective shear area of joint given by $b_j w_j$, in which b_j is the effective breadth of joint perpendicular to the direction of shear force and w_j the effective width of joint along the direction of shear force. The effective width of joint b_j (*see* Fig. 15) shall be obtained from following:

$\min [b_b;\ b_c + 0.5\ \ h_c]$ *if* $b_c < b_b$.

where

b_b = width of beam and b_c = width of column

h_c = depth of column in considered direction.

).1.2 *Design Shear Stress Demand on a Joint*

a) Design shear stress demand acting horizontally along each of the two principal plan directions of the joint shall be estimated from earthquake shaking considered along each of these directions, using

$$\tau_{jdX} = \frac{V_{djX}}{b_j w_j}$$ for shaking along plan direction X of earthquake shaking,

$$\tau_{jdY} = \frac{V_{djY}}{b_j w_j}$$ for shaking along plan direction Y of earthquake shaking

It shall be ensured that the joint shear capacity of joint concrete estimated using **9.1.1** exceeds both τ_{jdX} and τ_{jdY}.

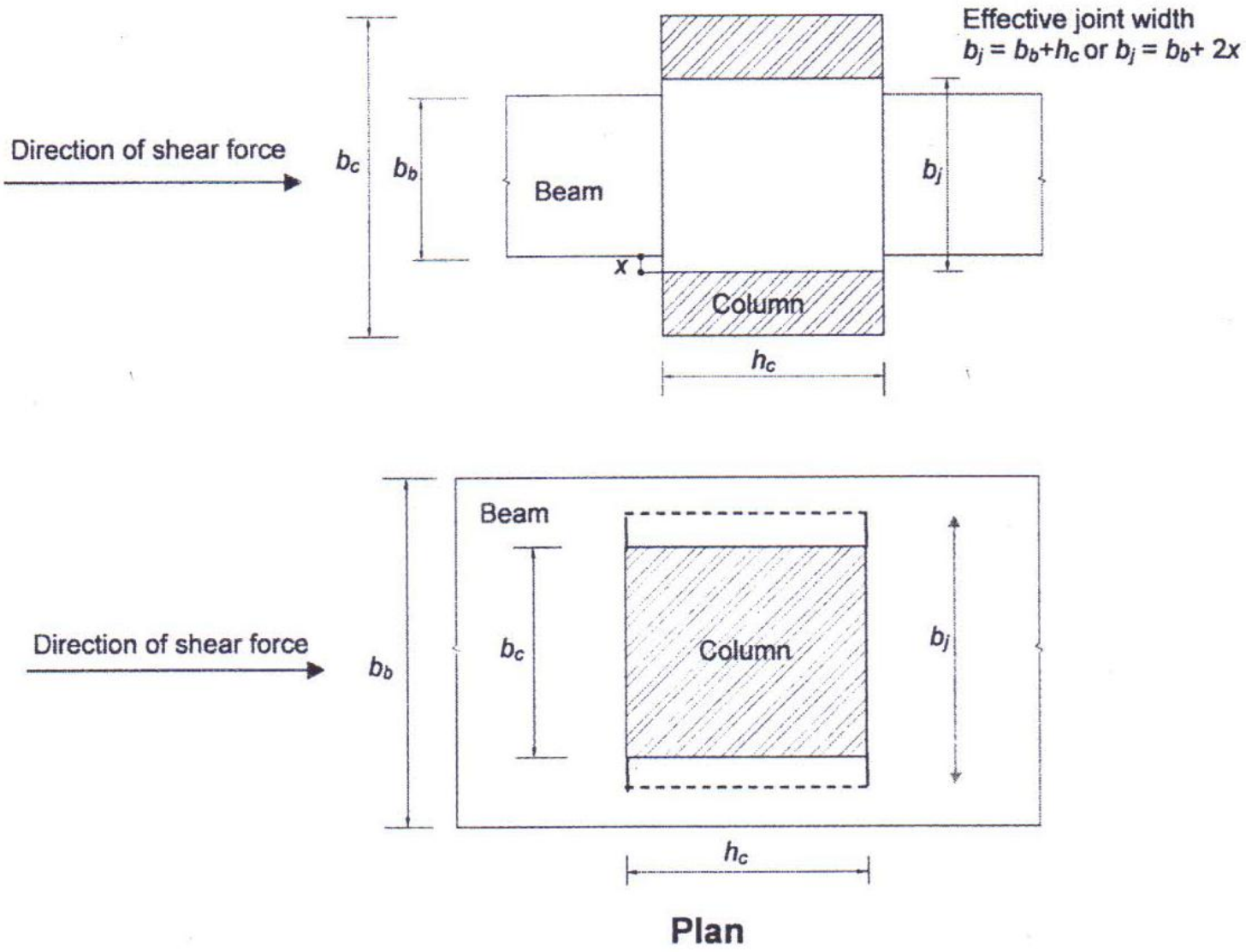
Beam – Column Joint

13920:2016

b) Design shear force demands V_{jdX} and V_{jdY} acting horizontally on the joint in principal plan directions X and Y shall be estimated considering that the longitudinal beam bars in tension reach a stress of $1.25 f_y$ (when over strength plastic moment hinges are formed at beam ends).

Beam – Column Joint

13920:2016

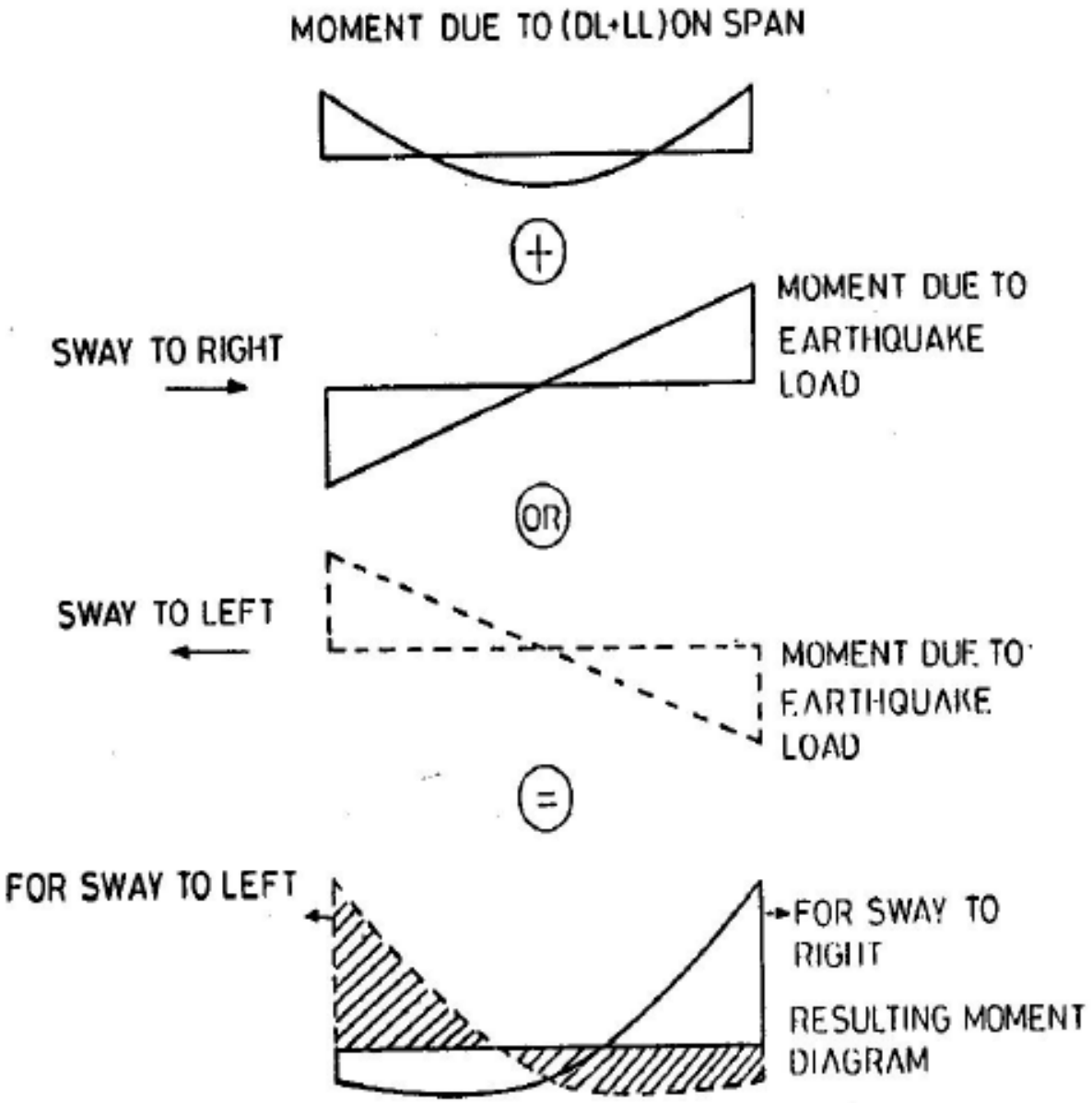


Grade of Concrete at Beam Column Junction (IS 16700: 2017, cl Annex-B s.no.4 pp 23

The grades of concrete used in slabs and beams shall not be less than 70 percent of that used in columns and walls in contact. When grade of concrete used in columns is different from that used in beams and slabs beyond the above limit, concrete used in columns and walls shall be used in the beam-column joints also; in such a case, puddling of concrete shall be done in such a way that column concrete is placed in the beam/slab at column location for a minimum of 0.6 m from face of column. This concrete shall be well integrated with the beam/slab concrete.

BEAMS IN RCC BUILDINGS

Reversal of Moment due to E.Q



BEAMS IN RCC BUILDINGS

- **The Indian Ductile Detailing Code IS13920-2016 prescribes that:**

(a) At least two bars go through the full length of the beam at the top as well as the bottom of the beam of dia 12 mm.

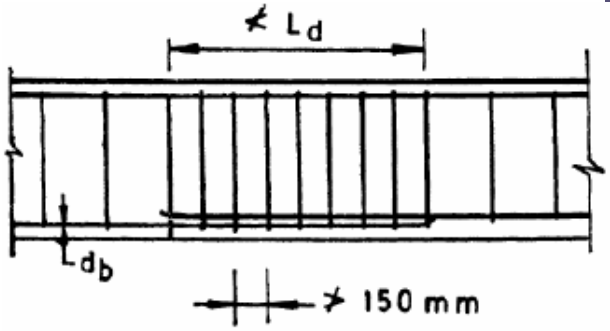
(b) At the ends of beams, the amount of steel provided at the bottom is at least half that at top.

(c) $B/D > 0.3$

(d) $B \geq 200mm$

(e) $D \leq 1/4$ of clear span

Location of lapping



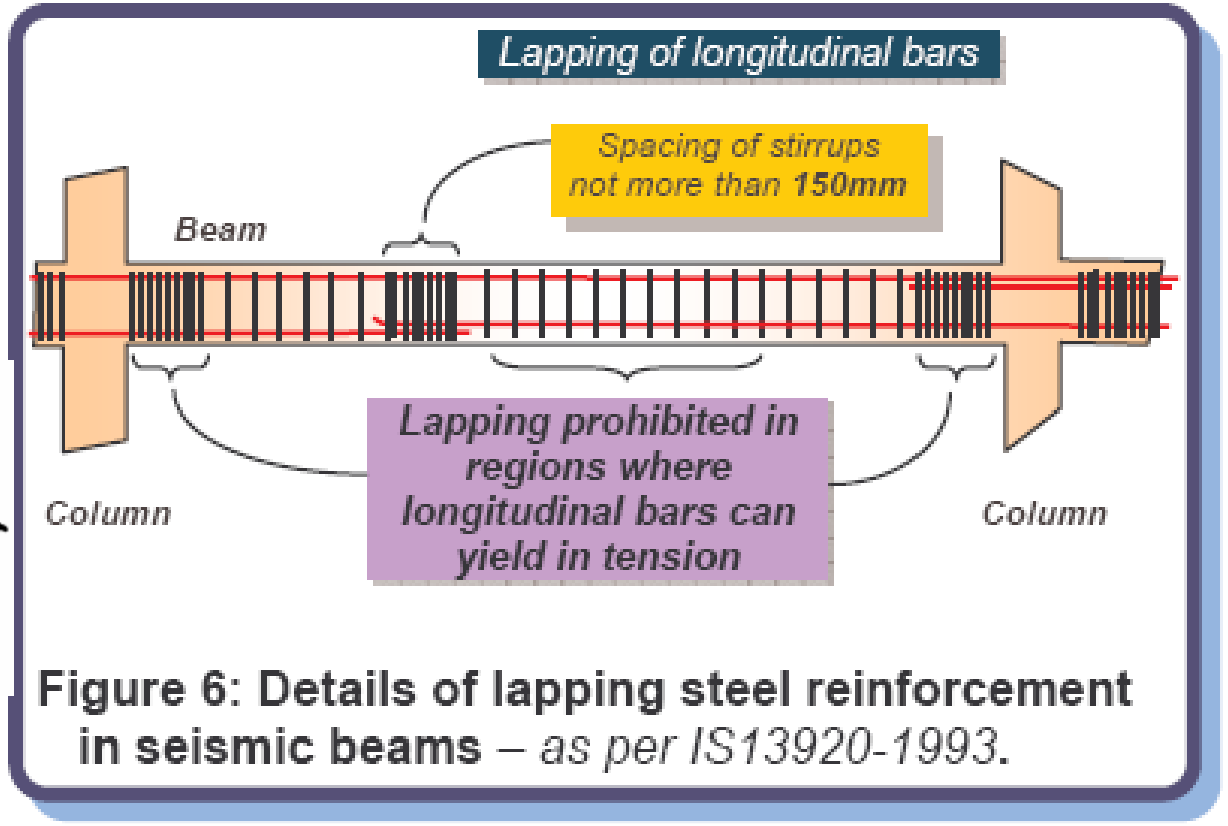


Figure 6: Details of lapping steel reinforcement in seismic beams – *as per IS13920-1993.*

Lap splices bottom rebar shall not be located :

(a) within a joint,

(b) within a distance of *2d from joint face, and*

(c) within a quarter length of the member where flexural yielding may occur under the effect of earthquake forces.

Not more than 50 percent of the bars shall be spliced at one section.

spacing of Shear R.I.

When adopted, closed links shall be provided over the entire length over which the longitudinal bars are spliced. Further,

a) the spacing of these links shall not exceed 150 mm (*see* Fig. 3).

b) the lap length shall not be less than the development length of the largest longitudinal reinforcement bar in tension.

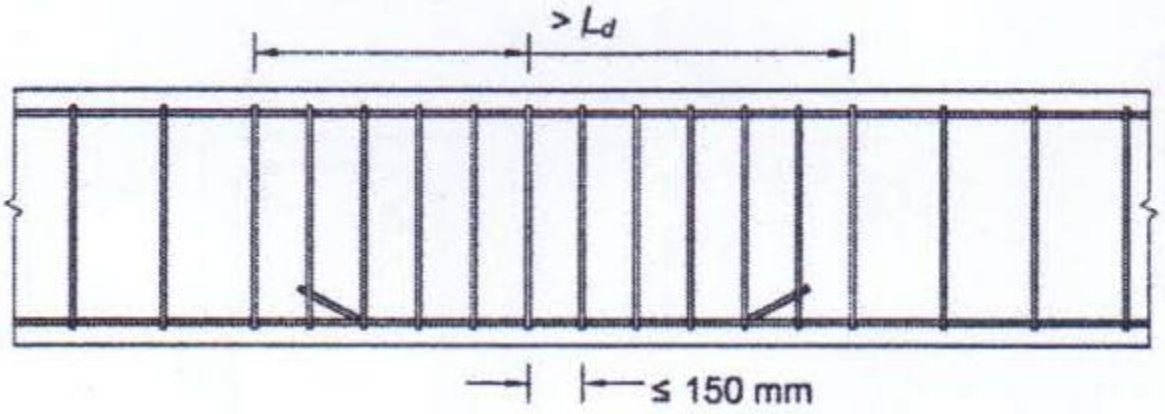
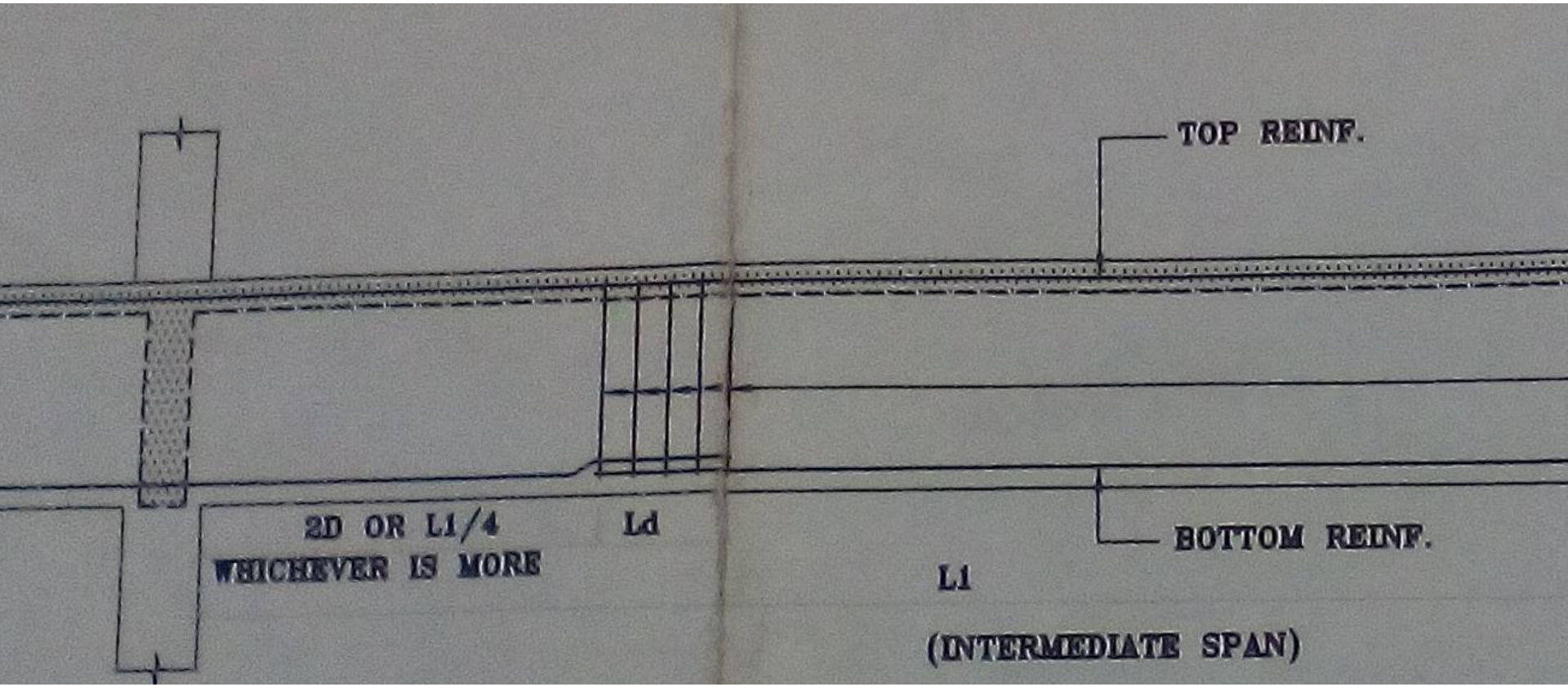


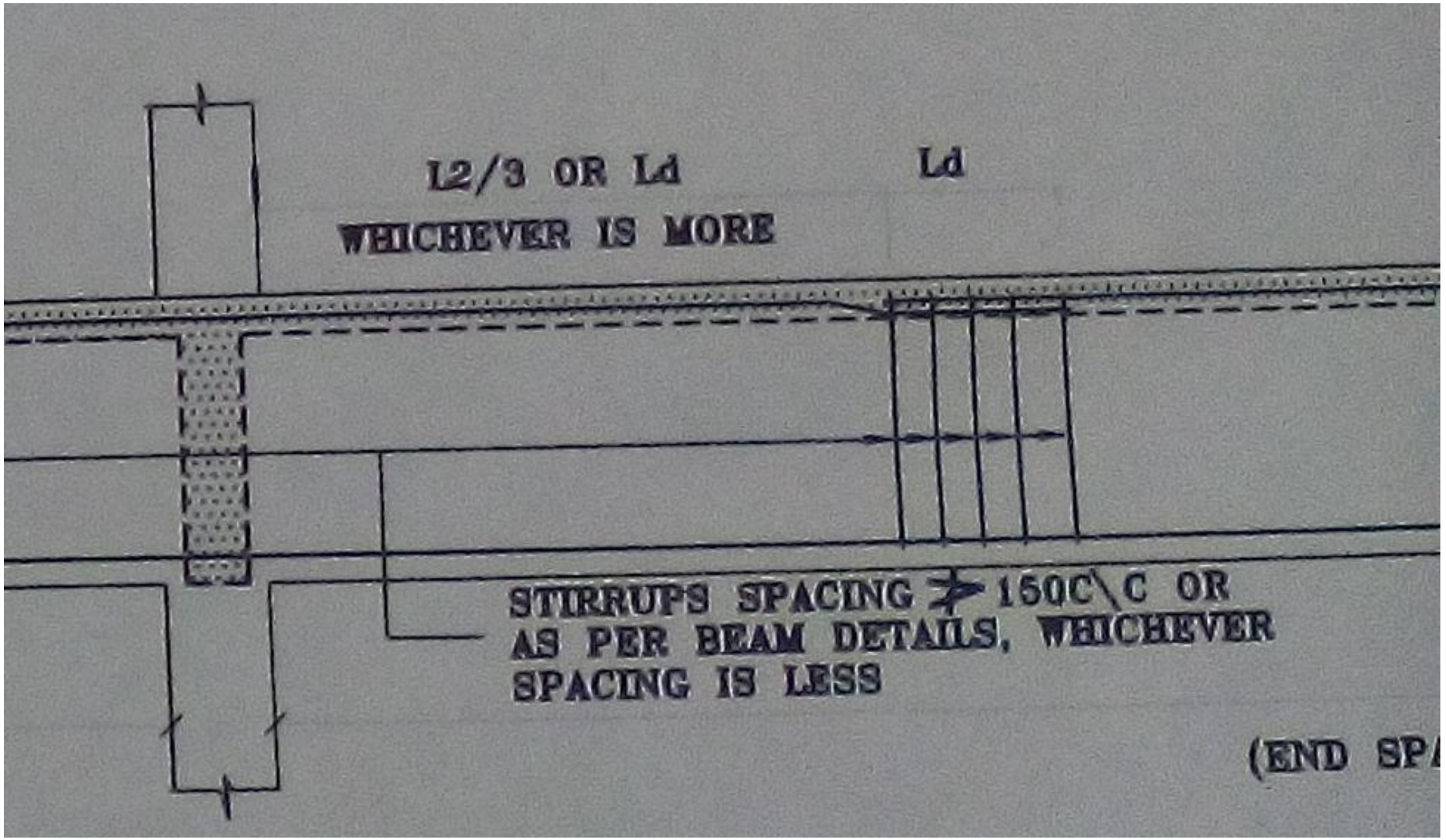
Fig.3

Lab in Beam



Lap Location in bottom

Lab in Beam



Lap Location in top

Stirrups in RCC beam

Hooks in Shear R.I.

Stirrups in the RCC beams help in three ways,

(i) They carry the vertical shear force and thereby resist diagonal shear crack

(ii) They protect the concrete from bulging outwards due to flexure, and

(iii) They prevent buckling of the compressed longitudinal bars due to flexure.

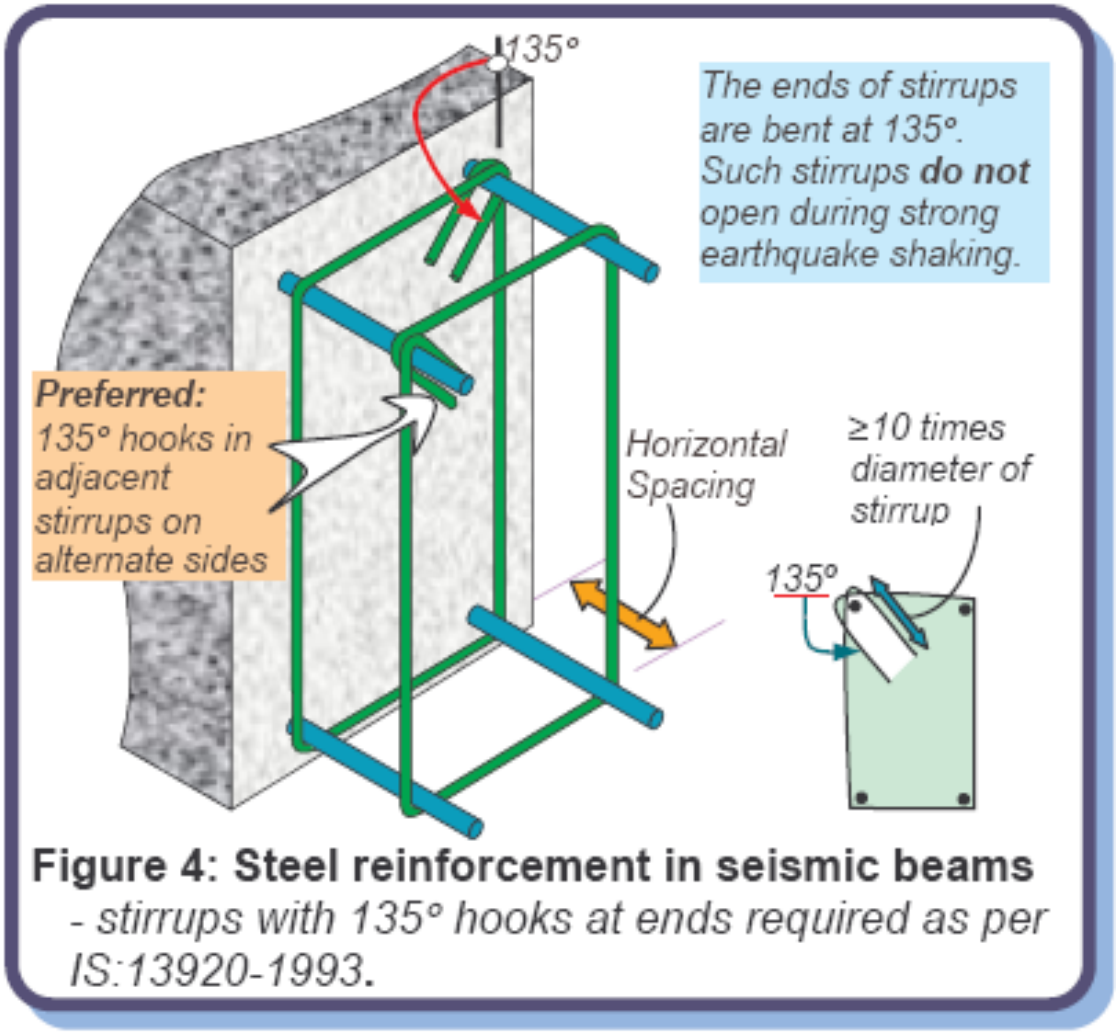
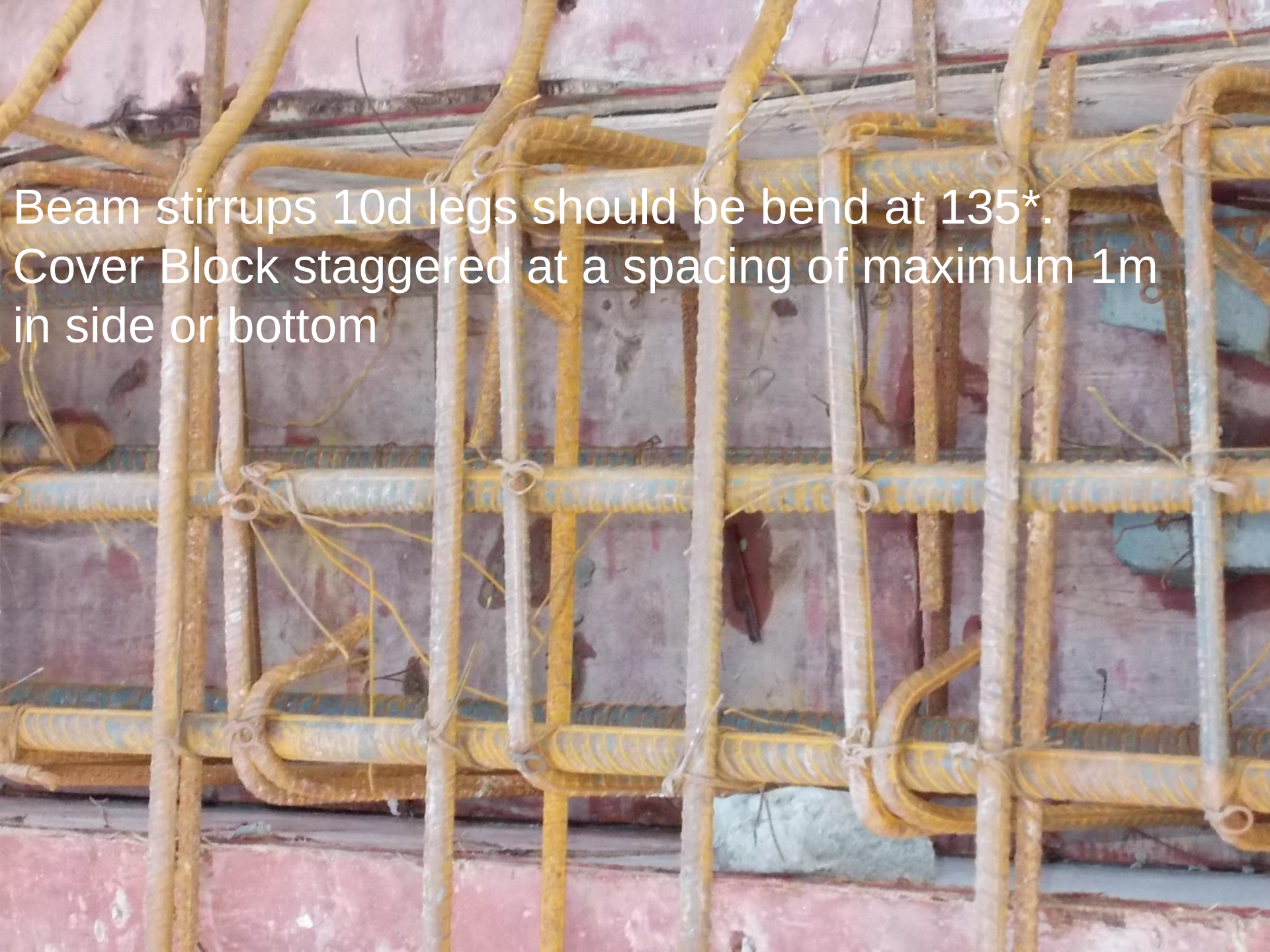
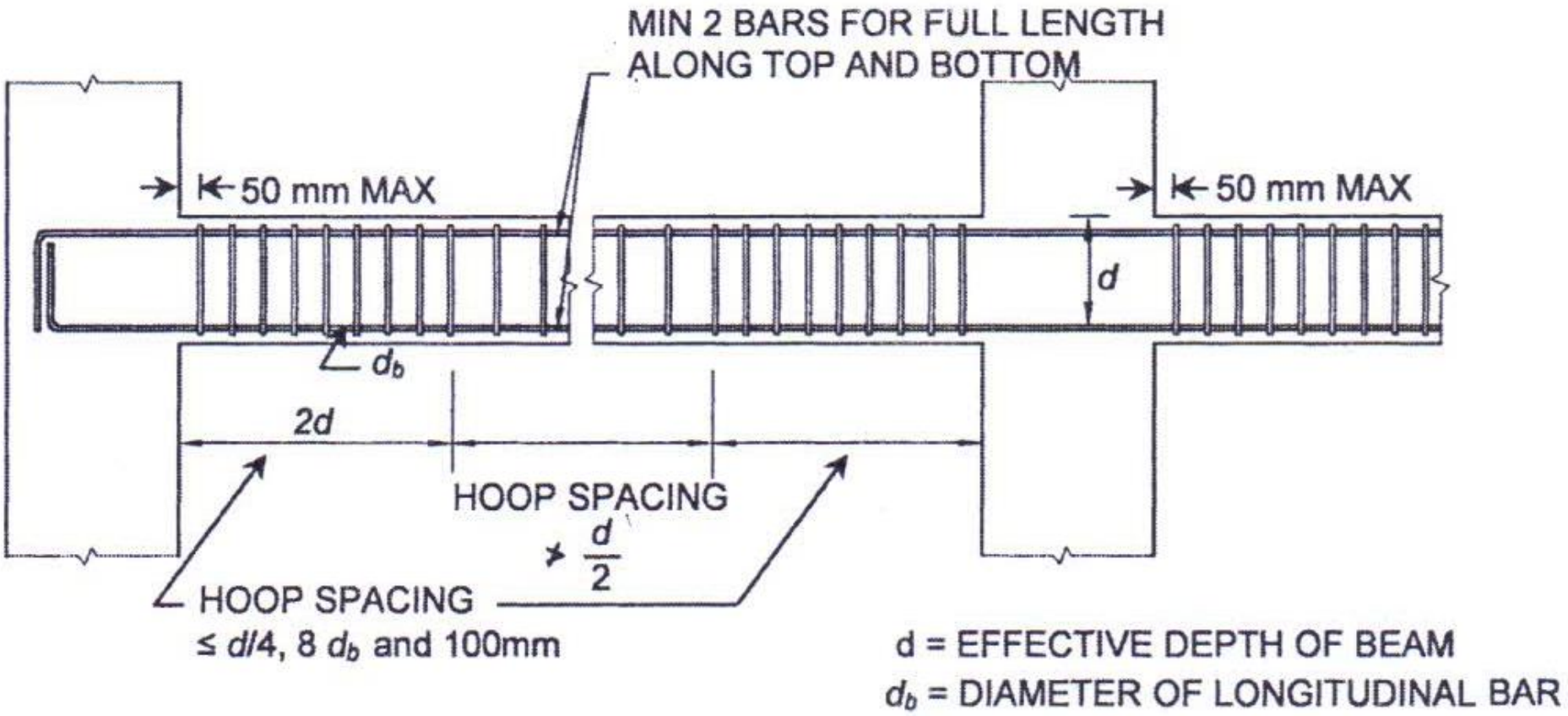


Figure 4: Steel reinforcement in seismic beams
- stirrups with 135° hooks at ends required as per IS:13920-1993.

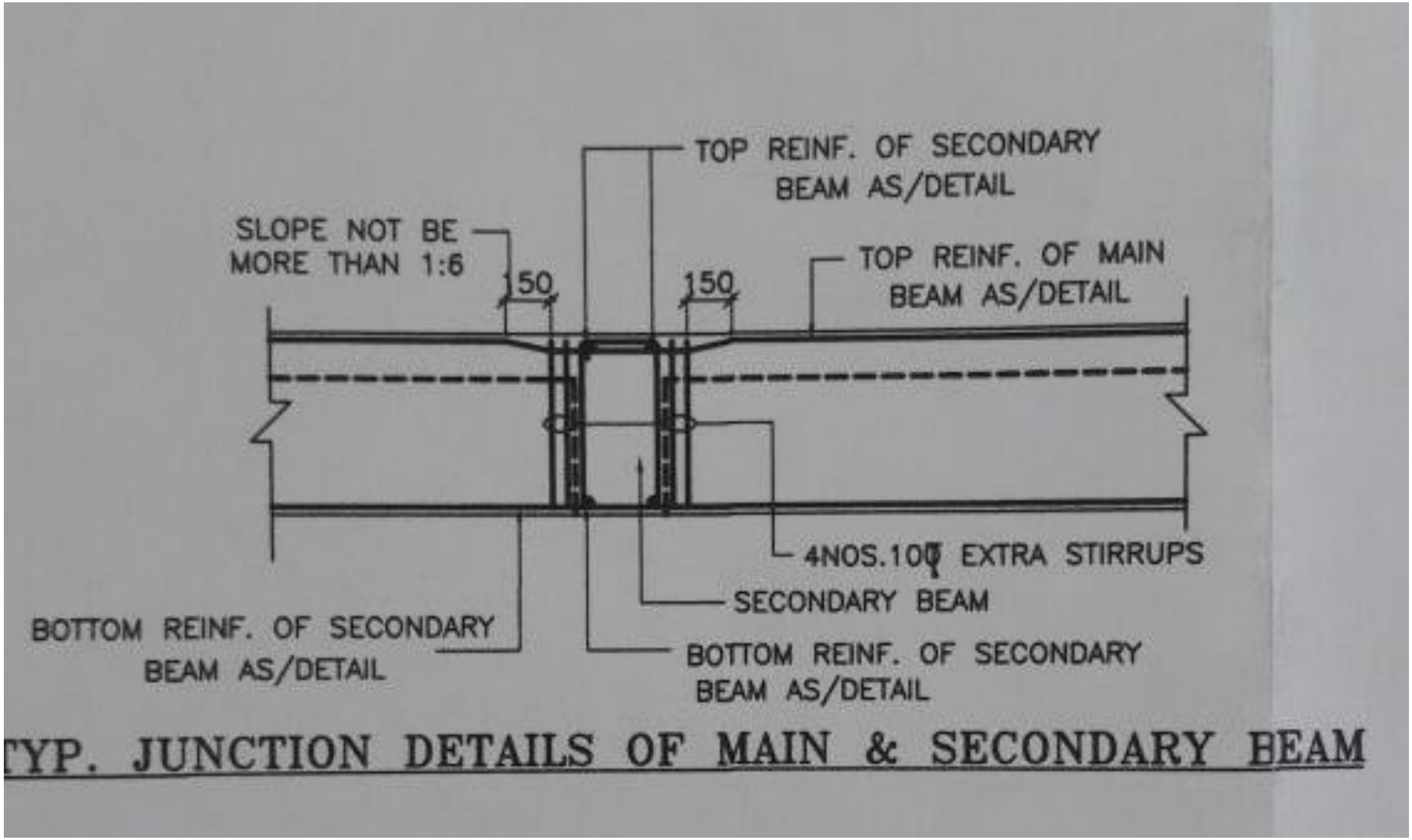

Beam stirrups 10d legs should be bend at 135*.
Cover Block staggered at a spacing of maximum 1m
in side or bottom

Beam Shear R.I.



- The first shear R.I. should be at a distance of not exceeding 50mm from the joint face.

JUNCTION DETAIL OF MAIN AND SECONDARY BEAM



TYP. JUNCTION DETAILS OF MAIN & SECONDARY BEAM

5.10.2 *Do's—Beams and Slabs*

a) Where splices are provided in reinforcing bars, they shall be, as far as possible, away from the sections of maximum stress and shall be staggered.

b) Where the depth of a beam exceeds 750 mm in case of beams without torsion and 450 mm with torsion, side face reinforcement shall be provided.

c) In two-way slab, reinforcement parallel to the short span of the slab shall be placed in the bottom layer at mid-span and in the top layer at support.

d) All spacing shall be centre-to-centre spacing of bars.

e) Deflection in slabs/beams may be reduced by providing compression reinforcement.

f) Only closed stirrups shall be used for transverse reinforcement for members subject to torsion and for members likely to be subjected to reversal of stress.

g) At beam-column intersections ensure that the main beam bars avoid the main column bars.

h) At beam-beam intersections, main reinforcement may be so arranged that layers in mutually perpendicular beams are at different levels.

j) To accommodate bottom bars, it is good practice to make secondary beams shallower than main beams, at least by 50 mm.

k) If it is required the beam cages may be preassembled with splice bars.

5.10.3 *Do's—Columns*

a) A reinforced column shall have at least six bars of longitudinal reinforcement for using in transverse helical reinforcement.

b) Spacing of longitudinal bars in column shall be along the periphery of the column, as far as practicable.

c) Column bars of diameters larger than 36 mm in compression can be spliced with dowels at the footing with bars of smaller sizes and of necessary area.

d) A dowel shall extend into a column, a distance equal to the development length of the column bar and into footing a distance equal to development length of the dowel.

e) Keep outer dimensions of column constant, as far as possible, for re-use of forms.

f) Preferably avoid use of two grades of vertical bars in the same element.

5.10.4 *Dont's—General*

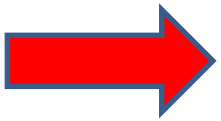
a) Reinforcement shall not extend across an expansion joint and the break between the sections shall be complete.

c) Lap splices shall not be used for bars larger than 36 mm diameter except where welded.

d) Bars larger than 36 mm diameter shall not be bundled.

e) Where dowels are provided their diameter shall not exceed the diameter of the column bars by more than 3 mm.

f) Where bent bars are provided, their contribution towards shear resistance shall not be more than half that of the total shear reinforcement.



Under no circumstances should the bending of bars at welds be permitted.