Training on NBC Compliant Computer Aided Design of buildings for Engineers/Designers of Kathmandu Valley

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Ductile Detailing of RC Frame Buildings

1 - 7 Sept , 2014

Kathmandu

Technical support from CoRD

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DETAILING OF RC MEMBERS

Detailing is often considered to be the preparation of working drawings showing the size and location of the reinforcement in a concrete structure.

Detailing involves the communication of the engineer's design to the contractors who build the structure. It involves the translation of a good structural design into the final structure.

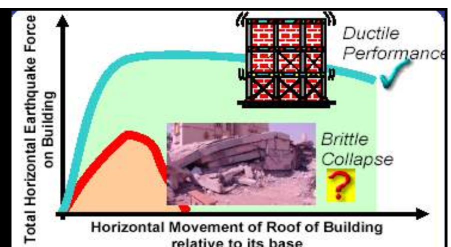
Good detailing ensures that reinforcement and concrete interact efficiently to provide satisfactory behavior throughout the complete range of loading.

DETAILING OF RC MEMBERS

1. ***IS 456:2000 Indian Standard for*** **Plane and Reinforced Concrete - Code of Practice (*Fourth* Revision)**

2. **IS 13920 Indian Standard for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces - Code of Practice**

DUCTILE DETAILING



(a) Building performances during earthquakes: two extremes – *the ductile and the brittle*.

- Better behavior
- To improve ductility of building

Earthquake-resistant design is concerned about ensuring that the damages in buildings during earthquakes are of the acceptable variety, and also that they occur at the right places and in right amounts.

MAKE BUILDING DUCTILE

The most common construction material:

- Masonry.
- Concrete.
- Steel is used as reinforcement.

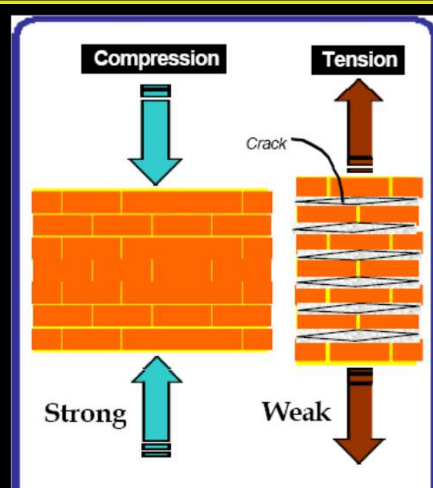
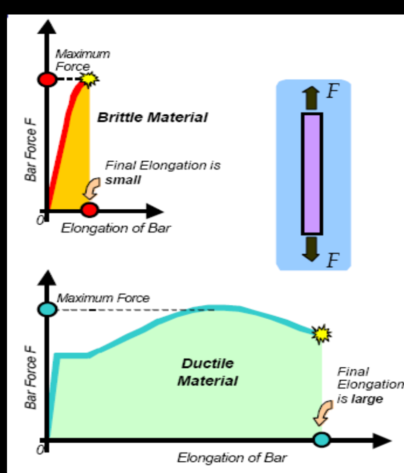
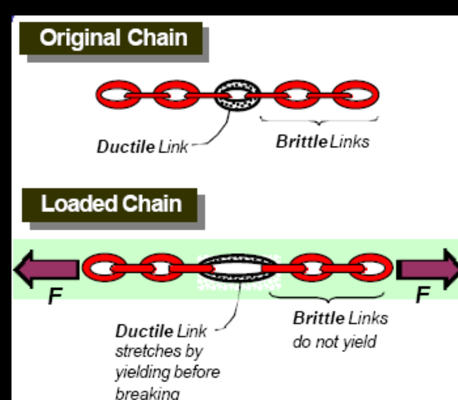


Figure 1: Masonry is strong in compression but weak in tension.

DUCTILITY FOR GOOD SEISMIC PERFORMANCE

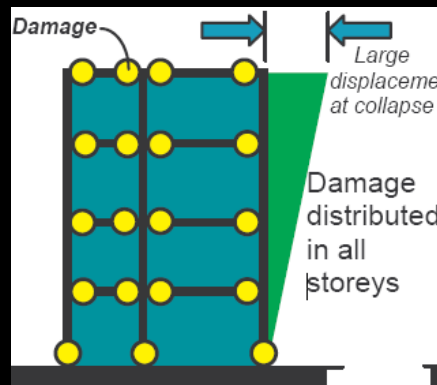


Brittle & Ductile Behaviour



Chain Analogy for Ductile Failure

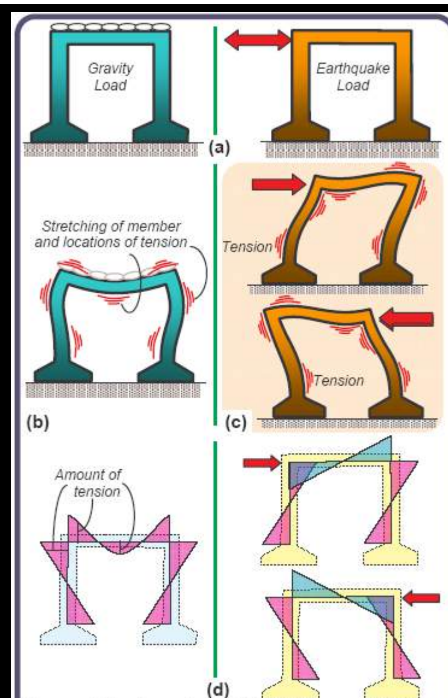
DETAILING



- Better behavior
- To improve ductility of building

Earthquake-resistant design is concerned about ensuring that the damages in buildings during earthquakes are of the acceptable variety, and also that they occur at the right places and in right amounts. This approach of earthquake-resistant design is much like the use of electrical fuses in houses. Likewise, to save the building from collapsing, you need to allow some pre-determined parts to undergo the acceptable type and level of damage.

DETAILING



Our Practice for Detailing : Ignorance?

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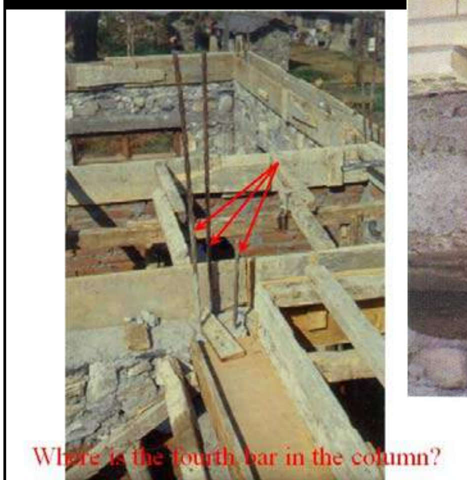

Our Practice for Detailing : Ignorance?

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Our Practice for Detailing : Ignorance?

How do Beams resist EQ

Long straight bars (longitudinal bars) placed along its length.

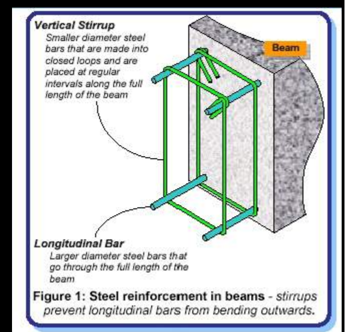
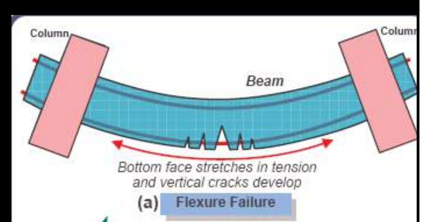


Figure 1: Steel reinforcement in beams - *stirrups prevent longitudinal bars from bending outwards.*

Closed loop of small diameter bars (stirrups) placed vertical at regular interval along its length.

2 Basic Types of Failure in Beams



Flexure (Bending) Failure:

ductile failure and hence is desirable.

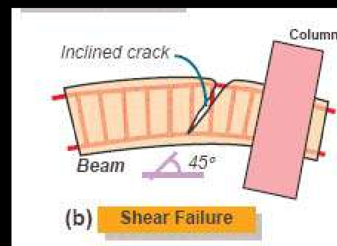
a) Brittle failure

Relatively more steel is present on the tension face, crushes in compression which is undesirable

b) Ductile failure

Relatively less steel is present on the tension face, steel yield first and redistribution occurs in the beam until eventually concrete crushes.

2 Basic Types of Failure in Beams



Shear Failure:

A beam may also fail due to shearing action.

Closed loop stirrups are provided to avoid such shearing action. Shear damage occurs when the area of these stirrups is insufficient.

Shear failure is brittle, and therefore, shear failure must be avoided in the design of RC beams.

GENERAL REQUIREMENT IS13920-1993

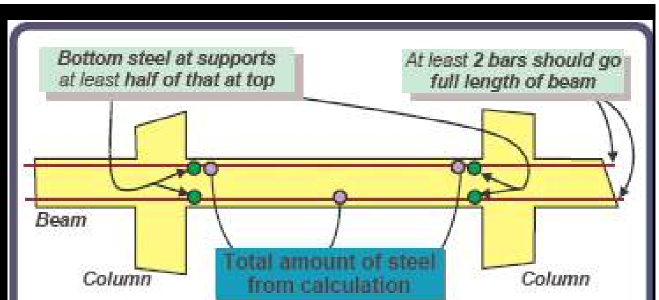
- **The factored axial stress on the member under earthquake loading shall not exceed 0.1 f_{ck}.**
- **The member shall preferably have a width-to-depth ratio of more than 0.3.**
- **The width of the member shall not be less than 200 mm.**
- **The depth D of the member shall preferably be not more than 1/4 of the clear span.**

BEAM

-Width, b ≥ 200mm
- Nominal Cover ≥ 25mm
-Width to effective depth ratio ≥ 0.3
-Steel percentage ≤ 2.5%
-minimum area of tension bar :
$As/(bd) = 0.85/(fy)$
-minimum ratio = $0.24\sqrt{(f_{ck}/f_y)}$
-max. ratio = 0.025

-minimum shear bar
$Asv/(b*Sv) \geq 0.4/(0.87*Fy)$
where ,Sv = stirrups spacing

Flexure

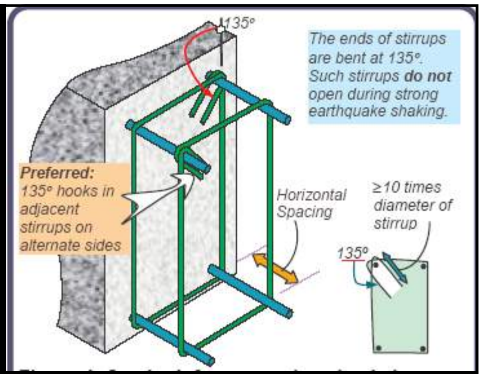


Longitudinal Bars : are provided to resist flexure
Requires on both faces at the ends and on the bottom face at mid length

✓At least two bars go through the full length of the beam at the top as well as at the bottom of the beam.

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

Shear

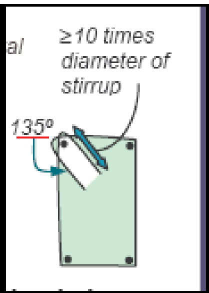


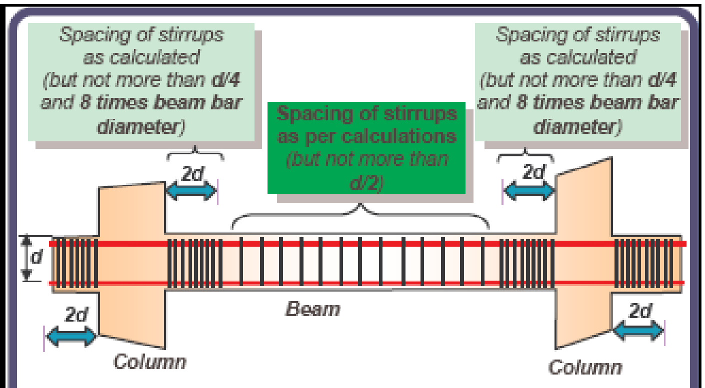
Stirrups help in three ways

✓**Carry vertical shear force and resist diagonal crack.**

✓**Protect concrete from bulging outward due to flexure**

✓**Prevent buckling of compressed longitudinal bar due to flexure**



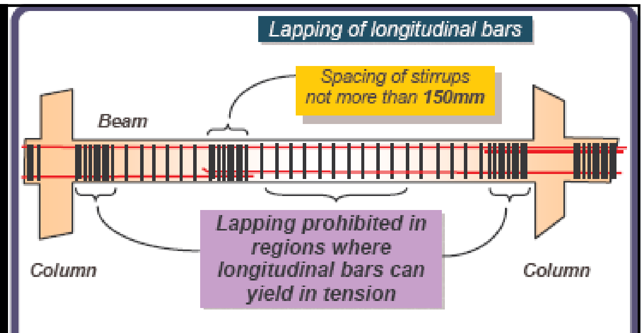


a) **Diameter at least 6 mm but not less than 8 mm for beam longer than 5 m.**

b) **135 hook at both end and 10 times diameter extension.**

c) **Maximum spacing less than half the depth of beam.**

d) **Maximum spacing less than quarter the depth of beam for twice the depth of beam from support.**



At the location of the lap, the bars transfer large forces from one to another

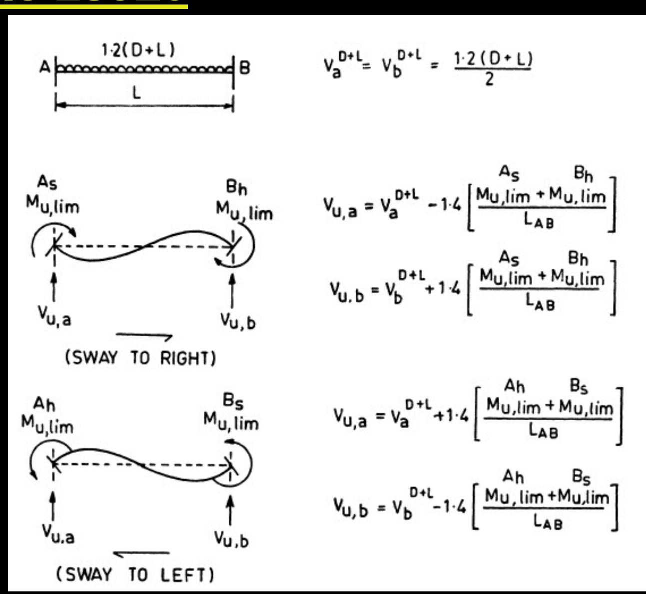
Laps of the longitudinal bars are:

a) Made away from the face of column.

b) Not made at locations where they are likely to stretch by large amounts and yield (eg. Bottom bars at mid length of the beam)

At the location of laps, vertical stirrups should be provided at clos er spacing

Calculation of Design Shear Force of Beam : IS 13920



How do Column resist EQ

Column can sustain 2 types of damage:

a) Axial Flexural (Combined Compression Bending) failure
b) Shear Failure (Brittle Damage) & must be avoided by providing lateral ties

Column

Design

-Width to Depth ratio ≥ 0.4
-0.8% ≤ Steel percent ≤ 4.0%
-Number of bars in rectangular section ≥ 4
-Longitudinal bar diameter (φ) ≥ 12mm
-Clear cover ≥ 40mm
-Minimum width of column = 300mm

Column

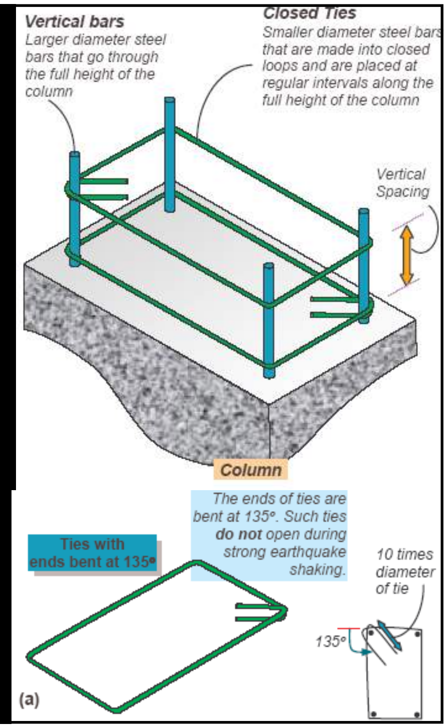
Closely spaced horizontal closed ties help in three ways,

(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, and

(iii) they contain the concrete in the column within the closed loops. The ends of the ties must be bent as 135° hooks. Such hook ends prevent opening of loops and consequently

buckling



Column

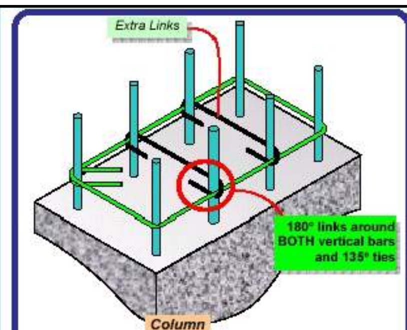


Figure 3: Extra links are required to keep the concrete in place – 180° links are necessary to prevent the 135° tie from bulging outwards.

In column where spacing between the corner bar exceeds 300 mm:

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

Height of Confinement Zone:
larger of D, h_c/6 or 450 mm

Spacing of ties in CZ:

$\leq$ D/4

but $\geq$75 mm and $\leq$ 100 mm

Spacing of ties in Lap Zone:

$\leq$ D/2 and $\leq$ 150 mm

Spacing of ties in rest :

$\leq$ D/2

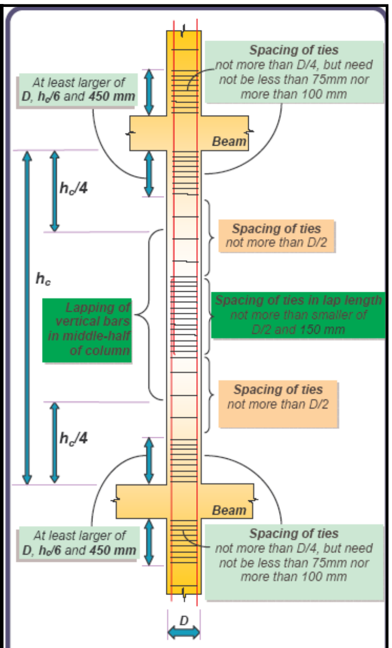


Figure 4: Placing vertical bars and closed ties in columns – *column ends and lap lengths are to be protected with closely spaced ties.*

Longitudanal Reinforcement

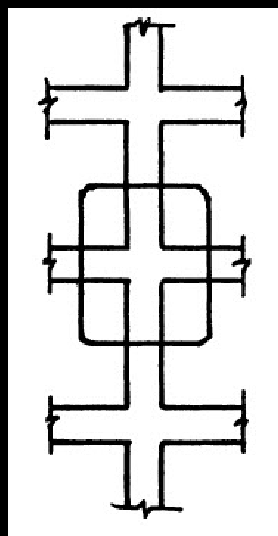
Lap splices shall be provided only in the central half of the member length. It should be proportioned as a tension splice. Hoops shall be provided over the entire splice length at spacing not exceeding 150 mm centre to centre. Not more than 50 percent of the bars shall be spliced at one section.

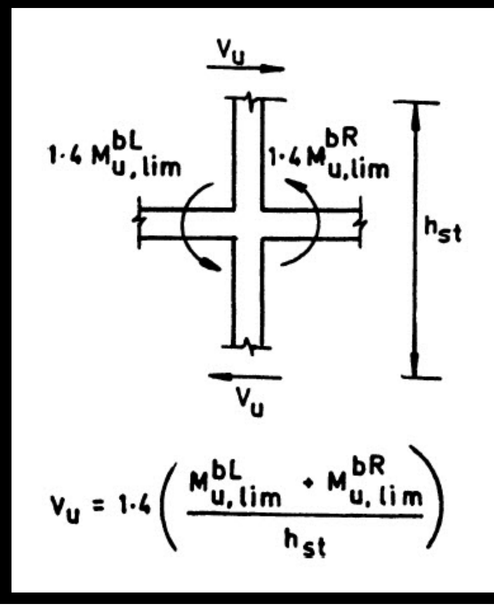
Transverse Reinforcement

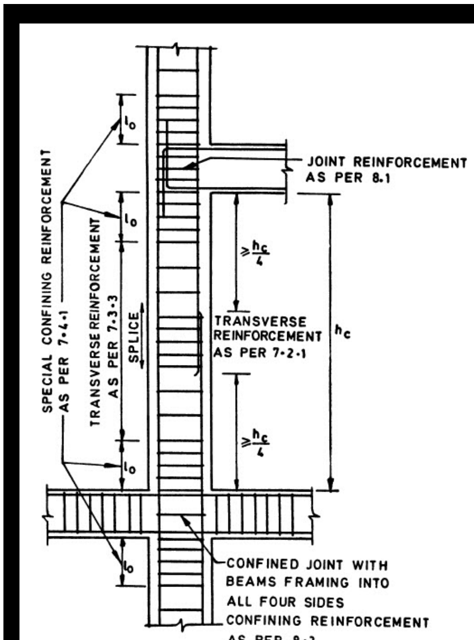
The design shear force for columns shall be the maximum of:

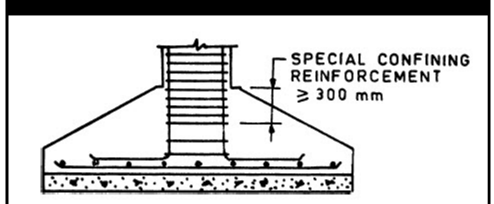
a) **calculated factored shear force as per analysis, and**
b) **a factored shear force given by….**

CALCULATION OF DESIGN SHEAR FORCE IN COLUMN IS 13920









PROVISION OF SPECIAL CONFINING REINFORCEMENT IN FOOTINGS

COLUMN AND JOINT DETAILING

AREA OF CROSS SECTION OF SPECIAL CONFINING REINFORCEMENT

- **Area of cross section, Ash of the bar forming rectangular hoop, to be used as special confining reinforcement shall not be less than**

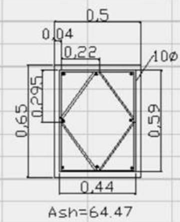
  Ash=0.18*S*hk*fck/fy*(Ag-Ak-1)

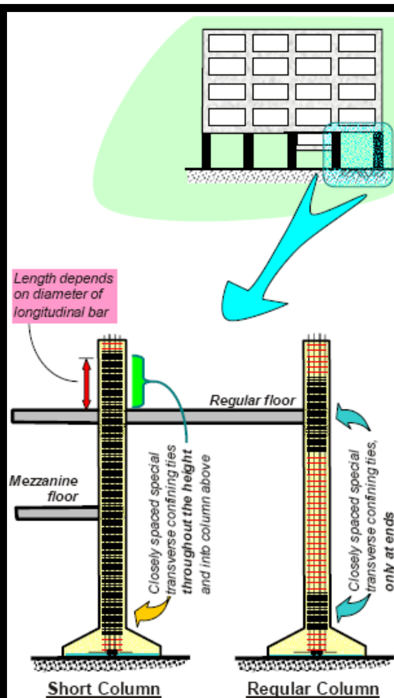
  Where hk=longer dimension of the rectangular confining hoop measured to its outer face

  S= Pitch

Area of cross section of special conforming reinforcement

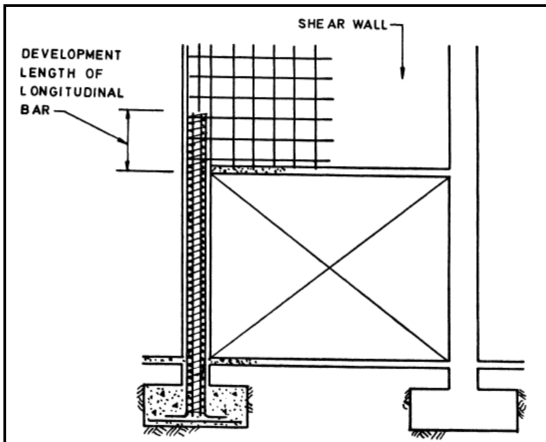
Column depth	566	Gross area	283000
Column width	500	Core area	222640
Cover to main bar	40	Ash	69.37811
Stirrup diametre	10		
Longer distance of hoop	295		
Pitch	100		
area of #7	39		
area of #8	50		
area of #10	79		
area of #12	113		





Detailing for Reducing Short Column Effect:

Provide Special Confining Reinforcement in the form of closely spaced ties throughout the height and into the column above.



Columns supporting reactions from discontinued stiff members, such as walls, shall be provided with special confining reinforcement over their full height.

This reinforcement shall also be placed above the discontinuity for at least the development length of the largest longitudinal bar in the column.

Where the column is supported on a wall, this reinforcement shall be provided over the full height of the column; it shall also be provided below the discontinuity for the same development length.

The area of cross section, *A_{sh}, of the bar* forming circular hoops or spiral, to be used as special confining reinforcement, shall not be less than

$$A_{sh} = 0.18\, Sh\, \frac{f_{ck}}{f_y}\left[\frac{A_g}{A_k} - 1.0\right]$$

A_{sh} = area of the bar cross section,
S = pitch of spiral or spacing of hoops,
***D_k = diameter of core measured to the* outside of the spiral or hoop,**
***f_{ck} = characteristic compressive strength of* concrete cube,**
***f_y = yield stress of steel (of circular hoop or* spiral),**
***A_g = gross area of the column cross section,* and**
A_k = area of the concrete core =
***h = longer dimension of the rectangular* confining hoop measured to its outer face**

Deformability (ductility) of reinforced concrete members is a necessity. Note the obvious differences of capability of concrete columns to take load after earthquake damage. The reinforced column with more stirrups (ductile reinforcing) has an obvious capacity to carry much more load than the column with less stirrups

Improper lapping of column bars

The pictures show damage concentration in the region of bar lapping. Because of interaction between overlapped bars and concrete for load transfer the overlapping section suffers higher level of damage. This interaction is further coupled with lack of stirrups which has led to buckling of bars, loss of concrete

BEAM COLUMN JOINT

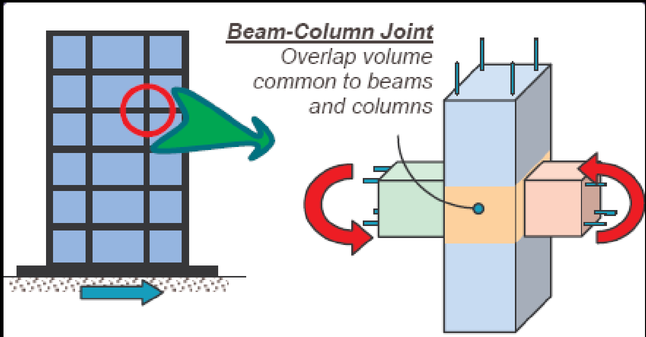


Figure 1: Beam-Column Joints are critical parts of a building – *they need to be designed.*

In RC buildings, portions of columns that are common to beams at their intersections are called beam-column joints. Repairing damaged joints is difficult, and so damage must be avoided.

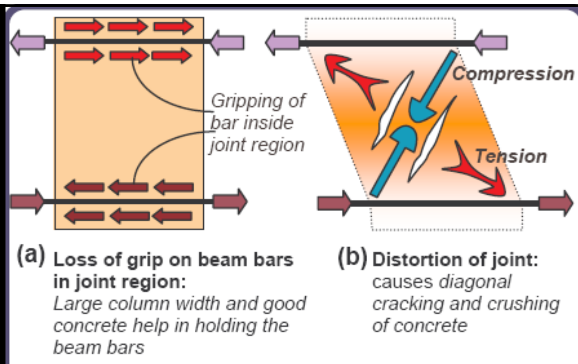


Figure 2: Pull-push forces on joints cause two problems – these result in irreparable *damage in joints under strong seismic shaking*.

Under earthquake moment, the top & bottom beam bars pull in opposite direction.
If size of joint is small or concrete strength is low – bar slips
Joint undergo geometric distortion and if the size is insufficient – diagonal crack occur.
Can be controlled by – providing large column size – providing closed ties.

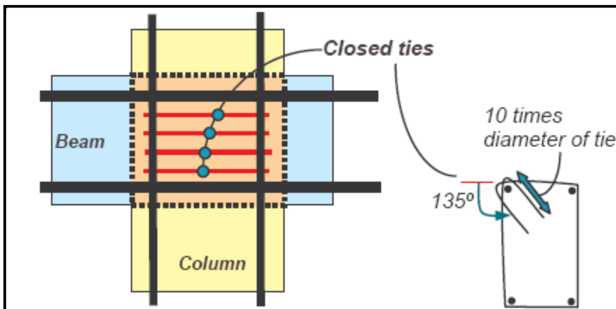


Figure 3: Closed loop steel ties in beam-column joints – *such ties with 135° hooks resist the ill effects of distortion of joints.*

Column width – at least 20 times the diameter of largest beam bar.
Closed loop steel ties in beam column joints confine the concrete in the joint.
It also resist the shear force reducing the cracking & crushing of concrete.

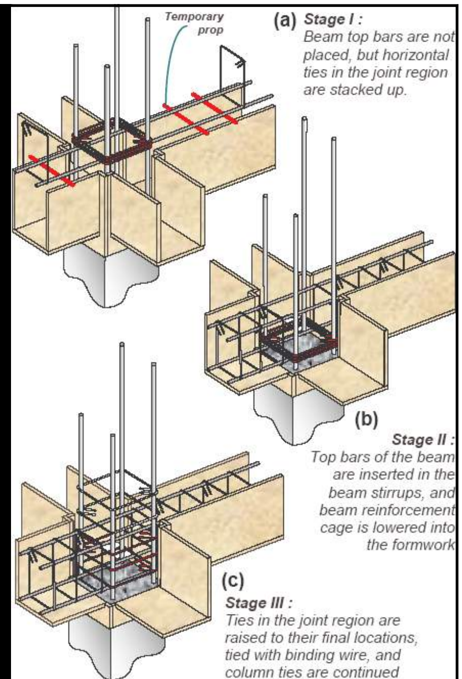


Figure 4: Providing horizontal ties in the joints – *three-stage procedure is required.*

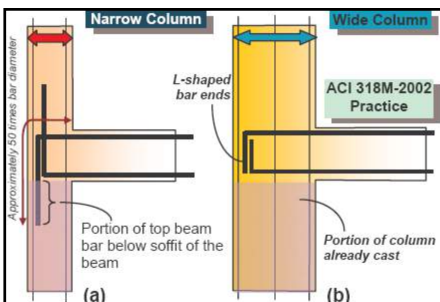


Figure 5: Anchorage of beam bars in exterior joints – *diagrams show elevation of joint region.*

In Exterior Joint – beam bar need to be anchored into column to ensure proper gripping.

In Interior Joint – beam bars need to go through the joint without any cut in the joint region. Also, these bars must be placed within column bars and with no bends.

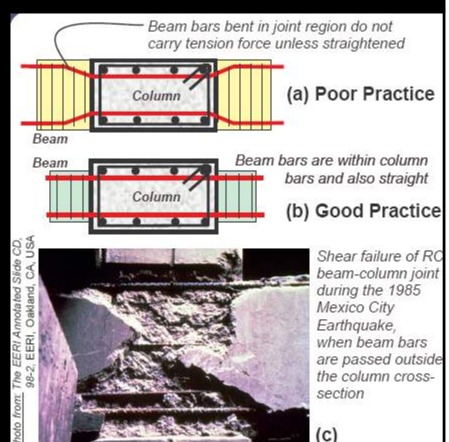


Figure 6: Anchorage of beam bars in interior joints – *diagrams (a) and (b) show cross-sectional views in plan of joint region.*

External Beam-Column Joint

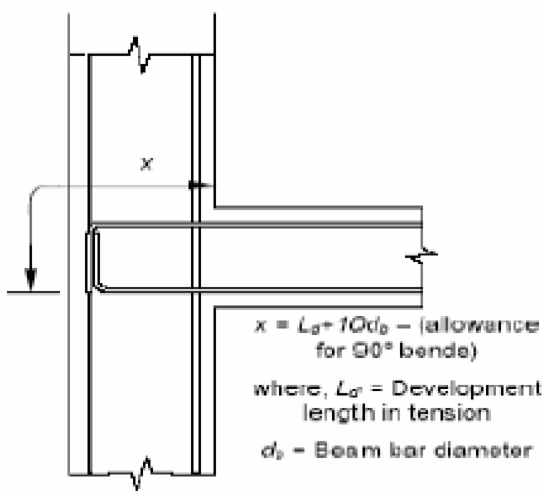


Figure 1 – Anchorage of beam bars in an external joint

26.2 Development of Stress in Reinforcement

The calculated tension or compression in any bar at any section shall be developed on each side of the section by an appropriate development length or end anchorage or by a combination thereof.

26.2.1 *Development Length of Bars*

The development length L_d is given by

$$L_d = \frac{\phi\ \sigma_s}{4\ \tau_{bd}}$$

where

ϕ = nominal diameter of the bar,

σ_s = stress in bar at the section considered at design load, and

τ_{bd} = design bond stress given in **26.2.1.1**.

NOTES

1 The development length includes anchorage values of hooks in tension reinforcement.

2 For bars of sections other than circular, the development length should be sufficient to develop the stress in the bar by bond.

	Concrete M20				Concrete M25				Concrete M30			
Φ	415		500		415		500		415		500	
12	47	564	57	680	40	484	49	583	38	451	49	544
16	47	752	57	906	40	645	49	777	38	602	49	725
20	47	940	57	1133	40	806	49	971	38	752	49	906
25	47	1175	57	1416	40	1007	49	1214	38	940	49	1133
28	47	1316	57	1586	40	1128	49	1359	38	1053	49	1269
32	47	1504	57	1813	40	1289	49	1554	38	1204	49	1450

Slab

Since slabs are not significantly affected by lateral loads, provisions of IS 13920 do not apply in this case . Following are relevant provisions of IS 456:2000

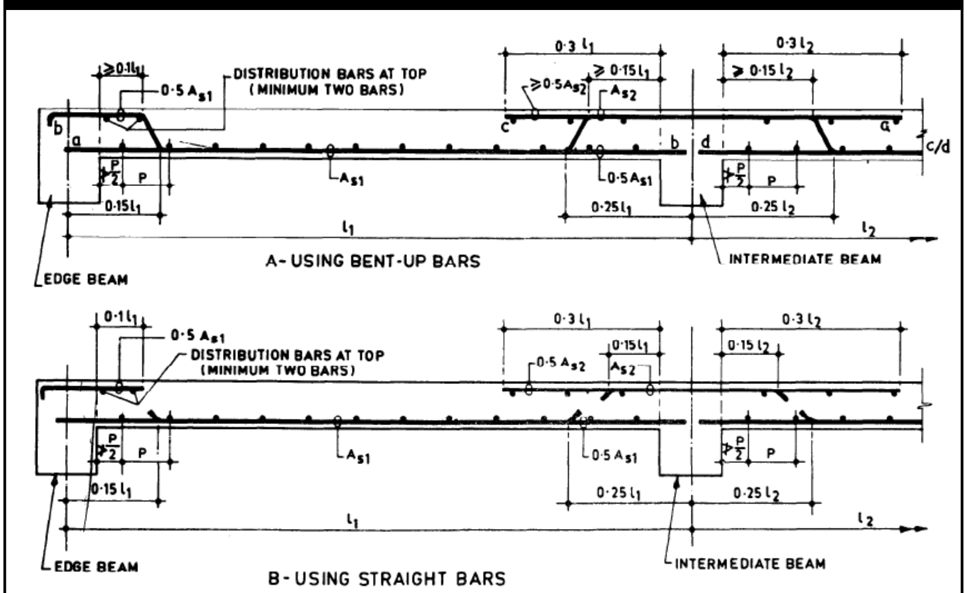
-**Reinforcement percentage ≥ 0.12%**

-**Nominal cover ≥ 15 mm**

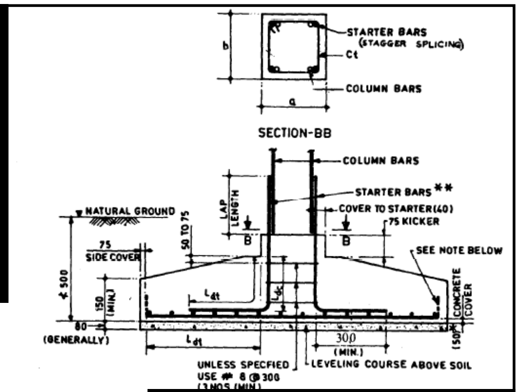
-**Main steel spacing ≤ minimum of (3d, 300mm)**

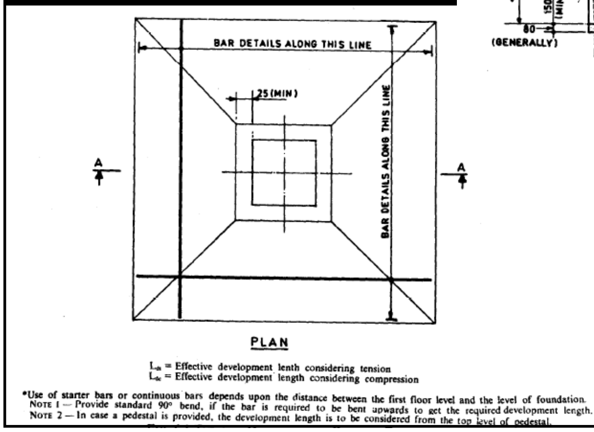
-**Distributor steel spacing ≤ minimum of (4d, 450mm)**

Slab

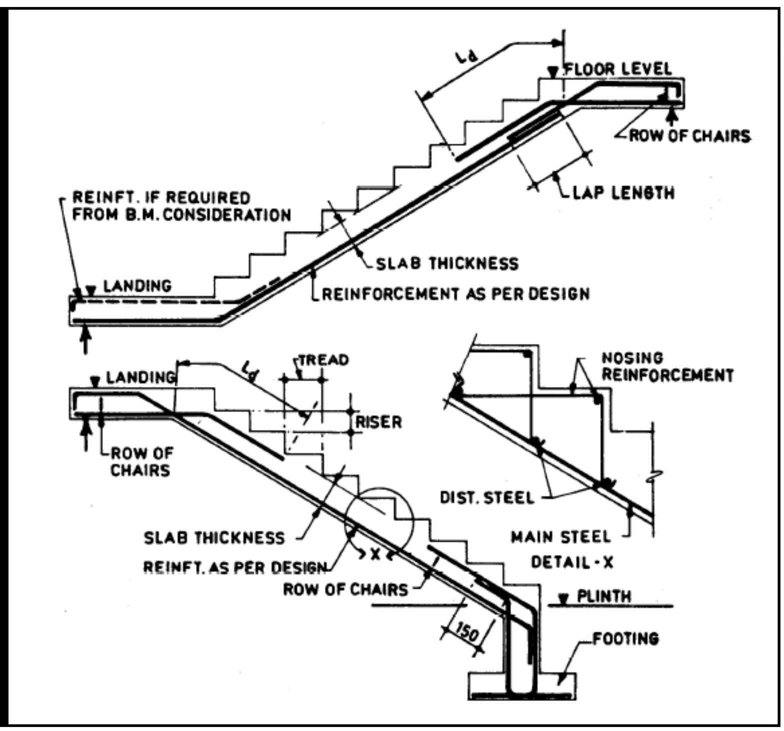


Foundation





Stair



Thank You !!!