Frequently Asked Questions

Question 01:

Explain in detail about the beams in RC buildings and their design strategies.

Answer:

- In RC buildings, the vertical and horizontal members (i.e., the columns and beams) are built integrally with each other.
- Thus, under the action of loads, they act together as a frame transferring forces from one to another.

Beams in RC Buildings and Earthquakes

- Beams in RC buildings have two sets of steel reinforcement, namely:

- long straight bars (called longitudinal bars) placed along its length,
- closed loops of small diameter steel bars (called stirrups) placed vertically at regular intervals along its full length.

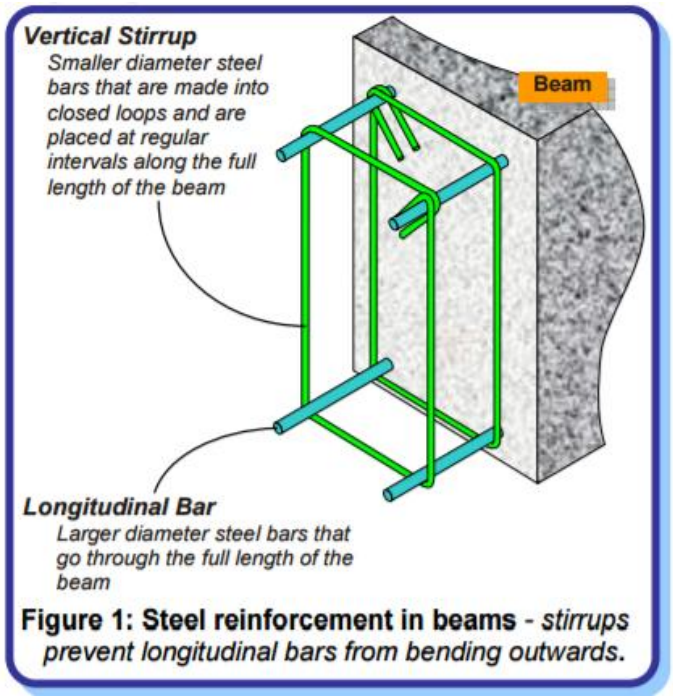

Figure 1: Steel reinforcement in beams - *stirrups prevent longitudinal bars from bending outwards.*

Beams sustain two basic types of failures, namely:

(a)Flexural (or Bending) Failure:

- As the beam sags under increased loading, it can fail in two possible ways. If relatively more steel is present on the tension face, concrete crushes in compression; this is a brittle failure and is therefore undesirable.
- If relatively less steel is present on the tension face, the steel yields first and redistribution occurs in the beam until eventually the concrete crushes in compression; this is a ductile failure and hence is desirable
- Thus, more steel on tension face is not necessarily desirable! The ductile failure is characterized with many vertical cracks starting from the stretched beam face, and going towards its mid-depth.

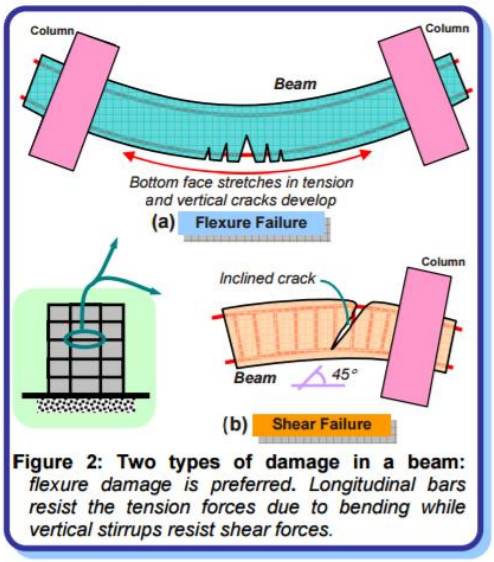

Figure 2: Two types of damage in a beam: *flexure damage is preferred. Longitudinal bars resist the tension forces due to bending while vertical stirrups resist shear forces.*

(b) Shear Failure:

- A beam may also fail due to shearing action. A shear crack is inclined at 45° to the horizontal; it develops at mid-depth near the support and grows towards the top and bottom faces.
- Closed loop stirrups are provided to avoid such shearing action. Shear damage occurs when the area of these stirrups is insufficient.

<u>Design Strategy:</u>

- Designing a beam involves the selection of its material properties, shape and size.
- These are usually selected as a part of an overall design strategy of the whole building. And, the amount and distribution of steel to be provided in the beam must be determined by performing design calculations.
- Longitudinal bars are provided to resist flexural cracking on the side of the beam that stretches. Since both top and bottom faces stretch during strong earthquake shaking longitudinal steel bars are required on both faces at the ends and on the bottom face at mid-length.
- Stirrups in RC beams help in three ways, namely

- they carry the vertical shear force and thereby resist diagonal shear cracks
- They protect the concrete from bulging outwards due to flexure, and
- They prevent the buckling of the compressed longitudinal bars due to flexure.

- In moderate to severe seismic zones, the following requirements related to stirrups in reinforced concrete beams:

- The diameter of stirrup must be at least 6mm; in beams more than 5m long, it must be at least 8mm.
- Both ends of the vertical stirrups should be bent into a 135° hook and extended sufficiently beyond this hook to ensure that the stirrup does not open out in an earthquake.

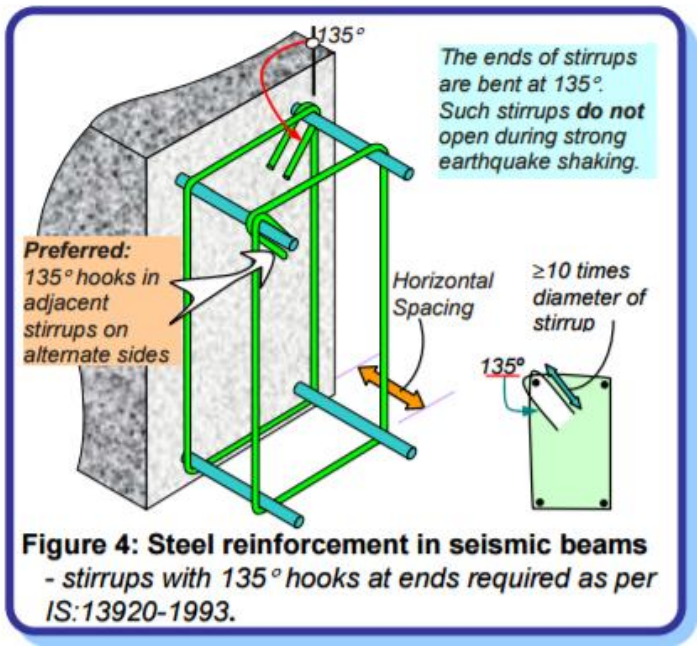

Figure 4: Steel reinforcement in seismic beams *- stirrups with 135° hooks at ends required as per IS:13920-1993.*

- The spacing of vertical stirrups in any portion of the beam should be determined from calculations
- The maximum spacing of stirrups is less than half the depth of the beam.
- For a length of twice the depth of the beam from the face of the column, an even more stringent spacing of stirrups is specified.

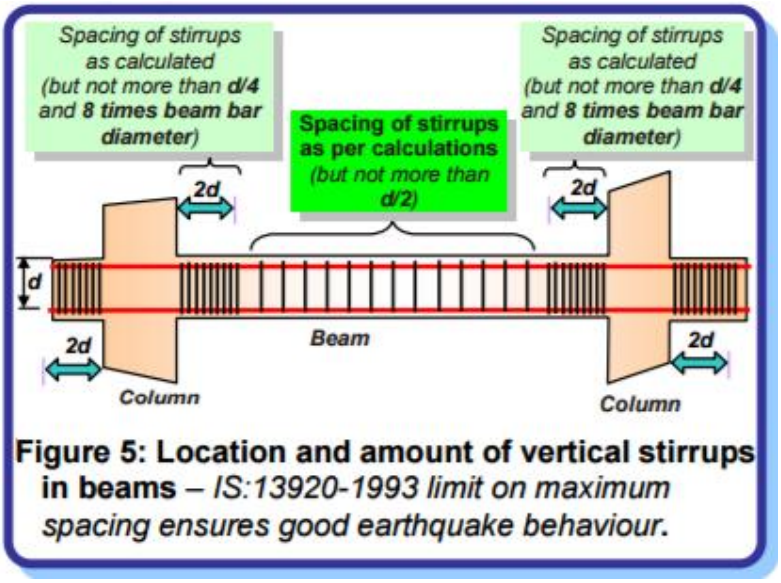

Figure 5: Location and amount of vertical stirrups in beams – *IS:13920-1993 limit on maximum spacing ensures good earthquake behaviour.*

✓ Steel reinforcement bars are available usually in lengths of 12-14m. Thus, it becomes necessary to overlap bars when beams of longer lengths are to be made.

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

Question 02:

Explain in detail about the columns in RC buildings and their design strategies.

Answer:

➢ Columns, the vertical members in RC buildings, contain two types of steel reinforcement, namely:

- long straight bars (called longitudinal bars) placed vertically along the length.
- closed loops of smaller diameter steel bars (called transverse ties) placed horizontally at regular intervals along its full length.

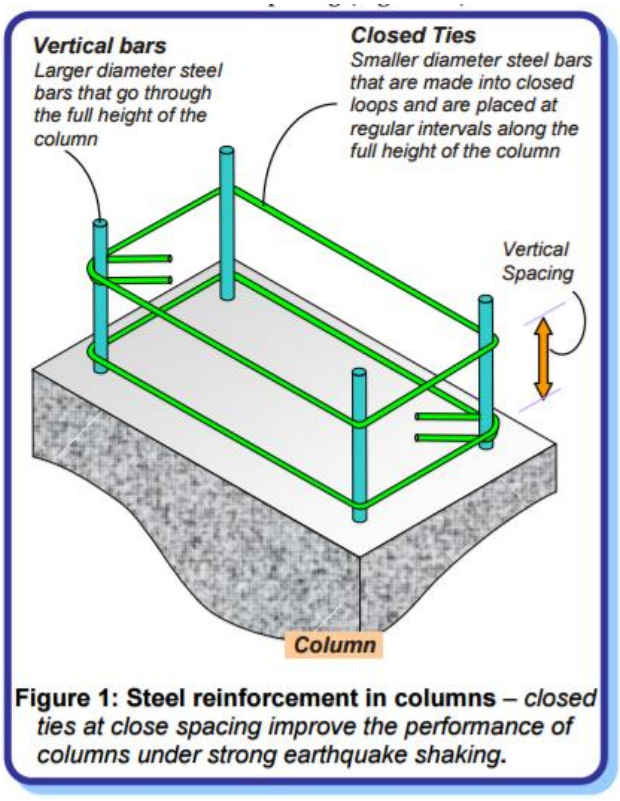

Figure 1: Steel reinforcement in columns – *closed ties at close spacing improve the performance of columns under strong earthquake shaking.*

➢ 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.

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.
- Closely spaced horizontal closed ties help in three ways, namely
    - They carry the horizontal shear forces induced by earthquakes, and thereby resist diagonal shear cracks
    - They hold together the vertical bars and prevent them from excessively bending outwards. This bending phenomenon is called buckling
    - 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 bulging of concrete and buckling of vertical bars.

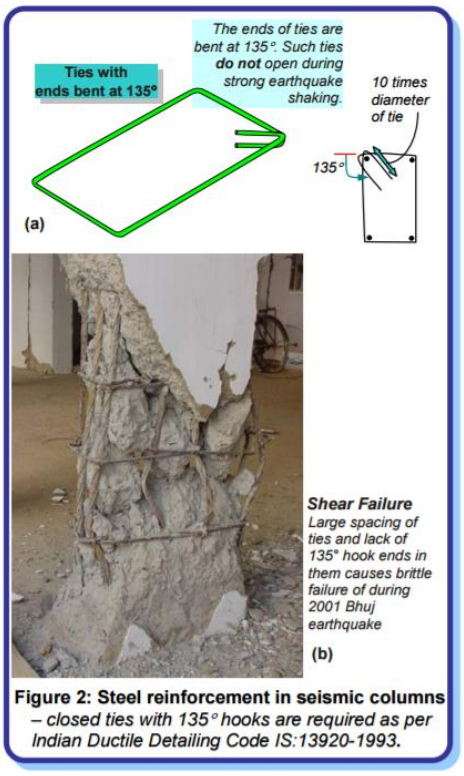

Figure 2: Steel reinforcement in seismic columns – *closed ties with 135° hooks are required as per Indian Ductile Detailing Code IS:13920-1993.*

The Indian Standard 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) 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 ;special care is required to implement this properly at site.

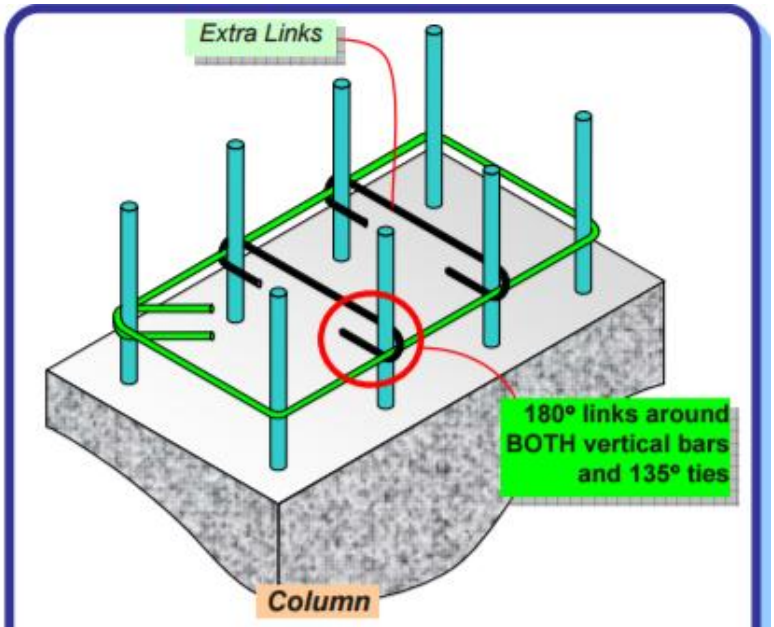

Figure 3: Extra links are required to keep the concrete in place – *180° links are necessary to prevent the 135° tie from bulging outwards.*

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.

- 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.

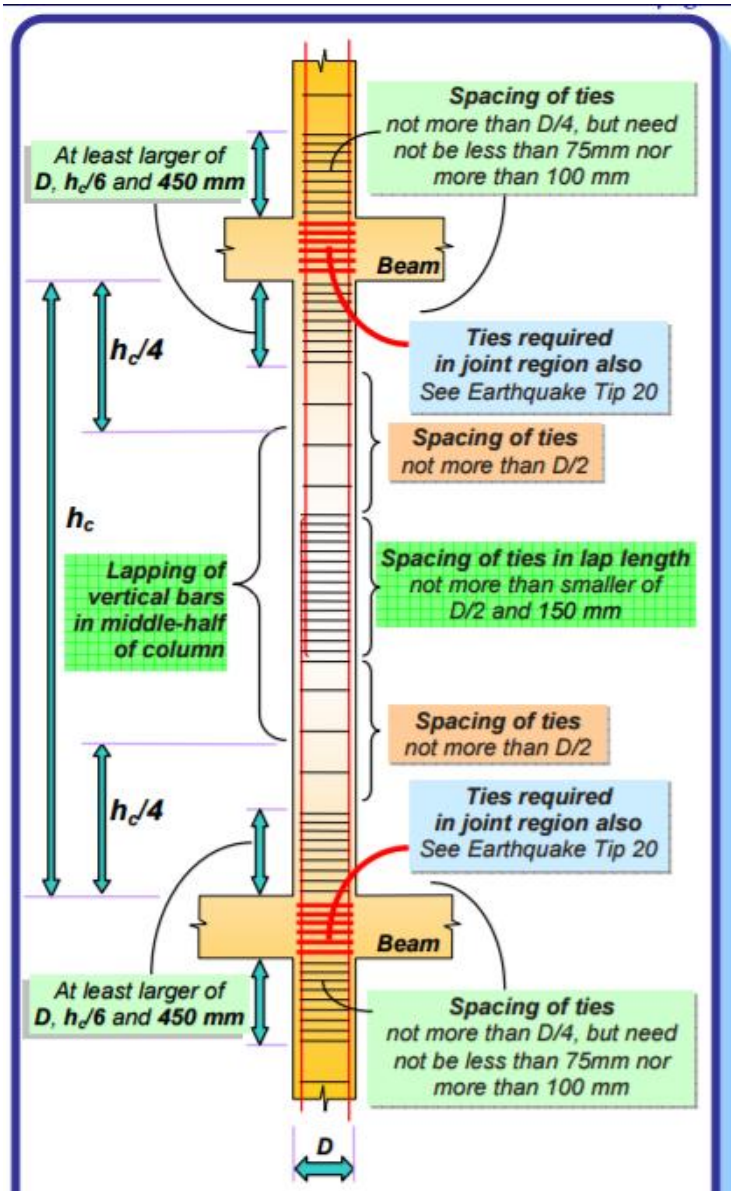

Figure 4: Placing vertical bars and closed ties in columns – *column ends and lap lengths are to be protected with closely spaced ties.*

Question 03:

Explain about the beam-column joints in RC structures and the behavior of joints during earthquakes.

Answer:

- In RC buildings, portions of columns that are common to beams at their intersections are called beam column joints.
- Since their constituent materials have limited strengths, the joints have limited force carrying capacity.
- When forces larger than these are applied during earthquakes, joints are severely damaged. Repairing damaged joints is difficult, and so damage must be avoided. Thus, beam-column joints must be designed to resist earthquake effects.

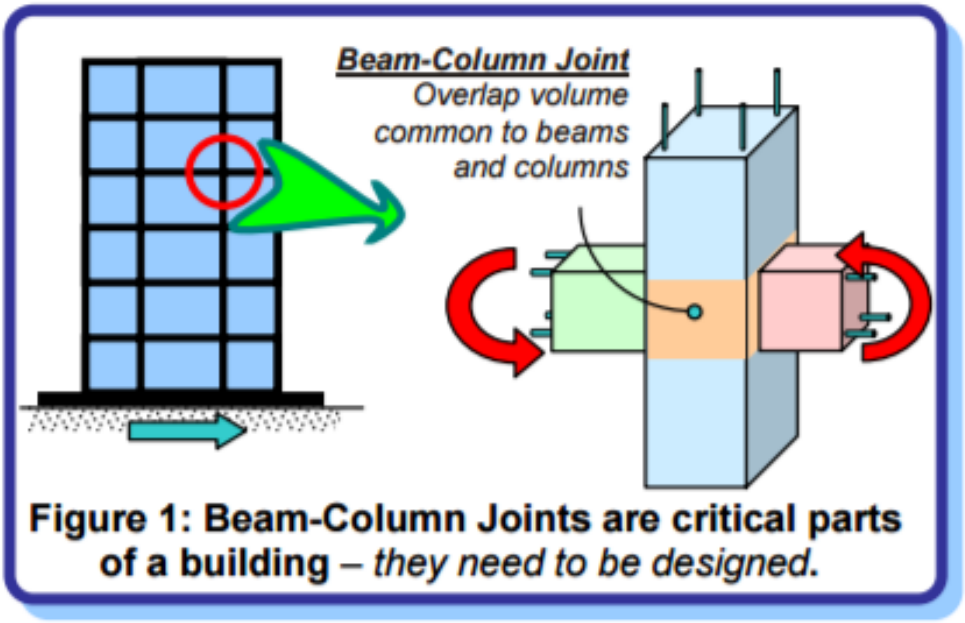

Figure 1: Beam-Column Joints are critical parts of a building – *they need to be designed.*

- Under earthquake shaking, the beams adjoining a joint are subjected to moments in the same (clockwise or counter-clockwise) direction.
- Under these moments, the top bars in the beam-column joint are pulled in one direction and the bottom ones in the opposite direction.

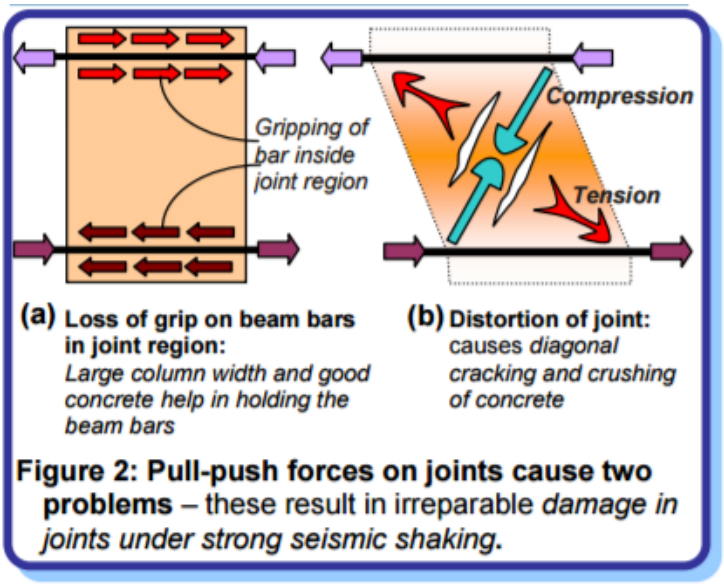

Figure 2: Pull-push forces on joints cause two problems – these result in irreparable *damage in joints under strong seismic shaking.*

- ✓ These forces are balanced by bond stress developed between concrete and steel in the joint region.
- ✓ If the column is not wide enough or if the strength of concrete in the joint is low, there is insufficient grip of concrete on the steel bars. In such circumstances, the bar slips inside the joint region, and beams loose their capacity to carry load.
- ✓ Further, under the action of the above pull-push forces at top and bottom ends, joints undergo geometric distortion; one diagonal length of the joint elongates and the other. If the column cross-sectional size is insufficient, the concrete in the joint develops diagonal cracks.