Code feature section

ECCENTRIC BEAM TO COLUMN JUNCTIONS

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May I, through the Society's Bulletin, draw attention to a stress condition occasionally occurring in framed structures which, I believe, is little recognised and seldom provided for. I refer to torsional and other stresses developed in columns as a result of lateral loads applied to frames with eccentric beam/column connections.

This condition arises to a lesser degree with normal wind loads, but under the action of seismic forces where in general magnitudes are of a higher order, the induced stresses may reach significant values. These should not be overlooked, particularly as they are superimposed on other stresses normally occurring and could result in failure through 'column hinging' in designs where a beam hinge mechanism has been assumed, with consequent greater increase in ductility demand.

A column which is acted on by lateral loads in a direction parallel to one of the principal axes of the frame is conventionally designed for forces and moments assumed to be acting about common gravity axes for the intersection, and for a competitive and economic design to be produced the section properties are tailored to allow the ultimate strength to be realised close to a specified multiple of the assumed applied load, that is to say, within near limits the full strength of the section is utilised under concentric conditions. This is, of course, a perfectly ordinary procedure, but it must be remembered that the analysis is only valid if the member axes are co-planar. Where eccentricity occurs, see figure 1, torsions will arise about a horizontal axis through the joint normal to the plane of the frame. Depending upon the exact configuration of the joint, a couple acting about a vertical axis may also be produced which causes bending across the column section and requires that restraint be provided by the floor construction.

Critical conditions in columns due to bending and shear normally occur immediately at beam boundary levels, but it is in this locality also that forces resulting from member eccentricity are diverted through the block common to both systems, thus producing more complex stress patterns. If the joint is already fully stressed by in-plane bending and shear, the additional effects due to eccentricity can only be catered for by an incursion into the load factor. Where the eccentricity is minor it may be possible to support the condition in this manner - the load factor is provided amongst other things to allow for small contingent items - but it is probable, especially for high-rise buildings and/or large eccentricities that the magnitude of the supposed 'secondary' effect will be appreciable, requiring separate examination and proper provision made for the additional stresses that are generated. It must also be borne in mind that a high shear stress, which in this case arises from the induced torsion, is associated with non-ductile failure and this is to be avoided at all costs.

In New Zealand, seismic design for concrete ductile moment-resisting space frames is based on the recommendations of the S.E.A.O.C. seismology committee, and these require that the total ultimate moment capacity of the column shall be greater than the total ultimate moment capacity of the beams along their principal planes at the joint. This provision ensures that the reinforcement in the beams yields first, thereby forming hinges in them rather than in the columns so that the greatest possible number of members are hinged with energy dissipation a maximum before a collapse mechanism becomes operative. If the calculated stresses in the columns are inflated by torsional effects not taken into account in the design, it is possible for the capacity of the columns to be less than the capacities of the beams and an unsatisfactory collapse mechanism will be set up, leading to early failure.

Differences between planar and non-planar bending can be conveniently illustrated by representing the configurations in 'equivalent' systems. It is not suggested however that an analytical approach through such systems will provide adequate information for design purposes. Figure 2 shows the 'truss' action for a system with co-incident member axes. For comparison the torsional effect may be represented by the offset truss system shown in figure 3. Additional forces and hence stresses are clearly evident and indicate that overstressing may occur unless additional material and/or higher material strengths are provided.

In practice the member forces do not lie in simple planes but are distributed across the sections and, as a further complication, member overlap occurs. Component dimensions are thus imprecise. Also, those parts of columns and beams contiguous with the block common to both will affect stress dispersion. It is, under such conditions, sensible to make simplifying assumptions to allow analyses to be readily carried out.

As joint stresses arising from lateral loads in, or parallel to, one plane often occur simultaneously with stresses originating from gravity loads applied to members framing in at right angles it is even more important that the additional complication of an eccentric connection is not simply brushed aside. In extreme cases it may be prudent to alleviate the problem by reducing eccentricities as far as other considerations will allow.

The probable order of magnitude of the torsional effect can be demonstrated by reference to the results of a simplified analysis executed recently on a multi-storey framed building having 13 inch wide beams positioned with a 6 inch accentricity on 30 inch wide columns where the frame was subjected to Zone 'A' seismic loading. The assumption was made that torsional stresses of significant magnitude did not occur outside a column height equal to the depth of the incoming beam plus half the breadth of the column above and below.

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Results showed that in the most severely affected joint an increase in column bars of 20% was required together with an increase of 25% in confining hoops. The additional steel inserted in the column restored the hinge to its required location in the beam.

It is hoped that a laboratory investigation into failure conditions at eccentric beam/column joints will be conducted in the not too distant future at one of our Universities. In the meantime, recognition of the possible effects is important, and action should be taken during the design process to counter the possible resulting overstress and ensuing premature failure that may otherwise occur.

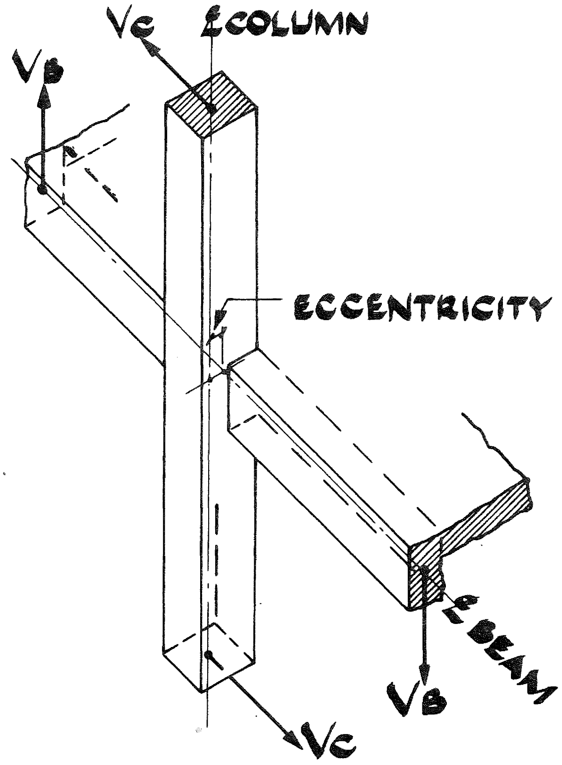

FIG. 1.

ECCENTRIC BEAM/COLUMN JOINT

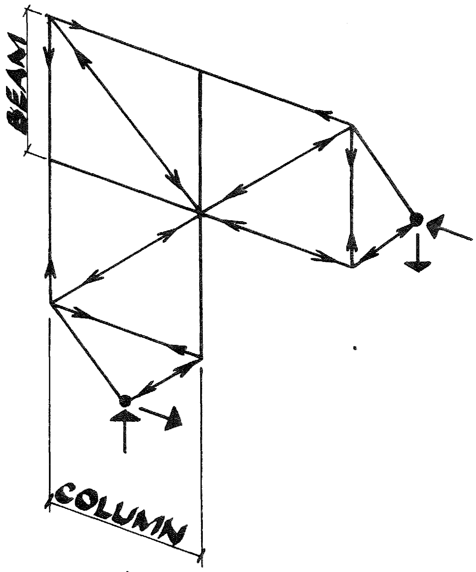

FIG. 2.

IN-PLANE TRUSS

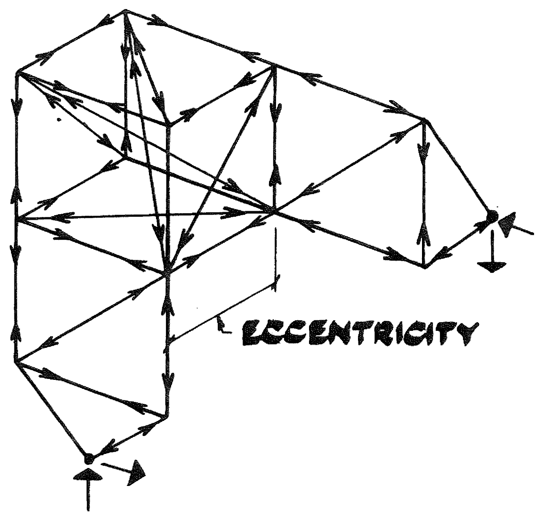

FIG. 3.

OFFSET TRUSS