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Reinforcement detailing in RCC building frames

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ABSTRACT: The importance of detailing of reinforcement in building frames to resist seismic forces need no emphasis. The ductility behaviour is ensured through proper reinforcement detailing. The paper presents the pattern of flow of stress resultants and the mechanism of transfer of compressive and bond stresses at a typical beam-column joint. Transfer of forces through right angle bends causes secondary stresses. A number of bar bending details to resist the primary and the secondary forces at joints is discussed. The reinforcement at joints is normally congested because of critical bending moments, laps of bars and closer spaced ties or stirrups. An experimental investigation was carried out on L-bents with a number of bar bending details. Initiation, propagation and widening of the cracks for different detailing are illustrated. Recommendations to minimize the crack widths are suggested. Even though the final failure was by crushing of the concrete, but wide diagonal tension cracks generated because of the transfer of the forces through 90 degree have caused early failure in faulty detail.

INTRODUCTION

Beam or column cross sections are designed based on simple element theories and invariably the same theory is extended to the design of joints. The beam face of a joint is designed as a beam while the column face is designed as a column. The beam and column faces of a joint are separated by a rigid continuum. The assumption that a joint is rigid, however strong the joint may be, is probably an over simplification and it may be considered as a design convenience. In steel frames, the joints are stiffened by additional fillets or stiffeners. A type of stiffened steel joint is shown in fig. 1. Increase in stiffness of a joint by stiffeners may provide adequate resistance against secondary failure but at the same time the ductility will be affected. Hence one has to aim at a trade off between stiffness and ductility.

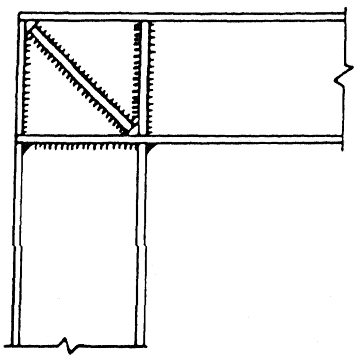

Fig 1 Stiffened steel frame joint.

Forces and cracking at rcc joints

Figure 2(a) illustrates major forces acting at a joint in which the axial force in the beam is neglected. The stress distribution on concrete and reinforcement at the limit state of collapse are illustrated in Fig. 2(b). These stresses can be replaced by an equivalent set of resultant compressive and tensile forces as indicated in Fig. 2(c). The resultant forces are reversible to some extent in case of seismic or wind load conditions. At a corner joint the flow of stresses result into an orthogonal set of forces as shown in Fig. 2(d), further a diagonal tension in the joint leading to a tension cracking is developed as illustrated in Fig. 2(e). The tensile force must

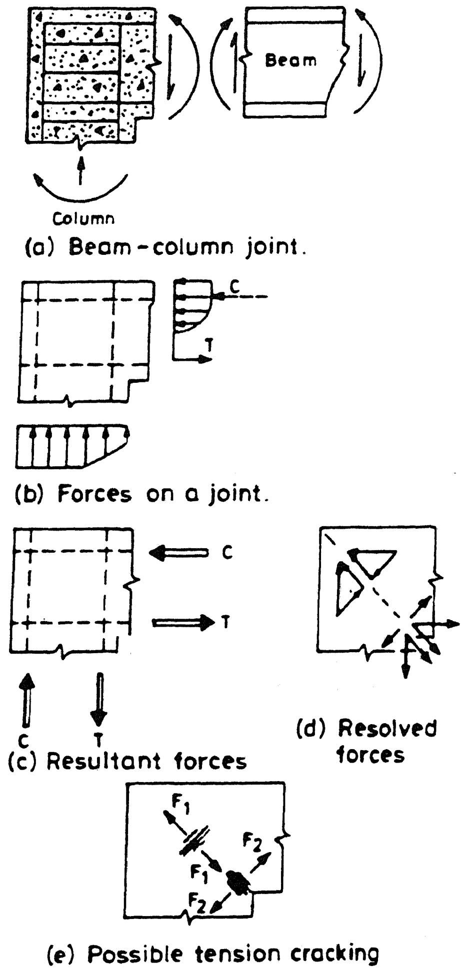

Fig 2 Force mechanism at joint.

be resisted by reinforcement. Invariably there is no reinforcement placed along the diagonals so the cracking gets widened. The tensile force occurs between middle of one third distance from compression face.

Experimental investigation

A corner joint with different sets of detailing of reinforcement is chosen as a specimen to study crack and strength characteristics. Two such identical joints were grouped into a U frame. Figures 3 and 4 illustrate the reinforcement details chosen for the experimental investigation. The figures also give the crack pattern observed in each case. The following conclusions are made from the investigation.

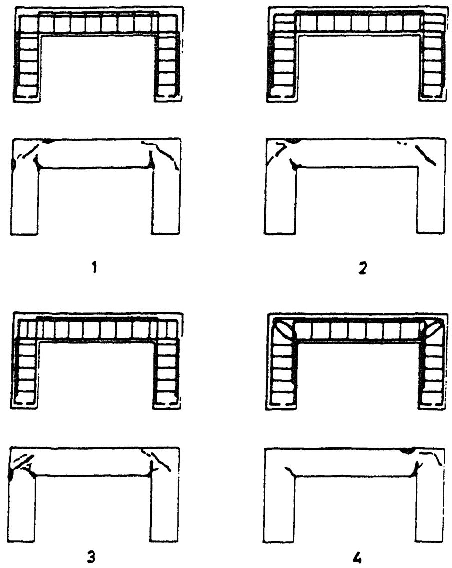

Fig 3 Test specimens and crack at failure.

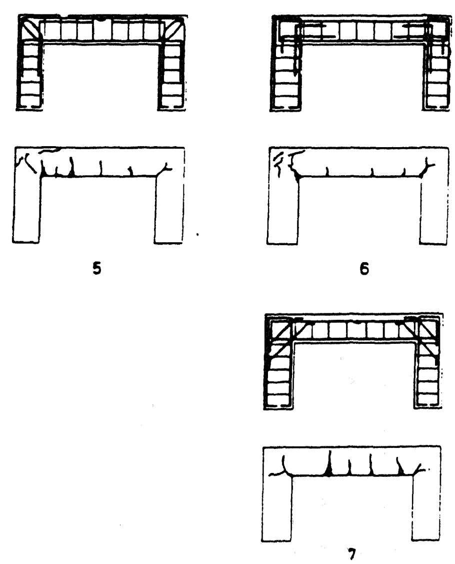

Fig 4 Test specimens and cracks at failure.

1 The initiation of cracking was always at the corner on primary tension face of beam, even though the moment was constant across the length of the beam, corner to corner. Infact the beam is subjected to tension and bending moment.

2. In all specimens, the cracks got initiated at the re-entrant corners and travelled close to the beam

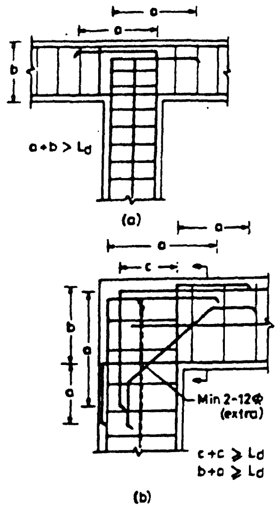

Fig 5 Conventional reinforcement detail.

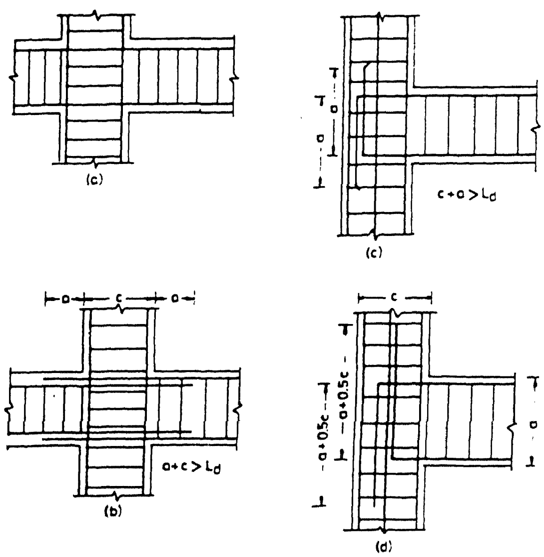

Fig 6 Conventional reinforcement detail.

face which can be predicted easily. The cracks were initiated at about 60 to 70 per cent of the failure load.

3. The diagonal tension cracks were developed as second level cracking in all specimens other than those with diagonal reinforcements at the corners. These cracks were initiated at about 70 to 80 per cent of the failure load and got widened to about 10 mm to 15 mm at the failure load.

4. Diagonal tension cracks did not develop in specimens having the

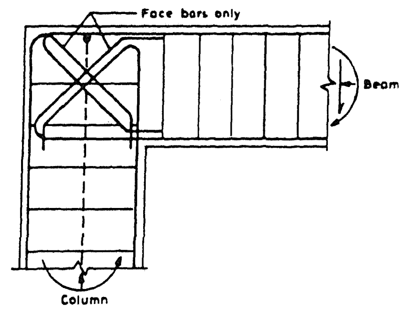

Fig 7 Corner joint detail.

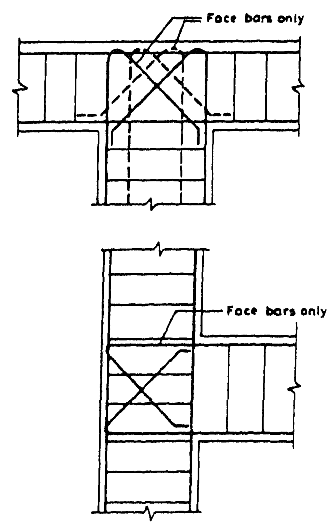

Fig 8 Detailing at T-joints.

surface bars bent at 45 degrees into the diagonal direction. Cracking is not wide spread in these specimens.

5. Failure of the specimens other than those with diagonal bars was primarily due to widening of the cracks, and secondary compression just before the collapse. The specimens with diagonal reinforcement have failed by primary compression of concrete.

Reinforcement detailing at joints

The ductility of a joint is reflected through the following factors :

a) Confinement of concrete through proper detailing,

b) Provision of compression reinforcement to increase the strain limits of concrete,

c) Closely spaced reinforcement to damp out the propagation of cracking and,

d) Suitably oriented reinforcement to resist tensile cracking efficiently.

It is important that the detailing of the joint reinforcement is done with care. The conventional practice of curtailment of bars at joints is illustrated in Figs. 5 and 6. The reinforcement bars on the faces of the member can be bent at 45 degrees as shown in the Figs. 7 and 8 thus reducing the congestion of the reinforcement in the end zones of the joint. Further, confinement of concrete is likely to be achieved and tension cracks will be damped out.

Acknowledgement

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