Seismic response of shear wall frames versus braced concrete frames

V. Kapur and Ashok K. Jain

Bracing members are widely used in steel structures to reduce lateral displacements and dissipate energy during strong ground motion. This concept is extended to concrete frames. The seismic response of braced frames is compared with that of five shear wall frames and three coupled shear wall frames, all having equal concrete volume. The behaviour of frames was studied both by the seismic coefficient method and modal analysis method. There appears to be some advantage in using reinforced concrete braced frames over shear wall frames as the former results in lesser member forces, floor displacements, and, consequently reinforcement.

Moment resisting frames and shear wall frames are two principal structural systems used in reinforced concrete buildings to resist wind and earthquake forces. Moment resisting frames are considered efficient for 10 to 15 stories by the ACI committee 442. Tall moment-resisting frames are undesirable for wind and earthquake resistance because with the increase in number of stories, the depth of beam required to ensure adequate rigidity becomes very large, leading to corresponding increase in storey height. Further, large interstorey displacements can cause severe damage to the moment resisting frames.

Shear walls attract a very large proportion of seismic force on account of their extremely high lateral stiffness and consequently, are more prone to damage. A case study of behaviour of shear walls in earlier earthquakes reveal that only properly designed shear wall buildings withstand strong-earthquake forces with minor damage. On the other side of the spectrum, there are two kinds of shear walls that suffered maximum damage: (i) shear wall with soft storey, and (ii) coupled shear walls with brittle linkage beams. Since, shear walls are normally provided around the elevator cores, it is very difficult to repair them in the event of a severe damage. Thus, there is a need to develop better structural systems to resist lateral forces.

Recent experience has shown that the twin requirements of safety and damage control can be better met by structures possessing adequate lateral strength, lateral stiffness and ductility. This is especially desirable for apartment and office buildings where considerable non-structural damage can result from excessive interstorey displacements. Bracing members are widely used in steel frames due to their ability to reduce lateral displacements and dissipate energy during strong ground motions. There are two options available in the reinforced concrete frames: to use either reinforced concrete bracing members or steel bracing members. It appears that both options are in use, but such braced frames are not popular because their seismic response is not well understood. The 47-storey Place Victoria concrete building in Montreal, Canada, has concrete bracing members to resist lateral forces. Recently, Kapur studied different aspects of reinforced concrete braced frames and concluded that their seismic response is much better as compared to that of moment resisting frames.

The purpose of this paper is to compare the seismic response of shear wall frames with braced concrete frames. Five shear wall frames, three coupled shear walls and four braced frames are analysed for elastic seismic behaviour. Axial forces and moments in members and floor displacements of shear wall frames are compared with those of IV pattern braced frames having equal volume of concrete. Only selected results are presented in the paper due to space limitations.

Selection of structure

A six-storey office building having two lateral bays and eleven longitudinal bays is assumed to be located in seismic zone V, Fig 1. The storey height is equal to 3.5m. Dead and live loads intensities are assumed at 400kg/m² each. There are four braced frames or four shear wall frames in the lateral direction that resist the entire lateral load.

A braced frame having inverted ‘V’ bracing pattern as shown in Fig 2 is adopted to study the influence of bracing members on its seismic response. This frame designated as IV forms a complete truss and is classified as concentric. The sizes of beams and columns determine for unbraced moment resisting frame are adopted for the braced frame. Four bracing sections are selected. Brace size for the first case is kept equal to that of the column. Its slenderness ratio is less than 50 which is gradually increased to 200 in other cases. The frame properties and corresponding designations are shown in Table 1.

Frame with symmetric shear wall is adopted as shown in Fig 3(a) and 3(b). The shear wall proportions in Fig 3(a) are arrived at by equating concrete volume of shear wall frames to that of IV frames. Shear wall frames shown in Fig 3(a) to are designated SWFI to SWF4 which are approximately equivalent in concrete volume to IV1 to IV4 braced frames. Beam and column proportions are kept same as for IV frames. A 300-mm wall thickness is adopted for SWFI frame which is minimum thickness for a short column of 3.5-mm length. Width of shear

V. Kapur, Executive Engineer, Himachal Pradesh PWD, Simla
Ashok K. Jain, Reader, Department of Civil Engineering, University of Roorkee, Roorkee 247 672, UP

Fig 1 Typical floor plan