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Seismic Behaviour of Multistorey Shear Wall Frame Versus Braced Concrete Frames

S.R. Thorat and P.J. Salunke

MGM College of Engineering and Technology, Kamothe, Navi Mumbai.

Abstract

It is observed that there is a need the study of structural systems for R.C.C framed structure, which resist the lateral loads due to seismic effect. Safety and minimum damage level of a structure could be the prime requirement of tall buildings. To meet these requirements, the structure should have adequate lateral strength, lateral stiffness and sufficient ductility. Among the various structural systems, shear wall frame or braced concrete frame could be a point of choice for designer. Therefore, it attracts to review and observe the behaviour of these structural systems under seismic effect. Hence, it is proposed to study the dynamic behaviour of reinforced concrete frame with and without shear wall and concrete braced frame. The purpose of this study is to compare the seismic response of above structural systems. Axial forces and moments in members and floor displacements will be compared.

Keywords: Shear wall, Bracing, Lateral force, Building structure.

1. Introduction

A Tall buildings are the demand of present situation. As the height of structure increases, lateral forces due to seismic becomes predominant. The major portion of these shall be resisted by the structural elements. Out of different structural systems, shear wall frames and Concrete braced frames are two principal structural systems used in reinforced concrete buildings to resist earthquake forces.

Reinforced concrete shear-walls are mostly used in buildings due to better-observed performance in recent past. In areas of high seismic risk, RC shear walls have been widely used as main lateral load resisting system in medium & high rise buildings because of their high lateral stiffness. Recent earthquake have shown that only properly designed shear walls can withstand strong earthquake forces with minor damage. The function of shear wall is to resist the effect of lateral and gravity forces and to provide lateral stability to a tall building. Reinforced concrete shear walls are relatively easy to construct because their reinforcing details are straight-forward, at least when compared to those of moment frames.

The most effective and practical method of enhancing the seismic resistance is to increase the energy absorption capacity of structures by combining bracing elements in the frame. The braced frame can absorb a greater degree of energy exerted by earthquakes. In braced frame reduces the column and girder bending moments. The shear is primarily absorbed by diagonals and not by girders. The diagonals carry the lateral forces directly in predominantly axial action, providing for nearly pure cantilever behavior. Bracing members are widely used in steel structures to reduce lateral displacements and dissipate energy during strong ground motions. This concept is extended to concrete frames. The various aspects such as size and shape of building, location of shear wall and bracing in building, distribution of mass, distribution of stiffness greatly affect the behavior of structures. These aspects need to be well understood and should be considered during design of structure.

Seismic response of braced concrete frames is compared with that of shear frames. The parameters studied are width of shear wall and bracing patterns-namely X, K and inverted V(IV) shaped. It observed that location of shear wall and brace elements have significant effect on performance of frame and there appear some advantages in using reinforced concrete braced frames over shear wall frames as former results in lesser member moments and floor displacements.

2. Method of Seismic Analysis

The code IS: 1893-2002 provides both static (seismic coefficient method) and dynamic (response spectrum method) procedures for the determination of seismic design forces for buildings. The code generally requires that the design for horizontal seismic forces be considered only in any one direction at a time. In both the seismic coefficient and the response spectrum methods, consideration is given to the seismic zone where the structure is located (The building is assumed to be located in seismic zone ‘III’), importance of the structure, soil-foundation system ductility of construction, flexibility of the structure, and weight of the building.The STAAD-PRO V8i are used for dynamic analysis and stiffness analysis.

Load Calculation:

1) Dead Load :- Dead load on frame includes self-weight of beams, shear-walls, brace elements, slabs, exterior walls and is calculated for center grid from assumed dimensions.

Unit weight of concrete = 25kN/m3

Unit weight of brick masonry= 20kN/m3

2) Live Load :- Live load intensity is adopted as 3 kN/m2, at each storey level & for roof level 1.5 kN/m2. (At roof, no live load is to be lumped)

3) Seismic Load:

Design base shear $V_B = A_h W$ ....(A)

Distribution of seismic force along height of building

$$Q = V_B \frac{W_i h_i^2}{\sum_{i=1}^{i-n} W_i h_i} \qquad \text{.(B)}$$

Calculate Design base shear (V_B) by using equation A and distribute along the height of building at each floor by using equation B.

3. Selection of Structure

To study the behavior of shear-wall frame and braced concrete frame, an building with simple symmetric plan having three bays in both the directions is selected(Fig. 1), Different shear wall frames and braced concrete frames are developed by placing shear walls and braced elements at various selected locations in 15-storey building. It has total eight plane frames in both the all directions. Four column locations (a, b, c, d respectively) of each plane frame are treated as shear-wall locations and three bays (B1, B2, B3 respectively) are treated as brace element locations. Solid cantilever shear-walls having width 1.5m in rectangular section are adopted. The X, K, IV-type brace patterns are adopted. In all a total of 24 frames have been analysed.

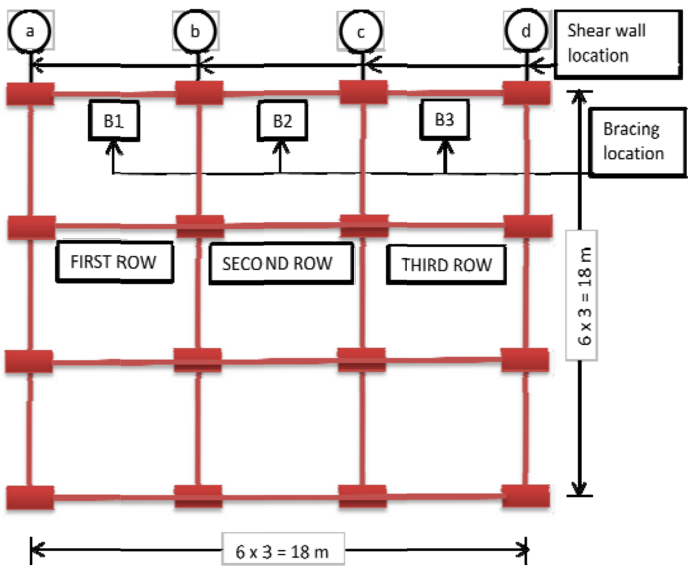

Fig. 1: Plan of building.

Preliminary data:
Size of all beams = 230 x 450 mm
Size of all columns = 300 x 600 mm

Size of shear-walls = 300 x 1500 mm
Size of bracings = 230 x 450 mm
Storey height = 4500 mm
Frame Spacing in both direction = 6000 mm
Slab thickness = 150 mm
Wall thickness = 120 mm (Brick masonry)

4. Shear-wall frame Systems

In these systems, shear-wall is provided in different manners at various selected locations from bottom floor to top floor. Accordingly different systems (frames) developed are as follows.

- Placing shear-wall at one location out of four locations at a time and repeating it for remaining locations, thus four systems are developed
- Placing shear-wall at two locations out of four locations at a time in different manner, another four systems are developed
- Placing shear-wall at first three locations, only one system is developed
- Placing shear-wall at all locations, another one system is developed
- In all, total 10 systems are developed. These ten systems are used for shear-wall width '1.5 m' resulting 10 systems with constant width from bottom to top floor (Fig.2).

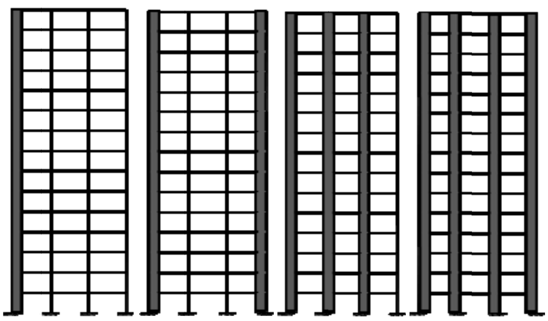

Fig. 2: Section of Shear wall Frame.

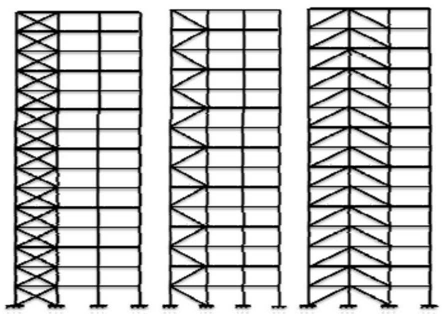

Fig. 3: Section of Brace Frame.

(X, K & IV respectively)

5. Braced Concrete Frame Systems

In these systems, brace elements are provided in different manner at various selected locations from bottom floor to top floor. Accordingly different systems developed are as follows.

Placing brace X and K type elements at one location out of three locations at a time and repeating it for remaining locations, thus Six system are developed

Placing brace X, K and IV type elements at two locations out of three locations at a time in different manner, another six systems are developed

Placing brace X and K type elements at all locations, two more system is developed.

In all, 6 systems are developed each for X and K-type brace patterns (total 12 systems). Placing brace elements in two adjacent bays to form ‘inverted V-type’ brace pattern in different manner, thus two additional systems are developed (Fig.3).

6. Result

Response of Shear-wall Frame Versus Braced Concrete Frame:

When column axial force of above system is compared, it is observed that more column axial force is induced in braced frame than shear wall frame. Column moments induced in braced frame are much less than shear wall frame. Beam moments induced in braced frame are less than shear-wall frame the drift induced in braced frame is less than shear wall frame.

The even column axial force induced in braced frame is more than shear-wall frame and plane frame, but column and beam moment are very small with less drift, hence braced frame is advisable.

The result of the analysis are presented in form of table. The 15-story building frame results are presented in tabulated form.

Abbreviated Name of Various Systems in table:

SWF Shear-wall frame

BR Braced Concrete Frames

‘A’ Shear wall or brace elements are provided at all locations

‘X,K,IV’ Type of bracing pattern provided

‘a, b, c, d’ Locations where shear-wall is provided (Example:- SWFa, SWFbc, SWFabc, SWFA)

‘B1,B2,B3’ Locations where brace elements are provided(Example:- BRXB1, BRKB2B3, BRIVB1B2, BRXA)

Summary of result and Discussion

Frame Name	Comment	Reason	Remark
SWFa	Not-recommended	More actions (axial force, shear, moment) & more drift	-
SWFb	Recommended	Less actions (axial force, shear, moment) & less drift	1st priority
SWFc	Recommended	Less actions (axial force, shear, moment) & less drift	1st priority
SWFd	Not-recommended	More actions (axial force, shear, moment) & more drift	-
SWFad	Not-recommended	More actions (axial force, shear, moment) & more drift	-
SWFbc	Recommended	Less actions (axial force, shear, moment) & less drift	1st priority

SWFab	Recommended	Less column shear , moment & less drift	2nd priority
SWFac	Recommended	Less column axial force	3rd priority
SWFabc	Not-recommended	Not equally effective in reducing actions & drift as compared with one & two shear wall locations	-
SWFA	Not-recommended	Not equally effective in reducing actions & drift as compared with one & two shear wall locations	Symmetrical Distribution of mass & stiffness
BRXB1	Recommended	Slightly more actions & drift	2nd priority
BRXB2	Recommended	Less actions & drift	1st priority
BRXB3	Recommended	Slightly more actions & drift	2nd priority
BRXB1B2	Recommended	Less actions & drift	1st priority
BRXB1B3	Not-recommended	More actions & drift	-
BRXA	Recommended	Equally effective in reducing actions & drift	1st priority
BRKB1	Not-recommended	More actions & drift	-
BRKB2	Recommended	Less actions & drift	2nd priority
BRKB3	Not-recommended	More actions & drift	-
BRKB1B2	Recommended	Less actions & drift	1st priority
BRKB1B3	Not-recommended	More actions & drift	-
BRKA	Recommended	Equally effective in reducing actions & drift	2nd priority
BRIVB1B2	Not-recommended	More actions & more drift	-
BRIVB2B3	Recommended	Less actions & less drift	1st priority

7. Concluding Remarks

1. The location of shear-wall and brace member has significant effect on the seismic response of the shear-wall frame and braced frame respectively. The central location of shear-wall and brace member are favorable as they are effective in reducing actions induced in frame with less horizontal deflection and drift.
2. Addition of shear-walls at all or unfavorable locations do not effectively in reduce the actions induced in frame. Hence it is advisable to provide
3. one shear-wall in frame instead of multiple shear-walls.

4. IV & X-type brace pattern are most efficient out of studied pattern, as less actions are induced in frame with less floor displacement and drift. The K-type brace pattern can be adopted as second choice. X-type brace pattern induces less drift and lateral deflection in frame out of various brace pattern considered in the present study.
5. Instead of providing brace elements in alternate bays, it is advisable to place them adjacent bays. Addition of brace elements equally reduces the actions, horizontal deflection and drift induced in the frame. Braced frame offers most of the resistance through axial action in term of column and brace axial force; hence moments induced in frame are very less.
6. Brace elements are very much efficient in reducing lateral displacement of frame as drift and horizontal deflection induced in braced frame are much less than that induced in shear-wall frame and plane frame. Though column axial force induced in braced frame is more than that in shear-wall frame and plane frame, however, the column and beam moments, and drift induced in braced frame are very less. Hence, braced frame is very efficient in resisting seismic force than shear-wall frame and plane frame.

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