Stiffening of Earthquake Resistant Green Buildings

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***Abstract**: Structural Engineers major challenge in present situation is constructing a seismic resistant structure. Energy efficiency and usage has become increasingly important to the public, government bodies and industries in recent years. Major per capita energy usage is associated with domestic used energy resources which also responsible for greenhouse gases. In optimizing energy efficiency of buildings, openings play a major role as they largely influence the energy load. This study aims to increase lateral stiffness of openings by providing different bracings. Frames considered are – (a) Bare frame, (b) Diagonal bracing, (c) Frame with X bracing, (d) Frame with V bracing, and (e) Frame with Chevron (inverted V) bracing.*

Key words: *Structural Engineers, Energy efficiency, Earthquake, Lateral stiffness, Bracings.*

1. INTRODUCTION

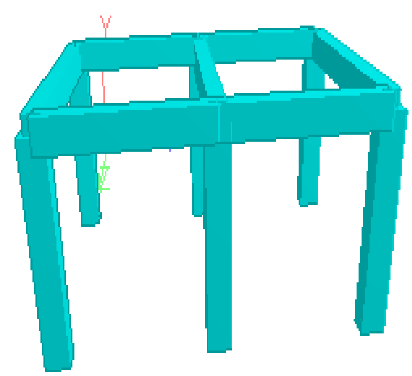
Buildings are major contributor of global major energy use produces significantly excess carbon emissions than those in the transportation automobiles, and so they are the major energy consuming sector in the world. As the responsibility about the environmental effects of building is increasing, private and public bodies are steadily requiring the building activities to design and construct structures with minimum environmental effect [1]. Accordingly, many researches have been done on energy efficient building design. In this regard, window openings are responsible for more than ten percent of the building energy load and so are understand to have considerable impact on the total energy usage [2].

1.1 IMPACT OF WINDOWS ON BUILDING ENERGY LOAD

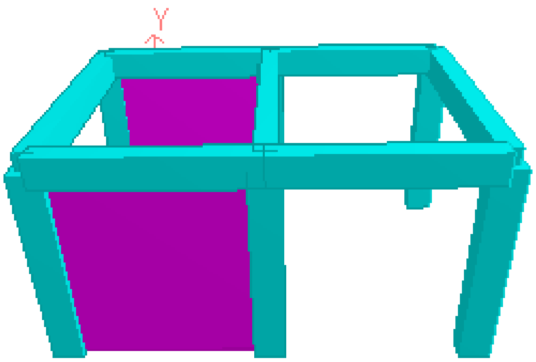
As one of the major approaches to minimum energy design is to invest in the building's arrangements and enclosure [3], many research considered the influence of enclosures on the energy load. Several works have been done on the influence of window design on building energy load regarding the elements such as openings size, position, glazing characteristics and orientation. In the beginning, one or two factors were analyzed simultaneously. The effect of openings size was analyzed only [4], and more research were done on position and openings size [5].Glazing characteristics and size are also taken into account [6], and the direction and window size were studied at the same time [7]. In addition, few earlier studies considered the effect of orientation, window size and glazing characteristics [8].

1.2 STRUCTURAL SYSTEMS AND COMPONENTS FOR STIFFENING

Using a suitable structural system is crucial to good earthquake performance of energy efficient structures. Moment-frame is the most widely used structural system for lateral load resistance, alternate structural systems also are usually used (Figure 1), same as structural walls, Frame-wall system and Braced-frame system. Occasionally, even more superfluous structural systems are essential, Example. Hollow cylinder, Hollow cylinder -in- Hollow cylinder and Group Hollow cylinder systems are essential in several buildings to enhance their earthquake behavior. These framed systems are adopted depending on the size of window openings, external loading, and other design necessities of the energy efficient building. One structural frame system widely used creates special challenges in achieving better earthquake performance of buildings, the Flat slab-column framed system. The openings made the structure flexible in the lateral direction and hence the building deflect significantly even under small amount of shaking. Again, it has relatively low lateral stability, and therefore ductility requirement during strong earthquake tends to be large. Wide openings should not be adopted without providing in the building stiff and strong lateral force resisting structural elements, like Braces and Structural walls.



(i)



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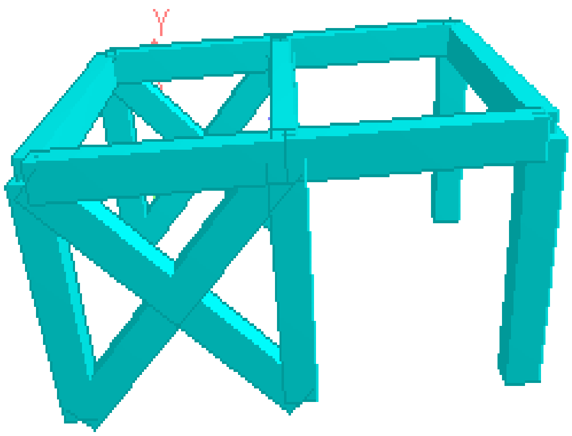

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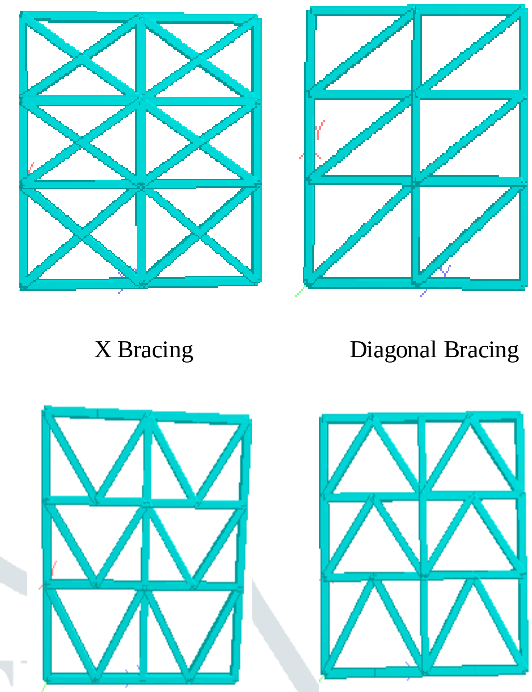
Figure 1: Most Common structural frame systems adopted in buildings: (i) Moment frames, (ii) Moment frames with structural walls, and (iii) Braced moment frames.

Walls and braces are shown in the Figure 1 only along one direction; Designers can choose to provide them in both directions.

1.3 BRACED FRAME SYSTEMS

The structural system consists of moment frames with all outer bays provided with braces throughout the height of the building (Figure 1 (iii)). Braces are provided in both X and Z directions so that no torsion is induced in the building developing unsymmetrical stiffness in plan. Braces help in increasing lateral stiffness of buildings, and in reducing deflection, bending moment and shear force on beams and columns of buildings. The earthquake force is transferred as axial tensile and compressive force in the brace members. Different types of bracings are shown in Figure 2.



X Bracing Diagonal Bracing

V Bracing Chevron Bracing (Inverted V Bracing)

Figure 2: Braced frames: Different types of bracings used in buildings

2. PROBLEM FOR ANALYSIS

Table 1: Problem Details

01	Type of structure	Multi – Story Rigid jointed Frame (Special RC Moment Resisting Frame (SMRF))
02	Zone	IV (Delhi)
03	Layout	Three bays in both X & Z direction, Each bay of size 3m x 3m
04	Story height	3m
05	No of stories	G+4
06	External walls	No infill wall
07	Internal walls	250 mm thick including plaster
08	Live load	3.5kN/m^2
09	Roof load	2 kN/m^2
10	Materials	M25 and Fe415
11	Seismic analysis	Equivalent Static method (IS 1893 (Part1)) : 2002 [13]
12	Size of exterior column	300 mm x 600 mm
13	Size of interior column	300 mm x 300 mm
14	Size of beams	300 mm x 450 mm
15	Total depth of slab	150 mm
16	Bracings	300 mm x 300 mm
17	Soil	Hard

18	Damping	5%

3. METHODOLOGY

Table 2: Steps Followed in Analysis

Step1	Modeling 5 SMRF a. SMRF without bracings b. SMRF X bracings c. SMRF Diagonal bracings d. SMRF V bracings e. SMRF Chevron bracings
Step2	Apply loading
Step3	Analyze
Step4	Results for one column a. Deflection b. Bending moment c. Shear force
Step4	Tables and graphs, Comparison of results
Step5	discussion
Step6	Conclusion

4. MODEL AND COLUMN CONSIDERED FOR STUDY

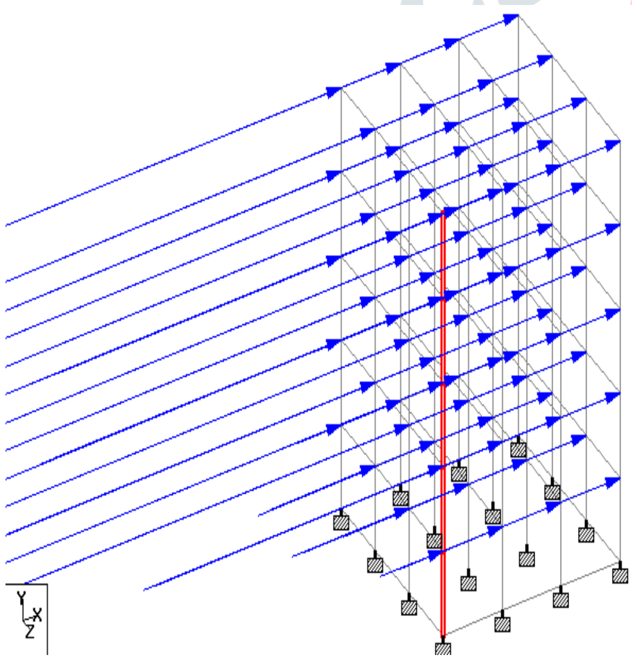


Fig 3: Model showing Column for Analysis

5. TABLE AND GRAPH

5.1. DEFLECTION (mm)

Table 3: Deflection Values at Various Levels

Levels (m)	Type of Bracings				
	No Brace	Diagonal Brace	V-Brace	Inverted V- Brace	X-Brace
0	0.000	0.000	0.000	0.000	0.000
3	1.977	0.773	0.419	0.340	0.199
6	5.459	1.626	0.977	0.808	0.596
9	8.682	2.348	1.521	1.288	1.039
12	11.217	2.920	1.991	1.699	1.446
15	12.832	3.339	2.352	2.011	1.781

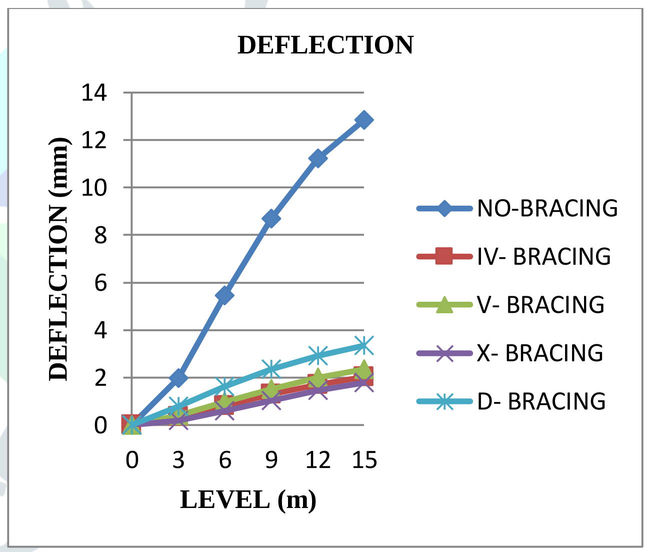


Fig 4: Comparison of Deflection for different Bracing System

The graph shows (Fig4) huge lateral deflection in Moment frame without bracings, but in Moment frame with bracings reduces deflection to minimum. X- Bracings are more effective. From serviceability point of view deflection should within the permissible limit mentioned in IS1983-2002. Excess deflection makes discomfort for the users. Excess deflection also develops huge bending moment.

5.2. BENDING MOMENT (kN-m)

Table 4: Bending Moment Values at Various Levels

Levels (m)	Type of Bracings				
	No Brace	Diagonal Brace	V- Brace	Inverted V- Brace	X- Brace
0	80.000	34.082	15.559	16.644	4.940
3	49.397	10.173	4.507	8.370	5.706
6	40.382	8.272	3.919	6.631	4.955
9	34.984	5.174	3.606	5.991	5.688
12	31.155	8.129	4.993	4.001	6.569
15	6.580	7.074	4.766	1.217	5.117

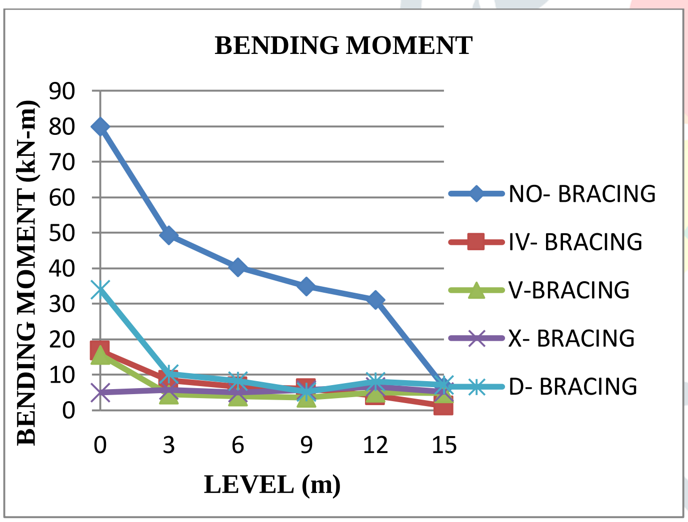


Figure 5: Comparison of Bending Moment for different Bracing System

The graph shows (Fig5) huge bending moment in Moment frame without bracings, but in Moment frame with bracings reduces bending moment to minimum. X- Bracings are more effective. More bending moment leads to provision of more size and reinforcement that leads to uneconomical. Corner columns under biaxial bending will be affected more.

5.3. SHEAR FORCE (kN)

Table 5: Shear Force Values at Various Levels

Levels (m)	Type of Bracings				
	No Brace	Diagonal Brace	V- Brace	Inverted V- Brace	X- Brace
0	30.124	14.751	4.905	8.246	3.865
3	29.926	14.751	4.905	5.000	3.274
6	19.624	7.565	2.809	3.998	2.706
9	14.449	2.207	1.896	2.155	2.552
12	4.01	5.068	2.682	2.155	0.254
15	0.41	5.068	2.705	0.901	0.254

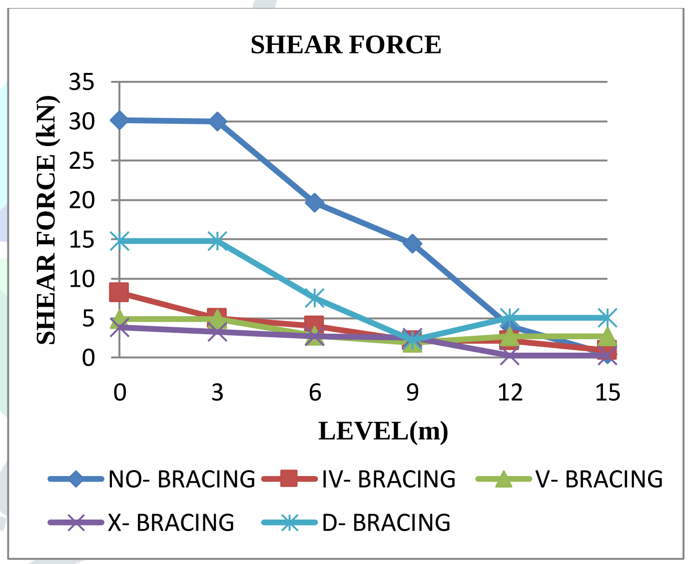


Fig 6: Comparison of Shear Force for different Bracing System

The graph shows (Fig6) huge shear force in Moment frame without bracings, but in Moment frame with bracings reduces shear force. X- Bracings are more effective. More shear force leads to soft storey failure. Majority of will fail due to soft story problem. Usually ground floor is soft story, because it is using for vehicle parking, it should be open. The columns in soft story will failure during earthquake effect. Soft story columns should be designed to resist huge shear. Extra longitudinal and lateral reinforcement should be provided to resist shear, also integrity should be developed between the elements.

6. DISCUSSIONS

It is found that openings without bracings subjected to more deflection, bending moment and shear force. Results clearly show bracings provided in the frame improves performance of structures, less likely to fail during earthquakes. In green buildings wide openings are unavoidable, openings reduces lateral stiffness of structures. Bracings are the best solution to improve stiffness of structures and to satisfy green buildings requirements.

7. CONCLUSIONS

After studying the results obtained from different bracings, X-bracing is the best to improve stiffness. Design of bracings is not done in this study, only analysis is done. Utmost care should be taken in the design of green building with more openings in the exterior wall by providing stiffeners.

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