



a) **Liquefaction Induced:** - Liquefaction is not a type of ground failure; it is a physical process that takes place during some earthquakes that may lead to ground failure. As a consequence of liquefaction, clay-free soil deposits, primarily sands and silts, temporarily lose strength and behave as viscous fluids rather than as solids. Liquefaction takes place when seismic shear waves pass through a saturated granular soil layer, distort its granular structure, and because some of the void spaces to collapse. Secondary hazards include ground failure, liquefaction, landslides and avalanches.

b) **Lateral Spreads:** - Lateral spreads involve the lateral movement of large blocks of soil as a result of liquefaction in a subsurface layer. Movement takes place in response to the ground shaking generated by an earthquake. Lateral spreads generally develop on gentle slopes, most commonly on those between 0.3 and 3 degrees. Horizontal movements on lateral spreads commonly are as much as 3 to 5 meter, but, where slopes are particularly favorable and the duration of ground shaking is long, lateral movement may be as much as 30 to 50 meter. Damage caused by lateral spreads is seldom catastrophic, but it is usually disruptive. Lateral spreads are destructive particularly to pipelines.

c) **Flow Failures:** - Flow failures, consisting of liquefied soil or blocks of intact material riding on a layer of liquefied soil, are the most catastrophic type of ground failure caused by liquefaction. These failures commonly move several meter and, if geometric conditions permit, several tens of meters. Flows travel at velocities as great as many tens of kilometer per hour. Flow failures usually form in loose saturated sands or silts on slopes greater than 3 degrees. Flow failures can originate either underwater or on land. Many of the largest and most damaging flow failures have taken place underwater in coastal areas.

d) **Loss of Bearing Strength** - When the soil supporting a building or some other structure liquefies and loses strength, large deformations can occur within the soil, allowing the structure to settle and tip.

## 2. Novel Technique for Making Structure Earthquake Resistant

### 1) Bracing Systems

In braced frames, vertical bracings are formed by diagonal members within the steel frame. These bracings may be of different form (cross-braced X shaped; V or inverted V shaped; symmetrical or unsymmetrical portal). Alternatives to steel bracings are the reinforced concrete shear walls or core.

#### a. Vertical Bracing

Vertical bracing to columns provides lateral stability to a structure and resistance to wind loading. The bracing is thus subject to horizontal loading acting in either the left-to-right or right-to-left direction. The most commonly used configurations are illustrated in Fig 1.1. Those shown in details (a) to (c) can be used in multi-storey buildings, with the floor beams being located at each panel height of the system. They could also be used, along with the

configurations shown in details (d) and (e), for tall columns in single-storey buildings. In this case the beams indicated in details (a) to (c) would be replaced by horizontal struts.

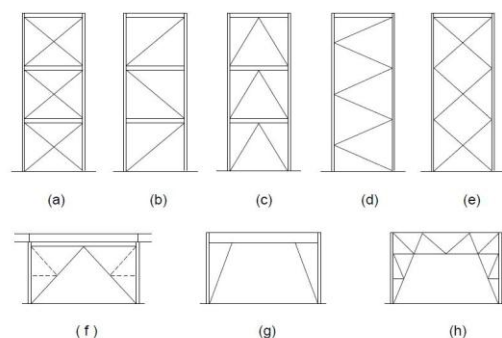
In type (a) the diagonals could be designed to act either in tension only or in combined tension compression; in the latter case the horizontal members would carry no load. The tension-only system is very efficient since the diagonals can be designed to minimum size and with a large slenderness ratio. It is especially applicable to bracing systems with large panel sizes, i.e. in height or width or both.

In detail (b) the diagonals act in tension and compression and thus need to be stiffer; the horizontal beams do not carry any bracing load. Note that at ground level the full horizontal load is resisted by a single column foundation, which is a less favorable situation than when it is shared between two column bases. It is nevertheless an efficient system, provided the lengths of the diagonals are not excessive, since a minimum number of members and connections are involved.

The inverted-V or chevron bracing in detail (c) is a tension compression system with shorter diagonal members and each horizontal member acting half in tension and half in compression. It is thus an efficient system, but if applied to a multi-storey building the bracings act as props at mid-length of each beam which would result in a lighter beam section, but a much heavier bracing section.

The system shown in (e) is similar to the tension compression bracing shown in (a), but with the horizontals omitted. For single-storey buildings any of the layouts shown in details (a) to (e) can be used, in one or more panel heights.

The bracing shown in detail (f) is equivalent to a single panel of the (c) type, but is used where the aim is to separate the overhead beam from the bracing itself, as in a crane gantry. In this case the bracing resists horizontal loading only and does not pick up any load from the beam.

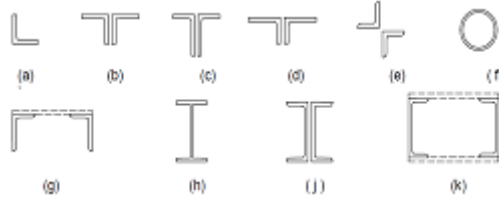


**Figure 1.1:** Different Types of Bracing

The configurations shown in (g) and (h) may be used for single-storey buildings where greater clearance between the columns is required. They are previously less economical than any of the others and are only used when called for. The (g) type may also be used in multi-storey buildings in special cases where clearance is required. Sub-bracings, as shown dotted, may be added to reduce the effective length of the bracing members in the plane of the frame. In present work three types of bracings are used namely X, diagonal and V bracing as shown in figure 1.10 (a, b, c) respectively.

### 2.1.2 Bracing Sections

As stated earlier, Rolled steel sections are often used for strut bracings in buildings and single angles for ties. For large structures and especially industrial applications such as buildings for plants, towers, mine headgears, conveyor trestles, etc., the bracing may have to take a different form. Fig. 1.11 shows a number of sections commonly used, ranging from light simple ties to heavy compound struts.



**Figure 1.2:** Bracing Sections

The double angles shown in details (b) to (d) are used for both ties and strut and are efficient as regards their end connections because the bolts are in double shear. They may be used in indoor locations in non-corrosive environments; if used in corrosive situations they should be galvanized or treated in some other form because of the difficulty during subsequent maintenance of painting between the angles.

The starred-angle strut shown in detail (e) is not as cost-effective as it might appear because of the stringent code requirements, and also because of the wide gussets required at the ends. It is, however, popular section in heavy structures with large racking lengths and forces.

The rolled steel bracing shown in detail (f) is very efficient structurally when used as a single strut. It should preferably not be used in the X-configuration because of the difficulty in providing a suitable gusset at the intersection of the X. When compared with a starred-angle section as used in long or heavily loaded compression members the rolled steel shows up well. The higher cost per unit mass and the welded T-connections at the ends are offset by the much higher mass per meter and the battens of the starred angle.

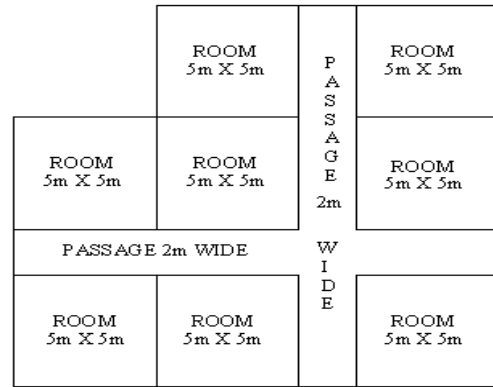
The twin-angle section shown in detail (g) is suitable as a strut. When used as a tie the battens or lacings could be omitted unless the slenderness ratio is very high.

The I-section in detail (h), or alternatively an H-section, is efficient when used in systems where a member with a depth perpendicular to the bracing plane is required; double-plane gussets are used, attached to the flanges. In present work single IS channel section is used for different bracing system.

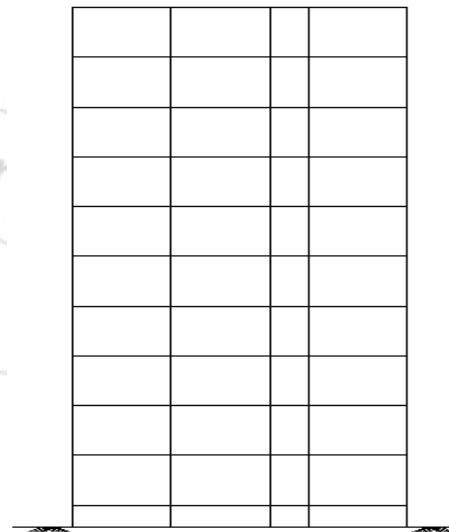
### 3. Objectives

- To compare response of braced and unbraced building subjected to lateral loads.
- To identify the suitable bracing systems for resisting the seismic loads efficiently.

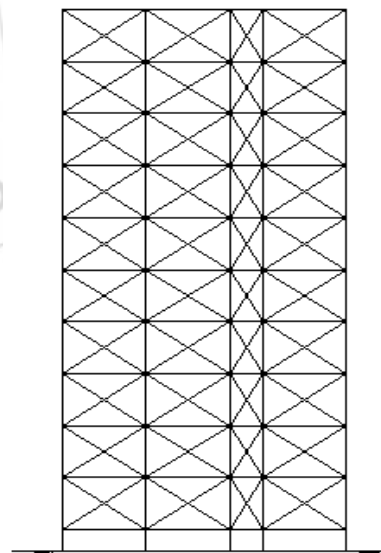
### 4. Modeling and Analysis of the Building



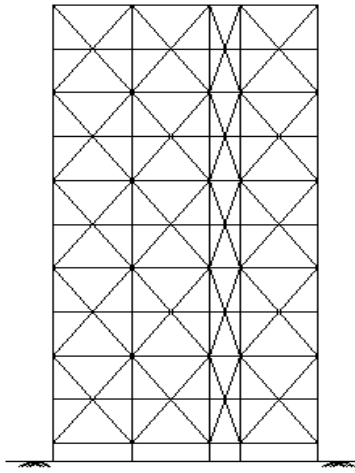
**Figure 4.1:** Plan of Building



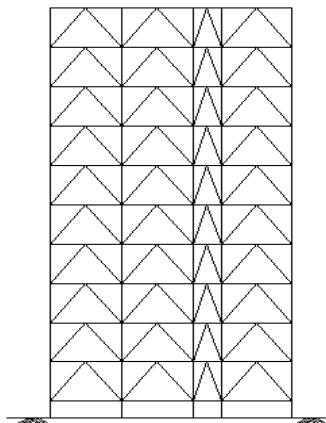
**Figure 4.2:** Elevation



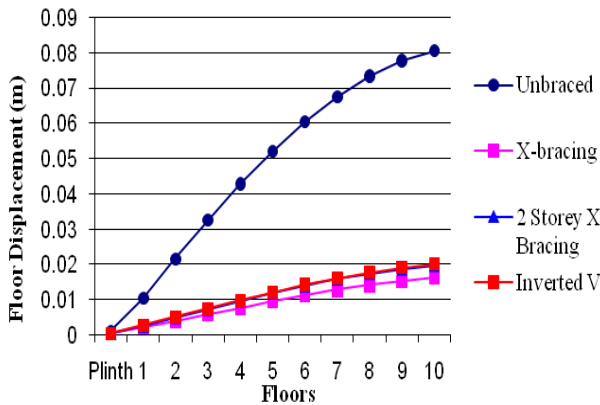
**Figure 4.3:** Elevation with X bracing



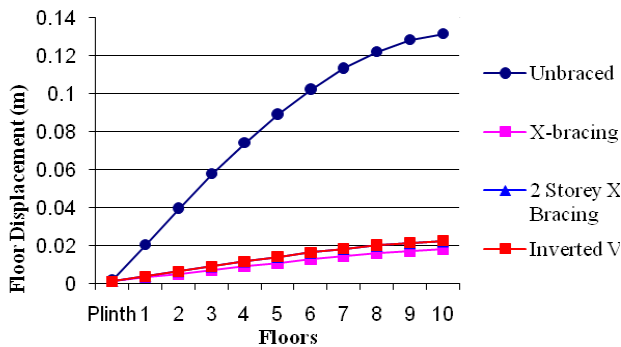
**Figure 4.4:** Elevation with 2X bracing



**Figure 4.5:** Elevation with V bracing



**Figure 4.6:** Displacement of floors in X-direction.

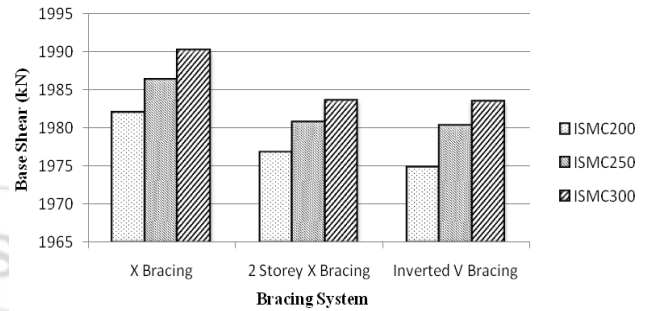


**Figure 4.7:** Displacement of floors in Y-direction

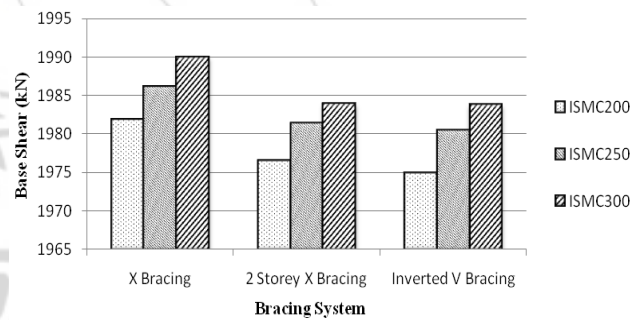
From fig. 4.6 and fig. 4.7 it can be seen that lateral displacements in braced building in both X and Y direction are reduced in comparison with the unbraced building. The displacement at the top storey in X direction reduces by 79.8%, 75.34%, and 74.97% and in Y direction by 86.14%, 83%, 82.67% for X bracing, 2-storey X bracing and inverted V bracing respectively.

#### 4.2 Base Shear

The maximum base shears at the base for unbraced and different braced building are shown in fig. 4.2.1 and fig. 4.2.2.



**Figure 4.2.1:** Base Shear in X- Direction



**Figure 4.2.2:** Base Shear in Y- Direction

Fig. 4.2.1 and fig. 4.2.2 shows that the base shear in X bracing system is more as compared to 2 storey X bracing system and inverted V bracing system. The base shear produce in X and Y direction is same because stiffness of building is same in both direction. As the stiffness of bracing sections increases, the base shear in building also increases in both directions.

#### 5. Conclusion

Based on analysis results following conclusion are drawn

1. The displacement of the building decreases depending upon the different bracing system employed and the bracing sizes.
2. The storey drift of the braced building decreases as compared to the unbraced building which indicates that the overall response of the building decreases.
3. It was also observed that as the size bracing section increases the displacements and storey drifts decreases for the braced buildings.
4. The overall performance of X braced building better than other two types of braced building.

## References

- [1] Nateghi F, Seismic Strengthening of Eight-Storey RC Apartment Building Using Steel Braces. Engineering Structures, Vol. 17(6) Pages 455-61, 1995.
- [2] N. K. Rai, G. R. Reddy, S. Ramanujam, V. Venkatraj , P. Agrawal, Seismic Response Control Systems for Structures, Defence Science Journal, Vol. 59, No. 3, Pages 239-251, May 2009.
- [3] Egor Popov, Seismic Steel Framing Systems for Tall Buildings, Sino-American Symposium on Bridge and Structural Engineering, Vol. 17 (3), Sept. 1982.
- [4] Federico M. Mazzolani, Gaetano Della Corte, Mario D'Aniello, Experimental Analysis of Steel Dissipative Bracing System For Seismic Upgrading, Journal of Civil Engineering And Management Vol. 15(1) Pages 7–19, 2009.
- [5] Ghobarah, Rehabilitation of a Reinforced Concrete Frame Using Eccentric Steel Bracing, Engineering Structures Vol. 23 Pages 745–755, 2001.
- [6] Hakan Yalciner and Amir A. Hedayat, Repairing and Strengthening of an Existing Reinforced Concrete Building: A North Cyprus Perspective, American Journal of Engineering and Applied Sciences Vol. 3 (1): Pages 109-116, 2010.
- [7] Kyoung Sun Moon, Structural Developments in Tall Buildings: Currents Trends and Future Prospects. Architectural Science Review, Vol. 50.3, Pages 205-223, 2007.
- [8] M. A. Youssef, H. Ghaffarzadeh, Seismic Performance of RC Frames With Concentric Internal Steel Bracing, Engineering Structures Vol. 29 1561–1568, 2007.
- [9] M. R. Maheri, A. Sahebi, Use of Steel Bracing In Reinforced Concrete Frames. Engineering Structures, Vol. 19, No. 12, Pages 1018-1024, 1997.
- [10] M. R. Maheri, Recent Advances in Seismic Retrofit of RC Frames, Asian Journal of Civil Engineering (Building and Housing) Vol. 6, No.5 Pages 373-391, 2005.
- [11] Mina Naeemi, Majid Bozorg, Seismic Performance of Knee Braced Frame, Engineering Structures, Vol. 17, No. 5, Pages 334-343, 1999.
- [12] Nateghi F, Seismic Strengthening of Eight-Storey RC Apartment Building Using Steel Braces. Engineering Structures, Vol. 17(6) Pages 455-61, 1995.
- [13] N. K. Rai, G. R. Reddy, S. Ramanujam, V. Venkatraj , P. Agrawal, Seismic Response Control Systems for Structures, Defence Science Journal, Vol. 59, No. 3, Pages 239-251, May 2009.