Seismic Analysis of High Rise Building Using Inverted V Bracings with ETABS Software

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ABSTRACT

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Earthquake load is becoming a great concern in our country as because not a single zone can be designated as earthquake resistant zone. One of the most important aspects is to construct a building structure, which can resist the seismic force efficiently. Study is made on the different structural arrangement to find out the most optimized solution to produce an efficient safe earthquake resistant building. The basic principles of design for vertical and lateral loads (wind & seismic) are the same for low, medium or high rise building. The vertical loads increase in direct proportion to the floor area and number of floors. In contrast to this, the effect of lateral loads on a building is not linear and increase rapidly with increase in height. Due to these lateral loads, moments on steel components will be very high. By providing bracing, these moments can be reduced. In the present analysis, 23 Storeys residential building is analyzed with columns, columns with Inverted V bracings at different locations in two different earth quake zones (zone 3 & zone 5) with respect to three soil types. Moments, Base Shear, Displacement, Storey shear were compared for different load combinations. It is observed that the deflection was reduced by providing the Inverted V bracing commercial package ETABS has been utilized for analyzing 23 storey's residential

building for different zones. The result has been compared using tables & graph to find out the most optimized solution. Concluding remark has been made on the basis of this analysis & comparison tables.

Keywords: ETABS, Wind & Seismic loads, Bracings

I. INTRODUCTION

All over the world bracing system has been considered as the most efficient measure against the lateral loads induced in the building due to the seismic forces. This paper aims at providing an efficient bracing system against such forces. In order to increase the stiffness of the columns and to reduce their net longitudinal reinforcement decreasing their effective length can be a good solution but the challenge is to how can we do so without changing the general building specifications(specially architectural) and not disturbing the basic building frame structure as a whole. In this study an 23 storey building having same plan in different type of zones (as per IS 1893 (Part I): 2002) and different type of soils is taken. The tall building with different types of braces introduce in the central location in two bays is consider to study the effect of lateral deflection, bending moment, shear force and axial force caused due to lateral load. i.e. due to quake load (both static and dynamic).

I.I Use of bracing system in decreasing the effective length of the column

A new bracing system shaped like inverted V Bracings is incorporated in the main building frame and its applicability is evaluated by detailed calculations.

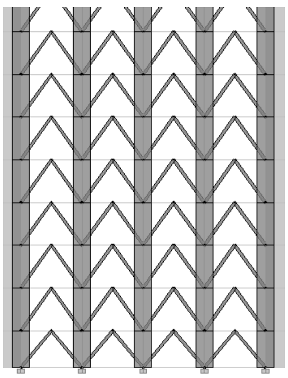


Fig-1 Showing inverted v bracings

Bracing is a very effective global upgrading strategy to enhance the global stiffness and strength of steel and composite frames. It can increase the energy absorption of structures and/or decrease the demand imposed by earthquake loads. Structures with augmented energy dissipation may safely resist forces and deformations caused by strong ground motions. Generally, global modifications to the structural system are conceived such that the design demands, often denoted by target displacement, on the existing structural and non-structural components, are less than their capacities (Figure 1). Lower demands may reduce the risk of brittle failures in the structure and/or avoid the interruption of its functionality. The attainment of global structural ductility is achieved within the design capacity by forcing inelasticity to occur within dissipative zones and ensuring that all other members and connections behave linearly.

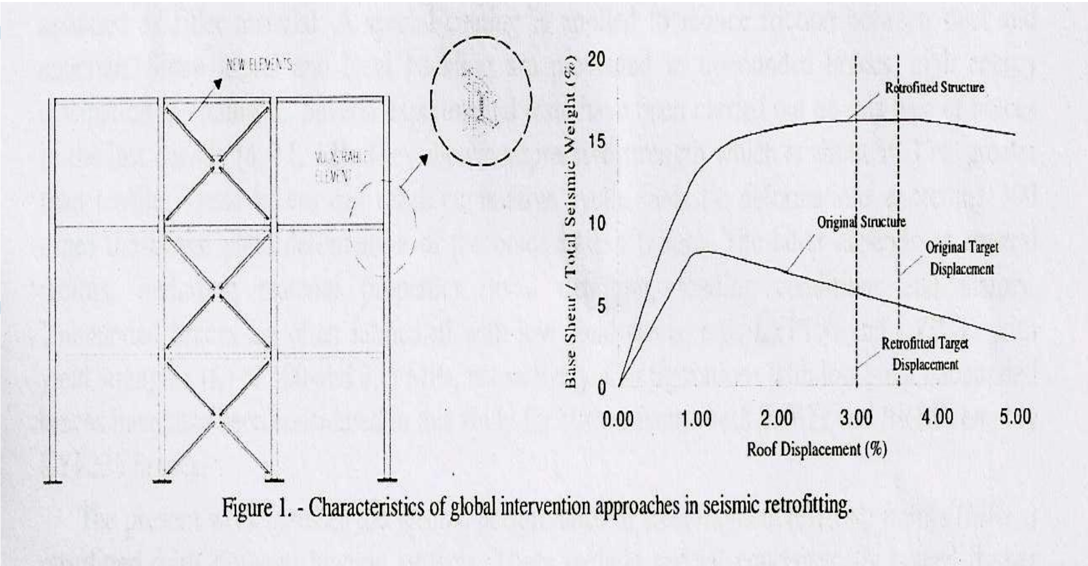


Figure 2 Characteristics of global invention in seismic retrofitting

Bracing may be inefficient if the braces are not adequately capacity-designed. Braces can be aesthetically unpleasant where they change the original architectural features of the building. In addition, braces transmit very high actions to connections and foundations and these frequently need to be strengthened.

II. METHODS AND STRUCTURAL SYSTEMS

The development of structural systems for tall buildings can be traced back to William LeBaron Jenny, in 1885. This combined with the invention of a safe passenger elevator by Otis in 1854 led to an explosion of high-rise buildings. In the ensuring 28-year period from 1885 to 1913, the first generation of skyscrapers culminated with the erection of Chrysler Building in New York in 1930, immediately followed by the Empire State Building in 1931, which held the record as the world's tallest building for 41 years. The second wave of tall buildings began in 1956 based on new building technology and new concepts in structural design, climaxing in 1974 with the completion of Sears Tower, a 110-storey, 1450-ft tall building in Chicago. Following the Sears Tower, the post second generation of super tall buildings has included only "mixed" construction, consisting of both steel and reinforced concrete. The 1476 -ft Petronas Towers, built in Kuala Lampur, Malaysia in 1997, and the 1667-ft tall Taipei 101 building, which attained its full height in Oct"03, unseating Malaysia's Towers are the world's tallest building, are two examples. Although today's building systems have evolved from an entirely different structural concept than those of the first generation of skyscrapers, it is of interest to group the systems into specific categories, each with an applicable height range. The rigid frame with an economical height range is about 20 storeys. In its simplest form it is composed of orthogonally arrange bents consisting of columns and beams with the beam rigidly connected to columns. At the other end, the bundled tube system used for the Sears Tower, consisting of an exterior framed tube stiffened by interior frame to reduce the effect of shear lag in the exterior columns. As the height increases the increase in the risk of design of tall building with lateral forces is more critical. So, the structural systems have to introduce in the tall buildings to get effective against the lateral loads (wind, earthquakes).

4.2 RIGID FRAME (MOMENT FRAME):

A frame is considered rigid when its beam-to-column connections have sufficient rigidity to hold virtually unchanged the original angles between intersecting members. A rigid-frame high-rise structure typically comprises of parallel or orthogonally arranged bents consisting of columns and girders with moment resistant joints. Resistance to horizontal loading is provided by the bending resistance of the columns, girders, and joints. The continuity of the frame also assists in resisting gravity loading more efficiently by reducing the positive moments in the centre span of girders. Typical deformations of a moment-resisting frame under lateral load are indicated in Fig. 3.1. The point of contra flexure is normally located near the mid-height of the columns and mid-span of the beams. The lateral deformation of a frame as will be seen shortly is partly due to frame racking, which might be called shear sway, and partly to column shortening. The shear-sway component constitutes approximately 80 to 90 percent of the overall lateral deformation of the frame. The remaining component of deformation is due to column shortening, also called cantilever or chord drift component.

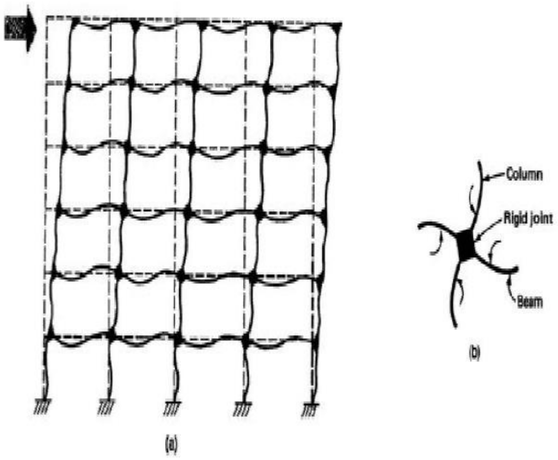


Figure: 3 Rigid frame deflections :(a) forces and deformations caused by external overturning moment; (b) forces and deformations caused by external shear.

The size of members in a moment-resisting frame is often controlled by stiffness rather than strength to control drift under lateral loads. The lateral drift is a function of both the column stiffness and beam stiffness. In a typical application, the beam spans are 6m to 9m while the story heights are usually between 3.65m to 4.27 m. Since the beam spans are greater than the floor heights, the beam moment of inertia needs to be greater than the column inertia by the ratio of beam span to story heights for an effective moment-resisting frame. Moment-resisting frames are normally efficient for buildings up to about 20-stories in height. The lack of efficiency for taller buildings is due to the moment resistance derived primarily through flexure of its members. The connections in steel moment resisting frames are important design elements. Joint rotation can account for a significant portion of the lateral away. The strength and ductility of the connection are also important considerations especially for frames designed to resist seismic loads.

4.2.1 Deflection Characteristics

The lateral deflection components of a rigid frame can be thought of as being caused by two components similar to the deflection components of a prismatic cantilever beam. One component can be likened to the bending deflection and the other to the shear deflection. Normally for prismatic members when the span-to-depth ratio is greater than 10 or so, the bending deflection is by far the more predominant component. Shear deflections contribute a small portion to the overall deflection and are therefore generally neglected in calculating deflections. The deflection characteristics of a rigid frame, on the other hand, are just the opposite; the component analogue to the beam shear deflection dominates the deflection picture and many amounts to as much as 80 percent of the total deflection, while the remaining 20 percent come from the bending component. The bending and the shear components of deflection are usually referred to as the cantilever bending and frame racking, each with its own distinct deflection mode.

A) Cantilever bending component

This phenomenon is also known as chord-drift. The wind load acting on the vertical face of the building causes an overall bending moment on any horizontal cross-section of the building. This moment, which reaches its maximum value at the base of the building, causes the building to rotate about the leeward column and is called the overturning moment. In resisting the overturning moment, the frame behaves as a Vertical cantilever responding to bending through the axial deformation of columns resulting in compression in the leeward columns and tension or uplift in the windward columns. The columns lengthen on the windward face of the building and shorten on the leeward face. This column length change causes the building to rotate and results in the chord drift component of the lateral deflection. Because of the cumulative rotation up the height, the story drift due to overall bending increases with height, while that due to racking tends to decrease. Consequently the contribution to story drift from overall bending may, in the uppermost stories, exceed that from racking. The contribution of overall bending to the total drift, however, will usually not exceed 10 to 20 percent of that of racking, except in very tall, slender, rigid frames. Therefore the overall deflected shape of medium-rise frame usually has a shear configuration.

For normally proportioned rigid frame, as a first approximation, the total lateral deflection can be thought of as a combination of three factors. Deflection due to axial deformation of column is 15 to 20 %. Frame racking due to beam rotation (50 to 60 percent). Frame racking due to column rotation (15 to 20) percent. In addition to the above, there is a fourth component that contributes to the deflection of the frame which is due to deformation of the joint. In a rigid frame, since the sizes of joints are relatively small compared to column and beam lengths, it is a common practice to ignore the effect of joint deformation. However, its contribution to building drift in very tall buildings consisting of closely spaced columns and deep spandrels could be substantial, warranting a close study. This effect is called panel zone deformation

B) Shear racking component

This phenomenon is analogous to the shear deflection in a beam and is caused in a rigid frame by the bending of beams and columns. The accumulated horizontal shear above any story of a rigid frame is resisted by shear in the columns of that story. The shear causes the story-height columns to bend in double curvature with points of contra flexure at approximately mid-story-height levels. The moments applied to a joint from the columns above and below are resisted by the attached girders, which also bend in double curvature, with points of contra flexure at approximately mid-span. These deformations of the columns and girders allow racking of the frame and horizontal deflection in each story. The overall deflected shape of a rigid frame structure due to racking has a shear configuration with concavity upwind, a maximum inclination near the base and a minimum inclination at the top. This mode of deformation accounts for about 80 percent of the total sway of Structure. In a normally proportioned rigid-frame building with column spacing at about 10.6 m to 12.2 m and a story height of 3.65 m to 4.0 m beam flexure contributes about 50 to 65 percent of the total sway. The column rotation, on the other hand, contributes about 10 to 20 percent of the total deflection. This is because in most unbraced frames the ratio of column stiffness to girder stiffness is very high, resulting in larger joint rotations of girders. So generally when it is desired to reduce the deflection of unbraced frame, the place to start adding stiffness is in the girders.

However, in non-typical frames, such as those that occur in framed tubes with column spacing approaching floor-to-floor height, it is necessary to study the relative girder and column stiffness before making adjustments in the member properties.

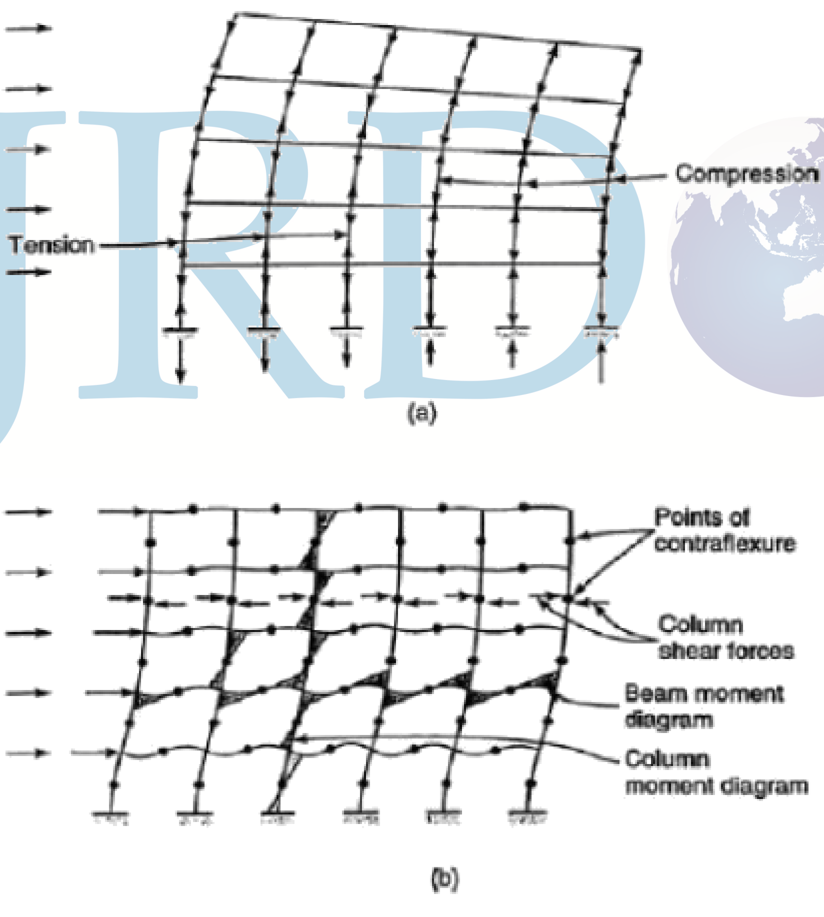


Figure 4: Rigid frame deflections :(a) forces and deformations caused by external overturning moment; (b) forces and deformations caused by external shear.

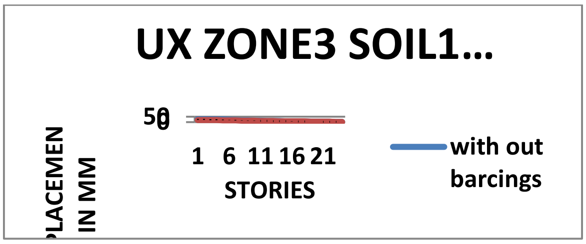
III. RESULTS AND DISCUSSIONS

For the purpose of study the top floor displacements 23 storey building is collected for three soils with respect to zones factors (Z3 and Z5) and for different kind of structural systems (bracings and without bracings) with reference to the different loading conditions.

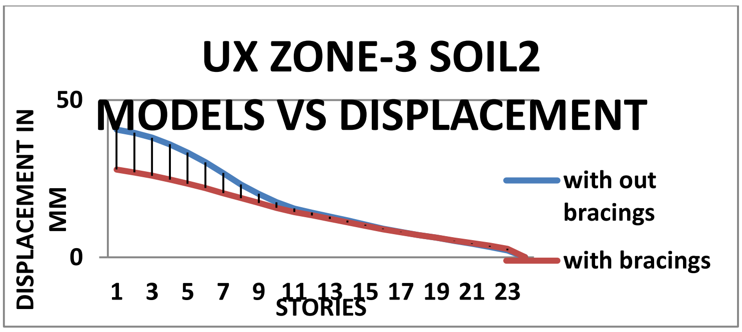
Displacement values and graphs for x- direction zone 3- soil 1 (1.2(dl+ll+eqx))

storey	without bracings	with bracings
23	29.3	20.4
22	28.5	19.8
21	27.4	19
20	25.9	18.2
19	24.1	17.2
18	22	16.2
17	19.6	15.1
16	17	13.9
15	15	12.8
14	13.1	11.7
13	11.7	10.7
12	10.7	10
11	9.8	9.2
10	8.9	8.4
9	7.9	7.6
8	7	6.8
7	6.3	6.1
6	5.5	5.4
5	4.8	4.8
4	4.1	4.1
3	3.4	3.5
2	2.6	2.9
1	1.8	2.2
BASE	0	0

Displacement values and graphs for x- direction zone 3- soil 2 (1.2(dl+ll+eqx))

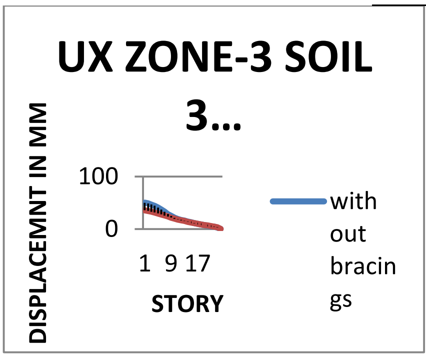


story	without bracings	with bracings
23	40.6	27.9
22	39.6	27
21	38	25.9
20	35.9	24.7
19	33.3	23.4
18	30.2	22
17	26.8	20.4
16	23.1	18.8
15	20.2	17.3
14	17.5	15.7
13	15.5	14.4
12	14.2	13.3
11	12.9	12.2
10	11.7	11.1
9	10.4	10
8	9.1	8.9
7	8.1	8
6	7.1	7.1
5	6.2	6.2
4	5.2	5.3
3	4.3	4.5
2	3.3	3.7
1	2.2	2.7
BASE	0	0

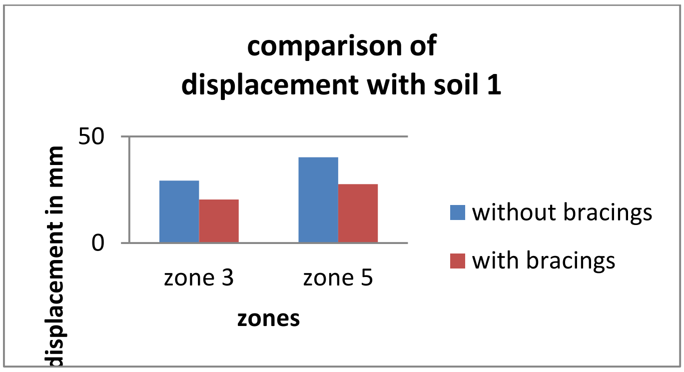


Displacement values and graphs for x- direction zone 3- soil 3 (1.2(dl+ll+eqx))

story	without bracings	with bracings
23	49.9	35.5
22	48.6	34.3
21	46.6	32.9
20	44	31.3
19	40.8	29.6
18	37.1	27.7
17	32.9	25.7
16	28.4	23.6
15	24.8	21.6
14	21.4	19.6
13	19	17.9
12	17.4	16.5
11	15.9	15.1
10	14.3	13.8
9	12.7	12.4
8	11.2	11
7	10	9.9
6	8.8	8.7
5	7.6	7.6
4	6.4	6.6
3	5.2	5.5
2	4.1	4.5
1	2.8	3.3
BASE	0	0

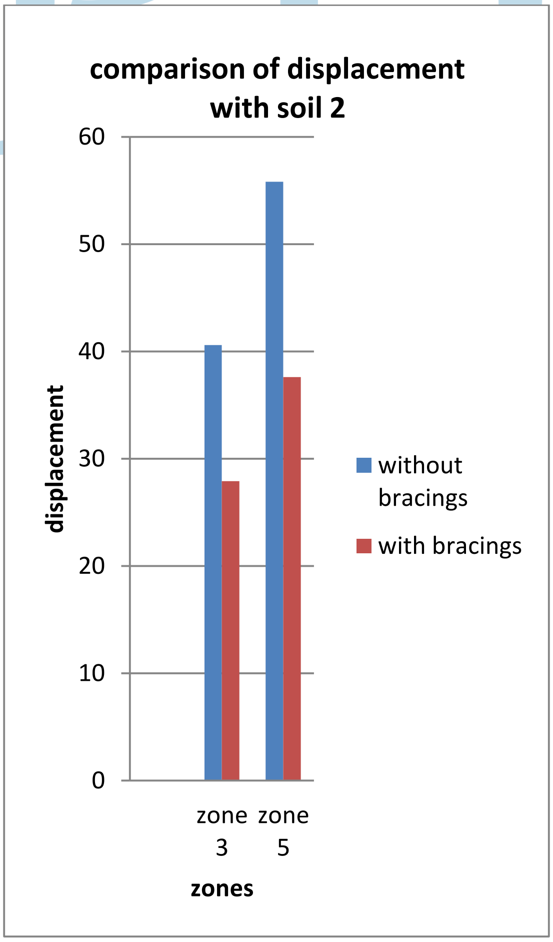


Comparison graphs for displacement in x- direction in zone 3&5-soil 1 (1.2(dl+ll+eqx))



Comparison graphs for displacement in x- direction in zone 3&5-soil 2 (1.2(dl+ll+eqx))

zones	without bracings	with bracings
zone 3	40.6	27.9
zone 5	55.8	37.6



CONCLUSIONS

By providing the bracings the stiffness of the structure is increased and storey shear is decreased with increase in height of structure. In the present research 23 storied building was designed using ETABS software to assess the seismic zones. From above discussions the following conclusion are made. . The structural performance is analyzed in two different models i.e. Without bracings; with bracings the variation of displacement is minimum only when the lateral systems are provided. By providing the bracings the stiffness of the structure is increased and storey shear is decreased with increase in height of structure. Time History analysis is performed for all the models i.e. without bracings & with bracings. Base Shear is increased with respect to time for the models with bracings. By providing lateral systems in the framed structures the reduction in the displacement, drift, storey shear, thereby increasing the stiffness of the structure for resisting lateral loads due to earth quakes.

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