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# Performance of Lateral Systems in Tall Buildings for Soft Soil Type and Different Seismic Zones

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***Abstract*—In this work, it is proposed to carry out an analytical study and performance on multistory building of 35 stories, was carried out accounting for different seismic zones and soft soil type. The suitability and efficiency of different lateral bracing systems that are commonly used and also that of concrete infills were investigated. The different bracing systems viz., X-brace, V-brace, inverted V or chevron brace and infills are introduced in these analytical models. These building models are analyzed, using SAP 2000 software, to the action of lateral forces employing linear static and linear dynamic approaches as per IS 1893 (Part I): 2002.**

***Keywords— Bracing systems, linear static and dynamic analysis, different seismic zones and soil type and RC frame.***

## 1. INTRODUCTION

Mankind has always had a fascination for height and throughout our history; we have constantly sought to metaphorically reach for the stars. From the ancient pyramids to today's modern skyscraper, a civilization's power and wealth has been repeatedly expressed through spectacular and monumental structures the design of skyscrapers is usually governed by the lateral loads imposed on the structure. As buildings have taller and narrower, the structural engineer has been increasingly challenged to meet the imposed drift requirements while minimizing the architectural impact of the structure.

The recent development of structural analysis and design software coupled with advances in the finite element method has allowed the creation of many structural and architecturally innovative forms. However, increased reliance on computer analysis is not the solution to the challenges that lie ahead in the profession. The basic understanding of structural behavior while leveraging on computing tools are the elements that will change the way structures are designed and built.

As per IS 1893 (Part I) – 2002, soils classification can be taken as Type – I, Rock or Hard soil: Well graded gravel and sand mixtures with or without clay binder and clayey sands poorly graded or sand clay mixtures, whose N (standard penetration value) should be above 30. Type – II, Medium soils: All soils with N between 10 and 30, and poorly- graded sands or gravelly sands with little or no fines. Type – III, Soft Soils: All soils other than whose N is less than 10.



## 2. SEISMIC ANALYSIS

Earthquake and its occurrence and measurements, its vibration effect and structural response have been continuously studied for many years in earthquake history and thoroughly documented in literature. Since then the structural engineers have tried hard to examine the procedure, with an aim to counter the complex dynamic effect of seismically induced forces in structures, for designing of earthquake resistant structures in a refined and easy manner.
Main features of seismic method of analysis (Riddell and Llera, 1996) based on Indian Standard 1893 (Part I): 2002 are described as follows:

(a) Equivalent lateral force
(b) Response Spectrum Analysis
(c) Elastic Time History Analysis

The method is relatively simple to be implemented, and provides information on the strength, deformation and ductility of the structure and the distribution of demands. This permit to identify critical members likely to reach limit states during the earthquake, for which attention should be given during the design and detailing process. But this method contains many limited assumptions, which neglect the variation of loading pattern, the influence of higher modes, and the effect of resonance.

## 3. MODELING

In this study a 35 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, base shear, bending moment, shear force and axial force caused due to lateral load .i.e. due to quake load (both static and dynamic).

The building is 40m x 40m in plan with columns spaced at 5m from center to center. A floor to floor height of 3.0m is assumed. The location of the building is assumed to be at different zones and different types of soils. An elevation and plan view of a typical structure is shown in fig. (a) and (b).

*Material and geometrical properties:*

Following material properties are considered for the modeling of the proposed structure frame:-

| S.No | Description | Parameter |
|---|---|---|
| 1 | Depth of foundation | 3.0 m |
| 2 | Floor to Floor height | 3.0 m |
| 3 | Grade of concrete | M-40 |
| 4 | Type of steel | Fe-415 |
| 5 | Column size (Bottom 6 storeys) | 1.4 m x1.4 m |
| 6 | Column size (From 7 to 12 storeys) | 1.2 m x1.2 m |
| 7 | Column size (From 13 to 18 storeys) | 1.0 m x1.0 m |
| 8 | Column size (From 19 to 24 storeys) | 0.8 m x0.8 m |
| 9 | Column size (From 25 to 30 storeys) | 0.6 m x0.6 m |
| 10 | Column size (Top 5 storeys) | 0.4 m x0.4 m |
| 11 | Beam size | 0.55 m x 0.6 m |
| 12 | Unit wt. of masonry wall | 20 kN/m3 |
| 13 | Slab thickness | 150 mm |
| 14 | Shear wall thickness | 120 mm |

**Loading conditions:**
Following loadings are adopted for analysis:-
1) Dead Loads:
**Top floor:**
a. External wall load =2.76 kN/m2
b. Floor Finish load = 1 kN/m2
c. Water proofing =1 kN/m2
**Remaining floors:**
a. External wall load =11.04 kN/m2
b. Floor Finish load = 1 kN/m2
c. Internal Wall Loads =5.52 kN/m2
2) Live Loads:
Live Load on typical floors = 4 kN/m2
3) Earth Quake Loads:
The earth quake loads are derived for following seismic parameters as per IS: 1893(2002)
a. Earth Quake Zone-II,III, IV,V
b. Response Reduction Factor: 5
c. Soil Type: Soft



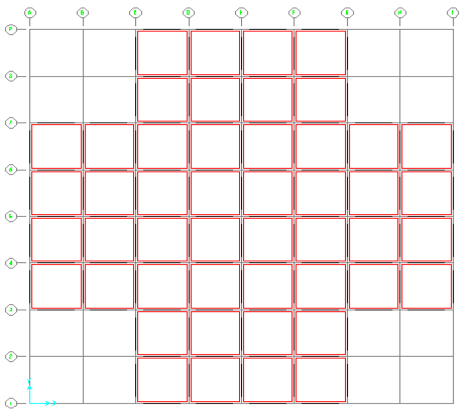


Fig (a): Building plan dimension
(Common to all floors, all models; units 'm').

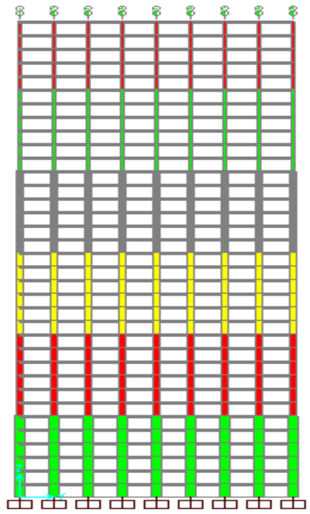
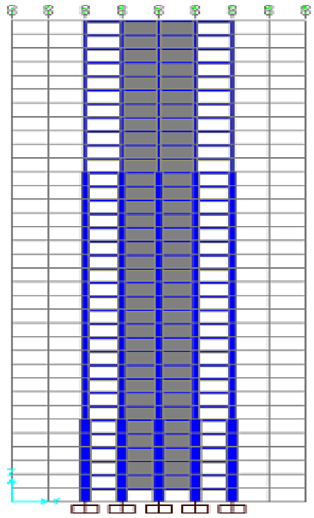
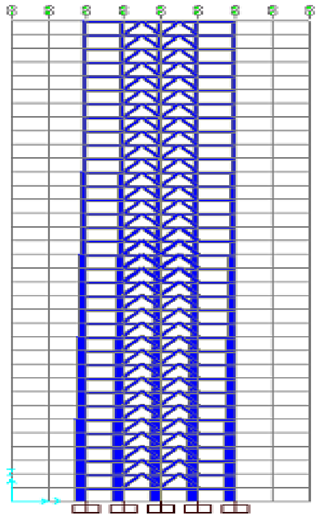


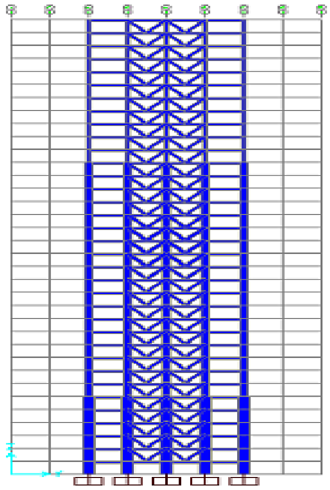
Fig (b): Storey Height
(Common to all models; units 'm').



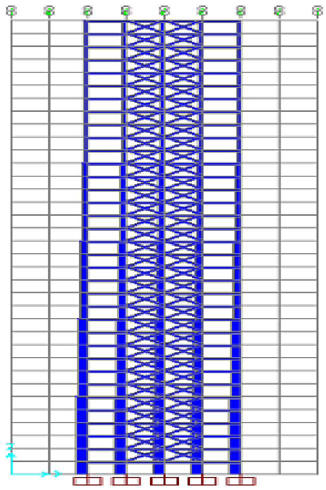
Elevation of 35 storey model showing infill
(Shear wall) in two central bays at outer periphery.



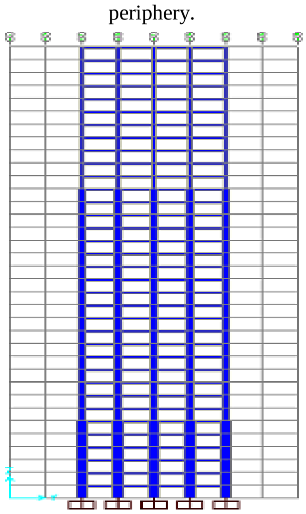
Elevation of 35 storey model showing Chevron
(inverted brace) in two central bays at outer periphery.



Elevation of 35 storey model showing V-braces in two central bays at outer periphery.



Elevation of 35 storey model showing X-brace in two central bays at outer periphery.



Elevation of 35 storey model showing no braces.

## 4. RESULTS AND DISCUSSION

Table-4.1: Showing Lateral displacements with respect to all Zone factors for Soil Type-III in Ux Direction loading Static.

| ZONE FACTORS | LATERAL DISPLACEMENTS | | | | |
|---|---|---|---|---|---|
| | WITHOUT BRACE | WITH X - BRACE | WITH V-BRACE | WITH INV.V-BRACE | WITH SHEAR WALL |
| Z2 | 106.4 | 93.5 | 93.9 | 94.9 | 87.9 |
| Z3 | 143.9 | 127.4 | 128 | 128.9 | 120.9 |
| Z4 | 193.9 | 172.5 | 173.4 | 174.2 | 164.8 |
| Z5 | 300.6 | 240.2 | 241.5 | 242.2 | 230.7 |
| NOTE: ALL UNITS ARE IN 'MM'. | | | | | |



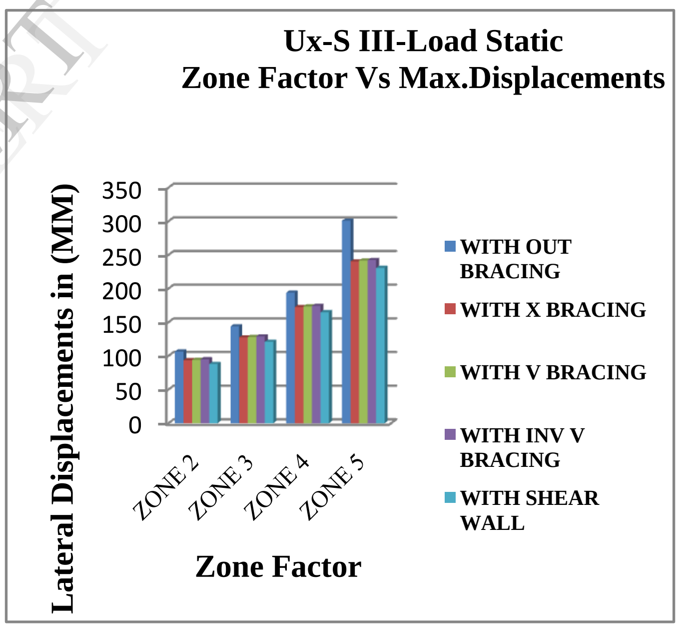



Fig-4.1:Zone Factors Vs Max. Displacement of different systems for Soil Type III, Static load.

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Table-4.2P: Showing Lateral displacements with respect to all Zone factors for Soil Type-III in Ux Direction loading Dynamic (Response Spectrum Analysis)

| ZONE FACTORS | LATERAL DISPLACEMENTS | | | | |
|---|---|---|---|---|---|
| | WITHOUT BRACE | WITH X - BRACE | WITH V-BRACE | WITH INV.V-BRACE | WITH SHEAR WALL |
| Z2 | 79.6 | 69.8 | 70.1 | 71.2 | 64.6 |
| Z3 | 101.1 | 89.5 | 89.9 | 91 | 83.6 |
| Z4 | 129.6 | 115.6 | 116.2 | 117.4 | 108.8 |
| Z5 | 172.4 | 154.9 | 155.7 | 156.9 | 146.7 |
| NOTE: ALL UNITS ARE IN 'MM'. | | | | | |

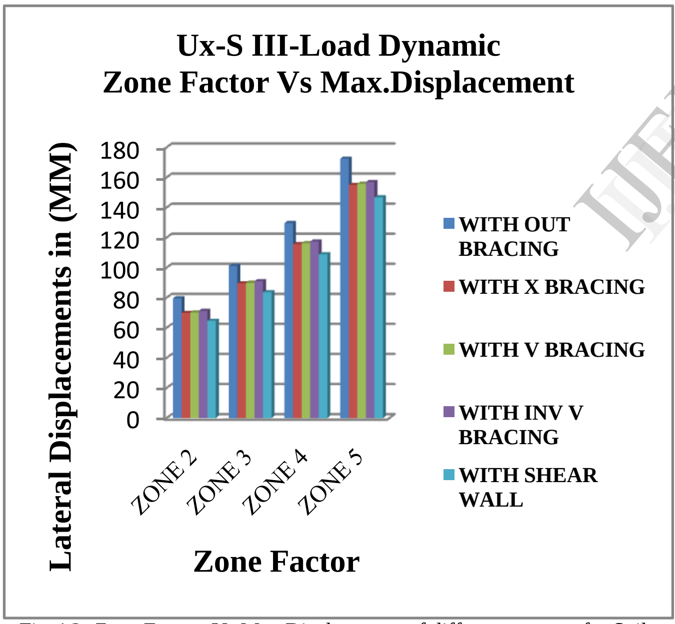


Fig-4.2: Zone Factors Vs Max Displacement of different systems for Soil Type III, Dynamic load

Table-4.3: Showing Base Shears with respect to all Zone factors for Soil Type-III loading Static

| ZONE FACTORS | BASE SHEAR | | | | |
|---|---|---|---|---|---|
| | WITHOUT BRACE | WITH X - BRACE | WITH V-BRACE | WITH INV.V-BRACE | WITH SHEAR WALL |
| Z2 | 5663 | 6325.2 | 6274.7 | 6173.7 | 6716.9 |
| Z3 | 9060.8 | 10120.3 | 10039.6 | 9877.9 | 10747.1 |
| Z4 | 13591.3 | 15180.5 | 15059.4 | 14816.9 | 16120.7 |
| Z5 | 20386.9 | 22770.7 | 22589.1 | 22225.3 | 24181 |
| NOTE: ALL UNITS ARE IN 'KN'. | | | | | |

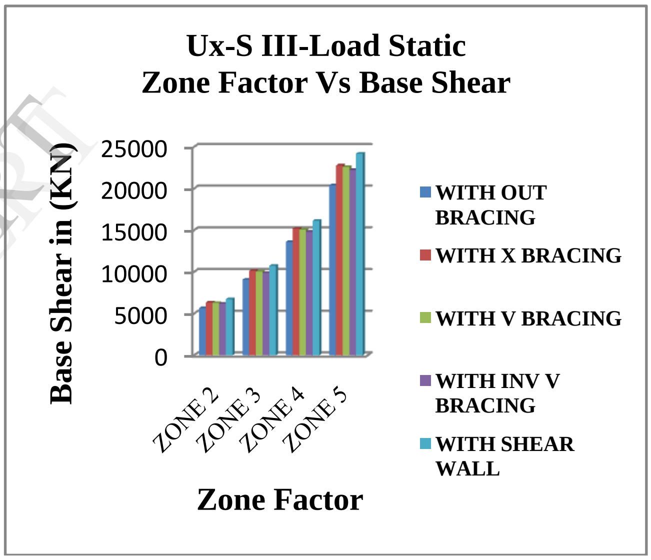


Fig-4.3: Zone Factors Vs Base Shear of different systems Soil Type III, Static load

Table-4.4: Showing Base Shears with respect to all Zone factors for Soil Type-III loading Dynamic (Response Spectrum Analysis)

| ZONE FACTORS | BASE SHEAR | | | | |
|---|---|---|---|---|---|
| | WITHOUT BRACE | WITH X - BRACE | WITH V-BRACE | WITH INV.V-BRACE | WITH SHEAR WALL |
| Z2 | 5694.5 | 5453.4 | 5386.4 | 5225 | 5934.5 |
| Z3 | 7511.1 | 8725.5 | 8618.3 | 8360 | 9494.2 |
| Z4 | 11266.7 | 13088.2 | 12927.5 | 12540 | 14242.7 |
| Z5 | 16900 | 19632.4 | 19391.2 | 18810.1 | 21364.1 |
| NOTE: ALL UNITS ARE IN 'KN'. | | | | | |

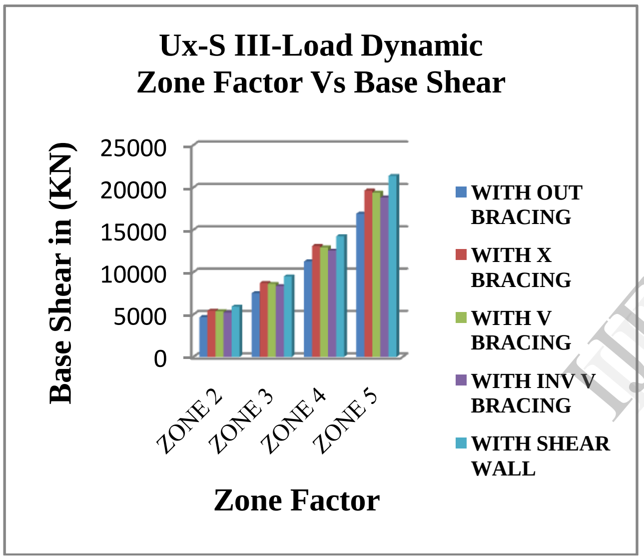


Fig-4.4: Zone Factors Vs Base Shear of different systems Soil Type III, Dynamic load

Table-4.5: Showing Shear Force with respect to Type of loading for Zone 5 and Soil Type III.

| DIFFERENT TYPE OF BRACINGS V2 (KN) | TYPE OF LOADING | |
|---|---|---|
| | STATIC LOADING | DYNAMIC LOADING |
| WITH OUT BRACING | 633.6 | 402.7 |
| WITH X BRACING | 493.1 | 327.7 |
| WITH V BRACING | 495.3 | 328.5 |
| WITH INV V BRACING | 512.9 | 336.1 |
| WITH SHEAR WALL | 457.5 | 303.2 |
| NOTE: ALL UNITS ARE IN 'KN' | | |

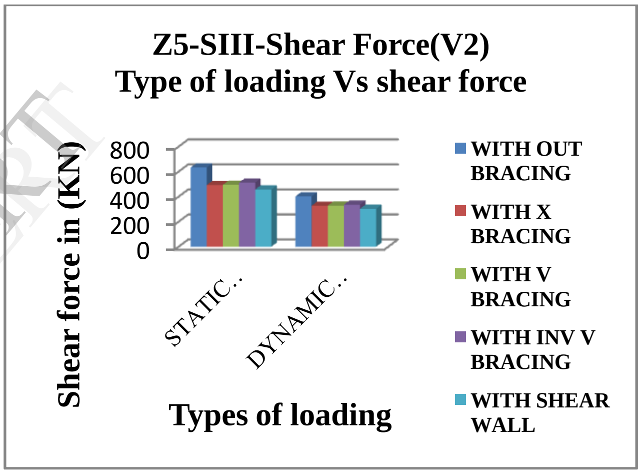


Fig-4.5: Type of loading Vs Shear Force of different systems for Zone Factor 5 and Soil Type III.

Table-4.6: Showing Moment with respect to Type of loading for Zone 5 and Soil Type III.

| DIFFERENT TYPE OF BR M3 (KN/M) | TYPE OF LOADING | |
|---|---|---|
| | STATIC LOADING | DYNAMIC LOADING |
| WITH OUT BRACING | 1140.5 | 784.1 |
| WITH X BRACING | 890.2 | 682.7 |
| WITH V BRACING | 893.5 | 685.9 |
| WITH INV V BRACING | 935.6 | 713.4 |
| WITH SHEAR WALL | 814.2 | 573.8 |
| NOTE: ALL UNITS ARE IN 'KN/M' | | |

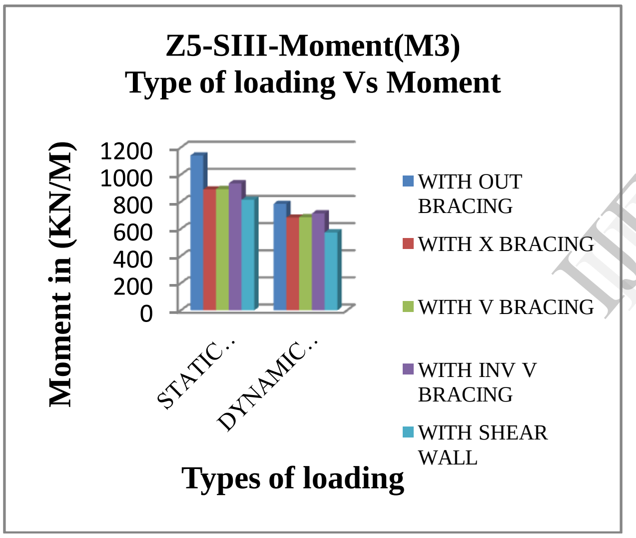


Fig-4.6: Type of loading Vs Moment of different systems for Zone Factor 5 and Soil Type III.

## 5. DISCUSSION OF RESULTS

Case 1: Displacement variation for different types of bracing in all zones and soil types:

It was observed that the roof displacement for 35 storeys building the displacement increases with the increase in the zone factor. Both for static and dynamic loads. For 35-storey model the variation of displacement is about 21% for zone Z2 to Z3 and about 28% from Z3 to Z4 and about 42% from Z4 to Z5 in Ux direction for static and dynamic.

Case 2: Base shear of Different type of system when compared to zone factors:

In this case the effect of base shear is study with reference to zone factors. The zone factors are taken on x-axis and the base shears taken is on y-axis, the graphs are plotted. For different types of loading conditions (Static and dynamic).

The observations made through this case study is, the base shear value increase with the increase of zone factors. The percentage of increase from Z2 to Z5 in Ux direction.

Case 3: Column forces of different type of systems for zone 5 and soil type III:

In this case the effect of column force is studied. The different type of systems is taken on x-axis and the column forces taken are on y-axis, the graphs are plotted. For different types of loading conditions (Static and dynamic).

The observations made through this case study is, the Shear force (V2) and Bending moment (M3) it can be say that the column forces of without brace model is comparatively larger than the x-brace, v-brace, inv-v- brace and infills.

## 6. CONCLUSIONS

Based on the study of analysis of results the following conclusions are drawn:

1. The structural performance among three bracing systems (X-brace, V-brace, Inverted V-brace), one infill (introduce at the place of braces), the variation of displacement is smaller in infill system.
2. Which the provision of bracings, infills the stiffness of the structure is increasing and there by the base shear is decreasing with the increase in height of the structure.
3. Structural capacity is greatly influence by the concrete infills.
4. The introduction of the bracing systems, infills were found to be much effective in reducing the displacement, base shear and thereby increasing the stiffness of the structures, increasing the structural capacity of the structure for resisting the lateral loads due to earthquakes. But among all for higher heights the infills are found to be more predominating in resisting the lateral forces.

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