Seismic Analysis in Tall Buildings for Hard Soil Type and Different Seismic Zones

K. Shaiksha vali [1]
[1]M-Tech. Student,
Computer aided structural engineering
Department of civil engineering
J N T U A College of engineering, Anantapur

B. Ajitha[2]
[2]Assistant Professor,
Department of civil engineering
J N T U A College of engineering, Anantapur
Anantapur

***Abstract*— In this work, it is proposed to carry out an analytical study, on multistory building of 35 stories, was carried out accounting for different seismic zones and hard 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, maximum displacements, different seismic zones and soil type and RC frame*.**

1. INTRODUCTION

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.

This undying quest for height has laid out incredible opportunities for the building profession. From the early moment frames to today's ultra-efficient mega-braced structures, the structural engineering profession has come a long way. 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.

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. In response to this challenge, the profession has proposed a multitude of lateral schemes that are now spoken in tall buildings across the globe.

This study seeks to understand the evolution of the different lateral systems that have emerged and its associated structural behavior, for each lateral scheme examined, its advantages and disadvantages will be looked at.

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.

Linear static analysis or equivalent static analysis can only be used for regular structures with limited height. Linear dynamic analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method. This analysis will produce the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way. They represent an improvement over linear static analysis. The significant difference between linear static and dynamic analysis is the level of force and their distribution along the height of the structure. Non – linear static analysis is an improvement over the linear static or dynamic analysis in the sense that it allows the inelastic behavior of the structure. The methods still assume a set of static incremental lateral load over the height of structure.

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

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:-

Table 3.1: Details of material and geometrical properties

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 0.6m
12	Unit wt. of masonry wall	20 kN/m^3
13	Slab thickness	150 mm
14	Shear wall thickness	120 mm

Loading conditions:

Following loadings are adopted for analysis:-

A) Dead Loads:

Top floor:

a. External wall load =2.76 kN/m^2
b. Floor Finish load = 1 kN/m^2
c. Water proofing =1 kN/m^2

Remaining floors:

a. External wall load =11.04 kN/m^2
b. Floor Finish load = 1 kN/m^2
c. Internal Wall Loads =5.52 kN/m^2

B) Live Loads:

Live Load on typical floors = 4 kN/m^2

C) 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: Hard

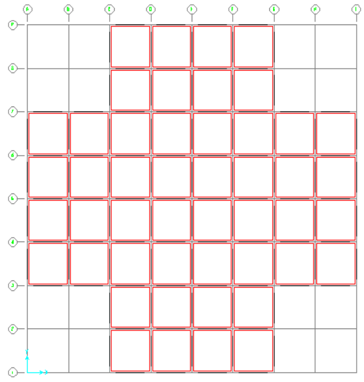

Fig 3.1: Building plan dimension (Common to all floors, all models; units 'm').

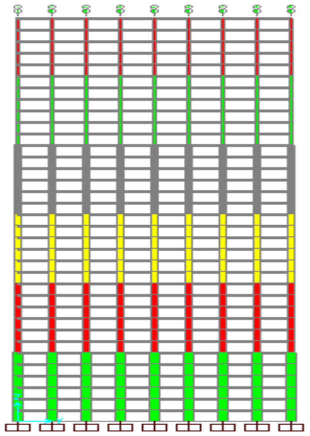

Fig 3.2: Storey Height (Common to all models; units 'm').

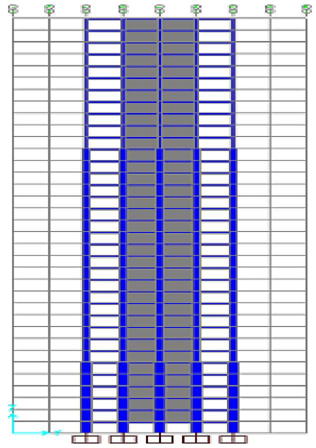

Fig 3.3: Elevation of 35 storey model showing infill (Shear wall) in two central bays at outer periphery.

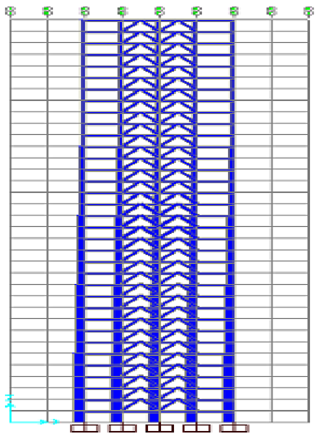

Fig 3.4: Elevation of 35 storey model showing Chevron (inverted brace) in two central bays at outer periphery.

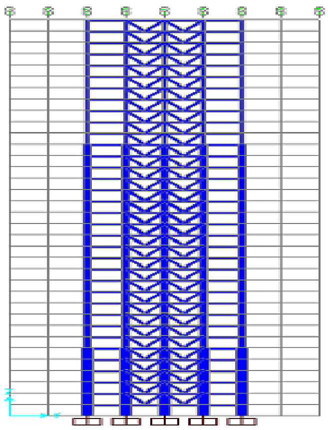

Fig 3.5: Elevation of 35 storey model showing V-braces in two central bays at outer periphery.

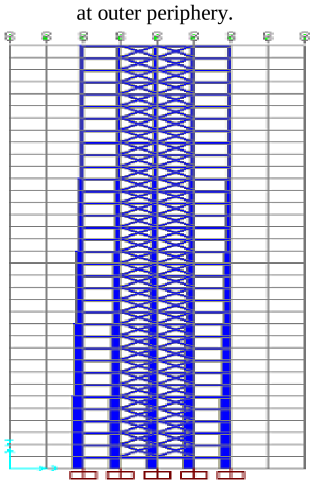

Fig 3.6: Elevation of 35 storey model showing X-brace in two central bays at outer periphery.

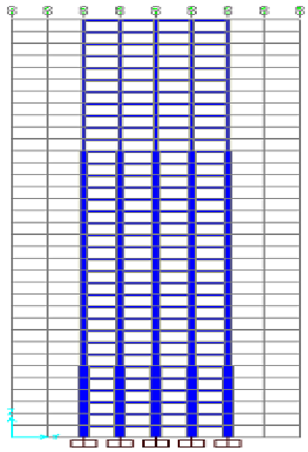

Fig 3.7: Elevation of 35 storey model showing no braces.

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'.					

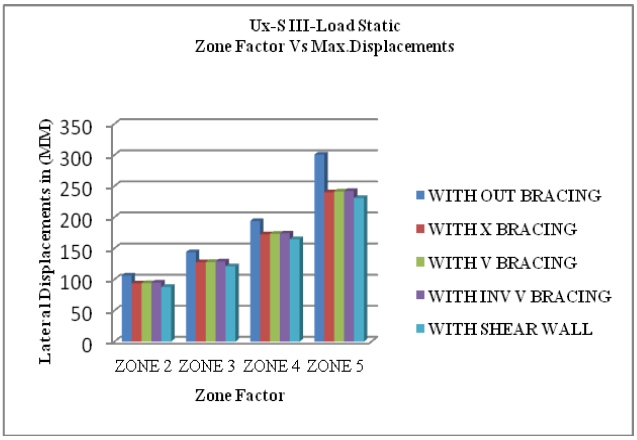

Fig 4.1: Zone Factors Vs Max. Displacement of different systems for Soil Type III, Static load.

Table 4.2: 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'.					

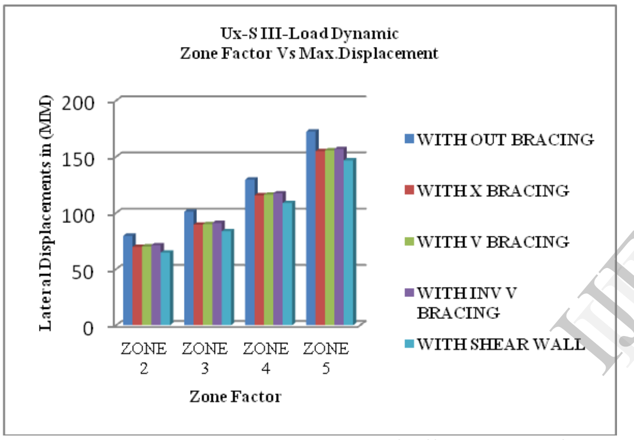

Fig 4.2: Zone Factors Vs Max Displacement of different systems for Soil Type III, Dynamic load

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'.					

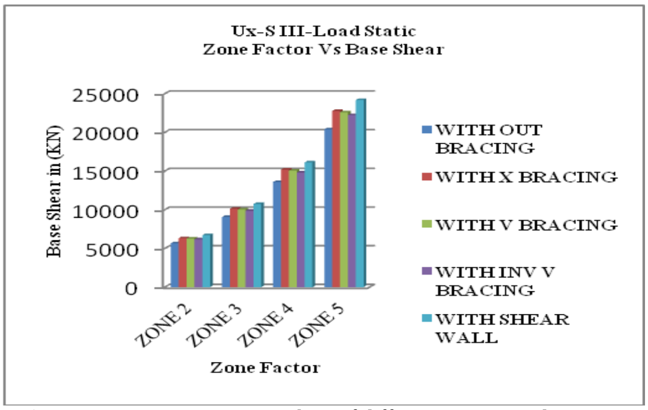

Fig 4.3: Zone Factors Vs Base Shear of different systems Soil Type III, Static load

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	4694.5	4553.4	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'.					

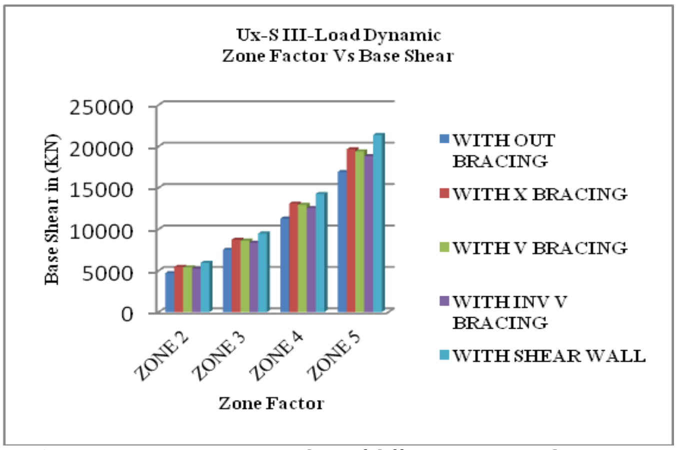

Fig 4.4: Zone Factors Vs Base Shear of different systems Soil Type III, Dynamic load

Table 4.5: Showing Total Weight and Seismic Weight of the building for Different types of systems.

TYPES OF BRACINGS	TOTAL WEIGHT OF THE BUILDING(DL+LL)	TOTAL SEISMIC WEIGHT OF THE BUILDING(DL+0.5LL)
WITH OUT BRACING	866221.2	783421.2
WITH X-BRACING	873516.9	790716.9
WITH V-BRACING	871107.3	788307.3
WITH INV.V-BRACING	871107.3	788307.3
WITH SHEAR WALL	878461.2	795661.2
NOTE: ALL UNITS ARE IN 'KN'.		

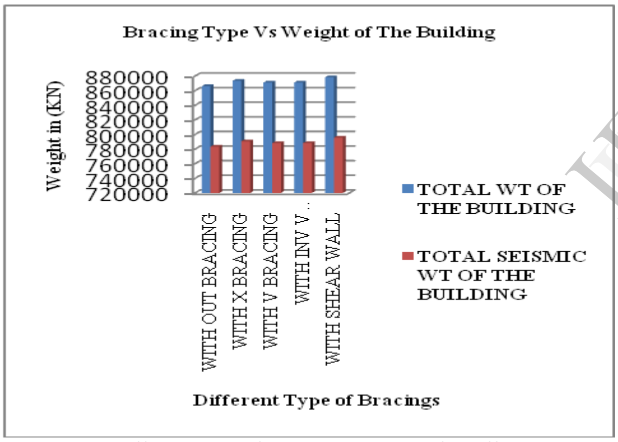

Fig 4.5: Different Type of Bracing Vs Weight for different systems

Table 4.6: Showing Stiffness of the Structure for Different type of systems.

TYPES OF BRACINGS	STIFFNESS OF A STRUCTURE
WITH OUT BRACING	83333.3
WITH X-BRACING	100000
WITH V-BRACING	100000
WITH INV.V-BRACING	100000
WITH SHEAR WALL	111111.1
NOTE: ALL UNITS ARE IN ‘KN / M’.	

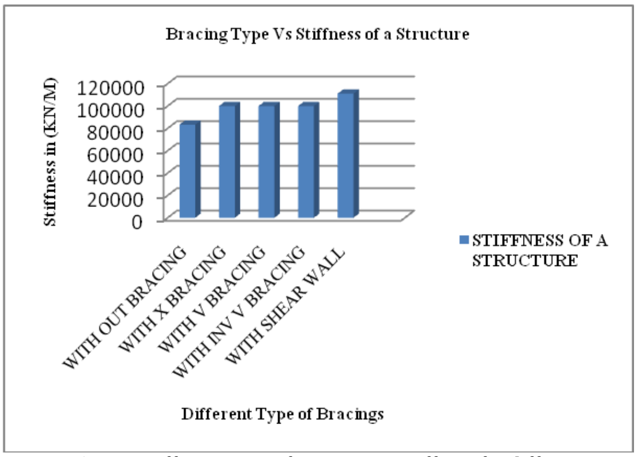

Fig 4.6: Different Type of Bracing Vs Stiffness for different Systems

Table 4.7: Showing Displacements in Ux-direction of different type of systems

DIFFERENT MODELS	DIFFERENT GROUND MOTIONS			
	NEW HALL	*PARKFIELD*	*PETROLIEA*	*NOCERA*
WITH OUT BRACING:	752.7	128.7	879.5	28.6
WITH SHEAR WALL:	583.2	145.9	787.3	30.4
WITH X BRACING:	675.8	155.4	815.4	27.5
WITH V BRACING:	683.5	157.5	823.8	27.1
WITH INV V BRACING:	678.9	146.5	821.1	26.1
NOTE: ALL UNITS ARE IN 'MM'.				

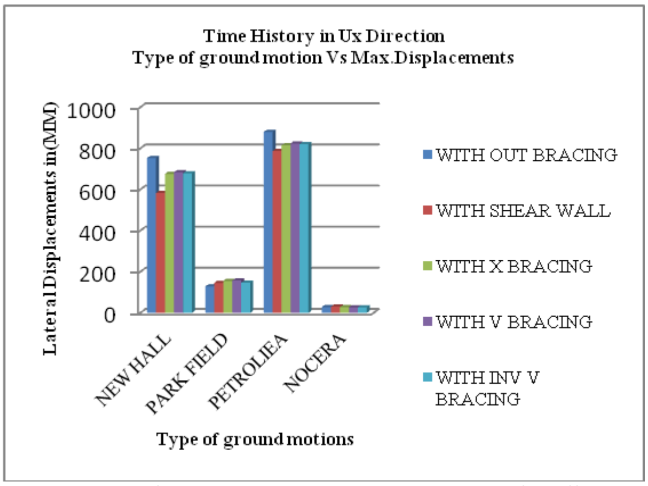

Fig 4.7: Type of ground motion Vs Lateral displacements for different systems

5. DISCUSSION OF RESULTS

Case 1:

Displacement variation for different types of bracing in all zones and hard soil type:

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 30.7% for zone Z2 to Z3 and about 30.8% from Z3 to Z4 and about 35% from Z4 to Z5 in Ux direction for static and for dynamic the variation of displacement is about 24.7% for zone Z2 to Z3 and about 25.4% from Z3 to Z4 and about 29% from Z4 to Z5.It means that the displacements in the zone factor are increases at linearly. This is true for dynamic loading case also. The higher the zone the more is the lateral displacements.

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:

Stiffness of the Structure of different type of systems:

In this case the Stiffness of the Structure is studied .The different type of systems is taken on x-axis and the stiffness 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 stiffness is of infill model is comparatively larger than the x-brace, v-brace, inv-v- brace and without brace.

Case 4:

Linear Modal Time History Analysis is done for different brace structures:

In this study we have done linear time history analysis, the displacement are drawn with respect to time. We have found the max displacement among all the ground motions is **PETROLIEA** for without bracing in Ux direction and min displacement among all the ground motions is **NOCERA** for inverted v barcing

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. with 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. Time history analysis is performed among the X-Brace, Infills and Without Brace structures and found that the infill system is have lesser displacements with respect to time

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