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Study on Lateral Resistance Behaviour of High Rise Building with Shear Wall and Bracings

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Abstract:
Shear walls and bracing systems are the most appropriate structural forms in the recent decades. A shear wall is a wall that is designed to resist shear i.e. the lateral force that causes bulk damage to the structures during earthquakes. Bracing is also a highly efficient and economical method of resisting horizontal forces in a frame structures. The aim of this work is to study the structural aspects of an R.C building with G+32 stories are to be considered for lateral forces using structural components such as R.C shear wall and bracings. This structural system using a core wall carries the seismic lateral forces which improves the design flexibility of super-high-rise condominium. Non-linear analysis was done in ETABS 9.7.4 to check the lateral force resistant behavior of components. By providing shear wall and bracing the lateral forces are resisted by the structural components which have increased stiffness, deformability and decreased drift. This analytical investigation on R.C shear wall and bracings for lateral load resisting is compared with ordinary R.C structures. The effects of various geometries were analyzed, results were compared and presented in this paper as per IS code methods.

Keywords: *Bracing system, Deflection, Lateral loads, Non-linear analysis, Shear wall, Storey drift*

1. Introduction

In the seismic design of buildings, reinforced concrete structural walls, or shear walls, act as major earthquake resisting members. Behavior of structure during earthquake motion depends on distribution of weight, stiffness and strength in both horizontal and planes of building. To reduce the effect of earthquake, reinforced concrete shear walls are used in buildings. Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. In some regions, they are known as braced wall lines for this very reason. An effective wall of this type is stiff and strong. A stiff, strong wall, on the other hand, resists lateral forces while providing support. In multi-story structures, shear walls are critical, because in addition to preventing the failure of walls, they also support the multiple floors of the building, ensuring that they do not collapse as a result of lateral movement in an earthquake.

Buildings are generally composed of vertical and horizontal structural elements. The vertical elements commonly used to transfer lateral forces to the ground are: 1) shear walls; 2) braced frames. They make the height of the concrete structures to be soared and act as major earthquake resisting members.

2. Literature Review

- Tsunehisa matsuura, Toshio matsumoto, Kazushi shimazaki [1] their experimental study is composed of two test series Lateral loading test and Uni-axial loading test and various failure modes were determined.
- Perry Adebar [2] presents the background to prescriptive design procedures that have recently been developed to permit the safe design of high-rise core-wall buildings using only the results of response spectrum analysis (RSA) at the MCE level of ground motion. He discussed about the following parameters, such as (i) effective stiffness of walls to estimate displacement demands at top of wall using RSA, (ii) procedures to estimate rotation demands on cantilever walls and coupled walls, (iii) procedures to estimate rotational demands on coupling beams, (iv) procedures to ensure the flexural hinge regions of the wall have adequate shear capacity, (v) procedure to design for shear reversal below flexural hinge due to stiff floor diaphragms connected to perimeter foundation walls, and finally (vi) some discussion on dynamic magnification of shear.
- O. Esmaili, S. Epackachi, M. Samadzad, and S.R. Mirghaderi [3] have studied the behavior of RC tall buildings with shear wall under both lateral and gravity loads. They concluded that increasing axial load level decreases ductility. So design base shear will be increased and moment of inertia of the section should be increased and also indicate that confinement of concrete in shear walls is a good way to provide more level of ductility and getting more stable.

3. Bracing on High Rise Building

Bracing is highly efficient and economical method of resisting horizontal forces in a frame structures. Bracing is accomplished with metal brackets and heavy timbers or support beams that keep the wall strong and sturdy. A braced bent consists of the usual column and girders. Whose primary purpose is to support the gravity loading and diagonal bracing members that are connected so that the total set of members forms a vertical cantilever truss to resist the horizontal loading. Bracing is efficient because the diagonal work in axial stress and therefore call for minimum member size in providing stiffness and strength against horizontal shear.

4. Shear Wall

Shear walls are vertical elements of the horizontal force resisting system. The walls are quite stiff in their own plane and flexible in the plane perpendicular. Thus a shear walls transfers a lateral force in its own plane by developing moment and shear resistance. It is usual to locate the walls on plan so that they attract an amount of gravity loading sufficient to suppress the maximum tensile bending stresses in the wall caused by lateral loading. In this situation only minimum wall reinforced is required. The system has a broad range of application and has been used for buildings as low as 10 stories to as high as 50 stories or even taller. The wall may be part of service core or a stairwell. Properly designed and detailed buildings with shear walls have shown very good performance such as, distribution of weight, stiffness and strength in both horizontal and planes of building in past earthquakes.

5. ETABS 9.7.4

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. ETABS Version 9 features an intuitive and powerful graphical interface coupled with unmatched modeling, analytical, and design procedures, all integrated using a common database. Although quick and easy for simple structures, ETABS can also handle the largest and most complex building models, including a wide range of nonlinear behaviors, making it the tool of choice for structural engineers in the building industry.

6. Structural Models Considered Using ETABS

In the present study, G+32 stories are considered for models. The various parameters are to be compared in the mentioned models such as storey drift, deflection and stiffness.

- Model I : without shear wall and bracings (Fig1)
- Model II : with shear wall structure (Fig2)
- Model III : with bracing system in outer location (Fig3)
- Model IV : replacement of shear walls with bracing (Fig4)

This G+32 storey of irregular building are modeled in ETABS software as a fixed base with mentioned models. Total height of the building is 117m, which has bottom three storey heights of 4 m and remaining storey height of 3.5 m. The beam and column sizes are varied and slab thickness is 0.1m.

6.1. Properties of Reinforced Concrete

The following are the properties of the reinforced concrete to model the structural element such as column, beam, and slab.

Mass per unit volume,

$m = 2500\ kg/m^3$

Weight per unit volume,

$w = 24.525\ kN/m^3$

Modulus of elasticity,

$E = 27386127.88\ kN/m^2$

Poisson’s ratio,

$\gamma = 0.2$

Co-efficient of thermal expansion,

$\alpha = 9E\text{-}6$

Shear modulus,

$G = 11410886.6\ kN/m^2$

Compressive strength of concrete,

$f_{ck} = 30000\ kN/m^2$

Yield strength of steel,

$f_y = 415000\ kN/m^2$

6.2. Size of Members

- Slab thick : 0.1m
- Bracing thick : 0.3mx0.3m
- Shear wall thick : 0.3m
- Beam sizes (mm): 0.25x0.35, 0.25x0.4, 0.3x0.45, 0.3x0.6, 0.3x0.75, 0.35x0.85, 0.35x0.6, 0.35x0.95, 0.35x1, 0.4x1.2 and 0.45x1.2

7. Load Calculation

7.1. Dead Load Calculation (IS 875 Part-I 1987)

a) Floor finish = 1kN/m^2 (table 1, cls7 page 30)
b) Water proof = 1.5 kN/m^2 (table 2, cls 8 page 30)
c) Wall load
 = (0.23x19) + (2x0.12x20) = 4.85 kN/m^2
d) Stair load
 = 13.5 kN/m (4.97 m span)
 = 14.5 kN/m (5.3 m span)
e) Head room load
 = 3x0.23x25 = 14.255kN/m

7.2. Live Load Calculation (IS 875 part-II 1987)

(cls 3.1 page 7, under hotel building)
= 3 kN/m^2
= 1.5 kN/m^2 (at roof level)

7.3. Wind Load Calculation (IS 875 part-III 1987)

Design wind speed $v_z = v_b k_1 k_2 k_3$ (cls 5.3 page 8)
Where,
Basic wind speed, v_b = 39 m/s (for Pune, page 8)
Risk co-efficient, k_1 =1 (table 1, page 11)
Terrain, height and structure size factor k_2 (cls 5.3.2 page 8)
k_2 =1.183 (terrain category-3, class-b)
Topography, k_3 = 1 (cls 5.3.3 page 12)

- Wind Pressure Co-efficients (cls 6.2.2 and cls 6.2.3 table 4)

Using conservative method
a) X- direction
 = Windward = 1.35
 = Leeward = -1.25
b) Y-direction

 = Windward = 1.35
 = Leeward = -1.25

7.4. Seismic Load Calculation IS 1893 (part I): 2002

Seismic co-efficient:
Seismic zone factor, Z (cls 6.4.2, table 2)
=0.16 (moderate and location in Pune)
Type of soil
type II (medium soil)
Importance factor, I (cls 6.4.2, table 6)
=1.0
Response reduction factor, R (cls 6.4.2, table 7)
= 5 (special RC moment-resisting frame)

7.5. Load Combination

As per IS 1893 (Part 1): 2002 Clause no. 6.3.1.2, the following load cases have to be considered for analysis:
1.5 (DL + IL)
1.2 (DL + IL ± EL)
1.5 (DL ± EL)
0.9 DL ± 1.5 EL
1.2 (DL + IL ± WL)
1.5 (DL ± WL)
0.9 DL ± 1.5 WL
DL – dead load
IL – imposed load
EL – earthquake load

WL – wind load

8. Analysis

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building system. ETABS can also handle the largest and most complex build in model, including a wide range of nonlinear behaviors, making it the tool of choice for structural engineer in the building industry. Dynamic analysis was performed as per response spectrum method. Mass matrix and stiffness matrix were arrived from the geometry of the structure. Then it was solved to obtain the Eigen values i.e. the natural period and frequency of the structure. For the analysis of fixed as well as base isolated building linear time history analysis and response spectrum method is used.

Analysis and design procedure is arranged the following steps:

- → The plan is studied and column locations are marked
- → Required code books and etabs software are studied
- → Define Material Properties
- → Draw Shear Wall and Define Pier Labels
- → Draw a bracing
- → Define and Assign Section Properties
- → Define "Similar Stories" Option
- → Modify Floor Plan at "G.F" to "STORY10"
- → Modify Floor Plan at "STORY11" to "STORY20"
- → Modify Floor Plan at "STORY21" to "STORY33"
- → Assign Auto Mesh Options at Shell Panels
- → Assign Supports
- → Assign "DEAD" and "LIVE" Load
- → Define and Assign Wind Load Case
- → Define Static Load Case for Equivalent Seismic Force
- → Run Analysis and View Results
- → Run Concrete Frame Design and View Results
- → Run Shear Wall Design and View Results

9. Results and Discussion

9.1. Storey Drift

Drift is generally defined as the lateral displacement of one floor relative to the floor below.

- Drift control is necessary to limit damage to interior partitions, elevator and stair enclosures, glass, and cladding systems. Stress or strength limitations in ductile materials do not always provide adequate drift control, especially for tall buildings with relatively flexible moment-resisting frames or narrow shear walls.
- The results were taken for the governing load combination (1.5D.L + 1.5WINDX) because this load combination gives maximum drift values in comparision with other load combinations.
- From IS 1893 (part I) : 2002 , (cls 7. 11. 1) Storey drift limitation should not exceed 0.004 time the storey height.

The values of storey drift for different cases are as follows.

1. without shear wall and bracings = 0.004186m (Fig 5)
2. with shear wall structure = 0.00280m (Fig 6)
3. with bracing system in outer location = 0.002309m (Fig 7)
4. replacement of shear walls with bracing = 0.00371m (Fig 8)

which has the model reduced the storey drift by using bracing system as well as shear wall. So increase the lateral resistance of the structure.

As above mentioned the value of storey drift for Model I (without shear wall and bracings) was exceed 0.004 times the storey height.After implimentation of shear wall and bracing systems,the values of storey drift for Model II & Model III comes under limitation.

9.2. Storey Lateral Displcement

Lateral displacement of the structure is reduced by using bracing system as well as shear wall. Storey deformation is depends upon the height of the structure. So the curve is plotted for wind intensity. From IS 456 : 2000 (cls, 20.5) under transient wind load the lateral sway at the top should not exceed H/500,

where,

H- the total height of the building

Maximum storey drift of mentioned models are following,

1. without shear wall and bracings = 0.23109m (Fig 9)
2. with shear wall structure = 0.17193m (Fig 10)
3. with bracing system in outer location = 0.13315m (Fig 11)

4. replacement of shear walls with bracing = 0.21064m (Fig 12)

From this analysis result, Model II and Model III are reduced a storey displacement within IS code limit.

10. Conclusion

Bracing has been efficient because of diagonal work act as an axial stress and therefore member size can be reduced in order to provide stiffness and strength against horizontal shear. Among four models, Model III (with bracing system in outer location) revealed the reduction in storey drift and lateral displacement with increased stiffness of this structure.

Floor level	Size(m)
G.F to 10th floor	0.85x1
11th floor to 20th floor	0.65x0.65
21th floor 33rd floor	0.55x0.55

Table 1: Column Sizes

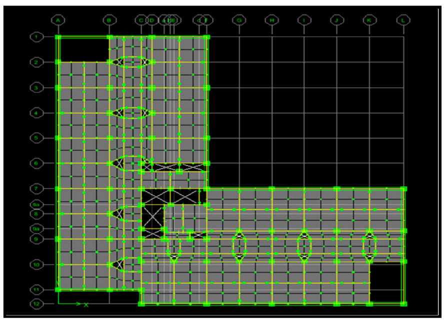

Figure 1: Without Shear Wall and Bracings

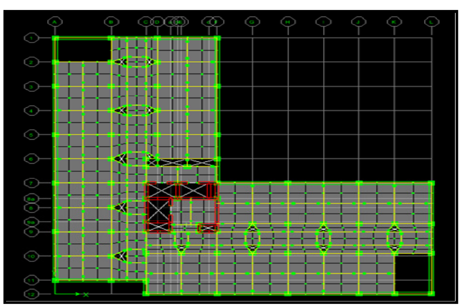

Figure 2: With Shear Wall Structure (Provision of Shear Wall is Indicated by Red Color)

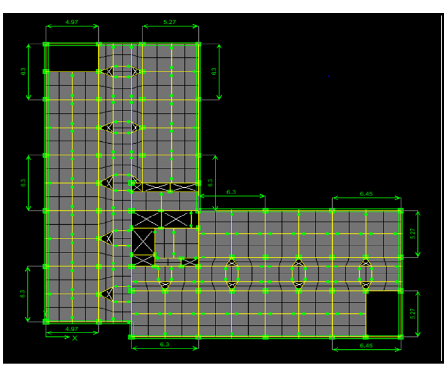

Figure 3: With Bracing System in Outer Location (Provision of Bracings are Indicated by Dimensions Marked Portions)

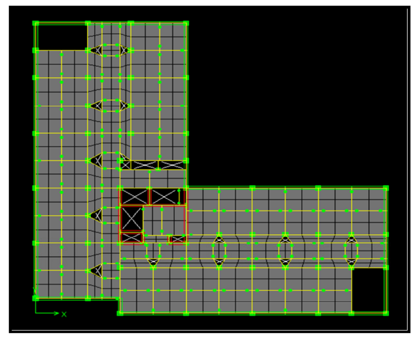

Figure 4: Replacement of Shear Wall with Bracing (Provision of Bracings Locations are Indicated in Red Color)

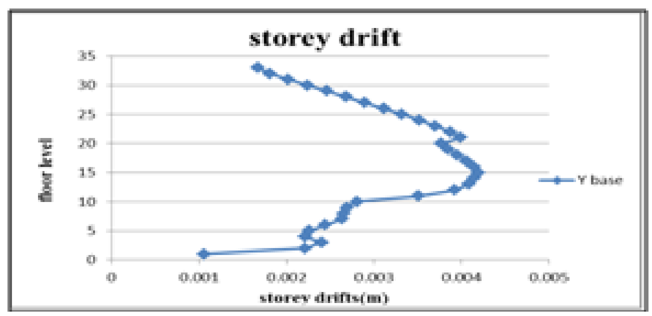

Figure 5: Storey Drift for without using Shear Wall and Bracing System

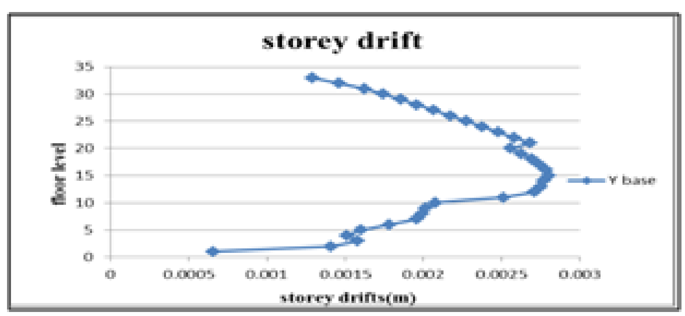

Figure 6: Storey Drift for using Shear Wall

Figure 7: Storey Drift for using Bracing System

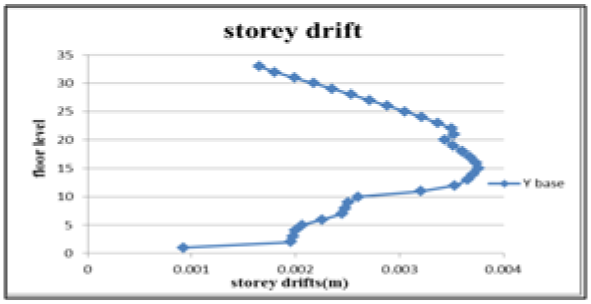

Figure 8: Story Drift Replacement of Shear Wall with Bracing

Figure 9: Story Lateral Displacement for without Shear Wall and Bracing

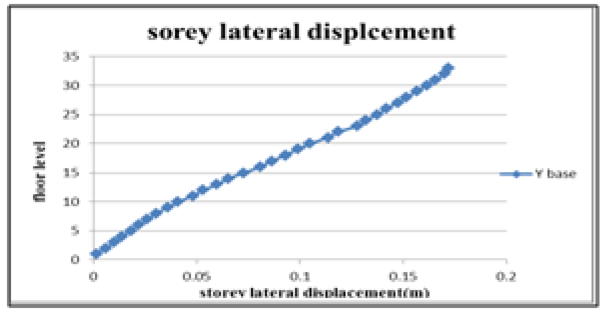

Figure 10: Story Lateral Displacement for Shear Wall

Figure 11: Story Lateral Displacement for Bracing Systebm

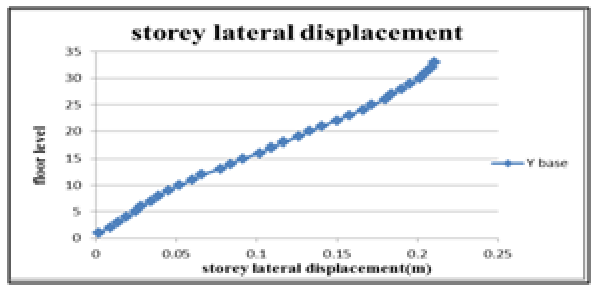

Figure 12: Story Drift Replacement of Shear Wall with Bracing

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