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SEISMIC ANALYSIS OF MULTI-STOREYED BUILDINGS STIFFENED WITH BRACES

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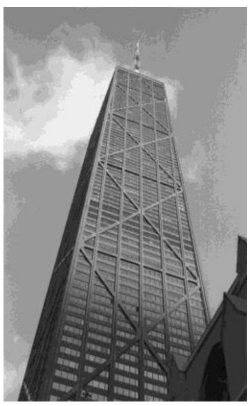
Abstract: *Many existing reinforced concrete frame buildings located in seismic zones are deficient to withstand moderate to severe earthquakes. Insufficient lateral resistance along with poor detailing of reinforcement is the main reasons for inadequate seismic performance of the buildings. Such buildings with no ductile detailing represents considerable hazard during earthquake. As a result, they suffer severe damage and are responsible for most of the loss of life even for small magnitude of earthquake. In recent years, a significant amount of research has been devoted to the study of various strengthening techniques i.e. to increase the lateral stiffness and resistance to enhance the seismic performance of reinforced concrete multi-storied buildings, however, the attempt by using various arrangements of bracing system in multi-storied building has not been made.*

It is therefore important to develop an effective and economical seismic resistance system so that the buildings can withstand to moderate or severe earthquake. In the present research study, an attempt has been made to increase the stiffness of the multi-storied or tall buildings by using bracing system. As a result of this, lateral maximum deflection can be controlled. To achieve these objectives, an analytical study has been carried out by studying G+10 storey reinforced concrete building by using versatile and practical analytical tool such as STAAD.pro 2007. A number of different models incorporating various positions of bracings have been developed. Of the different methodologies, Equivalent Static Method & Response Spectrum Method of seismic analysis has been adopted with view to understand the accurate dynamic parameters. The study reveals that, storey drift, as well as element displacements is reduced considerably and are well within permissible limits.

I. INTRODUCTION

Majority of today's structures built all over the world for dwelling purposes are of high-rise in nature. The rapid growth in population and migration of people from villages to cities has resulted into acute space problem in urban areas for housing purposes. In addition to that, rapid industrialization,explosion in popu-lation, escalation of cost, scarcity of land and raw materials, which are peculiar to our Indian condition, lead the designers to adopt multi-storeyed structures in a most economical way.

Multi-storied buildings are commonly constructed in metro cities and other areas for commercial and residential purposes. Many urban areas in the world have already reached the limits of hori-zontal growth and as a result, the only alternative left is vertical development. To cope with this situation, maxi-mum utilization of space vertically calls for cons-truction of multistoried buildings. Figure shows multi-storied building with exterior bracing.



Theme of Investigation:

Braces are one of the most effi-cient lateral force resis-ting elements in high rise building. It is increa-singly used by designers in new structure as well as rehabilitation of existing ones. Pure frame for high-rise buildings have almost disappeared, since they are technically less efficient and not economically viable. Braces are incorporated in conjunction with reinforced concrete moment resisting frame to resist the major portion of lateral load induced by an earthquake.

In tall structure, the vertical load, i.e. dead and live load do not pose many problems in the analysis or design, as they are mostly deterministic. But the lateral loads due to wind or earthquake, are a matter of concern. These require special consideration in the design of tall buildings. These lateral forces can produce critical stresses in the structure, induce undesirable vibrations or cause excessive lateral sway of the structure. Advancements in the design of multi-storeyed frame have emphasized the importance of limiting the side sway under the action of lateral loads. Braced frame building has less lateral sway when compared to buildings with traditional rigid frames. The presence of bracings in the frame alters the overall behavior especially when the structure is subjected to lateral loads.

Advantages:

In summary the bracing system has the following advantages:

1. It provides a very stiff struc-tural system that satisfies the serviceability requirements without imposing undue penalty on the weight of structural components.
2. The use of bracing system becomes imperative in high-rise structures if the inter storey deflections, caused by lateral loading, are to be controlled.
3. Eccentric beam elements, although yielding in shear, act as fuses to dissipate excess energy during a severe earth-quake.
4. The large lateral forces due to wind or earthquake are effectively resisted by bracings by increasing the overall stiffness of the structure.

Objectives of Present Study:

The aim of present research work is to study performance of G+10 reinforced concrete building with different arrangements of bracing system under dynamic load. In addition, the seismic properties i.e. base shear, storey drift using equivalent static method of analysis needs to be investigated. Analysis has been done by STAAD.pro-2007.

Effect of Bracing in Multi-storeyed Buildings:

The critical issue in the application of the advanced braced frames analysis, to earthquake application and the results obtained, there by. A braced frame attempts to improve upon the efficiency of rigid frame action by virtually eliminating the column and girder-bending factor. This is achieved by adding truss members such as diagonal between the floor systems. It is described that any rational configuration of the bracing can be used for bracing system. Also in an Eccentric Bracing system the connection of the diagonal brace is deliberately offset from the connection between the beam and vertical column. This system although originally conceived for satisfying ductility requirements in Seismic zones, can conveniently be employed in non-Seismic appli-cations. By keeping the beam to brace connec-tions close to the columns, the stiffness of the system can be made very close to that of concentric bracing.

Loads Acting on Buildings:

Loads acting on buildings are mainly of gravity loads and lateral loads.

1)Gravity Loads:

Gravity loads include self-weight of building, floor finish and part of live load that always stable on the structure in its working period.

2)Lateral loads:

In contrast to the vertical load, the lateral load effects on buildings are quite variable and increases rapidly with increase in height. Most lateral loads are live loads whose main component is horizontal force acting on the structure. Typical lateral loads would be a wind load, an Earthquake load, and an earth pressure against a beachfront retai-ning wall.Most lateral loads vary in intensity depending on the buildings, geographic location, structural mate-rial, height and shape.

3)Wind Load:

The most common lateral load is a Wind load. Wind against a building builds up a positive pressure on the windward side and negative pressure on leeward side. Wind loads vary around the world. Meteoro-logical data collected by national weather services are one of the most reliable sources of wind data. Factors that effect wind load include the geographical location, elevation, degree of exposure, relationship to nearby structures, building height and size, direction and velocity of prevailing winds. All these factors are taken into account when the lateral load is calculated.

The wind load is an external force, the magnitude of which depends upon the height of building, velocity of wind and the amount of surface area that the wind attacks.

4)Earthquake Load:

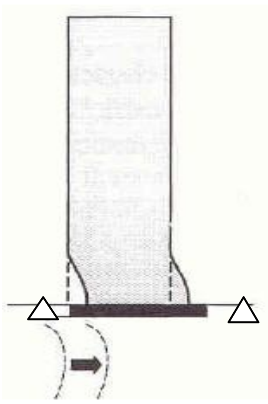
Earthquake loading is a result of the dynamic response of the structure to the shaking if the ground. Earthquake loads are another lateral live load. They are very complex, uncertain and potentially more damaging than wind loads. It is quite fortunate that they do not occur frequently. The Earthquake creates ground movements that can be categorized as a "shake", "rattle" and "roll". Every structure in an Earthquake zone must be able to withstand all three of these loadings of different intensities. Although the ground under a structure may shift in any direction, only the horizontal components of this movement are usually considered critical in analysis.

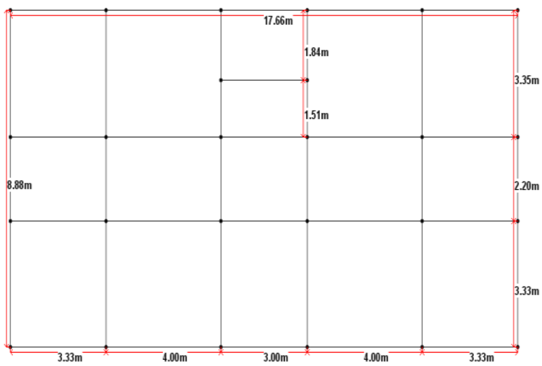
The magni-tude of horizontal inertia forces induced by earth-quakes depends upon the mass of struc-ture, stiffness of the structural system and ground acceleration.

The structural system of a building consists of two components, one is horizontal framing system (beam and slab) and other is vertical framing system (walls and columns). Horizontal framing system is primarily responsible for transfer of vertical loads and tensional forces to vertical framing systems that is responsible for transferring the vertical loads and lateral forces to the footing.

The figure below shows the effect of the distortions of the ground upon a building.The foundations of the building move with the ground displacements. However, the inertia of the mass of the building resists this displacement and causes it to distort. This distortion wave moves upward along the entire height of the building. As the shaking of the ground continues, the same shaking of the foundations lead the building to undergo a complex series of oscillations.

Lateral forces due to wind or seismic loading must be considered for tall buildings along with gravity forces. Very often the design of tall buildings is governed by lateral load resistance requirement in conjunction with gravity load. High wind pressures on the sides of tall buildings produce base shear and overturning moments. These forces cause horizontal deflection in a multi-storey building. This horizontal deflection at the top of a building is called drift. The drift is measured by drift index, /h, where, is the horizontal deflection at top of the building and h is the height of the building. Lateral drift of a typical moment resisting frame is shown in Figure.



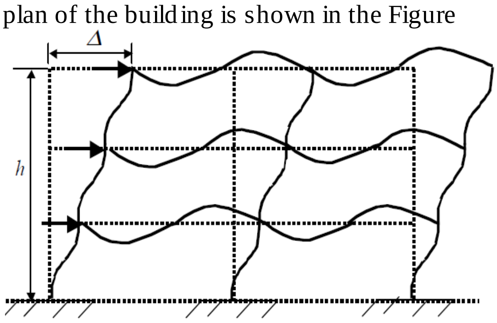


Methods of Seismic Analysis:

At present there are three accepted methods of analysis to find out magnitude and the distribution of the earthquake induced forces. These methods of analysis enable the designer to understand the response to earthquake on multi-storied building. The methods are:

1. Equivalent Static Method of Analysis.
2. Response Spectrum Method.

Types of Models: The analytical study is carried out on reinforced concrete moment resisting frame building having G+10 storeys situated in zone III. The plan of the building is shown in the Figure



Modeling of the Building: To study the behavior of multi-storeyed reinforced concrete building under the influence of lateral load, particularly seismic load a number of models have been analysed by using STAAD.pro 2007. Different Models are considered for analysis.Model 1 represents the building without bracing system, model 2 shows the building frame braced at top,model 3 represents the building frame braced at the middle,model 4 is the building frame braced at the bottom,model 5 is the building frame braced at corners(ext),and model 6 is the buil-ding frame braced at alternate spans.

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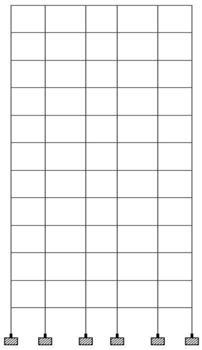
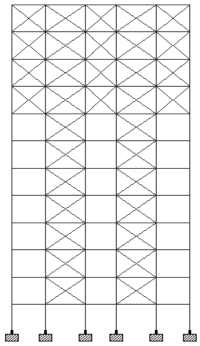
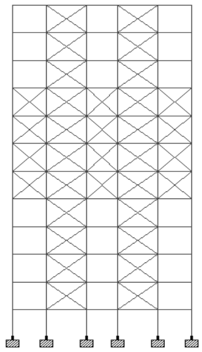


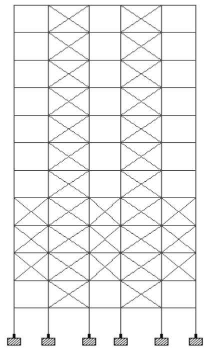
Model 1



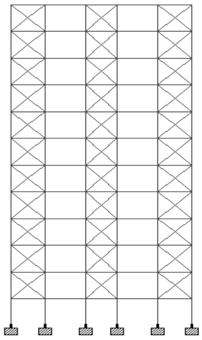
Model 2



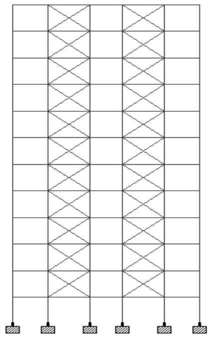
Model 3



Model 4



(Model 5)



(Model 6)

Analysis Data for All Models:

The data used for the analytical study comprising all the models is shown in above Table.

Analysis Data for All Models

Title	Values
Plan Dimensions	17.66 X 8.88m
Total Ht. of Build.	35.2m
Ht. of each storey	3.2m
Ht. of Parapet	1.00m
Depth of Foundation	3m
Size of Beams	230mmX350mm
Size of Columns	300mmX600mm
Size of Bracing	230mmX230mm
Thickness of Slab	125mm
Thick of Ext. Walls	230mm
Seismic Zone	III
Soil Condition	Medium soil
Response R. Factor	3
Importance Factor	1.5
Floor Finishes	1 kN/m^2
Liv Load Roof	1.5 kN/m^2
Live Load Floors	3.0 kN/m^2
Grade of Concrete	M20
Grade of Steel	Fe415
Density of Concrete	25 kN/m^3

Density of Brick	20 kN/m^3

Load Combination:

As per IS 1893(Part 1)2002 clause no.6.3.1.2 the following load cases have to be consider for analysis.

1.5(DL+LL)
1.2(DL+LL+-EL)
1.5(DL+-EL)
0.9DL+-1.5EL

Earthquake load must be considered for +X,-X,+Z,and –Z directions.

For above load combinations, analysis is performed and result of displacement,drift,base,shear,shear force,and bending moments are obtained.

RESULTS & COMPARISON

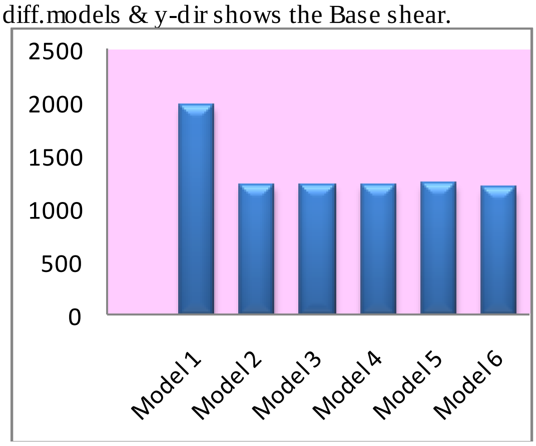
Storey Shears:

The distribution of base shears along the height of the building in case of equivalent static method and Response Spectrum method for different models are given in the Tables. In the Response Spectrum method the design base shear (V_B) is made equal to the base shear obtained from equivalent static method $\bar{V}_B$ as per IS: 1893-2002 (Part 1) by applying the scaling factors calculated as shown in Table.

Design Seismic Base Shear in Longitudinal Direction:

Model	Method of Analysis		Scale Factor
	Equi. Static Method ($\bar{V}_B$) kN	Response Spectrum Method (V_B) kN	
Model 1	1973.65	264.68	7.456
Model 2	1223.55	121.70	10.053
Model 3	1229.49	120.81	10.177
Model 4	1226.69	122.89	9.982
Model 5	1234.02	120.94	10.203
Model 6	1194.37	142.21	8.403

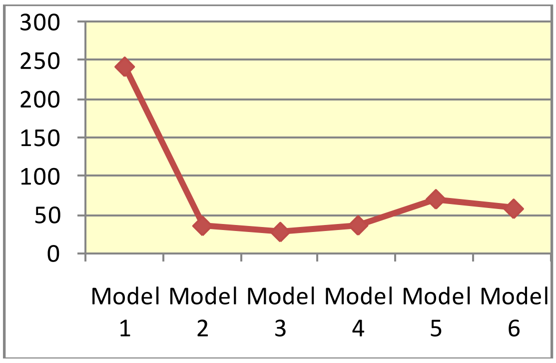
In following graph x-dir shows the diff.models & y-dir shows the Base shear.

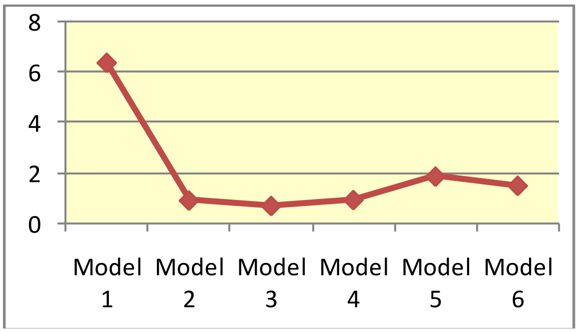


Comparison of Displacement & Drift at Top level:

(a)Equivalent Static Method:

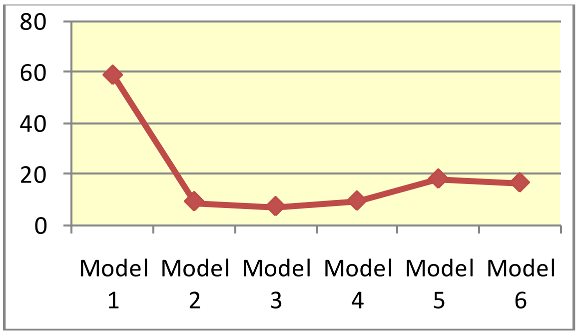
- Displacement & Drift at top level

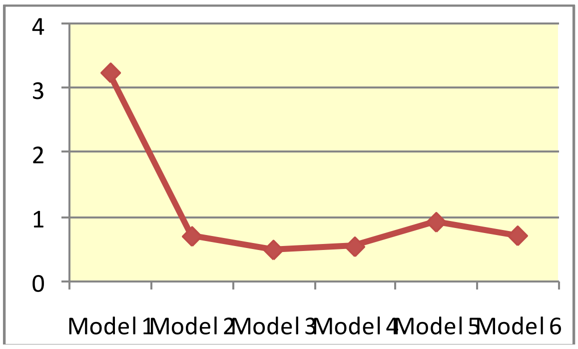




(b)Response Spectrum Method

- Displacement & Drift at top level





Member end Forces:

Shear Force at different levels

Model	SF at Top (kN)	SF at Mid (kN)	SF at Bottom (kN)
Model 1	65.30	212.80	273.75
Model 2	36.10	90.90	98.00
Model 3	37.00	90.50	96.95
Model 4	36.00	92.30	99.13
Model 5	60.30	98.70	101.90
Model 6	37.00	127.10	134.0

Bending Moments at different levels:

Models	BM at Top (kNm)	BM at Mid (kNm)	BM at Bottom (kNm)
Model 1	89.73	224.50	241.20
Model 2	25.70	71.65	69.20
Model 3	26.70	31.30	61.50
Model 4	29.50	67.31	53.30
Model 5	58.14	31.20	72.20
Model 6	32.26	101.84	73.00

Comparisons of models for response quantities with Bracings:

Following table shows percentage reduction in response quantities:

Models	M(2) Bracing at Top	M (3) Bracing at Middle	M (4) Bracing at Bottom	M (5) Bracing at Corners	M (6) Bracing at Alt.Span
Base Shear	37%	38%	36%	39%	40%
Displac-ment	85%	89%	86%	71%	76%

Drift	86%	88%	85%	70%	75%
Shear Force	44%	43%	45%	8%	43%
Bend.Moment	71%	70%	67%	35%	64%

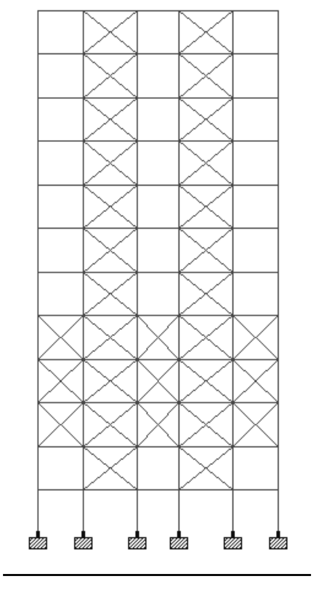
DISCUSSION

The above table shows the percentage reduction in response quantities for different models with bracing system. It is found that building with bracing system increases the stiffness of Building.

CONCLUSIONS

The performance of G+10 storey reinforced concrete building with bracing system have been investigated analytically for six types of bracing systems models to increase lateral stiffness and resistance. Based on the results of analysis, following conclusions are arrived at:

1. A significant amount of decrease in the storey displacement & drift has been observed in model 2, model 3, model 4,model 5 and model 6 in comparison to model 1.This implies that the stiffness of bracings increases the lateral stiffness of the buildings studied.
2. A significant amount of increase in the lateral stiffness has been observed in the model 2 in comparison with model 1, model 3, model 4,model 5 & model 6.
3. The bare frame idealization leads to severe overestimation of the lateral displacements compared to the braced frame.
4. The braced frame structure i.e. model 2, model 3 and model 4 is more efficient to resist lateral load in comparison with bare frame structure i.e. model 1.This is primarily because of increase in the lateral stiffness.
5. Shear force for beams at intermediate height of braced frame building are reduced for model 2, model 3, model 4, model 5,and model 6 as compared to the bare frame structure model 1.
6. Bending moments of beams at intermediate height of braced frame are reduced for model 2, model 3, model 4,model 5,and model 6 as compared to the bare frame structure i.e. model 1.
7. Due to significant amount of increase in the lateral stiffness of building by using bracing, the bracing system takes near about all the lateral forces acting on building.



Model 4 (Bracing at Bottom)

Base Shear	1226.69 kN
Storey Displacement	35.11 mm
Storey Drift	0.92 mm
Shear Force at Top	36.0 kN
Shear Force at middle	92.30 kN
Shear Force at Bottom	99.13 kN
Bending Moments at Top	29.25 kNm
Bending Moments at Middle	67.31 kNm
Bending Moments at Bottom	53.30 kNm

The frame braced at the bottom i.e. MODEL 4 is found to be most effective in resisting lateral loads.

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