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Comparative Study on Seismic Responses of Multistorey Building Frame Using Linear and Nonlinear Analysis

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Abstract: The effect of infill walls on the building is generally neglected in the analysis. In fact, an infill wall contributes to the lateral strength and stiffness of the structure. Seismic response analysis of multi storey building frame with infill was done by modeling the infill wall as an equivalent diagonal strut. For the equivalent diagonal strut, the thickness is taken equal to the thickness of the wall and width of the strut as per "Equivalent strut method". The comparison of seismic responses is done for the multi-storied buildings with infill as equivalent diagonal strut using linear and non-linear analysis. ETABS software is used for the present study.

Keywords: Linear Analysis, Non-linear Analysis, Equivalent Diagonal Strut, Seismic Responses.

1. INTRODUCTION

The Linear analysis in which structure which returns into original form after the removal of loads and there will be small changes in shape stiffness and no change in loading direction or magnitude. In the linear elastic analysis, the material is assumed to be unyielding and its properties invariable and the equations of equilibrium are formulated on the geometry of the unloaded structure. In this approach, the primary unknowns are the joint displacements, which are determined first by solving the structure equation of equilibrium.

Then the unknown forces can be obtained through compatibility consideration. In the nonlinear analysis, the structure will not regain its original shape after the removal of the load. Its geometry will change resulting in stiffness change. If a structure experiences large deformations, its changing geometric configuration can cause the structure to respond nonlinearly. Geometric nonlinearity is characterized by large displacements or rotations. It arises due to the lateral loading also. This stretching leads to a nonlinear relationship between the strain and the displacement

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2. LITERATURE REVIEW

Many authors in the past two decades have done research on infill effect on seismic parameters.

Wakchaure M.R, Ped S.P [1] studied the effect of masonry walls on high rise building is studied. Linear dynamic analysis on high rise building with the different arrangement is carried out. For, the analysis G+9 R.C.C framed building is modelled. Earthquake time history is performed. The results show that infill wall reduces displacements, time period and increases base shear. So, it is essential to consider in the analysis.

Prof. P. B. Kulkarni, Nikhil .S. Agarwal [2] made an attempt to access the performance of masonry infilled reinforced concrete frames with the soft storey of with and without opening. In this paper, the symmetrical frame of college building located in seismic zone ш is considered and linear static analysis is to be carried out on the models such as strut frame with 15%, 20%, and 25% center and corner opening using STADD. Pro software. Results show that infill increases the stiffness of structure, while the increase in opening percentage leads to a decrease in the lateral stiffness of the infilled frame.

Hemant B. Kaushik, Durgesh C. Rai, Sudhir K. Jain[3] carried out a comparative study considering different analytical models for masonry infills which include single strut model, 3- strut model, finite element models. By linear and nonlinear analysis it was observed that 3- strut model gives sufficient accuracy. It was also observed that the single strut model can be effectively used in cases where masonry infill walls are discontinued in the first storey to generate parking space.

Md. Ferdous wahid, Md. Nazml Islam [4] considered the performance of bare frame and infilled frame building to seismic load and determined in terms of displacements, drift and base shear. The analysis shows that the performance of an infilled frame is much better than a bare frame structure.

Konuralp Girgin and Kutler Davi Lamorz [5] conducted a parametric study of certain infilled frames, using the strut model to capture the global effects of infills was carried out. Pushover analysis was adopted and each frame is subjected to 4 different loading cases. The effect of infill walls on seismic behavior of two sample frames with different infill arrangements was investigated. The resulting yield is that it is essential to consider the effect of masonry infills since they have a significant effect on the reduction of global lateral displacement.

Sayed Mahmoud [6] investigated the change in dynamic characteristics of reinforced concrete moment resisting frame building with and without fully infilled walls. Different models are developed to perform the analysis. The equivalent diagonal strut method has been utilized in order to account for stiffness and structural action of the infills. Dynamic time histories using two ground motion records from near and far fault regions has been used to perform the seismic analysis. The structural software package ETABS has been used in developing the building models and performing the simulation analysis. Based on the results obtained, it is found that the dynamic storey responses for bare frame model significantly differ from the responses obtained for both full infill and partially frame model.

A. Mallika carried out the work in finding the effect of storey height on the structural responses of tall braced buildings. Response spectrum analysis is performed to investigate the structural responses like lateral displacements, storey shears, storey drifts and Overturning moments. The bracing patterns studied in the present paper are diagonal, X, V, and inverted V-bracings. 10-storeyed building with 3.0 m, 3.6 m, and 4.2 m storey heights is considered in zone V for the present study. In the present paper, ETABS software is used for investigating the structural responses of Tall Buildings.

3. AIM AND OBJECTIVES OF STUDY

1. To study the seismic response of multistoried building frame with infills by equivalent linear static analysis.
2. To study the seismic responses of the multi-storey building frame with infill by Non-linear static analysis.
3. Comparative study of responses from the linear and nonlinear analysis.

4. METHODOLOGY

The following methodology was adopted for the present study:

1. Modeling of multi-storied building frame is carried out using ETABS.
   Geometry: Plan area and storey height are considered.
   Material: Beam, Column are defined as concrete and infill as masonry.
   Loads: Assigning of live loads as per IS: 875: (part 2): 1987 [11] and earthquake loads as per
   IS 1893: 2002. [10]
2. Infills are modeled as diagonal strut using equivalent strut method.
3. Linear static analysis and Non-linear static analysis is performed.
4. Comparison and tabulation of results.

5. NUMERICAL STUDY

In this present study a multistoried building frame consisting G+4, G+6, G+9, G+12, G+20 located in seismic zone-v is considered. The Moment resisting frame is modeled in ETABS with infill's as equivalent diagonal strut.
The geometric parameters of the model considered are as below:
Plan area: 12m x 12m
Bay width: 4m
No. of floors: G+4, G+6, G+9, G+12, G+20
Floor height: 3.5m
Grade of concrete: M30
Grade of steel: HYSD 415
Seismic zone: V
Frame type: SMRF
Beam size: 300mmx500mm
Column size: 470mmx470mm
Exterior wall thickness: 230mm
Interior wall thickness: 115mm
Slab: 200mm
Live load: 3kN/m²
Earthquake load in both direction: IS 1893: 2002 (part 2).

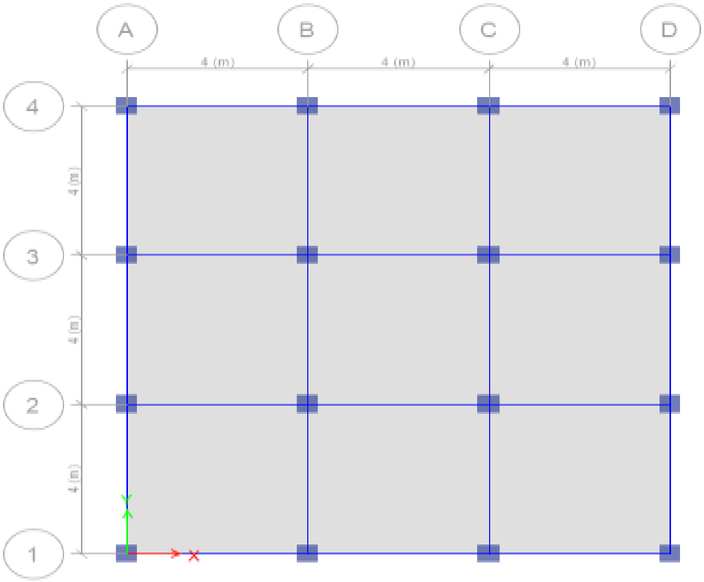

Figure 1: Plan view of Model

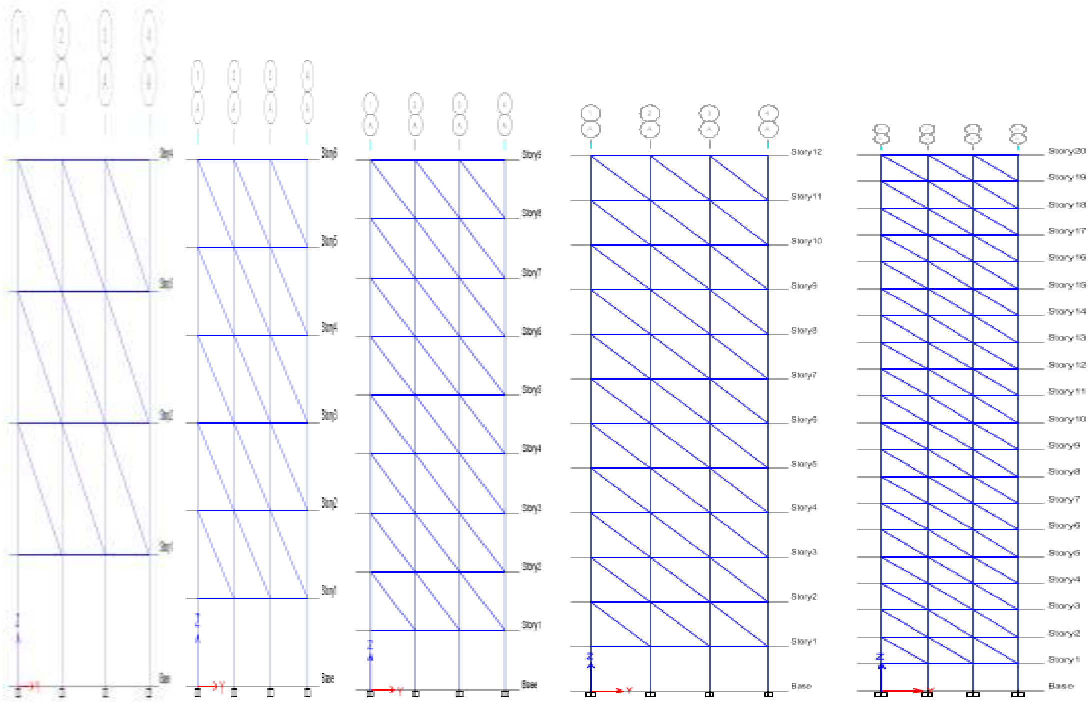

Figure 2: Elevation view of the models considered

5. ANALYSIS

Equivalent linear static and Nonlinear static analysis are performed for the multistoried building frame with infills. Indian standard code suggests IS 1893:2002 part-1: General provisions and building code book [10] for the relevant data to be considered for the analysis.

Base shear was calculated using the formula: $V_B = A_h W$

Where W= Seismic weight of building

A_h= Design horizontal seismic coefficient = (Z/2) x (I/R) x (S_a/g)

=0.135(G+4); 0.135(G+6); 0.08978(G+9); 0.067(G+12); 0.0404(G+20)

Z= Zone factor = zone-v = 0.36 (Table-2)

I = Importance factor = 1.5 (Table 6)

R = Response reduction factor = 5 (Table 7)

S_a/g = Response acceleration coefficient (clause.6.4.5)

T = ($0.09h/\sqrt{d}$) = 0.363(G+4); 0.545(G+6); 0.818(G+9); 1.091(G+12); 1.819(G+20)

5.1 Equivalent diagonal strut:

W= width of strut = $0.5x(\sqrt{\alpha_h^2+\alpha_l^2})$

W (230mm wall) = 1.391m;W(115mm wall)= 1.654m

α_h=(π/2)x$(4E_fI_ch^1/E_mtsin2\theta)^{1/4}$, α_l=πx$(4E_fI_bL^1/E_mtsin2\theta)^{1/4}$

E_f = Young's modulus of frame material= 5000√fck = 27386.128 Mpa

E_m= young's modulus of masonry = 13800Mpa

I_c = moment of inertia of column

I_b = moment of inertia of beam

t = thickness of the exterior wall = 230mm

t = thickness of the interior wall = 115mm

h^1 = height of the storey= distance between c/c of beam =3m

L^1 = bay width = c/c distance between columns= 3.53m

Ɵ = 1/ tan (h^1/L^1) = 40̊ 21'35.37"

6. RESULTS AND DISCUSSIONS

Multi storey building frame with infill's, modeled as equivalent diagonal strut is analyzed for buildings with same storey height and different no. of stories like G+4, G+6, G+9, G+12, G+20, and results are tabulated and discussed. Responses of the structure such as Time period, Base shear, Lateral Displacements are compared for both linear and non-linear analysis.

6.1 TIME PERIOD

The variation of the time period for the first five modes is considered for different building heights using linear and nonlinear analysis and the results are tabulated below in table 1 and are discussed.

Table 1: Time period (sec) for different stories

No. of Stories	Analysis	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
G+4	Linear	0.3	0.297	0.263	0.07	0.068
	Nonlinear	0.3	0.297	0.263	0.07	0.068
	%decrease	0	0	0	0	0
G+6	Linear	0.403	0.399	0.342	0.114	0.112
	Nonlinear	0.403	0.399	0.342	0.114	0.112
	%decrease	0	0	0	0	0
G+9	Linear	0.564	0.558	0.449	0.183	0.181
	Nonlinear	0.561	0.549	0.427	0.181	0.179
	%decrease	0.532	1.613	4.899	1.093	1.015
G+12	Linear	0.797	0.792	0.551	0.267	0.264
	Nonlinear	0.792	0.788	0.547	0.265	0.261
	%decrease	0.627	0.505	0.726	0.749	1.136
G+20	Linear	1.561	1.544	0.566	0.41	0.4
	Nonlinear	1.53	1.512	0.535	0.388	0.367
	%decrease	2.03	2.12	5.79	5.67	8.99

We know that as the height of the building increases time period increases since time period is directly proportional to the height of the building and from the above table it can be observed that there is no percentage variation in the time period for building heights up to 21m on performing both linear and nonlinear analysis. As building height increases from 21m to 70m, the time period decreases from linear to non-linear analysis and change in percentage variation is 0.564% to 2.03%.

6.2 BASE SHEAR

It is the total design lateral force at the base of the structure. The values of base shear and percentage variation is considered for G+4, G+6, G+9, G+12, G+ 20 stories's using linear and nonlinear analysis and the results are tabulated below in table 2 and are discussed.

Table 2: Base shear for different stories

No. of Storeys	Base shear(kN) in linear analysis	Base shear(kN) in non-linear analysis	% variation
G+4	897.253	897.253	0
G+6	1388.144	1388.144	0
G+9	1419.548	1419.548	0
G+12	1426.474	1426.490	0.001
G+20	1441.952	1442.804	0.06

From the above table, we can observe that percentage variation for base shear doesn't show any change up to building height of 31.5m using linear and nonlinear analysis. But with an increase in building height to 42m the variation is found to be 0.001% and on further increase in height of building to 70m, the variation is found to be 0.06%.

6.3 LATERAL DISPLACEMENT

The displacements at different storey levels have been tabulated in table 3 and the percentage variation is presented.

Table 3: Maximum Lateral Displacements (mm) at different storey heights

Storey number	Linear analysis	Nonlinear analysis	% variation
G+4	3.7	3.7	0
G+6	7.7	7.7	0
G+9	12.3	12.4	0.81
G+12	21.6	21.9	1.38
G+20	62	70.2	13.2

It is observed that there is no variation in lateral displacement up to a 21m height of building for linear and non-linear analysis but with an increase in height of building the maximum lateral displacement increases from linear to nonlinear analysis with a variation of 0.81% for 31.5m, 1.38% for 42m and 13.2% for 70m.

CONCLUSIONS

- It is observed from the results that the base shear, lateral displacements, time period don't show any changes on performing linear and nonlinear analysis for low height buildings.
- However, in the present study, it is observed that for the given plan dimensions, the seismic responses such as base shear shows a small variation for a building height of 42m and increases further.
- For the given plan dimensions increasing trend in displacements is observed in nonlinear analysis compared with linear analysis. For building height of 21m both the analysis resulted in the same values, however, the lateral displacements values increased by 0.81% for 31.5m and 1.38% for 42m and 13.2% for 70m.
- The time period is found to increase with the height of the building. There is no significant change in time period initially up to a height of 21m in both the analysis methods. But it is observed that from 31.5m height time periods showed decreasing trend compared to linear analysis.

FUTURE SCOPE OF STUDY

- Further study can be done by maintaining the same height of the building with varying storey heights.
- Analysis can be performed for irregular building and effect can be observed.
- Time history analysis can also be performed for the multi storey building frame with infills.
- The nonlinear dynamic analysis may be carried out to know the realistic behavior for both regular and irregular buildings.

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