Comparative Study of an Educational Building by Linear Static Analysis and Response Spectrum Analysis

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Abstract – *The increase in population and the scarcity of are in the expanding cities leads to the development of vertical buildings. The vertical construction helps in accommodate a huge amount of personnel in limited space. Natural hazards like earthquake, affects the stability of such structures. This requires advanced construction techniques as well as better design and analysis. Seismic analysis of such buildings should be done accurately and economically. This comparative study aims to find a median between static and dynamic analysis of a 3 storeyed building located in zone 3 in India. The main objective is to analyze and design such hazard resisting structures so, to save human life and avoid property damage and to choose an economical method of analysis.*

Key Words: **AUTOCAD, ETABS, Gravity Loads, Shear Force, Axial Force, Bending Moment, Displacement, Earthquake**

1. INTRODUCTION

Structural analysis is basically used to determine the behaviour of a structure when subjected to loads. The load may be dynamic or static. Load due to the weight of things such as people, furniture, etc. are termed as static loads. Loads due to dynamic loads as wind, explosions and an earthquake should also be considered. The seismic response of the building depends on the type of analysis method adopted where the loads act linearly or in a non-linear manner.

The analysis methods were confined to static approach due to its simplicity and the lacking in advanced technology.

Static analysis is based on replacing concept of the inertia forces at various considerable masses i.e. stories by equal horizontal forces that are corresponding to the weight of the structure and its acceleration. The loads act linearly and this is represented in the elastic region of a stress- strain graph.

The development of technology helped in the advancement of analysis programs that enables the researchers to move forward towards a more rational approach by simulating the actual effect of earthquakes on the building models. This helps to obtain the realistic seismic response and this method is categorized under dynamic analysis. Dynamic analysis describes and expects the structural movement cases under the influence of dynamic loads.

2. OBJECTIVES

- To draw the plan of school building using AutoCAD 2021 and the sections and lay out of its frames and slabs
- To calculate and apply the gravity loads and different load combinations as per Indian Codal provisions
- To analyse the building using linear static and response spectrum analysis using ETABS
- To determine the storey- displacements for a 3 storeyed school building.
- To make comparative study of the results of parameters such as bending moment, shear force, axial force and displacement, obtained from static and dynamic analysis.

3. METHODOLOGY

1. Preparation of plan in AutoCAD 2021
2. Exporting to ETABS
3. Assigning loads and load combinations
4. Linear Static Analysis has been used for static analysis
5. Response spectrum method has been used for dynamic analysis
6. Comparison of the result

3.1 Plan in AUTOCAD

A three storeyed educational building is drawn in AutoCAD keeping in mind the Indian standards.

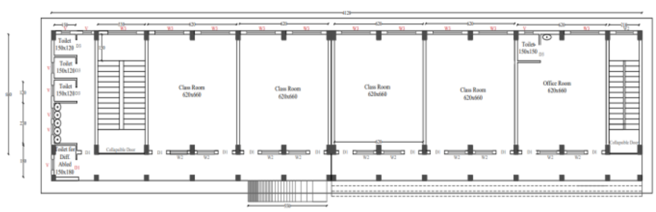

Fig. 1 Ground Floor

3.2 Design of Frames and Slabs

Fig. 2 Slab and Beam Center Line Drawings

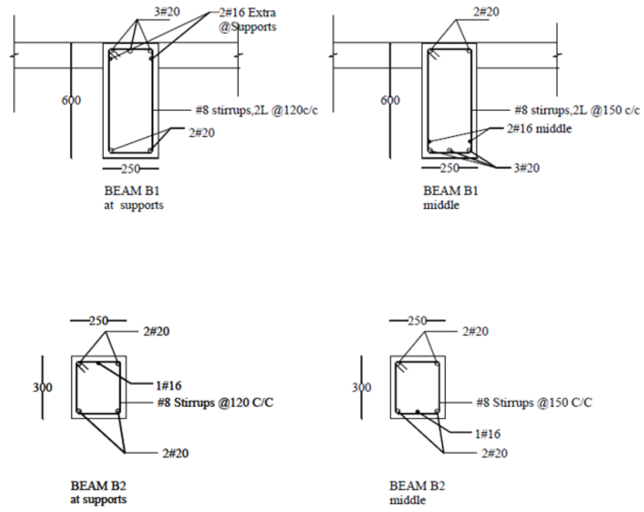

Fig. 3 Section of Beams

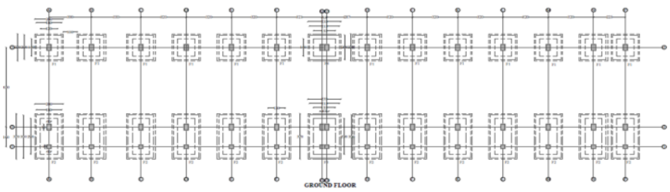

Fig. 4 Footing Center Line

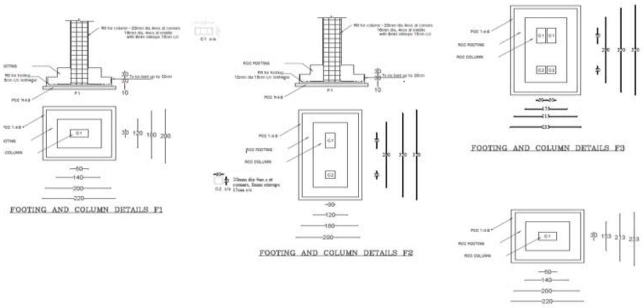

Fig. 5 Section of Footing

3.3 Exporting to ETABS

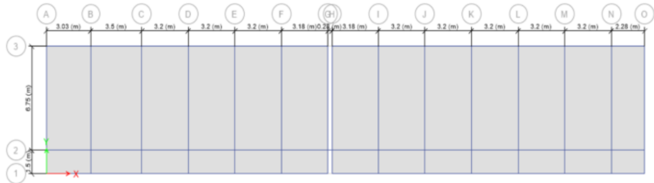

Fig. 6 Plan

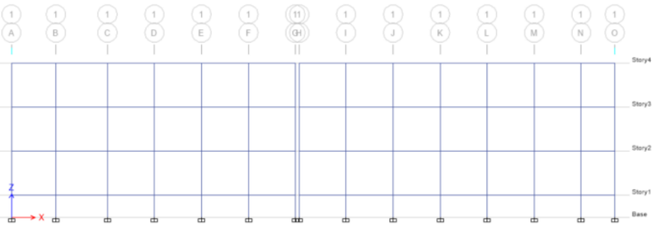

Fig. 7 Elevation

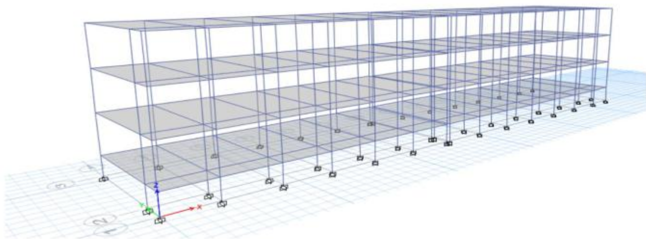

Fig. 8 3D View

3.4 Load Calculation for Frames

(Dead Load=Unit weight of concrete X Unit volume of the material)

Table 1 Plinth Beam

Plinth Beam	**Dead Load**
PB1	25×0.3×0.6=4.5 kN/m
PB2	25×0.3×0.5=3.75 kN /m
PB3	25×0.3×0.5=3 kN /m
PB4	25×0.3×0.3=2.25kN/m

Table 2 Wall

Beam	**Dead Load**
B1	25×0.25×0.6=3.75kN/m
B2	25×0.25×0.3=1.875kN/m

Table 3 Beam

Wall	**Dead Load**
W1	25×0.3=7.5kN/m
W2	25×0.3=7.5kN/m

Table 4 Slab

Floor Finish	1 kN/m2

Slab	**Live Load (IS 875 Part 2: 2002)**	**Dead Load**
S1	3 KN/m	25×0.12×1=3kN/m^2
S2	3 KN/m	25×0.12×1=3kN/m^2

3.8 Load Combinations

In the limit state design of reinforced and prestressed concrete structures, the following load combinations shall be accounted for:

1) DL+LL
2) 1.5(DL+LL)
3) 1.2(DL+LL+EQ x)
4) 1.2(DL+LL-EQ x)
5) 1.2(DL+LL+EQ y)
6) 1.2(DL+LL-EQ y)
7) 1.5(DL+EQ x)
8) 1.5(DL-EQ x)
9) 1.5(DL+EQ y)
10) 1.5(DL-EQ y)
11) 0.9DL+1.5EQx
12) 0.9DL-1.5EQx
13) 0.9DL+1.5EQy
14) 0.9DL-1.5EQy
15) Envelope

3.9 Seismic Loading- IS 1893.1.2016

1) Direction and eccentricity
   - The eccentricity of a circle = 0
   - The eccentricity of an ellipse = between 0 and 1
   - The eccentricity of a parabola = 1
   - The eccentricity of a hyperbola > 1
   - The eccentricity of a line = infinity
   - X direction Eq x
   - Y direction Eq y
   - Eccentricity ratio=0.05
2) Storey Range
   - Storey1 – Storey4
3) Factors

   Response reduction factor is the factor by which the actual base shear force should be reduced, to obtain the design lateral force during design basic earthquake shaking. The response reduction factor (R) is basically depends on the strength, Ductility, Redundancy. So, there is a need to come up with realistic R factors for different structural systems that changes in different regions consequently.

   - Response reduction factor= 5
4) Seismic coefficients (IS 1893:2016 for Zone 4 Gujarat)

   The Seismic coefficients are dimensionless coefficients which represent the maximum earthquake acceleration. It is represented as a fraction of the acceleration due to gravity.

   - Seismic zone factor= 0.24
   - Soil site type =II

   In seismic design, occupancy importance factor (IF) is a multiplier to increase or decrease the design base shear, according to different occupancy categories or the importance class of a building.

   - Importance factor = 1.5
5) Time period
   - T=0.075 h0.75
   - T=0.4374749979

3.10 Linear Static Analysis

A linear static analysis is an analysis where a linear relation holds between applied forces and displacements. In practice, this is applicable to structural problems where stresses remain in the linear elastic range of the used material. In a linear static analysis, the model's stiffness matrix is constant, and the solving process is relatively short. Therefore, for a first estimate, the linear static analysis is often used prior to performing a full nonlinear analysis.

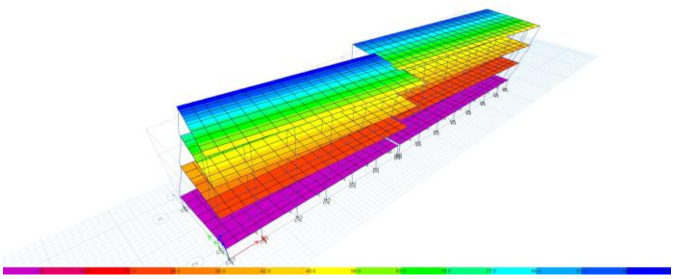

Fig. 9 Linear Static Analysis

The maximum displacement obtained is 102944.203mm and the minimum displacement obtained is -59002.072mm. The parameters that were taken into account for the comparison includes the bending moment, shear force and axial force values.

3.10.1 Bending Moment Diagram

The maximum bending moment obtained is 129.6246 kN m at storey 1.

Fig. 10 Bending Moment Diagram

3.10.2 Shear Force Diagram

The maximum axial force obtained is 98.3727kN at storey 1.

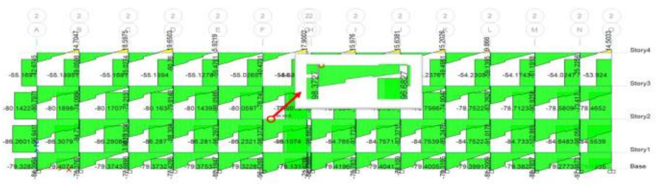

Fig. 11 Shear Force Diagram

3.10.3 Axial Force Diagram

The maximum axial force obtained is - 1461.6453kN.

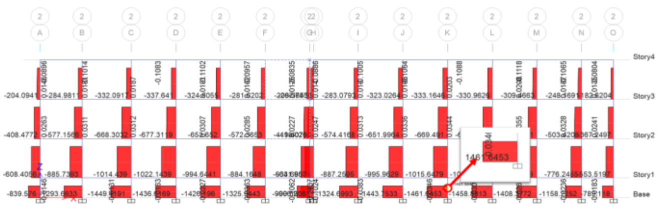

Fig. 12 Axial Force Diagram

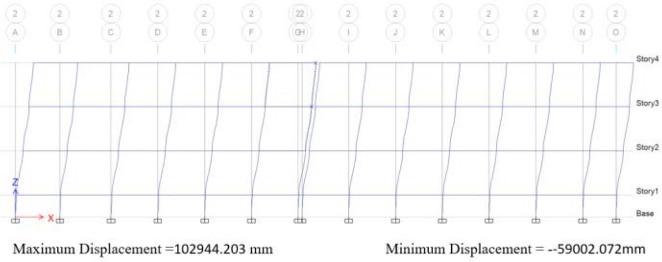

Fig. 13 Deformed Shape

3.11 Response Spectrum

The response spectrum analysis one of the most important methods of dynamic analysis. This analysis is also known as modal method or the mode superposition method. It is defined as the combination of plot of acceleration, velocity and displacement. They are asymmetrical or have areas of discontinuity irregularity, in their linear range of behavior and belong to the plastic region. From IS1893.1.2001 The design horizontal seismic coefficient Ah for a structure shall be determined by the following expression

Ah=ZISa/2Rg =0.0091

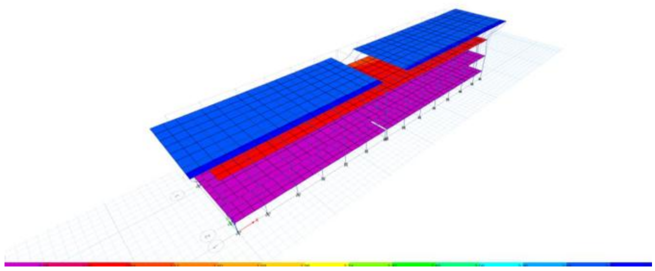

Fig. 14 Response Spectrum Analysis

The maximum displacement obtained is 3422.678mm and the minimum displacement obtained is -3432.84mm.

3.11.1 Bending Moment Diagram

The bending moment force obtained is 68.7349kNm at storey 4.

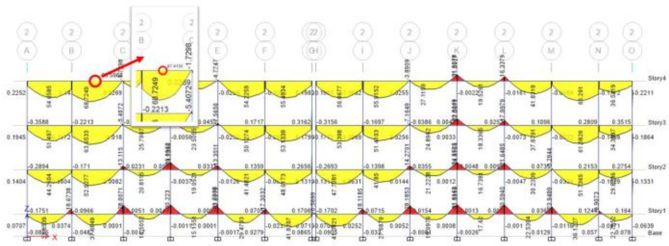

Fig. 15 Bending Moment Diagram

3.11.2 Shear Force Diagram

The bending moment force obtained is at 11.165kN at storey 3.

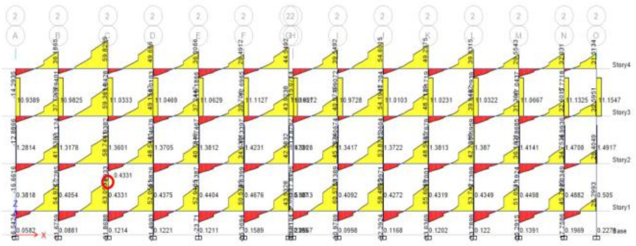

Fig. 16 Shear Force Diagram

3.11.3 Axial Force Diagram

The bending axial force obtained is -1451.0105kN.

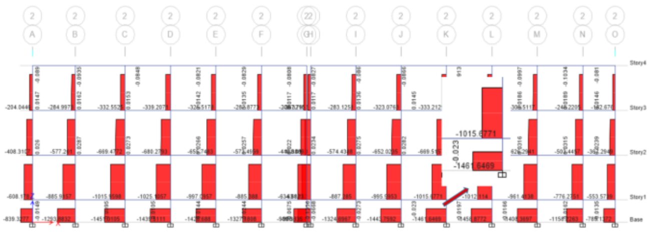

Fig. 17 Axial Force Diagram

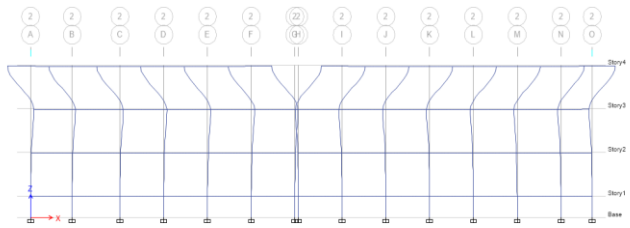

Fig. 18 Deformed Shape

4. RESULTS AND DISCUSSIONS

4.1 Linear Static Analysis

- Maximum displacement obtained = 102944 mm.
- The maximum bending moment obtained = 129.5Nm at storey 1.
- The maximum axial force obtained = - 1461.5 kN.
- The maximum shear force obtained = 98 kN at storey 1.

4.2 Response Spectrum Analysis

- Maximum displacement obtained = 3422.5 mm.
- The maximum bending moment obtained = 68.5 kNm at storey 4.
- The maximum axial force obtained is = -1451 kN.
- The maximum shear force obtained is = 68.5 kN at storey 3.

4.3 Comparison of Results

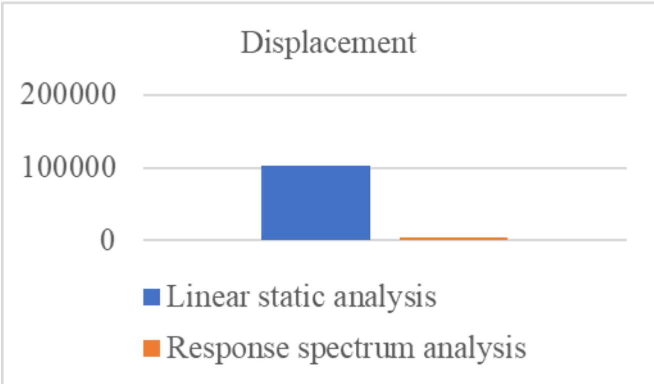

Fig. 19 Displacement Graph

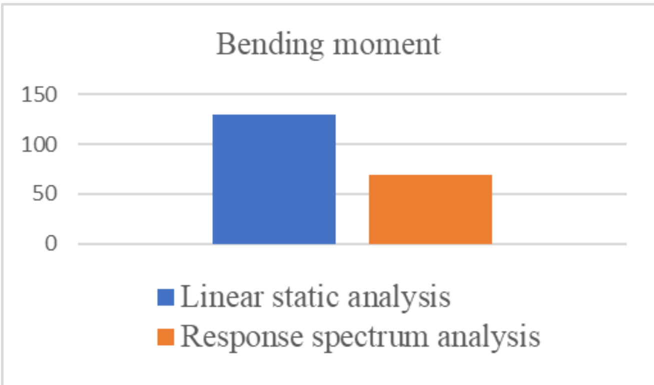

Fig. 20 Bending Moment Graph

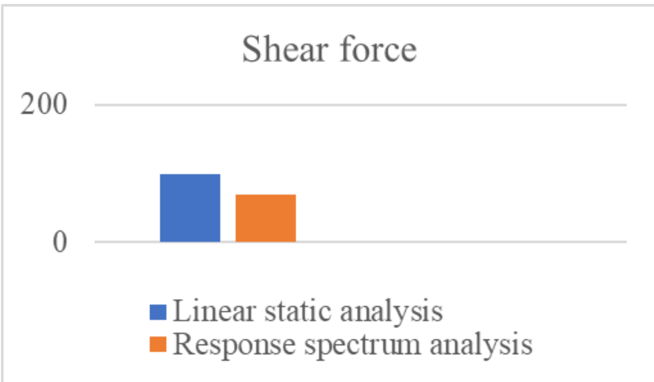

Fig. 21 Shear Force Graph

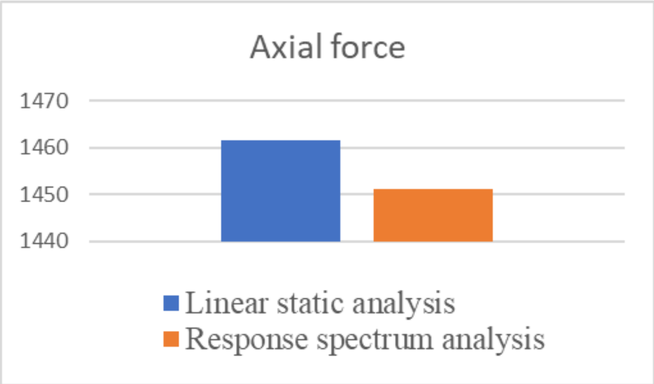

Fig. 22 Axial Force Graph

5. CONCLUSIONS

Results from Linear static analysis and Response spectrum analysis for a G+3 storied building in seismic zone 4 and soil type II. The bending moment is 88.5% more in linear static analysis than response spectrum analysis. The axial force is 0.73% more in linear static analysis than response spectrum analysis. The shear force is 43% more in linear static analysis than response spectrum analysis. The displacement value, bending moment value, axial force value and shear force values of linear static analysis are more than the values of response spectrum analysis. So, response spectrum analysis may be recommended.

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