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Seismic Analysis of Multi-Storied Regular Building by Response Spectrum and P-Delta Methods using Is 16700:2017

M.Jesse Leo Pragnan, Anirudh Maddi

Abstract: ***The turn of the century saw urbanisation like never before, which has led to the obvious problem of land scarcity and thus, land price spike, among others. To address this inadequacy of space, tall buildings have become commonplace. However, the safety of multi-storied buildings diminishes greatly in areas of moderate - high seismic intensity. The design of such buildings must facilitate the accommodation of loads applied laterally on them. Following the recently released IS code, "Criteria for Structural Safety of Tall Concrete Buildings 1S16700:2017" will ensure the safety of these high rise structures even in zones of high seismic intensity. This latest code lays emphasis on using P-Delta analysis for high-rise buildings, alongside the other conventional seismic analyses (like Equivalent Static Analysis, Linear Dynamic Analysis (Response Spectrum Analysis), Nonlinear Static Analysis (Pushover analysis) and Nonlinear Dynamic Analysis) that were used hitherto. In this study, modelling, analysis and design of a Tall RCC building was done employing IS code16700:2017. ETAB software was used to execute Equivalent static analysis, Response Spectrum analysis and P-Delta analysis in seismic zone-V and medium soil conditions. A variety of seismic parameters, for example, self-weight, displacement, time period, storey drift, base shear and storey shear, were evaluated and analyzed for Response Spectrum analysis and P-Delta analysis making use o the IS16700:2017 code. Although the storey shear was same in both the analyses, the storey drift was considerably more in P-Delta analysis in comparison to Response Spectrum analysis.***

Keywords: High-rise Building, Response spectrum analysis, P-Delta analysis, IS16700:2017.

I. INTRODUCTION

Urbanization's immediate impact was the enormous land scarcity that inevitably led to the construction of tall buildings, for both residential and business-related reasons, even more so in metropolises.

More than half of Indian terrain is at a risk of earthquakes (~58.6%). Improper survey and planning, prior to construction, leads to misfortune of gigantic proportions, as is apparent from the past 20 years after high-rise RCC buildings were introduced. The randomness and unpredictability of earthquakes, is all the more reason for engineers to focus on analysing the structure both statically and dynamically.

Although static analysis may be used to design buildings, extreme caution must be taken to render them disaster-proof. This is where dynamic analysis comes into play, modelling the seismic loads accurately and thereby providing economical designs. By carrying out Dynamic analysis, one obtains the design forces of the building and additionally, height-wise distribution of those forces.

A. What is Response Spectrum?

Response spectrum is a plot of peak response of linear, single degree of freedom oscillators for a specified part of the ground's earthquake motion.

This graph is attained by plotting the natural period on the X-axis and response quantity on the Y axis. Any of the following, maximum displacement, maximum velocity or maximum acceleration, can be chosen as the response quantity. The principle guiding the Response Spectrum analysis is that, once the structure's natural period is known, the highest response of the structure to a specified part of earthquake motion can be estimated from Response Spectrum Analysis.

B. What is P-Delta Effect?

P-Delta effect is the sum of storey weight (P) times the lateral displacement (Delta). It is an added moment in the members of the building. For multi-storied buildings, besides dynamic analysis, performing P-Delta analysis increases the credibility of the model rendered, as it takes into account the finer parameters.

Lateral displacements that exert influence on the structure, thereby producing second order overturning moments, are grossly ignored in static and dynamic analyses. The effect of P-delta is of second order, occurring non-linearly in any tall building, wherein the structural elements are exposed to loads, axially. This outcome is accurate, as the extent to which the axial load is applied (P) and the lateral displacement (Delta) are inter-dependent.

II. OBJECTIVE

The objectives of the current study are:

- Studying the effect of various combinations of load, on a regular, multi-storied building with height irregularity.

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* Correspondence Author

M.Jesse Leo Pragnan*, Structural Engineering, Vignan's Foundation for Science Technology and Research, Deemed to be University, Guntur, Andhra Pradesh, India.

Anirudh Maddi, Asst.Professor, Vignan's Foundation for Science Technology and Research, Deemed to be University, Guntur, Andhra Pradesh, India.

- Analysing how seismic load affects a G+15 storey building by means of Response spectrum and P-Delta effect.
- Evaluating the seismic parameters- time period, displacement, self-weight, base shear, storey shear and storey drift.
- Comparing the parameters- displacement, storey drift and storey shear, obtained from Response Spectrum analysis with that of P-Delta analysis.

III. METHODOLOGY

ETAB software was utilized to model a 16 storied building of dimensions 35m x 25m, in accordance with the architectural plan. According to IS 857 part 1, part 2 and part 3, loads were applied on to the structure. The combinations of loads were obtained from IS 1893:2002(Part 1). The structure so designed, was in agreement with IS 456:2000. The design of the building was followed by P-Delta analysis, in addition to Response spectrum analysis. Once the entirety of the structure cleared the design scrutiny, the seismic parameters such as time period, self-weight, base shear, displacement, storey drift and storey shear were evaluated and data from both the analyses were compared.

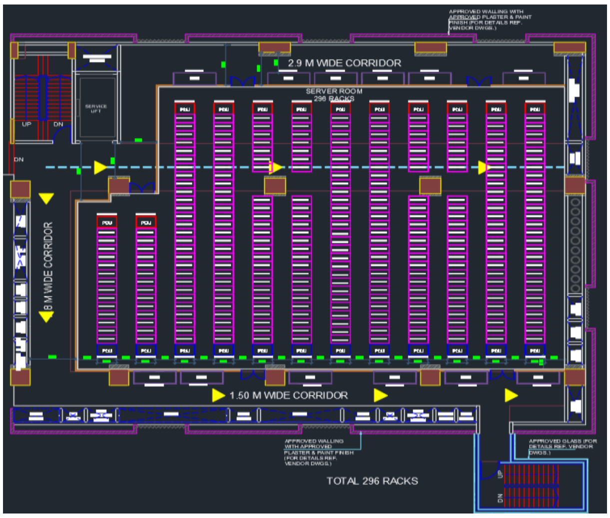

Fig1: AutoCAD plan

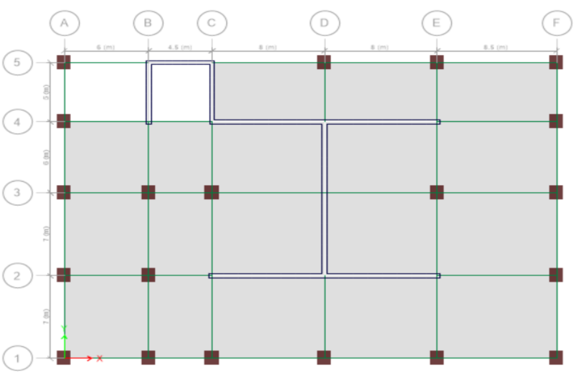

Fig2: Plan view of the structure.

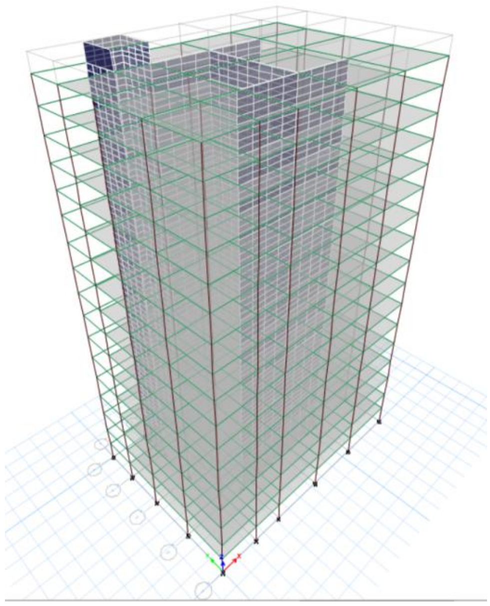

Fig3: 3-D model of the structure.

IV. MATERIAL PROPERTIES

The properties of materials utilized in creating a model structure in ETAB software are as follows:

- Grade of concrete used for frame sections: M45
- Grade of concrete used for slabs: M25
- Grade of steel used for overall height: Fe500
- Thickness of slab: 200mm
- Thickness of shear wall: 350mm
- Density of brick: 20kN/m^3
- Dimension of beams: 600 mm x 1000 mm
- Column dimensions: 1000 mm x 1200 mm;
  750 mm x 1000 mm and
  600 mm x 800 mm.

V. DESIGN DATA

Dead load value was acquired from IS 857:2015 (Part 1), value of Live load from IS 857:2015 (Part 2) and value of Wind load from IS 857:2015 (Part 3). Load combinations were obtained from Part 1of IS 1893:2002. The building was designed in line with IS 456:2000.

Seismic design data, collected from IS 16700:2017 is as follows:

Seismic zone = V
Zone factor = 0.36
Soil type = Type II
Importance factor = 2
Response reduction factor = 5

Wind design data taken from Part 3 of IS 875:2015 is as follows:

Design wind speed = 50 m/s
Terrain category = 3
Importance factor = 1.15
Risk coefficient k1 = 1.08
Topography factor k3 = 1

The aforementioned parameters were furnished to ETAB Software and the building so designed, was investigated using Response spectrum and P-Delta analyses. Time period, self-weight, base shear, displacement, storey drift and storey shear were the numerous seismic parameters that were obtained as output.

VI. RESULTS

The following table shows Time period, Self-weight and Base shear of the G+15 building for various Load patterns.

Load Pattern	Time Period	Self-Weight	Base Shear
	sec	kN	kN
EQ X+	1.044	289737.8	27175.41
EQ X-	1.044	289737.8	27175.41
EQ Y+	0.882	289737.8	32166.81
EQ Y-	0.882	289737.8	32166.81

Table1: Time period, Self-weight and Base shear of the G+15building

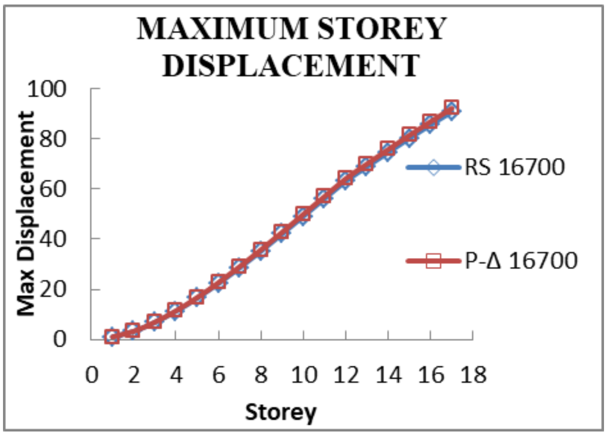

Fig 4: Plot of Maximum Storey Displacement for G+15 Building.

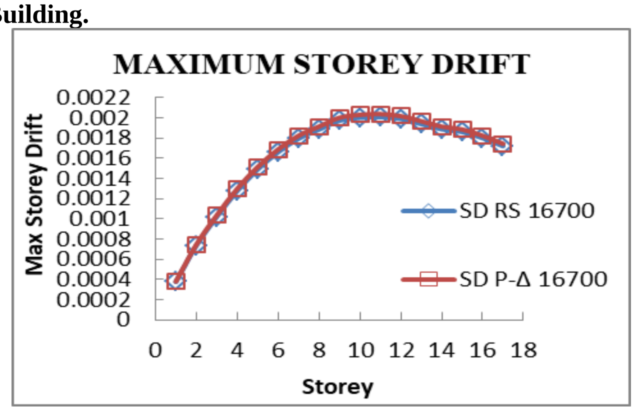

Fig 5: Plot of Maximum Storey Drift for G+15 Building.

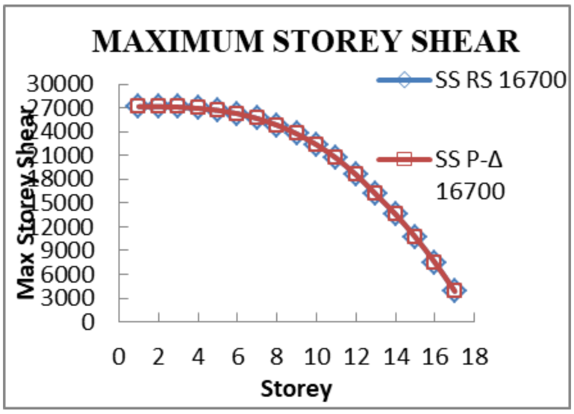

Fig 6: Plot of Maximum Storey Shear for G+15 Building.

VII. CONCLUSION

Analysis of G+15 RCC building was carried out using Response Spectrum and P-Delta methods of analysis in accordance with IS 16700:2017 "Criteria for Structural Safety of Tall Concrete Buildings". The necessity of using P-Delta analysis in conjunction with Linear dynamic analysis, for high-rise buildings (>50 m), was apparent from the above results which is in accordance with the IS code 16700:2017

- More the number of stories, more profound was the P-Delta effect.
- The maximum storey displacement and the maximum storey drifts of the building acquired by means of P-Delta analysis were more in comparison to the same attained via Response spectrum analysis.
- However, the maximum storey shear of the building remained the same in both the analyses.

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AUTHORS PROFILE

M.Jesse Leo Pragnan, P.G.(Structural Engineering) Student, Department of Civil Engineering, Vignan's Foundation for Science Technology and Research, Deemed to be University, Guntur, Andhra Pradesh, India

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Anirudh Maddi of Guntur, received PG (Structural Engineering) from NIT Trichi, Asst.Professor, Department of Civil Engineering, Vignan's Foundation for Science Technology and Research, Deemed to be University, Guntur, Andhra Pradesh, India.