Comparison Of Performance Levels of a G+11 Structure Using Time History Analysis for Different Seismic Zones in India

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ABSTRACT

India is a country wherein a large number of multi-storeyed buildings are erected because of high value and scarcity of land in the recent times. Earthquake is a phenomenon which could generate deadliest forces on the multi-storeyed buildings, which could be a point of concern with respect to the safety of the occupants residing in it. The basic thought of designing earthquake resistant structures is to resist the lateral forces arising due to ground vibrations. Seismic design based on performance levels has a remarkable significance over the traditional methods. According to FEMA the structural design of a structure must meet one of four performance criteria viz. Fully Operational, Immediate Occupancy, Life Safety, and Near Collapse. The primary objective of this paper is to perform seismic analysis and design of G+11 structure which is subjected to ground vibrations from recent earthquakes occurred in India, enterprising for different seismic zones by using ETABS. Analysis for the multi-storey structure is carried out for various load combinations. Time History Analysis is adopted to perform non-linear dynamic analysis. In this project a G+11 Residential building plan is taken into consideration and seismic calculations for earthquake zone II and III are performed. It was observed that the Performance level of the structure employed in Seismic Zone II and Zone III is Fully Operational. The change in maximum Displacement for top roof level is found out to be 14 percent more for Zone III compared to Zone II.

Keyword: ***- Earthquake, Performance Based Seismic design, Performance levels, Seismic zones, Time History Analysis.***

1. INTRODUCTION

1.1 Seismic Design based on Performance and Earthquake

Based upon the performance, Seismic Design is a process that can be performed to achieve acceptable and realistic outputs. In order to satisfy the client’s expectations, it helps the designer to define acceptable ground excitation levels and to alter the performance objectives of the structural and non-structural components of the structure. [6]

1.2 Seismic Design Performance criteria

1. Fully Operational: This performance category aims for minimal damage and it allows the structure for its operational purpose with no substantial repairs. The displacement requirement is typically 0.37% of the building’s overall height.

2. Immediate Occupancy: This performance criteria focuses on maintaining the occupant safety after the occurrence of an earthquake. Thus, allowing the inhabitants to safely migrate without posing any danger to their lives. The displacement criteria for this performance level is generally set at 0.70% of the overall building height.

3. Life Safety: A performance level prioritising human life protection. The structure should impose adequate structural integrity to prevent a catastrophic collapse during a seismic event. The displacement threshold is set at 2.5% of the building's entire height.

4. Near Collapse: The most severe performance rating, indicating that the structure may sustain major damage or partial collapse after an earthquake. The goal is to avoid total collapse, allowing safe evacuation of the residents. The displacement threshold is set at 5% of the building's entire height. [6]

1.3 Earthquake Zone Map of India

Every structure will experience a dynamic motion subjected to an earthquake. This is due to the fact that the inertia forces (also known as **'seismic loads'**) act in an opposite direction of the accelerating earthquake excitations on the structure. These loads are typically addressed by assuming exterior forces, having a significant magnitude acting onto the structure. Thus, it becomes a necessity to determine and quantify the magnitude of the seismic loads. [3]

The Earthquake zone map has classified India into 4 seismic zones, according to IS 1893 (Part-1) 2016. As per this code Zone V will experience highest level of seismicity, while Zone II experiences the least.

Zone V is considered to be the highest danger zone, assuming an earthquake of magnitude of MSK IX (Destructive) or greater represented by Medvedev-Sponheuer-Karnik scale. A zone factor value of 0.36 is assigned for the zone.

Zone IV is known as the High Damage Risk Zone and it includes places that are vulnerable to MSK VIII. A zone factor value of 0.24 is been assigned for this zone as per IS 1893-(Part-1):2016.

Zone III is being classified as Moderate Damage Risk Zone, and it includes places vulnerable to MSK VII. The Zone factor assigned for this zone is 0.16.

Zone II is called as the Low Damage Risk Zone, including places liable to MSK VI or less. The IS Code has assigned a zone factor of 0.10 for this zone. [1]

Shubham Borkar et al., in their study analysed a G+6 storeyed commercial building by adopting response spectrum analysis in different seismic zones and in different soil types using ETABS. The multistorey structure was analysed for all possible load combinations as per IS 1893: 2002. The comparison of various post analysis results of the building under different seismic zones were studied. Based on the analysis results, conclusions were drawn that, base shear varies from zone to zone and from soil to soil. It is also understood that soil-I has very low base shear compared to soil-II and soil-III. The storey drift value increases with the increase in seismic zone factor for all load combinations considered. [1]

Prasad et al., this analysis mainly deals with the study of an elliptical shaped G+12 residential structure. In this study the Time history analysis is considered by taking the previous data of an occurred earthquake in the past, and different results are compared with different earthquake zones as per IS: 1893-2002. Finally based on the governing loads the structural members are designed. Maximum storey displacement, storey drift were recorded. Post analysis results obtained and verified manually as per IS: 456-2000. [2]

2. METHODOLOGY

The Time History approach is often used to asses a structure's performance subjected to dynamic loading such as earthquakes. A Time History analysis determines the response of the structure and its components nonlinear behaviour taking into account the actual time-varying ground motion data obtained from past occurred earthquakes. In this approach the ground motion data is used as input to perform Time History Analysis. These ground motion data contain the acceleration, displacement, velocity generated for sub-sequent time periods. The ground motion data is then matched to the Target spectrum for respective Seismic zones (II and III) in which the structure is to be analysed. Time history analysis forecasts the dynamic response of the structure, by applying the earthquake data to the structure's mathematical model.

3. MODELLING

3.1 Creation of Floor Plan

A floor plan of an existing G+11 Residential Building is taken into account for the analysis purpose. After the finalization of the floor plan, a centre line drawing was prepared in order to determine the distances between the structural members of the RC structure, also allowing the accurate formation of the grid lines to be carried out in the ETABS Software.

Fig 1: Floor plan of Residential building

3.2 Modelling in ETABS Software

The G+11 Residential Building was modelled in the ETABS Software using AUTOCAD plan. The model was created in descriptive manner as mentioned below:

TABLE 1: Structural details and Material Properties

Sr. No.	GENERAL DATA	VALUES
1.	Type of building	Multi-storey Residential building
2.	Total height of the building	36 m
3.	Height of each storey	3 m
4.	Grade of concrete	M25
5.	Grade of steel	Fe-500

6.	Density of reinforced concrete	25 KN/m^3
7.	Slab thickness	125 mm, 130 mm, 150 mm
8.	Beam sizes	230mm X 500mm
9.	Column sizes	230mm X 700mm, 230mm X 900mm
10.	Soil type considered	Type I
11.	Masonry wall thickness	230mm
12.	Seismic zone	II, III

1. Formation of customised grid lines.
2. Defining material properties: (Concrete, Rebar)
3. Defining section properties for various structural members. (Beam, Column, Slab)
4. Drawing of beam, positioning of columns and placement of slabs at appropriate locations.
5. Defining and placement of Shear wall.
6. Application of loads taking into consideration various IS Codes. (IS: 875- Part I for Dead Loads, IS: 875- Part II for Live Loads and IS: 1893- (Part I) 2016 for Earthquake Loading.)
7. Defining earthquake loads (‘x’ and ‘y’ direction considering eccentricities). The soil type considered is I, Importance factor: 1.20, response reduction factor: 3.
8. Diaphragms were assigned for the slab element.
9. Assigning of Supports: Fixed Supports were assigned to the structure.
10. Analysis of the model in ETABS Software.

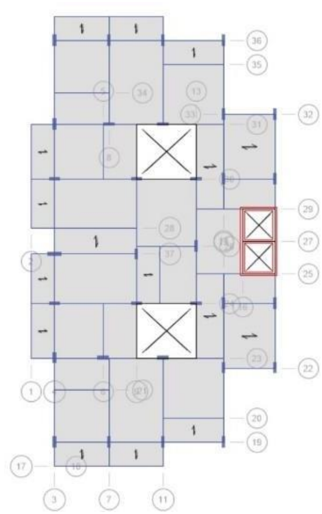

Fig 2: Plan view of ETABS Model

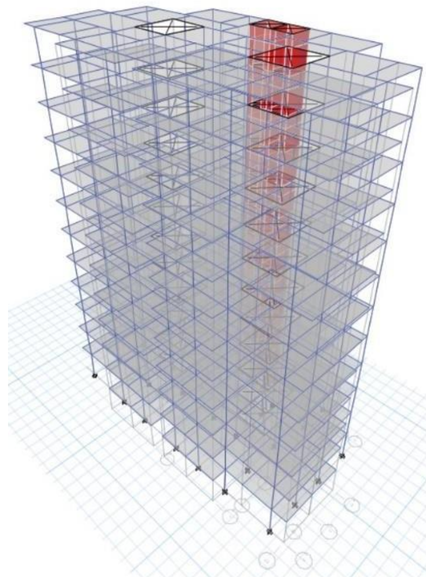

Fig 3: 3D view of ETABS Model

3.3 Analysis in ETABS Software

The structure developed in ETABS was examined for the ground motion data from the recent Bhuj earthquake in India.

Earthquake: Bhuj/Kachchh 2001-01-26 03:16:40 UTC

Station: Ahmedabad, India
Station Owner: Dept of Earthquake Eng., Indian Inst. of Technology, Roorkee, India
Station Latitude & Longitude: 23.4200, 70.2300
Hypo-central Distance: 239.0 km

Matched Plot:

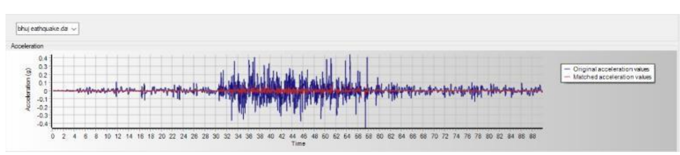

Fig 4: Acceleration Plot of Bhuj Earthquake matched for Zone II

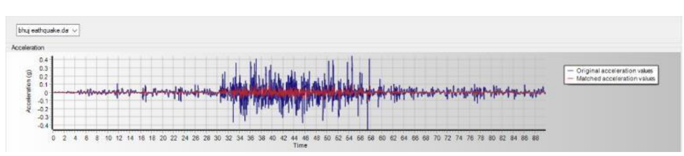

Fig 5: Acceleration Plot of Bhuj Earthquake matched for Zone III

Defining Response Spectrum function: A target Response spectra is added for each particular zone (Zone II and Zone III) for which the Time history function is to be matched in accordance with IS 1893:2016 (Part-1). The parameters chosen for the target response spectrum are mentioned below and a detailed function graph is achieved.

Table 2: Parameters chosen for defining response Spectrum

Parameters	Values
Seismic Zone	II, III
Seismic Zone Factor, Z	0.10, 0.16
Importance Factor, I	1.20
Soil Type	Type I
Response Reduction Factor, R	3.0
Function Damping Ratio	0.05

Defining Time History: The earthquake data in the form of Time vs. Acceleration was obtained from the website www.strongmotioncenter.org.. This data can be loaded into the ETABS Software in the form of .TH file. The image below depicts an example of the data file input in Time History function.

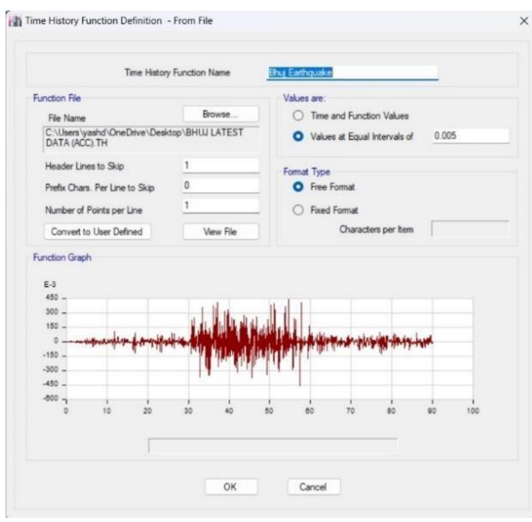

Fig 6: Input of Time History definition of earthquake data

A separate Time history function is generated for that particular zone for the purpose of matching it to the design response spectrum. Method used for spectral matching was Time domain and the Target response spectrum to be matched for that particular zone was performed. The picture below shows spectrally matched acceleration for Time History.

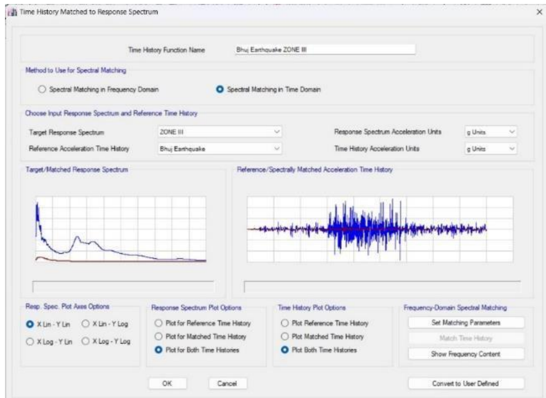

Fig 7: Time History matched to Response Spectrum

The structure was evaluated to determine the maximum roof level displacement employing Time History Analysis in order to determine the structure's performance level. As a result, the structure was assessed for different seismic zones (Zone II and Zone III) and the performance levels were determined. The performance levels were calculated using the data shown below. The structure's performance level is computed by dividing the Roof Displacement value by the total storey height of the structure, and the result is multiplied by 100. The calculated percentage was compared to the FEMA-specified objective performance level. For instance, the simulated structure is a G+11 Residential building bearing a floor-to-floor height of 3m. As a result, the structure stands 36 m tall. If the maximum roof displacement is 0.37% of 36000, the building is deemed to have an Operational performance level.

Sr. No.	Performance Levels	Target Roof Displacement (% of Height)
1	Operational	0.37
2	Immediate Occupancy	0.70
3	Life Safety	2.5
4	Collapse Prevention	5.0

Fig 8: Target performance

4. RESULTS AND DISCUSSION

Abbreviations: O = Operational, IO = Immediate Occupancy, LS = Life Safety and CP = Collapse prevention

4.1 Analysis of the structure in ZONE II

The results for the performance levels attained for the structure in Zone II are shown in the Observation Table below.

TABLE 3: Storey Response for Zone II

Storey	**Elevation (m)**	**Max roof level displacement (mm)**	**Displacement w.r.t Building height %**	**Performance level**
Story 12	36	21.73	0.060	O
Story 11	33	19.52	0.054	O
Story 10	30	17.55	0.049	O
Story 9	27	16.69	0.046	O
Story 8	24	15.74	0.044	O
Story 7	21	14.47	0.040	O
Story 6	18	12.91	0.036	O
Story 5	15	11.17	0.031	O
Story 4	12	9.172	0.025	O
Story 3	9	6.923	0.019	O
Story 2	6	4.454	0.012	O
Story 1	3	1.841	0	O
Base	0	0	0	O

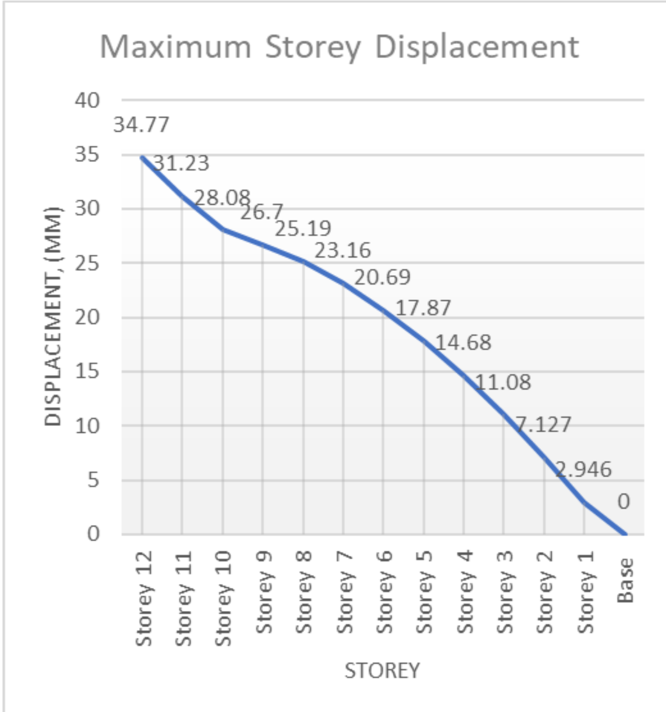

Chart 1: Graph of Storey Vs. Displacement for Zone II

4.2 Analysis of the structure in ZONE III

The results for the performance levels attained for the structure in Zone III are shown in the Observation Table below.

TABLE 4: Storey Response for Zone III

Storey	Elevation (m)	Max roof level displacement (mm)	Displacement w.r.t Building height %	Performance level
Story 12	36	34.77	0.097	O
Story 11	33	31.23	0.087	O
Story 10	30	28.08	0.078	O
Story 9	27	26.7	0.074	O

Story 8	24	25.19	0.07	O
Story 7	21	23.16	0.064	O
Story 6	18	20.69	0.057	O
Story 5	15	17.87	0.05	O
Story 4	12	14.68	0.041	O
Story 3	9	11.08	0.031	O
Story 2	6	7.127	0.02	O
Story 1	3	2.946	0	O
Base	0	0	0	O

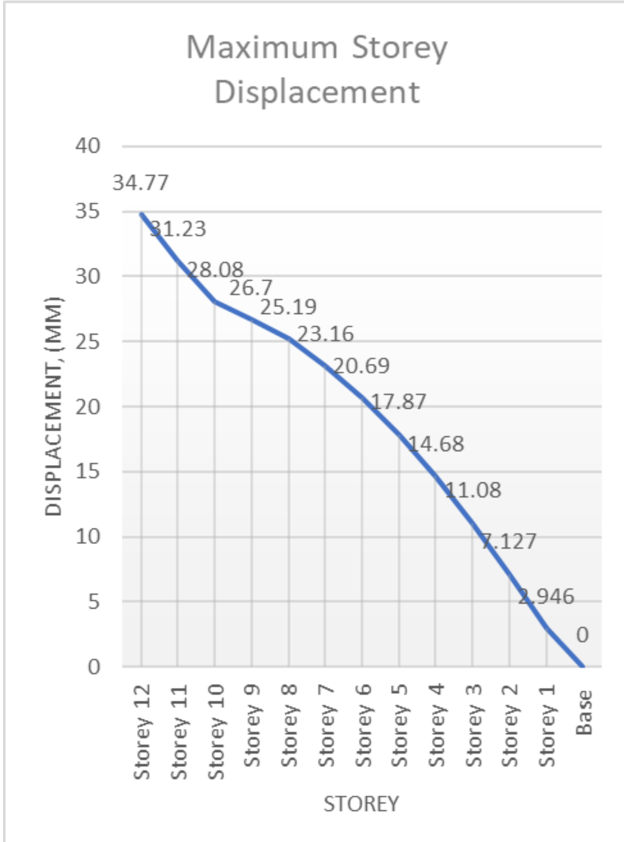

Chart 2: Graph of Storey Vs. Displacement for Zone III

5. CONCLUSION

In this work, the Performance levels of the G+11 structure were determined based on the Maximum Roof Level Displacements. The ground motion data used in the work was that of the Bhuj Earthquake Data. The Method employed was Non-linear Dynamic Analysis by Time History Analysis. Based on the study conducted the following conclusions were reported: -

1. The Maximum Roof Level Displacement for zone III is higher compared to the top roof displacement for zone II.

2. The Maximum Roof Level Displacement goes on increasing from base to top storey (12 Storey).

3. The performance level of the structure for Zone II and Zone III is fully operational.
4. The change in displacement for top roof level is 14 percent more for zone III as compared to zone II.

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