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Comparison of Performance Level of Symmetric andAsymmetric Structure in ETABS

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ABSTRACT

Nowadays due to land scarcity and rising property prices, multi-storey buildings with symmetric and asymmetric plans are particularly prevalent in urban areas to satisfy the needs. Structural damage which also significantly affects human lives caused by earthquakes has long been concerned Structural engineers. Recently Performance-based seismic design has gained its importance by surpassing conventional techniques with four performance criteria set forth by FEMA to be met for the structural design: Fully Operational, Immediate Occupancy, Life Safety, and Near Collapse. This paper aims to determine the performance level of symmetric and asymmetric (G+10) buildings. The time history analysis is performed using ETABS software. The BHUJ ground motion data is matched for zone III using ETABS. The structures are subjected to matched ground vibrations. The performance levels are determined and compared with help of storey displacement. Operational, Immediate Occupancy, Life Safety, and Collapse Prevention performance levels are 0.37 %, 0.70 %, 2.5 %, and 5.0 % of the overall height of the building, respectively. It was observed that the performance level for both type of buildings was found to be operational level. The percentage displacement for symmetric building was less as compared tothe compared to asymmetric building.

***Key Word:** symmetric building, asymmetric building, Performance Based Seismic design, Performance levels, time history, BHUJ earthquake.*

1. INTRODUCTION

Each year, there are about 50,000 earthquakes, 100 of which are large enough to cause significant damage. Millions of lives and significant property damage are caused annually on average by earthquakes .Plan irregularity is another one of the most common forms. Even in hilly areas of India that are in seismic zones IV and V, where Engineer are compelled to design asymmetric structures because of a shortage of available land, subpar urban planning, changing functional requirements, and arbitrary aesthetic construction criteria (Pokharel, Ganesh, & Sabarish, 2019). The majority of earlier models of building codes concentrated on confirming life safety. The structure's continual functioning and minimising the earthquake's economic damages were secondary priorities.

The continuing structural damage brought on by earthquakes emphasised the need for a new design methodology that made it possible to select a desirable level of seismic performance for the buildings. (keulekar & Velip, 2022).

Performance-based seismic design implementation is developed on the fundamental concepts of a consensus set of performance objectives. The performance objectives define the building's intended performance under an earthquake hazard with a specific intensity.

FEMA has defined four Target Performance Levels of Performance Based Seismic Design for Buildings which are,

- Operational Level: The least severe degree of overall building damage. Nearly all of the strength and stiffness prior to the earthquake will be retained in the building. Minor cracking of facades, walls, ceilings, and structural components are among the expected damages. The possibility of non-structural components being damagedis negligible.
- Immediate Occupancy Level: Damage to the building is light, with structural damage similar to the Operational Performance Level, but non-structural systems are expected to be more damaged which may need repair and clean-up. It is expected that Utilities necessary for life safety systems would be available but for normal functionwill not be available.
- Life Safety Level: Structural and non-structural damage is significant, with a loss of pre-earthquake strength and stiffness in the building, but gravity-load-bearing elements are still functional. Continuing the occupancy ofthe building may not be safe until repairs are done. Repairis feasible but may not be economically attractive.
- Near Collapse Level: The structure is severely damaged and close to collapsing. As the majority of the

pre- earthquake strength and stiffness is lost by the lateral force-resisting systems. But load-bearing walls and columns are in place. Also, significant damage is done to non-structural elements, resulting in falling issues. The building is unsafe for occupancy. Repair and restorationis probably not practically achievable.

Seismic Performance of Symmetric and Asymmetric Multi- Storeyed Buildings are conducted by Sammelan Pokharel et al. (2019).

In this paper, G+4 and G+10 Reinforced concrete structures were analysed in ETABS. For symmetric and asymmetric (shaped L and T) seismic responses like maximum storey displacement, storey shear and overturning moments were determined and compared. Seismic coefficient method and response spectrum method were used for analysis. It was observed for G+4 structure that the maximum storey displacement was found to be almost similar for symmetric structure and T shaped structure and when L shaped structure was analysed using static and dynamic method, 2.5% and 11.17% increase in storey displacement respectively was observed compared to symmetric structure. Maximum storey displacement was 15% lower in dynamic method than that obtained by static method. For G+10 structure, the maximum storey displacement was found to be almost similar for symmetric structure and L and T shaped structure. When L and T shaped structure was analysed using s dynamic method, 12.58% and 7.58% increase in storey displacement respectively was observed compared to symmetric structure. Maximum storey displacement was 21.3%, 10.5% and 15.4% lower in dynamic method than that obtained by static method for symmetric; L and T shaped structure respectively. Also, the percentage decrease in the maximum storey displacement due to shear wall in L and T shaped building is found to be about 19% and 18% when analysed by static method and 26% and 22% when analysed by dynamic method respectively.(Ingale & Nalamwar, 2017).

PERFORMANCE BASED SEISMIC DESIGN OF RCC BUILDING was conducted by Chetan Ingale and M. R. Nalamwar (2017). In this paper (G+5) RCC building was designed for zone 5, 4 and 3 for Maximum Considered Earthquake (MCE) and Design based Earthquake (DBE). The building was designed and analysed in ETABS software. Pushover Analysis was carried out and The Capacity Spectrum, Storey Displacement, Storey Drift, Demand Spectrum and Performance point of the building was found. Target roof displacement ratios at various performance levels (Lateral drift ratio= (δ/h)) is given for Operational = 0.37, Immediate occupancy = 0.7, Life safety 2.5, Collapse prevention 5. The results for Lateral drift ratio= (δ/h) for different zone observed were Zone 3 DBE = 0.17, Zone 3 MCE = 0.36, Zone 4 DBE = 0.33, Zone 4 MCE = 0.70, Zone 5 DBE = 0.40, Zone 5 MCE = 0.82. (Pokharel, Ganesh, & Sabarish, 2019).

2. METHODOLOGY

Symmetric and asymmetric structures are designed and analysed in ETABS software. The method adopted in this project is time history analysis. Ground motion data of BHUJ earthquake for the time history method is matched to zone III in ETABS software. The story displacement for symmetric and asymmetric structures is noted down and the ratio of displacement v/s total story height is calculated. The performance level of the structure is determined by the calculated ratio and both symmetric and asymmetric structures results are compared.

3. MODELLING

3.1 Preparation of Floor Plan

The symmetric and asymmetric residential building of G+ 10 stories was modelled in ETABS software. The floor plan for both building was imported from AUTOCAD software to ETABS software. The member properties and the dimension of beams, column, slab, shear wall were defined and assigned to the both the models in ETABS both the structures is loaded as per IS 875 for different load cases.

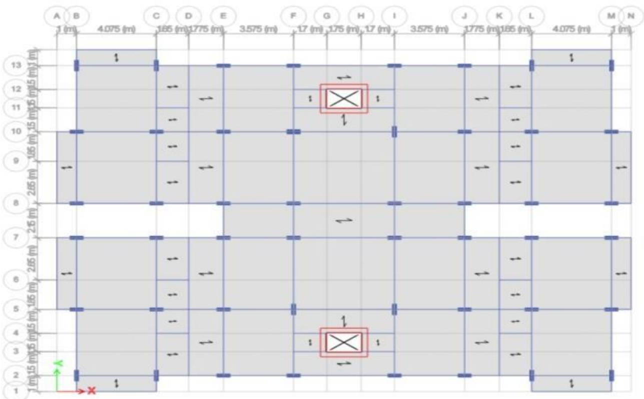

Fig-1 Floor plan of symmetric building

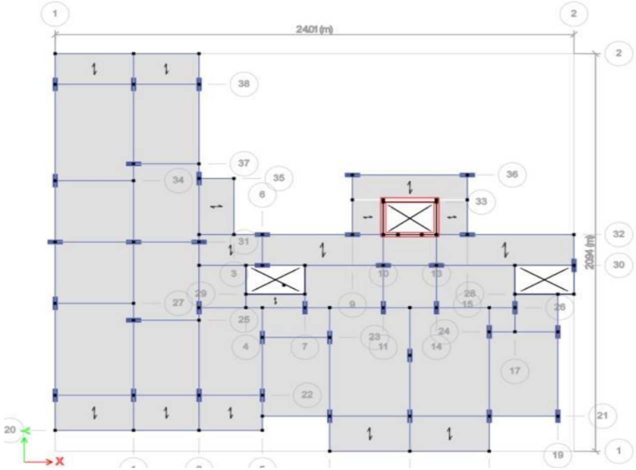

Fig-2 Floor plan of asymmetric building

3.2 Modelling in ETABS software

Table-1 Modelling Parameters

GENERAL DATA	VALUES
Type of building	Multi-story Residential building
Total height of the building	33 m
Height of each storey	3 m
Grade of concrete	M30
Grade of steel	Fe-500
Slab thickness	150 mm

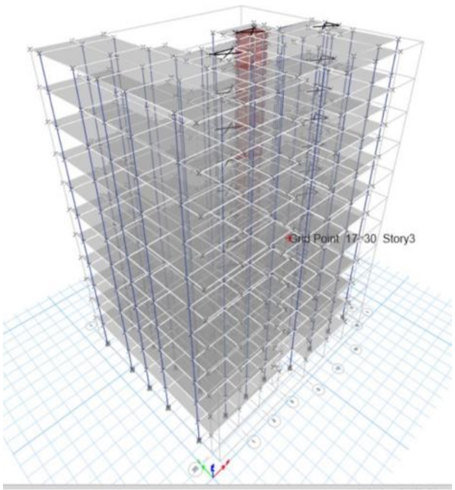

Fig-3 3D view of Model IN ETABS of symmetric building

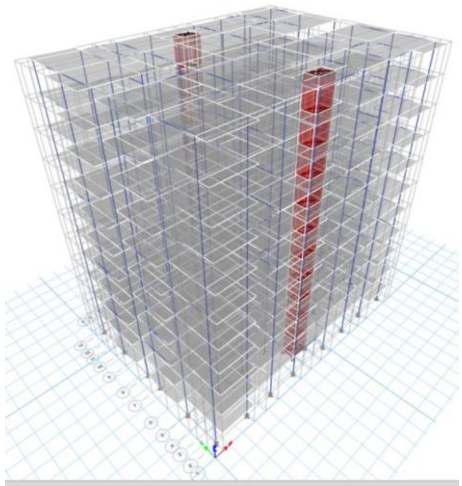

Fig-4 3D view of Model IN ETABS of asymmetric building

3.3 Analysis in ETABS Software

For analysis of the structures the target response spectrum was defined in ETABS as per IS 1893. Also ground data motion for BHUJ earthquake was defined in time history. In the ETABS software The BHUJ ground motion data is matched for zone III and applied for both the structures for time history analysis. The results were compared of both the structures.

Table-2 Response Parameters

Parameters	Values
Seismic Zone	III
Seismic Zone Factor, Z	0.16
Importance Factor, I	1.2
Soil Type	Type I
Response Reduction Factor, R	3.0
Function Damping Ratio	0.05

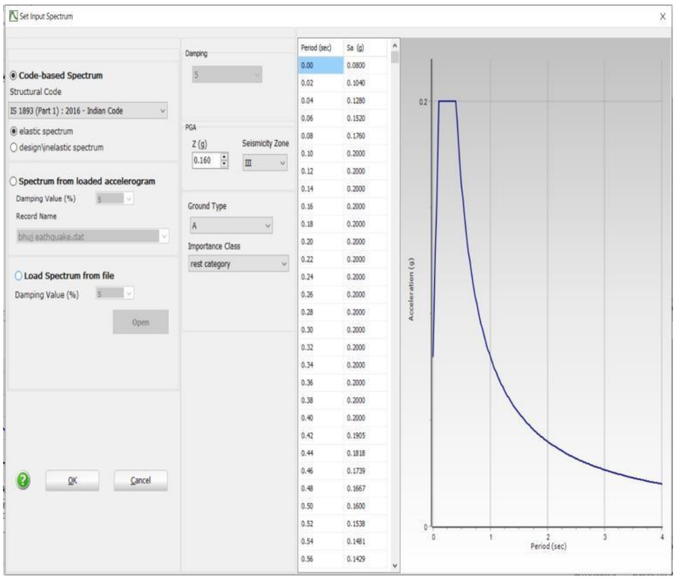

Fig-4 Target response spectrum for zone III

Time History definitions: Earthquake data of BHUJ earthquakes that occurred in state of Gujarat, India was collected from the website www.strongmotioncenter.org. The BHUJ data was input in ETABS software in form Time vs. Acceleration. The data entered in ETABS was of .TH file.

Earthquake: BHUJ/Kachchh 2001-01-26 03:16:40 UTCStation: Ahmedabad, India
Station Owner: Dept. of Earthquake Eng., Indian Inst. ofTechnology, Roorkee, India
Station Latitude & Longitude: 23.0300, 72.6300Hypocentral Distance: 239.0 km
Matched Plot:

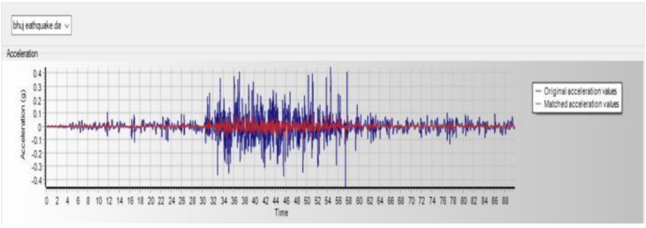

Fig-5 Acceleration Plot of BHUJ Earthquake matched to zoneIII

3.4 Calculations for performance levels

Max roof level displacement for time history after analysis of both the structures is observed and used for getting the performance level of both structures. The story displacement for both structures is tabled below. The performance level of the structure is calculated by dividing roof displacement by the total story heights of the building multiplied by 100. The percentage calculated was compared with the target performance level mentioned by FEMA. For e.g., the structure modelled is a G+10 school building having a floor-to-floor height of the 3m. Hence the building is 33m Tall. If the Max roof displacement occurs is 0.37% of 33,000mm then the building is said to achieve a performance level of Operational.

Table-3 Target performance

PERFORMANCE LEVEL	TARGET ROOF DISPLACEMENT (% OF HIEGHT)
OPERATIONAL	0.37
IMMEDIATE OCCUPANCY	0.7
LIFE SAFETY	2.5
NEAR COLLAPSE	5.0

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

4. RESULTS

Abbreviations: O = Operational, IO = Immediate Occupancy,LS = Life Safety and CP = Collapse prevention
The following Observation table shows the results for theperformance levels obtained

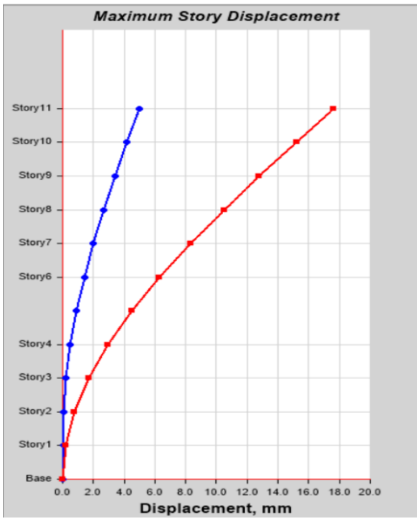

Chart-1 Displacement graph of asymmetric building

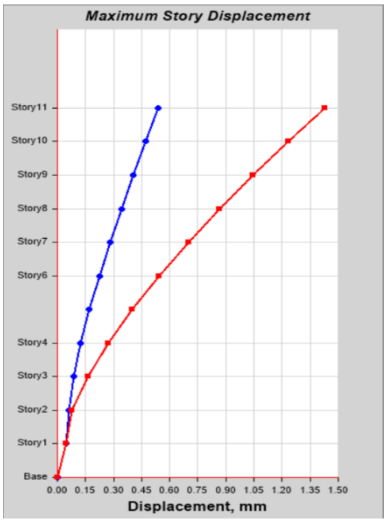

Chart-2 Displacement graph of symmetric building

Table-4 Max displacement for symmetric and asymmetric inmm

Storey	Elevation (in m)	Max displacement for symmetric (in mm)	Max displacement for asymmetric (in mm)
Storey 11	33	1.429	17.624
Storey 10	30	1.231	15.189
Storey 9	27	1.045	12.789
Storey 8	24	0.868	10.483
Storey 7	21	0.7	8.306
Storey 6	18	0.544	6.296
Storey 5	15	0.4	4.494
Storey 4	12	0.273	2.939
Storey 3	9	0.164	1.674
Storey 2	6	0.079	0.743
Storey 1	3	0.045	0.185
Base	0	0	0

TABLE-5 Max displacement for symmetric and asymmetricin %

Storey	Elevation (in m)	Max displacement for symmetric (in mm)	Max displacement for asymmetric (in mm)
Storey 11	33	0.0043303	0.053406
Storey 10	30	0.00410333	0.05063
Storey 9	27	0.00387037	0.047367
Storey 8	24	0.00361667	0.043679
Storey 7	21	0.00333333	0.039552
Storey 6	18	0.00302222	0.034978
Storey 5	15	0.00266667	0.02996
Storey 4	12	0.002275	0.024492
Storey 3	9	0.00182222	0.0186
Storey 2	6	0.00131667	0.012383
Storey 1	3	0.0015	0.006167
Base	0	-	-

Table-6 Performance Level

Type of structure	Max roof level displacement (mm)	Displacement w.r.t Building height %	Performance level
Symmetric	1.429	0.0043303	O

Asymmetric	17.624	0.053406	O

5. CONCLUSION

In this work the Performance levels of the G+10 structures was 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 used was Nonlinear Dynamic Analysis by Time History Analysis. Based on the study conducted the following conclusions were reported: -

- The performance level for both type of buildingswere found to be operational level.
- The percentage displacement for symmetric building was less as compared to the compared to asymmetric building.
- The displacement at every floor increases with the height.
- The top roof displacement to floor area ratio for asymmetric building was found to be more comparedto symmetric building.

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