International Organization of Research & Development (IORD)
ISSN: 2348-0831
Vol 10 Issue 01 | 2022

Effect on the Performance Levels of a G+7 Structure for Different Cross Sectional Area of Structural Members

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DOI: 10.5281/zenodo.7152404

ABSTRACT

In the past, structural engineers were concerned about earthquakes. Earthquakes not only cause structural damage, but they also have a significant impact on human lives. Performance-based seismic design has recently gained prominence over traditional methods. The structural design must meet one of four performance criteria set forth by FEMA. Fully Operational, Immediate Occupancy, Life Safety, and Near Collapse are the four performance levels. In this paper, a G+7 structure is subjected to ground vibrations from recent earthquakes in India, and the effect on performance levels for different cross sections of structural members such as beams, columns, and slabs of the structure is determined. The criteria used to classify the performance levels is 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. Time History Analysis is used to perform non-linear dynamic analysis. The analysis is carried out using the STAAD Pro software. It was observed that change in the cross sections of Beam and columns caused significant changes in the roof level displacements which in turn brought changes in Performance levels, while change in slab thickness caused no much changes in the performance levels of the structure.

***Keywords**: Performance Based Seismic design, Performance levels.*

1. INTRODUCTION

1.1 Performance Based Seismic Design and earthquake

Performance based Seismic design is a futuristic seismic design methodology that can be used to obtain realistic and appropriate results. Its major plus point is that it permits the design team to collectively work together in determining the appropriate levels of ground motion and Performance objectives for the structural and non-structural components of the building in consideration so as to meet the expectations of the client.

Most olden Model building codes primarily focussed on ensuring life safety. Reduction of economic losses caused by the earthquake and continued operation of the facility were secondary considerations (in case they were even considered at all). The continued damage caused by the earthquakes to structures therefore highlighted a need for a new design methodology that enabled to choose a desirable level of seismic performance for the buildings.

1.2 Performance levels of Performance Based Seismic Design

1. Operational: The term "operational performance level" refers to a structure's ability to endure any earthquake force without sustaining significant damage. The structure may have minor fractures that are apparent, but the structure is not in danger and people can live safely after the earthquake.

2. Immediate Occupancy: If a structure is damaged during an earthquake but not to the point that it cannot be rebuilt and people may return to it, it is considered to have a performance level of immediate occupancy. Some minor cracks, as well as damage to the infill walls, were among the damages. The structure is unsafe until the repairs are completed, but it is safe once they are completed.
3. Life Safety: This is the most critical performance level, and every structure should have at least one of these. If a structure is damaged by an earthquake and loses its main function, but the people inside can safely evacuate or exit without being injured, the structure is considered to have life safety performance standards. We have seen how many lives are lost when a significant earthquake occurs, thus every construction should have a high level of life safety performance.

4. Collapse Prevention: When an earthquake strikes, if a structure has lost all of its functions and is on the point of collapsing, it is said to be performing at a collapse prevention level. This performance level carries the danger of losing a human life and is generally avoided for reasons of life safety.

Sejal P. Dalal et al. analyzed a 20 storied Reinforced Concrete (RC) Moment Resisting Frame (MRF) and designed the same by Force Based Design (FBD) method and the Performance Based Plastic Design (PBPD) method. The PBPD frames were built for all three performance levels of the basic safety aim, namely Immediate Occupancy, Life Safety, and Collapse Prevention. The study took into account the criteria of the Indian Standards as well as known design concepts. The tool utilized to assess the seismic performance of the frames in terms of strength and deformation was nonlinear static pushover analysis. The fragility assessment was done in terms of Spectral displacement, which was calculated from the pushover analysis results for various damage states. It was concluded that the PBPD method outperforms the FBD method in terms of seismic performance and fragility.

Hassan Moghaddam et al in their study proposed a performance-based optimization framework for optimal cross-sectional distribution of steel moment resisting frames (MRFs) subject to earthquake excitations. The uniform distribution of damage (UDD) idea was used for the first time in the sophisticated optimization of moment resistant steel frames under dynamic seismic excitations A unique adaptive approach was presented to improve the computing efficiency of the optimization process, where the power functions alter dependent on the demand to capacity ratio of the structural parts. After that, the framework was utilised to optimise three, five, seven, ten, and fifteen-story steel MRFs using a set of sample earthquake records. The major performance parameters for deformation-controlled and force-controlled elements, respectively, were maximum plastic rotations and strength-based demand to capacity ratios. The findings showed that the proposed method is very effective in improving the seismic performance of designed structures in just a few steps while meeting all of the performance targets.

2. METHODOLOGY

The time history approach is employed in this analysis to determine the structure's performance level. A nonlinear dynamic analysis is time history analysis. The earthquake data, which is ground motion data, is used in the time history analysis. The earthquake data is information on previous earthquakes around the world.

3. MODELLING

3.1 Preparation of Floor Plan

A floor plan of a school building was obtained from the Pinterest Website. The .dwg file of the drawing was downloaded and opened in the AutoCAD Software. The drawing needed to be appropriately scaled and the dimensions needed to be transformed from feet inches to meters. Once the drawing file of the school building floor was finalized with centre lines, the modelling of the building was to be carried out in STAAD Pro Software.

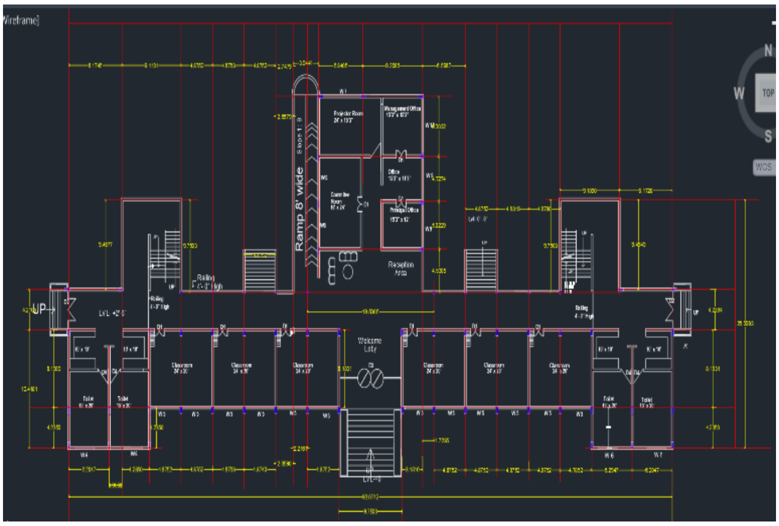


Fig 1: Floor plan of School building

3.2 Modelling in STAAD Pro Software

The G+7 school Building was modelled in the STAAD Pro software using the AutoCAD plan prepared in the step before. The model was prepared step by step as described below:

i. Nodes were placed with the help of dimensions obtained from the centreline plan.

ii. Nodes created were connected to each other using the add beam command.

iv Columns were Assigned between the Storeys.

v Diaphragm was assigned for the slab element.

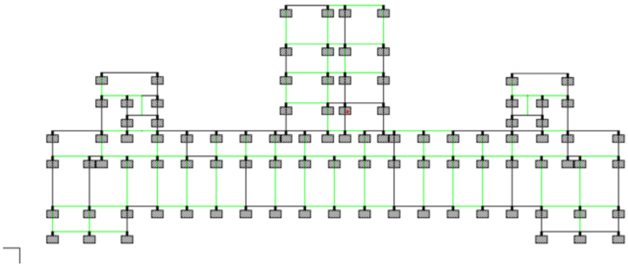


Fig 2: Plan view of STAAD Pro Model

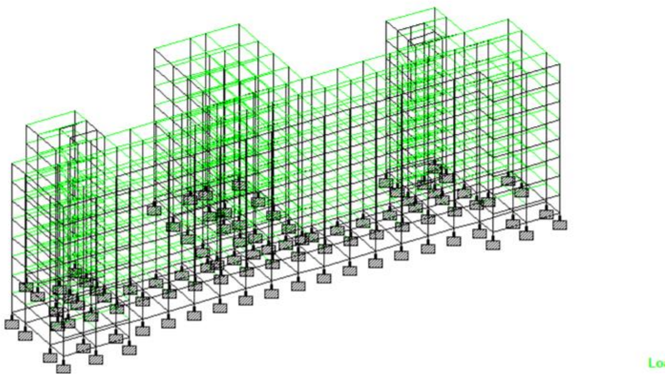


Fig 3: 3D view of STAAD Pro Model

Assigning of Supports: Fixed Supports were assigned to the structure.

Section Properties: For the Initial analysis the following sections were used i.e. i) Beam 0.50m x 0.23m, ii) Column 0.50m x 0.23m and Slab of 0.125m thickness.

Assigning of Load cases:

1. Dead Load = Self weight of -1 factor

2. Live Load = 3.5 kN/m^2

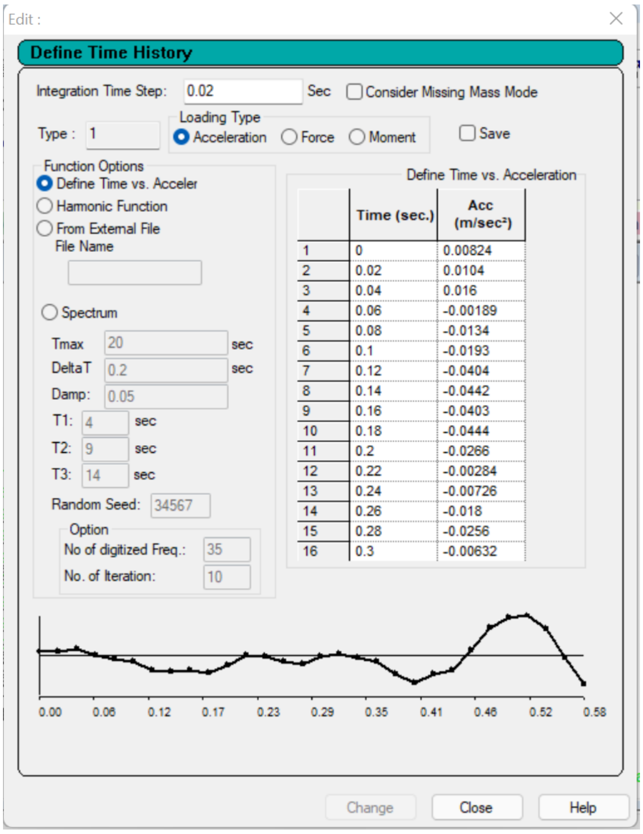
3.Member Load = wall height x wall width x density of masonry wall

= 3.0 x 0.23 x 20.65

= 14.25 kN/m^2

4. Dynamic Load: Self-weights of -1 factors were assigned in X, Y, and Z directions. Floor loads of 5.6 kN/m^2 were applied in X, Y and Z directions. Also, Time history load was assigned having Arrival time = 3:0.01 and Force Amplitude factor of 1.2.

5. Time History definitions: Earthquake data of Bhuj earthquakes that occurred in India was collected from the website www.strongmotioncenter.org. The data Collected was of the form Time Vs. Acceleration. The data can be input into STAAD Pro either entered manually or in the form of a .txt file. The Picture below shows an example of data entered in a manual form.



	Time (sec.)	Acc (m/sec²)
1	0	0.00824
2	0.02	0.0104
3	0.04	0.016
4	0.06	-0.00189
5	0.08	-0.0134
6	0.1	-0.0193
7	0.12	-0.0404
8	0.14	-0.0442
9	0.16	-0.0403
10	0.18	-0.0444
11	0.2	-0.0266
12	0.22	-0.00284
13	0.24	-0.00726
14	0.26	-0.018
15	0.28	-0.0256
16	0.3	-0.00632

Fig 4: Input of Time History definition of earthquake data

3.3 Analysis in STAAD Pro Software

The Structure modelled in STAAD Pro was analysed for Bhuj Earthquake data that occurred in India in recent times. The Data was collected in the form of Time VS. Acceleration.

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: 23.0300, 72.6300
Hypocentral Distance: 239.0 km

Plot:

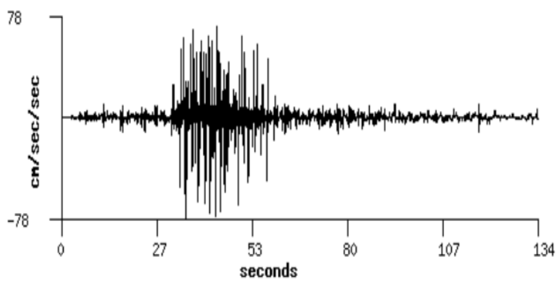


Fig 5: Acceleration Plot of Bhuj Earthquake

The structure was analysed for obtaining the max Time History displacement occurring at the roof level in order to get the performance level of the structure. Hence the structure in consideration was analysed for different cross sections of Beams, Columns and slab thicknesses and the performance levels were found out. The Performance levels were obtained based on the data given below in the table in Fig 6. For e.g., the structure modelled is a G+7 school building having a floor-to-floor height of the 3.5m. Hence the building is 28m Tall. If the Max roof displacement occurs in the range of 0mm – 103.6mm (0.37% of 28,000mm = 103.6mm) then the building is said to achieve a performance level of OPERATIONAL.

Table-1

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

4. RESULTS

Abbreviations: O = Operational, IO = Immediate Occupancy,

LS = Life Safety and CP = Collapse prevention

4.1 Analysis by Changing Beam cross sections

The following Observation table shows the results for the performance levels obtained by changing the beam cross sections.

Table-2

Dimensions (m)	Max roof level displacement (mm)	Displacement w.r.t Building height %	Performance level
0.23x0.40	172	0.61	IO
0.23x0.45	188	0.67	IO
0.23x0.50	204	0.72	LS
0.23x0.55	243	0.86	LS

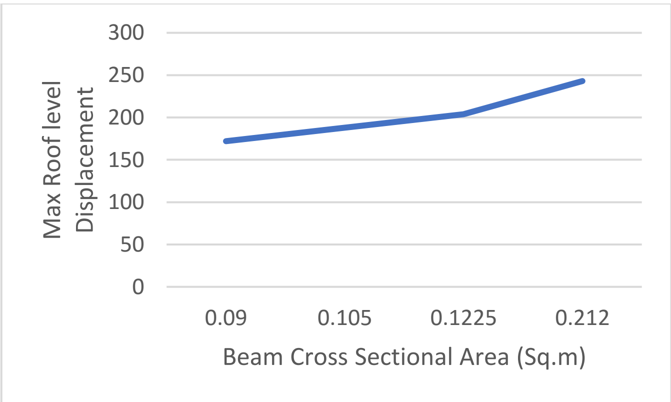


Fig 6: Plot of Max Displacement Vs Beam Cross Sectional Area

4.2 Analysis by Changing Column cross sections

The following Observation table shows the results for the performance levels obtained by changing the Column cross sections.

Table-3

Dimensions (m)	Max roof level displacement (mm)	Displacement w.r.t Building height %	Performance level
0.30x0.30	325	1.16	LS
0.30x0.35	257	0.91	LS
0.35x0.35	174	0.62	IO
0.35x0.40	153	0.54	IO
0.40x0.40	120	0.42	IO

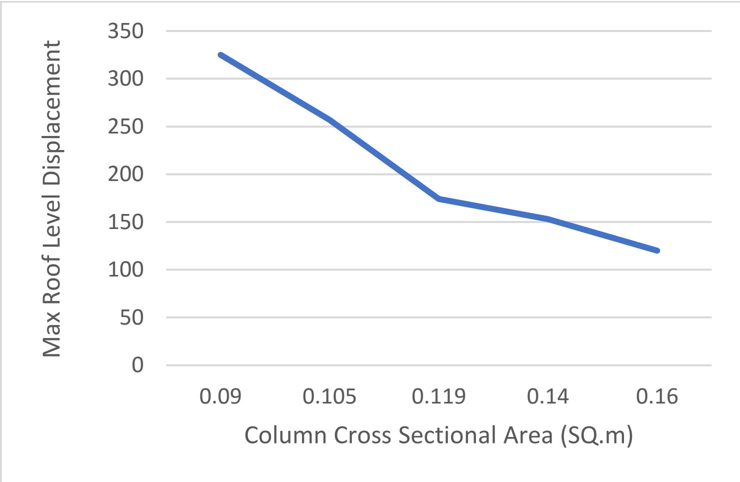


Fig 7: Plot of Max Displacement Vs Beam Cross Sectional Area

4.3 Analysis by Changing Slab Thickness

The following Observation table shows the results for the performance levels obtained by changing the Slab thickness.

Table-4

Slab thickness (mm)	Max roof level displacement (mm)	Displacement w.r.t Building height %	Performance level
120	233	0.83	LS
125	204	0.72	LS
130	217	0.77	LS
135	215	0.76	LS
140	223	0.79	LS
145	227	0.81	LS
150	231	0.82	LS
155	234	0.83	LS

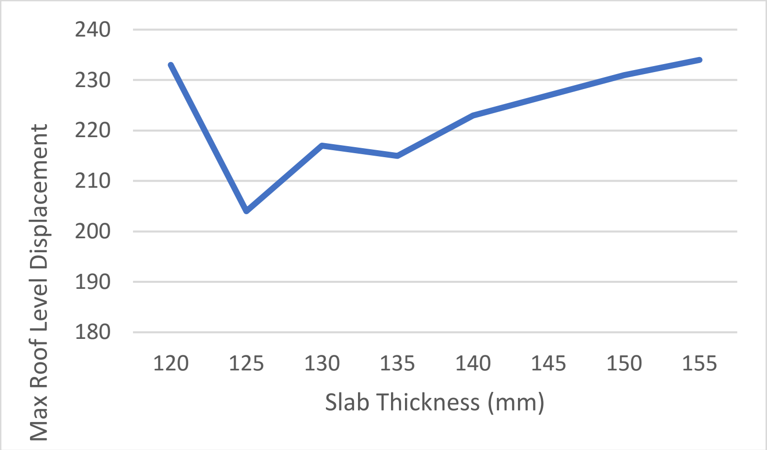


Fig 8: Plot of Max Displacement Vs Slab Thickness

5. CONCLUSION

In this work the Performance levels of the G+7 structure 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: -

1. The Max roof level displacement goes on increasing as we increase the Beam dimensions thus changing the Performance levels from Immediate Occupancy (Higher level) to Life Safety (lower level).

2. The Max roof level displacement goes on decreasing as we increase the Column dimensions thus changing the Performance Levels from Life safety (Lower level) to Immediate occupancy (Higher Level).

3. The Changes in the Slab thickness of the structure doesn't show any such specific trend in the changes of the Max roof level displacements. Thereby indicating no changes in the Performance levels.

6. REFERENCES

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