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The Effect on The Performance Levels of a G+10 Structure for Different Orientations of Shear Walls by Using Time History Analysis

Aristophanes D [1], Guruvendra V [2]
[1] *P.G. Student, Department of Civil Engineering, Goa College of Engineering, Farmagudi, India*
[2] *Assistant Professor, Department of Civil Engineering, Goa College of Engineering, Farmagudi, India*

ABSTRACT

Earthquakes have always been a cause of concern for structural engineers. In addition to causing structural damage, earthquakes significantly affect people's lives. Performance-based seismic design is now widely used over the traditional methods. One of the four performance requirements outlined by FEMA must be met by the structural design. The four performance levels are Fully Operational, Immediate Occupancy, Life Safety, and Near Collapse. In my paper, I have analysed a G+10 residential building, which is subjected to a recently occurred earthquake in India. The effect on performance levels for different arrangements of shear walls is determined. Displacement is the criteria used to categorise the performance level of the structure. The method of analysis used is non- linear Time History Method. ETABS software programme is used to do the analysis. It was observed that change in the arrangements of shear walls caused significantly altered the roof level displacements which in turn brought about changes in Performance level of the structure. Also, all the models with shear walls have performed better as compared to the model without a shear wall.

***Key Words:* Performance Based Seismic design, Performance levels, Shear Wall, Bhuj, Time History.**

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 main benefit is that it enables the design team to collaborate in deciding on the appropriate levels of ground motion and Performance targets for the structural and non-structural elements of the building under consideration in order to satisfy the client's expectations. Life safety was the main goal of the majority of older models of buildings. Reducing earthquake-related economic losses and maintaining continued operations of the building were secondary factors to be taken into account, if at all. As a result of the structural damage brought on by earthquakes, a new design process that allowed for the selection of a desired level of seismic performance for the buildings was required.

1.2 Performance levels of Performance Based Seismic Design

1. Operational: The phrase "operational performance level" describes a building's ability to undergo an earthquake force without experiencing any severe harm. Though the building may have a few visible tiny cracks, it is still considered safe for people to live in it after an earthquake event.
2. Immediate Occupancy: A building is deemed to have a performance level of immediate occupancy if it sustains earthquake damage but not to the extent that it cannot be reconstructed and also allows people to live there. The damages included damage to the infill walls as well as a few small fissures. Before the repairs are finished, the building is unsafe; thereafter, it is safe to live in.
3. Life Safety: This is the most important performance level, and each building needs to have one of them. A building is said to meet life safety performance criteria if, despite earthquake damage and loss of its primary functionality, occupants inside are able to safely leave or depart without suffering harm. Every building should perform well in terms of life safety since we have seen how many lives are lost whenever a severe earthquake happens.
4. Collapse Prevention: During an earthquake, a structure is considered to be operating at a collapse prevention level if it has lost all of its functions and is about to collapse.

Because of the potential loss of human life, this performance level is often avoided for concerns of life safety. [3]

A shear wall is a structural element in a building that is designed to resist lateral forces acting on the building, such as wind, earthquake, or other horizontal loads. Shear walls are typically constructed from reinforced concrete or masonry and they are designed to act as vertical cantilever beams that resist lateral forces by transferring them to the foundation of the building. A shear wall is a type of structural component used to support buildings and is designed to withstand lateral loads like wind, earthquakes, and other horizontal loads.

Shear walls are typically made of masonry or reinforced concrete, and they are intended to function as vertical cantilever beams that resist lateral forces by transferring those forces to the building's foundation.
The different types of shear walls are:-

1) Reinforced Concrete Shear Wall
2) Steel Shear Wall
3) Masonry Shear Walls

K. Sai Charan et al. prepared a 3D model of a multi-storey RCC building (G+10) using ETABS software and analysed the building for seismic analysis considering dead load, live load and earthquake load using equivalent static method (static) and response spectrum method (dynamic). They later compared the static and dynamic methods. Parameters such as displacement, story drift, base shear, time period and frequency were checked. They found out that Static investigation isn't adequate for tall structures. Also, it was found that the values of displacement among static and dynamic analysis are inconsequential for lower stories, but significant in higher stories. [1]
Hardik Mandwe et al. studied the effectiveness of shear wall to resist seismic forces. They analyzed the building by using seismic analysis method in the STAAD Pro software and studied the results of various parameters such as displacement, torsion and deflection. The number of stories were 50 and the site lied in seismic zone IV. The dead loads were taken as per IS:1893 (Part 1)-2016 and the live loads considered were as per IS:875 (part 2)-1987. From their analysis, it was observed that the maximum displacement against earthquakes is very less because of shear walls as compared to the bare frames. Thus shear walls make the structure more stiff in case of an earthquake and can therefore be used to reduce lateral deflections. [2]

2. METHODOLOGY

Time History method is used in the analysis of the G+10 residential building. Time History analysis is a non-linear dynamic type of analysis. Ground motion data of Bhuj earthquake is taken and matched to zone-III conditions in ETABS software itself. Maximum storey displacement parameter is recorded and the performance level of the structure is hence obtained.

3. MODELLING

3.1 Definition of the grid

Grids in ETABS can be classified as cartesian, or general free-form grid systems. The number of grid systems that can be included in a model is unlimited, and they can be positioned at any origin or rotated in any direction. Concrete design code IS 456:2000 and IS 800:2007.

3.2 Defining material properties

After defining the grid, the next step is to define the material properties. If the material we want is missing from the list, a new property needs to be added. The properties of two materials are specified, namely M25 grade concrete and Fe415 steel bars, when designing the building.

3.3 Defining section properties and placing elements

After material properties are defined, we need to define section properties. Here we define the slab, beam, column sections, i.e. their dimensions. Once we define the sections we then place them.

3.4 Define load pattern, load case, load combination.

The spatial distribution of a particular set of forces, displacements, temperatures, and other effects that affect a structure is known as a load pattern. The design type (DEAD, WIND, QUAKE, etc.) assigned to each load pattern categorises the load and starts the related computational process. Load patterns are then applied through load cases to generate analysis results.
A load case specifies the application of load patterns (statically or dynamically), the response of the structure (linearly or nonlinearly), and the method of analysis (modal analysis, direct integration, etc.). A load case is defined for each analysis that will be conducted.A load combination is created by adding together the desired load cases and multiplying a load factor.

3.5 Assigning loads to the shell and the frame.

We assign the loads that will be placed on the shell and frame in this step. The loads placed on the slab (or "shell load") in the project as the floor finish load and the live load.
Wall loads are assigned to the frame's beams. The programme automatically determines the self weight of the slabs and beams based on the defined member dimensions.

3.6 Placing of shear walls

The different models used for analysis are as follows.

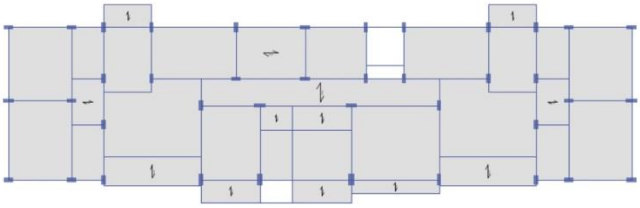

Fig 1: Model 1:- without shear wall.

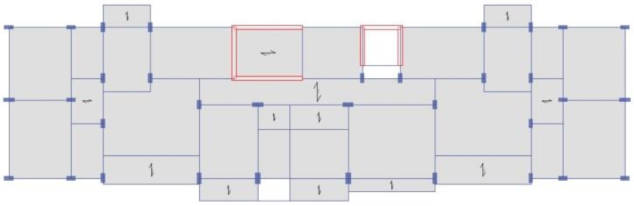

Fig 2: Model 2:- shear wall in elevator and staircase core.

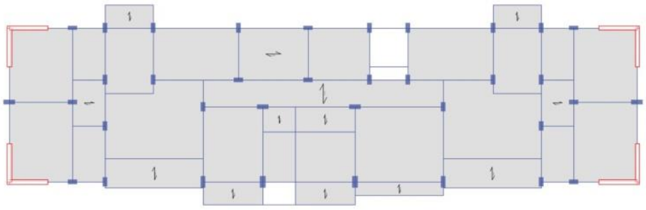

Fig 3: Model 3:- shear wall at all 4 corners of the building.

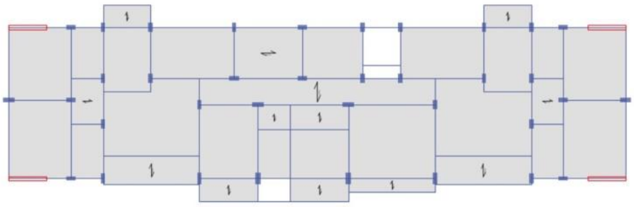

Fig 4: Model 4:- shear wall placed along the longer edges of the building.

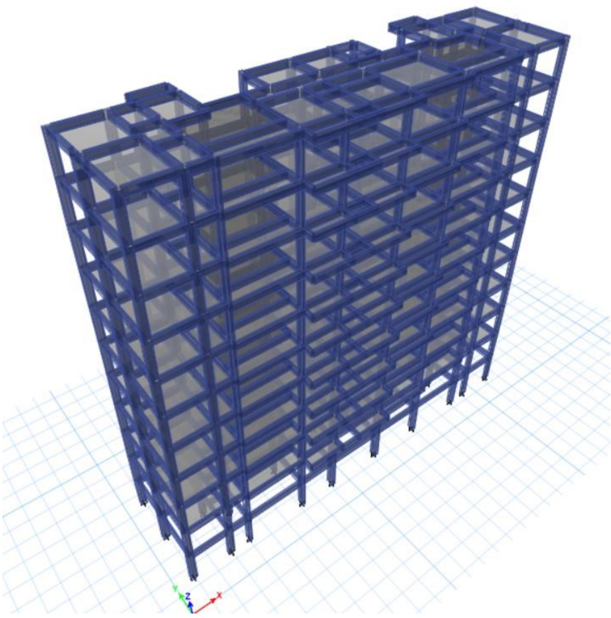

Fig 5: Extruded 3 D view of model.

3.7 Analysis in ETABS Software

Time History data about the Indian earthquake in Bhuj was gathered from the www.strongmotioncenter.org website. The information was gathered in the form of time versus acceleration. ETABS accepts data input in the form of a.TH file or manually typed data. In the model, the ground motion data was imported and matched to a target response spectrum, i.e. zone 3 to match Goa's seismic zone.

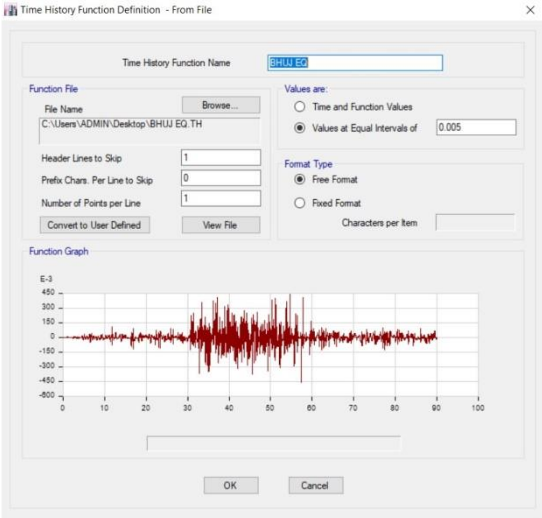

Fig 6: Ground motion data of Bhuj earthquake

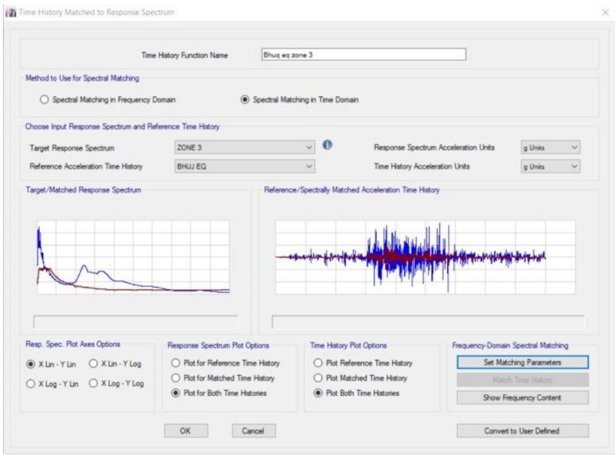

Fig 7: Matched ground motion data to zone 3 conditions

Data from the recent Bhuj Earthquake in India was the analysed for the structure modelled in ETABS. The information was gathered 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

In order to determine the structure's performance level, the structure was examined to determine the maximum Time History displacement that occurred at the roof level.
As a result, the performance levels of the structure under consideration were determined by analysing it for various shear wall configurations. The Performance levels were obtained based on the data given below in the table. For e.g., A G+10 residential building with a 3 m floor to floor height is modelled. Thus, the structure is 33 metres tall. The building is said to achieve an OPERATIONAL performance level if the Max roof displacement falls within the range of 0mm – 122.1mm (0.37% of 33,000mm = 122.1mm).

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

Abbreviations: O = Operational, IO = Immediate Occupancy,LS = Life Safety and CP = Collapse prevention
Model 1:- without shear wall.
Model 2:- shear wall in elevator and staircase core.
Model 3:- shear wall at all 4 corners of the building.
Model 4:- shear wall placed along the longer edges of the building.

The following table shows the percentage displacements and performance levels of the 4 structures.

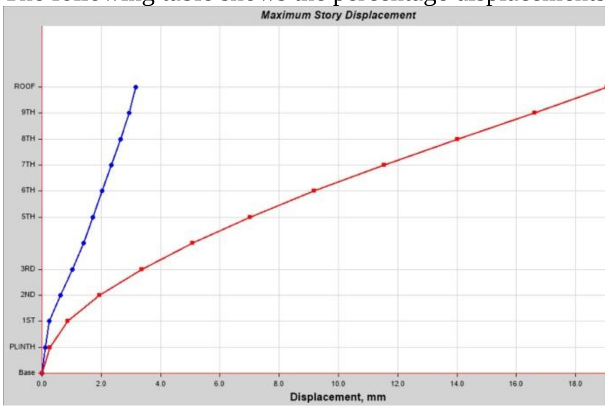

Fig 9: Displacement graph of model 1

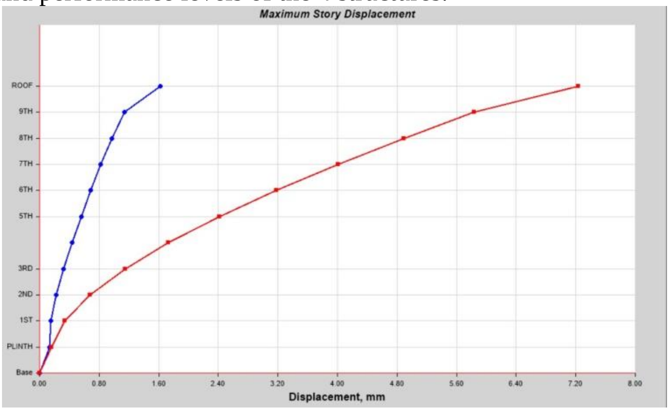

Fig 11: Displacement graph of model 3

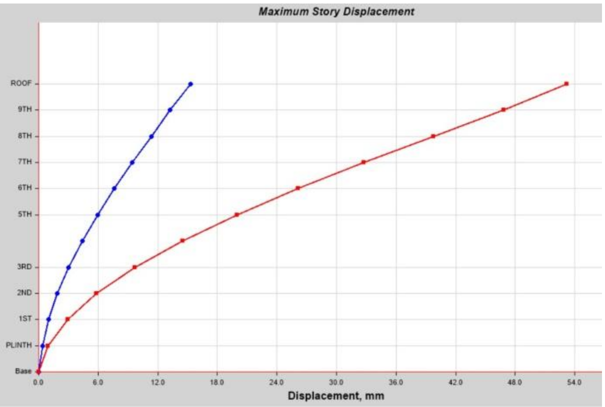

Fig 10: Displacement graph of model 2

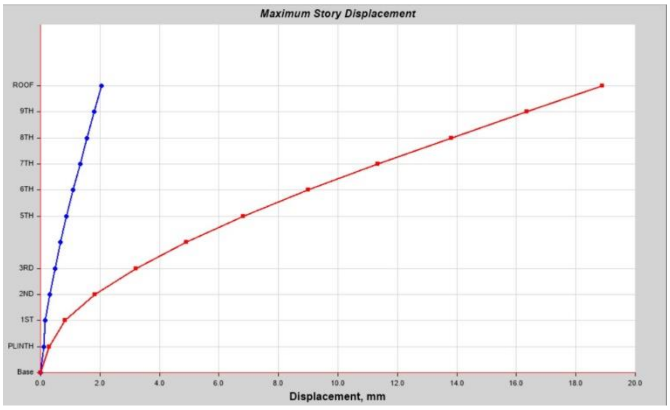

Fig 12: Displacement graph of model 4

TABLE 1: Top storey displacements and performance levels of each model

Model Number	Max roof level displacement (mm)	Displacement w.r.t Building height %	Performance level
1	19.063	0.058	O
2	53.183	0.161	O
3	7.238	0.022	O
4	18.957	0.057	O

5. CONCLUSION

In this work the Performance levels of the G+10 structure with different shear wall arrangements was determined based on the Maximum roof level displacements. The ground motion data used in the work was that of the Bhuj Earthquake. This data was matched to target response spectrum of zone III. The Method used was Nonlinear Dynamic Analysis by Time History Analysis. Based on
the study conducted the following conclusions were reported:

1. The model no 3 the top roof displacement was minimum.
2. Model number 2 exhibited higher top roof displacement.
3. The performance levels for all the building models was operational level

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