The Seismic Analysis of RCC Structure with Column Beam System and Slab Shear wall System

N. Sudheer Kumar[1] J. Vara Prasad[2] B. Sudharshan Reddy[3]
[1]M.Tech. Student [2,3]Associate Professor
[1,2,3]Department of Civil Engineering
[1,2,3]SVR Engineering College

Abstract— In the present scenario the high raised concrete buildings are increasing day-by-day in construction field. Construction became one of the significant sectors of Indian economy and is the major part of the development. For growing population the speed of construction needs to be given greater importance especially for large housing projects. And performance of structures under frequently occurring earth quake ground motions resulting in structural damages as well as failures have repeatedly demonstrated the seismic vulnerability of existing buildings, due to their design based on gravity loads only or inadequate levels of lateral forces. This necessitates the need for design based on seismic responses by suitable methods to ensure strength and stability of structures. Shear wall systems are one of the most commonly used lateral load resisting systems in high rise buildings. At present construction the typical floor plan in a structural system of high raised concrete buildings can be easily done by slab-wall form compared to column-beam system and the behaviour of the building under gravity and lateral loads is analysed by using ETABS 2015 version software for G+9 building. Comparing various parameters such as storey drift, deflection, etc., of a building under lateral loads based on strategic positioning of shear walls. Based on linear and nonlinear analysis procedures adopted, the effect of shear wall location on various parameters are to be compared.

Key words: RCC, Column Beam System, Slab Shear wall System

I. INTRODUCTION

Construction is a complex process involving basically the areas of Architectural planning, Engineering & Construction. There is growing realization today that speed of construction needs to be given greater importance especially for large housing projects. The Indian subcontinent has a history of earthquakes. The reason for the high frequency and intensity of earthquakes is the Indian plate driving into Asia at a rate of approximately 49 mm/year. Himalayan-Nagalushai region, Indo-Gangetic Plain, Western India, Kutch and Kathiawar regions are geologically unstable parts of the country, and some devastating earthquakes of the world have occurred there. A major part of the peninsular India has also been visited by strong earthquakes. The earthquake resistant design of structures taking into account seismic data from studies of these Indian earthquakes has become very essential, particularly in view of the intense construction activity all over the country.

Earthquake resistant structures are structures designed to withstand earthquakes. No, Earthquake alone won't kill people, it is unsafe buildings that are responsible for death troll. While no structure can be entirely immune to damage from earthquakes, the goal of earthquake resistant construction is to erect structures that fare better during seismic activity than their conventional counterparts.

A. Building plan

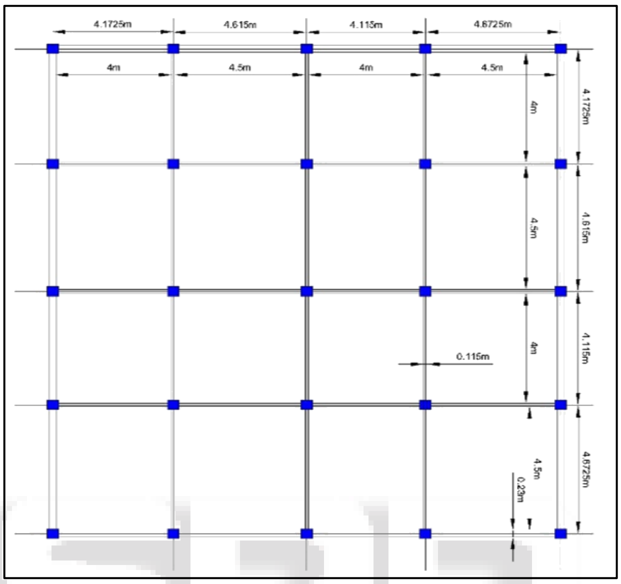

Fig. 1: Column grid plan view

B. Description of structure

No of floor = G+9
Floor height = 3m
Total height of building = 30m
Length of building is equal to width of building as per plan drawing.

C. Column beam and Slab shearwall system

In slab shearwall system the casting of whole structure and transverse walls done in a continuous operation, using controlled concrete mixers obtained from central batching, mixing plants and mechanically placed through concrete buckets using crane and compacted in leak proof moulds using high frequency vibrators.

In this system, the walls and floors are cast together in one continuous operation in matter of few hours and in built accelerated curing overnight enable removal and reuse of forms on daily cycle basis. The walls and ceilings also have smooth even surfaces, which only need colour or white wash. Textured or pattern coloured concrete facia can be provided; this will need no frequent repainting.

Column Beam system is normal type of construction of buildings in this the pace of construction is slow due to step by step completion of different stages of activity, column and beams with partition brick walls is used for construction. Cement used in this system is less than that used in slab shearwall system and reinforcing steel required is less as compared to the slab shearwall system construction as RCC framework uses brick wall as alternative. In this system structural framework of column and beams with partition brick walls is used for construction, the columns and beams show unsightly projections in room interiors.

II. METHODOLOGY

- Preparation of plan
- Modelling of structure (4 models)
- Application of gravity and lateral loads
- Analysing the structure to understand the behaviour.

A. Four models

The same plan (shown in figure 1) is executed as 4 models based on shear wall in ETABS 2015. The below figures shows the 4 models.

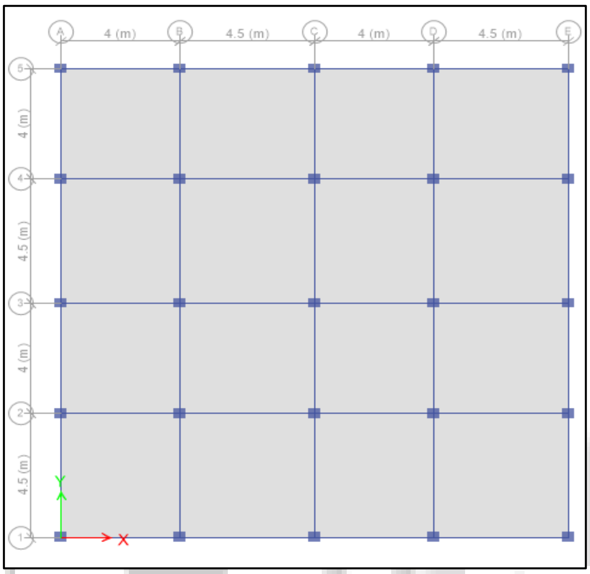

Fig. 2: Model 1(without shearwall)

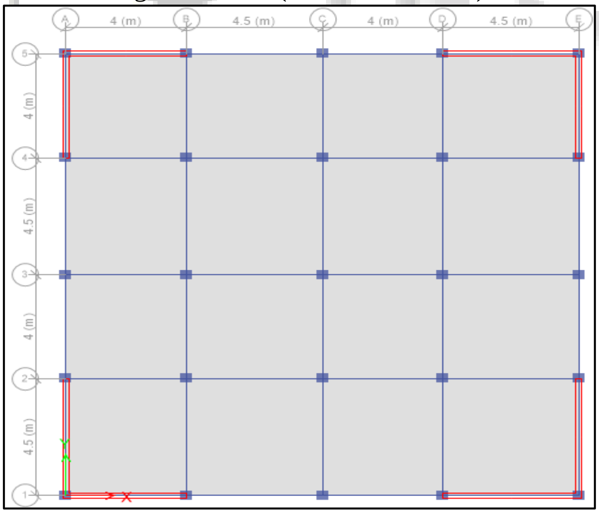

Fig. 3: Model 2

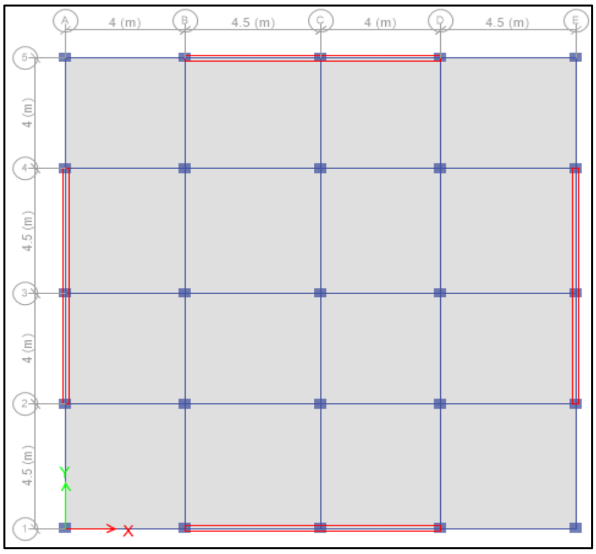

Fig. 4: Model 3

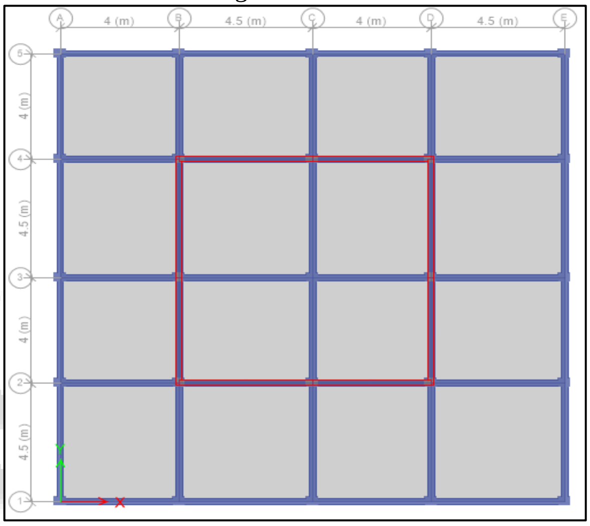

Fig. 5: Model 4

B. Material properties

The M25 concrete is used for all slabs and beams.
M30 concrete is used for all columns and shear walls.
Fe500 steel is used for longitudinal reinforcement.
Fe415 steel is used for transverse reinforcement.

C. Diaphragm

In structural engineering, a diaphragm is a structural element that transmits lateral load to the vertical resisting elements of a structure (such as shear walls or frames).

The diaphragm forces tend to be transferred to the vertical resisting elements primarily through inplane shear stress. The most common lateral loads to be resisted are those resulting from wind and earthquake actions, but other lateral loads such as lateral earth pressure or hydrostatic pressure can also be resisted by diaphragm action. Types of diaphragms

- Rigid diaphragm
- Semi rigid diaphragm.

Rigid diaphragm is used in this thesis.

D. Primary Loads

1) Dead Loads

Self-weight of RC columns, beams and slabs are calculated automatically based on the geometry by the software and is included in the analysis.
Slab thickness = 125mm
Floor finishes = 0.05X20 = 1kN/m^2
Outer wall load at at 350mm depth beam = 0.23X2.65X19.2 = 11.70kN/m
Outer wall load at at 400mm depth beam = 0.23X2.6X19.2 = 11.48kN/m
Inner wall load at at 350mm depth beam = 0.115X2.65X19.2 = 5.85kN/m
Inner wall load at at 400mm depth beam = 0.115X2.6X19.2 = 5.74kN/m
Parapet wall load = 0.115X1X19.2 = 2.2kN/m

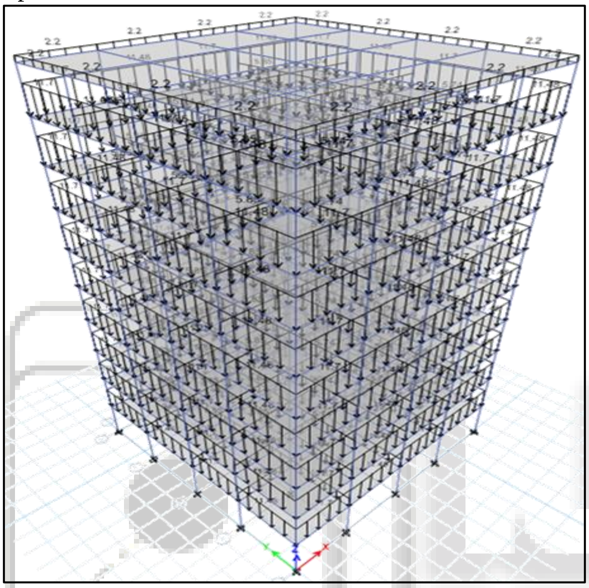

Fig. 6: Dead load on Model 1

2) Live Loads

Live loads are calculated as per IS 875 part 2.
All rooms and kitchens = 2kN/m^2
Toilet and bath rooms = 2kN/m^2
Corridors, passages, and store rooms = 3kN/m^2
At terrace live load = 1.5kN/m^2

E. Wind load

Calculation of wind load is as per IS 875 part 3.
Selected location = Vijayawada
Basic wind speed (V_b) = 50 m/s
Design wind speed (Vz) at any height z = $V_b(K_1)(K_2)(K_3)$
Probability factor (K_1) From Table 1 = 1
Terrain, height and structure size factor = (K_2) = 1.1
Terrain – Category 2, Structure size factor = Class B
Topography factor = K_3 = 1
So Design wind speed (Vz) = $V_b(K_1)(K_2)(K_3)$
(Vz) = 50X1X1.1X1
(Vz) = 55m/s at height z
Design wind pressure (Pz) = $0.6Vz^2$
P_z = 1815N/m^2

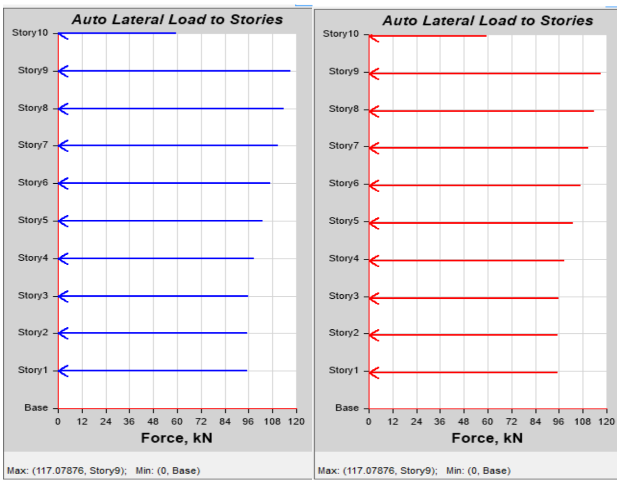

Fig. 7: Wind load on model 1 in x and y directions

III. SEISMIC ANALYSIS

A. Seismic coefficient method

It is a static linear case.
The structure is located in zone III of seismic map of India. The seismic loads on the structure are calculated as per IS1893-2002(Part 1).
Zone factor (Z) = 0.16
Soil type = II (Medium soil)
Importance factor (I) (Table 6) = 1
Response reduction factor (R) (Table 7) = 5
Fundamental natural period of vibration = $T_a = \frac{0.09h}{\sqrt{d}}$
Average response acceleration coefficient = $\frac{S_a}{g} = \frac{1.36}{T}$
Design horizontal seismic coefficient $A_h = \frac{ZIS_a}{2Rg}$

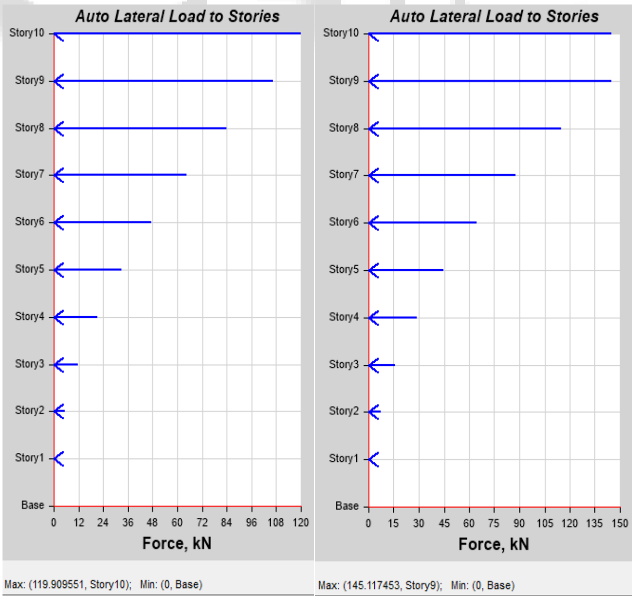

Figure 8 EQ load on x direction in model 1 and 2

B. Load Combinations

All the load cases are tested by taking load factors and analysing the building in different load combinations as per IS 456 and analysed the building for all the load combinations and results are taken.

C. P-Delta analysis

When a model is loaded, it deflects. The deflections in the members of the model may induce secondary moments due to the fact that the ends of the member may no longer be vertical in the deflected position. These secondary effects for members can be accurately approximated through the use of P-Delta analysis.

Coming to the Etabs program it has the ability to calculate the P-Delta effects by two different methods.

- Non-Iterative – Based on mass
- Iterative – Based on load cases

Iterative method with a load combination of dead load and live load is considered.

D. Modal analysis

Usually the first step in dynamic analysis is modal analysis.
Modal analysis is the study of the dynamic properties of structures under vibrational excitation. Modal analysis, or the mode superposition method, is a linear dynamic-response procedure which evaluates and superimposes free - vibration mode shapes to characterize displacement patterns. It will determine the natural mode shapes and frequencies of an object or structure.

When structure subjected to ground motion undergoes deformations in number of possible ways. These deformed shapes are known as modes of vibration or mode shapes. Each shape is vibrating with a particular natural frequency.

Modal analysis uses the overall mass and stiffness of a structure to find the various periods at which it will naturally resonate.

If a structure's natural frequency matches an earthquake's frequency, the structure may continue to resonate and experience structural damage.

Modal analysis is step one for response spectrum analysis and time history analysis.
Modal analysis types:

- Eigenvectors
- Ritz vectors

Eigen vector analysis determines the undamped free vibration mode shapes and frequencies of the system.

Ritz vector analysis seeks to find modes that are excited by a particular loading. Ritz vectors can provide a better basis than do eigenvectors when used for response spectrum or time history analyses that are based on modal superposition.
In this thesis Ritz method is considered.

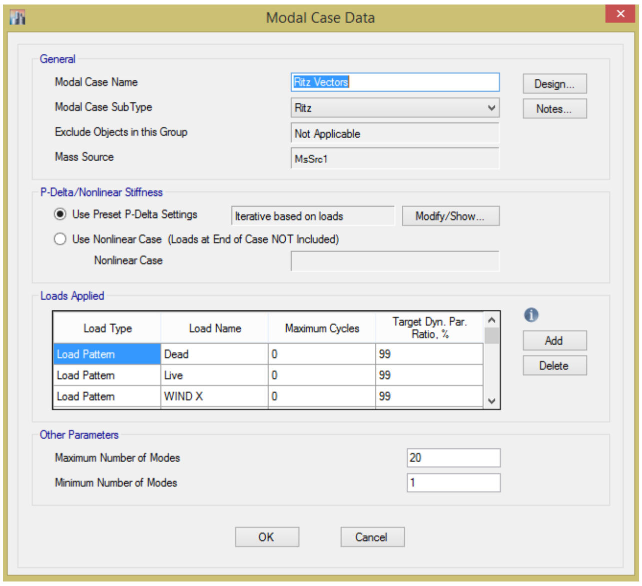

Fig. 9: Ritz vector method

E. Response spectrum method

It is a dynamic linear case. A plot showing the maximum response induced by ground motion in single degree of freedom oscillators of different fundamental time periods having same damping is known as Response spectrum.

The maximum response could be spectral acceleration, spectral velocity or spectral displacement. The response spectra can be plotted with any of the three parameters (acceleration, velocity and displacement) as ordinate and period/frequency as abscissa.
Factor Influencing Response Spectra:

- Energy release mechanism
- Epi central distance
- Focal depth
- Soil condition
- Richter magnitude
- Damping in the system
- Time period of the system

However, the final maximum response, r_{max} shall be obtained by combining the response in each mode of vibration using the modal combinations rules.
Some of the modal combinations rules commonly used are described here.

- Absolute Sum (ABSSUM) Method,
- Square Root of Sum of Squares (SRSS) method,
- Complete Quadratic Combination (CQC) method

The below figure 10 shows the input data of response spectrum function based on IS 1893-2002 (part1)

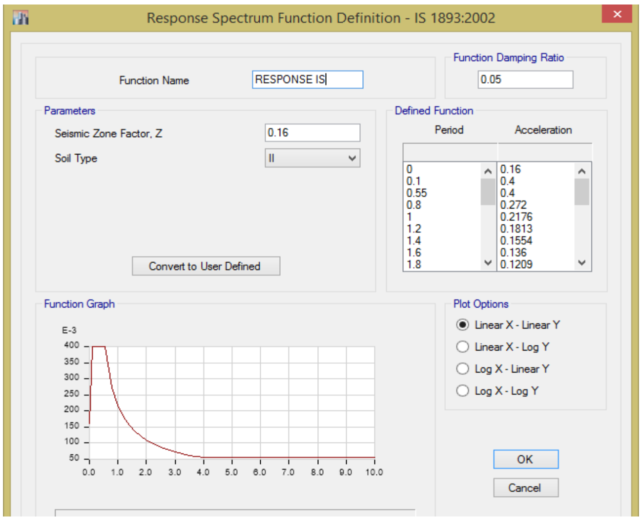

Fig. 10: Response spectrum function

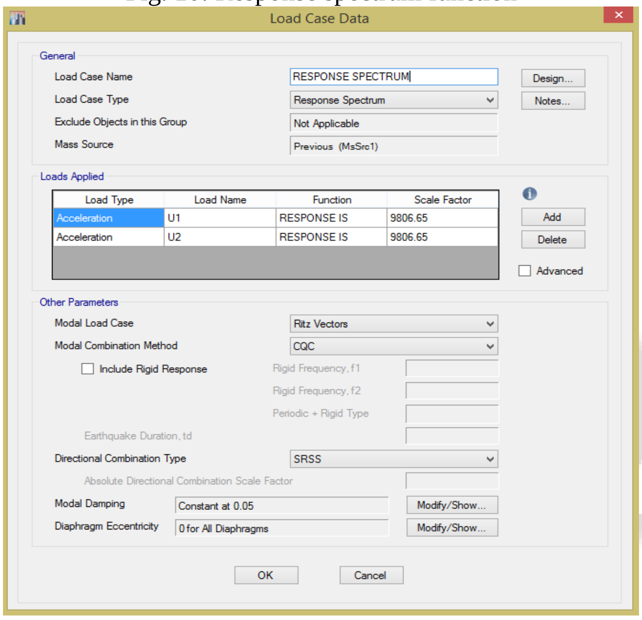

Fig. 11: Response spectrum load case

In ETABS 2015 the cases (Response spectrum) considered are,

Modal load case = Ritz vectors
Modal combination method = CQC method
Directional Combination type = SRSS method
The damping ratio = 5%
Soil type = Medium (II)

F. Time History analysis

Dynamic non-linear case considered

Time History analysis is a step by step procedure where the loading and the response history are evaluated at successive time increments, Δt – steps.

– A time history function may be
– A list of time and function values or
– A list of function values that are assumed to occur at equal spaced intervals.
– The function values in a time history function may be
– Ground acceleration values or
– Multipliers for specified load cases (force or displacement).

During each step the response is evaluated from the initial conditions existing at the beginning of the step (displacements and velocities) and the loading history in the interval. With this method the nonlinear behaviour may be easily considered by changing the structural properties (e.g. stiffness, k) from one step to the next.

Therefore this method is one of the most effective for the solution of nonlinear response, among the many methods available. The closer the spacing of time steps, the more accurate the solution will be.

First we have to define Time History function like Response spectrum analysis in Etabs program. The function is chosen as Matched to Response spectrum and named as time history function.

Seismic input to nonlinear dynamic analyses of structures is usually defined in terms of acceleration time series (time history function) whose response spectra are compatible with a specified target response spectrum. Various methods have been developed to modify a reference time series so that its response spectrum is compatible with a specified target spectrum.

Two of the most widely used methods, namely the

– Frequency Domain Method
– The Time Domain Method

The time domain method is generally considered a better approach for spectral matching since this method adjusts the acceleration time histories in the time domain by adding wavelets.

A wavelet is a mathematical function that defines a waveform of effectively limited duration which has a zero average. The wavelet amplitude typically starts out at zero, increases, then decreases back to zero. So time domain method is used.

The time history has 1500 data points at equal spacing of 0.02 seconds.

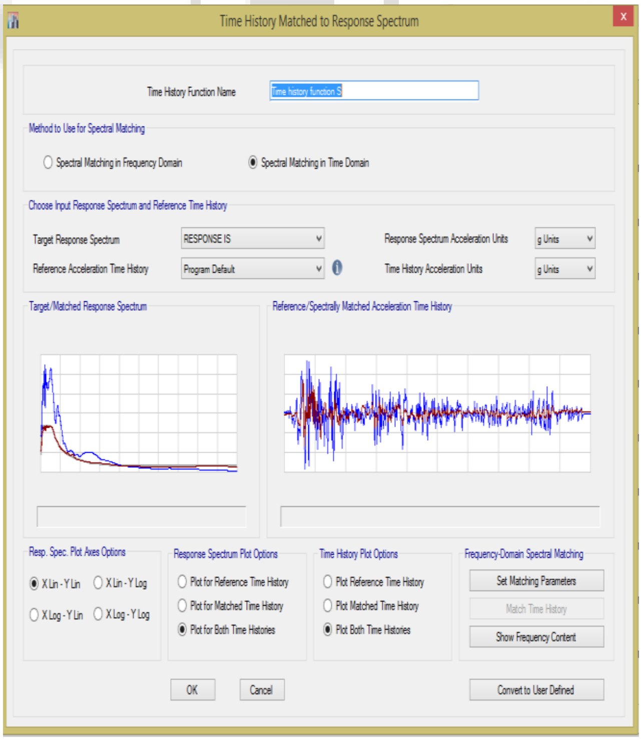

Fig. 12: Time history function

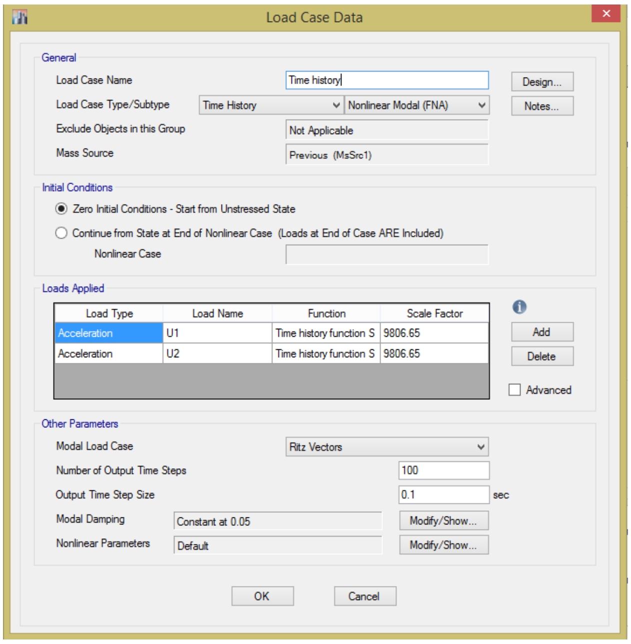

Fig. 13: Time history load case

Nonlinear modal time history analysis is also called Fast Nonlinear Analysis (FNA). It is a highly efficient, special purpose algorithm for analysing structures with limited nonlinearities. It is generally more accurate and efficient than direct integration time history analysis.

IV. Results and Discussions

The length of shear wall in x and y directions is same and is equal in model 2, model 3, and model 4.

Direction	Model 1 mm	Model 2 mm	Model 3 mm	Model 4 mm
DL	0.2 (in Y)	0.1 (in Y)	0.2 (in Y)	0.1 (in Y)
LL	0.04765 (in Y)	0.02467 (in Y)	0.03615 (in Y)	0.04516 (in Y)
WL X	38.1	5.4	3.7	1.7
WL Y	42	5.5	3.7	1.7
EQ X	27.5	5.7	3.8	1.7
EQ Y	30.2	5.8	3.9	1.7
Response spectrum	101 (in Y)	44.1 (in Y)	29.4 (in Y)	13.4 (in Y)
Time history	94.9 (in Y)	39.7 (in Y)	29.4 (in Y)	11.1 (in Y)

Table 1: Maximum displacements results

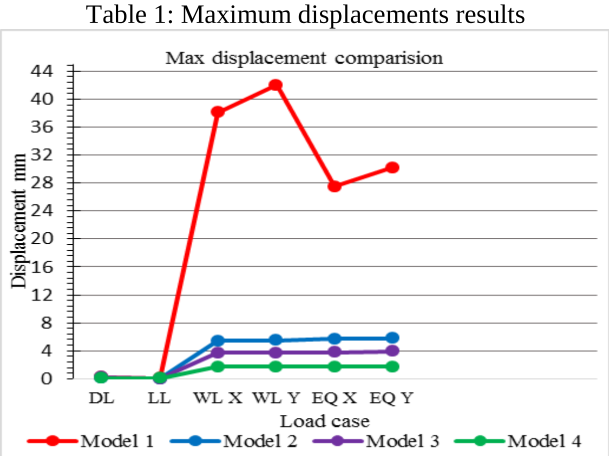

Fig. 14

Story	Elevation m	Model 1 mm	Model 2 mm	Model 3 mm	Model 4 mm
10	30	27.5	5.7	3.8	1.7
9	27	26.5	5	3.4	1.5
8	24	24.8	4.3	2.9	1.3
7	21	22.4	3.5	2.4	1.1
6	18	19.6	2.8	1.9	0.9
5	15	16.4	2.1	1.4	0.7
4	12	13	1.5	1	0.5
3	9	9.3	0.9	0.6	0.3
2	6	5.6	0.5	0.3	0.2
1	3	2.1	0.1	0.1	0.1
Base	0	0	0	0	0

Table 2 EQ X displacements

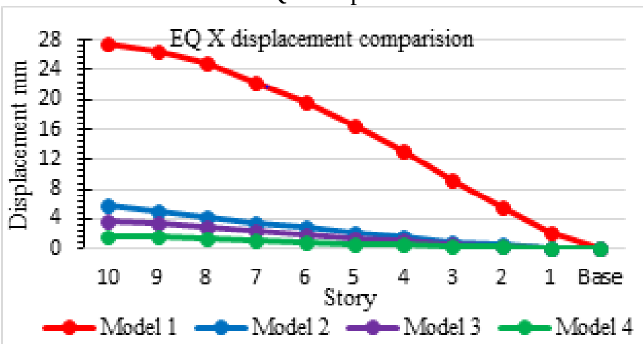

Fig. 15:

Story	Elevation mm	Model 1 mm	Model 2 Mm	Model 3 mm	Model 4 mm
10	30	30.2	5.8	3.9	1.7
9	27	29.1	5.1	3.4	1.5
8	24	27.2	4.3	2.9	1.3
7	21	24.7	3.6	2.4	1.1
6	18	21.6	2.8	1.9	0.9
5	15	18.2	2.1	1.4	0.7
4	12	14.4	1.5	1	0.5
3	9	10.4	0.9	0.6	0.3
2	6	6.4	0.5	0.3	0.2
1	3	2.5	0.1	0.1	0.1
Base	0	0	0	0	0

Table 3: EQ Y displacements

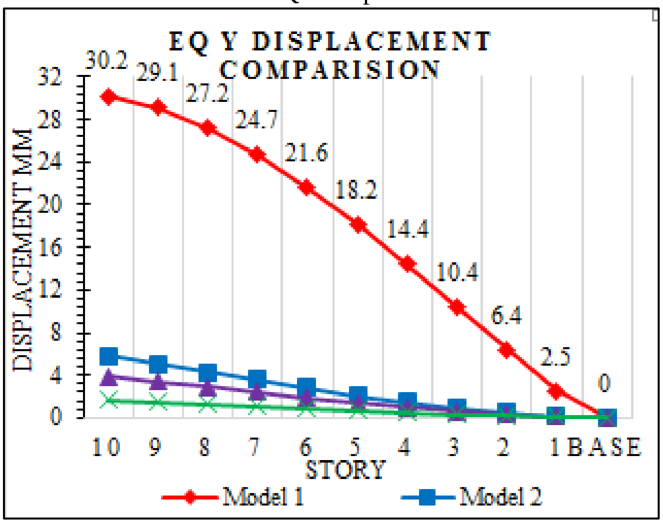

Fig. 16:

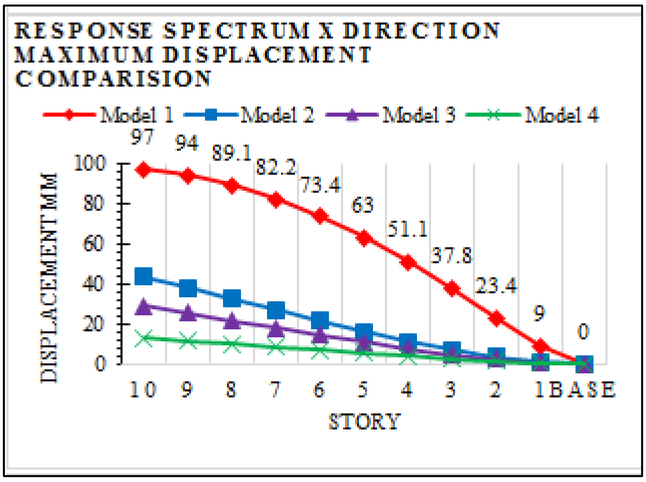

Fig. 17:

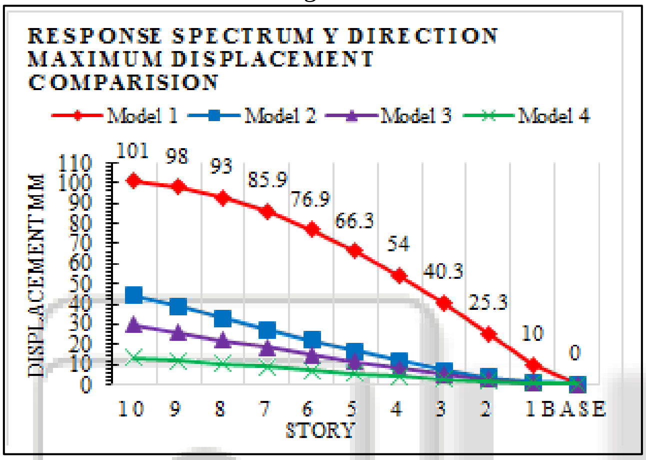

Fig. 18:

Story	Elevation m	Model 1	Model 2	Model 3	Model 4
10	30	0.000352	0.00024	0.00016	6.3E-05
9	27	0.000577	0.000245	0.000163	6.7E-05
8	24	0.000778	0.000246	0.000164	6.9E-05
7	21	0.00094	0.000242	0.000162	6.9E-05
6	18	0.001063	0.000231	0.000155	6.8E-05
5	15	0.001151	0.000213	0.000143	6.4E-05
4	12	0.001209	0.000186	0.000125	5.8E-05
3	9	0.001231	0.000151	0.000102	4.9E-05
2	6	0.001167	0.000105	7.2E-05	3.8E-05
1	3	0.000712	4.7E-05	3.5E-05	2.4E-05
Base	0	0	0	0	0

Table 4: Story drift in EQ X direction

V. CONCLUSIONS

This study deals with the analytical investigation of a structure subjected to gravity and lateral loads. Based on the results and comparisons the following conclusions are drawn.

The reduction in displacement is greatly achieved using slab shear¬wall.

The reduction in story drifts of about is achieved using slab shear¬wall.

The maximum spectral acceleration achieved in Shear wall models than column beam model1.

Base on the above results lateral load resisting capacity of structure is Model 4>Model 3> Model 2> Model . Placement of shear wall inside mid (Model 4) greatly resisted the lateral loads other than shear wall Models (2, 3) at outer corner and outer mid for the same length.

All the types of buildings whose length is same in X & Y direction, placing the shear wall like Model 4 would give the best resistant to lateral loads.

REFERENCES

[1] IS 1893-2002 Criteria for Earthquake Resistant Design of Structures Part 1 General Provisions and Buildings.
[2] Earthquake tips, C.V.R. MURTY
[3] IS 875-1987 Code of Practice for Design Loads (other than earthquake) for Buildings and Structures.
[4] IS 13920, (1993), “Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces”. Etabs manual.
[5] J. N. S. Suryanarayana Raju, “Detailed Analysis and Design of Slab-Wall System and Column-Beam
[6] System Concrete Building”, IJSRD, Volume 2, February 2014.