INTERNATIONAL JOURNAL FOR TRENDS IN ENGINEERING & TECHNOLOGY
VOLUME 6 ISSUE 1 – JUNE 2015 - ISSN: 2349 - 9303

Linear Static And Dynamic Analysis Of Shear Wall Building In Different Soil Conditions

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Abstract— The main objective of earthquake engineering is to design a structure with a minimal structural damage during the time of earthquakes. In recent days the usage of shearwall has become a vital role in high raised structures, in resisting lateral loads to a great extent. This paper aims towards the analysis of a reinforced concrete G+12 structures with response spectrum method of analysis and linear time history analysis in different soil conditions i.e., hard, medium and soft soils. Pile Foundation system is adopted for present structure. In these paper two regular plans has been developed for analysis purposes , a model without shearwall and a model with shearwall at the corners has been projected. Soil structure interaction is also included for both the structure in reducing the vibrations of structure which may results in increases for base shear, moment and torsion. In reducing the vibrations from the structure a dampers are set to be arranged in piles at a distance of 2 m from bottom, in distributing the vibrations from the structure to the soil and its surroundings. A complete analysis has been done in different soil conditions and earthquake parameters like story displacement, story drift and story shear are being compared in between the two models with shearwall and without shearwalls in different load cases. The residential high rise building is analyzed for seismic forces, analysis is being carried out by using standard package ETABS. Time history responses for the both the models with shear walls are evaluated

Keywords—Seismic analysis, Shear wall, Storey shear, Storey displacements, Time history responses.

I. INTRODUCTION

The reinforced concrete structural wall is an important lateral load resisting element. It is increasingly used by designers in new structures as well the rehabilitation of existing ones. There are models that represent the flexural behavior of walls to various degrees of accuracy. However, an efficient model is needed for accurate representation of the flexural and shear behavior of these walls. A macro model that represents the behavior of structural walls is developed.

Where the intensity of earthquake is more and where the bearing capacity of soil or week strata presents under the footings. Is weaker and where the intensity wind flow is more in such cases shear walls are adopted. Mainly shear wall are used to resist two types of forces are shear forces and uplift forces, connections are made in such a way that in transferring forces to shear walls, thus this transferring of lateral forces creates shear forces throughout the height of wall between the top and bottom shear wall connections.

The choice of using shear walls has been becoming more popular in earthquake proned areas, because shear walls are easy to construct of their reinforcement detailing of walls relatively straight forward and therefore easily implemented at site. Shear walls plays a major role in transferring lateral forces to next adjacent shear walls and other elements in widening the load path, other elements may be floors, foundation walls, slabs or footings, not only in resisting the lateral forces but also prevents from stiffness in preventing from floor and roof framing members from moving of their supports and also buildings that are sufficiently stiff will usually suffer less non-structural damage. In past earthquakes detailed buildings with shear walls have shown a very good performance and shear walls are being used as rehabilitation purposes as squat shear walls. Shear walls are efficient in minimizing earthquake damage in structural and non structural elements like glass windows and building contents

All the civil engineering structures involve some type of structural element with direct contact with ground. When the ground is subjected to external forces like earthquakes, which acts on these systems, which results neither the structural displacements nor the ground displacements, and both the displacements are independent of each other. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI). Conventional structural design concepts neglect the effect of soil-structure interaction. i.e., light structures in relatively stiff soil, such as simple rigid retaining walls and low raised reinforced concrete structures. However the effect of soil structure interaction plays a major role in high raised reinforced and steel structures, nuclear power plants and elevated highways on soft soils. A recent earthquake record proves that seismic behaviour of a reinforced concrete structure is highly influences not only by a response of super structure but also on sub structure of a building i.e. soil structure and foundation

Analysis of any structure i.e. regular or irregular are subjected to following type of analysis in determining the earth quake effects such as story displacements, story drifts, story stiffness etc. at story level.

a) Response spectrum analysis.
b) Linear Time history analysis

This method of analysis is considered to be the representation of the various processes that occur in the structure when it is subjected to time varying forcing functions, such as seismic excitations. For a linear analysis it is assumed that the structure is linear over the entire time history of their earthquake and forces which produced in the structure are directly proportional to the stresses generated in the structure. However this method gives an upper bound of forces generated in the structure as keeping these aspects in mind, a linear and non linear time history analysis of the model is proposed to be carried out.

Generally structures consists of multiple degrees of freedom systems, but when they are subjected to single point excitation at the base they behave as single degree of freedom systems. Response spectrum can be defined as it is a plot of responses with varying natural frequencies. Responses could be displacement, velocity or acceleration.

II. LITERATURE REVIEW

In 1998 A. Ghobarah M. Youssef explained about Modeling of reinforced concrete structural walls. A macro model that represents the behavior of structural walls is developed. The model consists of nonlinear springs connected by linear beam elements. In 2005, Christian Greifenhagen, Pierino Lestuzzi, explained about Static cyclic tests on lightly reinforced concrete shear walls. in This paper author addresses the strength and deformation capacity of squat reinforced concrete shear walls that are not designed for seismic actions. The seismic behavior of such walls is investigated in the framework of the study focusing on seismic evaluation of existing buildings. In 1991, A. Y. T. LEUNG, A. K. H. KWAN and W. E.ZHOU, explained about Static-dynamic distribution factors method for tall building analysis. A new approximate method of analyzing three-dimensional tall building structures is presented. In 1994, Y. L. Mo and Wen-Chang Shiau has been explained about, Effect of concrete strengths on dynamic response of framed shear walls. Hinges with ideal plastic properties in a regular plane frame. Dong-Guen Lee et al (2006) conducted study on Evaluation of seismic performance of multistory building structures based on the equivalent responses. In this study, an improved analytical method based on the equivalent responses of multistory building structures is proposed to estimate the inelastic seismic responses efficiently and accurately. Nishant K. Kumar et al (2013) have done Non-linear response of two-way asymmetric multistory building under

III. MODELING OF STRUCTURE

a) Geometry of structure

For carrying out complete earthquake analysis, a G+12 storied building has been considered

Details of the building:

Number of stories - 13
Number of bays along x-direction - 3
Number of bays along y-direction - 7
Height of the structure - 39.0m
Type of structure - special RC moment frame.
Seismic zone - IV
Type of soil -- - hard, medium and loose
Depth of slab (S1) --- - 150 mm
(S2) - 120mm
Unit weight of RCC - 25 kN/m^3
Beams (B1) --- - 400×600 mm
Columns (C1) - 450×.600 mm
Thickness of brick wall - 230 mm
Thickness of shear wall - 230mm
Clear cover of beam - 30 mm
Clear cover of column - 40 mm

b) Load calculations

Dead load due to slab = 3.75kN/m²
Dead load due to floor finish = 1.0kN/ m²
Live load = 2.0 KN/m²
Building type = Residential.

c) Material properties

The basic material properties used are as follows:

The material used for construction is reinforced concrete with M30 grade concrete and Fe415 grade reinforcing steel.

The stress-strain relationship used is as per IS456:2000.

d) Earthquake parameters

Seismic zone = IV
Zone factor = 0.24
Reduction factor = 5.0
Importance factor = 1.0.

e) Soil properties

Table.1 shows the properties of soil in different soil conditions

Property	Hard Soil	Soft Soil	Medium Soil
Shear modulus, G (kPa)	5850	3120	29300
Poisons ratio	0.35	0.45	0.3-0.35
Mass density (kN/m^3)	20.6	17.16	17.16

IV. ANALYSIS

a) Analysis of soil resting on piles

Table.2 shows the formulae in determining the soil properties in all the directions

Direction	Stiffness	Damping	Mass
Vertical	(4Gr)/(1-v)_	1.79√Kpr^3	$1.50pr^3$
Horizontal	18.2Gr*(1-v^2)/(2-v^2)	1.08√Kpr^3	$0.28pr^3$
Rotation	$2.7Gr^3$	0.47√Kpr^3	$0.49pr^3$
Torsion	$5.3Gr^3$	1.11√Kpr^3	$0.70pr^3$

Two models has been developed for response spectrum and time history analysis i.e., model 1 with no shear walls and model 2 with the positioning of shearwall at the corners

b) model 1

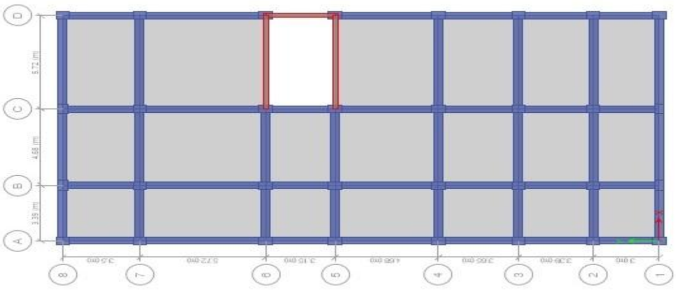

Fig.1 represents plan of model 1

3-D model

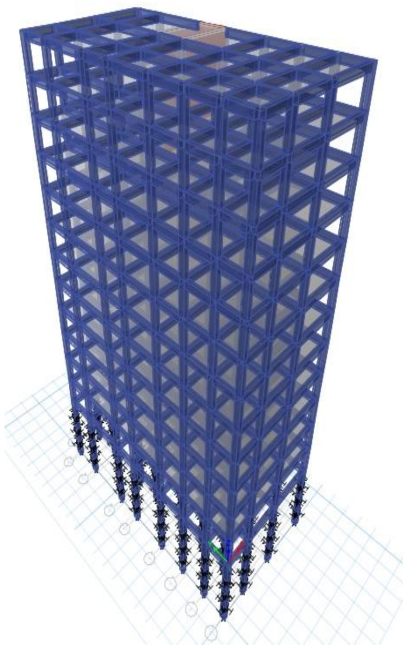

Fig.2 represents 3-D model of model 1

Model –II

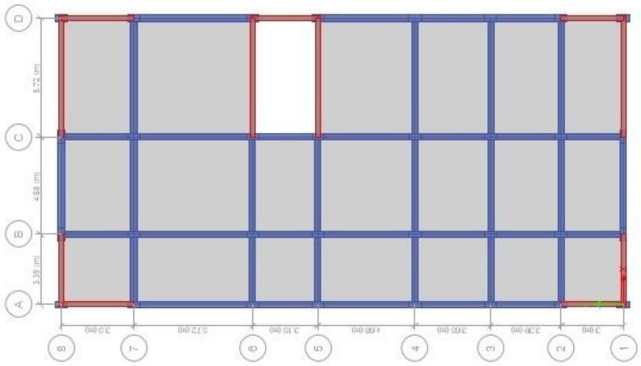

Fig3 Represents plan view of model –II

3D-Model

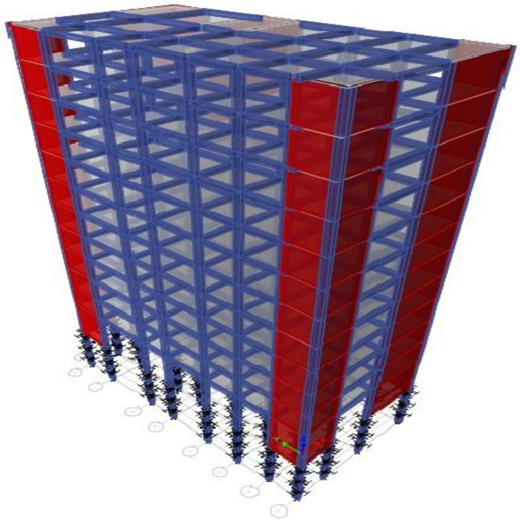

Fig.4 represents the 3D view of model 2

c) .Assigning of stiffness and damping values at pile location

Table.3 shows the stiffness values in hard, medium and soft soil conditions in all the directions

Stiffness (kN/m)	Hard	Medium	Soft
Translation-X	229668.97	93462	25193.45
Translation-Z	166153.84	67615	8509.09
Translation-Y	229668.97	93462	25193.45
Rotational –X (kN-m)	10251.56	4171.81	444.23
Rotational –Z	20123.43	8189.12	872.01
Rotational –Y	10251.56	4171.81	444.23

Table.4 shows damping values in hard, medium and soft soil in all the directions

Stiffness (kN/m)	Hard	Medium	Soft
Translation-X	539.45	314.08	163.06
Translation-Z	760.48	442.77	157.07
Translation-Y	539.45	314.08	163.06
Rotational –X (kN-m)	49.59	28.87	9.42
Rotational –Z	164.117	95.55	31.18
Rotational –Y	49.59	28.87	9.42

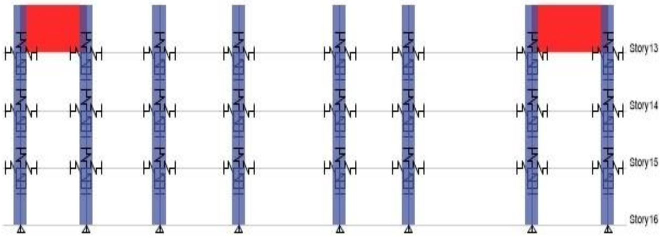

Fig.5 represents assigning of dampers

Dampers are assigned to the piles at a distance of 2 m from bottom.

e). Equivalent static analysis:

The natural period of the building is calculated by the expressions T= 0.075 x h0.75 for bare frame and T = 0.09h d for in filled frame as given in IS 1893 (Part 1) -2002, wherein h is the height and d is the base dimension of the building in the considered direction of vibration. The lateral load calculation and its distribution along the height are done as per IS: 1893 (part 1)-2002. The seismic weight is calculated using full dead load plus 25% of live load.

f). Time history analysis:

Time-History analysis is a step-by-step procedure where the loading and the response history are evaluated at successive time increments, Δt – steps. 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 non-linear behaviour may be easily considered by changing the structural properties (e.g. stiffness, k) from one step to the next. The parameters provided are Z=0.24, considering zone factor IV, I=1, considering residential building. R=5.0, considering special RC moment resisting frame.(SMRF).

V. RESULTS AND DISCUSSIONS:

From the analysis results obtained following parameters are taken into consideration for the present study.

a). Storey displacements:

When a earthquake force acts on a structure, tends to deflect based on intensity of seismic waves. Deflection at story level is independent to next or below stories

b). base shear:

Base shear is the maximum expected lateral force that will occur due to seismic ground motion at the base of structure.

The seismic base shear V_B in a given direction shall be determined in accordance with the following equation:

Where: $V_B = A_h W$

A_h = the seismic response coefficient

$A_h = \frac{S_a Z I}{2RG}$

Z = Zone factor given in

Sa/g = average response acceleration coefficient

R = the response reduction factor

I = the importance factor depending upon th

12	36	24.5	1.3	24.8	1.2	24.8	1.2
11	33	23.1	1.4	23.4	1.3	23.4	1.3
10	30	21.5	1.4	21.8	1.3	21.8	1.3
9	27	19.7	1.4	20	1.3	20	1.3
8	24	17.8	1.3	18.1	1.3	18.1	1.3
7	21	15.7	1.2	16.1	1.2	16.1	1.2
6	18	13.6	1.1	14	1.1	14	1.1
5	15	11.5	1	11.8	1	11.8	1
4	12	9.3	0.8	9.7	0.8	9.7	0.8
3	9	7.1	0.7	7.5	0.6	7.5	0.6
2	6	5	0.5	5.4	0.5	5.4	0.5
1	3	3	0.3	3.4	0.3	3.4	0.3
Base	0	1.2	0.1	1.5	0.1	1.5	0.1

Table.5 Deflections at each story in all soil conditions for a model 1 are tabulated below

Story	Height	Hard		Medium		soft	
		X-Dir	Y-Dir	X-Dir	Y-Dir	X-dir	Y-Dir
12	36	24.5	1.3	24.8	1.2	26.5	1.2
11	33	23.1	1.4	23.4	1.3	24.8	1.3
10	30	21.5	1.4	21.8	1.3	22.1	1.3
9	27	19.7	1.4	20	1.3	19.6	1.3
8	24	17.8	1.3	18.1	1.3	19.4	1.2
7	21	15.7	1.2	16.1	1.2	16.9	1.1
6	18	13.6	1.1	14	1.1	13.8	1
5	15	11.5	1	11.8	1	11.5	0.9
4	12	9.3	0.8	9.7	0.8	9.9	0.8
3	9	7.1	0.7	7.5	0.6	7.8	0.6
2	6	5	0.5	5.4	0.5	5.9	0.4
1	3	3	0.3	3.4	0.3	3.4	0.2
Base	0	1.2	0.1	1.5	0.1	1.1	0.1

Table.6 story shear at story level in all soil conditions for a model 1

Story	height	Hard(kN)	Medium(kN)	soft(kN)
12	36	139.70	166.20	192.77
11	33	269.92	329.43	386.87
10	30	372.36	466.73	554.99
9	27	453.94	583.17	701.36
8	24	522.18	684.22	830.30
7	21	582.65	773.89	944.87
6	18	638.25	854.27	1046.53
5	15	690.12	926.07	1135.67
4	12	738.66	989.49	1212.40
3	9	783.72	1044.57	1276.79
2	6	823.47	1090.60	1328.44
1	3	852.99	1124.60	1365.02
Base	0	861.26	1135.30	1376.09

c). story drift

Story drift can be defined as the lateral displacement of one level relative to the level above or below it: As per Clause no. 7.11.1 of IS 1893 (Part 1): 2002, the storey drift in any storey due to specified design lateral force with partial load factor of 1.0. By comparing the drift values obtained for 2 models obtained, it could be seen that in models with shear wall provided at corners the inter story drift has considerably been reduced when compared to the model 1.

Table.7 story drift at in all the soil conditions for a model 1

Story	height	Hard	Medium	soft
12	36	0.000551	0.00055	0.000553
11	33	0.000558	0.000558	0.000561
10	30	0.000592	0.000588	0.000591
9	27	0.000637	0.000633	0.000635
8	24	0.000674	0.00067	0.000672
7	21	0.000702	0.000698	0.0007
6	18	0.00072	0.000716	0.000718
5	15	0.000726	0.000723	0.000725
4	12	0.00072	0.000718	0.000721
3	9	0.0007	0.000701	0.000704
2	6	0.000666	0.000669	0.000673
1	3	0.000614	0.000623	0.000625
Base	0	0.000491	0.000531	0.000502

Table .8 Deflections at each story in all soil conditions for a model 2 are tabulated below

Story	Hard		Medium		soft	
	X-Dir	Y-Dir	X-Dir	Y-Dir	X-dir	Y-Dir
12	23.6	10.6	23	0.4	24	0.4
11	22	9.7	21.3	0.3	22.4	0.3
10	20.3	8.8	19.5	0.3	20.7	0.3
9	18.6	8	17.6	0.3	19	0.3
8	16.9	7.1	15.8	0.3	17.2	0.3
7	15.2	6.2	13.9	0.3	15.4	0.3
6	13.4	5.4	12	0.2	13.7	0.2
5	11.7	4.6	10.1	0.2	11.9	0.2
4	10	3.8	8.3	0.2	10.2	0.2
3	8.3	3.1	6.5	0.1	8.5	0.2
2	6.8	2.4	4.8	0.1	6.9	0.1
1	5.3	1.7	3.3	0.1	5.4	0.1
Base	4	1.2	1.9	0.1	4.1	0.2

Table.9 story shear at story level in all soil conditions for a model 2

Story	height	Hard(kN)	Medium(kN)	soft(kN)
12	36	441.33	-323.3058	-294.22
11	33	90.40	-669.8989	-609.63
10	30	-211.04	-967.6267	-880.57
9	27	-466.77	-1220.2004	-1110.42
8	24	-680.55	-1431.3315	-1302.56
7	21	-856.12	-1604.7311	-1460.36
6	18	-997.24	-1744.1106	-1587.2
5	15	-1107.67	-1853.1812	-1686.46
4	12	-1191.18	-1935.6542	-1761.51
3	9	-1251.51	-1995.241	-1815.74
2	6	-1292.43	-2035.6528	-1852.51
1	3	-1317.14	-2060.0566	-1874.72
Base	0	-1321.37	-2064.2364	-1878.53

Table.10 story drift for a model 2 in all soil conditions

Story	height	Hard	Medium	soft
12	36	0.000545	0.000588	0.000557
11	33	0.000556	0.0006	0.000563
10	30	0.000566	0.000611	0.000574
9	27	0.000574	0.000621	0.000583
8	24	0.00058	0.000627	0.000589
7	21	0.000581	0.000628	0.000591
6	18	0.000577	0.000623	0.000587
5	15	0.000566	0.00061	0.000576
4	12	0.000549	0.00059	0.000559
3	9	0.000524	0.00056	0.000534
2	6	0.000492	0.000523	0.000503
1	3	0.000843	0.000679	0.000975
Base	0	0.000931	0.000636	0.001059

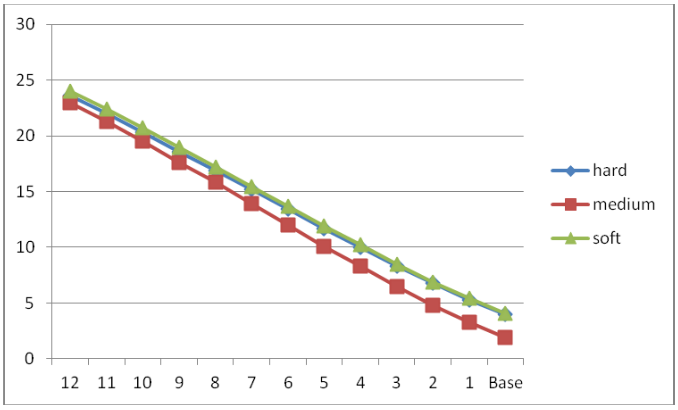

Fig.6 represents variation in deflection at story level in different soil conditions

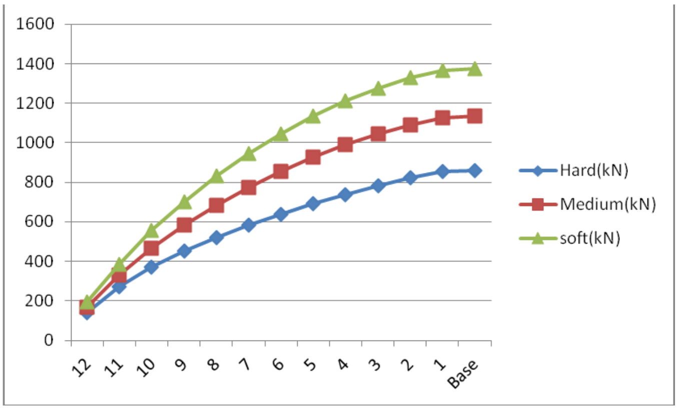

Fig.7 represents variation of story shear in different soils

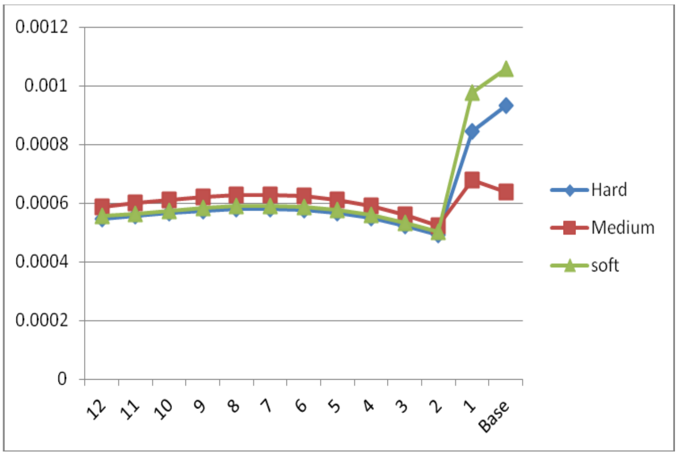

Fig.8. represents variation of story drift in different soil conditions

d). linear time history analysis results

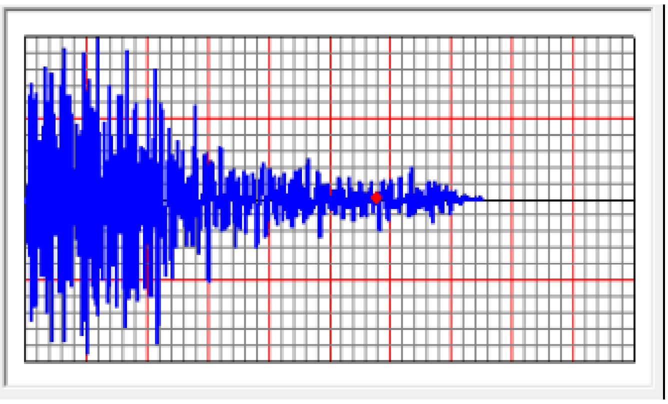

Fig.9 Elcentro graph.

Elcentro graph is used for linear time history analysis

Time history analysis of both the models at a particular joint is explained below with the help of graphs in between various parameters.

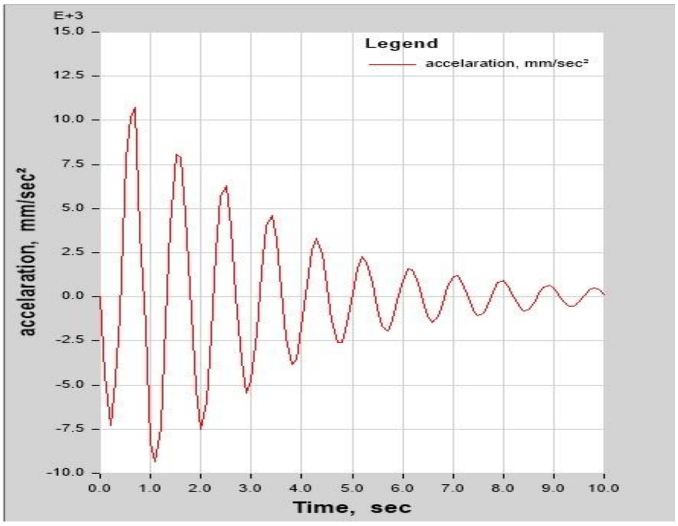

Fig.10 graph shows Time Vs acceleration

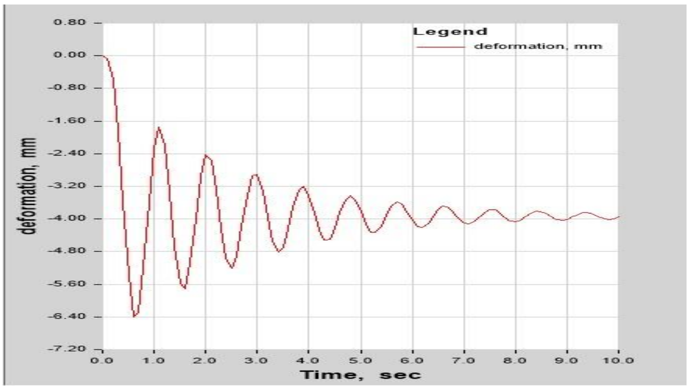

Fig.11 Time vs. displacement

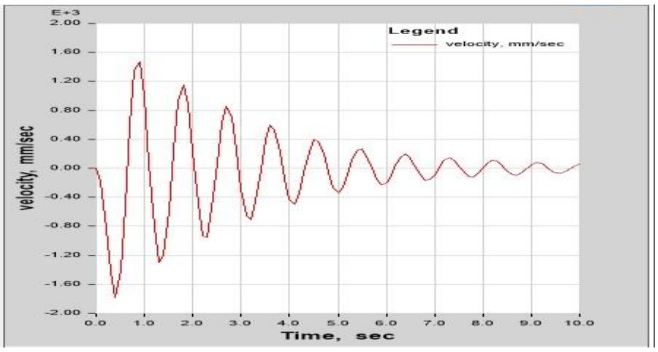

Fig.12. time vs velocity

VI.CONCLUSION

From response spectrum and linear time history analysis of a 13 storied structure, it is observed that building with shear wall at the corners has a significance role, during the time of earthquake. It is clearly evaluated that earthquake parameters like story displacements are consistently more in model 1 i.e, without any shear walls.

Assigning of dampers and springs to the pile foundation results the, behaviour of soft soil almost equal to the medium soil in all the cases, because dampers plays a major role in bearing the vibrations from the structure when a primary or secondary waves acts on a structure.

Model with shearwalls at the corners decreases the story drift of the building. Providing shear walls at adequate locations substantially reduces the displacements due to earthquake. the model analysis clearly demonstrated that in case of stiff buildings soil parameters plays a major role on the vibrational behavior of structure.

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