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Evaluation of Suitability of Dampers in different Soil Condition for Multi Storey Buildings under Seismic Conditions

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ABSTRACT

We are living in the age of multi storey building due to fast urban development where everyone want to live in the city centre to avail all comfort and accessibility to all facilities needed for daily to day life which resulted in huge demand of high rise and multi storey buildings. Engineers need to find out the different structural arrangements to provide robust design to withstand the earthquake which are common now a d Now-a-days without compromising the occupants comforts. Earthquake cause heavy deflections of the building even if it is design to withstand the earthquake forces safely which cause great discomfort and fear to the occupants in addition to the damage to the finishes and cladding/glazing of the buildings. I order to eliminate large displacement ill effects without designing the stiff building structure which may greater forces at base in terms of base share, dampers has been introduces in the high rise construction industry. This paper is the outcome of the structural analysis study conducted on 13 storey building models to compare the effects of utilizing dampers on building drifts using E-TABS software. After detailed analysis and comparison using E-TABS software it is concluded that the building with dampers performs better under seismic load conditions than the building without dampers under the same loadings and dampers effectively works to reduce to building drifts under seismic loading conditions.

Keywords : E-TABS, Dampers, seismic load, Storey displacement, storey shear, storey drift, building drift and base shear.

I. INTRODUCTION

Earthquake is a spasm of a ground shaking caused by a sudden release of energy in the earths lithosphere (i.e. the crust plus a part of the upper mantle).This energy arises mainly form stresses built up during the tectonic processes, which consist of interaction between the crust and the interior of the earth. In some parts of the world earthquakes are associated with volcanic activities.

Earthquake is essentially a sudden and transient motion and series of motions of the earth's surface originating in a limited underground region due to disturbance of the elastic equilibrium of the rock mass and spreading from there in all directions The source of the elastic energy i.e. the focal region is generally an extended volume of rock mass of irregular shapes. The centroid of this volume is the 'focus'. The centre of vertical projection of this volume of rock mass on the earth's surface is called the 'epicentre, of the earthquake and the distance from the epicentre to any point of interest is called the 'epicentre distance' as show in the figure below. A number of small size earthquakes take place before and after a big earthquake (i.e. the main shock). Those occurring before the big one is called fore shocks and the ones after are called aftershocks.

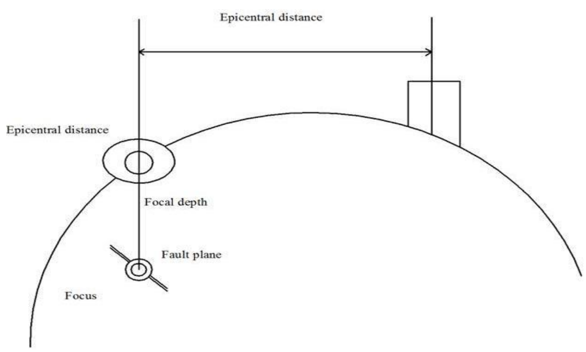


Figure 1. Graphical representation of occurrence of earthquake

Table 1 : Classification of earthquakes based on their focus

Type	Depth
Deep focus earthquakes	Exceeding 300 km
Intermediate focus earthquakes	Between 55-300 km
Shallow focus earthquakes	Less than 55 km

1.1 Harmful effects of earthquakes

- Cracks and fissures are formed on the ground.
- Fissures may change river courses and floods may occur.
- Landslides occur on hill slopes.
- Avalanches occur in snow covered hill slopes.

1.2 Seismic Behaviour and Design of Multistoried Buildings

Structurally a multi-storey building may consist of a frame with rigid connections, a frame with braces, parallel sets of shear wall, box units or a combination of these sets of elements. Design of multi-storey buildings for earthquake motions requires the consideration of several factors such as probable intensity of earthquake, stiffness of the structure and its ductility and without impairing its functional utility.

"The response of any structure during an earthquake is a dynamic phenomenon and the principles of dynamics must be used to explain the behaviour of the buildings during ground motions. Two broad approaches of earthquakes analysis of multi-storeyed structure in present day are:

I. Equivalent static approach
II. Dynamic method of analysis

1.3 Assumptions

The following assumptions shall be made in the earthquake resistant design of structures.
Earthquake causes impulsive ground motion, which is complex and irregular in character, changing in period and amplitude each lasting for small duration. Therefore, resonance of the type as visualized under steady state sinusoidal excitations will not occur, as it would need time to build up such amplitudes.

- Earthquakes are not likely to occur simultaneously with wind or maximum flood or maximum sea waves.
- The value of elastic modulus of materials wherever required may be taken for static analysis unless a more definite value is available to us in conditions.

IS 1893 (PART 1):2002
This code of practice recommends only one method of design i.e. RESPONSE SPECTRUM METHOD

1.4 Response Spectrum Method

The response acceleration is obtained for the natural period, damping of the structure and the design value of horizontal seismic coefficient is computed using the following expression.
Ah = (Z/2)*(I/R)*(Sa/g)
Where Ah is average horizontal acceleration,
Z is zone factor,
R is response reduction factor
There are only four zones according to the revised codes.
They are Zone II, Zone III, Zone IV and Zone V
Their values are as follows:
Zone II 0.10
Zone III 0.16
Zone IV 0.24
Zone V 0.36
Here the value of (Sa/g) max is 2.5(for 5% damping)
Important factor I=1.0
Base shear (VB) is given by the following formula
VB = Ah *W
Where Ah=(Z/2)*(I/R)*(Sa/g)
Design of live loads for seismic weight calculations
For various loading classes as specified in IS: 1893-2002 the horizontal earthquake force shall be calculated for full dead load and percentage of live loads as given below:

Load class percentage of design live loads
Upton and including 3.0 KN/m^2 =25%

More than 3.0 KN/m^2 = 50%
For calculating the earthquake force on roofs, the live load may not be considered

II. ANALYTICAL INVESTIGATION

For carrying out complete analysis of the structure, following methods are utilized.

2.1 Response Spectrum Method

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions. This chapter deals with response spectrum method and its application to various types of the structures. The coal provisions as per IS: 1893 (Part 1)-2002 code for response spectrum analysis of multi-story building is also summarized.

2.2. Time History Analysis

The response of buildings to earthquakes is a complex, three dimensional, nonlinear, dynamic problems. Limitations in technology and the depth of our understanding of this problem have led to the profession developing a number of simplified methods for representing it, most of which disregard one or more of its fundamental aspects: the LDP, or Response Spectrum Analysis, ignores nonlinearity; the NSP, or Pushover Analysis, ignores dynamic effects; the LSP, or Equivalent Static Analysis, ignores both. In contrast, the Nonlinear Dynamic Procedure (NDP), or Time History Analysis, attempts to fully represent the seismic response of buildings without any of these major simplifying assumptions.

Commonly cited reasons for using conventional analysis techniques rather than NDP include:

- Relative computational expense of the procedure
- Need for more detailed input including appropriate hysteresis rules and appropriately scaled acceleration records
- Lack of readily available computer software.

NDP is a relatively simple procedure to implement and extract results from. Recent developments in performance-based design including FEMA 356 [3] tend to push the NSP rather than the NDP, presumably for reasons such as those mentioned above. This seems unusual, given that the level of detail required to define the analysis model for these two procedures is almost identical, and in practice, the NSP is more cumbersome to implement, and has at least as much room for error. Concerns with the determination of appropriate earthquake records for NDP are derived more from inadequacies inherent in the conventional approach of using acceleration response spectra to define input loading. Time histories with similar response spectra can result in very different responses when used with the NDP. This indicates that acceleration response spectra do not contain all the information representing structural response, a problem that is largely ignored in conventional methods. The choice of time history records with appropriate source characteristics for a given site can overcome this perceived disadvantage with NDP.

III. MODELING USING FINITE ELEMENT SOFTWARE ETAB

3.1. Geometry of the Structure

In carrying out the complete earthquake analysis, a G+12 storied building is considered.

Details of building
Number of stories = 13
Number of bays along x-direction =3
Number of bays along y-direction =7
Height of the structure =36.0m
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) - 300X350 mm
Columns (C1) -450X300 mm
Thickness of brick wall= 230 mm

Thickness of shear wall = 230mm
Clear cover of beam= 25 mm
Clear cover of column =40 mm

3.2. Load Calculations

Table. 3.1 types of loads acting on structure

Type of Load	Loads
Dead load due to slab	3 kN/m²
Dead load due to floor finish	1. 0kN/ m²
Live load	4 KN/m²
Building type	Multi storied

Loads are assumed as per IS 456:2000, IS 875 Part I, II and III

3.3. Material Properties

The basic material properties used are as follows:
The materials used for construction are M30 grade concrete and Fe415 grade reinforcing steel. The stress-strain relationship used as per IS456:2000.

3.4. Earthquake Parameters

Table. 3.2 earthquake parameters

Parameters	Value
Seismic Zone	IV
Zone Factor	0.24
Reduction factor	5.0
Importance factor	1.0

3.5 Base Shear Calculations

3.5.1 Seismic Weight of Floors

The seismic weight of each floor is its full dead load plus appropriate amount of imposed load, as specified in 7.3.1 and 7.3.2 of IS 1893 part 1 2002 While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey.

3.5.2 Seismic Weight of Building

1) The seismic weight of the whole building is the sum of the seismic weights of all the floors.

3.5.3 Soil Properties

Table 3.3 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

3.5.4 Expressions Used in Finding Stiffness and Damping Values

Table 3.4 shows the formulae in determining the soil properties in all the directions

Direction	Stiffness	Damping	Mass
Vertical	(4GR)/(1-V)_	$1.79\sqrt{KPR^3}$	$1.50PR^3$
Horizontal	$18.2GR*(1-V^2)/(2-V^2)$	$1.08\sqrt{KPR^3}$	$0.28PR^3$
Rotation	$2.7GR^3$	$0.47\sqrt{KPR^3}$	$0.49PR^3$
Torsion	$5.3GR^3$	$1.11\sqrt{KPR^3}$	$0.70PR^3$

3.5.5 Stiffness Values

Table. 3.5 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

3.5.6 Damping Values

Table. 3.6 shows damping values in hard, medium and soft soil in all the directions

Damping (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

IV. MODELING

4.1 MODEL-1

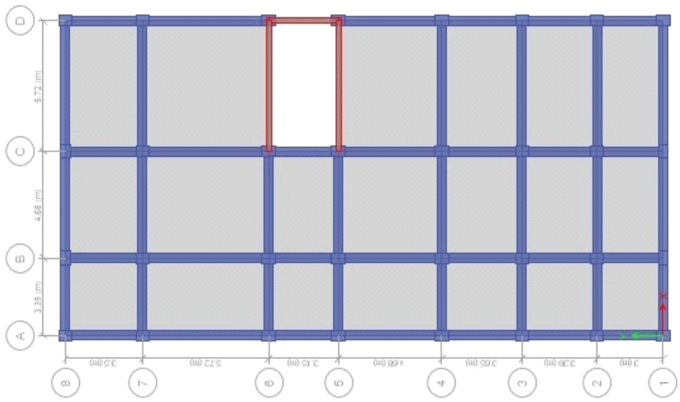


Figure 2. Represents Plan of Model 1

4.2 3-D MODEL

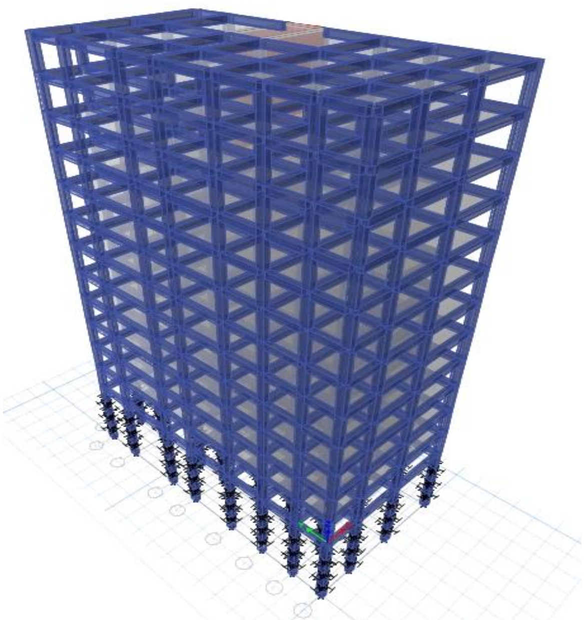


Figure 3. represents 3-D model of model 1

4.3 MODEL 2

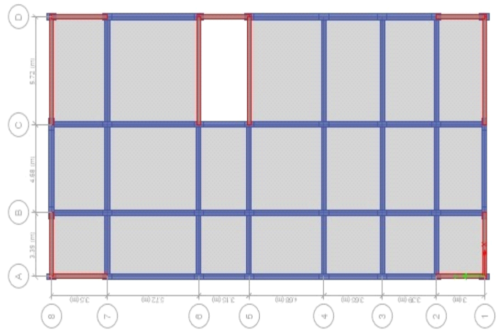


Fig. 3.3 Represents plan view of model –I

4.4 3-D MODEL

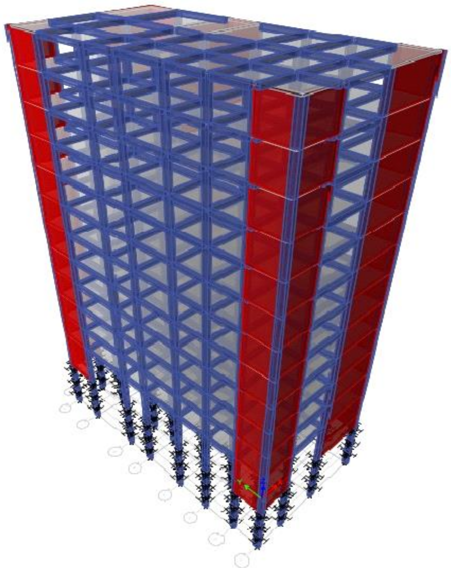


Figure 4. represents the 3D view of model 2

4.5 Assigning of Dampers

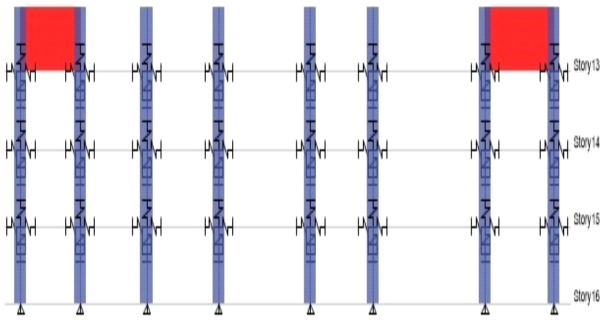


Figure 5. represents assigning of dampers

Springs and Dampers are arranged in the piles at a distance of 2 m from the bottom.

4.6 Assigning of Stiffness and Dampi Ng Parameters

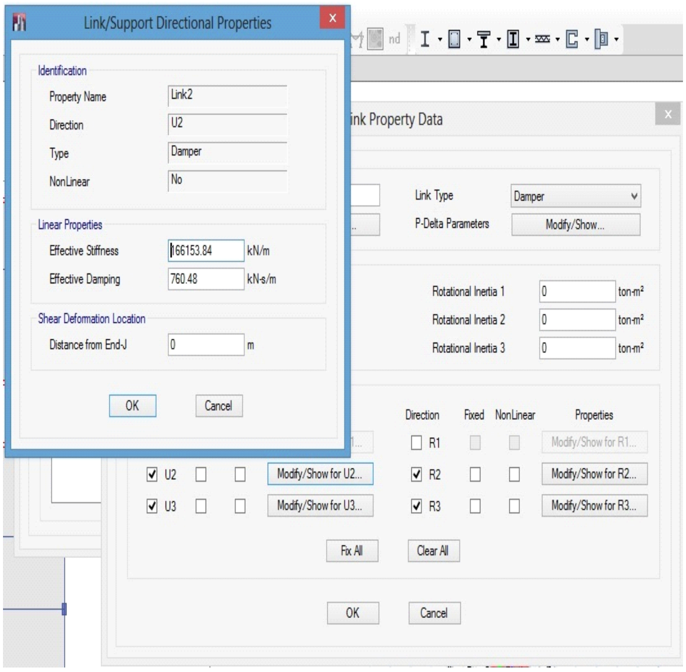


Figure 6. shows the assigning of stiffness and damping values

V. RESULTS AND DISCUSSIONS

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

5.1. 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. Below tables shows the storey displacement values for the both models.

5.2. Base Shear

MODEL.1

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 vb in a given direction shall be determined in accordance with the following equation:

Where:

Vb = Ah w

Ah = the seismic response coefficient

Ah =

Z = zone factor given in

Sa/g = average response acceleration coefficient

R = the response reduction factor

I = the importance factor.

1

5.3. STOREY 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

5.4. Graphical& Bar Charts Representation

5.4.1 Storeydisplacements(X-Storey Level, Y-Displacements)

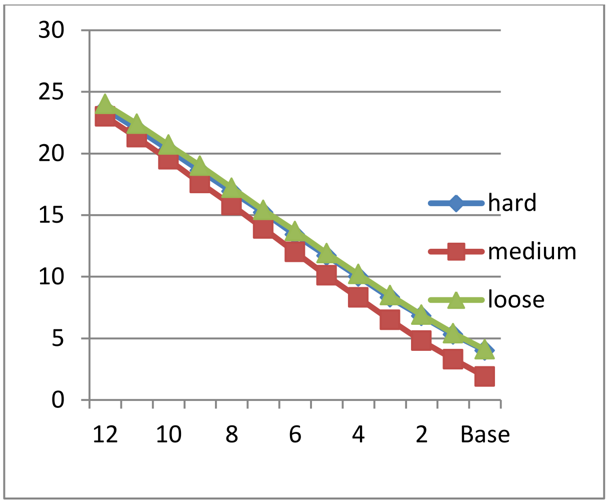


Figure 7. represents variation in deflection at story level in different soil conditions

5.4.2 Storey Shears (X-Storey Level,Y-Shear)

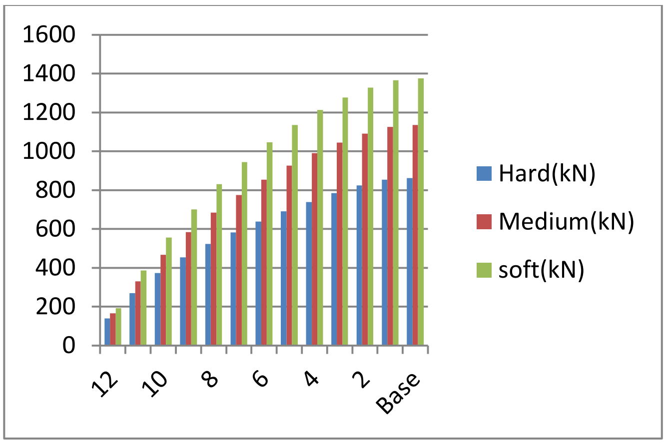


Figure 8. represents variation of story shear in different soils

5.4.3 Storey drifts(x-storey level, y-storey drifts)

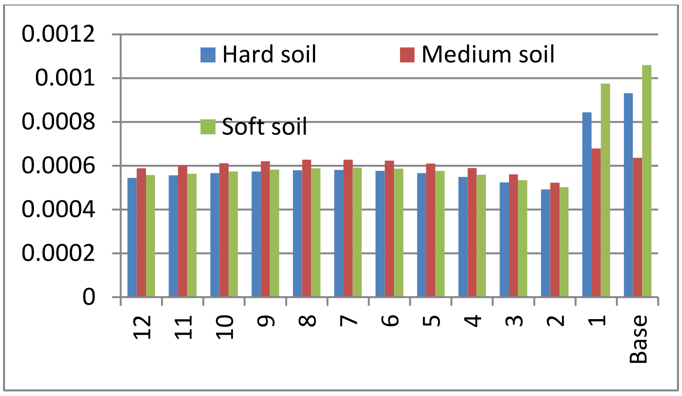
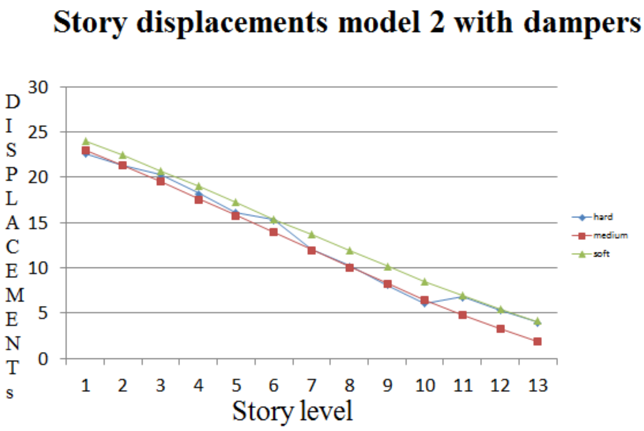


Figure 9. variation of story drifts in different soils



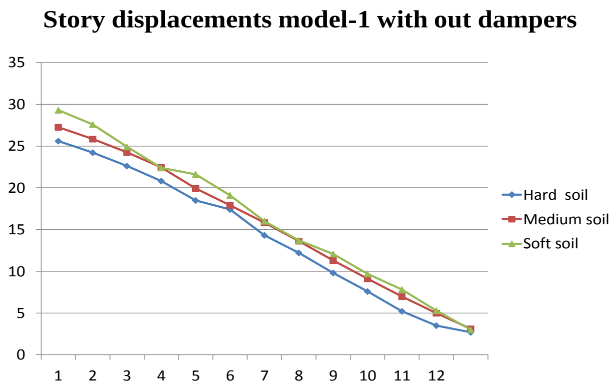
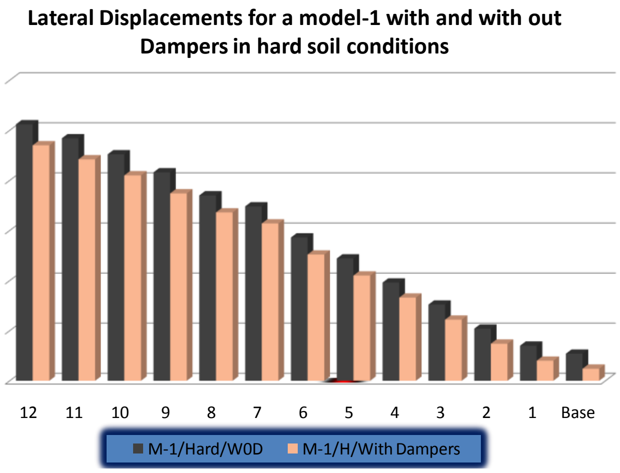
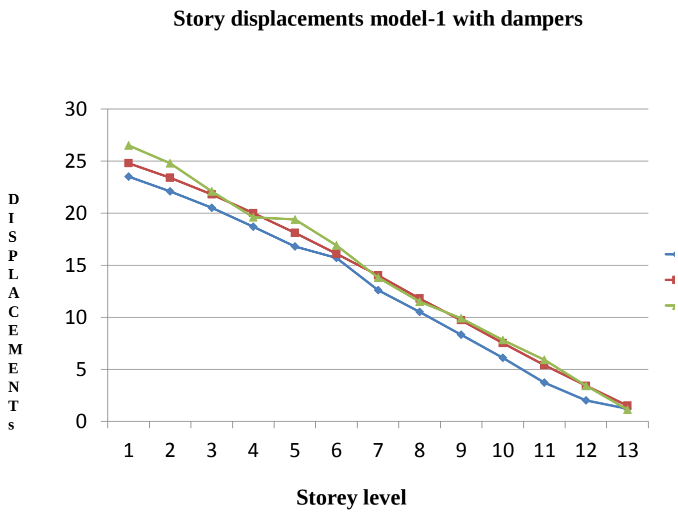
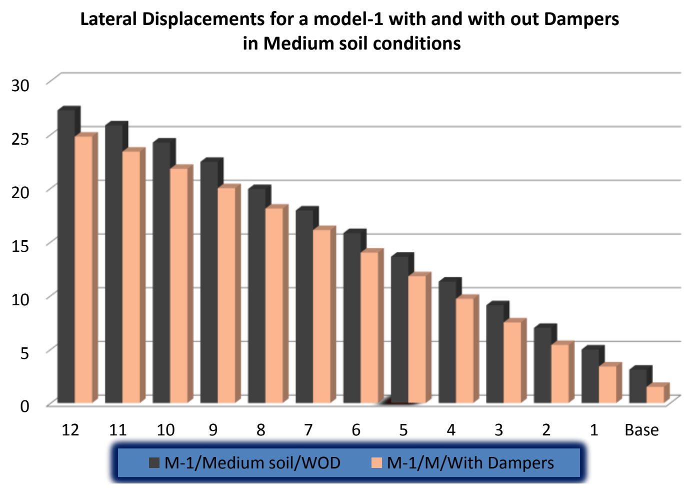


Figure 10. variation of story displacements without dampers

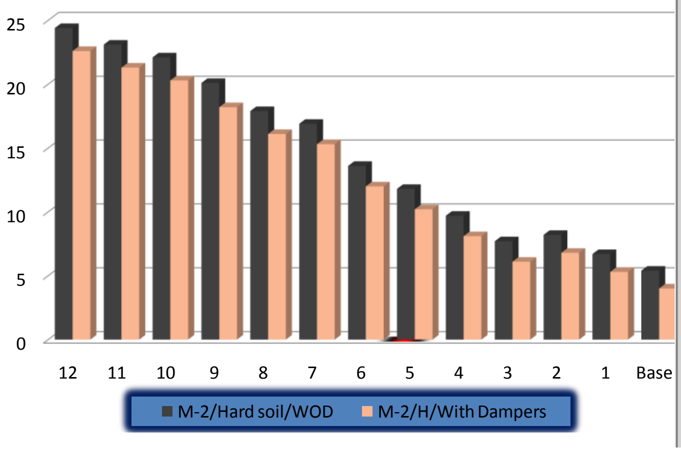


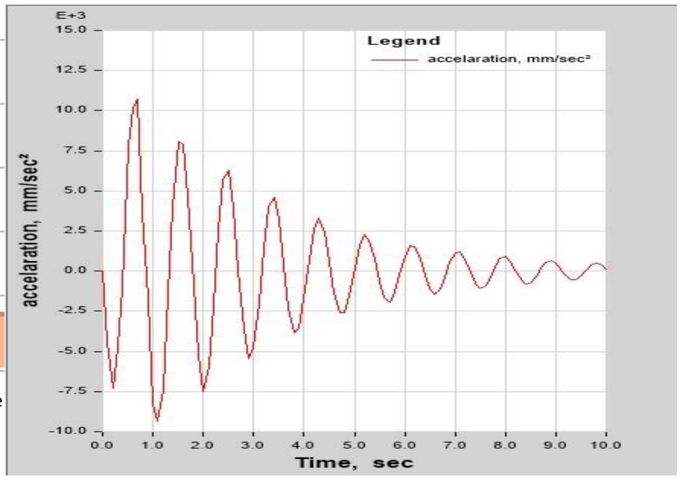




Time history analysis output files

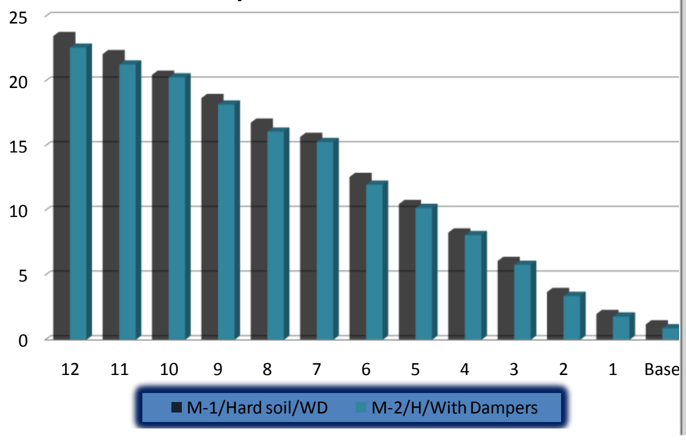
Lateral Displacements for a model-2 with and with out Dampers in Hard soil conditions

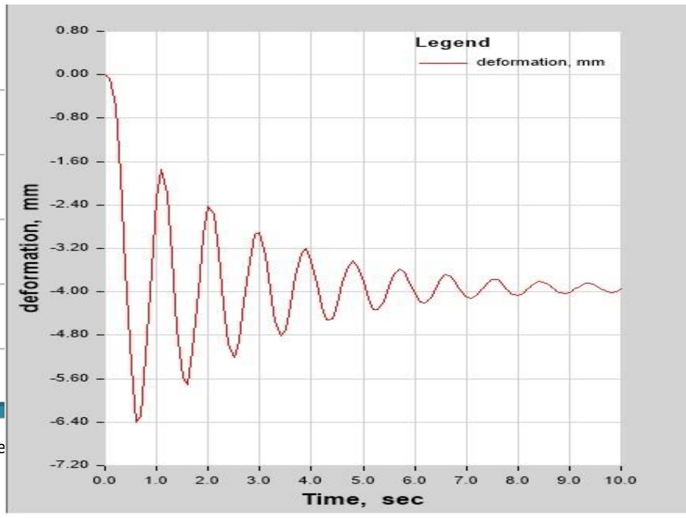




Time vs acceleration

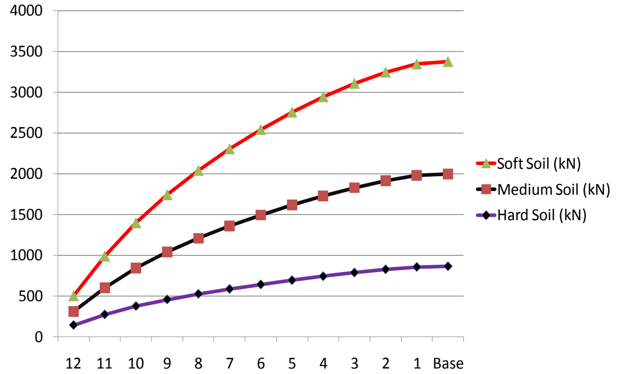
Lateral Displacements between Model-1 & Model-2 wit Dampers in Hard soil conditions.

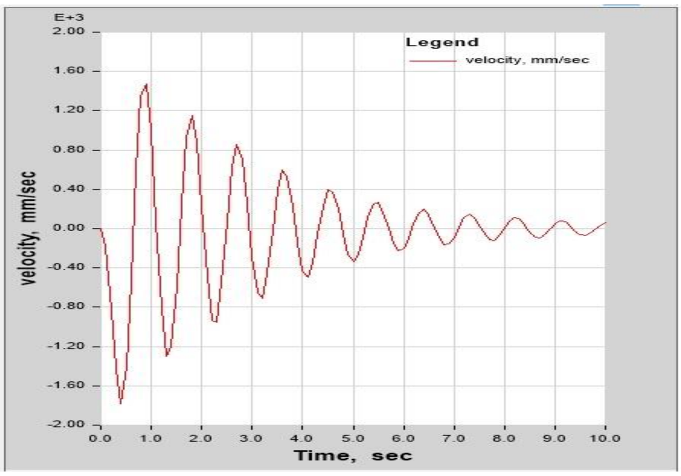




Time vs displacement

Storey Shear for Model-1 with Dampers in all soil Conditions





Time vs velocity

VI. CONCLUSIONS

- Lateral displacements for the model-1 are comparatively higher than model-2 (with damper).
- Results shows that assigning of dampers to the pile foundations decreases vibrations to some extent.
- Storey or base shear values decreases in models with the dampers.
- Model with damper results in decreases of the story drift of the building.
- The model analysis clearly demonstrated that in case of stiff buildings soil parameters plays a major role on the vibrational behavior of structure.
- For a model-2 with dampers building response is same in hard and medium soil conditions i.e. no much difference is noticed.
- Overall performance of the building models with dampers found to be better in all three type of soil condition as compare to the models without dampers.

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