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Seismic Analysis of Steel Frame using Soil Structure Interaction Considering BRB

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Abstract - *In the present work carried out, it is understood that, overcome the practical difficulties and to understand actual behavior of soil and structure using BRB and without BRB model are considered, so there are 12 models has been created using various shapes of braces and soil type. It has contain X bracing model , V bracing ,Y bracing model and without BRB along with 3 type of soil are considering sand ,silt and clay each one will make 4 model and total will have 12 model to perform. Building considered are G + 6 stories having height of 21 m and seismic zone 4 has been considered. Earthquake load combination will be taken account on multi-story steel frames installed with BRBs and without it. It is investigated through linear dynamic analyses using ETABS17. Results illustrate the variation of different parameters such as story displacement, story drift, story stiffness and story shear of the structure for seismic excitation against its seismic forces. From the result, it concluded that as the soil type changes story displacement, story drift, story stiffness changes drastically and various shapes of BRB contribute differently to resist deformation. That implies that soil structure interaction along with X BRB must be preferred against seismic excitation*.

Key Words: *BRB, multi-story steel frames, ETABS17, seismic excitation.*

1.INTRODUCTION

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 SSI. In this case neither the structural displacements nor the ground displacements are independent from each other.

Multi-story steel frames are popular building structures. For those with insufficient seismic resistance, their seismic capacity can be improved by installing buckling-restrained braces (BRBs), which are known for high energy dissipation capacity. However, BRBFs are frequently criticized because of excessive residual deformations after earthquakes, which impede the post-event repairing work and immediate occupancy. These were invented with a particular purpose of eliminating residual deformation for the protected structures, underwent fast development in recent years. Therefore, this aims to combine these two different braces to form a BRB. A total of Shapes BRBs are proposed to seek an optimal solution. The multi-story steel frames installed with BRB are numerically investigated through linear dynamic analyses. Interested seismic response parameters refer to the maximum story drift ratios, maximum story displacement, and base shear.

The phrase 'soil-structure interaction' may be defined as influence of the behavior of soil immediately beneath and around the foundation on the response of soil-structure subjected to either static or dynamic loads".

This research is aimed to compare the seismic behavior of different damping systems in steel buildings. This research will present the analysis of multi-story building considering soil structure interaction. A three dimensional modeling and analysis of the structure will carried out with the help of software. Equivalent static analyses will carried out on all structures. This analysis will compare with practical model of multi-story building with the help of shake table test. In this work BRB damping system are consider & it is compare with simple model.

2. LITERATURE REVIEW

Hector Guerrero et al. (2017) it has been widely recognized that the source of damping on structures is not viscous. However, an equivalent viscous damping, that generates similar dynamic response of structures, is used for simplification purposes. Under such consideration, this paper presents the experimental measurements of damping on structures equipped with Buckling-Restrained Braces (BRBs) working within their linear-elastic range. For comparison purposes, tests were also conducted on bare structures (without BRBs) and on a structure fitted with a conventional brace. All the experiments were conducted on a shaking table. The results show that, while the test with conventional brace did not show increase of the damping ratio, BRBs significantly did. This happened even when both, the main structure and the BRBs, exhibited linear-elastic response. A model is proposed to account for the dissipative forces observed on the experiments. The findings of this study are significant as they show that BRBs start dissipating energy at low levels of displacement; and this energy dissipation must be taken into account in the context of performance-based seismic design, so that the dynamic response demands on such structures are estimated properly.

F. Barbagallo et al. (2019) in the past, the use of Buckling Restrained Braces (BRBs) in buildings with braced structure has been proposed to overcome the drawback of steel Concentrically Braced Frames (CBF) caused by the low dissipative cyclic behavior of conventional buckling braces. The structure is conceived so that a few braced frames resist the entire seismic force and all the other frames sustain gravity loads only. According to the design practice adopted in European countries, all the beam-to-column connections are usually perfectly pinned. The use of these connections leads to low-redundant systems, which tend to form soft storey collapse mechanisms. The concentration of drift demand precludes the full exploitation of the deformation capacity of all the BRBs of the frame and partially reduces the benefit that may derive from these devices. A more effective structural system may be obtained by coupling frames with BRBs with frames with semi-rigid connections. In fact, the frame with semi-rigid connections provides a residual lateral stiffness after yielding of BRBs and thus promotes a more uniform distribution of the drift demand along the height of the building. This paper investigates the seismic performance of dual steel systems with BRBs and semi-rigid connections. A set of frames is designed considering several values of the behavior factor and the response of the obtained frames is determined by nonlinear dynamic analysis. Then, the behavior factor that allows the frames to meet the performance objectives of Euro code 8 is determined. The seismic performance of the frames is assessed in terms of ductility demand-to- capacity ratio of dissipative members, in terms of strength demand-to-capacity ratio of non- dissipative members, and residual drifts.

M. Bosco et al. (2015) Buckling restrained braces (BRBs) have been investigated extensively by means of experimental tests and their large ductility has been pointed out by many studies. Nevertheless, Euro code 8 (EC8) does not provide any rules for design of steel frames with BRBs. For this reason, a design procedure for steel frames equipped with BRBs is proposed in this paper. The proposed design procedure is obtained by modifying the rules stipulated in EC8 for steel chevron braced frames. As a consequence, the obtained design procedure is consistent with the framework of EC8. BRBs are designed in terms of ductility and strength based on two parameters: the design story drift Δ_{ud}, i.e. the maximum accepted story drift demand for earthquakes with a given probability of occurrence, and the behavior factor q, which is a seismic force reduction factor correlated with the expected ductility of the structure. Beams and columns are designed according to capacity design principles derived from those given in EC8 with reference to steel chevron braced frames. The design procedure is applied to a set of multi-story frames with BRBs assuming different values of Δ_{ud} and q. Their seismic response is evaluated by nonlinear dynamic analysis for two seismic excitation levels. The BRBs are modeled by a refined numerical model calibrated on the basis of a wide database of experimental data. For each value of Δ_{ud}, the highest values of q leading to seismic response that does not exceed the Significant Damage and Near Collapse limit states are determined. Then, the suggested behavior factor is given as a function of the design story drift.

S. A. Seyed Razzaghi (2018) in this paper seismic design of structures has been undergoing significant changes as a result of increasing demand for optimization and minimizing the level of damage and reducing the cost of structural repairs, the development of analytical methods and the remarkable improvements of computer performance have been among the factors which influenced the design of structures. A lot of research has been conducted on the development of better braces with perfect elasto-plastic behavior. The inventions and development of buckling restrained braces have been the results of these researches. In this study, the performance of Buckling Restrained Environmental Braces (BRB) in high- rise buildings were evaluated applying nonlinear time-history dynamics analysis with three pairs of acceleration and compared with conventional concentrically braced frame (CBF). The studied structures are 20, 40, and 60 stories building which braces were utilized peripherally. The acquired results reveal that the application of Buckling Restrained Brace Frames (BRB) instead of conventional braces frame (CBF) in high-rise steel buildings ameliorates hysteresis behavior of the braces and reduces lateral displacements and increase the capacity of base shear as well. It concludes that - Increasing the natural period of the structure and reducing the structural stiffness by boosting its ductility. The fundamental period of the examined structures increased about 20%.The lateral base shear capacity Increase for about 25% to 30%.

Hamdy Abou Elfath et al. (2019) in that paper the seismic design forces of building structures are generally influenced by three main factors: the design peak ground acceleration (PGA), response modification factor (R-factor), and permissible lateral drift. The magnitude of the seismic design force significantly affects the stiffness properties of the structures and thus, their fundamental periods. The period formulas available in seismic codes were developed by curve fitting to period data of buildings designed in California under high levels of seismic hazard. These period formulas are presented as functions of the building height without considering the level of the seismic design force applied to the structure. The current study analytically evaluates the fundamental periods of 768 buckling-restrained braced (BRB) steel buildings designed with variable levels of the design PGA, R-factor, and permissible lateral drift. The results obtained express the dependence of the calculated fundamental periods on the design PGA, R- factor, and permissible lateral drift of the BRB steel buildings. It concludes that the suggested period expression does not account for the effect of nonstructural components. The effect of nonstructural components on the fundamental period of BRB steel buildings needs to be assessed and integrated in the suggested period equations. More-over, the current study is limited to chevron-braced configurations because it is the most common configuration in BRB buildings. It is necessary to evaluate the fundamental periods of BRB buildings with other brace configurations in the future.

Nefize Shabanet et al. (2018) Seismic isolation systems designed for extreme events can likely experience low to moderate earthquakes during the design life of the structure rather than the extreme event itself. In new seismic building design codes, low and moderate earthquakes are also mandatory to be investigated in Turkey and some other countries. One of the main reasons is to protect the integrity of non-structural elements or machines during these types of earthquakes. The selection of appropriate seismic isolation is typically decided based on their force displacement characteristics and amount of energy dissipation per cycle. The same energy dissipation per cycle (EDC) can be achievedby high force-low displacement or low force-high displacement response. The focus of this research is given to identify the performance of ball rubber bearing isolation systems compared to different or similar EDC units such as elastomeric bearings and lead rubber bearings through a series of shake table tests performed at low to moderate earthquake levels. Shake table tests were conducted on an almost full scale short span bridge. The tests have revealed that the ball rubber bearings are superior to elastomeric bearings in terms of EDC and can match EDC of LRB. However, although LRB and BRB have the same EDC, BRB is more beneficial to use under low to moderate earthquakes since BRB can transmit less force with larger displacement compared to LRB and LRB can sometimes stay in elastic range with an ineffective EDC as a stiffer elastomeric bearing.

Antonios Flogeras et al. (2017) in this paper summarizes estimated seismic response results from three-dimensional nonlinear inelastic time-history analyses of some steel buckling-restrained braced (BRB) structures taking into account soil-structure interaction (SSI). The response results involve mean values for peak interstate drift ratios, peak interstate residual drift ratios and peak floor accelerations. Moreover, mean seismic demands in terms of axial force and rotation in columns, of axial and shear forces and bending moment in BRB beams and of axial displacement in BRBs are also discussed. For comparison purposes, three separate configurations of the BRBs have been considered and the aforementioned seismic response and demands results have been obtained firstly by considering SSI effects and then by neglecting them. It is concluded that SSI, when considered, may lead to larger inter-story and residual inter-story drifts than when not. These drifts did not cause failure of columns and of the BRBs. However, the BRB beam may fail due to flexure. It conclude that The seismic response of some steel buckling-restrained braced structures including soil-structure interaction (SSI) effects has been studied by using three-dimensional non-linear inelastic time- history analyses employing accelero-grams of recorded near-field ground motions. These structures have been designed for the highest seismic loads requirements holding for Greece.

3. METHODOLOGY

3.1 Software Development ETABS17

ETABs 2017 is a structural analysis and design software produced by Computer and Structures, Incorporated (CSI), a structural and earthquake engineering company. ETABs 2017 is a general purpose finite element program which performs the static or dynamic, linear or nonlinear analysis of structural systems.

3.2 Soil Structure Interaction

Soil – structure interaction plays an important role in the behavior of foundations. For structures like beams, piles, mat foundation and box cells it is very essential for consider the deformation characteristics of soil and flexural properties of foundations. It can be seen that when interaction is taken into account, the true design values arrived-at may be quite different from those worked out without considering interaction. In general in most of the case interaction causes reduction in critical design values of the shear and moments etc. However, there may be quite a few locations where the values show an increase. Because of these possibilities have their own roles to play in economy and safety of structure.

3.3 Concept of BRB

Buckling Restrained Braced Frame (BRBF) is a technically advanced type of Concentrically Braced Frame (CBF) that incorporates the effect of lateral forces subjected on to the structure. A technology introduced in late 1990, the BRBF represent the state of art in moment braced frame design. The major components of buckling restrained brace are steel core, bond preventing layer and casing as shown in Figure 1.

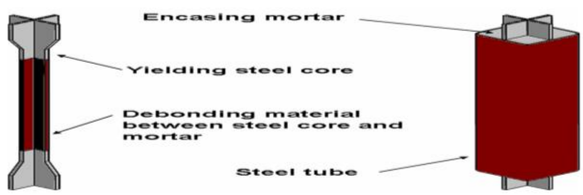

Fig -1. Steel core, bond preventing layer and casing

4. SOFTWARE ANALYSIS

This chapter presents brief introduction of ETABS17 software and procedure for modeling of formulated problem.

4.1 Introduction to ETABS17

ETABS17 which stands for Extended Three-Dimensional Analysis of Building System is used for the simplest problems or the most complex projects.

4.2 Modeling in ETABS17

ETABS17 is very much suited for analysis of building structures like high-rise buildings, towers, multi-story buildings, circular tank, etc. because of its flexibility in accounting for arbitrary geometry, loading, water pressure and variation in material properties. A number of models have been developed and analysis that perform satisfactorily in many situations in practice and are also computationally economical. Prepare model in ETABS 17.

Table 1: Model in ETABS 17

NO	SOIL CONDITION	BRACING
1	CLAY	Without Bracing
2		X bracing
3		V Bracing
4		Y Bracing
5	SAND	Without Bracing
6		X bracing
7		V Bracing
8		Y Bracing
9	SILTY	Without Bracing
10		X bracing
11		V Bracing
12		Y Bracing

a. Starting a new model and plotting grid lines

Start a new model by clicking the File menu > New model command to access the new model. Choose to start the model from default (initialize model with unit option). Set the current unit to those to be used most often in the model.

The new model formed has a variety of template buttons that display common types of structure. Click the appropriate template button as shown in Figure 2. After clicking any of the button, except the blank button or the grid only, use the resulting form to specify the initial geometry for the model. In the present study the grid only option is selected then a window as shown in Figure 2 pops up.

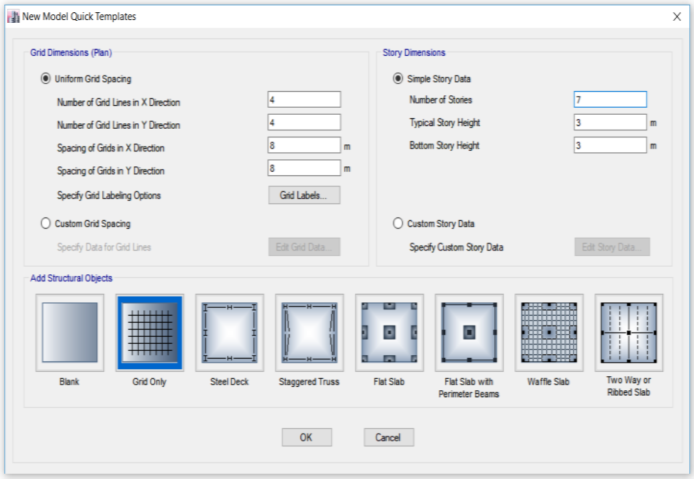

Fig -2: Select New Model

b. Define Properties

1. Select the define menu > Materials commands to add, modify or delete a material property definition. The material property definition is then used in defining the structural objects as shown in Figure 3.

2. For defining the frame section from toolbar click on define menu > section properties > frame section command can be used to (a) import sections from pre-defined database. (b) Define frame section properties on the basis of their dimension by adding new property. (c) Review and modify section properties. Out of these options add new property is selected for defining floor beam, roof beam, column and braces as shown in Figure 4 and Figure 5.

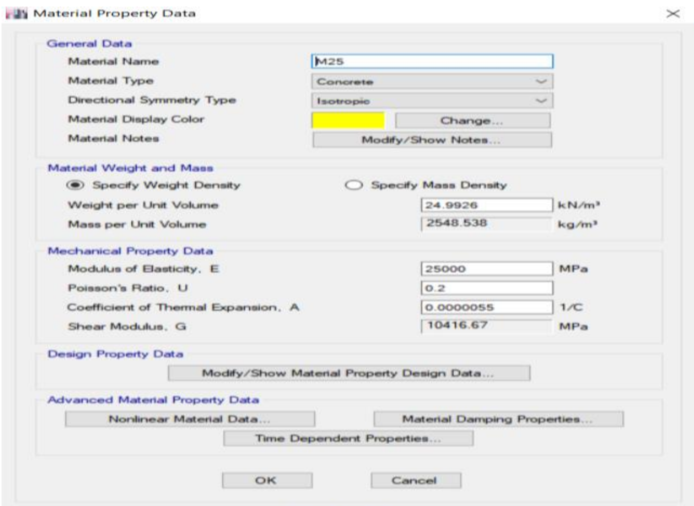

Fig -3: Define material property

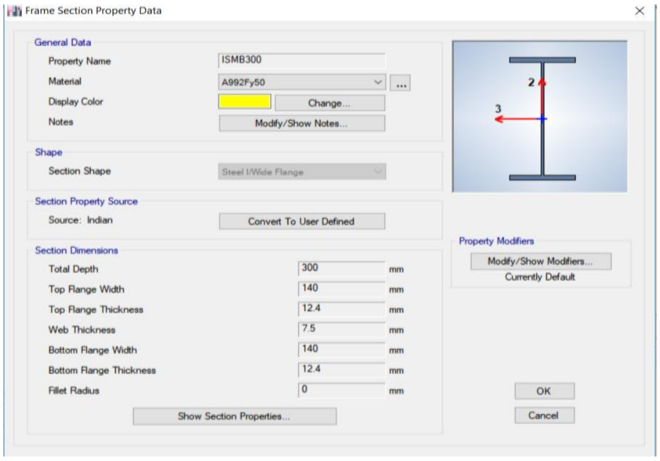

Fig -4: Define frame section

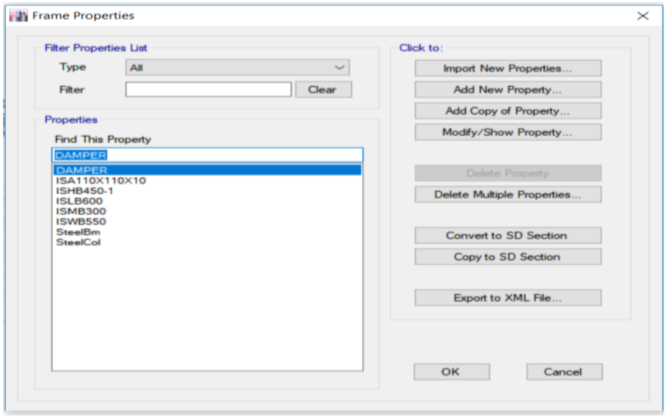

Fig -5: Define frame properties

3. For defining the area sections from toolbar click on define menu > section property > Area section command. The area property definition consists of geometrical and material properties as shown in Figure 6. Floor slab, roof slab are defined as shell element under the area section.

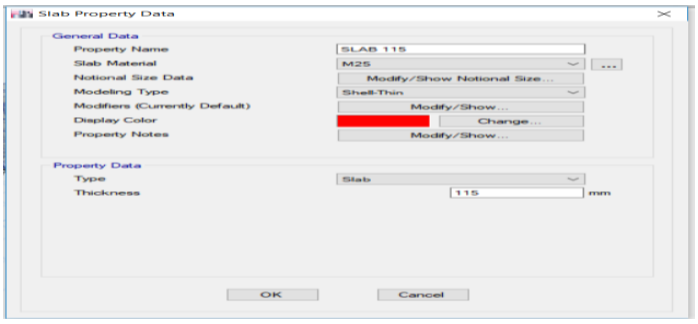

Fig -6: Define frame properties

c. Creating the model

In ETABS17 the toolbar on the left side of the window is mainly dedicated for drawing or creating the model. It includes drawing of joints, rectangular and polygonal areas, frame section and various methods. The two widely used commands are extrude and replicated. Extrude command is used to extrude points to frame. Replicate command is used to copy the object in any direction as shown in Figure 8. Joint restrained are applied by using spring constant command by soil structure interaction theory, as shown in Figure 7.

The braces are drawn by clicking on draw frame option on the toolbar and these braces are replicated at required heights and levels. Then the BRB properties are assigned to the defined braces.

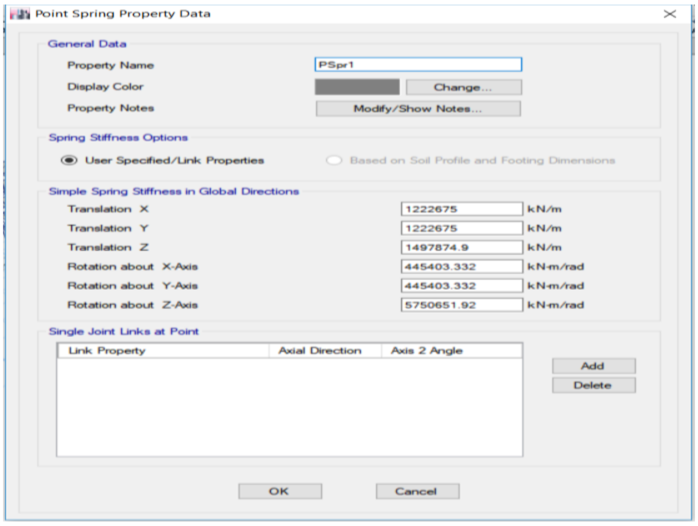

Fig -7: Spring Constant Restrained

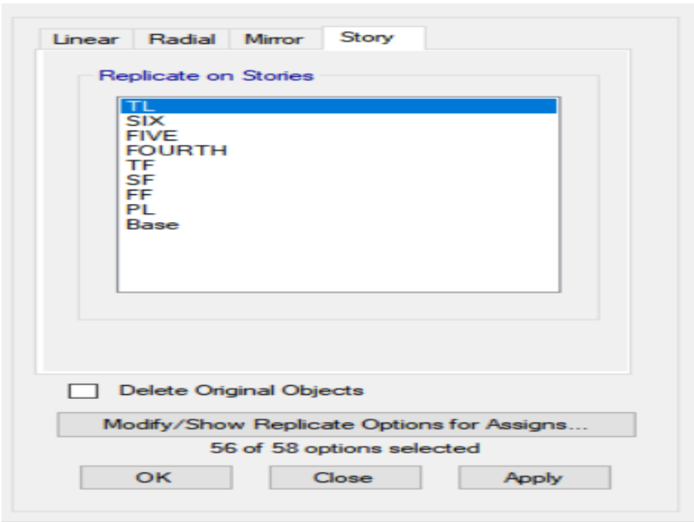

Fig -8: Replicate Command

d. Load patterns, load cases, mass source

Select the define menu > load patterns command to define static load pattern i.e., dead load, live load as shown in Figure 9. The load mentioned above are assigned to the respective areas by selecting the respective area section i.e., floor slab by clicking on assign > area load > uniform shape. Wall load is assigned as uniform distributed load.

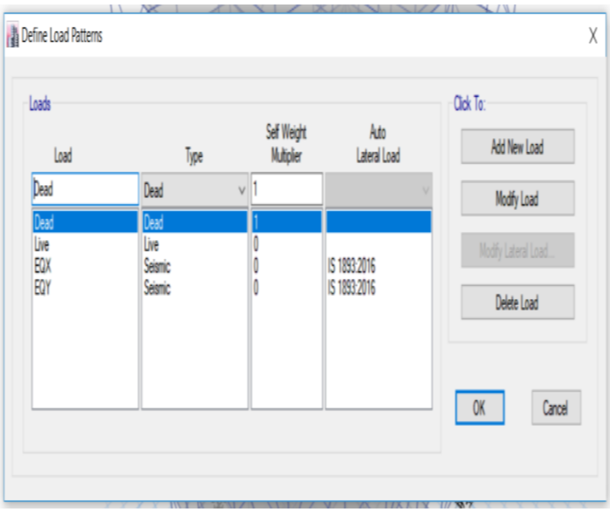

Fig -9: Define load patterns

For performing the linear dynamic analysis it is essential to define the mass source. Mass source is defined by selecting define menu > mass source command to specify the source of mass in the model as shown in Figure 10.

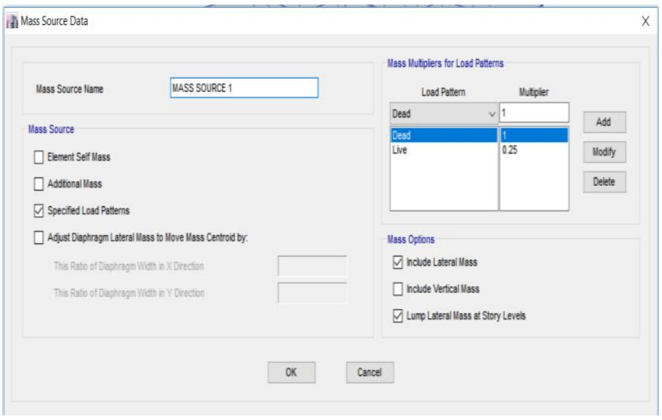

Fig -10: Define Mass Source

4.3 Analysis

The analyzed menu > set load cases to run and analyze menu > run analysis command to set load cases to run as shown in Figure 11.

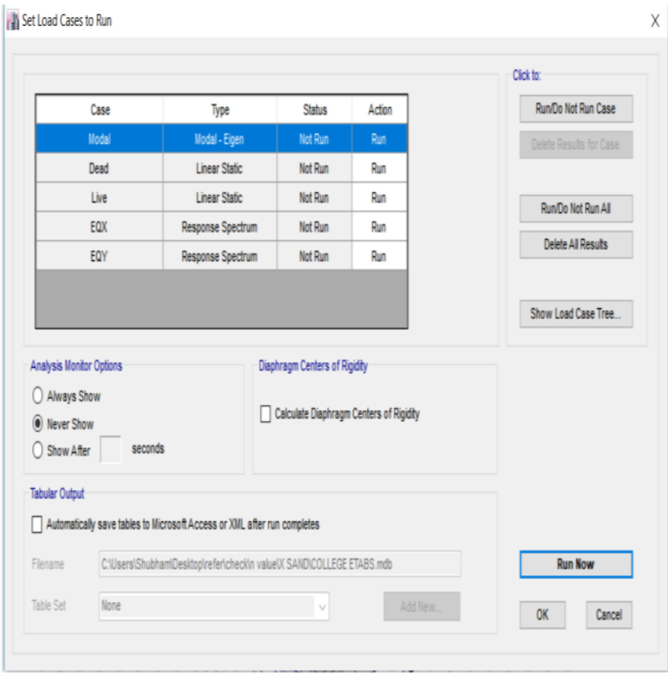

Fig -11: Windows showing the set load cases to run.

4.4 Interpretation of results and graph

When the analysis is complete a deformed shape of model will automatically be displayed. While displaying mode shapes, the mode being displayed can be instantaneously be changed with the '+/-' that will appear at bottom of screen.

The display tab on the tool bar is dedicated for interpreting results. It includes option for reviewing the behavior of structure under applied loading such as; show un-deformed shapes, show load assign, show miscellaneous. Assign, show deformed shapes, show forces/ stresses, show virtual work diagram and show plot function to display the result in tabular format, display menu > show tables. The detailed options included in display command are shown in Figure 12.

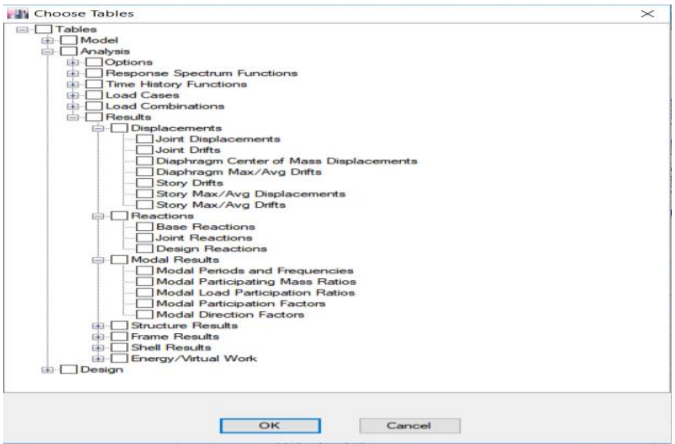

Fig -12: Display table

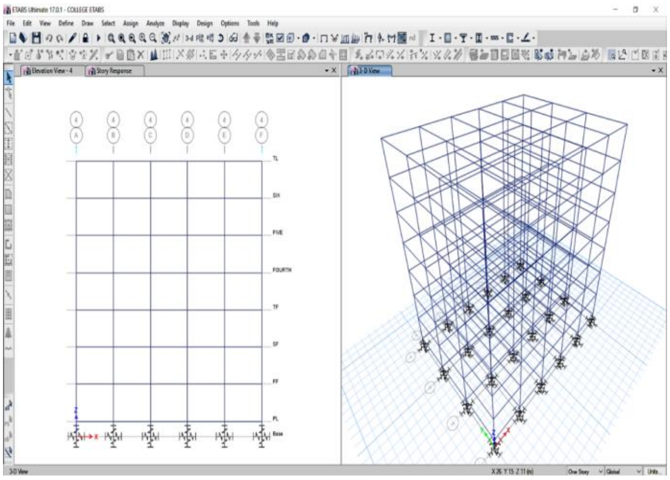

Fig -13: Model without Bracing

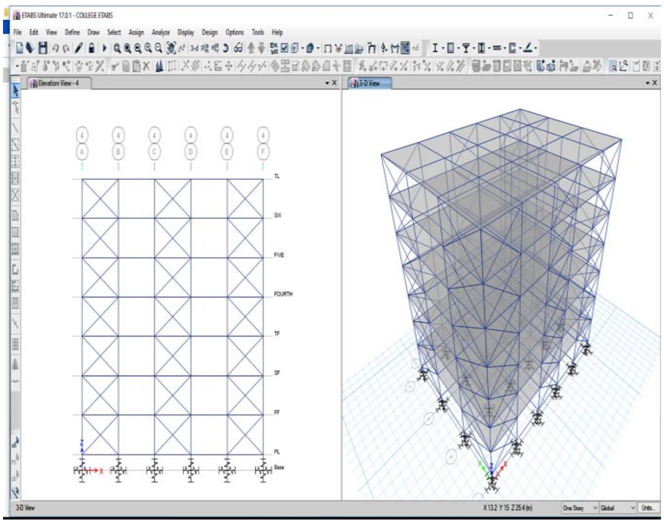

Fig -14: Model with X Bracing

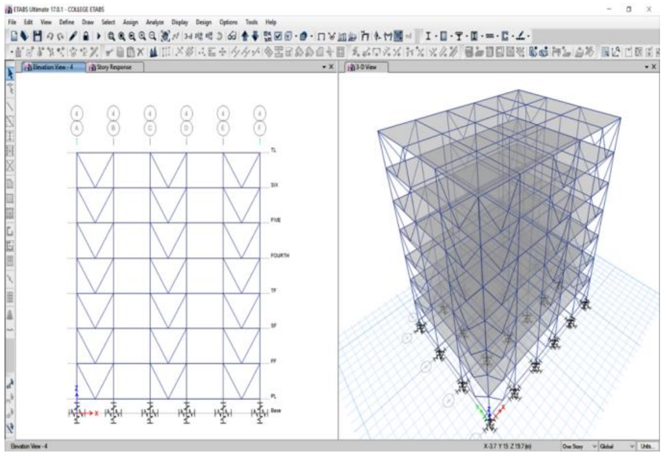

Fig -15: Model with V Bracing

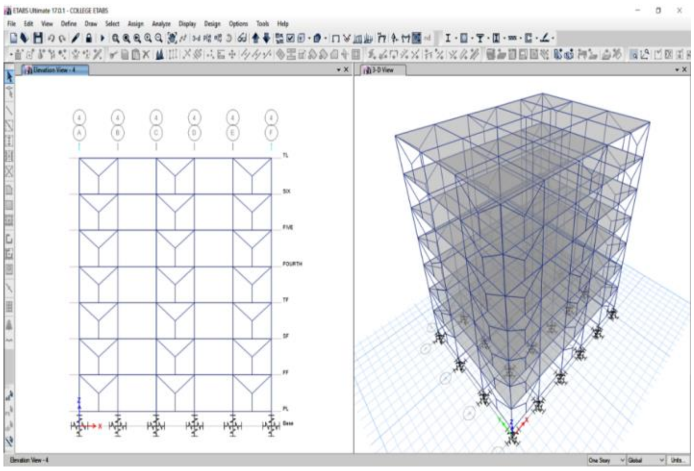

Fig -16: Model with Y Bracing

5. RESULTS AND DISCUSSION

In this research seismic analysis of building with BRB system using soil structure interaction is done with variation of BRB and soil variation, having 12 model has been carried out. This chapter presents the result obtained from software analysis using ETABS 17.1

To overcome the practical difficulties and to understand actual behavior of soil and structure using BRB and without BRB model are to be consider. The present study focuses on the response of steel frame model when lateral excitation is given so there will 12 model is created using various shapes of braces and soil type. It has contain X bracing model , V bracing ,Y bracing model and without BRB along with 3 type of soil are considering sand ,silt and clay each one will make 4 model and total will have 12 model to be perform. Building is considered are G+ 6 stories having height of 21 m and seismic zone 4 will be considered. Earthquake load combination will be taken account on multi-story steel frames installed with BRBs and without it investigated through linear dynamic analyses using ETABS17. The parameter to be studied is Story Displacement, story shear, story drift and story stiffness.

The comparative results of all three types of soil with Varying shapes of BRB system's seismic response in terms of story displacement, story drift, base shear and story stiffness are shown From Figure 17 to Figure 18.

a. Maximum Story Displacement

a. Maximum Story Displacement

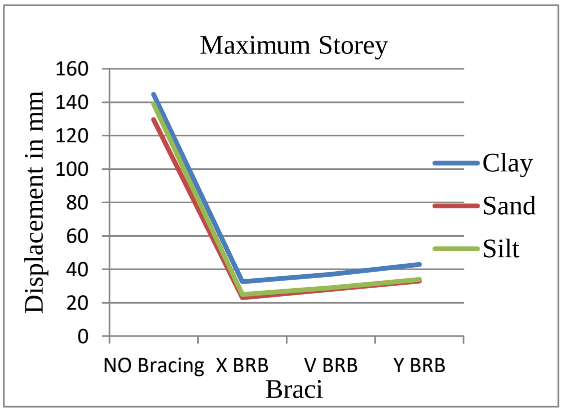

Chart -1: Maximum Story Displacement EQ-X

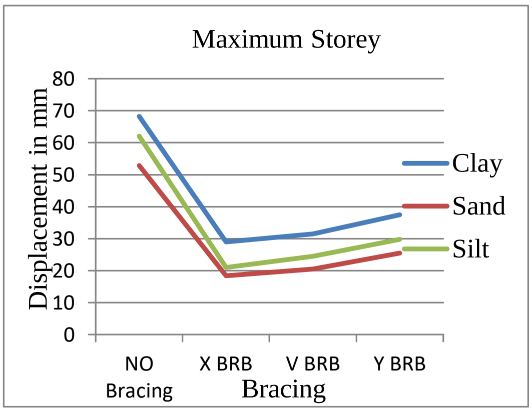

Chart -2: Maximum Story Displacement EQ-Y

b. Maximum Story Drift

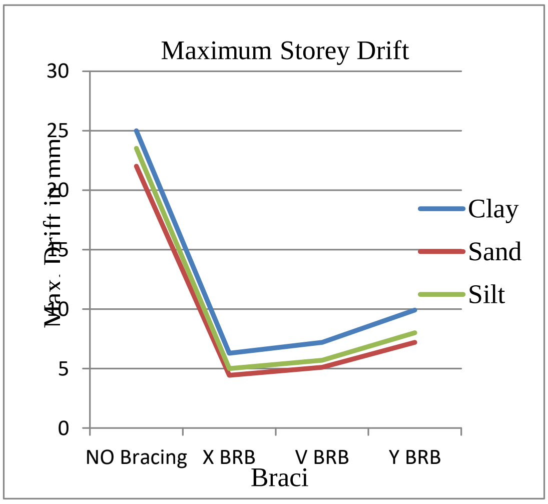

Chart -3: Maximum Story Drift EQ-X

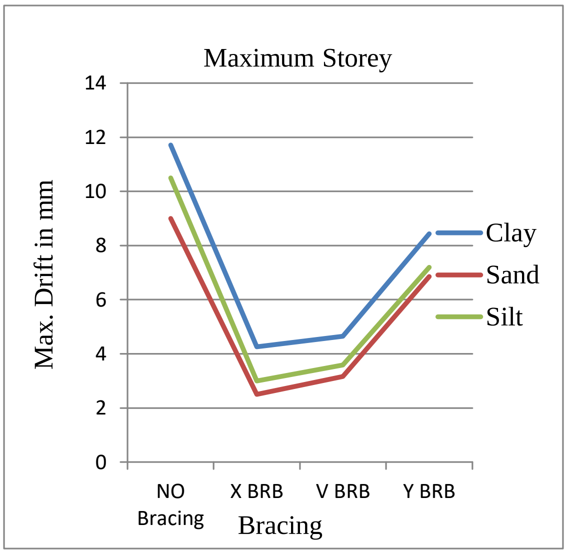

Chart -4: Maximum Story Drift EQ-Y

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c. **Base Shear**

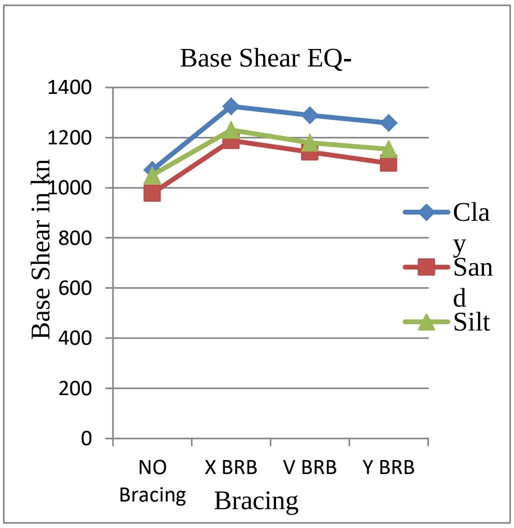

Chart -5: Base Shear EQ-X

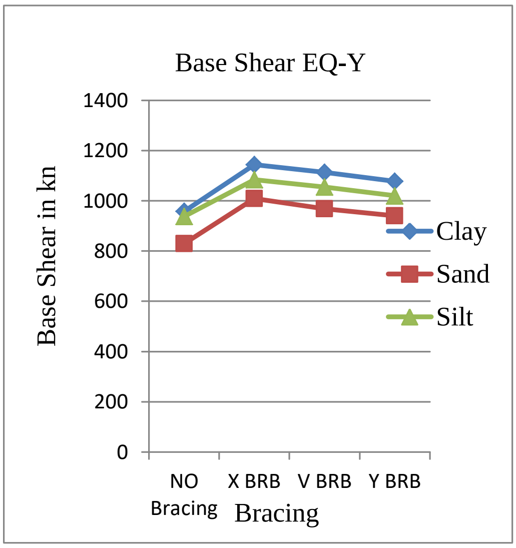

Chart -6: Base Shear EQ-Y

d. **Maximum Story Stiffness**

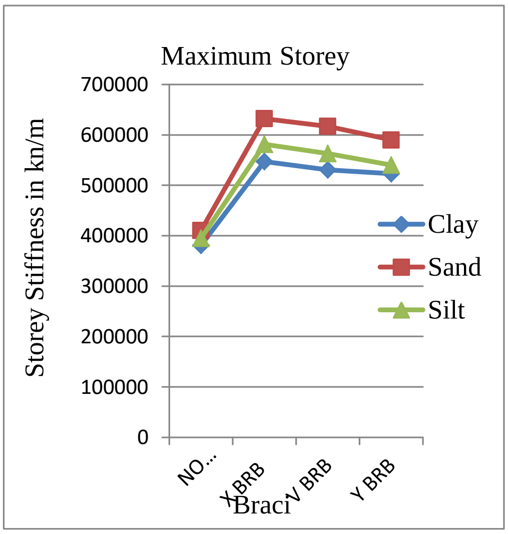

Chart -7: Maximum Story Stiffness EQ-X

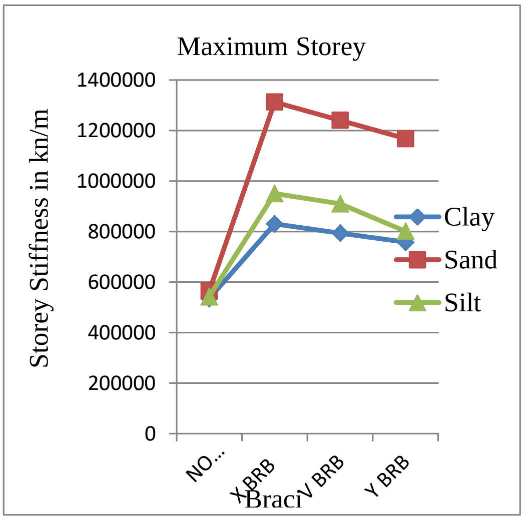

Chart -8: Maximum Story Stiffness EQ-Y

From Chart 1 to Chart 2 it is come to know that maximum story displacement are in clay soil than the sand and silt soil, it is because of less rigidity in the contact of soil and structure From Chart 3 to Chart 4 it is come to know that maximum story drift are lies in the graph of clay soil as the inter story displacement is high in clay soil. From Chart 5 to Chart 6 it tells us the highest base shear is occurring in clay soil. From Chart 7 to Chart 8 it is come to know that maximum story drift are lies in the graph of sand soil which is why lateral drift is most control in sand soil.

6. CONCLUSIONS

1. Story displacement is observed to decrease 30% in X bracing system in clay as well as sandy soil and Y bracing decreases 16% and V decreases just 11% compare to normal frame.
2. Base shear after comparison with soil structure interaction along X and Y direction it was observed that Varies between 15%-20% for different soil and highest base shear is in coming X bracing clay soil.
3. After comparison with and without soil structure interaction for story drift along X and Y direction it was observed that Story drift Varies between 15%-40% for different story. Hence it can be concluded that SSI need to be considered for higher zone, multi-story building and weak soil.
4. To restrict the excessive deformation in any soil then by using X bracing perform best than V and Y bracing.
5. Deformation due to self-weight is observed 16% more in with considering soil structure interaction.
6. Overall X bracings perform well than V and Y BRB and considering soil structure interaction helps us to trace actual behavior of frame system.

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