# Seismic Response Of Multistory Steel Frame With Brb System Using Soil Structure Interaction

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***Abstract-*** *In this research work to 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 story having height of 21mand 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*

## I. INTRODUCTION

### 1.1 General

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 3 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”.

Soil-structure interaction, SSI, sometimes plays an important role, especially for massive structures constructed on the relatively soft soil, which may alter the dynamic characteristics of structural responses. In the usual type of structural analysis, soil-structure interaction is neglected and the structural responses are just accounted for. The history of studies on SSI subject returns to the late 1970s, despite, the soil flexibility effects on the vibrating systems like machine foundations had previously attracted the attention of a number of researchers. The first areas, which were seemed to have considerable influence of SSI on the structural response, were nuclear power plants, as studied by Idriss et al. (1979) and Johnson (1981). During the recent decades, extensive researches have been conducted regarding the effects of soil-structure interaction (SSI) on the seismic responses of the structures. It was found that the interaction between soil and structure results in a decrease of the fundamental frequency of the response and a modification in the energy dissipation, which is attributed to radiation and material damping in the soil, Johnston (2003). The common practice usually ignores effects of SSI on seismic behavior of BRB structures, accounting on the flexibility of BRB buildings, despite, the recent studies on the BRB bridges and structures have shown the effectiveness of SSI on seismic responses of the systems. Hence, not only for the seismic design but also from economic aspects, SSI might be necessary to be considered in the design of a base-isolated building. The coupled effect of SSI and the BRB on structures has gained the interest of a number of researchers during the recent years. Soil-structure interaction has been mainly considered for base- isolated bridges and liquid storage tanks and multistory buildings.

A foundation is a means by which superstructure interfaces with underlying soil or rock. Under static conditions, generally only vertical loads of structure need to be transfer to supporting rock. In seismic environment, the loads imposed on a foundation from a structure under seismic excitation can greatly exceed the static vertical loads as even produce uplift; in addition, there will be horizontal forces and possibly movement at foundation level. The soil and rock at site have specific characteristics that can significantly amplify the incoming earthquake motions travelling from the earthquake source.

The foundation designer must consider the behavior of both structure and soil and their interaction with each other. The interaction problem is of importance to many civil engineering situations and it covers a wide spectrum of problems. These include the study of shallow and deep foundation, floating structure, retaining wall-soil system, tunnel lining, earth structure etc.

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.

### 1.2 Buckling restrained braces (BRB)

Buckling-Restrained Braces (BRBs) are a relatively recent development in the field of lateral load resisting structures. A braced frame is a structural system commonly used in structures subject to lateral loads such as wind and seismic pressure. The members in a braced frame are generally made of structural steel, which can work effectively both in tension and compression.

The beams and columns that form the frame carry vertical loads, and the bracing system carries the lateral loads. The positioning of braces, however, can be problematic as they can interfere with the design of the façade and the position of openings. Buildings adopting high-tech or post-modernist styles have responded to this by expressing bracing as an internal or external design feature.

### 1.2.1 Types of Bracing

The bracings that are commonly used are classified according to their shape are studied.

### 1.2**Single Diagonal Bracing**

This type of bracing is having just one leg to resist the lateral deformation exerted by the seismic event. It is quite effective in resisting unidirectional forces effectively.

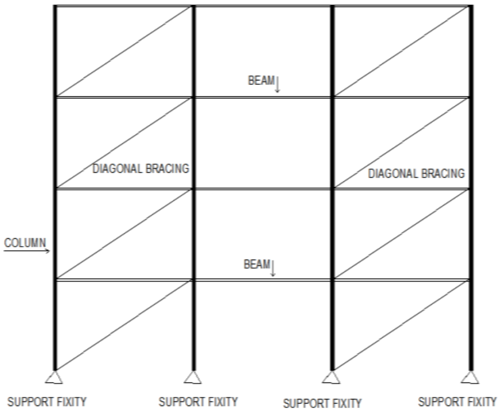


**Figure 1.1: Diagonal Bracing**

### 2. Cross-Bracing or X-Bracing

Cross-bracing (or X-bracing) uses two diagonal members crossing each other. These only need to be resistant to tension, one brace acting to resist sideways forces at a time depending on the direction of loading.

### 3. V-Bracing

This involves two diagonal members extending from the top two corners of a horizontal member and meeting at a Centre point at the lower horizontal member, in the shape of V. The buckling capacity of the compression brace is likely to be significantly less than the tension yield capacity of the tension brace..

### 4. Inverted V-Bracing

Inverted V-bracing (also known as chevron bracing) involves the two members meeting at a Centre point on the upper horizontal member. The working is like V bracing.

### Aim and Objective of the Study

The aim of this research work is to evaluate the structural response of steel frame using various shapes of BRB system considering soil structure interaction during seismic excitation with the following objectives.

1. To estimate the seismic Response of multistory steel frame with BRB Damping system by using ETABS17.
2. To study the different types of bracing systems and identify most effective bracing system to improve the properties of steel frame building.
3. Analysis models of G+6 story building with X bracing, V bracing, Y bracing models in different soil condition such as Clay, silt and sandy to know exact variation by taking soil structure interaction.
4. To study the parameter such as Displacement, Story drift, Base shear etc. comparison along with parameters which is obtain from seismic analysis of steel frame.
5. To evaluate effectiveness of damping system for structural improvement of earthquake resisting structure.
6. To suggest appropriate measures for improve the stability of structure against seismic response

### System development

Many researches have carried out their work on seismic behavior and analysis of BRB using different theories, methods and experiments. The research as seen in the literature develop various new method but still there is scope for various parameter to account into the consideration such as soil structure interaction, base isolation, elastomeric bearing, and many more, so in this research the effect of BRB system considering soil structure interaction is taken. The performance of steel frame having BRB during seismic excitation without considering soil structure interaction could prove vulnerable. By choosing the correct parameter and model for satisfying the safe design, we can obtain accuracy for result with seismic even.

## II. PROBLEM STATEMENT AND METHODOLOGY

### 2.1 Introduction

The main objective of this study is to examine the behavior of bracing system on steel frame building. Twelve various cases are analyzed by linear dynamic analysis. The analysis is carried out using ETABS17 software

### 2.2 Problem Statement

To overcome the practical difficulties and to understand actual behavior of soil and structure using BRB and without BRB model is considered, so there will 12 model will be created using various shapes of braces and soil type. It will 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 considers is G+6 story having height of 21 m and seismic zone 4 will be considered. Earthquake load combination has taken account on multi-story steel frames installed with BRBs and without 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.

### 2.3 Design data

Model 1- floors are designed based on limit state design philosophy. Since IS 456:2000 is also based on limit state methods, the same has been followed wherever it is applicable. The design should ensure an adequate degree of safety and serviceability of structure. The structure should therefore be checked for ultimate and service ability limit states.

### 2.4 Software Development ETABs 2017

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. It is also a powerful design tool to design structures following AASHTO specifications, ACI and AISC building codes. ETABs 2017 is a full featured program that can be used for the simplest problems or the most complex projects. It features powerful graphical user interface that is unmatched in terms of ease-of-use and productivity.

### 2.5 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

Several studies have indicated that the maximum bending moment in a foundation raft or beam could be substantially affected by interaction with superstructure. Reduction is as high as 80% is reported in certain cases. The rigidity of foundation raft relative to soil is of extremely high values of bending moments in relative rigid rafts as compared to those in flexible rafts. An elastic-plastic analysis also indicates similar trend, although to a much lesser degree. An equal settlement is the severest cause for cracking and even failure of superstructures. On the other hand, rigidity of superstructure helps in reducing differential settlements. Of course to realize this, only interactive analysis has to be carried out.

### 2.6 Soiltest:

For low-rise underground structures, depth of borings may be specified to be about 6 m below the anticipated foundation level, with at least one boring continuing deeper, to a lesser of 30 m, the least underground structure dimension, or refusal. At least one soil boring should be specified for every 230 square meters of the underground structure area for underground structures Over 12 m height, or having more than three stories'. For large under ground structures founded on poor soils, borings should be spaced at less than15m intervals. A minimum of five borings, one at the center and the rest at the corners of the underground structure, is recommended.

### 2.7 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

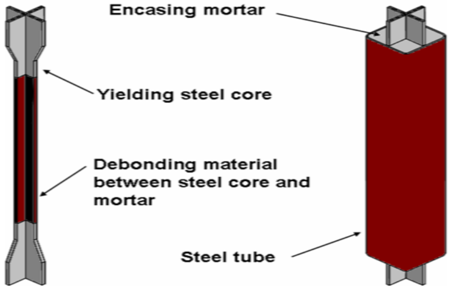


*Figure 1. Steel core, bond preventing layer and casing*

The required strength of framing members also enforces proportioning the system for braces to be the weak link: beams and columns are required to be sized to resist forces corresponding to the expected strength of braces, including factors accounting for strain hardening and other sources of over strength. Careful designers will also proportion braces over the height of the building to minimize concentrations of drift by performing dynamic analyses and taking advantage of the ability to size braces to within a small percentage of their required strength.

The introduction of BRBF into the list of standard systems available to designers comes as more attention is being paid to design and performance issues with conventional braced frames (CBF). Examination of recent testing, and reexamination of earlier testing, has led to renewed attention to proper design and detailing of braced frames to overcome potential limitations on their ductility. Steel core is designed to resist the axial forces developed in the bracing. Bond preventing layer decouples the casing and core. This allows steel core to resist full axial forces which develop in bracing. Casing provides lateral support against flexural buckling of the core.

### 2.8 Method of Seismic Analysis

A. **Equivalent Static Method:** The design lateral force due to earthquake is calculated as follow

**1. Design horizontal seismic coefficient**:

The design horizontal seismic coefficient Ah for a structure shall be determined by the following expressions:-

$A_h = (Z/2) \times (I/R) \times (S_a/g)$

Provided that for any structure with $T \leq 0.1s$, the value of Ah will not be less than Z/2 whatever the value of I/R.

Where,

Z = Zone factor.

I = Importance factor depending upon the functional use of the structure.

R = Response reduction factor, depending upon the perceived seismic damage Performance of the structure.

.

$S_a/g$ = Average response acceleration coefficient

**2. Design Seismic Base Shear:**

The total design lateral force or seismic base shear ($V_b$) along any principal direction is determined by the following expression:-

$V_b = A_h .W$

Where, W is the seismic weight of the building.

### 3. Distribution of design force:

The design base shear ($V_b$) computed is distributed along the height of the building as below:

$Q_i = V_b(w_i h_i^2 / \sum w_i h_i^2)$

Where,

$Q_i$ = Design lateral force at each floor level i

$W_i$ = Seismic weight of floor i.

hi = Height of floor i measured from the base.

### 2.9 Response Spectrum Method

This method is also known as modal method or modal superposition method. The method is applicable to those structures where modes other than the fundamental one significantly affect the response of the structure. In particular, it is applicable to analysis of forces and deformations in multi-story buildings due to medium intensity ground shaking, which causes a moderately large but essentially linear response in the structure. 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 using smooth design spectra that are the average of several earthquake motions.

In seismic coefficient method (single mode method), only one mode of vibration was considered. The time period for this mode was obtained in a very simplistic fashion without performing the free vibration analysis. In response spectrum method, the natural periods and mode shapes obtained using free vibration analysis are used to obtain seismic force. The representation of the maximum response of idealized single degree freedom system having certain period and damping, during earthquake ground motions. The maximum response plotted against of un-damped natural period and for various damping values and can be expressed in terms of maximum absolute acceleration, maximum relative velocity or maximum relative displacement.

Sufficient number of modes shall be used so that sum of modal mass of considered modes is more than 90% of the total mass of the structure. The effect of seismic shaking can be quantified as concentrated seismic inertia forces and moment corresponding to the translational and rotational degrees of freedom respectively, at each node of the discretize model of the structures. Each mode of vibration contributes to these seismic inertia forces and moments.

**1. Design Lateral Force at Each Floor in Each Mode:**

$Q_{ik} = A_k \emptyset_{ik} P_k W_i$

Where, $A_k$ = Design horizontal acceleration spectrum value

$\emptyset_{ik}$ = Mode shape coefficient at floor i in mode k

$W_i$ = Seismic weight of floor i.

$P_k$ = Modal participation factor.

**2. Story Shear Force in Each Mode**:

Acting in story i in mode k is given by

$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$

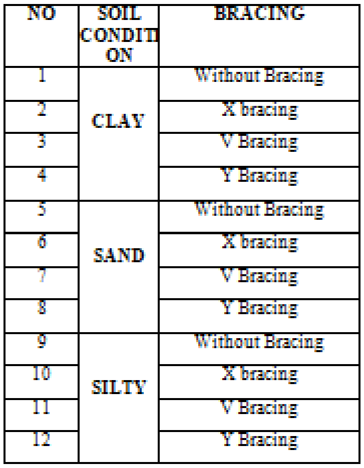
Story shear force due to all modes considered. The peak story shear force ($V_i$) in story i due to all modes considered is obtained by combining those due to the individual modes by various methods such as SRSS, CQC or absolute sum method etc.

## III. SOFTWARE ANALYSIS

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

### 3.1 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



| 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 |

## IV. RESULTS

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.

### 4.1 Results for clay soil

Varying shapes of BRB system's seismic response with clay soil in terms of story displacement, story drift, story shear and story stiffness are shown

Story Displacement ClaySoil

Lateral deformation of story varying with X bracing, V bracing, Y bracing and without bracing for clay soil are shown From **Table 5.1** to **Table 5.2** in EQ-X and EQ-Y direction.

Story Displacement ClaySoil

Lateral deformation of story varying with X bracing, V bracing, Y bracing and without bracing for clay soil are shown From **Table 5.1** to **Table 5.2** in EQ-X and EQ-Y direction.

**Story DisplacementEQ-X**

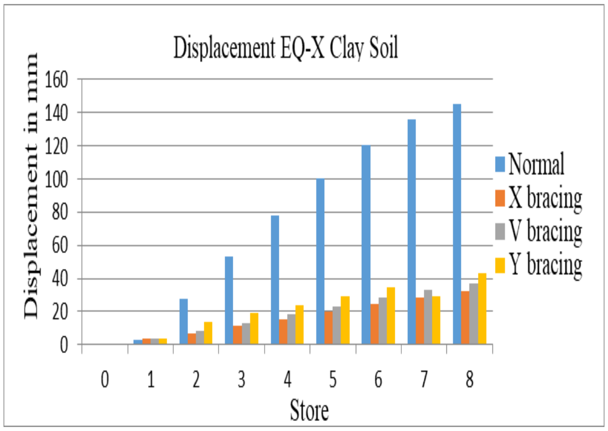


***Figure 1: Story Displacement EQ-X Clay Soil***

**Table .1: Story Displacement EQ-X Clay Soil in mm**

**Table 5.1: Story Displacement EQ-X Clay Soil in mm**

| Story | NORMAL | X BRACING | V BRACING | Y BRACING |
|---|---|---|---|---|
| 8 | 144.8 | 32.5 | 37 | 43 |
| 7 | 135.8 | 28.75 | 32.95 | 28.95 |
| 6 | 120.5 | 24.57 | 28.29 | 34.29 |
| 5 | 100.64 | 20.144 | 23.26 | 29.26 |
| 4 | 77.76 | 15.627 | 18.06 | 24.06 |
| 3 | 53 | 11.21 | 12.9 | 18.9 |
| 2 | 27.61 | 7.08 | 7.97 | 13.973 |
| 1 | 3.03 | 3.48 | 3.573 | 4 |
| 0 | 0 | 0 | 0 | 0 |

**Table 2: Story Displacement EQ-Y Clay Soil in mm**

**Table 5.2: Story Displacement EQ-Y Clay Soil in mm**

| Story | NORMAL | X BRACING | V BRACING | Y BRACING |
|---|---|---|---|---|
| **8** | 68.20 | 29.00 | 31.58 | 37.5 |
| 7 | 62.89 | 25.91 | 28.2 | 34.4 |
| 6 | 55.29 | 22.15 | 24.18 | 30.16 |
| 5 | 45.67 | 18.03 | 19.75 | 25.75 |
| 4 | 34.65 | 13.76 | 15.10 | 21.10 |
| 3 | 22.93 | 9.50 | 10.43 | 16.45 |
| 2 | 11.5 | 5.38 | 5.87 | 8 |
| 1 | 2.22 | 1.96 | 2.1 | 2.5 |
| 0 | 0 | 0 | 0 | 0 |

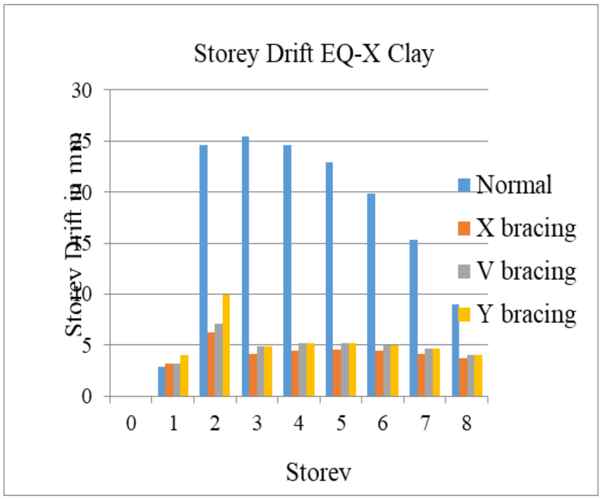


***fig2. Story Displacement EQ-Y***

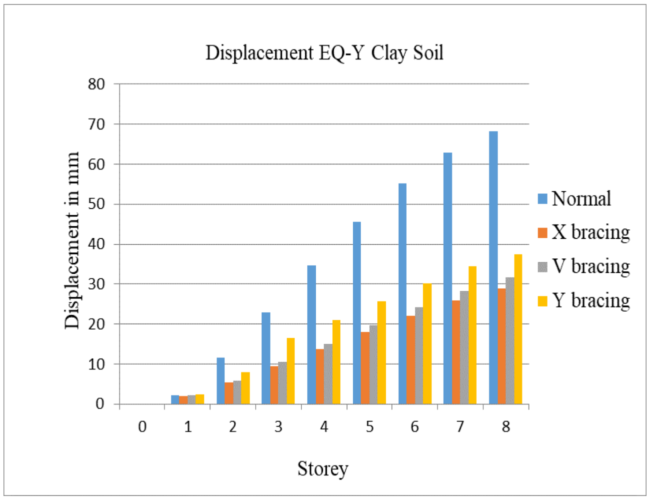


*Figure .3: Story Displacement EQ-Y Clay Soil*

- **Story Drift ClaySoil**

Lateral deformation of inter-story varying with X bracing, V bracing, Y bracing and without bracing for clay soil are shown in EQ-X and EQ-Y direction.

### Story DriftEQ-X

**Table3 : Story Drift EQ-X Clay Soil in mm**

| Story | NORMAL | X BRACING | V BRACING | Y BRACING |
|---|---|---|---|---|
| 8 | 8.97 | 3.75 | 4.068 | 4.05 |
| 7 | 15.3 | 4.176 | 4.656 | 4.66 |
| 6 | 19.86 | 4.43 | 5.03 | 5.034 |
| 5 | 22.881 | 4.518 | 5.2 | 5.21 |
| 4 | 24.663 | 4.416 | 5.16 | 5.17 |
| 3 | 25.488 | 4.130 | 4.926 | 4.928 |
| 2 | 24.651 | 6.27 | 7.06 | 9.9 |
| 1 | 2.89 | 3.18 | 3.15 | 4 |
| 0 | 0 | 0 | 0 | 0 |

**Table5.4: Story Drifts EQ-Y Clay Soil in mm**

| Story | NORMAL | X BRACING | V BRACING | Y BRACING |
|---|---|---|---|---|
| 8 | 5.3 | 3.189 | 3.369 | 3.38 |
| 7 | 7.6 | 3.759 | 4.02 | 4.03 |
| 6 | 9.6 | 4.113 | 4.437 | 4.4 |
| 5 | 11.02 | 4.278 | 4.65 | 4.7 |
| 4 | 11.71 | 4.3 | 4.67 | 4.8 |
| 3 | 11.43 | 4.11 | 4.56 | 8.43 |
| 2 | 9.315 | 4.26 | 4.65 | 5.5 |
| 1 | 2.03 | 1.59 | 1.62 | 2.5 |
| 0 | 0 | 0 | 0 | 0 |

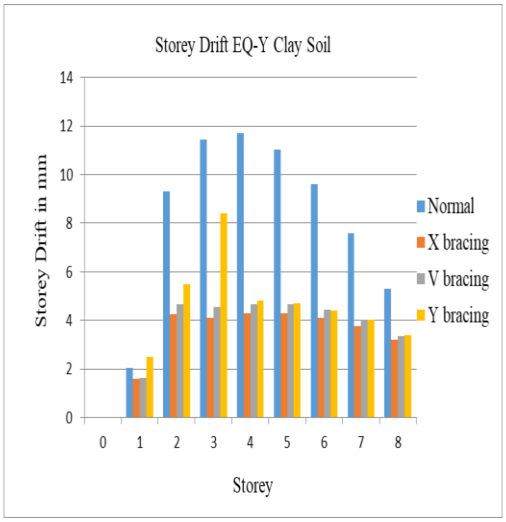


*Figure .4: Story Drift EQ-Y Clay Soil*

- **Story Shear for Clay Soil**

Lateral story shear floor wise varying with X bracing, V bracing, Y bracing and without bracing for clay soil are shown in EQ-X and EQ-Y direction.

### Story shear EQ-X

**Table.5: Story Shear EQ-X in kn**

| Story | NORMAL | X-BRACING | V-BRACING | Y-BRACING |
|---|---|---|---|---|
| 8 | 356.5 | 527.59 | 492.27 | 462.27 |
| 7 | 625.00 | 798 | 762 | 732 |
| 6 | 817 | 990 | 954 | 924.5 |
| 5 | 944 | 1138 | 1082 | 1051 |
| 4 | 1020 | 1194 | 1158 | 1128 |
| 3 | 1058 | 1232 | 1196 | 1166 |
| 2 | 1070 | 1285 | 1249 | 1219 |
| 1 | 1071 | 1325 | 1289 | 1259 |
| 0 | 0 | 0 | 0 | 0 |

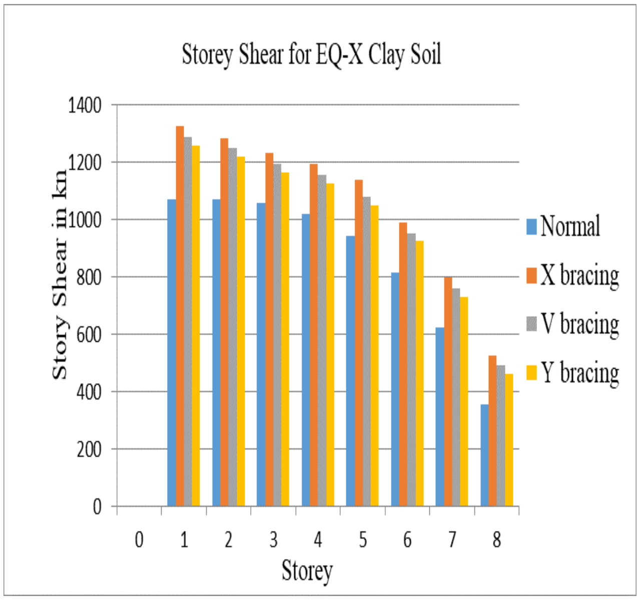


**Figure 5.: Story shear for EQ-X Clay Soil**

**Table6: Story Shear EQ-Y in kn**

| Story | NORMAL | X-BRACING | V-BRACING | Y-BRACING |
|---|---|---|---|---|
| 8 | 243.5 | 365.5 | 335.2 | 315.27 |
| 7 | 515 | 636 | 605 | 585.3 |
| 6 | 704 | 828 | 797.5 | 777.6 |
| 5 | 831 | 976.3 | 925.1 | 905 |
| 4 | 907 | 1032 | 1001 | 981 |
| 3 | 945 | 1070 | 1039 | 1019 |
| 2 | 957 | 1108 | 1077 | 1047 |
| 1 | 958 | 1144 | 1113 | 1078 |
| 0 | 0 | 0 | 0 | 0 |

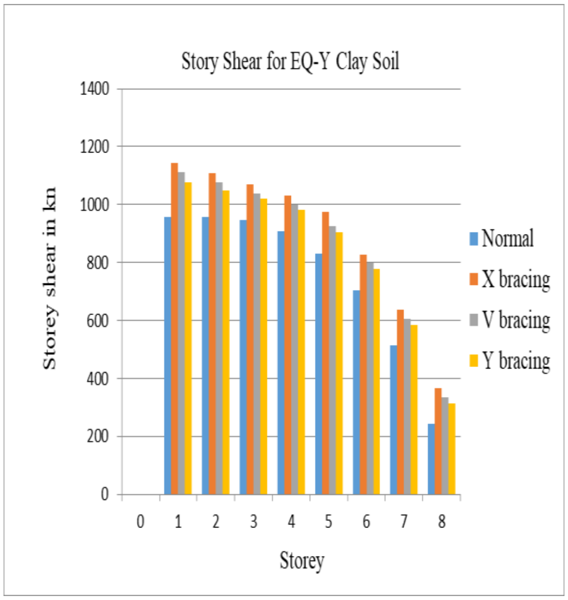


***Figure 6: Story Shear for EQ-Y Clay Soil***

- **Story Shear for EQ-Y**
- **Story Stiffness for Clay Soil**

Lateral story stiffness varying with X bracing, V bracing, Y bracing and without bracing for clay soil are shown

**Story Stiffness for EQ-X**

**Table 7: Story Stiffness EQ-X in kn/m**

| Story | NORMAL | X-BRACING | V-BRACING | Y-BRACING |
|---|---|---|---|---|
| 8 | 39626 | 95253 | 87852 | 80451 |
| 7 | 40889 | 150425 | 134750 | 119075 |
| 6 | 41141 | 185117 | 162835 | 140553 |
| 5 | 41270 | 209992 | 182098 | 154204 |
| 4 | 41367 | 232129 | 198331 | 164533 |
| 3 | 41511 | 257275 | 215398 | 173521 |
| 2 | 43511 | 218088 | 187399 | 156710 |
| 1 | 380955 | 547382 | 540686 | 533990 |
| 0 | 0 | 0 | 0 | 0 |

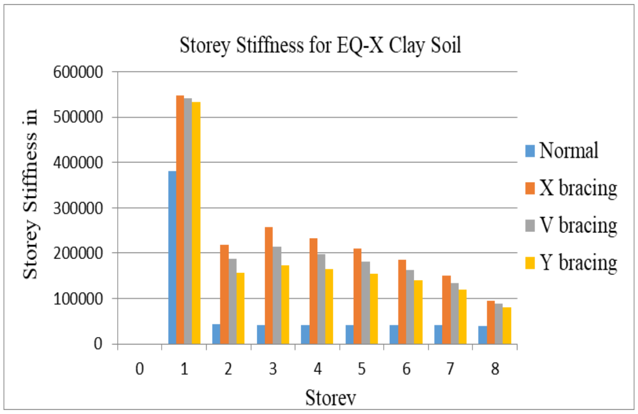


***Figure 7: Story Stiffness for EQ-X Clay Soil***

**Table.8: Story Stiffness EQ-Y in kn/m**

| Story | NORMAL | X-BRACING | V-BRACING | Y-BRACING |
|---|---|---|---|---|
| 8 | 67213 | 112149 | 106074 | 100000 |
| 7 | 82665 | 167079 | 156050 | 145022 |
| 6 | 84922 | 199505 | 184650 | 169795 |
| 5 | 85631 | 221743 | 203759 | 185776 |
| 4 | 87107 | 240695 | 219404 | 198113 |
| 3 | 92530 | 258029 | 232692 | 207355 |
| 2 | 115260 | 279897 | 255765 | 231633 |
| 1 | 534995 | 829975 | 793853 | 757730 |
| 0 | 0 | 0 | 0 | 0 |

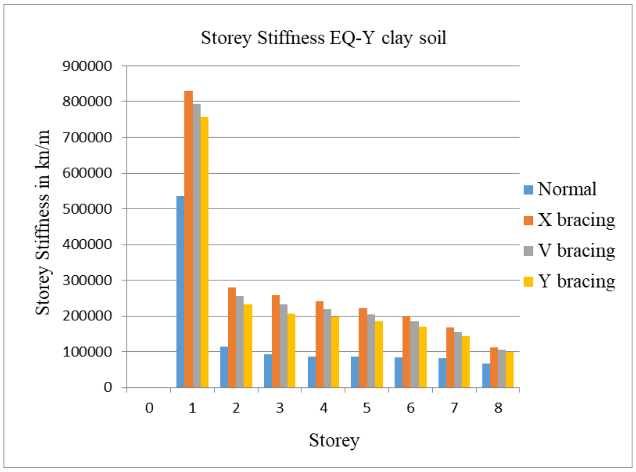


***Figure 8: Story Stiffness EQ-Y clay soil***

As we obtain result for clay soil. Same procedure is apply to obtain the result for silty soil and sand soil.

## 1. Comparative Results:

Overall 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

### Maximum Story Displacement

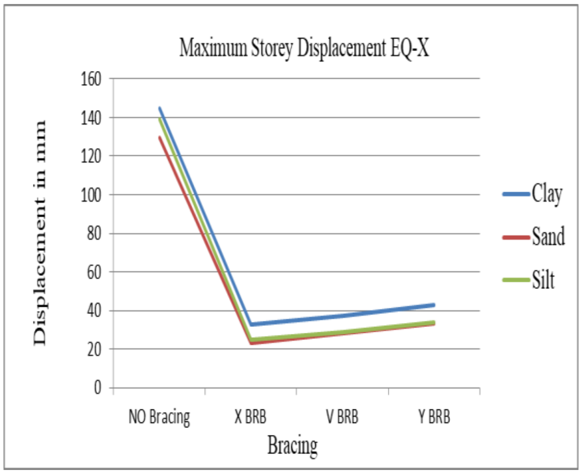


***Fig 9.Maximum Story Displacement EQ-X***

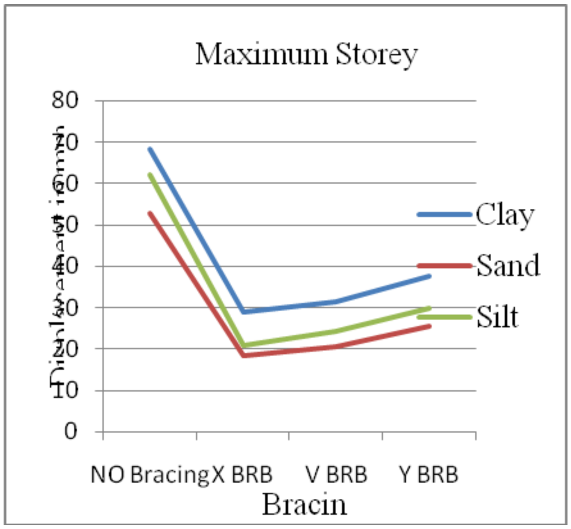


***Fig10. Maximum Story Displacement EQ-Y***

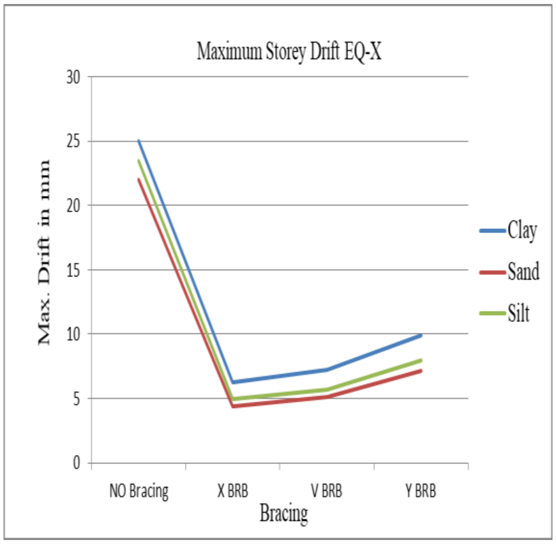


***Fig11 .Maximum Story Drift EQ-X***

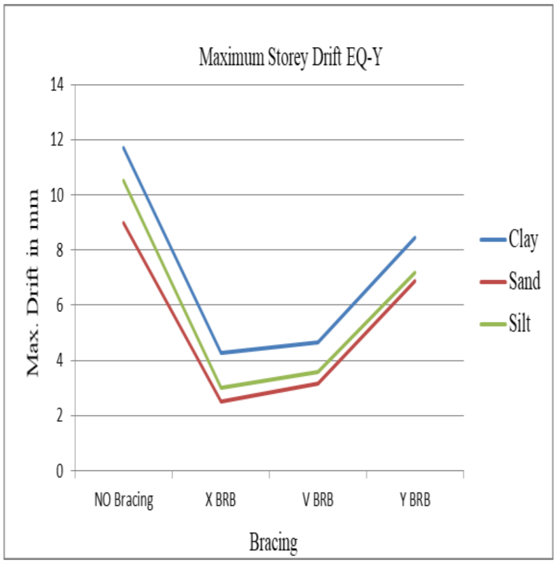


***Fig.13 Maximum Story Drift EQ-Y***

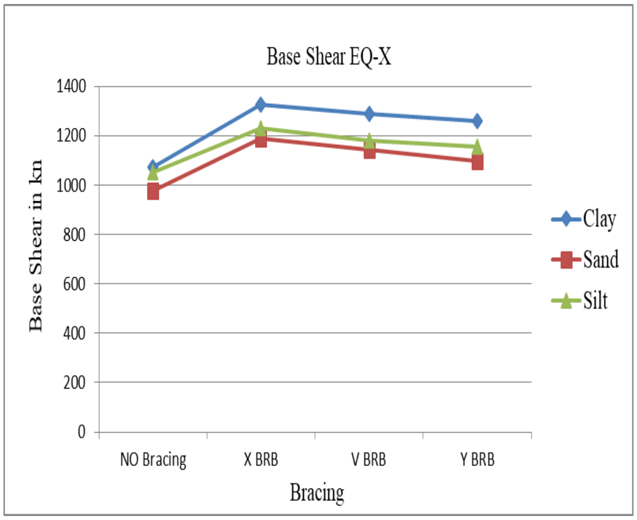


***Figure15: Base Shear EQ-X***

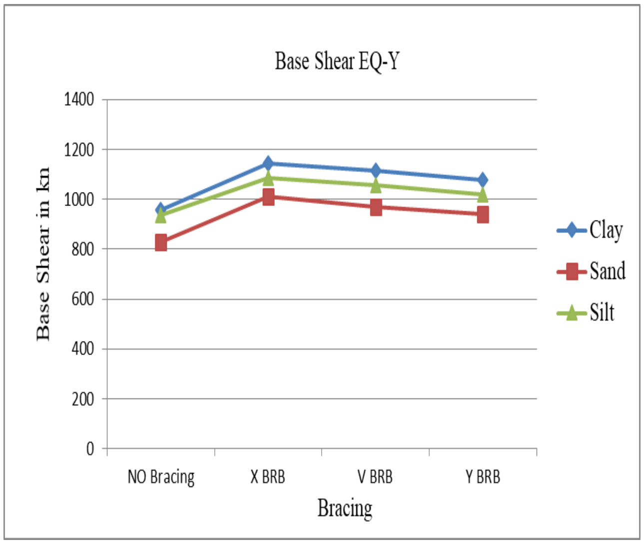


***Fig. 12 Base Shear EQ-Y***

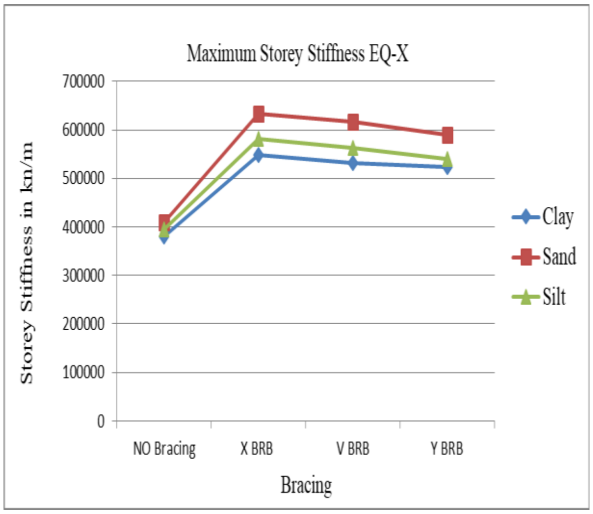


***Fig. 14 Maximum Story Stiffness EQ-X***

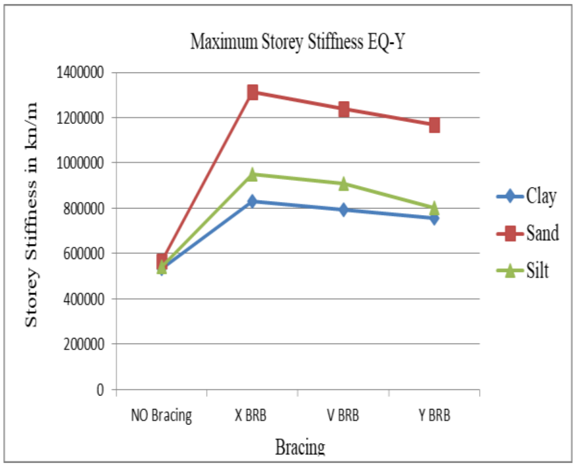


***Fig16. Maximum Story Stiffness EQ-Y***

## VI. CONCLUSION

### 6.1. Introducttion

In this dissertation work, structural performance of steel frame building during seismic excitation has been carried out using various shapes of BRB system. Software analysis using ETABS17 is prepared for obtaining results and calculations. The seismic load are carried out in accordance with IS 1893(2016) by response spectrum method. In accordance with previous results and discussion chapter, various conclusions are made in the following section. In the given study the building with various combination of BRB considering SSI is studied &from the above study following conclusion are drawn.

### 6.2. 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.

**Future scope**

Same work can be conducted by keeping the effect of change in degree of slopes for step back buildings with bracing system can be found out. Study can be continued further for finding the effective position of bracings for different configuration. Using the base isolation and different damper same work can be repeated.

## REFERENCES

[1] Hector Guerrero, Experimental damping on frame structures equipped with buckling restrained braces (BRBs) working within their linear-elastic response, Soil Dynamics and Earthquake Engineering, 20 December2017, pp 196 to 203.

[2] F. Barbagallo, Seismic design and performance of dual structures with BRBs and semi-rigid connections, Journal of Constructional Steel Research, 31 March 2019, pp 306 to 316.

[3] M. Bosco, M. Marino, Design of steel frames equipped with BRBs in the framework of Eurocode, Journal of Constructional Steel Research, 7 May2015, pp 43 to 57.

[4] S.A. Seyed Razzaghi, Evaluating the Performance of the Buckling Restrained Braces in Tall Buildings with peripherally Braced Frames, Journal of Rehabilitation in Civil Engineering , 5 February2018, pp 21 to 39.

[5] Antonios Flogeras, The seismic response of steel buckling-restrained braced structures including soil-structure interaction, Earthquake and Structures, March 2017, pp 45 to 63.

[6] Songye Zhu, Seismic Analysis of Steel Framed Buildings with Self-Centering Friction Damping Braces, 4th International Conference on Earthquake Engineering 2006, Vol. 14, pp 12-17.

[7] Rodolfo Antonucci, Shaking Table Testing of an RC Frame with Dissipative Bracings, 13th World Conference on Earthquake Engineering Vancouver, Vol. 13, March 2017

[8] Chien-Liang. Lee, An Experimental Verification of Seismic Structural Control Using in-Plane Metallic Dampers, International Journal of Structural and Civil Engineering Research, August 2018, pp 3 to 11.

[9] Marco Baiguera, Dual seismic-resistant steel frame with high post-yield stiffness energy-dissipative braces for residual drift reduction, Journal of Constructional Steel Research, May 2015, pp 198 to 212.

[10] Nefize Shaban, Shake table tests of different seismic isolation systems on a large scale structure subjected to low to moderate earthquakes, Journal of Traffic and Transportation Engineering, 7 October 2018, pp 480 to 490.

[11] G. Palazzo, Damping Coefficient Of A Building With BRB Subject To Three Types Of Earthquake Ground Motions, 16th World Conference on Earthquake Engineering, 16 January2017.

[12] Agarwal P. and Shrikhande M. (2006) “Earthquake resistant design of structures”, Prentice- Hall of India Private Limited, New Delhi, India.

[13] Gustavo L. Palazzo, A Steel Moment–Resisting Frame Retrofitted with Hysteretic and Viscous Devices, National TechnologicalUniversity.

[14] IS 1893 (Part 1) - 2016 “Criteria for earthquake resistant design of structure, general provision and building”, Bureau of Indian standards, New Delhi.

[15] Lorenzo Casagrandea, Innovative dampers as floor isolation systems for seismically-retrofit multi-story criticalfacilities,Engineering Structures, October 2019, pp 20 to 26.

[16] Xiaoli Wu, Seismic Performance Evaluation of Building-Damper System under Near-Fault Earthquake, Shock and Vibration, April2020, pp 145 to 163.

[17] Hamdy Abou-Elfath, Periods of BRB steel buildings designed with variable seismic-force demands, Journal of Constructional Steel Research, 11 February 2019, pp 192 to 201.

[18] Shuling Hua, Seismic evaluation of low-rise steel building frames with self- centering energy-absorbing rigid cores designed using a force-basedapproach, Engineering Structures, December 2019, pp 123 to 143.

[19] Angelos S. Tzimasa, Seismic analysis and behavior of mixed MRF/BRB regular steel space frames with uniaxial

eccentricity, Soil Dynamics and Earthquake Engineering, March 2019, pp 31 to 35.