Seismic Performance Evaluation of RC Building Connected with and without X-Braced Friction Damper

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Abstract - *Structures are mainly subjected to various types of loading conditions such as earthquake and wind loads. For the earthquake zone areas, the structures are mainly designed considering seismic forces. The structures which are present in higher earthquake zone areas are liable to get more damaged or collapse, hence to increase the safety of these structure a few retrofitting techniques or addition of materials to make the structures to stabilize against the earthquake forces are done. To stabilize the structure adding material externally to transfer the loads i.e. some protective devices have been made and developed. In this modern seismic design, the damping devices are used to reduce the seismic energy and able to control the structural response of the building to the vibration. Previous studies have shown that tension-only braced frames provide more structural stability and hence offer better resistance when the frame is subjected to lateral loads. In comparison between braced frames, additional efficiency offered by the bracing depends on the selection of bracing system.*

Key Words: Storey Building, Friction Damper, Storey Drift, Storey shear, Storey Stiffness, Friction Braced System, Overturning moment, Conventional Bracing System.

1. INTRODUCTION

1.1 General

There has been destruction of many residential buildings that has caused the death of many number of lives in past few years due to earthquake. This generally shows the seriousness of the earthquake problems. To achieve the concept of structural control, the modification in structural elements is carried out. Here, the structure is considered as dynamic system whose function variables are time, stiffness and damping. They may be adjusted to decrease effect of loads under considerable level. To achieve the structural system in control many techniques have been adopted.

1) Active damping system 2) passive damping system

To transfer the loads to the foundations and to dissipate the earthquake energy, these damping system are more helpful.

1.2 Active Damping System:

In a prescribed manner, the active damping system is considered with large external power source that may vary from ten kilowatts to several megawatts. The structure can be adopted to add or dissipate this energy. The energy required by the active system is very large. Active damping system includes- 1) Active brace system 2) Active mass damper system 3) Active tendon system

1.3 Passive Damping System

It is a device that is attached to the structure which may be designed to modify in damping or stiffness in a structure without requiring an external power in an appropriate manner to operate.

Passive damping system includes- 1) Tuned mass dampers (TMDs). 2) Magnetic dampers. 3) Viscous dampers. 4) Yielding dampers (Hysteretic, Metallic, X-plate or Elasto-plastic). 5) Friction dampers.

1.3.1 Tuned Mass Dampers it works on the principle of harmonic motion. The structure with TMD is made up of a mass and a spring attached to it. By resisting resonance frequency, it reduces the mechanical vibrations. It is made up of very large oscillating spring, mass, vico damper. To reduce the vibrations drastically, the components are light weight which acts as spring.

Applications: Transmission line, Automobiles, Tall buildings, Spacecraft.

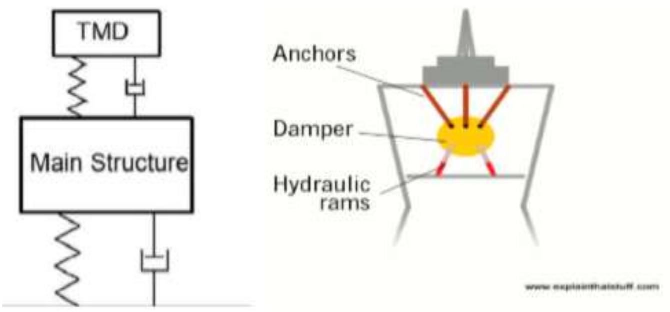

Fig -1.0: Tuned mass damper

1.3.2 Magnetic Dampers it is of electromagnetic damping with quad NdFeb magnet which is effective in cost. It is also not temperature dependent. It is very effective and easy to adjust. It is not so strong so that it is utilised in dynamic vibration where less damping is required by the absorbers. It is composed of two pinions, a copper disk, rear earth magnets and two racks. Because of the racks and pinions, the copper disk rotates when a relative motion is made. Applications: Automobiles, modern anti-earthquake building base construction and recoiling of the Gun.

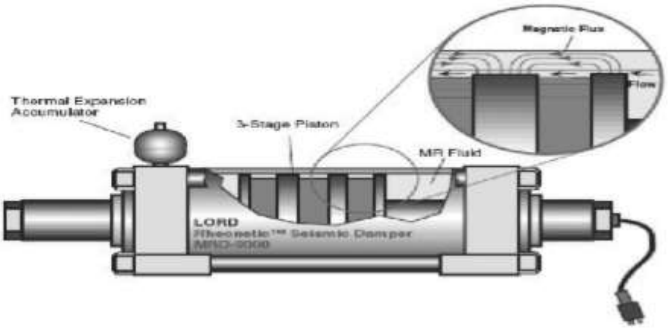

Fig -1.1: Magnetic damper

1.3.3 Viscous Dampers it works by pushing fluid through the orifice, which creates force producing a damping pressure. The earthquake or seismic forces are being reduced. Sometimes the horizontal floor acceleration and lateral deformation by 50% and more by addition of these viscous dampers. To make it durable material the viscous dampers are made of steel. The fluid to sustain for long period of time, the silicone oil is used because it is non-toxic, non-flamable and it is stable. The viscous dampers has many applications in retrofitting and designing due to availability in various sizes, adaptability and easy installation. Applications: Automobile, bracing in buildings, with base isolators, Bridges.

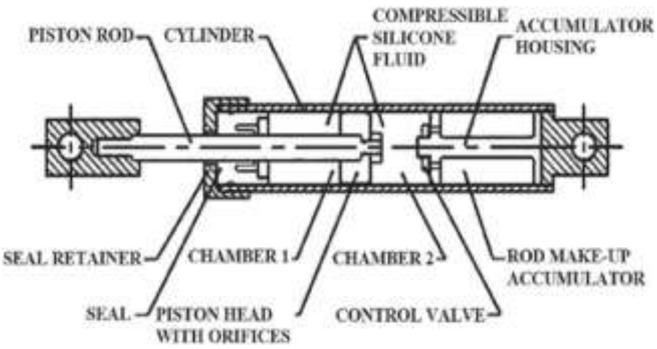

Fig -1.2: Viscous damper

1.3.4 Yielding Dampers the energy input to the structure is spent to submission and non- linear behaviour in used elements of the damper. The steel and lead for energy dissipation is used in dampers for inelastic deformation. The metallic dampers are more common in braces. Some parallel steel plates are used for this damper. The adsorption and energy dissipation are done by these dampers.

Application: Used to reduce the seismic response of inter-story drift

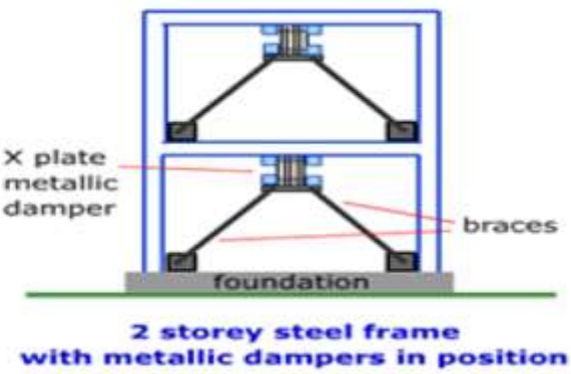

Fig -1.3: Yielding damper

1.3.5 Friction Dampers this works on principle by the virtue of solid friction developed between two sliding surface which dissipates the seismic energy. It is manufactured by Pall in the year 1979. It is now being used all over the world. It involves steel plates with high strength steel plates which connects in series for friction dampers. Friction pads are placed in middle of steel plates. In alternative, steel plates will be specially treated to have sufficient friction between them. Construction of the friction damper varies slightly depending upon the bracing system involved. It can be more reliable and economic mean to dissipate the energy. Here, the friction between the rubbing of surface will be utilised to dissipate seismic energy. Due to change in temperature the friction damper will not have vary in temperature. It can be converted as common type of damper as it is easy to install.

Working

The sliding surfaces start slipping when predominant value is reached by the friction damper. Before the yielding of the structural elements, the slipping should start. The load at which the slipping starts and at point which the seismic energy starts dissipating, it is called slip load. In friction damper the energy dissipation capacity will depend on the slip load and hence the structural response of the system. For the least response of the structure there is a optimal slip load for the structure where the damping system should be installed. At the optimum slip load the energy dissipation of the friction dampers is also maximum. Much effect is not observed in response of the structure for variation of 10% to 15%.

2. METHODOLOGY

1. Modelling of 12 story building with conventional bracing and friction damper

2. Modelling of 18 story building with conventional bracing and friction damper
3. Modelling of 24 story building with conventional bracing and friction damper
4. Linear static and dynamic analyses are carried out using ETABS software.
5. Comparisons of the results obtained from different models are done.
6. Conclusions are drawn

2.1 Modelling

For the digital appearances of the physical and functional depiction, the generation of elements and management is done in building modelling. For the testing of building a prototype is made and designed in the software for the analysis, this helps to know the likely performance of the building. For the best decision making the building models can be exchanged or networked. For demonstrating the procedure, modelling of the structure are illustrated below.

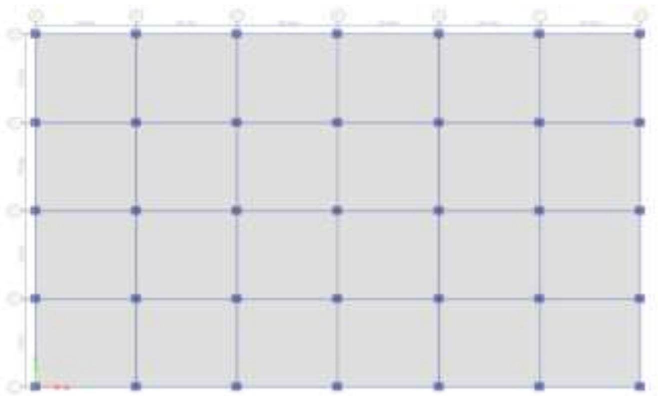

Fig -2.0: Plan

2.1.1 Material Property

Mainly 3 materials are used; M30 grade concrete, HYSD500 grade rebar and Fe250 grade steel. These properties are illustrated below in table 2.1, table 2.2 and table 2.3 respectively.

Table 2.1: Concrete Property of 12 and 18 storey Building

Material Name	M30
Directional Symmetric Type	Isotropic
Compressive Strength, f_{ck}	30MPa
Poisson's Ratio, U	0.2
Weight per Unit Volume	24.9926kg/m^3
Modulus of Elasticity, E	27386.13MPa
Coefficient of Thermal Expansion, A	0.0000055C^{-1}
Shear Modulus, G	11410.89MPa

Table 2.2: Rebar Property of 12 and 18 storey building

Material Name	HYSD500
Directional Symmetry Type	Uniaxial
Weight per Unit Volume	76.9729kN/m^3
Modulus of Elasticity, E	200000MPa
Coefficient of Thermal Expansion, A	0.0000117C^{-1}
Minimum Yield Strength, F_y	500MPa
Minimum Tensile Strength, F_u	545MPa
Expected Yield Strength, F_{ye}	550MPa
Expected Tensile Strength, F_{ue}	599.5MPa

Table 2.3: Steel Property of 12 and 18 storey building

Material Name	Fe250
Directional Symmetry Type	Isotropic
Weight per Unit Volume	76.9729kN/m^3
Modulus of Elasticity, E	210000MPa
Poisson's Ratio, U	0.3
Coefficient of Thermal Expansion, A	0.0000117C^{-1}
Shear Modulus, G	80769.23MPa
Minimum Yield Stress, F_y	250MPa
Minimum Tensile Strength, F_u	410MPa
Effective Yield Stress, F_{ye}	275MPa
Effective Yield Strength, F_{ue}	451MPa

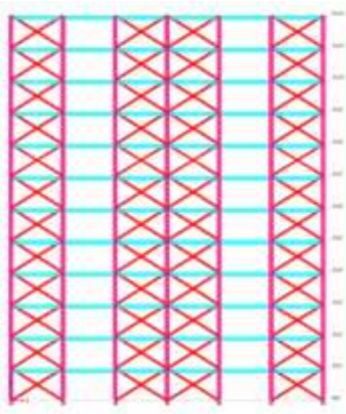

Fig-2.1: Elevation of 12-Storey Conventional Braced System

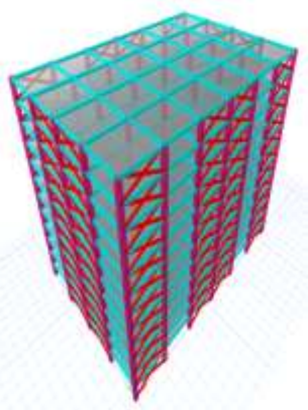

Fig-2.2: 3D View of 12-Storey Conventional Braced System

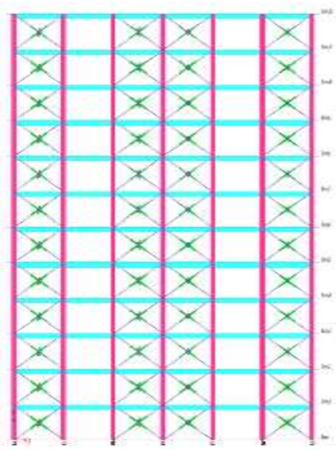

Fig-2.3: Elevation of 12-Storey Friction Braced System

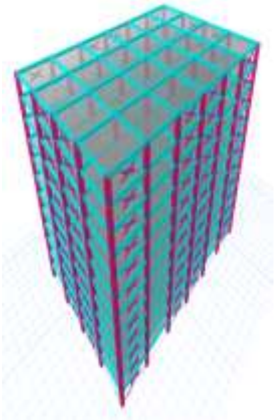

Fig-2.4: 3D View of 12-Storey Friction Braced System

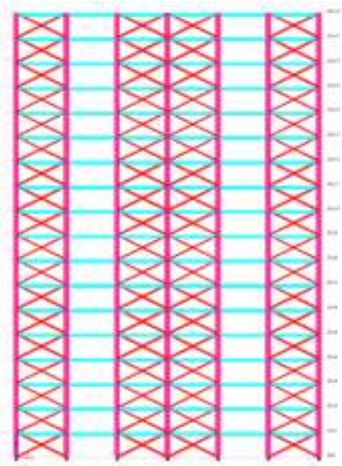

Fig-2.5: Elevation of 18-Storey Conventional Braced System

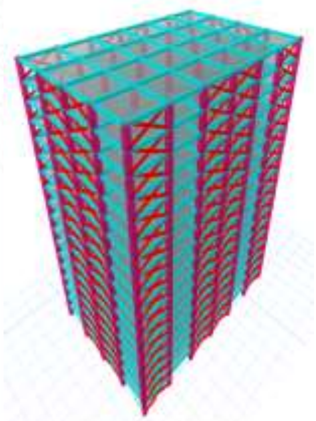

Fig-2.6: 3D View of 18-Storey Conventional Braced System

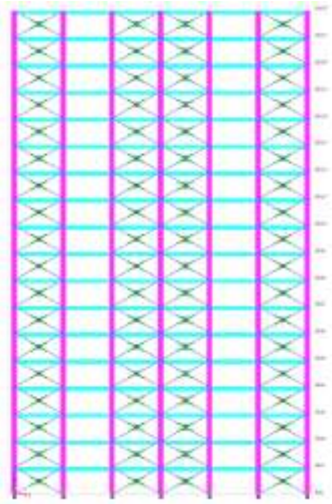

Fig-2.7: Elevation of 18-Storey Friction Braced System

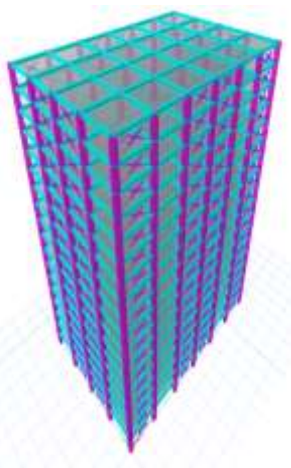

Fig-2.8: 3D View of 18-Storey Friction Braced System

2.2 Load Details

2.2.1 Dead Load

These are the natural permanent loads that are acting on the assembly and are dependent on the material properties used for unalike structural elements. IS 875-1987(Part I) affords the detail of unit weights for those materials used in structural elements.

2.2.2 Live Load

The live load on a structure or building is determined by the habitation or usage of that particular structure. IS 875-1987(Part II) defines the detail about the Live Loads for different usage of the structure. Since, the values of live loads for floors and roof are taken as 3kN/m^2 and 1.3kN/m^2 respectively.

2.2.3 Super Dead Load

These are dead loads which comprise of floor finishes and roof finish, these loads also depends on the unit weight of the materials used for the surfaces. The various material surfaces used and their weight per square meter are described in IS 875-1987(Part I). Since, the values of floor finishes and roof finish loads are taken as 1.3kN/m^2.

2.2.4 Earthquake Load

Earthquake forces are generated by the inertia of buildings as the buildings dynamically respond to ground motion. The dynamic nature of the earthquake loadings which makes it different from other building loads. The procedure to calculate the earthquake are described in IS 1893 (Part- I) because to calculate earthquake/ seismic force IS 1893 (Part- I) is used.

Table 2.4: The loading combinations are

Sl.No	Load Combination Details
a	1.5DL
b	1.5DL+1.5LL
c	1.2DL+1.2LL+1.2EQX
d	1.2DL+1.2LL-1.2EQX
f	1.2DL+1.2LL+1.2EQY
g	1.2DL+1.2LL-1.2EQY
h	1.5DL+1.5EQX
i	1.5DL-1.5EQX
j	1.5DL+1.5EQY
k	1.5DL-1.5EQY
l	0.9DL+1.5EQX
m	0.9DL-1.5EQX
n	0.9DL+1.5EQY
o	0.9DL-1.5EQY

2.3 Design of Structural members

A structural member designing is the method of examination of the stability, strength and rigidity. The basic objective of design is to produce a structural member capable of resisting all applied loads without failure in static and dynamic exploration. The primary purpose of a member is to spread or support loads applied to the building. The member will probably fail to perform its intended functionality if the member is not properly designed or if the actual applied loads exceed the design stipulations, with possible serious concerns. In this report, the designed sections are illustrated briefly in below design of structural members, occasionally in a simplified form.

Table 2.5: Columns Section Details of 12-storey building

PROPERTY NAME	MATERIAL	SECTION SHAPE	DEPTH	WIDTH
C950X950 M30	M30; Fe500	SQUARE	950mm	950mm

Table 2.6: Columns Section Details of 18-storey building

PROPERTY NAME	MATERIAL	SECTION SHAPE	DEPTH	WIDTH
C1150X1150 M30	M30; Fe500	SQUARE	1150mm	1150mm

Table 2.7: Beams Section Details of 12-storey building

PROPERTY NAME	MATERIAL	SECTION SHAPE	DEPTH	WIDTH
B500X600 M30	M30; Fe500	RECTANGULAR	500mm	600mm

Table 2.8: Beams Section Details of 18-storey building

PROPERTY NAME	MATERIAL	SECTION SHAPE	DEPTH	WIDTH
B550X650 M30	M30; Fe500	RECTANGULAR	550mm	650mm

Table 2.9: Slabs Section Details for both 12and18 storey building

PROPERTY NAME	MATERIAL	THICKNESS
S200M30	M30; Fe500	200mm

Table 2.10: Braces Section Details of 12 and 18 storey building

PROPERTY NAME	TUBE450X250X20
MATERIAL	Fe250
SECTION SHAPE	STEEL TUBE
DEPTH	450mm
WIDTH	250mm
FLANGE THICKNESS	25mm
WEB THICKNESS	25mm
WEIGHT	26.973kN

Table 2.11: VFD Properties of 12 and 18 Storey Building

PROPERTY NAME	FD
MASS Kg	1809.62
Weight KN	17.75
Effective Stiffness KN/m	0
Effective Damping KN-s/m	5280
Type	Friction Spring
Direction	U1
Non-linear	No

3. RESULTS AND DISCUSSION

This section defines about detail discussions of software results of different building models with and without BRBs. Comparative study of all types of building models are discussed with respect to storey shear, storey deflection, storey drift and time period etc.

3.1 Storey Displacement (mm)

Model	DISPLACEMENT, EQX	
	12-Storey	18-Storey
Conventional Bracing System	34.6637	57.6947
Friction Bracing System	77.6735	108.174

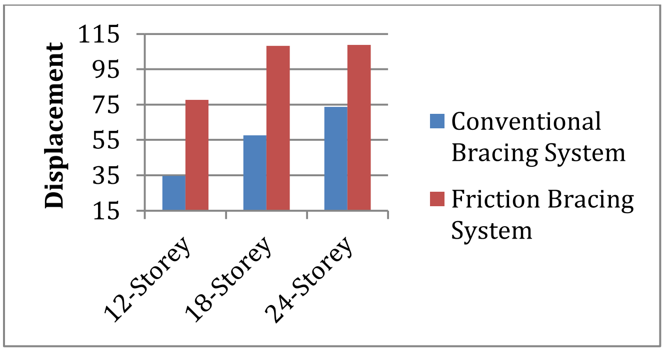

Fig-3.0: Maximum Storey Displacement (mm), (EQX)

In above graph the storey displacement of 12 and 18 storey is increased by 124.07% and 87.49% respectively in building consisting of friction damper system when compared with building consisting of conventional braced system**.**

Model	DISPLACEMENT, EQY	
	12-Storey	18-Storey
Conventional Bracing System	41.9621	68.0044
Friction Bracing System	79.8587	111.97

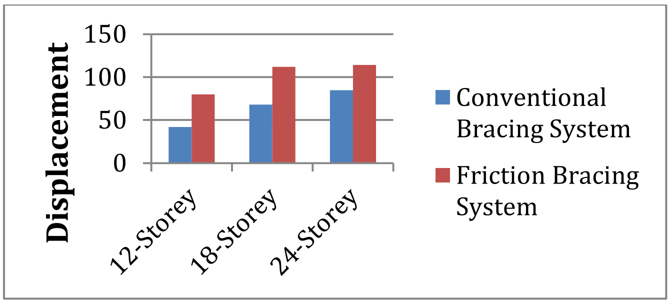

Fig-3.1: Maximum Storey Displacement (mm), (EQY)

In above graph the storey displacement of 12 and 18storey is increased by 90.31% and 64.65% respectively in building consisting of friction damper system when compared with building consisting of conventional braced system.

Model	DISPLACEMENT, RSX	
	12-Storey	18-Storey
Conventional Bracing System	26.6371	39.6284
Friction Bracing System	59.38516	81.0489

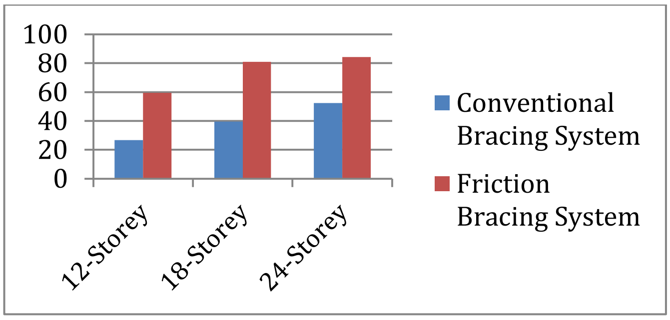

Fig-3.2: Maximum Storey Displacement (mm), (RSX)

Model	DISPLACEMENT, RSY	
	12-Storey	18-Storey
Conventional Bracing System	31.2747	48.6959
Friction Bracing System	61.108	85.323

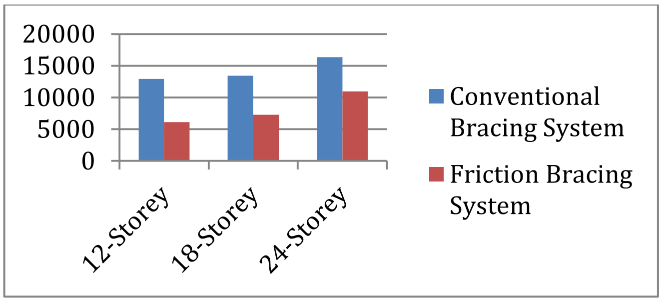

Fig-3.3: Maximum Storey Displacement (mm), (RSY)

3.2 Storey Drift

Model	DRIFT, EQX	
	12-Storey	18-Storey
Conventional Bracing System	0.000852	0.000953
Friction Bracing System	0.00222	0.002106

Model	DRIFT, EQY	
	12-Storey	18-Storey
Conventional Bracing System	0.001032	0.001127
Friction Bracing System	0.00228	0.002175

Model	DRIFT, RSX	
	12-Storey	18-Storey
Conventional Bracing System	0.000659	0.000675
Friction Bracing System	0.001863	0.00175

Model	DRIFT, RSY	
	12-Storey	18-Storey
Conventional Bracing System	0.000786	0.000826
Friction Bracing System	0.00191	0.001829

3.3 Storey Shear (KN)

Model	STOREY SHEAR, EQX	
	12-Storey	18-Storey
Conventional Bracing System	16088	16307
Friction Bracing System	6256	7508

Model	STOREY SHEAR, EQY	
	12-Storey	18-Storey
Conventional Bracing System	12944	13420
Friction Bracing System	6116	7303

Model	STOREY SHEAR, RSX	
	12-Storey	18-Storey
Conventional Bracing System	16088	16306
Friction Bracing System	6255.963	7507.99

Model	STOREY SHEAR, RSY	
	12-Storey	18-Storey
Conventional Bracing System	12944	13420
Friction Bracing System	6115.996	7302.996

3.2 Overturning Moment (KN-m)

Model	OVERTURNING MOMENT, EQX	
	12-Storey	18-Storey
Conventional Bracing System	605618	916656
Friction Bracing System	249010	450161

Model	OVERTURNING MOMENT, EQY	
	12-Storey	18-Storey
Conventional Bracing System	490095	760953
Friction Bracing System	244162	439846

Model	OVERTURNING MOMENT, RSX	
	12-Storey	18-Storey
Conventional Bracing System	475665	642877
Friction Bracing System	191527	341942

Model	OVERTURNING MOMENT, RSY	
	12-Storey	18-Storey
Conventional Bracing System	372801	555691
Friction Bracing System	187065	337641

3.3 Storey Stiffness (KN/m)

Model	STIFFNESS,EQX	
	12-Storey	18-Storey
Conventional Bracing System	10726420	12902870
Friction Bracing System	1985519	3149307

Model	STIFFNESS,EQY	
	12-Storey	18-Storey
Conventional Bracing System	6847069	8598026
Friction Bracing System	1928074	3044402

Model	STIFFNESS,RSX	
	12-Storey	18-Storey
Conventional Bracing System	11272207	13851346
Friction Bracing System	2120161	3320413

Model	STIFFNESS,RSY	
	12-Storey	18-Storey
Conventional Bracing System	7176610	9079481
Friction Bracing System	2067450	3218164

4. CONCLUSIONS

- The storey displacement in building including the friction damper system is increased by maximum amount of 124.07% when the height of the building is less in case of non-linear static analysis and it is increased by maximum amount of 122.94% as the height of the building less in case of non-linear dynamic analysis when compared to building with conventional bracing system.
- The storey drift of the building including the friction damper system is increased by maximum of 160.56% when the height of the building is less in case of non-linear static analysis and it is increased by maximum amount of 182.7% as the height of the building is less in case of non-linear dynamic analysis when compared to building with conventional bracing system.
- The storey shear of the building including the friction damper system is reduced by maximum of 61.11% when the height of the building is less in case of non-linear static analysis and it is reduced by maximum amount of 61.114% as the height of the building is less in case of non-linear dynamic analysis when compared to building with conventional bracing system.
- The Overturning moment of the building including the friction damper system is reduced by maximum amount of 58.88% when the height of the building is less in case of non-linear static analysis and it is reduced by maximum amount of 59.73% as the height of the building is less in case of non-linear

dynamic analysis when compared to building including the friction damper system

- The storey stiffness of the building including the friction damper system is reduced by maximum amount of 81.48% when the height of the building is less in case of non-linear static analysis and it is reduced by maximum amount of 81.19% as the height of the building is less in case of non-linear dynamic analysis when compared to building including the friction damper system.

REFERENCES

[1] M.H. Mehrabi, Zainah Ibrahim S.S. Ghodsi, Meldi Suhatril "Seismic characteristics of X-cable braced frames bundled with a pre-compressed spring" Journal paper of

[2] Soil Dynamics and Earthquake Engineering-2019

[3] Ciro Del Vecchio, Robert Gentile, Marco Di Ludovico, Giuseppina Uva and Stefano Pampanin " Implementation and validation of the simple lateral mechanism analysis (SLaMA) for the seismic performance assessment of a damaged case study building" Journal of Earthquake Engineering- 2018

[4] Shameena Khannavar, M.H. Kolhar, Anjum Algur "Seismic Analysis of RC structures using Friction Dampers". IJRASET-2017

[5] Liu Jin, Shuai Zhang, Dong Li, Haibin Xu, Xiuli Du and Zhenbao Li " A combined experimental and numerical analysis on the seismic behaviour of short reinforced concrete columns with different Structural sizes and axial compression ratios" International Journal of Damage Mechanics-2017

[6] M. Alirezaei, M. Mofid and H. Tajamolian "An investigation into the Seismic Behaviour of single-story concrete frames equipped with metallic yielding dampers". Scientia Iranica-2015

[7] S.I. Khan Prof. P.O. Modani "Seismic evaluation and retrofitting of RC building by using Energy Dissipating Devices". IJERA -2013

[8] S.I Khan and Prof. P.O Modani " Seismic retrofitting of RC building by using bracing Systems" IJERT-2013

[9] Farzin Zareian , Helmut Krawinkler, Luis Ibarra and Dimitrios Lignos " Basic concepts and performance of collapse of building under earthquake ground motions". The structural design of tall and special buildings- 2010.