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Study of Steel Frame with Different Bracing Systems under Dynamic Loading

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Abstract—*Earthquake is a dynamic loading. To generate this type of load for experimental work, shake table with arrangement for producing lateral motion is required. A framed structure made up of steel with the rigid connections is used for the present study. Steel frame with different arrangements of bracing system is tested on uniaxial shake table and the response of structure is recorded with the help of Data Acquisition System and sensors like accelerometer. A low cost shake table with uniaxial motion is developed for testing the steel frame. Shake table is developed with help of DC motor to produce sinusoidal motion waves which is connected to the table with help of cam follower that produces forward and backward motion of table to generate thee loading. RPM of motor can be controlled with a panel. Experimental data is obtained with the help of DAQ system and is validated by analytical model of frame developed using SAP2000.*

1. INTRODUCTION

The structures may crumble like a house of cards during a major or minor earthquake if it is not designed for resisting earthquake loading. To design reliable earthquake resistant structures it is required to understand the response of structure subjected to the earthquake loading. To get the realistic behaviour of structure during earthquake experimental analysis is required. Shake table test is one of experimental test that generates earthquake motion and one can check how the structure may response during the earthquake.

In this work behavior of steel frame with and without bracing systems is studied using low cost shake table developed in the laboratory. Steel frame model with E250 grade of structural steel is fabricated with different types of bracing arrangement for shake table test. Analytical study of steel frame is done using SAP2000 software. Linear time history analysis on frame is performed to obtain acceleration data. As an input data the acceleration generated using low cost shake table is used in SAP2000 for analysis.

2. EXPERIMENTAL SETUP

2.1 Bare Steel Frame

Steel frame model without bracing is used and the dimensional detail of model is given in Table 1.

Table 1: Details of bare frame model

Part	Depth (D) (mm)	Width (B) (mm)	Length (L) (mm)
Column	$D_A = 5.00$	$B_A = 25.4$	$L_A = 450$
slab	$D_B = 5.00$	$B_B = 150$	$L_B = 300$

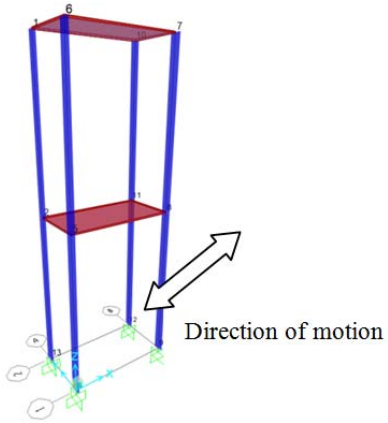


Figure 1: Model of Steel Frame without bracing.

2.2 Steel Frame with Diagonal Bracing

Diagonal bracing system is added to bare frame.

Table 2: Details of diagonal bracing model

Part	Depth (D) (mm)	Width (B) (mm)	Length (L) (mm)
Column	$D_A = 5.00$	$B_A = 25.4$	$L_A = 450$
Slab	$D_B = 5.00$	$B_B = 150$	$L_B = 300$
Bracing	$D_C = 3.00$	$B_C = 25.4$	$L_C = 550$

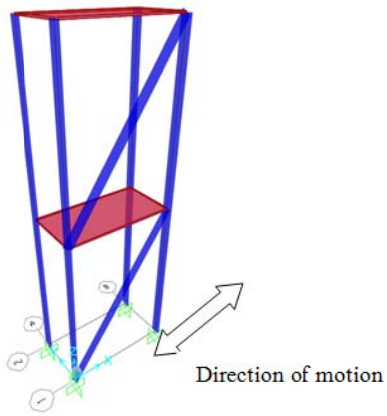


Figure 2: Model of Steel Frame With Diagonal Bracings.

2.3 Steel Frame with X-Type Bracing

X-type bracing system is added to bare frame.

Table 3: Details of X-type bracing model

Part	Depth (D) (mm)	Width (B) (mm)	Length (L) (mm)
Column	$D_A = 5.00$	$B_A = 25.4$	$L_A = 450$
Slab	$D_B = 5.00$	$B_B = 150$	$L_B = 300$
Bracing	$D_C = 3.00$	$B_C = 25.4$	$L_C = 550$

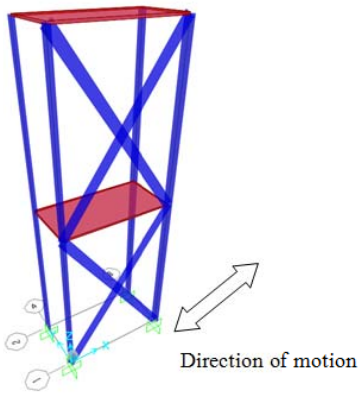


Figure 3: Model of Steel Frame With Diagonal Bracings.

2.4 Shake Table

Generally three types of shake tables are there:

1. Uniaxial shake table
2. Biaxial shake table
3. Triaxial shake table

These shake table can be operated using different types of actuators i.e. pneumatic, servomotor, electro dynamic, mechanical actuator.

In this work a low cost shake table is developed using 0.5 HP motor. And it is an unaxial shake table. Size of shake table is 0.7m X 0.7 m and this table is placed on a 1.0m x 1.5 m table. Motor of 0.5 HP with current 2.2 AMPS, volts 130VDC is used for moving the table in one direction. A proximity switch is also attached to measure the RPM. Frequency of linear motion can be controlled with controlling RPM. Payload of 15 kg to 20 kg can be placed to move in uniaxial direction. In shake table to convert the rotational motion to linear motion cam follower system is used. Roller follower is used as it has less friction. Cam with rise of 2 cm and the base circle with diameter of 50 cm are used.

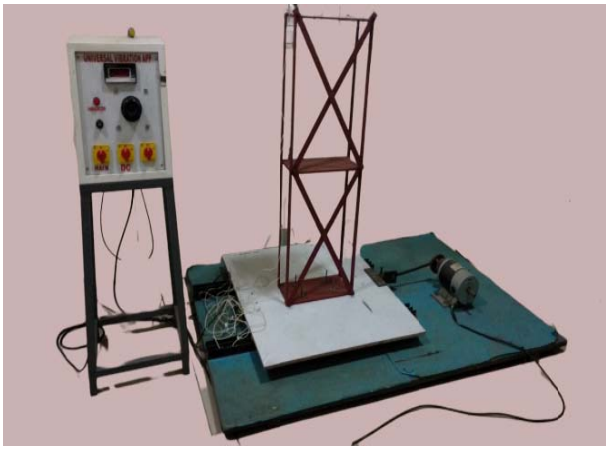


Figure 4: Shake Table Setup and RPM controller of D.C. motor.

3. RESULTS AND DISCUSSION

Different types of steel frame are tested on the uniaxial shake table. The Results are compared with analytical results obtained from SAP2000 model linear time history analysis.

Acceleration input data recorded with the help of accelerometer from shake table is shown below.

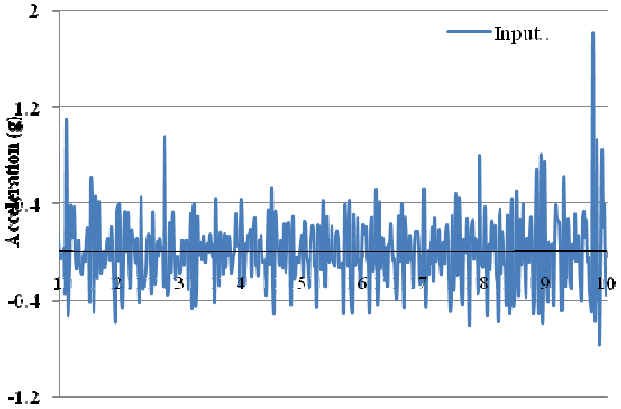
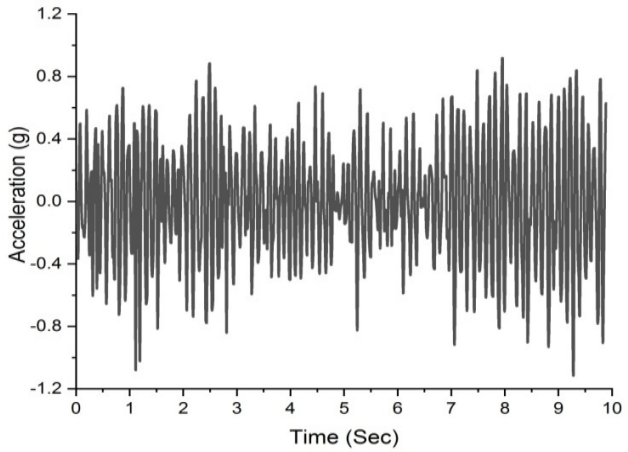
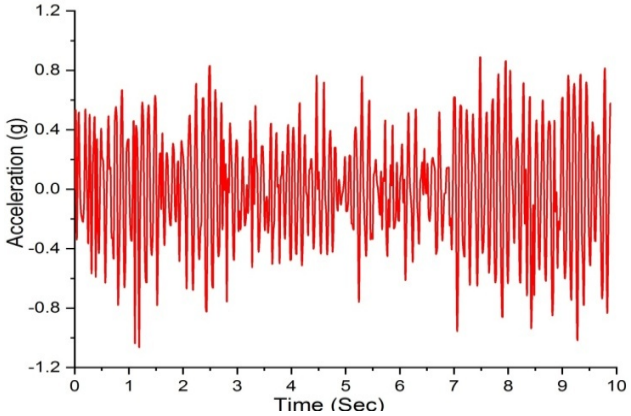


Figure 5. Input data of shake table test.

Experimental and analytical response of frame without bracing

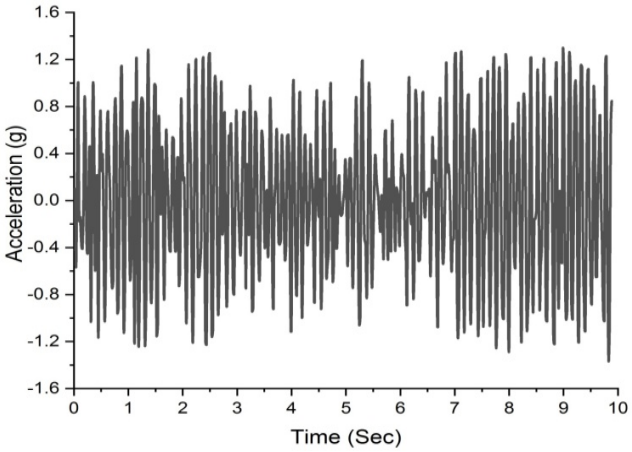


(a)

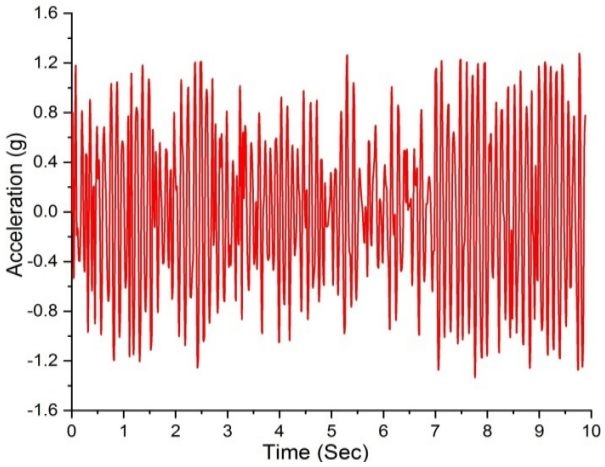


(b)

Figure 6. First Floor response of rigid steel frame without bracing: a) Analytical b) Experimental.



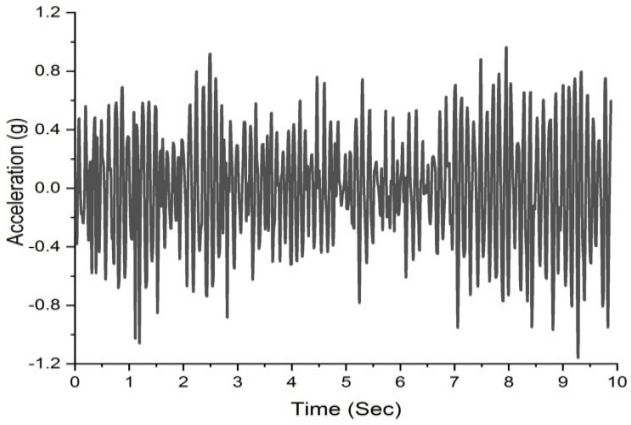
(a)



(b)

Figure 7. Roof response of rigid steel frame without bracing,: a) Analytical b) Experimental.

Experimental and Analytical response of frame with Diagonal Bracing system



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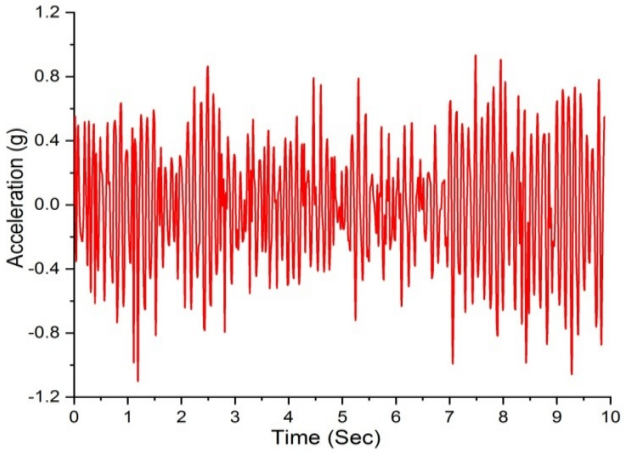
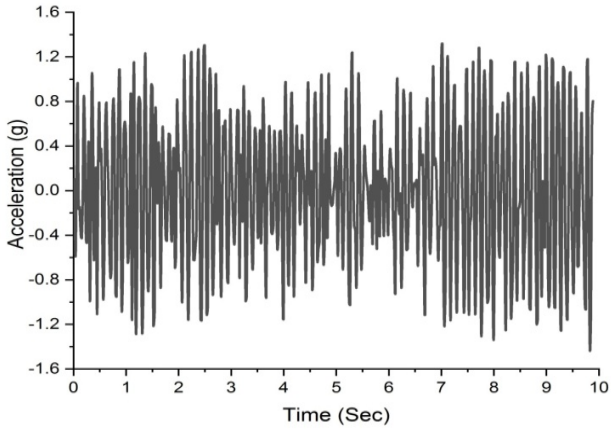


(b)

Figure 8. First Floor response of rigid steel frame with Diagonal bracing: a) Analytical b) Experimental.



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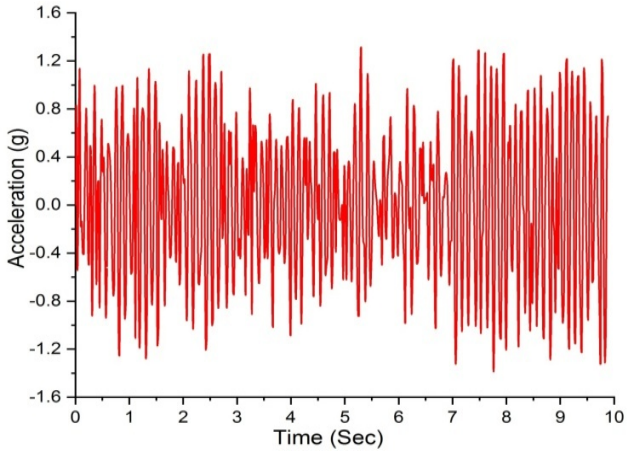
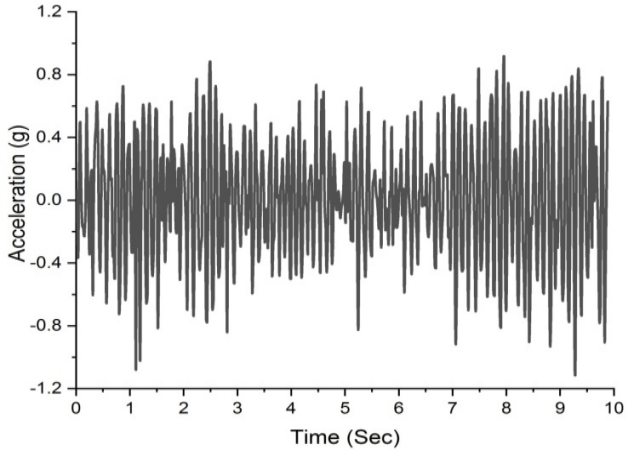


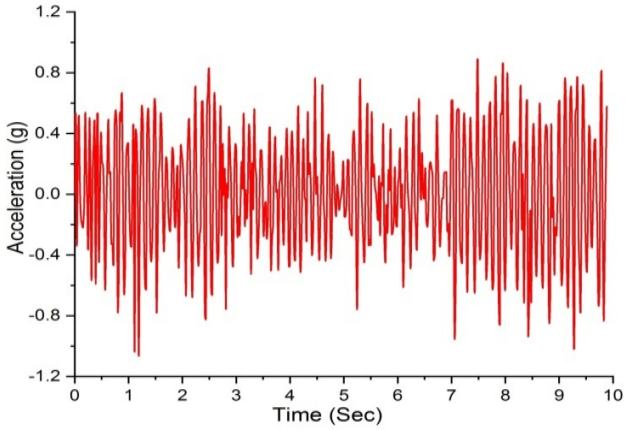
(b)

Figure 9. Roof response of rigid steel frame with Diagonal bracing, a) Analytical b) Experimental.

Experimental and Analytical response of frame with X-type bracing system-

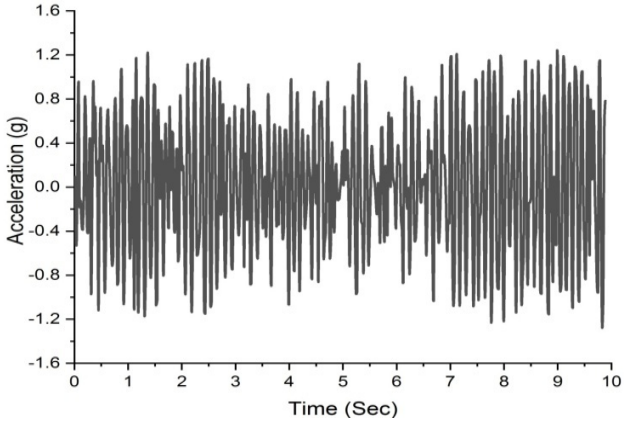


(a)



(b)

Figure 10. First Floor response of rigid steel frame with X-type bracing: a) Analytical b) Experimental.



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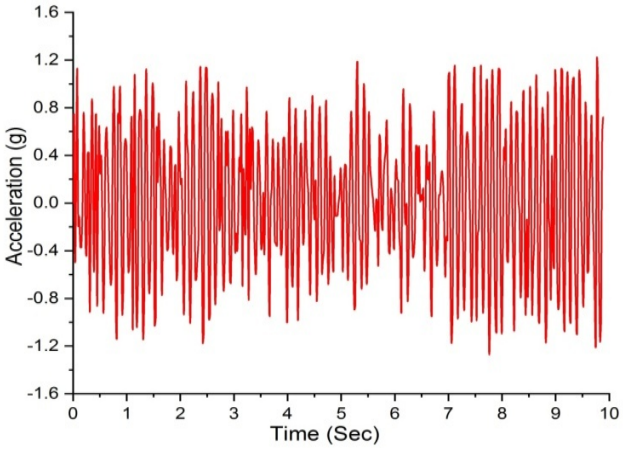

(b)

Figure 10. Roof response of rigid steel frame with X-type bracing, a) Analytical b) Experimental.

Above results show the acceleration response reduction of structure with the bracing system experimentally and analytically both. In both the floors acceleration values are reduced with the bracing system.

4. CONCLUSIONS

The experimental and analytical study is carried out to compare the response of bare steel frame with steel frame having diagonal and X-type bracing. There is a reduction of up to 5% in the response of steel frame with diagonal bracing when compared with bare steel frame. For X – type bracing the reduction is up to 10%. It can be concluded that the X-type bracing arrangement is more efficient than Diagonal Bracing system.

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