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Seismic performance of G+10 RCC frame with baseisolation system using time history analysis

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1. ABSTRACT

The most successful and extensively used strategy for shielding a structure against seismic forces is base isolation. The base isolation considerably decouples a structure from its base lying on the shaking earth, protecting the building's integrity by allowing it to withstand seismic forces without damage and protecting the lives of people. In the present study, an investigation is done to assess the seismic response of the structure with conventional fixed base and isolated base conditions. The isolation is configured with an elastomeric rubber isolator analysed and designed in accordance with the International Building Code, IBC: 2000. The analytical study is performed using ETABS software corresponding to G + 10 and building frame. The study is carried out by applying three-time histories, namely El-Centro, Uttarkashi, and Indo-Burma. The study reveals that the acceleration produced in the base-isolated structure is reduced in the range of 35–65% in comparison with the fixed base condition. Also roof velocities are 30-55% less for the isolated condition than the fixed base condition. In this paper roof displacement is also compared for fixed base and isolated base which reveals that roof displacements are 10-40% less for isolated base condition than fixed base. Thus, the study reveals that in case of mid-rise building (G+10) the base isolation effect is more prominently observed throughout all stories which remains almost constant. Energy demand in the Isolated Base Buildings is reduced to the tune of 10 to 80% showing the effectiveness of Isolation to keep the structure from deterioration.

2. KEY WORDS

Fixed base, base isolation, Elastomeric rubber isolator, Nonlinear Time history analysis, Software (ETABS 2018)

3. INTRODUCTION

An efficient method for enhancing the seismic performance of structures is to use seismic isolation and energy dissipation devices [4]. By extending the structure's vibrational period, isolation facilitates the reduction of Earthquake forces. The base isolation idea is already well known as a viable option for the seismic safety of structures like buildings and bridges. The way isolation works is like how shock absorbers isolate a car from the ground to prevent Vibration transfer. But not all the vibrations are mitigated but the frequency and magnitude can be reduced to a safer limit. A similar working principle is used in base isolation shown in Fig.1.1 where the first building is fixed base and the second is isolated base. When an earthquake strikes a building with a fixed base, the roof story moves more and the rate of movement slows down as it descends, causing story drift and shear, whereas when an earthquake strikes a building with an isolated base, the entire structure moves as the isolator itself absorbs almost the entire energy, leaving the structure essentially stable [12]. Isolation systems such lead rubber bearings, friction pendulum bearings, elastomeric rubber bearings, high damping rubber bearings, and spring isolators are used. The elastomeric bearings are one of the isolation technologies that have been used most frequently in recent years [11].

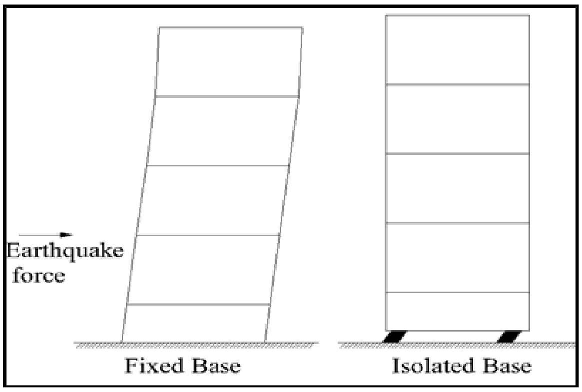


Fig. 3.1 Fixed Base vs Isolated Base

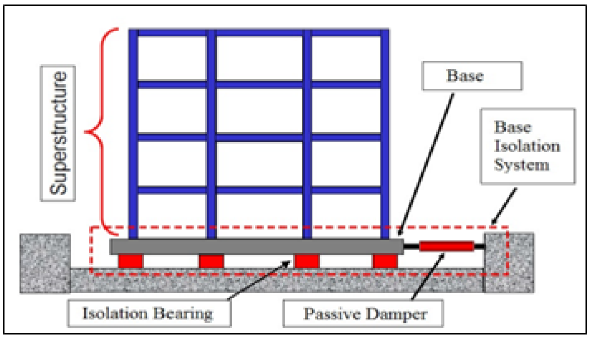


Fig. 3.2 Components in an Isolation system

4. Proposed Study

The present study is aiming to evaluate the behavior of G+10 building frame which are analyzed for two conditions one being the Fixed Base condition and other being the Isolated base condition in which the elastomeric rubber bearing is provided under each column. The models are tested with three Time Histories Namely El-Centro, Indoburma & Uttarkashi. The results are obtained for Fixed and Isolated Base condition.

5. Objectives of proposed work

- To design isolation system using International Building Code: 2000.
- To evaluate the effect of isolation for three different configurations of RCC building frames with various time history motions**.**
- To compare roof acceleration of RCC buildings with and without isolation.
- To compare roof velocity of RCC buildings with and without isolation.
- To compare roof displacement of RCC buildings with and without isolation.

6. Methodology

- Create G+10 RCC models in ETABS (2018) Software.
- Define materials, section properties, and assign them.
- Assign various loads.
- Perform Time History analysis with Fixed Base condition [12].
- Determine Maximum Load on Columns.
- Design base Isolation System
- Perform Time History analysis with isolated Base condition.
- Compare results from analysis for variation parameters.

7. DESIGN OF BASE ISOLATION SYSTEM

Table 7.1: - Geometric and material properties of G+10 building frame.

Contents	
Structure	SMRF
No. of stories	G+10
Storey Height	3.3 m
Grade of Concrete	M 40
Grade of Steel	Fe500
Bay width (Both Direction	4 m.
Slab thickness	0.15 m
Size of Column	0.7 m x0.7m
Size of Beam	0.75mx0.5m
Floor finish	1kN/m²
Live load	2.5 kN/m²
Seismic Zone	V

According to IBC: 2000 there are three basic elements in anypractical seismic isolation system. These are:

1. A flexible mounting so that the period of vibration of the total system is lengthened sufficiently to reduce the force response.
2. A damper or energy dissipater so that the relative deflections between building and ground can be controlled to a practical design level.
3. A means of providing rigidity under low (service) load levels such as wind and minor earthquakes.

7.1 Design Displacement

$$D_D = \left(\frac{g}{4\pi^2}\right)\frac{S_{D1}T_D}{B_D}$$

g - Is the gravitational acceleration.

SD1 - spectral coefficients, available from the maps shown in Fig.4.12accompanying the IBC-2000

TD - is isolated period,

BD - damping coefficients corresponding to the DBE level responses shown in Table 1623.2.21 of IBC 2000

7.2 The effective stiffness of rubber is given by equation,

$$k_H = \frac{W}{g}\left(\frac{2\pi}{T}\right)^2$$

7.3 Area of Rubber can be calculated from

$$A = \frac{k_H T_r}{G}$$

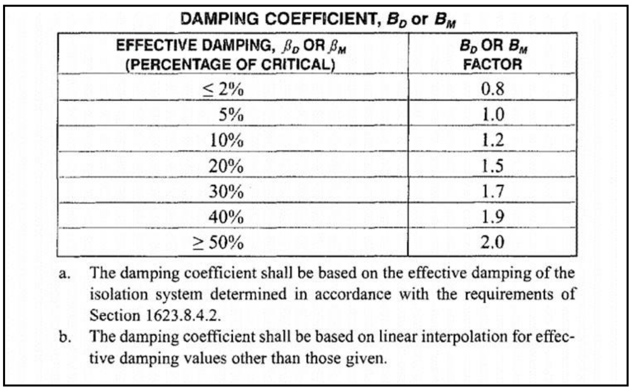
K_H- Effective Horizontal stiffness of Rubber

T_r- Thickness of Rubber

G- Shear modulus of Rubber

w – Max. Support Reaction

Table 7.2: - Values of BD or BM factor (Table 1623.2.21 of IBC: 2000)



DAMPING COEFFICIENT, B_D or B_M

EFFECTIVE DAMPING, β_D OR β_M (PERCENTAGE OF CRITICAL)	B_D OR B_M FACTOR
≤ 2%	0.8
5%	1.0
10%	1.2
20%	1.5
30%	1.7
40%	1.9
≥ 50%	2.0

a. The damping coefficient shall be based on the effective damping of the isolation system determined in accordance with the requirements of Section 1623.8.4.2.

b. The damping coefficient shall be based on linear interpolation for effective damping values other than those given.

Energy dissipated per cycle, WD.

$WD = 2\pi \times k_{eff} \times ß \times D^2$

Characteristics strength, Q;
$Q = WD / (4(D-Dy))$

Post-yield stiffness of the isolator, k_2;

$K_2 = k_{eff} - (Q/D)$

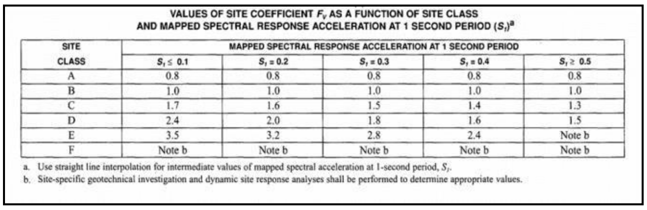
Yield displacement, Dy is given by.

$Dy = Q / (k_1 - k_2)$

Yield strength, Fy

$Fy = Q + kd. Dy$

Table 7.3: - Values of site Coefficient Fv (Table 1615.1.2(2) of IBC: 2000)



VALUES OF SITE COEFFICIENT F_V AS A FUNCTION OF SITE CLASS AND MAPPED SPECTRAL RESPONSE ACCELERATION AT 1 SECOND PERIOD $(S_1)^a$

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT 1 SECOND PERIOD				
	$S_1 \le 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \ge 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	Note b
F	Note b	Note b	Note b	Note b	Note b

a. Use straight line interpolation for intermediate values of mapped spectral acceleration at 1-second period, S_1.

b. Site-specific geotechnical investigation and dynamic site response analyses shall be performed to determine appropriate values.

Based on the equations and by taking the shear modulus of rubber as 0.89 Mpa obtained from manufacturers catalogue for the hardness scale IRHD 60 rubber. The design code provisions are having coefficient factors and Spectral acceleration for the specific region i.e., United States.

We designed the isolator under Column load below every column of G+10frame. We take damping to be 20%.

storey	Earthquake	Maximum Support Reaction (KN)	Effective Isolation Time Period (Sec)
G+10	El-centro	9800.51	2
	Indoburma	3665.7	2
	Uttarkashi	6228.32	2

Therefore, from Table 1623.2.2.1 of IBC: 2000, BD=1.50. We take a typical high damping rubber compound with G=0.89Mpa (referring Table 7.4)

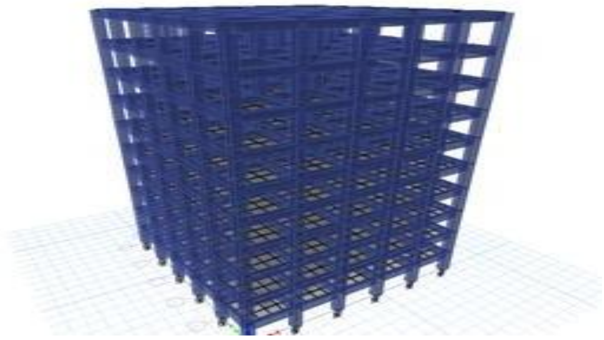
Table 7.4: - Values of Maximum support reaction after time history analysis for fixed base condition.

Table 7.5: - Properties for Analysis in ETABS Software-

storey	Earthquake	Linear Stiffness in U2 &U3 direction (KN/M)	Nonlinear stiffness in U2&U3 direction (KN/M)	Yield strength of rubber (KN)	Post yield stiffness ration
G+10	El-Centro	9830	83112.05	324.063	0.1
	Indoburma	3676.8	31086.45	121.2	0.1
	Uttarkashi	6247.24	52439.9	205.95	0.1

8. Modelling of Building Frames in ETABS

Fig. 8.1 3D model of G+10 Building.



Analytical model for G+10 building is developed in ETAB's and are tested using the FNA technique in the software. The results for various parameters such as Acceleration, Velocity and Displacement are obtained for

Each story subjected to three-time histories. The results are then processed and are plotted for the further comparison.

9. Results and discussion

9.1 Comparison of Roof Acceleration, velocity, and displacement.

The results of G+10 building have been studies and plotted. The Roof Story Acceleration, Velocity and Displacements are plotted and the several of each parameter is studies by plotting the response of all stories in a single plot. The Responses are illustrated further.

9.1.1 Comparison of Roof acceleration of G+10 Building frame for El-Centro Time History –

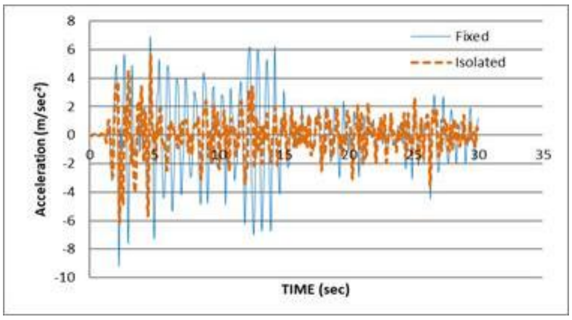


Fig. 9.1 Acceleration response of G+10

9.1.2 Comparison of Roof acceleration of G+10 Building frame for Indo Burma Time History –

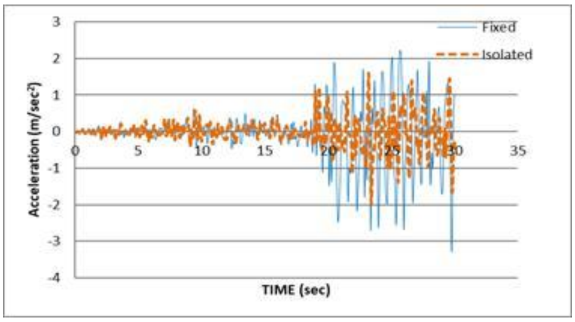


Fig. 9.2 Acceleration response of G+10

9.1.3 Comparison of Roof acceleration of G+10 Building frame for Uttarkashi Time History –

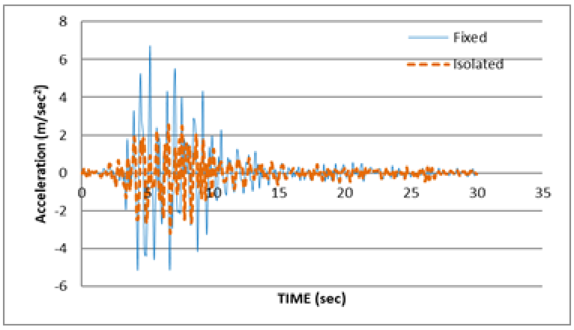


Fig. 9.3 Acceleration response of G+10

9.1.4 Comparison of Roof velocity of G+10 Building frame for El-Centro Time History –

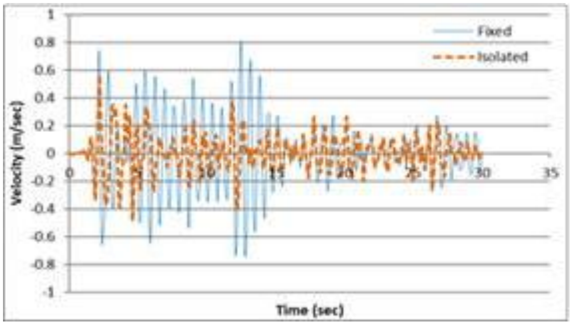


Fig. 9.4 Velocity response of G+10

9.1.5 Comparison of Roof velocity of G+10 Building frame for Indo Burma Time History –

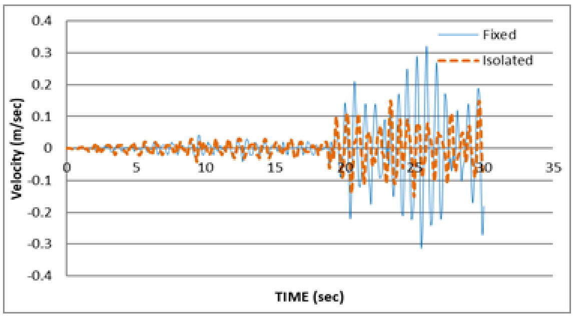


Fig. 9.5 Velocity response of G+10

9.1.6 Comparison of Roof velocity of G+10 Building frame for Uttarkashi Time History-

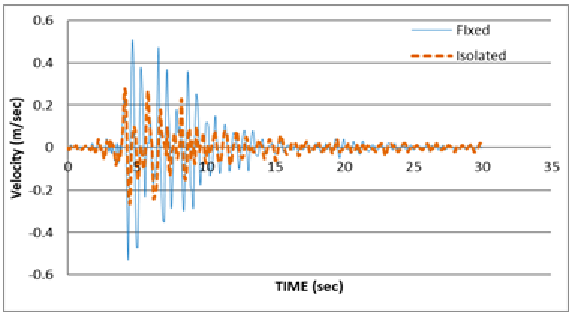


Fig. 9.6 Velocity response of G+10

9.1.7 Comparison of Roof Displacement of G+10 Building frame for EL-Centro Time History-

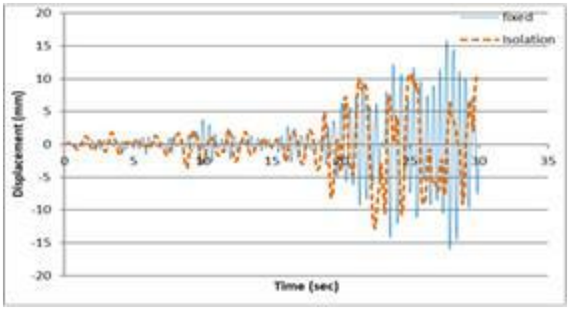


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Fig. 9.7 Displacement response of G+10

9.1.8 Comparison of Roof Displacement of G+10 Building frame for Indo Burma Time History-

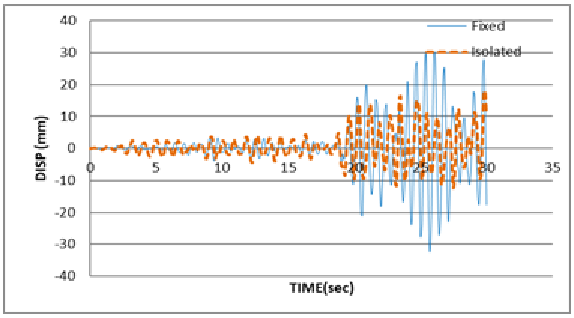

Fig. 9.8 Displacement response of G+10

9.1.9 Comparison of Roof Displacement of G+10 Building frame for Uttarkashi Time History-

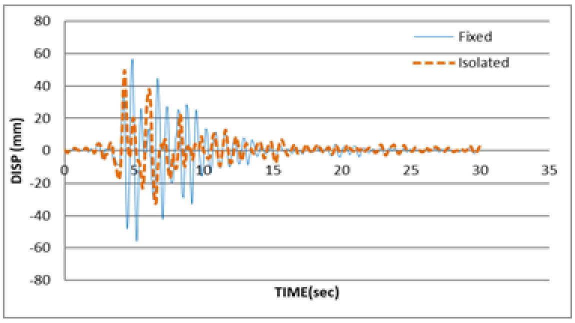

Fig. 9.9 Displacement response of G+10

From the above graphs it is illustrated that the acceleration response of all stories subjected to all three-time histories as shown in Fig.9.1, 9.2 and 9.3. The reduction in roof acceleration for isolated base condition in analytical study is almost 19% for El-Centro (from 6.86 m/s2 to 5.56 m/s2), 29 % for Indoburma (from 2.23 m/s2 to 1.59 m/s2) and 63 % (from 6.7 m/s2 to 2.48 m/s2) for Uttarkashi time history. It is observed from Fig.9.1 to 9.3 that the accelerations go on increasing with higher rate (almost nonlinear) in case of fix base condition whereas in case of Isolated base condition the acceleration are observed to be increasing with lower rate (almost linear).

The velocity results are shown in Fig.9.4 to 9.6. The reduction in roof velocity in analytical study is almost 31 % for El-Centro (from 0.81 m/s to 0.57 m/s), 54 % for Indoburma (from 0.3244 m/s to 0.15 m/s) and 46% (from 0.513 m/s to 0.28 m/s) for Uttarkashi time history.

The reduction in velocity is almost constant throughout each story in case of El-Centro & Uttarkashi Time History, whereas in case of Indoburma Time Histories it is reducing variably from roof story to bottom story.

The displacement results are shown in Fig.9.7 to 9.9. The reduction in roof displacement in analytical study is almost 24.19% for El-Centro (from 85.2 mm to 64.5 mm), 40% for Indoburma (from 30.08 mm to 18.234 mm) and 13% (from 56.66 mm to 49.445 mm) for Uttarkashi time history, shown in Fig. respectively.

9.2 Energy demand

The total energy required to support the earthquake during the event is illustrated in Fig.9.10 for the G+10 Building,

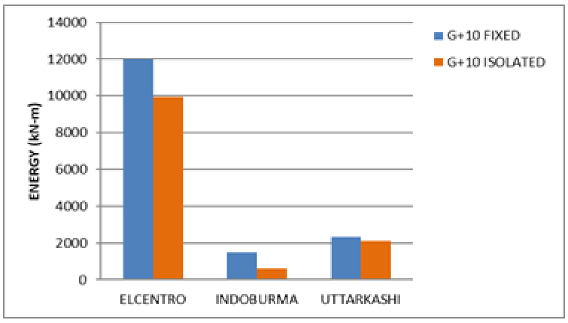

Fig. 9.10 Energy Demand for G+10 Building.

For the G+10 Building the energy demand in fixed base condition is17% more for El-Centro Time History Similarly, for Indoburma and Uttarkashi approximately 60% & 10% more energy is required as compared to Isolated Base condition.

10. Conclusion

i. As acceleration has been lowered by 65% and displacement has been decreased by 40%, base isolation is clearly effective. This pattern is seen to remain almost unchanged all-time histories. As a result, isolation's consistent effects are seen throughout a range of time histories. Base isolation will therefore provide the stability and security of a structure with a larger safety margin. Additionally, base isolation improves a building's ability to endure powerful earthquakes.

ii. iv. The Base Isolation increased the Time Period of the Buildings, in accordance with the design. With the use of the isolation system, the structure's time period is altered to the appropriate Target Time Period, which is achieved at all damping levels, in order to achieve zero or minimal ductility demand.

iii. iii. Energy demand in the Isolated Base Buildings is reduced to the tune of 10 to 80% showing the effectiveness of Isolation to keep the structure from deterioration.

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