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Seismic Performance of Base Isolated & Fixed Based RC Frame Structure using ETABS

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Abstract

The earthquake causes a great damage to the structure. It is very important to protect the structure from earthquake forces and it can be done by various methods. One of the methods is seismic base isolation. The modeling procedure of not only fixed base but also of base isolated building in ETAB software is carried out. Also the design steps of isolators and linear static analysis using UBC 97 for isolated building has been discussed in the present work. Analytical seismic response of (G+14) storied building supported on base isolation system is investigated and compared with fixed base building. The results of various parameters such as the variation in maximum storey displacement, maximum storey drift, lateral loads to stories, and storey overturning moment and storey shear of isolated building is studied. Using base isolation system at (G+14) storied, it is found that the base isolation technique was protected and better for structure more than 10 storey. It was observed that the variation in maximum displacement of stories in base isolated model is very low while compared with fixed base model. It was also observed that storey overturning moment & storey shear are also found to be reduced in base isolated building.

Keyword: ETABs.

Introduction

The structures constructed with good techniques and machines in the recent history have affected due to earthquakes loading to enormous loss of life and property. It has ultimately compelled the engineers and scientists to think of innovative techniques and methods to save the buildings as well as structures from the destructive forces of earthquake. The earthquakes in the recent history have provided enough evidence of performance of different type of structures under different earthquake conditions and at different foundation conditions as a food for thought to the engineers and scientists. This has really given birth to different type of techniques to save the structures from the earthquakes effects.

Conventional seismic design attempts to make buildings that do not collapse under strong earthquake shaking, but may sustain damage to non-structural elements (like glass facades) and to some structural members in the building. This may render the building non-functional after the earthquake, which may be problematic in some structures, like hospitals, which need to remain functional in the aftermath of the earthquake. Special techniques are required to design buildings such that they remain practically undamaged even in a severe earthquake. Buildings with such improved seismic performance usually cost more than normal buildings do. However, this cost is justified through improved earthquake performance.

Two basic technologies are used to protect buildings from damaging earthquake effects. These are Base Isolation Devices and Seismic Dampers. The idea behind base isolation is to detach (isolate) the building from the ground in such a way that earthquake motions are not transmitted up through the building, or at least greatly reduced. Seismic dampers are special devices introduced in the building to absorb the energy provided by the ground motion to the building (much like the way shock absorbers in motor vehicles absorb the impacts due to undulations of the road).

Earthquakes cause inertia forces proportional to the product of the building mass and the ground accelerations. As the ground accelerations increases, the strength of the building must be increased to avoid structural damage. It is not practical to continue to increase the strength of the building indefinitely. In high seismic zones, the accelerations causing forces in the building may exceed one or even two times the acceleration due to gravity. Base isolation is one of the most widely accepted techniques to protect structures and to mitigate the risk to life and property from strong earthquakes. Earthquakes will happen and are yet uncontrollable. So it should be tried to increase the capacity of structures to withstand during earthquake.

Base isolation concept was introduced by engineers and scientists as early as in the year 1923 and thereafter different methods of isolating the buildings and structures from earthquake forces have been developed world over. Countries like USA, New Zealand, Italy Japan, China and European countries have adopted these techniques as their normal routine for many public buildings and residential buildings as well. Hundreds of buildings are being built every year with base isolation technique in these countries.

As of now, in India, the use of base isolation techniques in public or residential buildings and structures is in its inception and except few buildings. Base isolation technique was first demonstrated in India after the 1993 Killari (Maharashtra) Earthquake. Two single storey buildings (one school building and another shopping complex building) in newly relocated Killari town were built with rubber base isolators resting on hard ground. Both were brick masonry buildings with concrete roof. After the 2001 Bhuj (Gujarat) earthquake, the four-storey Bhuj Hospital building was built with base isolation technique. Also an experimental building at IIT, Guwahati was constructed by using base isolation. National level guidelines and codes are not presently available for the reference of engineers and builders.

Base isolation is also known as ‘seismic base isolation’ or ‘base isolation system’. It is one of the most popular means of protecting a structure against earthquake forces. It is a collection of structural elements which should substantially decouple a superstructure from its substructure resting on a shaking ground thus protecting a building or non-building structure’s integrity. Seismic isolation separates the structure from the harmful motions of the ground by providing flexibility and energy dissipation capability through the insertion of the isolated device so called isolators between the foundation and the building structure.

Base Isolation

The fundamental principal of base isolation is to modify the response of the building so that the ground can move below the building without transmitting these motions into the building. In an ideal system this separation would be total. In real world, there needs to be some contact between the structure and the ground.

A building that is perfectly rigid will have a zero period. When the ground moves the acceleration induced in the structure will be equal to the ground acceleration and there will be zero relative displacement between the structure and the ground. The structure and ground move the same amount.

A building that is perfectly flexible will have an infinite period. For this type of structure, when the ground beneath the structure moves there will be zero acceleration induced in the structure and the relative displacement between the structure and ground will be equal to the ground displacement.

All real structures are neither perfectly rigid nor perfectly flexible and so the response to ground motions is between these two extremes. For periods between zero and infinity, the maximum accelerations and displacements relative to the ground are a function of the earthquake.

Literature Review

S.J.Patil, et al [1] studied State Of Art Review-Base Isolation Systems for Structures gives base isolation techniques with special emphasis and a brief on other techniques developed world over for mitigating earthquake forces on the structures.

A. B. M. Saiful Islam, et al [2] studied Seismic isolation in buildings to be a practical reality: Behavior of structure and installation technique & gives a number of articles on base isolation incorporation in building structure in his paper. Lead rubber bearing (LRB), high damping rubber bearing (HDRB), friction pendulum system (FPS) have been critically explored. This study also addressed the detail cram on isolation system, properties, characteristics of various device categories, recognition along with its effect on building structures.

Y. Ribakov, et al [3] studied Experimental Methods for Selecting Base Isolation Parameters for Public Buildings & has done detailed study on experimental methods for selecting base isolation parameters for public building. The idea of base isolation was known hundreds years ago, however practical implementation of base isolators started in the last few decades. Hundreds of buildings all over the world are provided by such isolators and proved enhanced dynamic behavior. Design of base isolation systems and selection of their properties usually depend on dynamic characteristics of the isolated building. Effective variable friction dampers were proposed and tested by the authors. These dampers significantly reduce the displacements between the first floor column and foundation and additionally yield further improvement in the structural seismic response.

Tsutomu Hanai, et al [4] studied Comparison of seismic performance of base-isolated

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house with various devices give various base-isolated devices corresponding to the low-rise house. However, the common information for designers to select specific device has not been gathered. Therefore, a full scale vibration test was conducted to grasp the difference of the isolated response by replacing only base-isolated devices system using common superstructure. The result of the test shows that each devices system fulfills the basic performance demanded for base-isolated houses.

Farzad Naeim, et al [5] studied Design of seismic isolated structures from theory to practice, serves as a guide to understand the concepts and procedures involved in analysis, design, and development of specifications for seismic isolated structures. It provides a complete and up-to-date coverage of the subject and numerical examples and systematic development of the concepts in theory and practical application.

R.Ivan Skinner, et al [6] studied Seismic Isolation for designers and structural engineers provides both theory and design aspects of seismic isolation. It also explains practical examples of computer applications as well as device design examples so that the structural engineer is able to do a preliminary design.

Peng-Hsiang,Charng [7] studied Base Isolation for Multistoried building structures gives the application of the base isolation techniques to protect structures against damage from earthquake attacks has been considered as one of the most effective approaches and has gained increasing acceptance during the last two decades. In this research work, a series of dynamic analyses are carried out to investigate in detail the seismic responses for stiff and flexible 12-storey multi storey buildings to the various isolation systems and to consider the effects of foundation compliance on their responses when subjected to different earthquakes.

Modeling Procedure in ETAB

The modeling procedure of fixed base and base isolated building in ETAB is carried out. Also the design steps of Isolators and linear static analysis using UBC 97 for isolated building has been discussed.

Building details and plan

Table 1: Building Details

Grade of Concrete	M20
Steel Grade	Fe415
Floor to Floor height	3.5m
Plinth height above GL	0.9
Depth of Foundation below GL	0.6m
Parapet height	1m
Slab thickness	150mm
External wall thickness	230mm
Internal wall thickness	150mm
Size of Columns	230*450mm
Size of Beams	230*380mm
Live load on floor	3 KN/m^2
Live load on Roof	1.5 KN/m^2
Site located in Seismic zone 4, i.e. Z	0.24
Importance factor	1
Building frame type	SMRF
Density of Concrete	25 KN/m^3
Density of Masonry wall	20 KN/m^3

Bedroom 4.2*3.2	Kitchen 4.2*3.2
Living Room 4.2*3.2	Dining 4.2*3.2
Lobby/Lift 4.2*2.1	
Living Room 4.2*3.2	Dining 4.2*3.2
Bedroom 4.2*3.2	Kitchen 4.2*3.2

Fig. 1 Plan of the Building

Results

The comparative result of 13 storied fixed base with the base isolated building is made. The isolation system is composed of high damping rubber bearing. Design displacements are estimated using UBC-97 parameter. The comparison is made for the parameters like maximum storey displacement, maximum storey drift, base shear in X as well as in Y direction.

Result of fixed base building

Table No 2: Storey displacement in X & Y direction

Storey No.	Storey Displacement (m)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	0.2782	0	0.1133	0
10	1.1534	0	0.4617	0
5	1.6643	0	0.6327	0
1	1.7961	0	0.1418	0
Base	0	0	0	0

Maximum storey drift –

Storey drift is calculated as displacement at top storey minus displacement at bottom storey divided by height of storey.

Table No 3: Storey Drift in X & Y direction

Storey No.	Story Drift (m)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	0.2782	0.002	0.1133	0
10	1.1534	0.008	0.4617	0.002
5	1.6643	0.014	0.6327	0.003
1	0.2977	0.0031	0.1418	0.001
Base	0	0	0	0

Storey Shear-

In ETAB software, Storey shear is reported in the global coordinate system. The forces are reported at the top of the storey, just below the storey level itself, and at the bottom of the storey, just above the storey level below.

Table No 4: Storey Shear in X & Y direction

Storey No.	Storey Shear (KN)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	59.6	0.37	93.14	0.37
10	234.93	1.65	365.81	1.65
5	312.66	2.61	488.64	2.6
1	317.85	2.82	496.74	2.82
Base	317.85	2.82	496.74	2.82

Lateral Load to Stories

Table No 5: Lateral Load to Stories in X & Y direction

Storey No.	Lateral Load to Stories (KN)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	59.84	0.37	95.74	0.37
10	39.84	0.31	61.92	0.31
5	10.73	0.16	16.65	0.16
1	1.14	0.04	1.56	0.04
Base	0	0	0	0

Storey Overturning Moment

Table No 6: Storey Overturning Moment in X & Y direction

Storey No.	Storey Overturning Moment (KN-m)			
	In X- Direction		In Y- Direction	
	(Fixed Base)	(Base Isolated)	(Fixed Base)	(Base Isolated)
14	105.66	0.62	162.58	0.64
10	433.37	3.07	645.39	2.95
5	619.61	5.17	881.87	4.69
1	248.92	2.23	379.95	2.14
Base	245.32	2.2	379.95	2.14

Conclusion

Analytical seismic response of (G+12) storied building is supported on base isolation system is investigated and compared with fixed base building. The variation in maximum storey displacement, maximum storey drift, lateral loads to stories, and storey overturning moment and storey shear of isolated building is studied under different parameters. From the results of this study following points have been concluded.

1. Base isolation system is very promising technology to protect structures like multi-storied RCC frame.
2. The variation in maximum displacement of stories in base isolated model is very low while compared with fixed base model. It is observed that when increasing the number of stories this variation of maximum displacement of stories will be somehow considerable.
3. The significant characteristic of base isolation system were affected the superstructure to have a rigid

movement and as a result shows the relative storey displacement & storey drift of structural element will decrease and consequently the internal forces of beams and columns will be reduced.

4. Due to decrease in lateral loads to stories, the accelerations of the stories are reduced. This results in the reduction of inertia forces.
5. Storey overturning moment and storey shear are also reduced in base isolated building resulting in making the superstructure above the isolation plane as rigid and stiffer.
6. Using base isolation system at (G+14) storied building, it is found that the base isolation technique was protected and better performed for structure more than 10 storey.

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