Seismic response analysis of an irregular base Isolated building .

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ABSTRACT

Seismic isolation enables the reduction in earthquake forces by lengthening the period of vibration of the structure. The conventional period of isolated structures is generally kept as 2 sec. Therefore; the significant benefits obtained from isolation are in structures for which the fundamental period of vibration without base isolation is short, less than 1.0 sec. This paper consists of analytical study of base-isolation for buildings with higher natural period ranging from 1.0 to 3.0 second. Different possibilities are explored to increase the feasibility of base isolation for such type of buildings. Strategies proposed in this study are (i) increasing superstructure stiffness, (ii) increasing superstructure damping and (iii) increasing flexibility of isolation system. It is observed that the effectiveness of base isolation for these buildings may be increased by incorporating such provisions.

The purpose of this study is to investigate the effect of Performance based design of base isolated building and implementing the above strategies in enhancing the effectiveness of base isolation to buildings with matched Time history with response spectrum seismic analysis. G+7 storey buildings are considered in this study.

Seismic isolation enables the reduction in seismic forces by increasing the time period of the structure. The usual period of isolated structures is generally kept as 2 sec. Therefore; the significant benefits obtained from isolation are in structures for which the fundamental period of vibration without base isolation is short, less or upto 1.0 sec. This dissertation represents analytical study of base-isolation for buildings with higher natural period ranging about 2.5 second. Different possibilities are explored to increase the feasibility of base isolation for such type of buildings. Strategies proposed in this study are (i) increasing superstructure stiffness, (ii) increasing superstructure damping and (iii) increasing flexibility of isolation system. It is observed that the effectiveness of base isolation of buildings may be increased by incorporating these provisions.

Keywords: *Base isolation · Seismic assessment · Structural analysis · Modeling , Rubber isolators · Seismic codes*

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1 INTRODUCTION

The aim of this work is to design a Base Isolation system for a low rise building and to evaluate its performance using various techniques including dynamic Time History Analysis, Response Spectrum Analysis. Characteristics of Base Isolation devices currently available on the market will be evaluated. The main comparison criteria are Bending Moment, Shear Force, Mode Shape, Displacement at the Base and Time Period of the building.

The principle of seismic resistance of buildings is to provide the structural safety and comfort by controlling the internal forces and displacement within the particular limits. The common method for protecting the structures against the destructive effects of earthquakes is to damp the seismic energy for limiting the seismic energy by the structural elements, thus providing the resistance against the earthquake. In spite of using this method for a certain level of protection, the structure could be damaged for real sometimes.

Base isolation of the structures against the earthquake is to isolate the building from the ground by installing seismic energy dissipating devices at the base of the building. With this method, better protection could be provided, by designing properly against the earthquake and therefore significant building structural damage could be reduced.

Seismic isolation in a building, when considered within the framework of basic principles of dynamics, can be maintained by taking under the control, modifying and changing the characteristics of both restoring-force when affected by seismic forces, and damping of the building, and also the mass of the building and seismic forces that affect the building. As it is known, the equation of motion of a building that is subjected to the ground motion depends on mass, stiffness, and energy damping nature of the building, as well as on external seismic forces affecting the building. The characteristics of response forces can be controlled, by changing stiffness of the building. When stiffness of the building is decreased, the response acceleration also decreases and displacements increase. On the other hand, response of acceleration and displacement can be decreased, by increasing the damping effect of the building.

Seismic isolation enables the reduction in earthquake forces by lengthening the period of vibration of the structure. The typical period of isolated buildings is generally kept as 2.0 second (Constantinou [1]). Therefore, the significant benefits obtained from isolation are in structures for which the fundamental period of vibration without base isolation is short, less than 1.0 second. Buildings with comparatively higher natural period attract low earthquake forces even without seismic base isolation. In the early stages of development of seismic

Isolation, prevention of collapse of the structure was the primary goal. Therefore, seismic isolation has mostly been used for low-rise buildings (Kelly [2]). However, later other additional considerations like comfort of occupants, functionality of important buildings during and after earthquakes, non-damage to non-structural elements and contents etc. have exerted an increasingly important influence. There have been proposals to use isolation to new tall buildings (Okoshi [3]) and to retrofit buildings with relatively long fixed-base periods, which are deficient in seismic resistance (Honeck [4]; Qamaruddin [5]). There seems to be a possibility of increasing effectiveness of base isolation for relatively tall buildings by employing some strategies viz. (i) stiffening their superstructure, (ii) increasing damping in the superstructure and (iii) increasing flexibility of isolation system. The purpose of this study is to investigate the effect of implementing the above strategies in enhancing the effectiveness of base isolation to buildings with fundamental period ranging from 1.0 second to 3.0 seconds. Eight, and Sixteen storey buildings are considered in this study. The isolation system considered in the study is low damping laminated rubber bearings combined with viscous damper.

2. **METHODS USED IN STUDY**

In this study the performance of a G+7 story RCC frame structure subjected to severe earthquake loads was evaluated using elastic/linear analyses. Based on the findings from the analysis, a Base Isolation system was designed for the structure. The parameters of Base Isolation system were chosen using the theory of multi degree of freedom dynamic systems. Then Base Isolation parameters were included into the initial model and the performance of the isolated structure subjected to the same seismic loads was evaluated. The two sets of results were compared and the structural effectiveness of Base Isolation system for that particular building was discussed. In addition, economic and practical aspects of Base Isolation systems were discussed and the conclusion with regard to feasibility of the system was drawn based on both structural and economic arguments.

The general methodology adopted for this study was as follows:

- A model of a G+7 RCC frame was made using the structural analysis software ETABS. Detailed description of the building model is given in section 3.2. For this study, the code design methods of Indian Standard code IS 456:2000 were used.
- Modal analysis of the building was performed and the actual fundamental period of the structure was calculated.
- Static Response Spectrum Analysis of the structure was performed in accordance with the code methods of IS 456:2000.
- Dynamic time-history analysis of the structure was performed. The structure was subjected to the IS Compatible Time History earthquake.
- Base Isolation parameters were chosen and the bearings were designed.
- Same response spectrum and time-history analysis were performed but on an isolated building.

- Based on the results feasibility of Base Isolation system was discussed both from structural and economic point of view.

2.1 BUILDING DESCRIPTION

The building is G+7 Storey Reinforce Concrete Frame. It is square in plan, with dimensions 8x8 m. Story height is 4 m and therefore the total height of the building is 32 m& 64m respectively. Spacing between columns is 8 m in both directions. All the column sections are 750X750 mm in dimension and all the beam sections are 600X800 main beams & secondary beams 350x600 mm in dimension. The floor system is the same at all floors with 125 mm thin shell. Figure 7 shows the floor framing arrangement. All columns are oriented in the same direction with their stronger bending axis in the X-Z plane. The concrete mix used is M30. Shear wall thickness 230 mm thick.

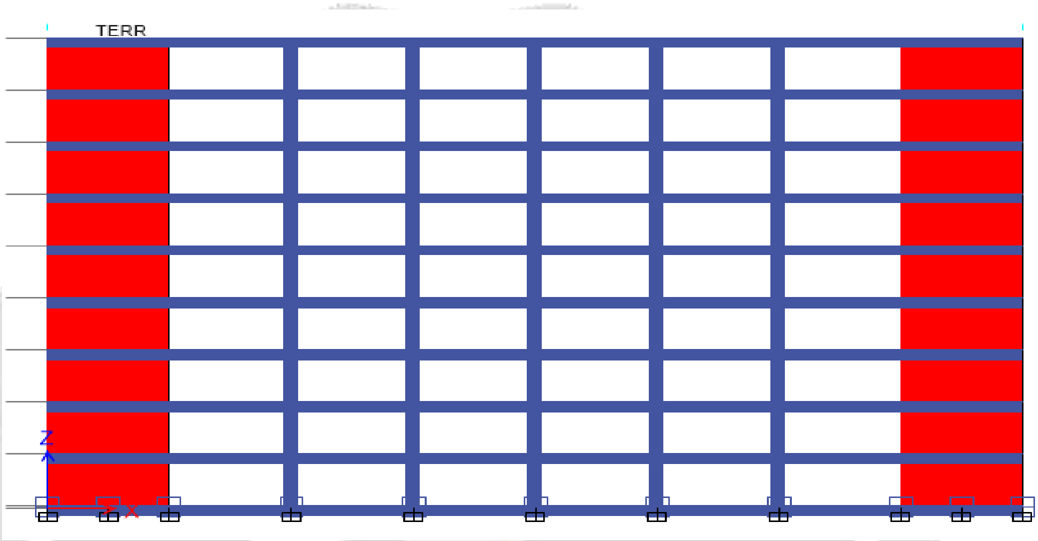

Figure 2.1 Building frame elevation view 8 storey

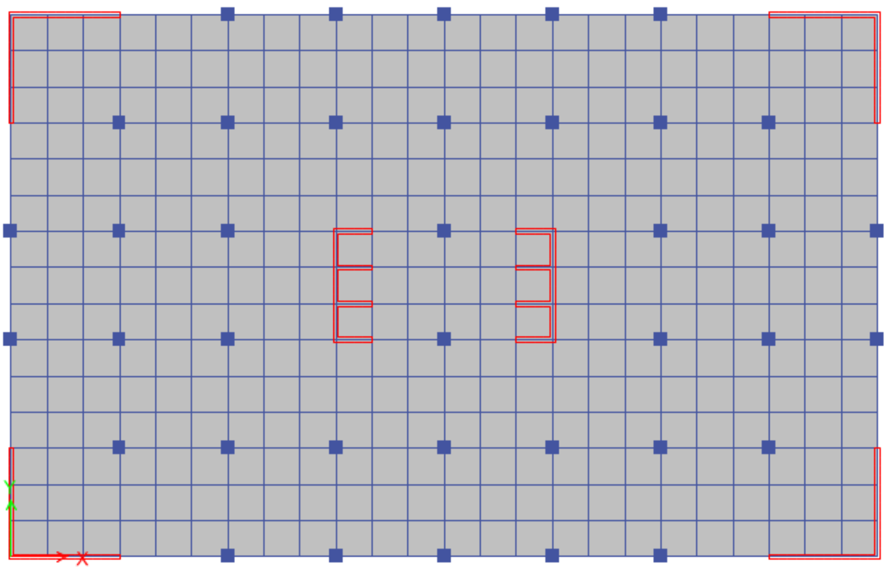

Figure 2.2 Floor framing plan

Loading Parameters

a)	**DEAD LOAD**		
	Self-weight of RCC members	=	25.0 KN/m^3
	Floor Finish in general areas (75mm thick flooring)	=	20.0 KN/m^3
	Wall load (Burnt Clay Bricks)	=	20.0 KN/m^3
	Sunken Load (Light Weight)	=	6.0 KN/ m^3
	Façade Load (GRC + Glass)	=	3.50 KN/m
	Basement roof (600mm soil filling/Finishes)	=	12.0 KN/m^2
	Finishes on Terrace	=	3.0 KN/m^2
b)	**LIVE/ IMPOSED LOAD -** Terrace	=	1.50 KN/m^2
b.1)	**LIVE LOAD** - FLOOR		
	Office/OPD rooms	=	2.50 KN/m^2
	Dining/Cafeteria/Restaurants/Balconies	=	4.00 KN/m^2
	Corridors/ Passages/Staircases/Lobby	=	4.00 KN/m^2
	Kitchen/ Laundries/Laboratories	=	3.00 KN/m^2
	Boiler/ Plant rooms, Ramps, Car Parking.	=	5.00 KN/m^2
	Toilets/ Bathrooms	=	2.00 KN/m^2

3. DATA ANALYSIS

In order to successfully design the base isolating system for the structure the dynamic response of the un-isolated structure needs to be studied. A series of analyses involving fixed-base structure was performed on the building using ETABS software. The primary objective of the analyses is to study the displacements, Bending Moment and Shear Force in the structure under extreme earthquake loads. The fundamental period found through modal analysis was compared for both the structured.

TABLE 6.1: Modal Periods and Frequencies

Fixed base					Base Isolator			
Case	**Mode**	**Period**	**Frequency**		**Case**	**Mode**	**Period**	**Frequency**
		sec	cyc/sec				sec	cyc/sec
Modal	1	1.432	0.698		Modal	1	2.697	0.371
Modal	2	1.284	0.779		Modal	2	2.683	0.373
Modal	3	0.884	1.131		Modal	3	2.356	0.424

Modal	4	0.356	2.812		Modal	4	0.833	1.2
Modal	5	0.308	3.248		Modal	5	0.783	1.278
Modal	6	0.208	4.814		Modal	6	0.58	1.724
Modal	7	0.168	5.947		Modal	7	0.279	3.579
Modal	8	0.147	6.816		Modal	8	0.239	4.179
Modal	9	0.109	9.161		Modal	9	0.159	6.278
Modal	10	0.106	9.448		Modal	10	0.148	6.771
Modal	11	0.097	10.297		Modal	11	0.128	7.836
Modal	12	0.085	11.76		Modal	12	0.104	9.65

TABLE 6.2: Modal Load Participation Ratio										
Fixed Base						**Base Isolator**				
Case	**Item Type**	**Item**	**Static**	**Dynamic**		**Case**	**Item Type**	**Item**	**Static**	**Dynamic**
			%	%					%	%
Modal	Acceln.	UX	99.99	91.62		Modal	Acceln.	UX	100	100
Modal	Acceln.	UY	99.99	91.74		Modal	Acceln.	UY	100	100

3.1 RESPONSE SPECTRUM ANALYSIS

The response spectrum curve was constructed in accordance with the IS 456:2000 code. The site parameters were deliberately chosen so that the conditions were unfavourable and earthquake induced accelerations were increased. The value of Sa/g was chosen as 0.42, with accordance to time period of 2.58 s. get to generalize the results the soil type is chosen to be of medium type. Therefore, the site soil type was chosen as medium type. Long period transition period, T was set to 10 s. using these parameters the response spectrum curve is plotted as shown in Figure 21. The period of natural oscillation of our building, T=0.86 s places the structure almost at the top plateau of the response spectrum curve.

TABLE 6.3 : RESPONSE SPECTRUM MODAL INFORMATION											
For Fixed Base								**For Base Isolation**			
Response Spectrum Case	**Modal case**	**Mode**	**Period**	**Damping Ratio**	**U1 Acceleration**	**U2 Acceleration**		**Period**	**Damping Ratio**	**U1 Acceleration**	**U2 Acceleration**

			sec		m/s²	m/s²		sec		m/s²	m/s²
SPEC1	Modal	1	1.432	0.05	0.34	0		2.697	0.071	0.16	0
SPEC1	Modal	2	1.284	0.05	0.38	0		2.683	0.0743	0.16	0
SPEC1	Modal	3	0.884	0.05	0.55	0		2.356	0.0804	0.18	0
SPEC1	Modal	4	0.356	0.05	0.88	0		0.833	0.0742	0.52	0
SPEC1	Modal	5	0.308	0.05	0.88	0		0.783	0.0722	0.56	0
SPEC1	Modal	6	0.208	0.05	0.88	0		0.58	0.0683	0.78	0
SPEC1	Modal	7	0.168	0.05	0.88	0		0.279	0.0586	0.85	0
SPEC1	Modal	8	0.147	0.05	0.88	0		0.239	0.0574	0.85	0
SPEC1	Modal	9	0.109	0.05	0.88	0		0.159	0.0556	0.86	0
SPEC1	Modal	10	0.106	0.05	0.88	0		0.148	0.0542	0.86	0
SPEC1	Modal	11	0.097	0.05	0.87	0		0.128	0.0537	0.87	0
SPEC1	Modal	12	0.085	0.05	0.8	0		0.104	0.0516	0.87	0
SPEC2	Modal	1	1.432	0.05	0	0.34		2.697	0.071	0	0.16
SPEC2	Modal	2	1.284	0.05	0	0.38		2.683	0.0743	0	0.16
SPEC2	Modal	3	0.884	0.05	0	0.55		2.356	0.0804	0	0.18
SPEC2	Modal	4	0.356	0.05	0	0.88		0.833	0.0742	0	0.52
SPEC2	Modal	5	0.308	0.05	0	0.88		0.783	0.0722	0	0.56
SPEC2	Modal	6	0.208	0.05	0	0.88		0.58	0.0683	0	0.78
SPEC2	Modal	7	0.168	0.05	0	0.88		0.279	0.0586	0	0.85
SPEC2	Modal	8	0.147	0.05	0	0.88		0.239	0.0574	0	0.85
SPEC2	Modal	9	0.109	0.05	0	0.88		0.159	0.0556	0	0.86
SPEC2	Modal	10	0.106	0.05	0	0.88		0.148	0.0542	0	0.86
SPEC2	Modal	11	0.097	0.05	0	0.87		0.128	0.0537	0	0.87
SPEC2	Modal	12	0.085	0.05	0	0.8		0.104	0.0516	0	0.87

TABLE 6.8 : COLUMN DESIGN SUMMARY - BASE ISOLATOR							
			For Fixed Base			For Base Isolator	
Story	**Label**	**Design Section**	**As**	**PT**		**As**	**PT**
TERR	C10	C75X75	4500	0.80		4500	0.80
7F	C10	C75X75	4500	0.80		4500	0.80
6F	C10	C75X75	4500	0.80		4500	0.80
5F	C10	C75X75	4500	0.80		4500	0.80
4F	C10	C75X75	4500	0.80		4500	0.80
3F	C10	C75X75	4500	0.80		4500	0.80
2F	C10	C75X75	8790	1.56		8567	1.52
1F	C10	C75X75	13045	2.32		12898	2.29
GF	C10	C75X75	17265	3.07		16613	2.95
TERR	C14	C75X75	4500	0.80		4500	0.80
7F	C14	C75X75	4500	0.80		4500	0.80
6F	C14	C75X75	4500	0.80		4500	0.80
5F	C14	C75X75	4500	0.80		4500	0.80
4F	C14	C75X75	4500	0.80		4500	0.80
3F	C14	C75X75	4500	0.80		4500	0.80
2F	C14	C75X75	4817	0.86		4739	0.84
1F	C14	C75X75	8609	1.53		8527	1.52
GF	C14	C75X75	12266	2.18		12131	2.16
TERR	C15	C75X75	4500	0.80		4500	0.80
7F	C15	C75X75	4500	0.80		4500	0.80
6F	C15	C75X75	4500	0.80		4500	0.80
5F	C15	C75X75	4500	0.80		4500	0.80
4F	C15	C75X75	4500	0.80		4500	0.80
3F	C15	C75X75	4500	0.80		4500	0.80

2F	C15	C75X75	5472	0.97		5390	0.96
1F	C15	C75X75	9299	1.65		9180	1.63
GF	C15	C75X75	13188	2.34		13026	2.32
TERR	C20	C75X75	4500	0.80		4500	0.80
7F	C20	C75X75	4500	0.80		4500	0.80
6F	C20	C75X75	4500	0.80		4500	0.80
5F	C20	C75X75	4500	0.80		4500	0.80
4F	C20	C75X75	4500	0.80		4500	0.80
3F	C20	C75X75	4500	0.80		4500	0.80
2F	C20	C75X75	5052	0.90		4844	0.86
1F	C20	C75X75	8946	1.59		8697	1.55
GF	C20	C75X75	12810	2.28		12445	2.21
TERR	C25	C75X75	4500	0.80		4500	0.80
7F	C25	C75X75	4500	0.80		4500	0.80
6F	C25	C75X75	4500	0.80		4500	0.80
5F	C25	C75X75	4500	0.80		4500	0.80
4F	C25	C75X75	4500	0.80		4500	0.80

3F	C25	C75X75	4500	0.80		4500	0.80
2F	C25	C75X75	4862	0.86		4651	0.83
1F	C25	C75X75	8712	1.55		8451	1.50
GF	C25	C75X75	12487	2.22		12127	2.16
TERR	C4	C75X75	4500	0.80		4691	0.83
7F	C4	C75X75	4500	0.80		4500	0.80
6F	C4	C75X75	4500	0.80		4500	0.80
5F	C4	C75X75	4500	0.80		4500	0.80
4F	C4	C75X75	4500	0.80		4500	0.80
3F	C4	C75X75	4500	0.80		4500	0.80
2F	C4	C75X75	4500	0.80		4500	0.80

1F	C4	C75X75	4500	0.80		4500	0.80
GF	C4	C75X75	4500	0.80		4500	0.80
TERR	C48	C75X75	4500	0.80		4876	0.87
7F	C48	C75X75	4500	0.80		4589	0.82
6F	C48	C75X75	4500	0.80		4500	0.80
5F	C48	C75X75	4500	0.80		4500	0.80
4F	C48	C75X75	4500	0.80		4500	0.80
3F	C48	C75X75	4500	0.80		4500	0.80
2F	C48	C75X75	4500	0.80		4500	0.80
1F	C48	C75X75	4500	0.80		4500	0.80
GF	C48	C75X75	4500	0.80		4500	0.80
TERR	C49	C75X75	4500	0.80		4500	0.80
7F	C49	C75X75	4500	0.80		4500	0.80
6F	C49	C75X75	4500	0.80		4500	0.80
5F	C49	C75X75	4500	0.80		4500	0.80
4F	C49	C75X75	4500	0.80		4500	0.80
3F	C49	C75X75	4500	0.80		4500	0.80
2F	C49	C75X75	4500	0.80		4500	0.80
1F	C49	C75X75	4500	0.80		4500	0.80
GF	C49	C75X75	4500	0.80		4500	0.80
TERR	C50	C75X75	4500	0.80		4500	0.80
7F	C50	C75X75	4500	0.80		4500	0.80
6F	C50	C75X75	4500	0.80		4500	0.80
5F	C50	C75X75	4500	0.80		4500	0.80
4F	C50	C75X75	4500	0.80		4500	0.80
3F	C50	C75X75	4500	0.80		4500	0.80
2F	C50	C75X75	4500	0.80		4500	0.80
1F	C50	C75X75	4500	0.80		4500	0.80
GF	C50	C75X75	4500	0.80		4500	0.80

Conclusion:

It saves a major amount of destruction and its maintenance. The success of this system is largely depends upon development of isolation devices and proper Planning and placements in the structures which works as energy scattered or damping The addition of damping to the isolation systems serves to reduce displacements in the seismic isolators. The entire superstructure is to be supported on isolators separate the structure from the ground motion.

This attempt is made to analyze the result of base isolation for the buildings having fundamental time period for mode 1are 1.432and2.697 sec. offixed base and base isolated buildings analyzed respectively Two approaches are explored viz. (i) building with fixed base and (ii) building with base isolator. The conclusions based on this analytical study shall be as follows:

Base isolation of superstructure affects the response of the base-isolated buildings. Base isolation results in significant reduction in base shear, Time periods, storey acceleration and story drift of base isolated buildings as compared to fixed base building. There is no significant difference between the response of the base isolated buildings with and without superstructure stiffening though the influence of superstructure stiffening shall be more in case of taller buildings. Stiffening of superstructure of base-isolated buildings results in reduction of the maximum roof acceleration and the maximum storey drift and it increases maximum base slab displacement.

Increase in the damping of base isolator reduces the seismic response of base-isolated buildings. Response reduction due to increase in superstructure damping is more for high frequency base motions. Also the reduction is generally more for taller buildings. Superstructure damping has negligible effect on maximum base displacement of base-isolated buildings. Increase in the flexibility of isolation system is very effective in reducing the response of the buildings. However, displacement at base is more in base isolated building but effective displacement at roof is less if it compared with fixed base support building

The design Reinforcement in column 0.6% and shear wall 4.76% is less in Base Isolator Building while beams top and bottom reinforcement is 3.39% and 1.39% is less in Fixed Base supported building.

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