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EFFECT OF SEISMIC BASE ISOLATION ON MULTI-STORIED RC FRAME BUILDING RESTING ON DIFFERENT SOIL CONDITIONS

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ABSTRACT

Base isolation is a tool which has been developed to reduce the effects of ground motions on buildings and its components. It is one of the best method to achieve inter storey drift and floor accelerations reductions. Base isolation involves installation of mechanisms which results in decoupling the structures from damaging earthquake-induced ground motions. The primary objective of this research is to compare the seismic responses of G+5 storey building, designed as per Indian Standards (IS) with different soil conditions i.e. soft, medium and hard soil, with fixed and isolated base. Different types of isolators i.e. Rubber Base Isolator (RB) and Friction Pendulum Isolator (FPI) are used at the base with Nl link. A FEM tool i.e. SAP 2000 is used for the analysis. It is observed from the analysis that the base shear has greatly reduced in the model with RB and FPI as compared to that of FB. The increase in period for structure with isolated base makes building safe from the resonance effect of the earthquake. Effect of soil condition is considerable in all the cases of fixed base as well as in isolated base.

KEYWORDS: Base isolation, Response spectrum analysis, Seismic analysis, Different soil conditions.

INTRODUCTION

Nepal earthquake in April 2015, killed nearly 9000 people and injured nearly 22000 and severely damaged to the properties. Thus to reduce the severe effects of earthquakes on buildings many technologies have been developed over the years. Reducing the effects of severe ground motions on the buildings and their contents is always one of the challenging area to the structural engineer. [1] described the physical properties of a seismic isolation layer system which is built at a middle-story of a building. By conducting the nonlinear time history analysis it was shown that base isolation increases the flexibility at the base of the structure which helps in energy dissipation due to the horizontal component to the earthquake and hence superstructure's seismic demand drastically reduced as compared to the conventional fixed base structure [2]. Base isolated structures results in the ability to significantly decrease the ductility in the superstructure compared with those of un-isolated structures. A base isolated structure design aims at: (i) providing a relatively stiff superstructure that will behave like a rigid body with small inter-storey drift and (ii) concentrating most of the horizontal deformation to the flexible mounting isolators that supports the structure. The increase in period for structure with isolated base makes sure that the structure being completely removed from the resonance range of the earth quake. For building with base isolation, the bases hear, relative drifts and torsion values are adequate due to the higher time period which results in lower acceleration on the structure [3]. A core of laminated rubber bearing provides base isolation through the parallel action of friction, damping as well as restoring springs [4]. [5] develop a new base isolator referred to as the sliding resilient-friction (SR-F) base isolation system by replacing the elastomeric bearings of the Electricite de France (EDF) base isolation system [6] by the resilient-friction base isolation (R-FBI) system. The rubber foundation elements can actually help to minimize earthquake damage to buildings, considering the tremendous forces these buildings must endure in a major quake [7]. Contrasting the conventional design approach based on an increased resistance (strengthening) of the structures, the seismic isolation concept is aimed at a significant reduction of dynamic loads induced by the earthquake at the base of the structures themselves [8], [9]. Invention of lead rubber bearing (LRB) and high damping rubber bearing (HDRB) gives a new dimension to the seismic base isolation design of base isolated structure [10]. Parametric study were done on reinforced concrete (RC) building using response spectrum method. He consider the design spectra recommended by Indian Standard Code IS 1893-2002 (part I), Uniform Building Code, and Euro Code-8 for comparison. From the comparative study that the response of building using IS code is higher in all the cases, when compared to that of with other codes [11]. [12] seismic analysis of fixed base and base isolated building is presented. The base isolation helps in reducing the design parameters like base shear, bending moment, etc.

STRUCTURAL DATA

Sample buildings described herein were selected as typical six story reinforced concrete building and has a symmetrical floor plan. The plan dimensions of building, typical at all floors are 22.7 m by 13.75 m, with a story height of 3 m. The structural system of the building is selected as consisting of structural walls and moment resisting frames in x direction. It is assumed that the structural systems have nominal ductility level. Seismic load reduction factor (R) for special moment resisting frame is taken as 5. Fig.1 show the normalized spectra drawn for ground types described in IS 1893(Part I)-2002 [13]. Columns, beams, structural walls and slabs are sized considering the requirements given in IS code given in Table 1 and shown in Fig. 2. A dead load and live load of 1 kN/m^2 is taken respectively. To evaluate the seismic response of the building, elastic analyses were performed by the response spectrum method using the computer program SAP2000 [14]. Fig. 3 shows an aerial perspective of the structure. For base isolation, the seismic isolators in the scheme are defined as Nl-link components 0.5 m in length placed between the base and the columns as shown in Fig. 4. The values selected to define RB that are utilized as isolators is given in Table 2. In addition to RB, the building is also analysed with FPI. The parameters selected to define the FPI are given in Table 3.

Table 1. Dimensions of structure members of building

Structural members	Six story building			
	1-3 story		4-6 story	
	b_x (mm)	b_y (mm)	b_x (mm)	b_y (mm)
C1	600	600	500	500
C2	900	900	700	700
W1, W2	250	1750	250	1750
Slab thickness	150 mm			
Beam size	250 x 500 mm			

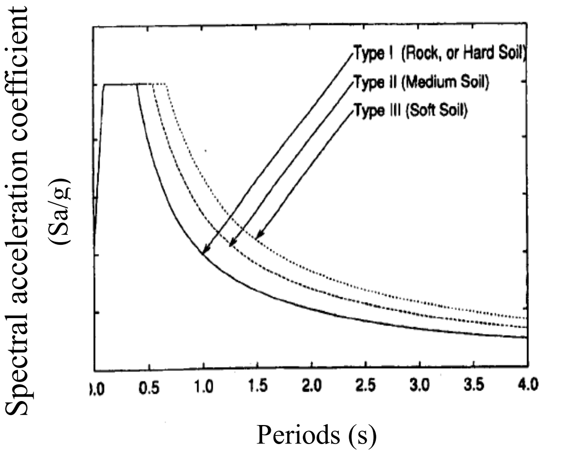

Fig. 1. Response Spectra for 5% damping

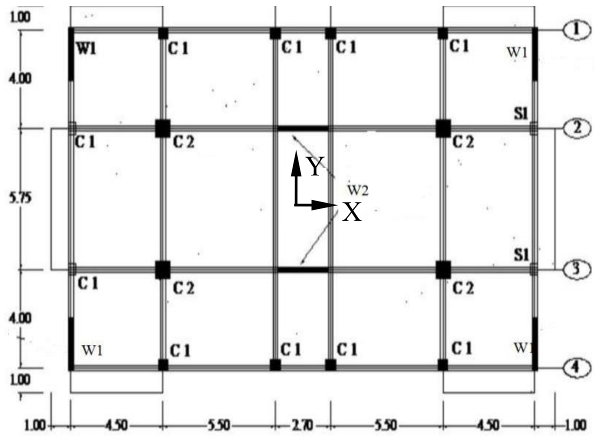

Fig. 2. Plan of RC building

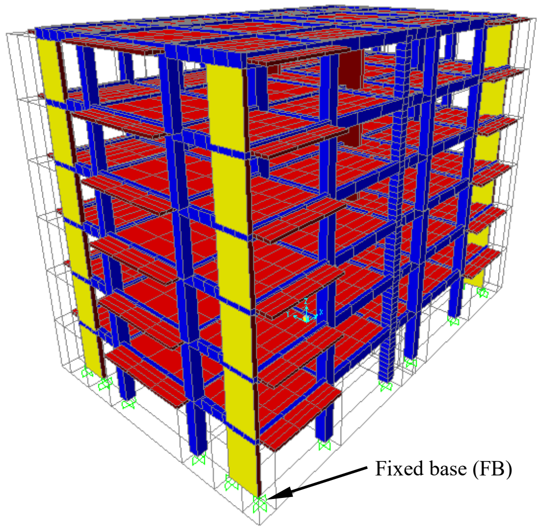

Fig. 3. An aerial perspective of the structure

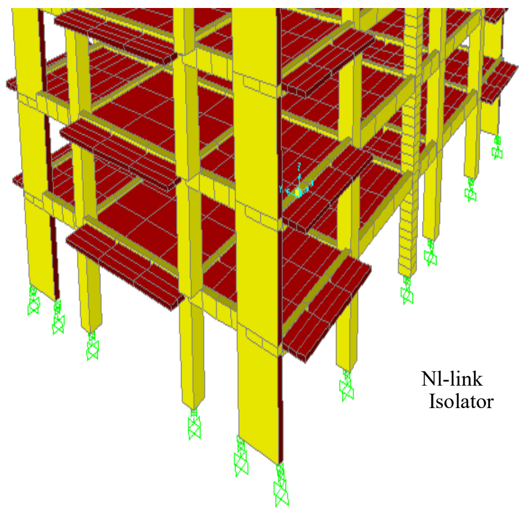

Fig. 4. Nonlinear link element

Table 2. Properties of Rubber bearing (RB) isolator

Particulars	Value
U1(x) total linear effective stiffness	1500000 kN/m
U2(y) and U3(z) linear effective stiffness	800 kN/m
U2(y) and U3(z) yield strength	80 kN
U2(y) and U3(z) nonlinear stiffness	2500 kN/m
U2(y) and U3(z) post yield stiffness ratio	0.1

Table 3. Properties of Friction pendulum isolator (FPI)

Particulars	Value
U1(x) linear effective stiffness	15000000 kN/m
U2(y) and U3(z) linear effective stiffness	750 kN/m
U2(y) and U3(z) nonlinear stiffness	15000 kN/m
U2(y) and U3(z) friction coefficient	slow: 0.03, fast: 0.05
U2(y) and U3(z) rate parameter	40
U2(y) and U3(z) radius of sliding surface	2.23

RESULT ANALYSIS AND DISCUSSION

PERIOD OF THE STRUCTURE

The first three modes with periods for the buildings with fixed base and isolated base are presented in Table 4. For fixed base (FB) case, the fundamental periods are in the range between 0.588 s and 0.165 s. For isolated base with RB, the fundamental periods are in the range between 2.33 s and 2.069 s and in the range between 1.52 s and 1.19 s with FPI. In case of RB, the modal period is higher compared to FPI, which show that rubber bearing are more promising than the friction pendulum.

Table 4. Modal period of building with different base conditions (sec.)

Mode Number	FB	RB	FPI
1	0.588	2.069	1.52
2	0.365	2.035	1.40
3	0.165	2.33	1.19

TOP AND BOTTOM DISPLACEMENT OF BUILDING WITH DIFFERENT SOIL CONDITIONS

As the spectra has been applied in x direction the results has been presented in that direction only. The top and base displacements with various specifications are shown in a Table 5. In case of hard soil, it is observed that the displacement is higher in all cases at base and top of the building when compared to that of soft and medium soil respectively.

Table 5. Top and bottom displacement of building in x-direction (m)

Base Type	**Soft soil**		**Medium soil**		**Hard soil**	
Displacement →	Base	Top	Base	Top	Base	Top
FB	0	0.0124	0	0.017	0	0.018
RB	0.024	0.032	0.033	0.044	0.040	0.053
FPI	0.019	0.0187	0.023	0.033	0.028	0.041

BASE SHEAR

The base shear of the building was acquired from seismic analysis using the design spectra corresponding to 5% critical damping considering both fixed base condition and isolated base condition. It is observed from the results obtained as shown in Table 6, the base shear is higher in all the cases of hard soil compared to that of medium soil and soft soil. In case of hard soil the variation is in the range of 25% to 40% when compared to that of the soft soil and in the rage of 4% to 18.56% when compared to that of the medium soil.

In case of soft soil, the base shear reduces by approximately 55% using RB when compared with FB, also when FPI is introduced at the base, base shear reduces by 35% approximately to that of FB.

In case of medium soil, the base shear reduces by approximately 52% using RB when compared with FB, also when FPI is introduced at the base, base shear reduces by 36% approximately to that of FB.

In case of hard soil, the base shear reduces by approximately 45% using RB when compared with FB, also when FPI is introduced at the base, base shear reduces by 25% approximately to that of FB.

Table 6. Base shear in x-direction (kN)

Base Type	**Soft soil**	**Medium soil**	**Hard soil**
FB	11942.09	15262.60	15910.67
RB	5373.38	7307.79	8973.54
FPI	7879.47	9734.647	11950.30

ACCELERATION OF BUILDING

The acceleration responses of a structure are noted in Table 7 and compared. It is observed that the reduction in the acceleration is approximately 80% in case of RB and 70% in case of FPI respectively, when compared to that of FB. This is again supports the statement that isolation helps in decoupling the structures from damaging earthquake-induced ground motions.

Table 7. Acceleration of the building in x-direction (m/s^2)

Base Type	**Soft soil**	**Medium soil**	**Hard soil**
FB	8.45	8.8	8.82
RB	1.714	2.33	2.86
FPI	2.36	3.15	4.10

CONCLUSION

Based on the analysis of G+5 building, it can be concluded that,

- As the natural time period of isolated structure increases, it has being completely removed from the resonance range of the earthquake. Hence isolation makes building safe from complete collapse.
- Though the displacement is higher in case of isolated building compared to that of fixed base building but it is within the range suggested by IS code.
- The base shear has greatly reduced in the model with RB and FPI as compared to that of FB. This will help in optimising the dimensions of the components of the building which makes the building light in weight.
- Effect of different soil condition is considerable in all the cases of fixed base as well as in isolated base and needs careful analysis before designing of RC building.

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