Retraction

Retraction: Design of Base Isolation System for a Six Storey Reinforced Concrete Building (IOP Conf. Ser.: Earth Environ. Sci. 796 012034)

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This article has been retracted by IOP Publishing following a request by the authors that this article may contain potential research errors.

IOP Publishing has investigated in line with COPE guidelines, and during the course of the investigation were made aware the article contains potential similarities to other published works [1-4]. Due to the nature of the overlap identified, and the extent of the changes requested by the authors, the journal has lost confidence in the validity of the findings presented and agree this article should be retracted.

The authors have neither confirmed whether they agree or disagree to this retraction.

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Design of Base Isolation System for a Six Storey Reinforced Concrete Building

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Abstract

The aim of the seismic design is to protect the important building such as museums, hospitals, official buildings etc., and reduce the damages after a seismic event. Many researchers have done a lot of research to get the best solutions to resist earthquakes and protect survival. One of those solutions is base isolation, the main goal of seismic isolation is to shift the fundamental frequency of a structure away from the dominant frequencies of earthquake ground motion and the fundamental frequency of the fixed base-superstructure, the other purpose of an isolation system is to provide an additional means of energy dissipation, thereby reducing the transmitted acceleration into the superstructure. In the present study, a six-story RCC building has been designed and analyzed according to IS Code for seismic analysis by (STAAD PRO V8i) software using response spectrum analysis, the study considered two models one of the models represents conventional building and the second model represents base isolation (BI) building. The results obtained shows the reduction in base shear and storey drift in both direction and increase in the displacement and the time period for the base isolated structure. Finally, parameters such as storey displacement, storey drift, mode and base shear are compared and obtained result where presented by both graphically and in tabular format.

Keywords: seismic design, base isolation, STAAD Pro, response spectrum, storey drift, base shear

1. Introduction

In past, there has been a whole lot of evolution in design and execution of base isolation systems (BIS) which is being traced in accordance with the changes inspired by previous pioneering incidents. These have impacted a rigid base design process and resulted in a low design vibration period and shorter displacements. The role of tributary area has been analyzed in the superstructure fixed grid due to the new design strategy linking with the structure of BIS design. The adaption to using bigger grids in larger areas have deduced a significant number of devices which can sustain long design periods [1]. The test results of high-damping natural rubber (HDNR) bearings application in the sample buildings were quite efficient in isolating the main structure from the floor motions. The highest floor acceleration was less than the ground accelerations. Also, the interstorey drifts have decreased exponentially as compared to fixed based model [2]. The Institute of geological and nuclear sciences have released the earthquake acceleration records and published all info about elastic acceleration response spectra for all the important Canterbury earthquake. It is known as this level of acceleration is higher than any of the other earthquakes in New Zealand [3]. Base isolation is a progressive method for seismic structural design, such as, the design of the Foothill Communities Law & Justice Center (FCLJC) in Rancho Cucamonga. It was originally made for an 8.3 Richter event on the San Andreas Fault, with all fixed members being in the elastic range and all functions staying operational even after the day was over. In the end, when it was contrasted with the initial design, the base isolation showed a decrease of forces.

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transmitted into the building by a factor of seven [4]. The base isolation in Japan had increased exponentially since the 1995 Kobe earthquake, having way over 150 new projects every year. The floor area, height and natural period of base-isolated building structures are going up since then, and the largest shear applied into the superstructure is kept low, which is a straightforward symbol of the confidence and maturity of seismic isolation design in Japan [5]. The structural upgrading for the purpose of compensating the effects of earthquakes resulted into two sections--one to solidify the structural foundation and the other to isolate the structure from the seismic ground motion. Both these methods are allowed in the design working parameter for new construction [6]. Researchers are able to relate to the intensities used in creating a design which takes the overall building stock performance into account. In the event of an earlier earthquake, the total structural damage can be determined by assess the vulnerability of building stocks along with recording probabilities of displacement-based method [7]. The major principle of forming a building on sloping ground has its fundamental focus on seismic isolation so as to showcase horizontal flexibility in a vertically stiff material. This was done at the base of a model to majorly uncouple the superstructure of the building from a large frequency of the earthquake shaking. The primary idea of this isolation system is taking up the natural period of the base building. Due to this, there are two known advantages i.e. of putting an additional base isolation system at the foundation which are lengthening of the spectral acceleration for the amount of earthquake shaking and dampening the seismic isolators in order to decrease displacements [8]. Various attempts of research and development for anti-seismic structures or similar building materials that can afford the seismic hazards and provide ground resistance in earthquakes have been in the past but none of them have given any significant conclusions. Although there have been numerous studies and application of advanced designing, execution and maintenance tactics in high rise structures, various construction elements have found other ways to deal with structural hazards. Still the issues of seismic hazards do not have any major answers [9].

The aim of the seismic designs to act as a shield for the major vital buildings such as museums, hospitals, official buildings and many others on similar lines, this ideology assisted in reducing the amount of damages after a seismic event. There has been many research conducted to find usable solutions to resist earthquakes and uplift survival. One among those research results is base isolation, the primary aim of seismic isolation is to shift the fundamental frequency of a structure away from the dominant frequencies of earthquake ground motion and the fundamental frequency of the fixed base-superstructure [10]. The base isolation system is known far and wide and quite accepted at the present times. To reach this destined behavior of the base-isolated buildings, the primary design for base isolation system is justified as the most prominent aspect of the success of isolated buildings. Even though this base isolation design can be achieved using Uniform Building Code 1997, the overall conceptual design is yet essentially analyzing to react the closest effective values of this termed design [11]. The prime goal of this research is to contribute to the knowledge of seismic isolation technology to achieve a viable, efficient and cost-effective seismic protection system to prevent loss of lives and properties due to earthquake induced ground motion. In this attempt, the prime intention is to effectively protect low-rise buildings in the high seismic zones. The main objective of the research is to investigate the design procedure of elastomeric base isolation system for reinforced concrete building. A six storey reinforced concrete building for a commercial complex [12] is considered for steel reinforced elastomeric base isolation(SREIs) application. The building is in seismic zone III with medium soil and design of the building for seismic loads as per IS 1893 (Part 1): 2002.

2. Base isolation concept

In base isolation system, a flexible layer is applied between the superstructure and the foundation, the upper structure will act as a rigid body and the actions can be projected by linear theory for 2 degrees of freedom system. the behavior of isolation system is obtained by, linear spring and linear viscous damping will be applied to this simple 2-DOF system model. The model shown in Fig.1 symbolizes a rigid body sitting on a layer of flexible bearings [11].
M, Us are the mass and the shear displacement of the superstructure, respectively. Mb, Ub are the mass and the shear displacement of the base floor above the isolation layer. Ks, Cs are the structure stiffness and structure damping, respectively. Kb, Cb are the stiffness and damping of the isolation and Ug is the ground displacement. The governing equation of motions is expressed in equation 1. For the fixed-based building, the frequency and the fundamental period by is calculated using equation 1.

\[ M\ddot{u} + C\dot{u} + Ku = -M(\ddot{u}_g + \dot{u}_b) \]  

(1)

Because of such lower value of stiffness, we will find the new much longer period \( T_b \) with respect to fundamental period \( T_f \) of the building. The effective factor that reduces the force impacts to the structure is the long period of vibration. In the calculation, by introducing the flexible layer to the foundation, it is understandable that the response of the second mode is negligible in comparison with the first mode. The dynamic response of the isolated floor is reflected by first mode while the structure above inclines to act rigidly. The high energy in the ground motion at higher frequencies cannot be transmitted to the structure because of higher modes, which produce the floor inter-story drift and accelerations, have very small participation factors. Stated that an isolation system transmits earthquake energy rather than absorb it, an isolation system doesn't depend on damping, even though additional damping can be a supplemental tool to moderate earthquake excitations. Since the damping is not major factor in isolation efficiency, we did not include the effect of damping in previous analysis, a means of energy dissipation can be provided with a Supplementing isolation with damping, and this is a second factor in reducing structural responses.

3. Base isolation design

Base isolation increases the time period for base isolated building as compared to fixed base building. Therefore, initially fixed base six storey reinforced concrete building was modeled in STAAD PRO. For fixed base building, the translations and rotations of all columns node at base were suppressed. A free vibration analysis was carried out for Eigen-vector solution. The fundamental time period and mode shapes of the building were obtained. A practical seismic isolation system should meet the following requirements:

- Enough horizontal flexibility to increase the structural period and spectral demands, except for very soft soil sites.
- Enough energy dissipation capacity to limit the displacement across the isolators to a practical level.
- Adequate rigidity to make the isolated buildings not much different from a fixed base building under general service loading.

Based on above mentioned requirements and code procedures, as per IBC 2000 three different types of isolators, namely, Lead Rubber Bearing (LRB), High Damping Rubber bearing (HDR) and Friction Pendulum System (FPS), were designed. As per IBC 2000 formulations, the effective stiffness to provide lateral stability for all types of bearings was calculated. The properties like damping, hardness, modulus of rigidity, modulus of elasticity and poisons ratio, for rubber were considered from Section 623 of IBC 2000. However, wherever possible, the provision of Indian seismic code IS: 1893-2002 part-1 was taken into considerations [10]. Building under consideration here requires different size of isolators, as gravity loads acting on all the columns are varied in magnitude. However, to maintain uniformity and ease of designing, same size of isolators is advisable for all the column of the building. For rubber bearing, horizontal stiffness \( K_H = \frac{E_A t_r}{t_r} \), \( A= \)Cross sectional , \( t_r= \) total thickness of Rubber , \( G= \)Shear Modulus of elastomer , Maximum Shear Strain \( \gamma = \frac{D}{t_r} \). The vertical stiffness of a rubber bearing \( K_V = \frac{E_A}{t_r} \) and Shape Factor \( S = \frac{\text{load carrying force/area}}{\text{free area}} \). Data considered for isolator design in shown in table 1.
| Sl.No. | Description                                      | Value          |
|-------|--------------------------------------------------|----------------|
| 1     | Target period                                    | 2.5 sec        |
| 2     | Target maximum shear strain                      | 1.5            |
| 3     | Composite damping                                | 10%            |
| 4     | Reinforced concrete shear wall                   | Building type  |
| 5     | Type A bearing                                   | 16 Nos         |
| 6     | Type A bearing stiffness                          | 2.35 MN/m      |
| 7     | $\gamma$                                        | 1.5            |
| 8     | $t_r$                                            | 200 mm         |
| 9     | B D                                             | 1.2            |
| 10    | C VD                                            | 0.56           |
| 11    | Design displacement D D                          | 0.289 m        |
| 12    | C/S area using Type A bearing stiffness formula  | 0.47 m²        |
| 13    | Dia. Calculated                                  | 0.774 m        |
| 14    | Dia. Taken                                      | 600 mm         |
| 15    | Area provided                                    | 0.283 m²       |
| 16    | Radius of curvature for type A                   | 7.08 MPa       |
| 17    | Actual bearing stiffness                         |                |
| 18    | Type A KH                                        | 1.415 MN/m     |
| 19    | actual frequency                                 | 22.64 MN/m     |
| 20    | $\omega_H$                                      | 3.803763441    |
| 21    | $T$                                             | 1.98 rad/sec   |
| 22    | $\beta$ (damping factor)                         | 3.17 sec       |
| 23    | $BD_{new}$                                       | 1.22           |
| 24    | New design displacement                          | 0.914 m        |
Proposed based isolator as shown in Fig. 2 is being modeled as spring at each node at plane 1.1 m above the ground. As per the Uniform Building Code 1997, the Z, N, D, M, R, W, G, A, are considered as 0.4, 1, 1.25, 2 and 1MPa respectively. Bearing type, A, having bearing stiffness 2.35 MN/m, 16 in numbers are used with cross-sectional area of 0.47 m². As per the calculation the bearing diameter calculated is 0.777 meters but we have considered 600 mm bearing diameter. Fig. 2 represents the prototype design of steel reinforced elastomeric base isolator and Fig. 3 shows the modeling of the isolator as a spring element in x and z direction at 1.1m height from the foundation face.

| Table 3: Bearing Details |
|--------------------------|
| Eccentricity e           | 0.05 x 22.5 |
| Allowance for Torsion D  | 1.19 m      |
| Torsional stiffness K Θ  | 3184 MN/m   |
| Additional displacement θ | 0.05 m     |
| Min. allowance for torsion as per code | 1.1 D |
| Total new displacement D T | 0.239 + .078 |
| Elastic base shear from code | 3.27 MN |
| V s                       | 3.27 MN     |
| C s                       | 6.10%       |
| Bearing details           |             |
| selected vertical frequency f_v | 10 Hz |
| Eccentricity e           | 0.05 x 22.5 |
| Allowance for Torsion D  | 1.19 m      |
| Torsional stiffness K Θ  | 3184 MN/m   |

![Fig. 2: Proposed based isolator](image-url)
4. Results

Using STAAD PRO software the fixed base and base isolated symmetric building are analyzed. The main objective of this work is to reduce dynamic response of a structure by providing steel reinforced elastomeric base isolation system (SREBs). Thus, from above design of SREBs, a building model is created and analyzed by using STAAD PRO software. After the modeling and analysis, the floor distance vs story drifts graph models of fixed and base isolated building for symmetric case is as shown in Fig. 4 and Table 2. From Fig. 4, the data is with respect to x and z direction. It is observed that in the base isolated building, the drift for the base at distance 0 meter is same in both the bases. On the level 1 at distance 1.1 the drift is increased but after we cross the level 1 the drifts start decreasing. Story drift at the top floor significantly reduces with 47.05% as compared to the corresponding fixed base models. The aim of isolators is shifted and increasing the time period of earthquake.
From the results in and Fig. 5 and table 3, it is observed that the time period increases in case of base isolated with 24.93% for first modal (fundamental modal). As we move down the table the values of percentages for the upmost story becomes 16.62%.
Table 3 Modal periods of Base Isolation & Fixed base

| MODE | PERIOD BASE ISOLATION | PERIOD FIXED BASE |
|------|-----------------------|-------------------|
| 1    | 4.02146               | 3.0186            |
| 2    | 3.823                 | 2.934             |
| 3    | 2.487                 | 2.356             |
| 4    | 2.132                 | 2.027             |
| 5    | 1.961                 | 1.835             |
| 6    | 1.618                 | 1.349             |

Table 4 and 5 and Fig. 6 and 7 shows the maximum displacement for both cases in x and z direction respectively, the base isolated and fixed base. the results show that at top floor the base isolation produces (0.135498) m as compared to fixed base (0.084789) m for x direction. And for the Z direction the displacement of the top storey is 0.207676 and for the fixed base 0.127486. The value increased by 59.80% and 38.61% for X and Z direction resp. This gives us an evidence that the base isolation buildings are more flexible than fixed base buildings.

Table4: Story Displacement for x direction at each story

| DISTANCE (meter) | DISPLACEMENT BASE ISOLATOR (meter) | DISPLACEMENT FIXED BASE (meter) |
|-----------------|-----------------------------------|---------------------------------|
| 0               | 0                                 | 0                               |
| 1.1             | 0.000683                          | 0.000352                        |
| 5.2             | 0.02763                           | 0.009152                        |
| 10.2            | 0.059477                          | 0.0288318                       |
| 15.2            | 0.086907                          | 0.048347                        |
| 20.2            | 0.095724                          | 0.06528                         |
| 25.2            | 0.110923                          | 0.07739365                      |
| 30.2            | 0.135498                          | 0.084789                        |
Table 5: Story Displacement for z direction at each story

| DISTANCE (meter) | DISPLACEMENT BASE ISOLATOR (meter) | DISPLACEMENT FIXED BASE (meter) |
|------------------|------------------------------------|---------------------------------|
| 0                | 0                                  | 0                               |
| 1.1              | 0.00839                            | 0.00656                         |
| 5.2              | 0.029209                           | 0.016553                        |
| 10.2             | 0.067299                           | 0.048366                        |
| 15.2             | 0.096034                           | 0.075896                        |
| 20.2             | 0.139854                           | 0.092622                        |
| 25.2             | 0.186539                           | 0.109815                        |
| 30.2             | 0.207676                           | 0.127486                        |

Fig. 6: Story Displacement for x Direction
Fig. 7: Story Displacement VS Story Distance for Z Direction

Table 6 and Fig. 8 indicates the decrease in the values of base shear as we go down the table. The graph shows us the decrease in values as for the 1ST story the value decreases by 16.90% and for the top floor the value is decreased by 44% of fixed base. The values were only same for 4th floor which was 0.

| STORY NO | BASE SHEAR BASE ISOLATOR | BASE SHEAR FIXED BASE |
|----------|---------------------------|------------------------|
| 1        | 37.8                      | 45.49                  |
| 2        | 239.63                    | 253.34                 |
| 3        | 0.17                      | 0.25                   |
| 4        | 0                         | 0                      |
| 5        | 128.48                    | 140.93                 |
| 6        | 0.039                     | 0.07                   |
5. Conclusion

The present study showed the importance of keeping the superstructure stable while the foundation is being shaken by an earthquake. Effectiveness of isolation technology can be perceptible when it is compared to the results obtained from the analysis of non-isolated buildings. Base isolation system is an extraordinary and widely recognized advancement that is used to save innumerable lives and money spend in destruction made by earthquakes. The storey drift values in X and Z direction, before adding the isolator, the story drift values for the fixed base were high i.e. 0.0019863 m while base isolation has 0.0009346m. After the adding of isolator, the story drift for all the floors were decreased and for the top floor the drift was 47.05% reduced. This shows us that the drift of the storey is decreases after using the base isolator. After providing SREBIs the fundamental period mode of structure increased by 24.93 % for G+6 stories building. It is concluded that the mode period is increased after providing isolator due to the flexible property of the isolator. When compared with fixed base structure, the base shear is reduced in base isolated structures, the graph shows us the decrease in values as for the 1st story the value decreases by 16.90% and for the top floor the value is decreased by 44% of fixed base. Thus, the response of building is good in base isolated structures than fixed base structures. The maximum displacement for both cases in X and Z direction were shown in the results. The results show that at top floor the base isolation produces (0.135498) m as compared to fixed base (0.084789) m for X direction. And for the Z direction the displacement of the top storey is 0.207676 and for the fixed base 0.127486. The value increased by 59.80% and 38.61% for X and Z direction resp. This gives us an evidence that the base isolation buildings are more flexible than fixed base buildings.

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