International Journal of Engineering Innovations in Advanced Technology
ISSN: 2582-1431 (Online), Volume-7 Issue-1, March 2025

# Friction Dampers and Base Isolation Techniques for Seismic Vibration Control of Buildings

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***Abstract:*** **Studies on the methods to mitigate the effects of earthquake on structures has gained up pace since the last four decades with the invention of base isolation techniques and then the energy dissipating seismic devices. Here in this work an effort has been made to study the effects of Lead Rubber Bearing (LRB) as base isolator and Friction Dampers as energy dissipating devices when installed individually and when as a dual combination in the eight storey 'C' shaped building considered by the use of ETABS software. The building is assumed to be located in earthquake zone 4 and the method of seismic analysis chosen is linear Response Spectrum analysis. The response parameters that are studied in this work are time period, base shear, storey displacement and storey drifts. The results show that these devices have improved seismic resistance of the building by decreasing the responses of the structure when included as individually and when as a combined control strategy. The improved results are in comparison with the conventional model.**

***Keywords:*** **Lead Rubber Bearing (LRB), base isolator, Friction Dampers, time period, base shear, storey displacement and storey drifts**

## 1. INTRODUCTIONS

Earthquake in the simplest terms can be defined as Shaking and vibration at the surface of the earth resulting from underground movement along a fault plane. The vibrations produced by the earthquakes are due to seismic waves. Seismic waves are the most disastrous one. However, modern high-rise buildings and tall structures cannotconveniently be geared up with these techniques. The safety and serviceability of any structure is thus endangered with the increasing elevation. As per the standard codes, a structure that can resist the highest earthquake that could possibly occur in that particular area can be called as an earthquake resistant structure. However, the most efficient way of designing earthquake resistant structure wouldbe to minimize the deaths as well as minimize the destruction of functionality of the structural element. The most disastrous thing about earthquake is its unpredictability of time and place of occurrence. These possess a great challenge to the economy and safety of structure. From the past and few present records, the world has experienced number of destroying earthquakes, causing in number of increase the loss of human being due to structural collapse and severe damages to structure. Because of such type of structural damages, during seismic (earthquake) hazards clearly explains that the buildings / structures like residential buildings, public life-line structures, historical structures and industrial structures should be designed to seismic force design and very carefully to overcome from the earthquake hazards. The approach in structural design using seismic response control device is now widely accepted for structure and frequently used in civil engineering field. Structural control concept into a workable technology and such devices are installed in structures.

A thorough literature study has been conducted studying journal papers related to the use of base isolation technique and friction dampers in the reinforced concrete structures for reducing the earthquake effects and the following objectives are set for the study,

- To perform Response Spectrum Analysis on an irregular “C” shaped concrete framed structure using ETABS software.
- To design the Lead Rubber Bearing as a base isolation system for the considered multi-storey building and to study the seismic behaviour of the structure upon incorporation of LRB to it.
- To study the seismic response parameters of the considered structure with the incorporation of just Friction Dampers to it.
- To carry out seismic analysis by introducing both LRB and Friction Dampers as a Dual system in the considered structure and study the Response parameters.
- To conduct comparative study on all the four cases, reinforced concrete framed structure, framed structure with LRB, framed structure with Friction dampers, framed structure with LRB and Friction dampers, by considering time period, base shear, storey displacement and storey drifts as the response parameters.

Here in this work, the study has been conducted to check the effectiveness of the use of both lead rubber bearing and friction dampers as a dual system in order to mitigate the earthquake effects of an eight storey RC structure.
The results of response parameters are compared for four different models, conventional model, model with base isolation, model with friction damper and at last themodel with both base isolation system and friction dampers

## 2. BASE ISOLATION AND FRICTION DAMPERS

### 2.1 Base Isolation

Base isolation, also known as seismic base isolation or base isolation system 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.
Base isolation system is the frequently adopted earthquake resistance system. It reduces the effect of ground motion and thus leads to nullify the effect of earthquake toon the structure.
Base isolation has become popular in last couple of decades in its implementations in buildings and bridges. Base isolation has become a traditional concept for structural design of buildings and bridges in high risk areas. The isolation system decouples the structure from the horizontal components of the ground motion and reduces the possibility of resonance as shown in Figure 1 This decoupling is achieved by increasing the flexibility of the system, together with appropriate damping by providing isolator at the basement level of the structure.

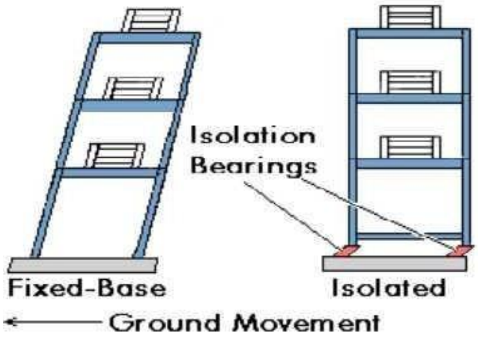


Figure 1: Typical explanation of base isolation system

### 2.2 Lead-plug Rubber Bearings-(LRB)

Lead-plug rubber bearings were invented in New Zealand in 1975. The mechanism of lead-plug rubber bearings is very similar to that of low-damping natural rubber bearings. As show in Figure 3.3, there are three main pieces of equipment, layers of steel plates, rubber layers and lead core, respectively. Same as the steel shims in natural rubber bearings, the layers of steel provide vertical stiffness and thelayers of rubber supply the device with high lateral flexibility. Lead core is the device that will supply extra stiffness to the isolators and appropriate damping to the system. Owing to current well-developed technologies, it is possible to manufacture lead-plug rubber bearings with high stiffness and enormous shear deformation. Innovations in materials and design related technologies such as analysis software and construction methods have enabled the concept of isolation become a reality.

### 2.3 Friction Dampers

Earthquake cause ground vibration due to the sudden release of energy. This energy can be absorbed by using the vibration control device called friction damper. The friction dampers are designed to have moving parts that will slide over each other duringa strong earthquake. When the parts slide over each other, they create a friction which uses some of the energy from earthquake that goes into the building. This Friction damperincreases the stiffness of the building as a result vibration of the building is reduced. The structural response to the seismic excitation has reduced by applying friction dampers based on different construction techniques. Friction dampers come under passive seismic control system does not require any external energy source to operate and is activated by the earthquake input motion only. The friction surfaces of these systems are clamped with pre-stressing bolts. Since the amount of energy dissipated is proportional to displacement these systems are referred as displacement dependent systems. Contact surfaces of these systems used are lead–bronze against stainless steel or Teflon against stainless steel.

## 3. METHODOLOGY

It describes the software package used in the modelling and describes some of the important area in the mode lling and analysis using ETABS in brief.

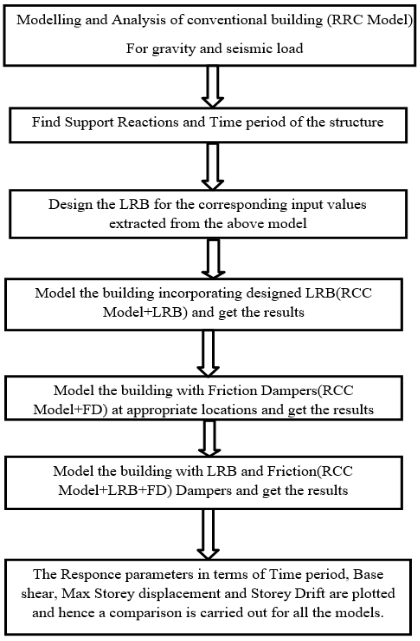


Figure 2: Flow chart of methodology

### 3.1 Description of analytical model

Shows the plan of the building having 40m*20m as the dimension, 5 and 5 bays along X and Y respectively. Figure 2 is about sequence of methodology steps.

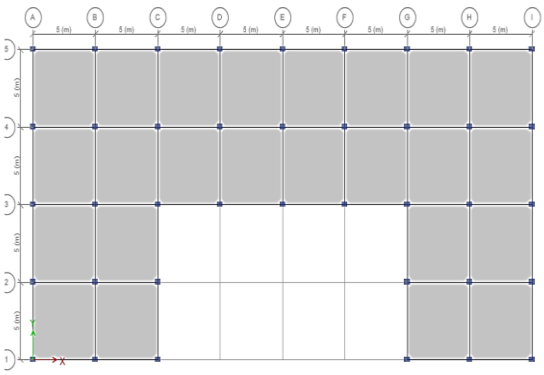


Figure 3: Plan of the building.

- M30 Grade of concrete.
- HYSD rebar of Fe500 are considered.
- Column size of 350X450mm of M30 grade concrete utilizing Fe500 rebars.
- Beam size of 300X450mm of M30 grade concrete utilizing Fe500 rebars.
- The slab of 150 mm thickness of M30 grade concrete utilizing Fe500 rebars. areconsidered for modelling of a structure.

Table 1: Loads assigned on building

| | |
|---|---|
| Live Load As Per IS-875 Part 2 | 4 kN/m² and 1.5kN/m² at terrace |
| Wall Thickness | 230 mm |
| Wall Load | 14 kN/m² |
| Floor Finish | 1 kN/m² |
| Terrace Finish (WPC) | 1.75 kN/m² |
| Parapet wall load | 4 kN/m² |

Table 2: Seismic data

| Sr. No | Particulars | | Codes | Values |
|---|---|---|---|---|
| 1 | Zone Factor | Z | IS 1893:2016( part 1) | 0.24 |
| 2 | Importance Factor | I | IS 1893:2016(part 1) | 1.5 |
| 3 | Soil Type II | Sa/g | IS 1893:2016 (part 1) | 2.5 |
| 4 | Reduction Factor | R | IS 1893:2016 (part 1) | 5 |

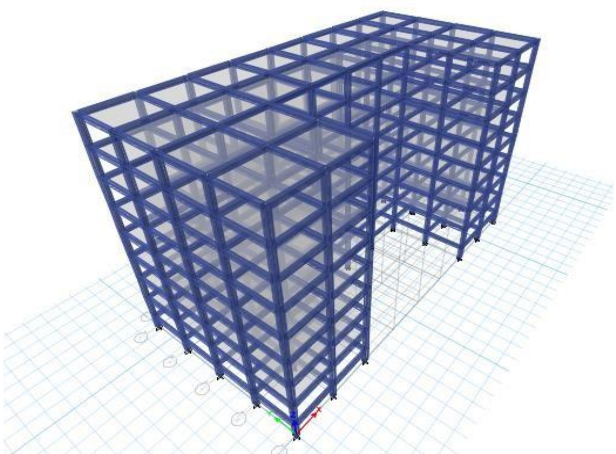

Figure 4: 3D Model of the conventional building

### 3.2 Modelling of the LRB using ETABS

After the designing process is completed, the values from the design are use tomodel LRB in ETABS by the following steps,

Go to Define>Section>Link/Support Properties>Define the Support, Go to Define>Point Springs>Define Point Springs using above mentioned link supports. (Axial Direction Z+ for Etabs), Assign LRB at base for all the Columns

The Figure 5 is about the LRB definition in Etabs modeled as the Rubber isolator in the link property option. Figure 5 is of the picture of the structure after the incorporation LRB to it. At the support reactions region, we can see those LRBs installedinstead of fixed supports

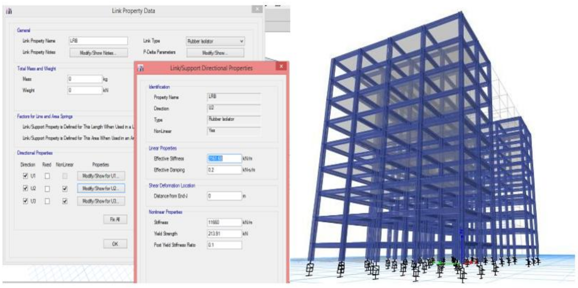

Figure 5: Building after the incorporation of LRBs at the base of it

### 3.3 Modeling of the Friction Dampers using ETABS

To modelling Friction Dampers, have referred Quaketek ( ... ch is a Canada based con ... ıufacturing of Friction da ... en modelled as according ...

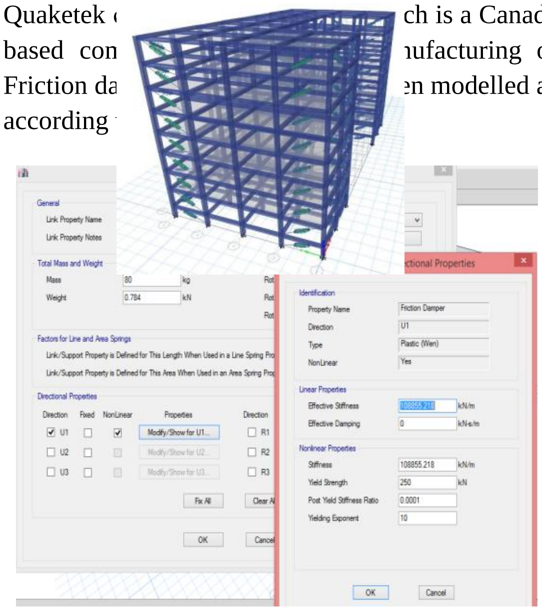

Figure 6: Building after the incorporation of Friction Dampers

### 3.4 Modelling of the Building with both LRB and Friction Dampers

There is no extra work required for modelling the building with the inclusion of both LRB and Friction damper. It is just applying the above-mentioned steps in the individual cases here as a dual system. The same design values are used here also. After modelling the building looks as in Figure 7 below, The analysis procedure chosen for the study is linear dynamic analysis which is Response Spectrum Analysis. After the analysis, the response parameters such as Time period, Base shear,Storey displacements and Storey drift values, plotted and compared.

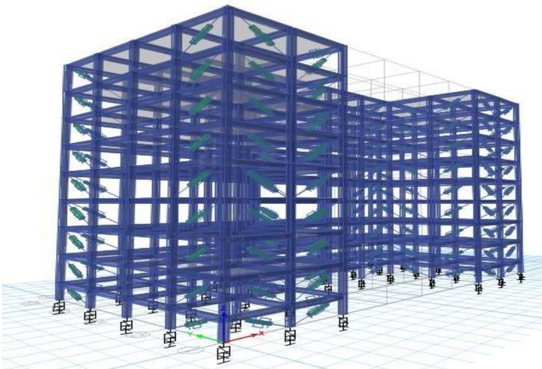

Figure 7: Building with the inclusion of LRB and Friction Dampers

## 4. RESULTS AND DISCUSSIONS

3-Dimensional analysis. The parameters discussed in this analysis includes Base shear, Time period, Storey displacement and storey drift values for Response spectrum analysis. The results obtainedare given below under various topics.

### 4.1 Time Period

The time taken by the wave to complete one cycle is called its time period. After modelling on ETABS following results are obtained as shown in table 3.

Table 3: Time Period results of all the models

| Mode | RCC Model (sec) | RCC Model+ FD (sec) | RCC Model+ LRB(sec) | RCC Model +LRB+FD (sec) |
|---|---|---|---|---|
| 1 | 1.93 | 1.252 | 2.798 | 2.398 |
| 2 | 1.777 | 1.201 | 2.622 | 2.33 |
| 3 | 1.695 | 1.029 | 2.608 | 2.168 |
| 4 | 0.634 | 0.407 | 0.82 | 0.588 |
| 5 | 0.583 | 0.393 | 0.76 | 0.564 |
| 6 | 0.553 | 0.336 | 0.735 | 0.499 |
| 7 | 0.37 | 0.234 | 0.441 | 0.285 |
| 8 | 0.34 | 0.225 | 0.408 | 0.275 |
| 9 | 0.319 | 0.192 | 0.388 | 0.238 |
| 10 | 0.258 | 0.181 | 0.297 | 0.228 |
| 11 | 0.237 | 0.168 | 0.275 | 0.205 |
| 12 | 0.219 | 0.16 | 0.257 | 0.199 |

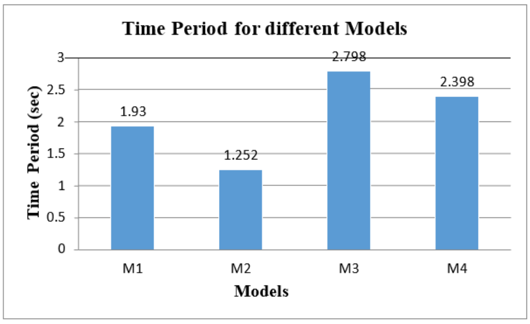


Figure 8: Time periods of all the models considering only the first mode

The Figure 8 shows the comparison of time period of different models in seconds. With the incorporation of LRB at base of the building, has increased time period to an extent of 44% that is from 1.93 seconds to 2.798 seconds, with only FDs reduced time period to 35% that is from 1.93 seconds to 1.252 seconds and upon the inclusion of both LRB and FDs, have resulted in increase of time period to 24% that is from 1.93 seconds to 2.398 seconds, on comparing with time period of first mode of conventional model which is fixed base and without dampers.

The maximum storey displacement values decrease to an extent of 16.68% in Xand 25.56% in Y direction that is from 46.679 mm to 38.891mm in X and52.58 mm to
39.139 mm in Y for the model with FDs. For the model with LRB, the maximum storey displacements increase to an extent of 23.47% in X and 20.42% in Y directions that is from 46.679 mm to 57.638 mm in X and 52.58 mm to 63.321 mm in Y. For the model with both LRB and FDs there is increase of 8.95% in X and 2.27% in Y directions that is from 46.679 mm to 50.857 mm in X and 52.58 mm to 53.777 mm in Y as compared with conventional case.

### 4.2 Base Shear

Base shear is the total estimate of the lateral force that would act at the base of the building. The base shear values have been taken for the Load combinations 1.5DL+1.5 RSX and 1.5DL +1.5 RSY and the results are plotted for the same.

Table 4: Base Shear results of all the models

| Models | Base Shear in X direction, kN | Base Shear in Y direction, kN |
|---|---|---|
| RCC Model | 3234.417 | 2839.98 |
| RCC+FD Model | 4571.989 | 4386.222 |
| RCC+LRB Model | 2088.447 | 1956.878 |
| RCC+FD+LRB | 2352.887 | 2285.644 |

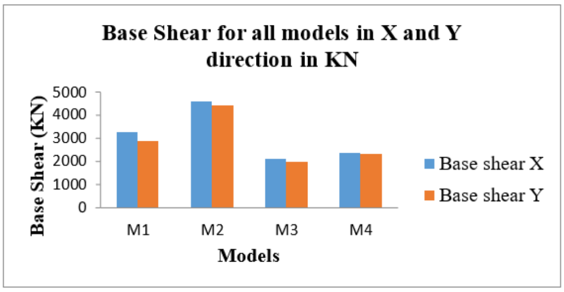


Figure 9: Base Shear of all the models in both X and Y direction

When LRBs are introduced at the base of building, it has reduced the base shear values to 35% in X and 31% in Y directions. With the inclusion of only FDs in the model,base shear values have increased to an extent of 41% in X and 54% in Y direction. But in the combined control strategy , that is LRB with FD, the base shear values decrease to 27.25% in X and 19.51% in Y direction as compared with conventional model which is clearly depicted in the Figure 9.

### 4.3 Storey Displacement

According to IS 1893-2016, allowable displacement is calculated as h/250. Where h" is the total height of building in millimetres (mm). Adopting this practice, the displacement in X and Y direction must lie within 110.4 mm (27600/250) where 27600 isthe height of model building. The table 5.5 and 5.6 helps us to compare the displacement of the different models along X and Y direction respectively. The storey displacement values have been taken for the 1.5DL+1.5RSX and 1.5DL+1.5RSY Load combinations and plotted for the same.

Table 5: Storey Displacement results of all the models in X direction

| Story | Elevation m | RCC Model mm | RCC Model +FD mm | RCC Model+ LRB mm | RCC Model+ LRB+FD mm |
|---|---|---|---|---|---|
| Story8 | 27.6 | 46.679 | 38.891 | 57.638 | 50.857 |
| Story7 | 24.4 | 45.188 | 37.011 | 56.726 | 50.065 |
| Story6 | 21.2 | 42.298 | 34.138 | 55.11 | 48.938 |
| Story5 | 18 | 38.079 | 30.333 | 52.813 | 47.432 |
| Story4 | 14.8 | 32.717 | 25.753 | 49.787 | 45.567 |
| Story3 | 11.6 | 26.32 | 20.536 | 46.068 | 43.375 |
| Story2 | 8.4 | 18.943 | 14.809 | 41.691 | 40.871 |
| Story1 | 5.2 | 10.727 | 8.694 | 36.677 | 38.01 |
| Plinth | 2 | 2.383 | 2.529 | 30.59 | 34.677 |
| Base | 0 | 0 | 0 | 25.972 | 33.8 |

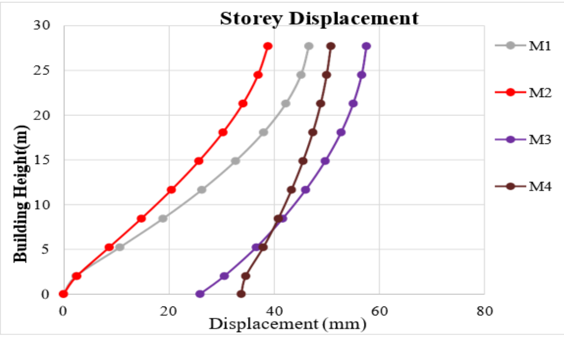


Figure 10: Storey Displacement of all the models in X direction

## 5. CONCLUSIONS

- The seismic control methods that are used, base isolation (LRB) and Friction Dampers (FD) have effectively reduced the response parameters caused due to earthquake.
- With the incorporation of LRB at base of the building, has increased time period to an extent of 44.50%, with only FDs reduced time period to 35.12% and upon the inclusion of both LRB and FDs, have resulted in increase of time period to 24.24% on comparing with time period of first mode of conventional model which is fixed base and without dampers.
- When LRBs are introduced at the base of building, it has reduced the base shear values of 35.43% in X and 31.09% in Y directions. With the inclusion of only FDs in the model, base shear values have increased to an extent of 41.35% in X and 54.44% in Y direction. But in the combined control strategy, that is LRB with FD, the base shear values decrease to 27.25% in X and 19.51% in Y direction as compared with conventional model.
- The maximum storey displacement values decrease to an extent of 16.68% in X and 25.56% in Y direction for the model with FDs. For the model with LRB, the maximum storey displacements increase to an extent of 23.47% in X and 20.42% in Y directions. For the model with both LRB and FDs there is increase of 8.95% in X and 2.27% in Y directions as compared with conventional case. In the model with LRB and in the model with both LRB and FDs, shows some little displacement at base level to an extent of 25 mm in X and 34 mm in Y, which iszero in case of fixed base building.
- The storey drift values significantly decrease in all the models with LRB, with FDs and even in the dual system that is with both LRB and FDs as compared with conventional building.
- The storey drift values have reduced to an extent of 25% in X and 37% in Y directions for model with FDs. Those drift values have decreased to 35% and 32% in both X andY directions for model with LRB and to 64% in the case of model with both LRB and FDs in both X and Y directions as compared with conventional case.
- The decrease in storey drifts in the case of combined strategy, that is with LRB and FDs, is because of the seismic energy dissipation and increased stiffness of the structure due to both LRB and FDs. Hence this combined control strategy can be adopted to mitigate the effects of earthquake.

## REFERENCES

1. Aparna Bhoyar and Bhupesh Nandurkar, “Seismic Evaluation of Reinforced Concrete Building with Friction Dampers”- International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056,p-ISSN: 2395-0072, Volume: 06 Issue: 03 , Mar 2019.
2. Base Isolated and Fixed Based RC Frame Building”- International Journal for Scientific Research & Development -IJSRD ,Vol. 4, ISSN (online): 2321-0613, Vol. 4, Issue 06, 2016.
3. Bhavana Balachandran and Susan Abraham, “Effect of Base Isolation in Multi- Storeyed RC Building”-2018. IOSR

Journal of Engineering (IOSRJEN), ISSN(e): 2250-3021,ISSN (p): 2278-8719, Vol. 08, Issue 6, June,2018.

4. Chandak N.R , " Effect of Base Isolation on the Response of Reinforced Concrete Building " - Journal of Civil Engineering Research , 3(4): 135-142, 2013.
5. IS 1893-2002(Part-1): Criteria for Earthquake Resistant Design of Structures.
6. IS 456-2000, "Plain and Reinf0rced c0ncrete-Code 0f Practice", Bureau 0f Indian Standards, New Delhi
7. IS 875(Part 1) : 1987, code of practice for Design Loads(other than earthquake), Dead L0ads-Unit Weights 0f Building Materials and St0red Materials For Buildings and Structures.
8. IS 875(Part 2) : 1987, code of practice for Design Loads(other than Earthquake), Imp0sed L0ads For Buildings and Structures.
9. Kishan Bhojani, Vishal B. Patel and Snehal V. Mevada, "Seismic Vibration Control of Building with Lead Rubber Bearing Isolator"- 2017
10. Mohammed Irfan Faraaz and Amaresh S.Patil,"Comparative Seismic Analysis of
11. S. Lakshmi Shireen Banu and Kothakonda Ramesh, "Seismic Response Study and Evaluation of Vibration Control of ElevatedRCC Structure using Friction Damper"- International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-7, May, 2019.
12. S.M. Dhawade , "Comparative Study for Seismic Performance of Base Isolated & Fixed Based RC Frame Structure"- International Journal of Civil Engineering Research, ISSN 2278-3652 Volume 5, Number 2 (2014), pp. 183-190
13. S.S. Sanghai, "Seismic Response of Unsymmetric Building with Optimally placed Friction dampers"- International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 2, February 2017, pp. 72–88 Article ID: IJCIET_08_02_008
14. Siddhant Kishore Laddha, " Effect of Friction Damper on Seismic performance of Multistoreyed Frame Structure in High Rise Building-A Review"- International Engineering Journal For Research & Development (IEJRD), E-ISSN NO:-2349-0721, Impact factor : 6.03,Vol-4, Issue-4,2018