# Effectiveness of Friction Damper and Outrigger System on 3d RC Frame for Seismic Loading

**Naveena K N, Vanishree P S**

***Abstract**: The effectiveness of the friction damper and outrigger system on a 3D RC frame for seismic loading is studied. Friction dampers have the unique property of absorbing and dissipating energy through a simple mechanism. The mechanism involved in response control involves transforming the seismic energy into heat energy through frictional forces, thus avoiding structural collapse. In the seismic active zone, the structural performance of the 3D RC frame is poor, which shows an increasing time period and excessive drifts when subjected to lateral forces. These issues can be minimized by providing lateral load-resisting elements, such as an outrigger system, at different heights of the building. Based on this G+12-storeyed 3D RC frame model, the different locations of the friction damper and outrigger system are considered in this study. Following which, the FE analysis involving the modal, equivalent static, and response spectrum analyses is performed, and results are obtained in terms of time period, base shear, storey displacement, storey drift, and acceleration, which are all tabulated and discussed.*

***Keywords**: Frictional forces, Seismic loading, Outrigger system, Structural collapse, Lateral forces.*

## I. INTRODUCTION

Tall structure has always fascinated visions and dreams, leading technical advancements to improve their ideas spread throughout the world. In the current era of rapid urbanization and technological advancements, tall structures have emerged as a suitable option for both office and residential buildings. Tall buildings are commonly intended to be used for residential, office, or commercial purposes. The response to the hasty development of the city populace along with the required needs by business tricks toward securing every extra at the same time as probable. Earthquakes are phenomena that occur frequently in the world. Earthquakes transpire due to the movement of tectonic plates, and the borders of these tectonic plates are the regions that experience more frequent and severe earthquakes. On the basis of these boundaries of the tectonic plates, the seismic zones are divided. Earthquakes cause a significant amount of damage to mortal beings as well as structures. The earthquake may be characterized as a wavelike motion propagating through the earth's crust. The strong ground vibrations caused by the earthquake are the reason for the damage to the structure. The effect of an earthquake on a structure is simulated to be that of a dynamic lateral force, and as the height of the structure increases, the effect of lateral forces such as wind and earthquake also increases. Thus, a highrise structure with an RC frame may not be sufficient to resist the lateral loads due to the earthquake. Various structural systems have been introduced in tall structures that make structures resistant to lateral loads such as wind and earthquake.

### A. Objectives of the Project

1. The effectiveness of the friction damper and outrigger systems on a 3D-RC frame with a lift core wall at its center is studied.
2. The performance of the friction damper and outrigger systems is varied to find out their effectiveness in the 3D-RC frame.
3. FE analyses involving modal, equivalent static, and response spectrum analyses are considered

## II. METHODOLOGY

1. The following methodology was adopted in this work:
2. A detailed literature review is carried out on the seismic response of 3D RC frames with friction damping and an outrigger system.
3. 3D RC frames with a lift core wall at the center, a G+12 storey with friction dampers, and an outrigger system are considered.
4. Friction dampers, middle, and corner details are considered.
5. Outrigger systems are considered top and middle, and top and middle responses are made.
6. The combination of the friction damper and outrigger system at corners and middles is considered.
7. FE analyses performed on the G+12 storey with different configurations in the location of friction dampers and outriggers system to obtain time period, base shear, storey displacement, and storey drift are obtained, tabulated, discussed, and conclusions drawn.

## III. MODELLING

The studies are carried out for G+12-story buildings under seismic zone V.

**Manuscript received on 17 July 2024 | Revised Manuscript received on 05 August 2024 | Manuscript Accepted on 15 August 2024 | Manuscript published on 30 August 2024.**

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The models considered in this work have been tabulated in Table 1. All the models have been analyzed using the Etabs software.

**Table 1: Nomenclature the Models**

| S. No | Model | Nomenclature |
|---|---|---|
| 1 | RC bare frame. | BF |
| 2 | RC bare frame with dampers at middle. | BDM |
| 3 | RC bare frame with dampers at corner. | BDC |
| 4 | RC bare frame with outriggers at top. | BOT |
| 5 | RC bare frame with outriggers at middle | BOM |
| 6 | RC bare frame with outriggers at top + dampers at middle. | BOTDM |
| 7 | RC bare frame with outriggers at top + dampers at corners. | BOTDC |
| 8 | RC bare frame with outriggers at top + middle | BOTM |
| 9 | RC bare frame with outriggers at middle + dampers at middle. | BOMDM |
| 10 | RC bare frame with outriggers at middle + dampers at corner. | BOMDC |
| 11 | RC bare frame with outriggers at top + middle, dampers at middle | BOTMDM |
| 12 | RC bare frame with outriggers at top+ middle, dampers at corners | BOTMDC |

Elevation of Bare Frame RC Structure G+12 Created in Software as shown Figure 1.

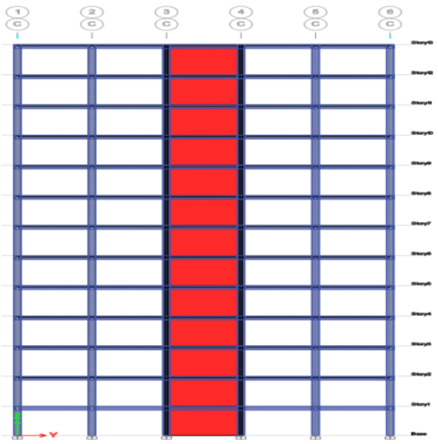

**Fig. 1: RC Bare Frame (BF)**

Elevation of Bare Frame RC Structure G+12 with Dampers at Middle Created in Software as Shown Figure 2.

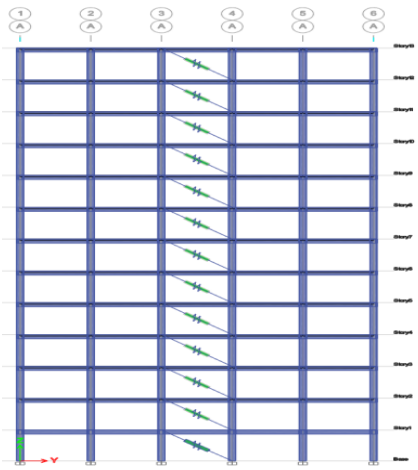

**Fig. 2: RC Bare Frame with Dampers at Middle (BDM)**

Elevation of Bare Frame RC Structure G+12 with Outrigger at Middle Created in Software as Shown Figure 3.

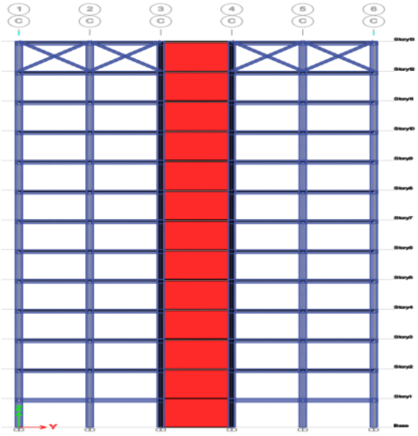

**Fig 3: RC Bare Frame with Outriggers at Middle (BOM)**

The Structural Configuration is FE Modal Creation Using Data are have been Tabulated in Table 2.

**Table 2: Structural Configuration**

| Type of Structure | Special Moment Resisting RC Frame |
|---|---|
| Grade of concrete | M 30 ($f_{ck}$=30 N/mm$^2$) |
| Grade of reinforcement | Fe 500 ($f_y$=500 N/mm$^2$) |
| Number of stories | G+12 |
| Each floor height | 3.1m |
| Column size | 500 x 500mm |
| Beam size | 400 x 400mm |
| Density of concrete | 25 kN/m$^3$ |
| Live Load on Floor | 3 kN/m$^2$ |
| Live load on Roof | 1.5 kN/m$^2$ |
| Floor finish | 1.5 kN/m$^2$ |
| Importance factor | 1.5 |
| Zone | V |
| Response reduction factor | 5 |
| Boundary condition | Fixed |

## IV. RESULTS AND DISCUSSIONS

### A. Time Period

Modal analyses Time Period are Plotted in Figure 4.

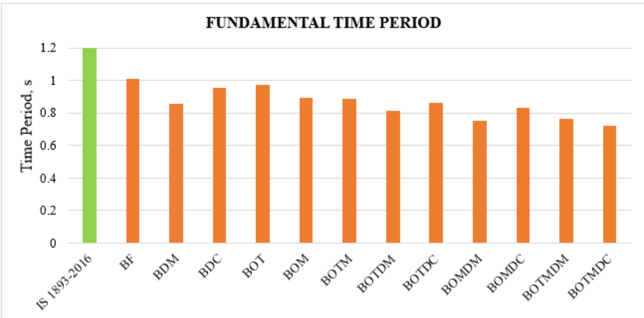


**Fig. 4: Time Period**

1. The time period calculated according to IS 1893-2016 (Part I) does not match the time period determined by modal analysis for all models displaying the inefficiency of the code.
2. The time period of BDM and BDC decreases by 17.22% and 5.66%, respectively, with respect to the bare frame.
3. The time period of BOT, BOM, and BOTM decreases by 3.6%, 12.63%, and 13.52%,

*Retrieval Number: 100.1/ijese.F452313060824*
*DOI: 10.35940/ijese.F4523.12090824*
*Journal Website: www.ijese.org*



*Published By:*
*Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)*

respectively, with respect to the bare frame.

4. The time period of BOTDM, BOTDC, BOMDM, BOMDC, BOTMDM, and BOTMDC decreases by 23.52%, 16.68%, 34.44%, 21.17%, 32.15%, and 40%, respectively, with respect to the bare frame.
5. Outrigger Top & Middle and Dampers at Corner (BOTMDC) is the best combination due to the shorter time period compared to all other models. Due to an increase in stiffness.

### B. Base Shear

The Base Shear Obtained from Response Spectrum Analysis are Plotted in Figure 5.

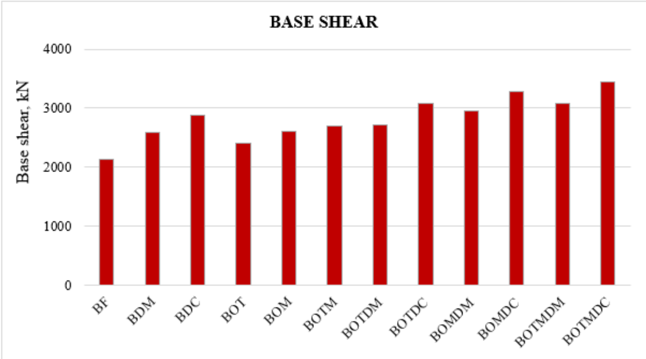


**Fig. 5: Dynamic Base Shear**

1. Base Shear is directly proportional to mass of the frame as mass increases base shear also increases hence Bare frame as least base shear.
2. Outrigger Top & Middle and Dampers at corner (BOTMDC) is having the 60.90% more Base Shear compare to all other model this shows the influence of outriggers and damper.

### C. Storey Displacement

Maximum Storey Displacement is Plotted in Figure 6

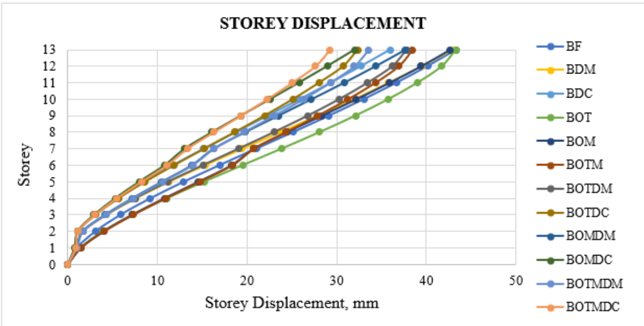


**Fig. 6: Maximum Storey Displacement**

1. The Displacement of BOT is more compared to other models due to presence of outriggers at top adds mass at top storey.
2. Displacement of BOTDM, BOTDC, BOMDC, BOTMDM, and BOTMDC decreases by 14.55%, 34.05%, 14.85%, 35.58%, 28.86%, and 48.28%, respectively, with respect to the bare frame.
3. The displacement obtained by BOTMDC is almost 48.28% less than in a bare frame due to the stiffness provided by outriggers and dampers.

### D. Storey Drift

Maximum Storey Drift is Plotted in Figure 7

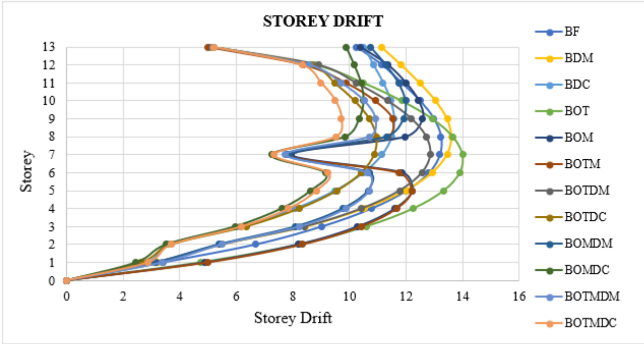


**Fig. 7: Maximum Storey Drift**

1. The storey drift of BDC and BDM decreases by 2.94% and 14.34%, respectively, with respect to the bare frame.
2. In the case of BOM, BOTM, BOMDM, BOMDC, BOTMDM, and BOTMDC, there is a sudden decrease in the storey drift at storey 7. This is due to outriggers in the middle.
3. The storey drift for all models is within the safe permissible limit, i.e., 0.004H, as per IS 1893-2016.

## V. CONCLUSION

The Following are the Conclusions:

1. The time period calculated according to IS 1893-2016 (Part I) does not match the time period determined by modal analysis for all models displaying the inefficiency of the code.
2. Comparing the RC Bare Frame with Dampers, model BDC has the least time period, and model BDM has the highest time period.
3. Comparing the RC Bare Frame with Outriggers models, BOTM has the least time period, and BOT has the highest time period.
4. Comparing the RC Bare Frame with a combination of outriggers and dampers, BOTMDC has the least time period, and BOTDM has the highest time period.
5. Excluding the bare frame condition BOT has the highest time period, and BOTMDC has the least time period.
6. Comparing the RC Bare Frame with Dampers, model BDC has the highest base shear, and model BDM has the least base shear.
7. Comparing the RC Bare Frame with Outriggers models, BOTM has the highest base shear and BOT has the least base shear.
8. Comparing the RC Bare Frame with a combination of outriggers and dampers, BOTMDC has the highest base shear and BOTDM has the least base shear.
9. Excluding the bare frame condition BOT has the least base shear, and BOTMDC has the highest base shear.
10. Comparing the RC Bare Frame with Dampers, model BDC has the least displacement, and model BDM has the highest displacement.
11. Comparing the RC Bare Frame with Outriggers models, BOTM has the least displacement and BOT has the highest displacement.

*Retrieval Number: 100.1/ijese.F452313060824*
*DOI: [10.35940/ijese.F4523.12090824](https://doi.org/10.35940/ijese.F4523.12090824)*
*Journal Website: [www.ijese.org](http://www.ijese.org)*



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12. Comparing the RC Bare Frame with a combination of outriggers and dampers, BOTMDC has the least displacement and BOMDM has the highest displacement.
13. Excluding the bare frame condition, BDM has the highest displacement, and BOTMDC has the least displacement.
14. Comparing the RC Bare Frame with Dampers, model BDC has the least drift, and model BDM has the highest drift.
15. Comparing the RC Bare Frame with Outriggers models, BOTM has the least drift and BOT has the highest drift.
16. Comparing the RC Bare Frame with a combination of outriggers and dampers, BOTMDC has the least drift and BOTDM has the highest drift.
17. Excluding the bare frame condition BOT is having the highest drift, and BOTMDM is having the least drift.

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## DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Financial Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted with objectivity and without any external influence.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is attributed equally to all participating authors.

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