Grenze International Journal of Engineering and Technology, June Issue

Seismic Behaviour of Hybrid Braced RC High Rise System with Buckling Restrained Brace and Viscous Damper

PriyankaGahane[1], Amey Khedikar[2] and Nayana Sangole[3]
[1-3]Tulsiramji Gaikwad Patil College of Engineering & Technology/ Civil Engineering, Nagpur, India
Email: priyankagahane123@gmail.com, amey.khedikar@gmail.com, nayana.civil@tgpcet.com

***Abstract*— To examines the study of seismic behavior of a novel hybrid bracing system integrating (BRBs) and (VDs) in reinforced concrete (RC) multistorey structures. For the hybrid structure purposes to improve the structural resilience by combining the energy dissipation capabilities of BRBs with the vibration control efficiency of VDs. Nonlinear dynamic analysis using STAAD.Pro software system is achieved on a 16-story RC high-rise model to assess seismic performance under realistic earthquake loading. Results indicate significant reductions in inter-story drift, residual displacement, and highest level acceleration compared to conventional RC frames and frames with only BRBs. The findings demonstrate the potential of the hybrid system for improved seismic safety and structural stability in high seismic zones.The findings demonstrate the potential of the hybrid system for improved seismic safety and structural stability in high seismic zones.**

***Index Terms*— Seismic behaviour, Hybrid bracing system, Buckling Restrained Braces, Viscous Dampers, Reinforced Concrete, High-rise buildings.**

I. INTRODUCTION

The earthquake resistance of tall RC structures is still a matter of concern owing to the displacement of the structure generated by lateral forces of the earthquake. Conventional brace systems commonly show some limitations for buckling of the brace under compression, and the energy dissipated by the brace is thereby reduced. Buckling Restrained Braces (BRBs) are proven as an actual element of the seismic resistant system, that guarantees the hysteretic stability by avoiding the buckling and extending the braces to straight in both tension and compression. Moreover, viscous dampers can be used as a supplementary energy dissipation system to convert the kinetic energy into heat thus, reducing the structural response of the structure to seismic excitation. This study estimates the seismic behavior of a hybrid system for use in high-rise reinforced concrete (RC) buildings that combines the positive features of buckling restrained braces (BRBs) and viscous dampers (VDs). The hybrid system is designed to utilize BRBs to absorb energy and provide structural stiffness to limit total story drift while concurrently using VDs to minimize peak floor acceleration and limit the amount of interstory drift resulting from earthquake ground motion.[1]
The combined effects of utilizing BRBs and VDs in conjunction should produce superior seismic performance when compared to either BRB or VD system alone.

Grenze ID: 01.GIJET.12.2.377_22

However, recent research has suggested that hybrid systems incorporating both BRBs and VDs may be able to improve seismic performance even further than each device individually.[2]

Nonlinear time history analysis and pushover analysis of the seismic response of a high-rise RC moment-resisting frame building system equipped with a hybrid bracing system consisting of BRBs and VDs. An overview of the seismic hazards associated with tall, multiple-story RC structures. A detailed presentation of all of the various loading conditions as well as all possible combinations of these loads according to the International System (IS) standards, which include descriptions of the entire structure; that includes both braced. This chapter [3] illustrates the geometry of the structure through the use of a plan view, elevation view, position of the bracing structures within the construction, and a three-dimensional (3-D) view of the RC frame with bracing systems.

B. Aim and Objective

To calculate the seismic performance of a reinforced concrete (RC) high-rise structure equipped with a hybrid bracing system using Buckling Restrained Braces and Viscous Dampers, through nonlinear dynamic analysis, in order to enhance structural resilience and minimize earthquake- induced damage

To determine the building model's response spectrum analysis using a steel bracing system called Concentric Braced Frame (CBF).

To determine the suitable bracing method for the seismic zone in a reinforced concrete framed structure.

To analyze under different types of bracing system using STAAD.PRO a design solution for enhanced earthquake resistance is proposed.

To evaluate the enhance the structural performance, stability, and safety under seismic loading condition by optimizing bracing configurations and assessing dynamic response characteristics.

To examine the limitations i.e., the various models' extreme bending moment, peak storey shear, and base shear, and compare the outcomes.

To perform nonlinear time history and pushover analysis Utilize software to simulate and analyze the structure under various earthquake ground motions.

II. Related Work

Previous studies have shown that BRBs improve seismic performance by reducing inter-story drift and residual deformation, while VDs effectively dissipate energy and control vibrations. Hybrid systems combining BRBs and VDs have demonstrated superior seismic behavior, including stable hysteresis, reduced residual drifts, and better re-centering capabilities [4].

Optimizing the yielding length of BRB cores and the placement of dampers enhances the overall structural response under seismic loads. Performance-based seismic design frameworks have been proposed to integrate these hybrid technologies effectively [7].

Enhancing the seismic solidity of buckling-restrained steel blocked edges in subduction boundary seismic areas with viscoelastic dampers to Inclusion of BRBs improves structural reliability, reduces probability of drift exceedance, better performance under strong ground motions. Helps in cost vs performance optimization.[4]

Damping optimization critical to achieve target performance Encourages performance-based design using hybrid control. This paper[5] discusses BRBs can be accurately modeled using nonlinear elements.To find in this research paper Placement of BRBs in lower stories is most effective for drift control. Steel braced frames (BRBFs) used in subduction boundary regions; they added viscoelastic dampers (VE) into BRBFs (called VE BRBF).

Analytical (numerical) models[4]. High-Rise Frame Systems of Hybrid Braced Reinforced Concrete (RC) Frames With Buckling Restrained Braces(BRBs) and Viscous Dampers for Enhanced Seismic Resilience: This work focuses on the study, analysis, design and testing of damage-resilient RC systems that incorporate both buckling-restrained braces (BRBs) and viscous dampers (VDs).[10] Such hybrid braced system displays superior seismic resilience compared to conventional RC frame s due to the synergistic energy dissipation at low inter-story drift levels while keeping these levels below 1-2% under severe ground motions; as-supported ductility potential increased with little strength degradation.[6]

Postulating Seismic Strength with BRBs for RC Frames BRBs are very important for improving lateral force resisting systems of RC high-rise buildings with special reference to those designed without taking into account the effect of horizontal forces or with non-energy dissipation detailing. The devices are made of a strengthen central part enclosed with a warning mechanism, such the same as a steel tube filled with grout or mortar.[8][9]

III. MATERIALS AND METHODS

A. Methodology

The seismic performance study investigates of a hybrid bracing system in a reinforced concrete (RC) high-rise structure, integrating Buckling-Restrained Braces and Viscous Dampers. This methodology includes modeling, analysis, and comparison of structural configurations under seismic loading using nonlinear time-history analysis.

DAMPER- One of the best methods for dissipating energy is the damper, which is now commonly used in lateral load-resisting systems. Despite being more costly than other structural systems, this new technique dissipates energy and significantly reduces base shear when compared to bracing, core shear walls, and other structural systems.

FLUID VISCOUS DAMPER- A novel method for stabilizing buildings against lateral forces is the fluid viscous damper. This technique has been widely use like a lateral load-resisting system in modern days, especially for building retrofitting. Three primary components make up a fluid viscous damper: a viscous fluid, a piston, and a cylinder.

Piston rods generate reciprocating movement in the tube to strength the damping standard to shift reverse and forward the lateral power when a fluid viscous damper is subjected to any lateral force. This system is simple to install and be able to be set up in sloping, V-, or inverted V shapes.

Fluid viscous damper is existing by means of special load carrying capability; for example 250KN, 500KN, 1000KN, 1500KN, 3000KN and 8000KN.

Structural System Description

A baseline RC high-rise building (16 stories) is designed according to IS 1893 / ACI 318.

Multiple configurations are considered:

Model 1: RC frame (no supplemental damping)

Model 2: RC Frame + (BRBs)

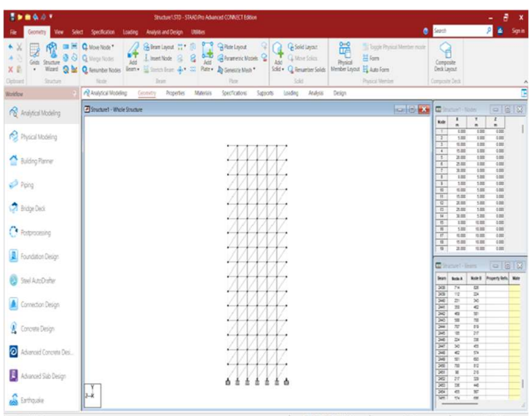

Figure1. RC Frame Diagonal Bracing in STAAD Pro

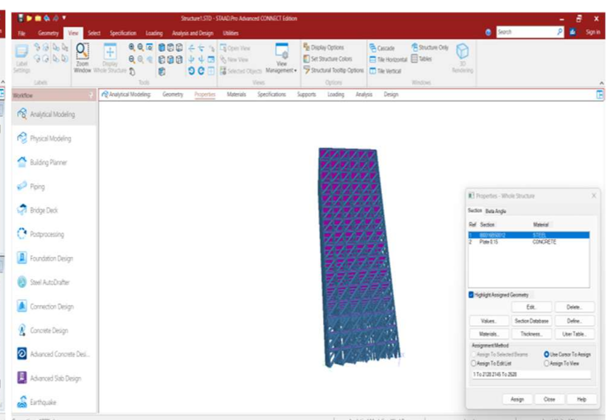

Figure 2. RC Frame Rendering view Diagonal Bracing

Modeling and Simulation

Model Development in STAAD Pro

Building Geometry & Layout

Selected a high-rise RC building model (G+16, floors).

Use a symmetrical layout to avoid torsional effects.

Floor height: 3.0 m; Bay width: 5 m

Material Properties

Concrete Grade: M30 or M35.

Steel: Fe500 for reinforcement. BRB and VD properties as per manufacturer data

Structural Elements

Beams and columns are represented as frame components. Plate elements can be used to model slabs or rigid diaphragm assumption. BRBs as truss elements (with special non-linear spring behavior or equivalent stiffness). VDs modeled using dashpot elements or equivalent damping devices in STAAD Pro.

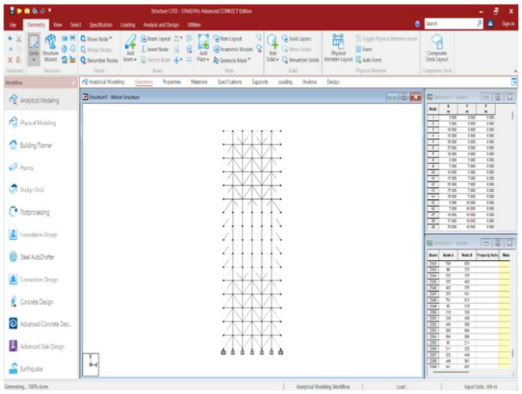
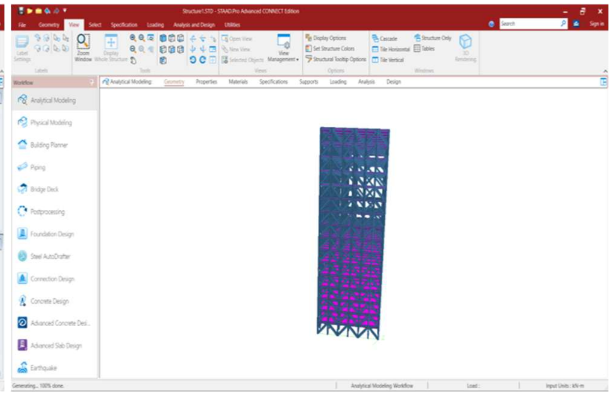

Figure 3. RC Frame Inverted V Type Bracing in STAAD Pro   Figure 4. RC Frame Rendering view Inverted V Type Bracing in STAAD Pro

Loading Conditions
Dead Load (DL) Self-weight of structure, slab, finishes.
Live Load (LL) As per IS 875 Part 2
Seismic Load As per IS 1893 (Part 1): 2016
Response Spectrum Analysis
Use standard response spectrum (IS 1893) or custom spectra for the selected seismic zone.
Parameters:
Seismic Zone (Zone IV) Importance Factor: 1.0
Response Reduction Factor: Varies by system (bare frame: 3; with BRBs: 5; hybrid: up to 6)

TABLE I: PARAMETERS

Sr.no	Column size in mm	Beam size in mm	Total height in m	Story height in m	Slab thickness in mm	Grade of concrete	Grade of steel
1	700x500	500x400	50	3.5	150	M35	Fe500

IV. RESULTS AND DISCUSSION

The hybrid system with BRBs and viscous dampers exhibits superior seismic performance. Inter-story drift ratios are reduced by up to 40% compared to the conventional braced frame, indicating enhanced lateral stiffness and deformation control. Base shear request appears a direct diminish, reflecting improved load distribution and energy absorption. Hysteresis curves make known stable and full-range yielding of BRBs, whereas viscous dampers contribute to further damping, smoothing the answer peaks. The synergistic outcome of BRBs and viscous dampers consequences in better control of remaining deformations and enhanced post-earthquake structural reliability. The conclusion propose that the hybrid system be able to efficiently moderate harm and expand the check life of RC high-rise buildings in seismic regions.
Time Period:

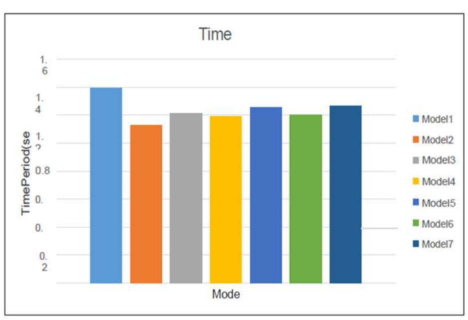

Figure 5. Time Period

For the time period perception, a RCC surrounded organization with bracing structure in seismic zone is examined. In Chart indicates the value of time period of different models described of bracing system. The chart appears that, in connection to the uncovered outline, the time period reduces in the case of various bracing systems.

Base Shear:

The information in the chart illustrate the sum of the braced system increment in the building's base shear. The Base shear greatness is nearly consistent over different bracing plans is indicating in the investigation of chart. Agreeing to the base shear connection, the adequacy of the base shear is expansive in comparison to other bracing and uncovered outline in the case of X bracing.

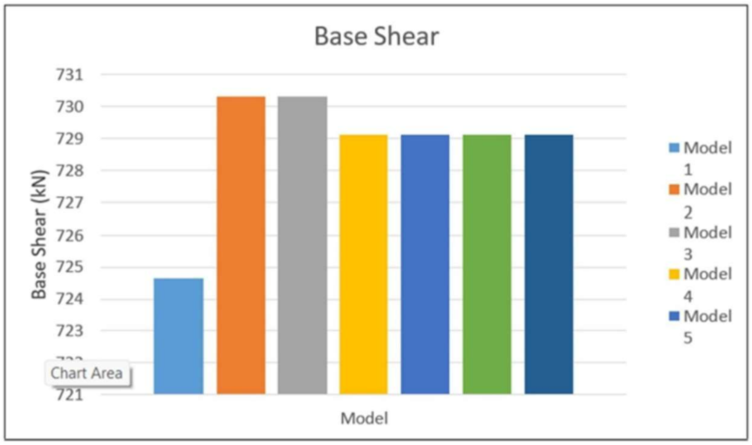

Figure 6. Base Shear

IV. CONCLUSION

The BRBs and VDs in braced RC high-rise building having integrated significantly examined in seismic zone. Also the model parameters like time period, base shear, and storey movement was examined. Hybrid system offer different improved result for better as several bracing was studied and discover approach efficiently for seismic design for contribute the environment among the models. Moderately talking, some was discovered that model-2, or the model with X-Bracing accessible on the external of the structure.

REFERENCES

[1] Y. Ahmad and A. P. J. Abdul, "SEISMIC ANALYSIS OF MULTI STOREY RC BUILDING WITH BRACING USING STAAD. PRO V8i," vol. 243001, no. June 2023, 2023.

[2] D. R. Johnson, "Seismic Design Innovations in High-Rise Building Construction," Am. J. Civil, Constr. Environ. Eng., vol. 4, no. 03, pp. 1–5, 2023, [Online]. Available: https://australiansciencejournals.com/ajccee/article/view/1926

[3] K. Ravi and M. S. Thakur, "AC," vol. 03001, pp. 1–15, 2024.

[4] B. Hariri, M. Montgomery, C. Zhong, and C. Christopoulos, "Enhancing the seismic stability of buckling-restrained steel braced frames in subduction interface seismic regions using viscoelastic dampers," Earthq. Spectra, vol. 41, no. 2, pp. 1364–1388, 2025, doi: 10.1177/87552930241298916.

[5] D. Catalan, Ariel & Rizzo, Fabio & Cahís, Xavier & Sabbà, Maria & Foti, "Modelling and Application of Bucking Restrained Braces for Performance-Based Earthquake Engineering Frameworks.," J. Vib. Eng. Technol. 13. 10.1007/s42417-024-01698-1..

[6] F. Erdil, E.F., Ozcelik, R. & Erdal, "External strengthening of RC structures with buckling-restrained braced frames," Bull Earthq. Eng 22, vol. 1931–1963.

[7] M. Meshaly and H. Abou-Elfath, "Seismic response of RC frames equipped with buckling-restrained braces having different yielding lengths," AIMS Mater. Sci., vol. 9, no. 3, pp. 359–381, 2022, doi: 10.3934/matersci.2022022.

[8] M. (2022). Ramdas, Laxmi & Santhi, M.Helen & Ganesan, "A study on high-rise RC structure with fluid viscous damper using python.," Res. Eng. Struct. Mater. 10.17515/resm2022.362ea1101..

[9] V. Baca et al., "Enhanced seismic structural reliability on reinforced concrete buildings by using buckling restrained braces," Shock Vib., vol. 2021, 2021, doi: 10.1155/2021/8816552.

[10] S. K. P. Sima S. Ijmulwar, "Seismic design of reinforced concrete buildings equipped with viscous dampers using simplified performance-based approach, Structures".