

Comparative Analysis of Shear Wall, Column and Grid System in Composite Buildings Under Seismic Loading

Anil Mali Patil¹, Dr Shruti G²

PG Scholar, Department of Civil Engineering, PDA College of Engineering, Kalaburagi, India¹

Assistant Professor, Department of Civil Engineering, PDA College of Engineering, Kalaburagi, India²

Abstract: The rapid growth of urban population, the lack of spaces in the cities and the high cost of land have already forced the developers to focus on the high-rise buildings. As the height of the building increases, the lateral load resistant system becomes more important than gravity load resistant system. That's why it is important to define lateral load resistant system in high rise buildings. So, the lateral load resistant systems such as shear wall and diagrid are introduced since they are better in terms of cost, aesthetic and performance. However, the diagrid structural system has become more popular these days due to its efficiency and aesthetic look provided by the unique geometric configurations of the system. In this study, a comparative analysis has been done on the buildings with different lateral load resisting systems. Five different building model of G+9 story building has been modeled with shear wall and diagrid structure to compare their performance. The design is analysed for seismic zone V and medium soil condition as per IS 1893:2016 using ETABS software. The building is kept the same except for the lateral load resisting system. From the patterns of the results, it was concluded that building models with the combination of shear wall and diagrid module has better performance in term of the maximum story displacement, story stiffness, story drift, base shear, and time period.

Keywords: Shear Wall, ETABS, Seismic Analysis, Composite Buildings.

I. INTRODUCTION

In skyscrapers and high-rise buildings, lateral load-resisting systems are essential to control lateral displacements caused by wind and seismic forces, which in turn produce significant shear and bending in structural elements. These systems can be broadly classified into two categories:

1. **Internal systems:** These include solid frames, shear wall structures, and interior structural cores.
2. **External systems:** These consist of space trusses, exoskeleton structures, diagrids, and super-frames.

1.1 Shear Wall

A shear wall is a vertical reinforced concrete (RCC) element designed to resist both lateral and vertical (gravity) loads. Shear walls transfer lateral forces efficiently to the foundation, enhancing the seismic performance of the building. Studies on the comparative behavior of buildings with shear walls, as well as observations from past earthquake-affected regions, have demonstrated their effectiveness in improving structural stability. Properly designed shear walls not only provide earthquake resistance but also carry significant gravity loads, making them an economical and reliable solution for multi-storey RCC buildings.

1.2 Bracings

Bracings are one of the most cost-effective and efficient lateral load-resisting systems for high-rise buildings. A bracing system consists of vertical columns and diagonal members that form truss-like arrangements to resist horizontal forces. By providing lateral support, bracings reduce the size of primary structural elements while enhancing overall stiffness and stability. Bracings improve the natural frequency of the building, reduce lateral vibrations, and generally limit lateral displacements. Compared to shear walls, bracing systems are lighter and particularly suitable for tall structures where minimizing structural weight is critical.

1.3 Diagrid

Diagrid systems consist of load-bearing members arranged in a diagonal grid, forming interconnected triangular units along the exterior of the building. By eliminating conventional vertical columns, diagrid structures efficiently transfer both gravity and lateral loads through the perimeter framework. Diagrids provide excellent structural efficiency while offering architectural flexibility, often resulting in aesthetically appealing façades. These systems are highly economical for high-rise buildings, as they reduce the overall quantity of structural steel compared to conventional truss systems while maintaining superior lateral load resistance.

II. OBJECTIVES

The rapid growth of urban infrastructure has led to an increased demand for medium- and high-rise buildings, where structural safety and serviceability under lateral loads become critical considerations. Conventional frame systems, though widely adopted, often exhibit limitations in resisting earthquake and wind forces as building heights increase. To address these challenges, alternative lateral load-resisting systems such as shear walls and diagrids have been introduced, offering improved stiffness, stability, and energy dissipation. In this context, the present study is undertaken with the following objectives:

1. To analyse how buildings with diagrid and shear walls perform compared to traditional frame structures, focusing on parameters like maximum storey displacement, storey drift, base shear, storey stiffness and time period.
2. To compare the effect of mass irregularity and lateral load resistant system on the seismic behaviour of the buildings.

III. LITERATURE REVIEW

Chandurkar and Pajgade (2013) performed a dynamic analysis on a G+9 building with four different models using ETABS to study the effect of shear walls. The models incorporated shear walls at varying locations to compare displacement, storey drift, percentage of steel reinforcement in columns, concrete quantity, steel consumption, and overall construction cost. Their findings revealed that the placement of shear walls significantly affects structural performance, with optimal placement leading to reduced displacements and minimum drift under earthquake loading.

Kumar (2018) carried out a dynamic analysis of a five-storey building in seismic zone V using ETABS, in compliance with IS codes. Multiple models were generated by altering the position of shear walls to examine displacement, shear forces, and accelerations in both X and Y directions. The results demonstrated that shear walls greatly enhance the seismic performance of buildings, making them more resistant during earthquake conditions.

Singh, Garg, and Sharma (2014) compared the structural behavior of a reinforced concrete diagrid building against a conventional frame building. The study considered a five-storey RCC structure with a 15 m × 15 m plan located in seismic zone V. Their analysis showed that diagrid structures, due to the presence of diagonal columns along the periphery, exhibited superior resistance to lateral loads. The diagrid building had lower lateral displacement and drift compared to the conventional frame and achieved approximately 33% savings in steel without compromising structural efficiency.

Shankar and Priyanka (2018) analyzed diagrid and conventional structures of identical plan size and storey height to investigate the influence of diagrid angle and member length. The analysis, conducted using the Equivalent Static Method, highlighted that diagrid structures exhibited reduced lateral displacement compared to conventional frames. While the diagrid system experienced higher base shear and storey shear, it proved advantageous in high-rise structures as inter-storey drift decreased with increasing height. Overall, diagrid systems were found to be more effective for controlling drift than conventional frames.

Nehdi et al. (2015) described the evolution of diagrid systems, which are characterized by their diagonal grid pattern forming triangular modules. These systems distribute both gravity and lateral loads efficiently, reducing the dependence on internal columns and enabling greater architectural flexibility.

Aslani et al. (2016) emphasized the superior rigidity and strength of diagrid structures, attributed to the triangular configuration of their members. These triangular units work collectively to transfer lateral loads such as wind and seismic forces diagonally to the foundation. This mechanism results in uniform stress distribution, reduced bending moments, and more efficient material usage, thereby enhancing both strength and economy.

Yang et al. (2021) The shear wall system depends on vertical structural walls to resist lateral forces, thereby enhancing a building's seismic performance. Strategically positioned within the structure, these walls provide additional stiffness and strength and are typically constructed from reinforced concrete or masonry. Shear walls are vital for maintaining structural integrity, particularly in regions with high seismic risk, as they effectively control lateral movements during earthquakes. Moreover, they can be integrated with moment-resisting frames or diagrid systems to form hybrid structural configurations, combining the advantages of multiple lateral load-resisting mechanisms.

IV. METHODOLOGY

A model of a 10-storied RCC building with each story of 3m and the uniform plan will be modeled using the software ETABS. Engineer uses ETABS software for the design and analysis of the buildings.

TABLE 1: CATEGORIZATION OF THE MODEL USED IN THE STUDY

Model Notation	Category of model
M-1	Conventional frame structure
M-2	Conventional structure with shear wall at core
M-3	Conventional structure with mass irregularity
M-4	Diagrid structure
M-5	Structure with combination of shear wall at core and diagrid at exterior

TABLE 2: GEOMETRIC DETAILS OF THE BUILDING MODELS

S.N.	Description	Specification
1	Building type	RCC & Diagrid structure
2	Number of storeys	10
3	Length of building	24 m
4	Width of building	24 m
5	Height of building	30 m
6	Height of each storey	3 m
7	Column size	450 mm × 450 mm
8	Beam size	300 mm × 300

TABLE 3: DETAILS OF THE LOADING APPLIED ON MODELS

Item Description	Criteria / Value
Seismic zone considered	Zone V
Zone factor (Z)	0.36
Response reduction factor (R)	5
Basic wind speed	44 m/s
Terrain category	3
Class of structure	Class C
Probability factor (k_1)	1
Topography factor (k_3)	1

TABLE 4: SEISMIC AND WIND LOAD PARAMETERS

Description	Criteria (kN/m ²)
Dead load on terrace level	5.0
Dead load on floor level	4.0
Live load on terrace level	1.5
Live load on floor level	4.0

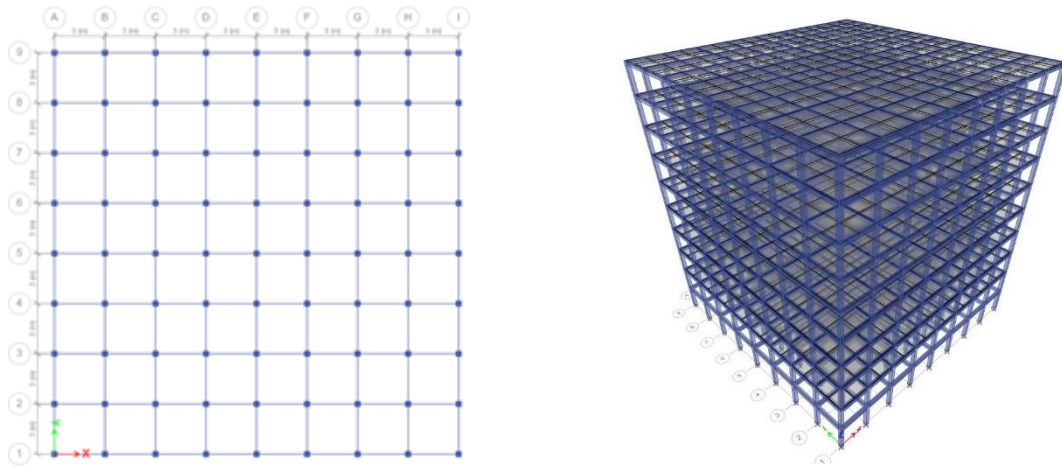


Figure 1: Plan layout and 3D View of the conventional frame structure

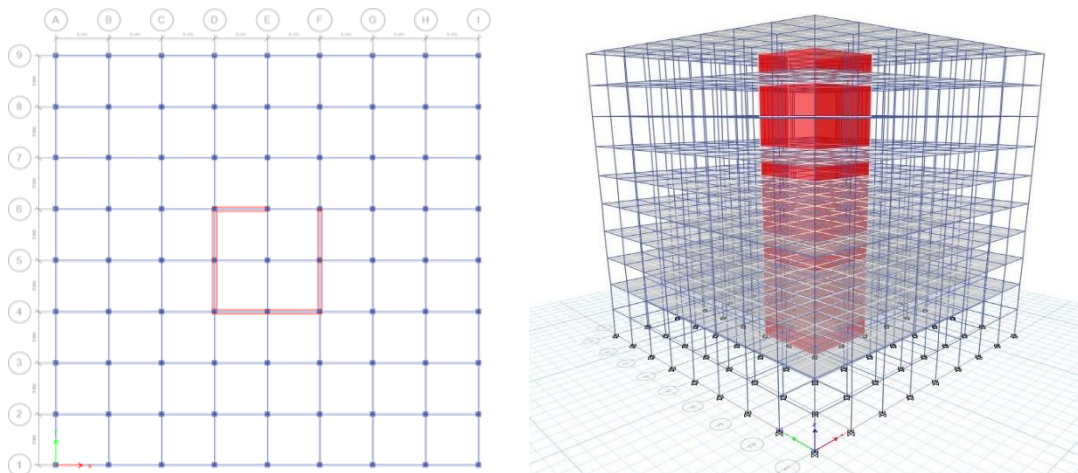


Figure 2: Plan layout and 3D View of the Conventional Structure with shear wall at core

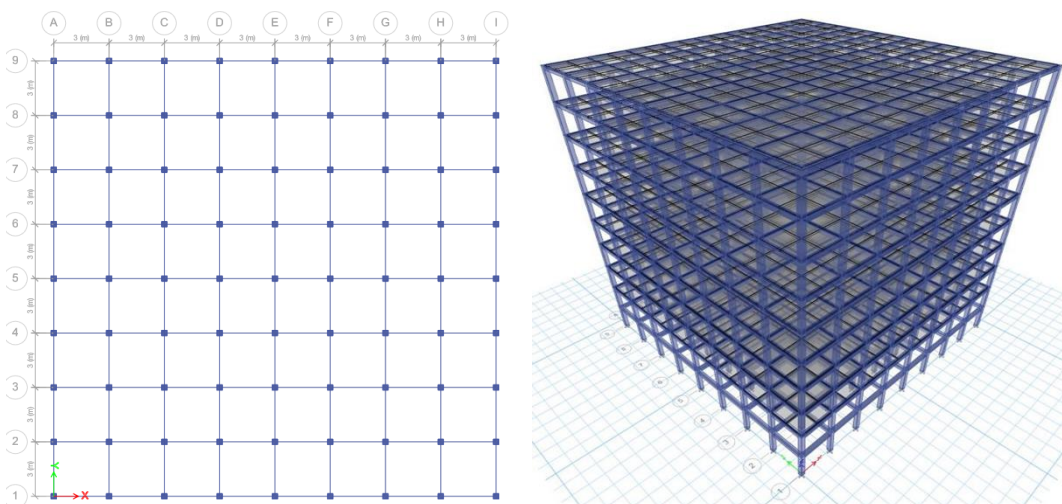


Figure 3: Plan layout and 3D View of the Conventional Frame Structure with mass irregularity

V. RESULTS AND DISCUSSION

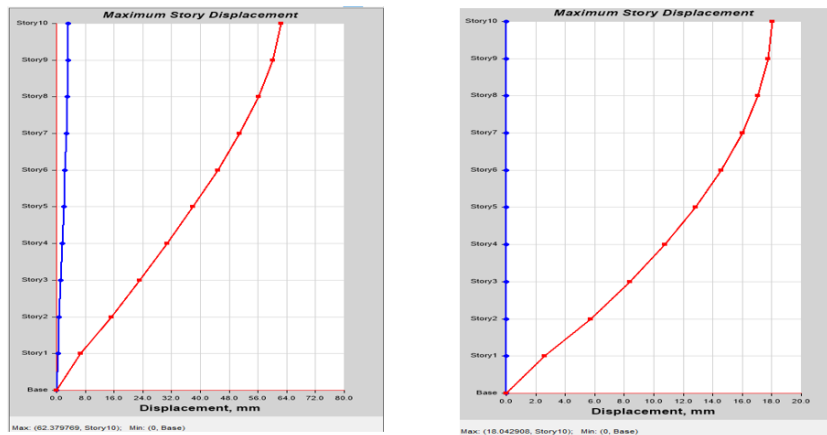


Figure 4: Model M-1: Max story displacement (mm) in EQY and UY

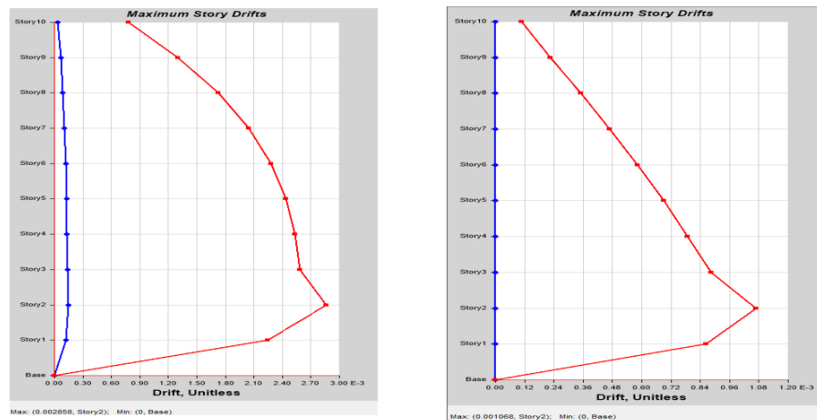


Figure 5: Model M-1: Max story drift in EQY and UY

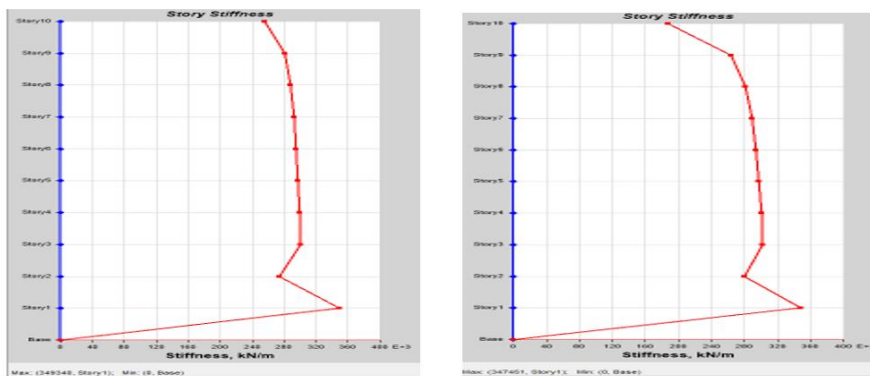


Figure 6: Model M-1: Story Stiffness in EQY and UY

TABLE 5: MODELS VS TIME PERIOD

Models	Period(sec)
M-1	2.478
M-2	1.735
M-3	2.538
M-4	1.645
M-5	0.489

From the Table-5, it was noted that the time period is minimum for the Model-5.

The structural analysis of the five building models (M-1 to M-5) under earthquake (EQY) and wind (UY) loading conditions revealed significant differences in lateral performance. Maximum story displacement results indicate that the conventional frame structure (M-1) experienced the highest displacements under both EQY and UY, while the hybrid configuration of shear walls at the core combined with a diagrid exterior (M-5) exhibited the lowest displacements. Models incorporating diagrids (M-4) or shear walls (M-2) showed intermediate performance, highlighting the effectiveness of these systems in controlling lateral movement. Mass irregularity in Model M-3 led to irregular displacement patterns, emphasizing the influence of vertical mass distribution on structural response.

Story drift comparisons further corroborated the displacement trends, with M-5 demonstrating minimal inter-storey drift, staying well within the permissible limits specified by IS 1893. The presence of shear walls and diagrid bracing effectively reduced relative floor movements, enhancing stability. Models M-1 and M-3 showed higher drift values due to the absence of distributed lateral stiffness or irregular mass distribution, respectively, making them less favorable under seismic and wind loads. The base shear analysis also confirmed that M-5 could resist higher lateral forces compared to all other configurations, demonstrating superior load transfer to the foundation.

Story stiffness and fundamental time period evaluations indicated that hybrid and diagrid systems substantially improve overall lateral rigidity. Model M-5 exhibited the highest story stiffness and the shortest natural time period (0.489 s), reflecting enhanced structural stability and reduced susceptibility to dynamic excitations. In contrast, M-1 and M-3 had lower stiffness and longer time periods, indicating greater flexibility and potential vulnerability under lateral loads. Overall, the results consistently highlight that the combination of a central shear wall and peripheral diagrid system offers the most efficient, economical, and resilient solution for medium- to high-rise buildings subjected to seismic and wind forces.

TABLE 6: SUMMARY OF STRUCTURAL PERFORMANCE FOR MODELS M1 TO M5

Model	Max Story Displacement (mm)	Max Story Drift	Base Shear (kN)	Story Stiffness (kN/mm)	Fundamental Time Period (s)
M-1 (Conventional Frame)	Highest	Highest	Lowest	Lowest	2.478
M-2 (Shear Wall at Core)	Moderate	Moderate	Moderate	Moderate	1.735
M-3 (Mass Irregularity)	Irregular / High	High	Low	Low	2.538
M-4 (Diagrid Structure)	Low	Low	High	High	1.645
M-5 (Shear Wall + Diagrid)	Lowest	Lowest	Highest	Highest	0.489

- Displacement and drift values are relative; “Highest” indicates the worst performance, “Lowest” indicates the best.
- Base shear reflects the lateral load capacity at the foundation; higher values indicate better resistance.

- Story stiffness is a measure of lateral rigidity; higher values indicate stiffer and more stable structures.
- Fundamental time period indicates the dynamic response; lower periods correspond to stiffer, less flexible structures.

VI. COMPARISON

A comparative evaluation of five building models (M-1 to M-5) was carried out using linear static analysis under both earthquake (EQY) and wind (UY) load conditions, in accordance with IS 1893:2016 and IS 875 (Part 3):2015. The structural performance of the models was examined through critical response parameters, namely maximum storey displacement, storey drift, base shear, and natural time period.

Performance Assessment

Model-1 (Conventional Frame):

This model exhibited the highest storey displacement and drift values, reflecting inadequate lateral stiffness. The absence of a dedicated lateral load-resisting system makes it unsuitable for use in high-rise buildings located in seismic or high-wind zones.

Model-2 (Shear Wall at Core):

The inclusion of a central shear wall enhanced stiffness and substantially reduced lateral displacements under both EQY and UY loading conditions. However, as stiffness was concentrated only at the core, the peripheral regions remained comparatively vulnerable to lateral effects.

Model-3 (Mass Irregularity):

Due to its uneven mass distribution, this model experienced irregular displacement profiles and increased inter-storey drift. Such irregularity heightened vulnerability to seismic forces by inducing torsional effects and reducing overall stability.

Model-4 (Diagrid Structure):

The diagrid system demonstrated good control over lateral displacements and effectively reduced the natural time period. By distributing lateral forces through the periphery, it improved stability; however, the absence of central shear wall stiffness limited its effectiveness in comparison to hybrid systems.

Model-5 (Shear Wall at Core + Diagrid at Periphery):

This hybrid system outperformed all other configurations, achieving the lowest storey displacement and drift along with an optimal time period. The combination of central shear walls and peripheral diagrids ensured balanced stiffness, efficient load distribution, and superior lateral resistance under both wind and seismic actions.

The comparative study establishes that Model-5 provides the most effective and reliable solution among the evaluated configurations. Its hybrid approach—integrating the concentrated stiffness of shear walls at the core with the distributed stiffness of diagrid systems at the periphery—offers significant advantages in terms of displacement control, drift reduction, and structural stability. Consequently, this system is the most suitable for the design of medium- to high-rise buildings in earthquake-prone and high-wind regions.

VII. CONCLUSION

7.1 Conclusion

In this study, several structural models were developed to resist lateral loads in medium-rise buildings. A building plan of 24 m × 24 m with a total height of 30 m was modeled and analyzed using ETABS. Results indicate that lateral load-resisting systems are more efficient in carrying gravity loads compared to conventional frame systems, especially as building height increases. Among all models, Model-5 (featuring a shear wall at the core and a diagrid system along the exterior) demonstrated the best overall performance in terms of maximum story displacement, maximum story drift, base shear, story stiffness, and fundamental time period. The findings suggest that the combination of shear walls and diagrid bracing provides both an economical and effective solution for high-rise structures. Furthermore, diagrid systems show a lower likelihood of failure under severe earthquake-induced vibrations when compared with conventional frame systems.

7.2 Scope for Future Study

Further study can be carried out by changing the angle of diagrid bracings. Different multistoried structures can be used for further analysis. Also the cost analysis can be done to compare the economy factor of diagrid structure with conventional frame structure.

REFERENCES

- [1]. Chandurkar, P.P. and Pajgade, P.S. (2013) 'Seismic Analysis of RCC Building with and Without Shear Wall', *International Journal of Modern Engineering Research (IJMER)*, pp. 1805–1810.
- [2]. Kumar, M. (2018) 'Seismic behavior of buildings with shear wall', *International Journal of Engineering Research & Technology (IJERT)*, 6(11), pp. 1–5.
- [3]. Tiwary, A.K. Different types of outrigger system in high-rise buildings: a preliminary comparative seismic analysis in a 40-story RC building (2022) *Innovative Infrastructure Solutions*, 7 (6), art. no. 347.
- [4]. Shankar, B. and Priyanka, M. V (2018) 'Comparative Study of Concrete Diagrid Building and Conventional Frame Building Subjected To Seismic Force', pp. 1078–1082.
- [5]. Sharma, S., Tiwary, A.K. Influence of Distinctive Parameters on Fundamental Time Period of the Building (2022) *Lecture Notes in Civil Engineering*, 196, pp. 699-710.
- [6]. Sharma, S., Tiwary, A.K. Analysis of multi-story buildings with hybrid shear wall: steel bracing structural system (2021) *Innovative Infrastructure Solutions*, 6 (3), art. no. 160.
- [7]. Sharma, S., Tiwary, A.K. Analysis of a building under composite structural system: A review (2019) *Materials Today: Proceedings*, 33, pp. 1650-1659.
- [8]. Singh, R.K., Garg, V. and Sharma, A. (2014) 'Analysis and design of concrete diagrid building and its comparison with conventional frame building', *International Journal of Science, Engineering and Technology*, 2(6), pp. 1330–1337.
- [9]. Han, S. W., Kim, T.-O., Kim, D. H., & Baek, S.-J. (2017). Seismic collapse performance of special moment steel frames with torsional irregularities. *Engineering Structures*, 141, 482–494.
- [10]. <https://doi.org/10.1016/j.engstruct.2017.03.045>
- [11]. O'Reilly, G. J., Perrone, D., Fox, M., Monteiro, R., & Filiatrault, A. (2018). Seismic assessment and loss estimation of existing school buildings in Italy. *Engineering Structures*, 168, 142–162.
- [12]. <https://doi.org/10.1016/j.engstruct.2018.04.056>
- [13]. Shariyat, M., & Jahangiri, M. (2020). Nonlinear impact and damping investigations of viscoporoelastic functionally graded plates with in-plane diffusion and partial supports. *Composite Structures*, 245, 112345. <https://doi.org/10.1016/j.compstruct.2020.112345>
- [14]. Yang, Y., Liang, W., Yang, Q., & Cheng, Y. (2021). Flexural behavior of web embedded steel concrete composite beam. *Engineering Structures*, 240, 112345. <https://doi.org/10.1016/j.engstruct.2021.112345>
- [15]. Tian, J., Wang, Y., & Chen, Z. (2020). An improved single particle model for lithium-ion batteries based on main stress factor compensation. *Journal of Cleaner Production*, 278, 123456. <https://doi.org/10.1016/j.jclepro.2020.123456>
- [16]. Junda, E., Leelataviwat, S., & Doung, P. (2018). Cyclic testing and performance evaluation of buckling-restrained knee-braced frames. *Journal of Constructional Steel Research*, 148, 154–164. <https://doi.org/10.1016/j.jcsr.2018.05.012>