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Enhancing Structural Stability: A Comprehensive Review of Composite Building Frames

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Abstract- With the world's population continually rising, the demand for tall multistorey structures has become imperative. Civil engineering designers face the challenge of ensuring structural safety, appropriate ventilation, and resistance to lateral forces such as seismic activity and wind pressure. Composite structures, comprising materials with complementary properties, offer a promising solution to this challenge. This paper reviews the literature on composite structures, focusing on their effectiveness in resisting lateral forces, particularly seismic loads. The study evaluates various research papers, highlighting the advantages of composite structures over traditional reinforced concrete (RCC) and steel structures. It discusses the economic viability of composite construction, especially in medium to high-rise buildings, and compares its performance with RCC and steel structures under seismic conditions. The results indicate composite structures exhibit enhanced stability and reduced seismic forces compared to RCC and steel structures.

Furthermore, they offer potential cost savings due to their lighter weight and efficient material usage. However, while the literature underscores the benefits of composite structures, it also identifies the need for further research into their design principles and cost-effectiveness. Despite this gap, the consensus among the reviewed studies is clear: composite structures present a compelling option for enhancing structural stability and mitigating the impact of lateral forces, particularly seismic activity. This paper contributes to the existing body of knowledge by providing insights into the advantages of composite structures and highlighting avenues for future research and development in this field.

Keywords- Composite Structures, Seismic Resistance, Structural Stability, Lateral Forces, Cost Effectiveness

I. INTRODUCTION

In light of the significant increase in global population, there is a growing demand for multistorey structures to accommodate this rise. Civil engineering designers face the challenge of planning tall buildings and prioritising structural safety, proper ventilation, and load resistance. Designing tall structures capable of withstanding lateral forces, such as seismic and wind pressure, requires using materials and techniques that offer sufficient resistance and stability. Composite structures, composed of two or more materials combined to provide both compression and tensile strength, play a crucial role in addressing these requirements. Lateral forces have long been recognised as a threat to structures and communities, causing devastating impacts on lives, property, and infrastructure. Recent events, such as those experienced by the neighbouring country Nepal, serve as stark reminders of the unpredictable nature of these hazards. Ensuring buildings can withstand seismic forces is imperative for survival, prompting ongoing research worldwide to develop techniques for mitigating such risks and ensuring structural stability. Although structures designed to resist lateral loads, especially during earthquakes, may incur higher construction costs compared to standard buildings, prioritising safety against these hazards remains paramount. Therefore, despite the associated expenses, investing in structures equipped with effective lateral load-resisting techniques is essential for safeguarding against the destructive impacts of lateral forces.

II. COMPOSITE STRUCTURES

Population density has sparked a growing interest in tall structures, increasing the exploration of composite structures as an alternative to steel constructions. Composite structures' advantages drive this shift over traditional RCC (Reinforced Concrete Cement) and the unexpectedly high costs associated with steel structures. Traditionally, structural analysis tends to focus on static loading conditions, overlooking the effects of dynamic loads. However, neglecting dynamic loading, especially in seismic regions, can pose significant hazards. Unlike other natural disasters, such as floods, seismic events allow little time for evacuation, resulting in substantial property damage and loss of lives. Consequently, designing and analysing structures equipped with lateral load-resisting members to withstand seismic forces emerges as the most viable solution. Each seismic event offers valuable insights into improving structural design processes, aiming to enhance occupant safety. Composite structures, formed by combining two or more distinct materials, play a pivotal role in enhancing the performance and stability of structural members to bolster overall structural integrity.

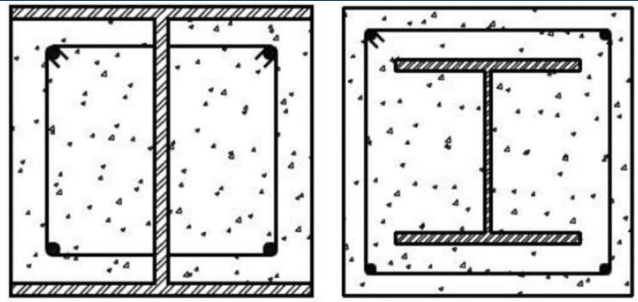

Figure 1. Cross section of composite structure

III. LITERATURE REVIEW

Salekin et al. (2013) explored the cost-effectiveness of composite construction for medium- to high-rise buildings in Bangladesh. They presented a cost versus number of storey curve, indicating that the RCC frame system was cheaper for low-rise buildings compared to the composite system. However, they found that composite construction became more economical than RCC construction for buildings with more than 15 stories. The research concluded that the steel-concrete composite frame system was a superior choice for medium to high-rise buildings, considering both economy and serviceability. For high-rise buildings constructed with composite frames, costs decrease due to using smaller cross-sectional elements, less steel, reduced formwork for concrete, and lower labour costs. Therefore, steel-concrete composite frame systems can be an economically viable solution for high-rise buildings in Bangladesh. Kumawat et al. (2014) conducted a comparative study of steel-concrete composite and RCC options for a G+9-storey commercial building in earthquake zone III. The study considered earthquake loading according to IS: 1893 (Part 1)-2002 provisions. They used SAP 2000 software for three-dimensional modelling and analysis of the structures. Identical static analysis methods and response spectrum examination strategies were employed for composite and RCC structures. The outcomes indicated that the dead weight of the composite structure is 15% to 20% less than that of the RCC structure, resulting in a reduction of seismic forces by 15% to 20%.

Additionally, stiffness in the composite structure increased by 12% to 15% transversely and about 6% to 10% longitudinally compared to reinforced concrete structures. Moreover, the shear strength was 31% to 47% less transversely and about 30% to 45% less longitudinally in the composite section than in the RCC section. Overall, the study concluded that due to the high ductility of steel, the composite structure offers increased seismic resistance and is more economical. Sutar and P. M. Kulkarni (2016) performed an inelastic nonlinear static analysis of steel-concrete composite frames using E-tab 9.7. Parameters such as storey drift, storey displacement, base shear, and shear power were considered to evaluate the performance of the composite frame. The study concluded that the steel-concrete composite frame has a higher lateral load capacity compared to RCC frames. No sudden plastic hinges were observed in the inelastic analysis of both RCC and composite frames, indicating better performance of the composite frame in high seismicity conditions. Mahajan et al. (2016) investigated the impact of Fully Encased Composite (FEC) materials on a G+20-storey special moment frame. They conducted seismic analysis and compared two structures using direct static analysis and nonlinear static analysis (Weakling examination) with ETAB software. The results showed significant variations in base shear, modal time span, storey displacement, and storey drift due to the increased lateral stiffness of the composite material. In nonlinear static analysis, the performance of the FEC model considerably surpassed that of the RCC model. Chaudhary et al. (2011) examined the seismic behaviour of steel-concrete composite walls and compared it with RC walls. They conducted inelastic seismic analysis using ABAQUS finite element software and performed modal and time history analysis for both types of shear walls. The results indicated that composite walls with rigid connections between steel and concrete exhibited higher natural frequencies and less deformation compared to reinforced concrete shear walls, demonstrating superior rigidity and control over drift.

Moreover, the composite walls showed less damage due to cracking compared to RC walls, making them a viable alternative for high-rise structures and nuclear power plants. Edoardo et al. (2005) reviewed the fundamental structural response characteristics and technological issues of composite steel and concrete systems. They assessed the pros and cons of composite structural systems and evaluated the efficacy of beam-column members. The research concluded that further experimental and numerical work is needed to understand the interaction between steel and concrete and the behaviour of beam-to-column and base-column connections, as current design rules rely on limited datasets. Sudarshan Bhutekar et al. (2018) compared the performance of G+15-storey steel and composite (steel-concrete) structures under incremental earthquake loading. They highlighted the advantages of composite construction, such as lower cost, rapid construction, and fire protection, compared to steel structures with a high strength-to-weight ratio. The study found that the steel structure outperformed the steel-concrete composite frame structure, suggesting that steel frame structures could be more economical and efficient in seismic zones. Sanjay Kulkarni et al. (2017) conducted a comparative study of RCC and composite structures in seismic zone III. They evaluated the seismic behaviour of the structures using response spectrum and nonlinear time-history analysis with ETABS software. The results indicated that hinges formed first in the beam elements rather than in columns, supporting the concept of a strong column weak beam or capacity-based design for composite frames. Mohdamir Khan (2017) investigated the seismic performance of RCC, steel, and composite building frames in earthquake zone IV. The study utilised concrete and deck slabs in composite buildings and compared RCC or structural steel-concrete composite sections for pillar and beam elements. Similar static and response spectrum methods were employed for seismic and nonlinear static pushover analyses.

IV. RESEARCH FINDINGS

The literature review on composite building frames reveals compelling findings regarding their efficacy in withstanding lateral forces, particularly seismic loads. Research conducted by Salekin et al. (2013) and Sudarshan Bhutekar et al. (2018) highlights the economic viability of composite construction, indicating that while initial costs may be higher compared to traditional reinforced concrete (RCC) structures, composite frames become more cost-effective for medium to high-rise buildings. Additionally, studies such as Kumawat et al. (2014) and Mahajan et al. (2016) demonstrate the structural benefits of composite frames, showcasing reductions in seismic forces and increased stiffness compared to RCC structures. Furthermore, the research underscores the superior performance of composite walls in seismic regions, as evidenced by Chaudhary et al. (2011), who found that composite walls exhibit higher natural frequencies and less deformation than reinforced concrete shear walls. However, despite the advantages highlighted in the literature, there remains a need for further research into the design principles and cost-effectiveness of composite structures, as emphasised by Edoardo et al. (2005). Nonetheless, the consensus among the reviewed studies is clear: composite building frames present a compelling option for enhancing structural stability and mitigating the impact of lateral forces, particularly seismic activity. These findings contribute valuable insights into the potential of composite structures and suggest avenues for future research and development in this field.

V. CONCLUSION

In conclusion, the literature review on composite building frames underscores their potential to address the increasing demand for tall multistorey structures while ensuring structural safety, ventilation, and resistance to lateral forces, particularly seismic activity and wind pressure. Various research papers highlight the advantages of composite structures over traditional reinforced concrete (RCC) and steel structures, emphasising their enhanced stability and reduced seismic forces. Moreover, composite structures offer potential cost savings due to their lighter weight and efficient material usage, making them economically viable options for medium to high-rise buildings. However, the literature also identifies the need for further research into composite structures' design principles and cost-effectiveness to harness their benefits fully. Despite this gap, the consensus among the reviewed studies is clear: composite building frames present a compelling option for enhancing structural stability and mitigating the impact of lateral forces, particularly seismic activity. These findings contribute valuable insights into the potential of composite structures and suggest avenues for future research and development in this field, paving the way for safer and more resilient infrastructure in the face of evolving architectural demands and environmental challenges.

REFERENCES

[1]. Mahbuba Begum, Md. Serajus Salekin et al. (2013), "Cost analysis of steel concrete composite structures in Bangladesh," Asian Journal of Civil Engineering (BHRC), Vol. 14, No. 6, 2013.

[2]. Mahesh Suresh Kumawat and L. G. Kalurkar (2014), "Analysis and design of a multistorey building using composite structure," 2014 IJSCER, Vol. 3, No. 2, May 2014.

[3]. S. R. Sutar & P. M. Kulkarni (2016), "Comparative inelastic analysis of RCC and steel-concrete composite frame," IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 13, Issue 4 Ver. IV, Jul. - Aug. 2016, pp. 22-32.

[4]. Abhishek Sanjay Mahajan & Laxman G. Kalurkar (2016), "Performance analysis of RCC and steel concrete composite structure under seismic effect," IJRET: International Journal of Research in Engineering and Technology, Volume: 05 Issue: 04, Apr. 2016.

[5]. Edoardo Cosenza, Luigi Di Sarno, et al. (2005), "Composite Steel and Concrete Structures: Technology and Design," Conference Paper, January 2005, ISBN: 978231581785.

[6]. Sudarshan Bhutekar & Mohammed Ishtiyaque (2018), "Pushover analysis of G+15 steel and steel-concrete composite frame structure," International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 05, May 2018.

[7]. Dr. Sanjay Kulkarni, Vishwajeet Kadlag, et al. (2017), "Inelastic analysis of RCC and composite structures," International Journal of Scientific & Engineering Research, Volume 8, Issue 5, May 2017.

[8]. Mohd Amir Khan (2017), "Comparative study of R.C.C & structural steel-concrete composite frame for linear and nonlinear analysis," International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 07, July 2017.

[9]. Ilgın, Hüseyin Emre. "High-rise residential timber buildings: emerging architectural and structural design trends." Buildings 14.1 (2023): 25.

[10]. Zhang, Wei, et al. "Experimental study of a composite beam externally bonded with a carbon fibre-reinforced plastic plate." Journal of Building Engineering 71 (2023): 106522.

[11]. Qing, Zhang Qing, and Zhang Li Na. "A comparative analysis of RCC and composite buildings using the new plastic deformation (PD) method." Scientific Reports 14.1 (2024): 5666.