Literature Review on Comparative Seismic Performance analysis between RCC and Composite structure

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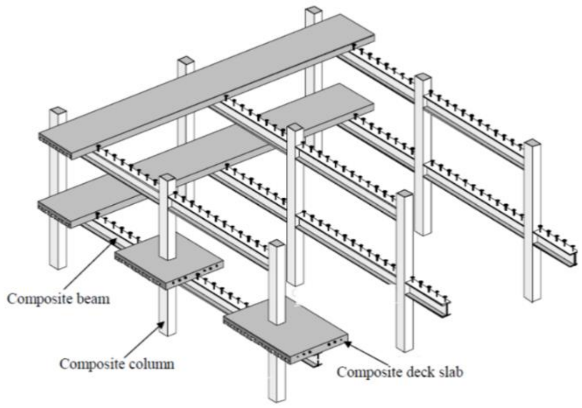
Abstract – In recent years, there has been a burgeoning interest in exploring the seismic performance of structural systems, with a particular focus on the comparison between traditional Reinforced Concrete (R.C.C) structures and innovative Composite structures. Numerous researchers have delved into this subject, conducting analytical and experimental investigations to shed light on the advantages and applications of steel-concrete composite structures. This paper synthesizes the key findings from these diverse studies, emphasizing their significance in the context of seismic performance. The research endeavors to unravel the inherent strengths of steel-concrete composite structures, showcasing their behavior under various loading conditions and their potential suitability for high-rise buildings. Researchers have dedicated considerable efforts to conducting extensive experiments and analyses, leading to the development of novel shear connections and design guidelines for composite bridges, ensuring their structural integrity and performance. Composite structures, as elucidated by the collective body of work, offer superior ductility, strength, and stiffness when compared to conventional R.C.C. structures, rendering them economically advantageous and well-suited for contemporary building designs. The studies underscore the importance of considering the impact of temperature loads in the design of extended R.C. structures, proffering methods to mitigate issues such as cracking and leakage. Additionally, researchers have probed into fatigue analysis and the resilience of composite structures, further advancing construction methods. Collectively, these findings advocate for the adoption of steel-concrete composite structures in the construction of high-rise buildings, where they not only offer cost-effectiveness and expedited construction but also demonstrate remarkable earthquake resistance, ultimately contributing to the advancement of seismic performance analysis in structural engineering.

Index Terms – composite column, composite building, seismic analysis

I. INTRODUCTION

Composite structures are increasingly gaining attention in seismic-prone areas due to their superior performance and efficiency. This paper provides a comprehensive comparison of composite structures and Reinforced Concrete (R.C.C) structures, specifically focusing on their seismic response. Composite structures are engineered materials formed by combining two or more constituent materials with distinct properties to create a single, unified structure. This amalgamation of materials is strategically done to capitalize on their individual strengths and mitigate their weaknesses. In the context of civil engineering, composite structures are typically composed of steel and concrete.

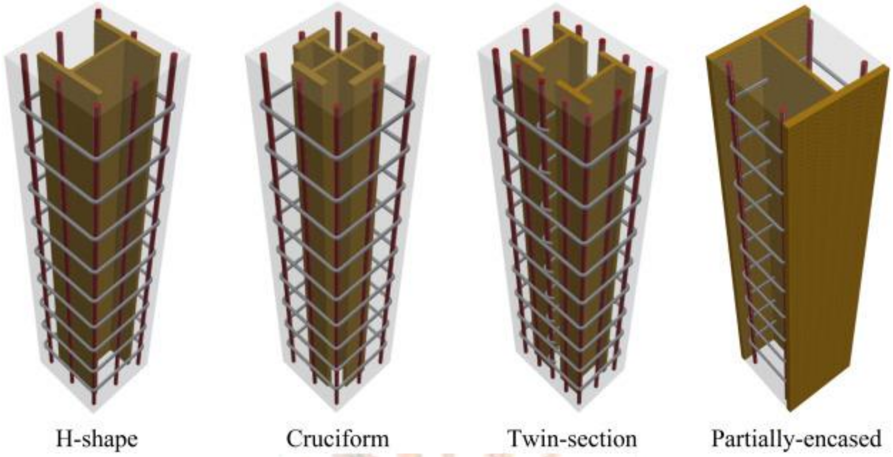


Steel-Concrete Composite Frame

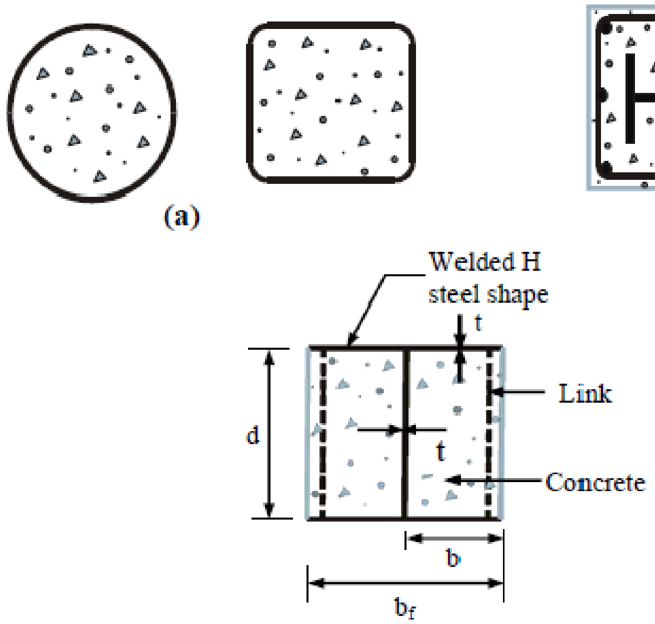
Seismic Performance

The seismic performance of a structure is its ability to withstand and dissipate the energy of an earthquake. Composite structures exhibit several advantages over R.C.C. structures in terms of seismic performance:

- Superior stiffness and strength: Composite structures are typically stiffer and stronger than R.C.C. structures, which allows them to better resist seismic loads.
- Enhanced ductility: Composite structures are also more ductile than R.C.C. structures, meaning they can undergo larger deformations without failure. This is important because ductility is essential for dissipating seismic energy.
- Reduced weight: Composite structures are typically lighter than R.C.C. structures, which reduces the seismic mass and forces on the structure.
- Better confinement: The steel beams in composite structures provide better confinement for the concrete, which improves the overall strength and ductility of the structure.



One of the key challenges in designing composite structures for seismic resistance is ensuring that the shear connectors are able to transfer the shear forces between the steel and concrete. This is important because the shear connectors are the only connection between the two materials. If the shear connectors fail, the composite structure will lose its integrity and fail. Another challenge in designing composite structures for seismic resistance is dealing with the potential for buckling of the steel beams. Buckling is a mode of failure in which the steel beam deforms laterally and loses its ability to support load. Buckling can be prevented by providing adequate lateral support to the steel beams. Despite these challenges, composite structures offer a number of advantages over R.C.C. structures for seismic-resistant design. Composite structures are stronger, stiffer, more ductile, and lighter than R.C.C. structures. Additionally, composite structures provide better confinement for the concrete and are more resistant to brittle failure modes.



Examples of composite columns

II. LITERATURE SURVEY

Sougata Chattopadhyay et al. [1] focused on steel-concrete composite construction, which combines steel and concrete to create structures with high ductility, strength, and stiffness. The study reviews the structural performance of composite beams under various loading actions. Additionally, nonlinear analysis using ANSYS software was conducted to examine the behavior of these beams under static loading. Numerical investigations were carried out using beam models with two-point loading. The load versus mid-span deflection was plotted to understand the response. The analysis results were validated by comparing them with experimental results from previous studies. The findings indicate that the dimensions of shear connectors used in the composite beams influence their ultimate load capacity under static loading.

Yinhan Luo [2] researched new connectors becomes vital for the continuous development of composite beams. This paper discussed the current research and application status of steel-concrete composite structure connectors. It also highlights the main trends in new connector development and analyzes relevant case studies. The findings offer valuable insights for future designs of steel-concrete composite structure connectors.

Rachakonda Divya et al. [3] conducted a comparative study on the design of Steel Structures and RCC frame Structures, focusing on column spans. The column span, along with the building's height, plays a significant role in the design, analysis, and cost of the structure. The scope of the study includes comparing design, analysis, and construction costs for long and short spans of columns in G + 8 RCC Structure and Steel Structure using ETABS-2018 software. The findings will aid in making informed decisions on the most suitable construction type for different scenarios and building types.

Bhanu Prakash P.M et al. [4] explored the growing popularity of composite structures in developing countries. As medium and high-rise buildings face challenges with RCC structures such as increased dead weight and span restrictions, steel and concrete composite structures offer a safer and more economical solution. The paper discusses various research results comparing RCC, Steel, and composite structures in building construction, highlighting the advantages of the latter for modern buildings.

Abdul Qahir Darwish [5] highlighted the shift from traditional reinforced concrete (R.C.C.) structures to composite construction in the residential building industry. R.C.C. has drawbacks like increased dead weight and slow construction, making it less economical. In contrast, steel-concrete composite structures offer numerous advantages, such as reduced seismic weight, faster construction, and better earthquake resistance. The combination of steel and concrete properties in composite structures provides cost-effectiveness, rapid construction, and improved fire protection. The research emphasized the need for seismic design criteria to promote the successful implementation of composite construction in India. Overall, this study sheds light on various aspects of building construction, advocating the adoption of modern composite structures for their benefits over conventional methods.

Umesh Rajendra Tubachi et al. [6] analyzed a G+30 high-rise structure using static, dynamic, and wind analysis with ETABS-software. Results are compared through graphs, revealing that Steel Concrete Composite Structures outperform RCC structures. Ultimately, the research concludes that composite structures are more recommendable for high-rise construction due to their enhanced performance and efficiency.

Anargha.B.S et al. [7] aimed to study the behavior of reinforced concrete, steel, and composite structures under seismic loading conditions. By understanding their responses to seismic forces, the research seeks to provide valuable insights for developing sustainable construction practices.

Mustafa M. Wagh et al. [8] presented a comprehensive comparison of various aspects of building construction for steel, RCC, and composite buildings. By considering multiple research studies, the paper sheds light on the benefits and potential applications of composite structures, aiding contractors, and owners in making informed decisions about construction materials and techniques.

A. Sattainathan Sharma et al. [9] focused on comparing a framed structure made of Reinforced Cement Concrete (R.C.C) and Composite material in an earthquake-prone area. Using Equivalent Static analysis and seismic analysis with SAP2000 and E-TABS software, the study examines various aspects like story displacement, drift, deflection, and stiffness. The findings reveal that steel-concrete composite frames exhibit desirable wind force and seismic responses compared to R.C.C structures. While the composite structure shows slightly higher inter-story drift, it remains within permissible limits. The study concludes that using composite materials in construction is more effective and economic than reinforced concrete. Composite structures are particularly well-suited for high-rise buildings, offering advantages in deflection, stiffness, and reduced dead weight.

S. S. Charantimath et al. [10] carried out an extensive research on composite column, composite beam and deck slab in which structural steel section are encased in concrete. However, for medium to high-rise buildings R.C.C structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. The results of this work show that the Composite structures are the best solution for high rise structure as compared to R.C.C structure.

Shweta A. Wagh et al. [11] discussed the growing acceptance of steel-concrete composite construction worldwide, as it offers an alternative to pure steel and concrete structures. The research focuses on composite columns, beams, and deck slabs, where structural steel sections are encased in concrete. The study concluded that composite structures are the best solution for high-rise buildings compared to R.C.C structures due to economic and performance advantages. Another study highlights the potential for increasing the use of steel in construction in India to meet current development needs. It compares multi-storeyed commercial buildings using STAAD-Pro software and MS-Excel programming for design and cost estimation, allowing for a comparison between R.C.C and composite structures. Overall, both studies emphasize the benefits of steel-concrete composite construction and its potential to improve the efficiency and economy of high-rise buildings.

D. R. Panchal et al. [12] focused on a comparative study of steel-concrete composite, steel, and R.C.C. systems for a G+30 storey commercial building located in earthquake zone IV. Mechanical shear connectors are used to connect the steel beam to the concrete slab, forming a single unit. Equivalent Static Method of Analysis is applied, and ETABS software is used for modelling and comparing the results. The findings show that the composite structure is more economical compared to steel and R.C.C. options. The study highlights the advantages of steel-concrete composite systems for building construction, emphasizing their cost-effectiveness.

Chang-Su Shim et al. [13] focused on prefabricated composite bridges with full-depth precast decks. Extensive experiments and finite element analyses were conducted to propose a new shear connection and design provisions for steel-concrete composite bridges. The study investigated the effects of bedding layers, filling materials, and group arrangement for the shear connection of precast decks. To ensure the integrity of the precast decks, longitudinal prestressing was introduced, and design guidelines for prestress magnitude were suggested. To prevent cracking and leakage at joints during the bridge's service life, it is essential to maintain compressive joints. The design neglected bonding strength. The concept of incremental prestressing was adopted for continuous prestressed concrete girders to maximize the advantages of precast slabs. The suggested design guidelines were verified through model tests based on experimental research on joints and connections. The paper also introduced design characteristics and construction details for two bridges using precast decks, not only for steel but also for concrete bridges.

Pham Thai Hoan [14] investigated the design of long reinforced concrete (RC) structures subjected to uniform temperature loads. Three RC frame building models of different lengths (45 m, 135 m, and 270 m) were analyzed using ETABS. The results show that the uniform temperature load mainly affects the internal forces of RC members at the first storey and has a slight impact on the second storey.

Spacone and El-Tawil [15] discussed the most recent developments in non - linear analysis of composite steel and concrete structures. Frame elements, which can be computed more quickly than continuum finite element models, were the main focus of work. Following a review of the resulting and fiber models and a discussion of potential real-world applications, section models were first presented. Then came the unveiling of the frame's components. The authors also discussed models with lumped and distributed in-elasticities, as well as models with full and partial connections. Then a thorough review and discussion of joints that are rigid and partially restricted followed.

Nie et al [16] presented a literature review paper on analysis of China's current cutting-edge technological and research advancements in steel-concrete composite structures, including the engineering of buildings, bridges, and special projects. The authors claimed that the comprehensive superiority of steel-concrete composite structures could be well elicited by enhancing and updating conventional construction kinds. The authors' research findings also suggested that there is a good chance that high-performance steel-concrete composite structures would become more widely used in the future.

Liew et al [17] examined the recent advancements in SCS sandwich constructions that are susceptible to blast, impact, fatigue, and static loads. The experimental findings presented in this study were crucial for comprehending the structural behavior of SCS sandwich structures and for supplying information for the creation of analytical models for the application of design.

Xu et al [18] attempted to address the issue of the non-uniform distribution of shear stresses at the interface between steel and concrete elements in composite constructions by using a headed stud covered in a rubber sleeve. The authors also ran a computer simulation to examine the shear connectors' nonlinear behavior. The findings demonstrated that rubber-sleeved stud's shear strength variation was insignificant when compared to regular stud, but the stiffness was significantly reduced and the shear mechanism changed.

Nastar et al., [19] focused on small-scale connection flaws that might have caused the observed cracks. The creation of plastic hinges and the yielding of the material in the connection region were also thought to contribute significantly to the observed connection damage. The research concentrated on the role of low-cycle fatigue in the connection damage in a steel building with ten stories that had been damaged by the Northridge Earthquake. Based on the Palmgren-Miner approach, a thorough fatigue analysis procedure was created, and using the scant test data that is currently available, S-N curves built for the high-cycle fatigue range are extended to the low-cycle zone. Using the specified approach, fatigue analysis is carried out at key places of a sample moment frame.

Lorenzon et al [20] described the viability of a method that starts with CFD and proceeds via a series of numerical simulations to calculate the fatigue of a big, complicated structure. By conducting a literature study and paying particular focus to how these models were used to case studies involving substantial steel structures, the state of the art of turbulence models for CFD was demonstrated.

Alshareef et al [21] described the creation of an application framework software for precisely forecasting the spent fatigue life of overhead sign highway infrastructures. The programme was created as a package tool to generate several simulations while incorporating the findings into a fatigue calculation using a 45-year wind model and the finite element software Staad Pro platform.

Al Shboul et al [22] wanted to propose a comprehensive approach in order to precisely anticipate the residual fatigue life of full-span overhead highway sign support structures exposed to a prolonged and persistent wind variation. Two members of the structure had their end-of-fatigue lives predicted by the software. The axial truss component stresses from a finite element solution corresponding to each wind speed in every specified time range were used by the researchers to conduct fatigue studies. Each structural member's potential for fatigue failure was evaluated after the stress range was amplified using an average dynamic amplification factor.

Zhao and Roddis, [23] located the Arkansas River Bridge's fatigue cracks in three different locations. This article evaluated fatigue stresses at the details of the cracks during traffic, analysed two potential repair strategies to stop future crack propagation, and suggested retrofit techniques to prolong the life of the bridge. The authors came to the conclusion that the maximum stress range after repairs was reduced by 50% to a level where recapitulation of cracks was not anticipated.

Chanda et al., [24] discussed the findings of a fatigue life evaluation on a railway steel truss that is currently in place in Kolkata. STAAD Pro was used to model the truss bridge with shifting loads. The Indian Railways provided the data to the authors. Following analysis, the reservoir approach was used to assess the damage after the stress range time spectra were acquired. The risk of 77% damage to the critical members after 80 years was calculated based on the bridge's chance of fatigue failure. According to observations, fatigue failure should happen after 80 to 90 years of service.

III. CONCLUSIONS

[1]. Composite structures offer enhanced ductility, strength, and stiffness compared to traditional reinforced concrete (R.C.C.) structures, making them more economical and suitable for modern buildings.
[2]. Steel-concrete composite structures are particularly well-suited for high-rise buildings, where they provide cost-effectiveness, rapid construction, and superior earthquake resistance.
[3]. Extensive experiments and analyses have been conducted to develop new shear connections and design guidelines for composite bridges, ensuring their integrity and performance.
[4]. The effects of temperature loads should be carefully considered in the design of long RC structures to prevent cracking and leakage.
[5]. Fatigue analysis and the resilience of composite structures have also been explored, contributing to the development of improved construction methods.
[6]. Composite structures have a higher energy dissipation capacity, which enables them to withstand more severe seismic events
[7].

Overall, the findings of the literature review paper recommend the adoption of steel-concrete composite structures for a wide range of applications, including high-rise buildings, bridges, and other large-span structures.

In conclusion, the reviewed literature presents a diverse and comprehensive body of research on the composite structures. It focuses on how composite structures offer significant advantages over RCC structures in terms of seismic performance, economy, and construction speed. Few authors also focussed on the superior ductility, strength, stiffness, and energy dissipation capacity of composite structure making them more resilient to seismic loads and better able to withstand severe earthquakes. Additionally, composite structures require smaller member sizes and less reinforcement, which reduces construction costs and accelerates construction time. This makes them a more attractive option for buildings in seismic-prone regions.

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