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# Analysis of the Behavior of Steel-Concrete Composite Structures against Dynamic Loads in Multi-Storey Buildings

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## ABSTRACT

This study aims to analyze the behavior of steel-concrete composite structures to dynamic loads in high-rise buildings. Steel-concrete composite structures are one of the innovations in the world of construction that combines the tensile strength of steel and the compressive strength of concrete to produce an efficient structural system that is resistant to various types of loads, including dynamic loads such as earthquakes and winds. This study uses a qualitative approach with the literature study method (library research) to examine various previous research results, technical standards, and relevant theories regarding the response of composite structures to dynamic loads. The main data sources come from international journals, civil engineering books, as well as globally recognized composite structure design guidelines. The results of the analysis showed that composite structures have better performance than conventional structures in responding to lateral forces due to dynamic loads, especially in terms of energy dissipation and plastic deformation. In addition, the integration of steel and concrete elements can improve the rigidity of the structure as well as reduce the risk of local failure. However, the effectiveness of these structures is highly dependent on the details of the joints, the method of execution of the construction, and the suitability of the design to the

## KEYWORDS

*Composite Structures, Steel-Concrete, Dynamic Loads, Multi-Storey Buildings, Literature Studies.*

characteristics of the dynamic load. These findings make an important contribution to the development of safer and more efficient multi-storey building structure designs, as well as the basis for further research related to the strengthening of composite structures in earthquake-prone areas.

## 1. INTRODUCTION

In recent decades, developments in construction technology have driven the adoption of steel-concrete composite structures as an alternative solution in the construction of high-rise buildings, especially in areas that are prone to dynamic loads such as earthquakes and winds (Johnson, 2018). Composite structures take advantage of the advantages of steel and concrete materials simultaneously, which allows for the creation of a more efficient structural system that is resistant to lateral forces (Chen & Duan, 2014). This combination has been shown to increase the rigidity and load capacity of the structure without significantly increasing the dead load (Li et al., 2019).

Although various studies have discussed the performance of composite structures to static loads and some to dynamic loads, there are still limitations in the overall understanding of the dynamic behavior of such structures in the context of complex multi-storey buildings (Zhou et al., 2020). Previous studies have tended to focus on material and connection aspects, with little attention to the integration of the structure's global behavior into varying dynamic load scenarios (Ahmed & Saka, 2015; Zhang et al., 2021).

The research gap lies in the lack of a comprehensive approach that examines the systemic behavior of composite structures to dynamic load combinations, as well as the lack of up-to-date literature that integrates analytical and empirical aspects (Kim & Choi, 2017). Therefore, this research is important to provide conceptual and applicative understanding in designing composite structures that are resistant to complex load dynamics.

The urgency of this research is strengthened by the increasing need for safe and efficient high-rise buildings in urban areas, especially in earthquake-prone areas such as Indonesia and Pacific Ring of Fire countries (Setiawan & Nugroho, 2022). On the other hand, the development of planning standards and construction technology requires a strong theoretical basis to support technical decision-making (FEMA, 2020).

Several previous studies have evaluated the performance of single-element composite structures against lateral loads (Han et al., 2014), but not many have evaluated the behavior of the overall structural system in the context of multi-storey buildings. This is where the original contribution (novelti) of this study lies, namely by presenting a thorough and systematic conceptual analysis of the dynamic behavior of steel-concrete composite structures in multi-storey buildings through a literature study approach.

The main objective of this study is to identify the characteristics, advantages, and limitations of steel-concrete composite structures in the face of dynamic loads, as well as to compile a synthesis of knowledge that can be the basis for the development of more adaptive multi-storey building structure design and construction. The benefits of this research are expected to make a theoretical contribution to the development of civil engineering science, as well as practical recommendations for structural designers and policy makers in the high-rise building construction sector in disaster-prone areas.

**Steel-Concrete Composite Structure: Basic Concepts and Principles**

Steel-concrete composite structure is a structural system that combines two main materials, namely steel and concrete, which work together in bearing loads. Concrete that has high compressive strength is combined with steel that has excellent tensile strength, so that the two complement each other in the structural system (Johnson, 2018). Generally, these composite structural elements are composite beams, composite columns, and composite slabs connected via shear connectors to ensure effective interaction between steel and concrete. The main principle of this composite structure is that not only the strength of each material is utilized, but also the interaction between the materials increases the efficiency and rigidity of the overall system.

**Advantages and Applications of Composite Structures**

Composite structures have various advantages over conventional structures that use only one type of material. Some of these advantages include increasing load capacity, efficiency in the use of materials, and reducing the dimensions of structural elements so that the space in the building can be maximized (Chen & Duan, 2014). In addition, composite structures have good performance in withstanding dynamic loads such as earthquake and wind loads due to their greater flexibility and energy dissipation ability (Kim & Choi, 2017). Because of these advantages, composite structures are widely applied in the construction of high-rise buildings, bridges, and other modern infrastructure, especially in areas with high seismic risk. The use of these systems can also speed up construction time, especially when combined with modular precast and assembly methods.

**Challenges and Design Aspects of Composite Structures**

While composite structures offer many advantages, their application also presents some technical challenges that need to be considered in the planning and implementation process. One of the main challenges is the design of shear connectors that function to bind steel and concrete components to work together without slipping (Han et al., 2014). The design and calculation of these joints requires careful analysis so as not to become a weak point in the structure. In addition, the influence of dynamic loads on composite structures requires special attention, especially in designing lateral rigidity and deformation capacity. Another factor that is also important is construction quality control in the field, because errors in implementation can cause steel-concrete interactions to be suboptimal. Therefore, a thorough understanding of the behavior of composite structures is essential to guarantee the safety and efficiency of multi-storey buildings using these systems.

## 2. METHODS

This study uses a qualitative approach with the type of literature study research (library research), which aims to study and analyze the behavior of steel-concrete composite structures to dynamic loads in high-rise buildings. The literature study was chosen because it allows researchers to examine a variety of relevant and up-to-date literature sources in order to gain an in-depth understanding of the structural characteristics, dynamic strengths, and technical design of composite structural systems (Zed, 2004; Creswell & Poth, 2018). This research does not conduct direct experiments in the field, but relies on critical analysis of secondary data obtained from various scientific and technical documents.

The data sources in this study are derived from primary and secondary literature, including reputable international journals, civil engineering textbooks, conference proceedings, international design standards such as Eurocode and AISC, as well as technical reports from relevant agencies such as FEMA and ASCE. The literature used was selected based on its relevance, timeliness, and credibility, especially those that discuss the structure of steel-concrete composites and their response to earthquake, wind, and other dynamic loads (Johnson, 2018; Zhou et al., 2020).

The data collection technique is carried out through documentation studies, namely by searching, identifying, and reviewing library sources through academic databases such as ScienceDirect, Scopus, SpringerLink, and Google Scholar. Each document obtained is systematically analyzed using content analysis techniques, to identify patterns, key concepts, and relevant findings related to the research topic (Krippendorff, 2019). The data analysis process is carried out by grouping information based on themes such as composite element type, dynamic load type, design method, and structural performance, then synthesized to produce a comprehensive understanding. The validity of the data is maintained through source triangulation and cross-checking between literature to ensure the accuracy and consistency of information (Patton, 2002).

## 3. RESULTS AND DISCUSSION

Based on the results of literature searches through various academic databases such as ScienceDirect, Scopus, SpringerLink, and Google Scholar, a number of scientific articles have been found that discuss the behavior of steel-concrete composite structures to dynamic loads in multi-storey buildings. From a total of more than 50 articles identified, a strict selection process was carried out based on the criteria of relevance, up-to-date (publication in the last 10 years), and completeness of discussion on dynamic responses and composite structure systems. Finally, 10 main articles were obtained which were used as core literature data in this study. These articles are analyzed and summarized in the following Table 1:

**Table 1.** Summary of Literature Study Literature Data

| Author & Year | Article Title | Key findings |
|---|---|---|
| Johnson (2018) | Composite Structures of Steel and Concrete | *The interaction between steel and concrete increases structural capacity and rigidity.* |
| Kim & Choi (2017) | Dynamic response of multi-story composite buildings under seismic loads | *The composite structure shows more controlled deformation and is resistant to earthquakes.* |

| | | |
|---|---|---|
| Zhou et al. (2020) | Nonlinear analysis of steel-concrete composite frames under seismic loading | *A well-designed connection is important for maximum energy dissipation.* |
| Li et al. (2019) | Structural behavior and design of steel-concrete composite frames | *High material efficiency with resistance to lateral loads.* |
| Han et al. (2014) | Behavior of concrete-filled steel tubular columns | *The compressive capacity and local stability are significantly improved.* |
| Zhang et al. (2021) | Performance of composite columns under combined dynamic loads | *Specific design is needed for the resistance of the combination of lateral and axial loads.* |
| Ahmed & Saka (2015) | Optimum design of composite steel beams using hybrid genetic algorithm | *Optimal design can be achieved with an AI-based numerical approach.* |
| Chen & Duan (2014) | Bridge Engineering Handbook: Fundamentals | *The composite principle is also relevant for multi-storey buildings.* |
| Setiawan & Nugroho (2022) | Seismic vulnerability analysis of multi-storey buildings in Indonesia | *Adaptive structures such as composite systems are required.* |
| FEMA (2020) | Seismic Evaluation and Retrofit of Multi-Unit Buildings | *Composite structures are recommended for retrofitting existing buildings.* |

This table shows that most of the literature concludes that steel-concrete composite structures have significant advantages in responding to dynamic loads, both in the context of initial design and reinforcement of existing structures. The findings of these articles are the basis for formulating conclusions and recommendations in this study.

The results of the analysis of the ten main articles that have been selected show that steel-concrete composite structures provide an effective technical solution to overcome the challenges of dynamic loads in multi-storey buildings. In a theoretical context, Johnson (2018) and Chen & Duan (2014) emphasized that the concept of interaction between steel and concrete allows for an increase in load capacity and structural rigidity without having to significantly increase mass. This basic principle is the foundation of the entire development of composite structural systems that have been studied in other articles.

In more applicable studies, such as those conducted by Kim & Choi (2017) and Zhou et al. (2020), it was seen that composite structures are able to respond to earthquake loads more efficiently than conventional structures. They found that the use of composite elements in building truss systems was able to reduce lateral deformation, increase energy dissipation, and reduce the likelihood of sudden collapse. This is very important in building design in an active seismic area such as Indonesia. The findings also emphasize the importance of joint quality, as the connecting element between steel and concrete plays a major role in ensuring the cooperation of the two materials.

Furthermore, several articles such as Li et al. (2019) and Han et al. (2014) focus their studies on the specific elements of composite structures, namely composite columns and composite beams. These studies indicate that the element not only has high structural strength, but also resistance to simultaneous axial and lateral loads. Concrete in concrete-filled steel tubes has been proven to make a major contribution to local stability, reduce the risk of bending, and extend the service life of structures.

Aside from the strength and rigidity side, the optimal design approach is also an important focus in the literature. Ahmed & Saka (2015) used a genetic algorithm approach to design composite beams efficiently, suggesting that digital technology and artificial intelligence can now be leveraged to improve the effectiveness of structural design. Optimal design not only reduces construction costs, but can also improve the performance of structures against unexpected dynamic loads.

In terms of application in the field, Setiawan & Nugroho (2022) and FEMA (2020) underline the urgency of using composite structures in the context of disaster mitigation. Their study provides empirical evidence that multi-storey buildings in earthquake-prone areas such as Indonesia should adopt structural systems that are flexible and strong against earthquake loads, and composite structures are one of the most viable alternatives. FEMA even recommends this system in the process of retrofitting existing buildings to significantly improve structural resilience.

Overall, the synthesis of the ten articles reviewed shows that steel-concrete composite structures are not only promising from a theoretical point of view, but have also been empirically proven as a structural solution that is adaptive to load dynamics in multi-storey buildings. Whether in new design or retrofitting existing buildings, the composite structure approach is able to respond to the challenges of strength, efficiency, and structural safety in a balanced manner. Thus, the results of this literature review strengthen the scientific basis for recommending the use of steel-concrete composite structures in the development of multi-storey buildings in urban and disaster-prone areas.

## Discussion

The findings of the literature study show that steel-concrete composite structures have significant advantages in dealing with dynamic loads, especially in high-rise buildings. These findings become particularly relevant when associated with the increasing frequency of earthquakes and extreme wind loads due to global climate change. Indonesia, as a country in the Pacific ring of fire, is very vulnerable to earthquakes, so the need for a structural system that is able to respond to dynamic loads in an adaptive manner is very urgent.

Theoretically, composite structures refer to the principle of cooperation between concrete that excels in withstanding compressive loads and steel that is strong against tensile. This basic theory, as described by Johnson (2018), is the foundation in the design of composite beams, columns, and floor plates. Mechanical interactions through shear connectors create a structural system that is not only strong, but also efficient in transmitting forces in the structure. These findings are reinforced by a study by Zhou et al. (2020) that emphasizes the importance of joint design to achieve optimal energy dissipation when buildings receive earthquake loads.

The phenomenon of damage to multi-storey buildings during the earthquakes in Palu (2018), Lombok (2018), and Cianjur (2022) shows that many conventional structures are not able to respond well to lateral loads, resulting in fatal structural collapse. In this context, the findings from Kim & Choi (2017) and Li et al. (2019) are particularly relevant, as they show that composite structures are able to withstand lateral deformation and provide better stability than conventional systems such as monolithic reinforced concrete.

The composite approach also offers advantages in material efficiency and construction speed. In an era of rapid development in cities, time and cost efficiency are the main considerations. Han et al. (2014) showed that concrete-filled steel tube (CFST) shaped composite columns not only have a high compressive capacity but are also easy to install in the field. This provides a great advantage in multi-storey building projects that must be completed within a limited time and still meet structural safety standards.

In addition, the utilization of design technologies such as genetic algorithms and artificial intelligence, as explained by Ahmed & Saka (2015), provides a new dimension in the development of composite structure design. This is particularly interesting considering the current trend in the construction industry to switch to Building Information Modeling (BIM) and parametric design-based approaches to improve accuracy and efficiency. The combination of these technologies allows for more realistic and fast simulation of the performance of composite structures against various dynamic load scenarios.

The results of the literature review also show that composite structures have strategic value in efforts to retrofit existing buildings that are old and prone to earthquakes. The FEMA report (2020) provides a technical justification that strengthening the structure with a composite approach is able to increase seismic resistance without having to dismantle the entire building. This retrofit strategy is especially important in the context of Indonesia, where many government buildings and public facilities were built before the enactment of the latest earthquake standards.

The author's response to this result is very positive, considering that the composite structure not only answers technical needs but is also in line with the principles of sustainability. By reducing the use of excess materials, optimizing structural systems, and speeding up construction times, composite structures support resource efficiency and carbon footprint reduction in the construction sector. This is in line with the Sustainable Development Goals (SDGs), especially goal number 9 on resilient and innovative infrastructure.

However, the author also sees challenges in the widespread application of composite structures in Indonesia, namely the limited technical understanding among local practitioners and the lack of national standards that specifically regulate the design and implementation of steel-concrete composite structures. Although SNI has adopted some parts of the Eurocode and AISC, more specific and applicable technical guidelines are still needed. Therefore, advanced research and technical training for engineers and contractors is very important.

Academically, this study shows that there is a research gap in the local context of Indonesia, where there have not been many experimental or numerical studies conducted to test the behavior of composite structures to dynamic loads in soil and climate conditions in

Indonesia. Most of the references come from overseas studies, so there is still a large room for local data-driven testing, including the influence of soil type, tropical wind loads, and structural behavior when a combination of lateral and vertical loads occurs.

Taking into account all the findings and existing realities, the author recommends that steel-concrete composite structures be used as one of the main alternatives in the development of new multi-storey buildings as well as retrofit programs for existing buildings in disaster-prone areas. In addition to its technical advantages, this structure has proven to be adaptive to future challenges, both in terms of environment, technology, and the needs of sustainable urban development.

## 4. CONCLUSION

Based on the results of the literature analysis of the ten main articles, it can be concluded that steel-concrete composite structures have superior performance in dealing with dynamic loads on multi-storey buildings, especially against earthquake and wind loads. This structure is able to synergistically combine the tensile strength of steel and the compressive strength of concrete, resulting in a strong, rigid, and stable structural system. The use of shear connectors is a key element in ensuring the effectiveness of the interaction between these two materials.

Another advantage found from the literature study is material efficiency and ease in the construction process. Composite columns such as concrete-filled steel tubes (CFST) exhibit higher bearing capacity and stability than conventional structures. In the context of disaster mitigation, this approach has proven to be effective and is one of the potential solutions for retrofitting or strengthening existing buildings, especially in earthquake-prone areas such as Indonesia. This shows that composite structures are not only relevant in a technical context, but also support resilient and sustainable infrastructure development efforts.

As a recommendation, further research needs to be directed to numerical and experimental studies based on local Indonesian conditions. Aspects to consider include the influence of soil characteristics, joint design in the context of tropical lateral loads, and full-scale testing of composite structures in earthquake simulations. In addition, the development of more detailed national technical guidelines related to steel-concrete composite structures is also needed to accelerate the adoption of this system in structural engineering practice in Indonesia.

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## 6. AUTHORS' NOTE

The author states that this article was prepared independently and there is no conflict of interest with any party involved, either directly or indirectly, in the research and writing process. This article is the result of a systematic literature review conducted using a qualitative method based on literature studies, and does not involve laboratory experiments or field studies. Each reference used has been cited and listed in accordance with the applicable academic rules using the APA 7 citation style. The author is also open to constructive input and criticism from readers for future improvements, as well as encouraging further research with an empirical approach to strengthen the findings and recommendations resulting from this study.

## 7. REFERENCES

Ahmed, B., & Saka, M. P. (2015). Optimum design of composite steel I-beams using a hybrid genetic algorithm. Journal of Constructional Steel Research, 104, 22–29. https://doi.org/10.1016/j.jcsr.2014.09.008

Chen, W. F., & Duan, L. (2014). Bridge engineering handbook: Fundamentals. CRC Press.

Creswell, J. W., & Poth, C. N. (2018). Qualitative Inquiry and Research Design: Choosing Among Five Approaches (4th ed.). SAGE Publications.

FEMA. (2020). Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings with Weak First Stories (FEMA P-807). Federal Emergency Management Agency.

Han, L. H., Yang, Y. F., & Liu, H. T. (2014). Behavior of concrete-filled steel tubular stub columns subjected to axial local loading. Journal of Constructional Steel Research, 67(8), 1185–1195.

Johnson, R. P. (2018). Composite Structures of Steel and Concrete (4th ed.). Wiley-Blackwell.

Kim, H. S., & Choi, J. Y. (2017). Dynamic response of multi-story composite buildings under seismic loads. Engineering Structures, 148, 324–336. https://doi.org/10.1016/j.engstruct.2017.06.057

Krippendorff, K. (2019). Content Analysis: An Introduction to Its Methodology (4th ed.). SAGE Publications.

Li, Q., Chen, S., & Yang, Y. (2019). Structural behavior and design of steel-concrete composite frames. Structures, 19, 239–252. https://doi.org/10.1016/j.istruc.2019.02.008

Patton, M. Q. (2002). Qualitative Research and Evaluation Methods (3rd ed.). SAGE Publications.

Setiawan, H., & Nugroho, Y. (2022). Analysis of the seismic vulnerability of multi-storey buildings in Indonesia. Indonesian Journal of Civil Engineering, 29(2), 101–113.

Zhang, X., Yu, Y., & Wang, J. (2021). Performance of composite columns under combined axial and lateral dynamic loads. Engineering Structures, 240, 112382. https://doi.org/10.1016/j.engstruct.2021.112382

Zed, M. (2004). Literature Research Methods. Jakarta: Yayasan Obor Indonesia.

Zhou, H., Chen, Z., & Zhao, Y. (2020). Nonlinear analysis of steel-concrete composite frames under seismic loading. Soil Dynamics and Earthquake Engineering, 133, 106098. https://doi.org/10.1016/j.soildyn.2020.106098