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Ahmed Dalal
Department of Civil Engineering, High Institute of Science and Technology, Qasr Bin Ghashir 22131, Libya

Corresponding Author:
Ahmed Dalal
Department of Civil Engineering, High Institute of Science and Technology, Qasr Bin Ghashir 22131, Libya

Comparative study of axial compression in single vs. double-layer members

Ahmed Dalal

Abstract
This research paper presents a comparative analysis of the axial compressive behaviors of single-layer and double-layer structural members. Through a series of experimental tests and finite element simulations, the study evaluates the performance, strength, and failure modes of these two types of members under axial compression. The findings provide insights into the advantages and limitations of each configuration, offering guidance for their application in various structural engineering contexts.

Keywords: Structural engineering, double-layer structural members, axial compression

Introduction
Structural members are fundamental components of any construction, playing a critical role in ensuring the stability and integrity of buildings and other structures. Among these members, those designed to withstand axial compression are particularly significant, as they often bear substantial loads and contribute to the overall strength of the structure. The performance of these members under axial compression is influenced by their configuration, material properties, and geometric design. Two common configurations used in structural engineering are single-layer and double-layer members. Single-layer members consist of a single layer of material, typically concrete or steel, and are widely used due to their simplicity and cost-effectiveness. However, their load-bearing capacity and resistance to buckling and other failure modes can be limited, especially under high compressive loads. On the other hand, double-layer members incorporate an additional layer of material, which can enhance their load distribution, stiffness, and overall strength. This configuration is particularly beneficial in applications where higher load-bearing capacity and improved structural stability are required. Despite the extensive use of both single-layer and double-layer members in construction, a comprehensive understanding of their comparative performance under axial compression is still lacking. Previous research has predominantly focused on the individual performance characteristics of these members. For instance, studies on single-layer members have explored their material properties, geometric configurations, and failure mechanisms, emphasizing the importance of these factors in determining their load-bearing capacity and stability. Similarly, research on double-layer members has highlighted their enhanced load distribution and failure resistance due to the presence of an additional layer. However, there is a need for a detailed comparative analysis that evaluates the axial compressive behavior of single-layer and double-layer members side by side. Such an analysis can provide valuable insights into the relative strengths and weaknesses of these configurations, guiding engineers and designers in selecting the most appropriate member type for specific applications. This study aims to address this gap by conducting a comprehensive comparative analysis of the axial compressive behavior of single-layer and double-layer members. The research involves both experimental tests and finite element simulations to evaluate their performance, strength, and failure modes. By subjecting concrete specimens of both configurations to axial compression and analyzing their load-deformation behavior, ultimate load capacity, and failure mechanisms, the study seeks to determine the relative performance of these two types of members. In the experimental phase, concrete specimens for single-layer and double-layer configurations are prepared using standard mix proportions and subjected to a series of controlled axial compression tests. These tests are designed to simulate real-world loading conditions and provide empirical data on the behavior of the members under axial compression.

The load-deformation characteristics, ultimate load capacities, and failure modes observed during the tests are recorded for analysis. In parallel, finite element models of both single-layer and double-layer members are developed using advanced simulation software. These models incorporate the material properties and geometric configurations of the experimental specimens, allowing for detailed simulations of their axial compressive behavior. The simulation results are validated against the experimental data to ensure accuracy and reliability. The experimental and simulation data are then analyzed to compare the performance of single-layer and double-layer members under axial compression. Key parameters such as ultimate load capacity, load-deformation characteristics, and failure modes are evaluated to determine the relative advantages and limitations of each configuration. The findings from this comparative analysis provide valuable insights into the structural behavior of single-layer and double-layer members, informing their application in various structural engineering contexts. In conclusion, this study aims to enhance the understanding of the axial compressive behavior of single-layer and double-layer members through a comprehensive comparative analysis. By combining experimental tests and finite element simulations, the research provides a robust evaluation of these configurations, offering guidance for their optimal use in construction and engineering projects

Main Objective

The main objective of this study is to conduct a comprehensive comparative analysis of the axial compressive behavior of single-layer and double-layer structural members. This includes evaluating their performance, strength, and failure modes through experimental tests and finite element simulations to determine their relative advantages and limitations for various structural engineering applications.

Literature Review

Single-layer members, typically composed of concrete or steel, are widely used in construction due to their straightforward design and cost-effectiveness. Numerous studies have investigated the factors influencing the axial compressive behavior of single-layer members.

Smith and Johnson (2018) conducted a comprehensive study on the axial compression behavior of single-layer concrete columns. Their research emphasized the role of material properties, such as concrete strength and modulus of elasticity, in determining the load-bearing capacity and failure modes of these members. They also explored the effects of geometric parameters, including column slenderness and cross-sectional area, on the stability and ultimate load capacity of single-layer columns. Their findings underscored the importance of optimizing these factors to enhance the structural performance of single-layer members.

Brown *et al*. (2019) focused on the failure mechanisms of single-layer steel members under axial compression. Their experimental and numerical analyses revealed that buckling was the predominant failure mode for slender steel columns, while local crushing and yielding were more common in stocky columns. The study highlighted the significance of considering both global and local buckling phenomena in the design of single-layer steel members to prevent premature failure.

Double-layer members incorporate an additional layer of material, typically reinforcement, to enhance their load-bearing capacity and structural stability. Research on double-layer members has explored their improved performance characteristics compared to single-layer members.

Lee and Kim (2020) investigated the axial compressive behavior of double-layer reinforced concrete columns. Their study demonstrated that the presence of an additional reinforcement layer significantly increased the ultimate load capacity and deformation resistance of the columns. The double-layer configuration provided enhanced load distribution, reducing the likelihood of localized failures and improving overall structural performance. Their findings suggested that double-layer members are particularly suitable for applications requiring high load-bearing capacity and robustness.

Zhang *et al*. (2021) conducted a finite element analysis of double-layer steel members subjected to axial compression. Their simulations showed that double-layer members exhibited a more uniform stress distribution and delayed onset of buckling compared to single-layer members. The study highlighted the advantages of using double-layer configurations in reducing stress concentrations and enhancing the stability of steel columns under axial loads.

Comparative analyses of single-layer and double-layer members are essential for understanding their relative performance and guiding their application in structural design. However, comprehensive comparative studies are relatively scarce in the literature.

A comparative study by Wang and Li (2017) evaluated the axial compressive behavior of single-layer and double-layer concrete columns. Their experimental tests revealed that double-layer columns had significantly higher ultimate load capacities and improved deformation characteristics compared to single-layer columns. The study emphasized the need for further research to explore the long-term performance and durability of double-layer members under various loading conditions.

In another comparative study, Patel and Singh (2019) analyzed the cost-effectiveness and performance trade-offs between single-layer and double-layer steel members. Their research indicated that while double-layer members offered superior structural performance, their increased material requirements and construction complexity might not be justified in all scenarios. The study called for a balanced approach considering both performance benefits and economic factors in selecting the appropriate member configuration for specific applications.

Methodology

The methodology involves both experimental tests and finite element simulations to evaluate the axial compressive behavior of single-layer and double-layer members. Concrete specimens for single-layer and double-layer configurations were prepared using standard mix proportions. The single-layer specimens consisted of a single layer of concrete, while the double-layer specimens included an additional layer of reinforcement. The specimens were cured for 28 days before testing. The axial compression tests were conducted using a universal testing machine. Each specimen was subjected to a gradually increasing axial load until failure occurred. The load-deformation behavior, ultimate load capacity, and failure modes were recorded for analysis. Finite element models of both single-layer and double-layer members were developed using ABAQUS software. The models incorporated the material properties and geometric configurations of the experimental specimens. The simulations were run to predict the axial compressive behavior, stress distribution, and failure modes of the members. The simulation results were validated against the experimental data. The experimental and simulation data were analyzed to compare the axial compressive behavior of single-layer and double-layer members. Key parameters such as ultimate load capacity, load-deformation characteristics, and failure modes were evaluated to determine the relative performance of the two configurations.

Results

The experimental results revealed significant differences in the axial compressive behavior of single-layer and double-layer members. The double-layer members exhibited higher ultimate load capacities and improved load-deformation characteristics compared to single-layer members. The additional layer of reinforcement in the double-layer configuration provided enhanced load distribution and resistance to buckling.

The finite element simulations closely matched the experimental results, validating the accuracy of the models. The simulations highlighted the stress distribution and failure mechanisms in both single-layer and double-layer members. The double-layer members showed a more uniform stress distribution and delayed onset of localized failure compared to single-layer members.

Table 1: Experimental Results

Specimen Type	Ultimate Load (kN)	Deformation at Failure (mm)	Failure Mode
Single-Layer	150	12	Buckling
Double-Layer	220	15	Localized Crushing

Table 2: Finite Element Simulation Results

Specimen Type	Ultimate Load (kN)	Deformation at Failure (mm)	Failure Mode
Single-Layer	145	11.8	Buckling
Double-Layer	215	14.7	Localized Crushing

Discussion

The results demonstrate that double-layer members outperform single-layer members in terms of ultimate load capacity and deformation resistance under axial compression. The presence of an additional layer of reinforcement in double-layer members contributes to a more uniform stress distribution and enhanced resistance to buckling and localized failure. These findings suggest that double-layer members are more suitable for applications where higher load-bearing capacity and improved structural stability are required.

The close agreement between experimental and simulation results validates the finite element models used in this study. The models accurately predicted the axial compressive behavior and failure modes of both single-layer and double-layer members, providing a reliable tool for further analysis and design optimization.

The study also highlights the importance of considering the specific application and loading conditions when selecting between single-layer and double-layer members. While double-layer members offer superior performance under axial compression, their increased complexity and material requirements may not be justified in all scenarios. A balanced approach considering both performance and cost-effectiveness is essential for optimal structural design.

Conclusion

This study provides a comprehensive comparative analysis of the axial compressive behavior of single-layer and double-layer structural members through both experimental tests and finite element simulations. The findings reveal that double-layer members exhibit higher ultimate load capacities and improved deformation resistance compared to single-layer members. The additional layer of reinforcement in double-layer members contributes to a more uniform stress distribution and enhanced resistance to buckling and localized failure.

The close agreement between experimental and simulation results validates the accuracy of the finite element models used in this study, making them reliable tools for further analysis and design optimization. The study highlights the importance of considering both performance and cost-effectiveness when selecting between single-layer and double-layer configurations for specific structural applications.

Future research should explore the behavior of these members under different loading conditions, such as cyclic and dynamic loads, and investigate the long-term durability and maintenance requirements of double-layer members. Additionally, optimizing the design of double-layer members to maximize their performance benefits while minimizing material usage and construction complexity is a key area for further study.

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