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Research Article

Axial compressive behavior of recycled aggregate concrete steel composite columns

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Abstract

In this Study the axial load-carrying capacity and behavior of a "Axial Compressive behavior of Recycled Aggregate Concrete Steel Composite Columns" (RACSCC) is investigated experimentally and simulated numerically. The study emphasizes the utilization of materials contributing to the circular economy in construction, specifically integrating steel and recycled aggregate into concrete. The environmentally sustainable concrete columns are formed by filling square steel tube sections with recycled aggregate concrete (RAC). The study includes six SRACC specimens and one bare conventional steel column. The specimens are subjected to axial compressive loading using the displacement control method. The investigation explores the impact of different coarse aggregate sizes of 12 mm, 16 mm, 22.4 mm, 25 mm, and 30 mm, obtained through sieving of demolished buildings materials. The study aims to address the impact of varying aggregate sizes on parameters such as maximum load-carrying capacity, strain, stress, lateral displacement, and failure patterns. The experimental results are validated and compared with the maximum load-carrying capacity, Strain, Stress, Lateral displacement, and failure patterns using numerical simulations conducted with the Ansys Workbench tool. The SRACC column comprises a hollow tube with 20 mm to 22.4 mm and 22.4 mm to 25 mm recycled aggregate and has a maximum load carrying capacity of 610.28 kN at 10 mm displacement. The local buckling failure occurred near the area load applied. The numerical simulations result for the composite columns agreed well with the experimental results. The results show the recycled aggregate concrete (RAC) have a massive potential for construction support in circular economy. To create composite columns using the RAC as an alternative building material that will help to create an environmentally Sustainable construction.

1. Introduction

As natural resources continue to be depleted, the mounting environmental issues highlight the necessity for sustainable growth in a variety of industries, including civil engineering. With its ability to reduce solid waste in landfills, protect the ecosystem, save precious resources, and create self-sustaining material cycles, recycling used concrete stands as a powerful tool to encourage sustainable practices. Additionally, considering to the growing intensity of environmental degradation and resource depletion, the need to recycle and repurpose destroyed concrete has acquired substantial worldwide traction in recent years. The piling of leftover concrete that results from natural catastrophes like earthquakes and hurricanes makes the need for repurposing even more urgent. This predicts a likely

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development whereby demolition firms everywhere will be encouraged to expand their use of waste concrete recycling techniques.

Recycled aggregates could potentially be involved into composite steel columns, which has considerable potential for reducing the environmental effect of building operations. This is accomplished through lowering garbage that goes to landfills and the use of natural resources. Additionally, the use of recycled materials to concrete is showing a remarkable potential for improving its mechanical properties, including compressive and flexural strengths [1-3]. While increasing the total strength of large constructions, the combination of steel and concrete in building structures has shown a demonstrable potential for enhancing resistance to seismic occurrences [4-6]. In the field of construction and high-rise design, where optimization of composite parts has developed into an essential precept, this concept becomes more and more significant.

The outcomes of the research indicate the viability of recycling additional concrete and highlight the importance of recycled aggregate concrete (RAC) because of its advantageous characteristics, such as reduced thermal conductivity, improved ductility, and decreased specific gravity. Additionally, most of the Recycled Aggregate Concretes' (RACs) present applications are concentrated in non-structural areas such pavements and road embellishments. The potential for integrating RACs into structural frameworks, however, is yet largely unreached [7].

The utilization of recycled aggregates in place of natural aggregates in the creation of fresh concrete is at the basis of the current rise in interest in recycling waste concrete [8]. Utilizing their built-in seismic reliability, RACs show considerable potential for a variety of structural applications, prompting more study [9]. This type of recycled concrete, also known as recycled aggregate concrete (RAC), has its roots in early building techniques meant to protect rare natural aggregate supplies while resolving issues with waste storage. Through a series of operations that include crushing, washing, grading, and mixing crushed concrete particles in certain ratios, recycled aggregate is created by partially or entirely replacing recycled aggregate for natural aggregate [10-11]. The effects of aggregate particle size on mechanical characteristics are significant since bigger particles tend to increase compressive strength but may degrade flexural strength [12]. Therefore, it is still important to research how different aggregate sizes affect the flexibility of composite steel columns.

Recycled Aggregate Concretes (RACs) are making themselves competitors in the field of environmentally friendly construction materials, seamlessly collaborating with initiatives to promote low-carbon and sustainable development practices. [13-15]. Since RACs replicate the energy absorption and ductility characteristics of Natural Aggregate Concretes (NACs), which are crucial for obtaining strong aseismic performance, this relevance is especially relevant to seismically active areas [16-20].

The spacing of glass fiber-reinforced polymer (GFRP) spirals was reduced, which improved ductility and lateral confinement. The highest load-carrying capability was demonstrated by GFRP-reinforced recycled aggregate geopolymer concrete columns with eight longitudinal GFRP bars. Because of the greater confinement effect of thicker FRP on the recycled aggregate concrete-filled steel tube column, the specimen contained by a thicker fiber-reinforced polymer (FRP) has a higher axial strength and a larger ultimate strain. Failure mode, ultimate state, axial load-lateral deflection curves, load-strain curves, and dilation behavior are all factors to consider. Using the experimental database, a new ANN model for the load-carrying capacity of concrete-filled steel tube circular elements was also proposed [21-24].

Ali Faghidian studies the residual stress for Thick-Walled Tubes. For reconstructing residual fields and eigenstrains from constrained strain measurements in axially symmetric tubes, the smoothed inverse eigenstrain approach is reexamined. The salient feature of the smoothed inverse eigenstrain method is its capacity to produce an inverse solution that satisfies the requirements of continuum mechanics, in addition to mitigating the disparity between measurements and model predictions. The fewer experimental measurements are required to reconstruct the residual fields in their entirety [25-27].

This research examines the axial compressive behavior of composite steel columns that use -recycled aggregates of varying sizes, including 12 mm, 16 mm, 22.4 mm, 25 mm, and 30 mm. Composite steel column specimens will be subjected to various loading conditions to determine their ultimate compressive strength. This study's findings will be beneficial in understanding how well composite steel columns with recycled aggregates of various sizes perform. The results can be used to improve the design of composite steel columns made from recycled aggregates, resulting in more environmentally friendly and cost-effective building techniques. The study also contributes to the growing body of knowledge on the use of recycled aggregates in the construction industry, which is crucial for creating a more sustainable built environment.

The aim of this research is to investigate how the use of recycled aggregates of varying sizes affects the axial compressive behavior of composite steel columns. The results will inform the development of eco-friendly building techniques and provide valuable insights into the performance of composite steel columns.

The potential integration of Recycled Aggregate Concretes (RACs) into structural frameworks remains largely unexplored, creating a significant knowledge gap in the field. Furthermore, while previous studies have acknowledged the positive mechanical properties of recycled materials, there is a lack of comprehensive research on how different aggregate sizes, particularly in the context of composite steel columns, affect flexibility. This study aims to fill this critical knowledge gap by investigating the axial compressive behavior of composite steel columns utilizing recycled aggregates of varying sizes (12 mm, 16 mm, 22.4 mm, 25 mm, and 30 mm). The research seeks to advance our understanding of the performance of such columns, contributing valuable insights to the design and implementation of more sustainable and cost-effective building techniques. Ultimately, the study strives to bridge the gap between existing knowledge and the potential applications of recycled aggregates in structural frameworks, enhancing the eco-friendliness of construction practices.

2. Materials and Methods

The careful and thoroughly development of a detailed approach, combined with the creative integration of resources accurately chosen for their applicability, serve as the fundamental foundation of this inquiry. This methodical methodology is used to enable a thorough investigation into the many complications that underlying.

Six RACSCC with a 100 x 100 mm cross section and 1000 mm length with different aggregate sizes were subjected to axial compressive loading and studied using the displacement control method. The parameters examined included the aggregate size range of 10 mm, 16 mm, 22.4 mm, 25 mm, and 30 mm, which was sieved from the demolished building. The investigation's primary objective was on the M20 grade of concrete that had been utilized in the Study. The results of the experimental study indicate that recycled aggregate concrete filling inner steel tubes results in an increase in the axial compressive strength and a slight decrease in the ultimate axial strain of concrete compared with conventional hollow steel tubes. It was observed that increasing the amount of recycled aggregate leads to a slight increase in the ultimate axial stress and strain of the RACSCC.

The 6 specimens are validated numerically using the Ansys Workbench simulation tool. The results are compared with the maximum load-carrying capacity and failure patterns.

3. Methodology

Six RACSCC specimens with a 100 x 100 mm cross section and 1000 mm length with different aggregate sizes were subjected to axial compressive loading and studied using the displacement control method. The parameters examined included the aggregate size range of 10mm, 16mm, 22.4mm, 25mm, and 30 mm, which was sieved from the demolished building. The grade of concrete was M20 was used for the study. The results of the experimental study indicate that recycled aggregate concrete filling inner steel tubes results in an increase in the axial compressive strength and a slight decrease in the ultimate axial strain of concrete compared with conventional hollow steel tubes. It was observed that increasing the amount of recycled aggregate leads to a slight increase in the ultimate axial stress and strain of the RACSCC. The 6 specimens are validated numerically using the Ansys Workbench simulation tool. The results are compared with the maximum load-carrying capacity and failure patterns. The flowchart of the methodology is shown in Figure 1.

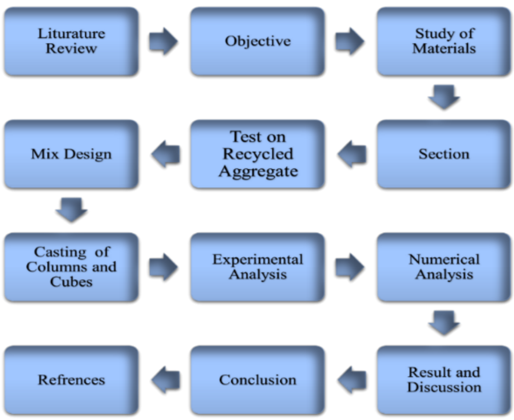

Fig. 1. Flowchart of methodology

3.1. Experimental Analysis

In the experimental work, six composite columns were constructed using steel and concrete with varying sizes of recycled coarse aggregates. The dimensions of the columns were 100 x 100 mm for the cross section and 1000 mm for the length. The primary goal was to investigate how these columns behaved under compression loading until they experienced an axial displacement of 10 mm. The test included six composite column specimens (C1, C2, C3, C4, C5, and C6) along with the Hollow Steel Tube (H), and their descriptions were provided in table 1.

The reference column, C1, had a nominal aggregate size, while the other composite columns had different aggregate sizes. To ensure consistent material qualities, each column underwent a complete curing and drying process. Progressive loads were applied to the columns using a compression test setup, and axial displacement measuring devices (LVDT) were installed to precisely record deformations.

The loading continued until the desired displacement was reached for each column. During the tests, maximum load capacities and deformation characteristics were recorded, while closely monitoring any signs of distress or failure. The failure mode was analyzed, and the impact of recycled coarse aggregate size on the behavior of the composite columns under compression forces was studied.

This part serves as a gateway to the experimental component of the study, providing a broad overview of the experiments that were performed out together with an in-depth description of their results and implications.

3.1.1. Experimental Test Setup

The compression testing equipment that was used as the starting point of the test setup for the composite column included a load frame and hydraulic actuators. Throughout the testing procedure, this specialized equipment performed an important role of systematically and methodically applying incremental loads to the columns. The steel and recycled aggregate concrete composite columns, featuring dimensions of 100 x 100 mm for the cross section and 1000 mm for the length, were securely positioned within the compression testing machine. Each specimen underwent testing, including the hollow tube (H) and the specimens with various aggregate sizes (C1, C2, C3, C4, C5, and C6). Axial displacement measurement systems known as LVDTs (Linear Variable Differential Transformers) were installed to accurately measure the deformations during the test as shown in figure 2. These tools allowed for precise recording of how the columns deformed as the load was gradually applied. The specimens were subjected to compression loading until an axial displacement of 10 mm was obtained. During the loading process, the columns were carefully observed for any indications of distress or failure while their maximum load capacities and deformation characteristics were recorded. The comprehensive analysis of the column's performance and the influence of recycled coarse aggregate size on their structural behavior under compression forces was analyzed.

Table 1. Description of specimens

S. No.	Specimen No.	Description of Specimens
1	H	Hollow Steel Tube
2	C1	Steel tube filled with concrete, mixed with nominal size of recycled coarse aggregates ranges from 4.75 mm to 30 mm.
3	C2	Steel tube filled with concrete, mixed with recycled coarse aggregate size ranges from 30 mm to 25 mm.
4	C3	Steel tube filled with concrete, mixed with recycled coarse aggregate size ranges from 25 mm to 22.4 mm.
5	C4	Steel tube filled with concrete, mixed with recycled coarse aggregate size ranges from 22.4 mm to 20 mm.
6	C5	Steel tube filled with concrete, mixed with recycled coarse aggregate size ranges from 20 mm to 16 mm.
7	C6	Steel tube filled with concrete, mixed with recycled coarse aggregate size ranges from 16 mm to 10 mm.

This section illuminates the carefully regulated environmental circumstances to which... was subjected through a complex description of the specifics relevant to the experimental analysis test setup. This diligent oversight ensures full research with the possibility for replication, acting as a cornerstone in achieving the goal of trustworthy and informative results.

Table 1 below methodically presents the whole information about the specimens, including numerous characteristics and features. This table explores the detailed differences in recycled coarse aggregate sizes that were specifically chosen for the wide range of specimens under study. This is in addition to providing a thorough summary of the specimen data.

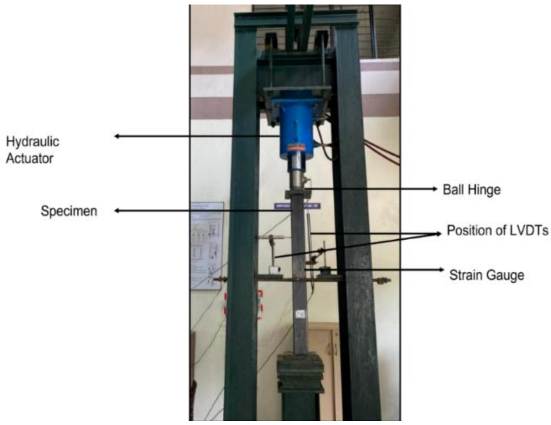

Fig. 2. Axial compression testing machine setup

3.2. Numerical Analysis

The numerical analysis of the composite columns was conducted using ANSYS software. The modeling of composite column is done in ANSYS space claim. The implementation of ANSYS for Numerical Analysis makes it possible for an immersive exploration of the simulated environment, where precise simulations are performed to investigate the complex behavioral characteristics displayed by steel recycled aggregate concrete composite columns under a range of different conditions. This computational effort explores the core of the column's reaction and offers an in-depth understanding of how it responds to various influences and elements in the simulated environment.

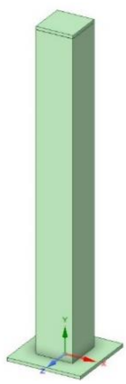

Fig. 3. Composite column modeling in ANSYS space claim

The specimens, labeled as C1, C2, C3, C4, C5, C6, and H (Hollow Steel Tube), were modeled and simulated to examine their response to axial compression. The dimensions of the columns, measuring 100 x 100 mm in cross-section and 1000 mm in length, were accurately represented in the numerical models shown in figure 3. The material properties, including steel and recycled aggregate concrete, were assigned based on their known characteristics and the results of concrete cube testing. In the numerical simulation, the columns were gradually subjected to increasing axial stresses until a displacement of 10 mm was achieved. The analysis yielded valuable findings, such as the distributions of strain and stress within the columns. By performing the numerical analysis in the ANSYS software, a comprehensive understanding of the mechanical response of the composite columns under axial compression was obtained, complementing the results of the experimental tests.

4. Results and Discussion

4.1. Test Observation and Failure Modes

This section presents a comprehensive narrative that intricately depicts the actual structural behavior exhibited by Steel Recycled Aggregate Concrete Composite Columns. The investigation delves deeply into the realm of test observations and failure mechanisms, offering a detailed tapestry of the columns' response to axial compressive behavior. The paper combines meticulous experimental exploration and advanced numerical analysis to provide insights into the ever-changing behavior of the columns. The understanding, derived from both experimental data and numerical insights, is extensive and multidimensional.

All six test specimens of the steel recycled aggregate concrete composite columns underwent failure analysis during axial compressive loading, as depicted in Figure 3. The resulting failure patterns reveal compressive failure at the uppermost part of the column due to the impact of compressive force. Unequal load distribution, stemming from eccentricity caused by factors like stress distribution variations, cross-sectional area differences, or initial misalignment, leads to non-uniform compressive force distribution along the column's length. This eccentricity, influenced by stress concentration, uneven cross-sectional areas, or structural imperfections, particularly the column's original out-of-straightness, results in greater compressive stress on the upper portion, leading to premature collapse.

Table 2. Comparative analysis of experimental and numerical results for SRACC columns

Column Specimen	Experimental simulation			Numerical simulation		
	Axial load, kN (max)	Axial displacement, mm (max)	Lateral displacement, mm (max)	Axial load, kN (max)	Axial displacement, mm (max)	Lateral displacement, mm (max)
H (hollow tube)	86.69372	10	2.68	100.744	10	2.773
C1	610.28	10	5.44	596.341	10	5.1589
C2	557.9329	10	5.73	597.924	10	5.829
C3	567.1965	10	5.17	598.995	10	5.271
C4	539.5923	10	5.08	598.552	10	5.203
C5	544.81	10	5.6	599.239	10	5.6987
C6	576.7239	10	5.2	610.285	10	5.663

The consistent failure pattern across all specimens, unaffected by the use of recycled coarse aggregate concrete in various size ranges, points to an initial flaw, such as a deviation in straightness, intensifying local stress concentration. This study not only sheds light on the behavior of steel recycled aggregate concrete composite columns under compressive loads but also underscores the critical significance of accurate design and detailing in averting premature failure. The findings emphasize the imperative role of meticulous design and additional information in preventing instances of early failure by gaining profound insights into the behavior of these composite columns under compressive pressures.

Figure 4. Failure mode in experimental investigation

A detailed summary of the observed outcomes for each sample of SRACC columns, based on both experimental testing and numerical simulations, is shown in Table 2 below. The table is an invaluable resource that provides a concise, in-depth analysis that highlights the degree of agreement between numerical forecasts and experimental trial results. We compare these findings in order to verify that numerical simulations are a reliable means of forecasting the complex behavior of SRACC columns under different loading scenarios. Important parameters are included in this comparison study, which enables a thorough assessment of the model's dependability and correspondence with experimental data.

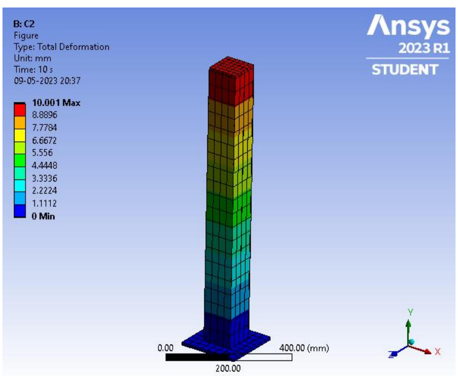

Fig. 5. Total deformation schematic view in numerical analysis

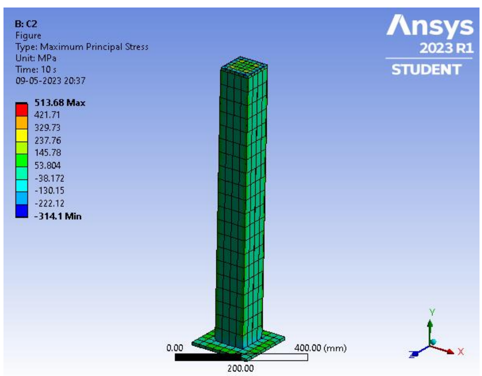

Fig. 6. Stress schematic view in numerical analysis

4.2. Axial Load–Axial Displacement Relationship

The relationship between axial load and axial displacement revealed significant information regarding the structural response to varying compressive pressures. The distinctive patterns in the axial load-axial displacement curves highlighted the column's deformation characteristics as the load increased. The curve in Figure 8 and Figure 9 illustrates the relationship between axial load and axial displacement for all specimens exposed to axial compressive stress for experimental analysis and numerical analysis, respectively. Each specimen was evaluated for a displacement of 10 mm, and both experimental analysis and numerical analysis were done on it.

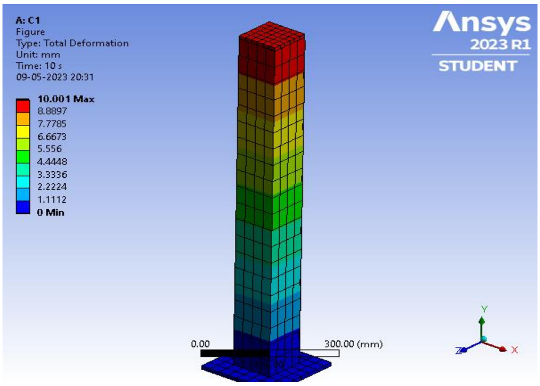

Fig. 7. Schematic view axial displacement in ANSYS

The axial displacement curves for the columns, indicated by the characters C1, C2, C3, C4, C5, C6, and H (Hollow Steel Tube), were observed. Among the columns, C1 exhibited the highest load at the displacement of 10 mm. In the experimental analysis, column C1 reached a maximum load of 610.28 kN, while in the numerical analysis, it achieved a maximum load of 596.72 kN. These values demonstrate the column's response to the applied axial stress. Three separate stages—elastic, yielding, and failure were seen on the curve. The graph shows linear displacement proportional to the increasing load during the elastic period. As soon as the yield point was reached, irreversible plastic deformation caused the yielding phase to behave nonlinearly. Additionally, it was found that the peak load rose as the size of the recycled coarse aggregate decreased, indicating changes in the compression behavior.

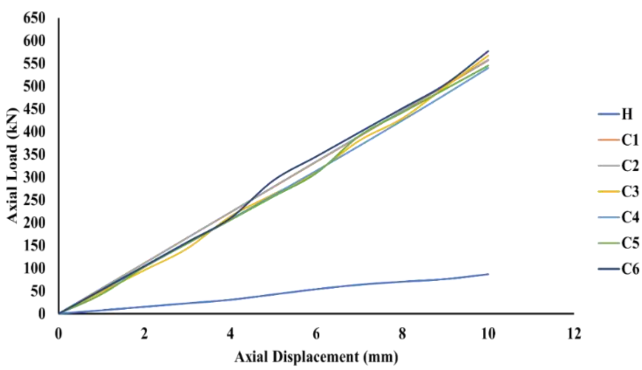

Fig. 8. Axial load vs axial displacement experimental analysis result curve

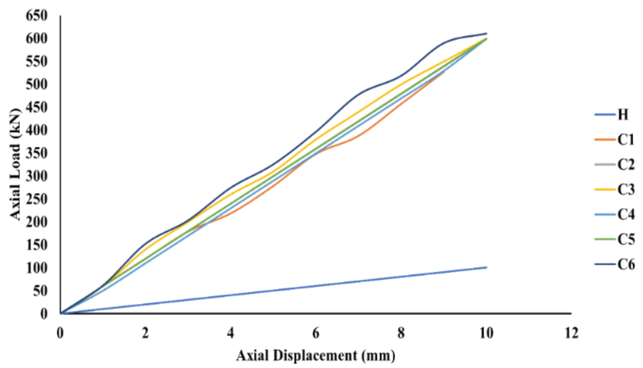

Fig. 9. Axial load vs axial displacement numerical analysis result curve

4.3. Axial Load–Lateral Displacement Relationship

The curve in Figure 11 and Figure 12. illustrates the relationship between Axial Load–lateral displacement relationship for all specimens exposed to axial compressive stress for experimental analysis and numerical analysis, respectively. The comparison between experimental and numerical data for the axial load-lateral displacement relationship allowed us to gain insight into the behavior of the composite columns. The numerical analysis yielded a slightly higher result of 5.829 mm compared to the experimental study, where a maximum lateral displacement value of 5.73 mm was observed.

The reliability and accuracy of the numerical simulation are certainly highlighted by the strong concordance between these two different approaches. The exact same patterns in the curves of the axial load-lateral displacement connection were clearly shown by both the thoroughly experimental investigation and the complex numerical analysis. These curves were initially defined by a linear response, but when lateral displacement increased gradually, they gracefully crossed over into the domain of nonlinear behavior.

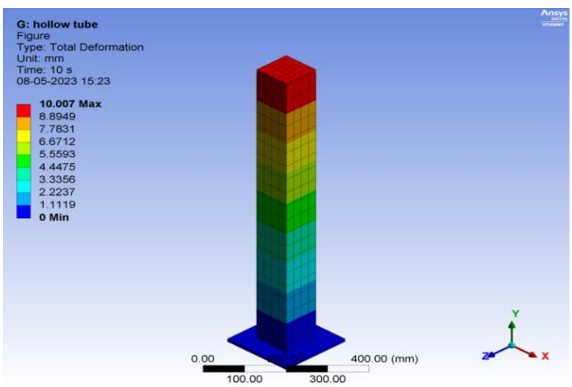

Fig. 10. Simulation Result in ANSYS

A more comprehensive understanding of the material's complex lateral response as it continuously interacts with increasing axial loads can be obtained through an in-depth investigation of the relationship between axial load and lateral displacement. This incisive analysis offers a lot of insightful information that is relevant to both theoretical and practical design and engineering considerations, as well as theoretical research.

Understanding how axial loading and lateral displacement interact allows for the development of effective and solid structural designs that take into consideration the behavior of the material under actual stress circumstances.

This perfect learning of findings from the experimental and numerical worlds adds a lot to our understanding. We obtain insights by examining the unique characteristics of these behaviors under axial loads that not only enhance our understanding but also enable observation and improving of composite column designs, leading the way for improved efficiency and analysis.

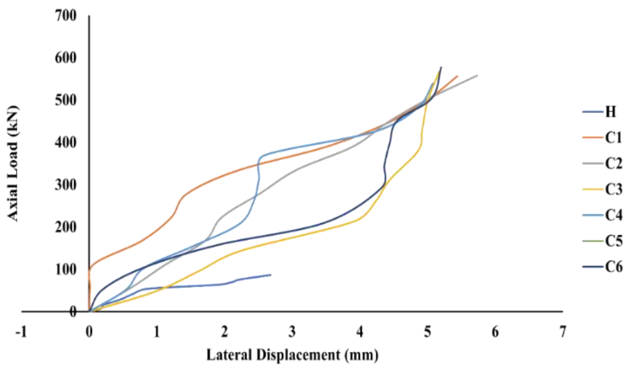

Fig. 11**.** Axial load vs lateral displacement experimental analysis result curve

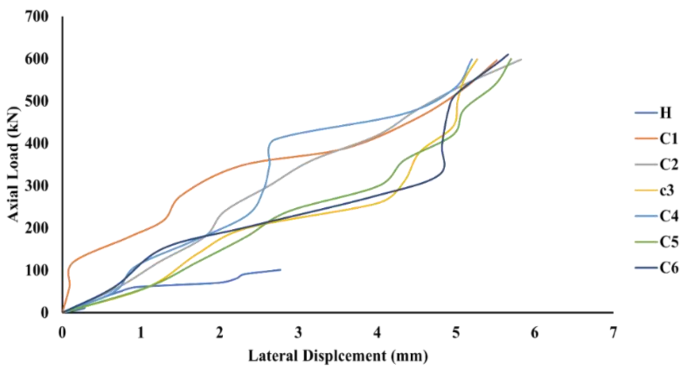

Fig. 12. Axial load vs lateral displacement numerical analysis result curve

4.4. Axial Load–axial strain relationship

The relationship between axial load and axial strain for all specimens exposed to axial compressive stress for experimental analysis and numerical analysis, respectively, is shown by the curve in Figure 14 and Figure 15 respectively. The columns' stress-strain curves, named C1, C2, C3, C4, C5, C6, and H (Hollow Steel Tube), were observed. The experimental analysis provided the following relationship graphs between axial load and axial strain: After being Displaced by 10 mm, the analyzed column's axial load and axial strain relationship curve showed a typical reaction. As the load increased, the curve transitioned from an initial linear elastic area into a plastic zone. It is noted that column C1 showed a maximum strain in the numerical analysis of 0.004465 and an associated axial load value of 596.34 kN. According to the experimental study, column C3 experienced a maximum strain of 0.004442, on an axial load of 567.19 kN.

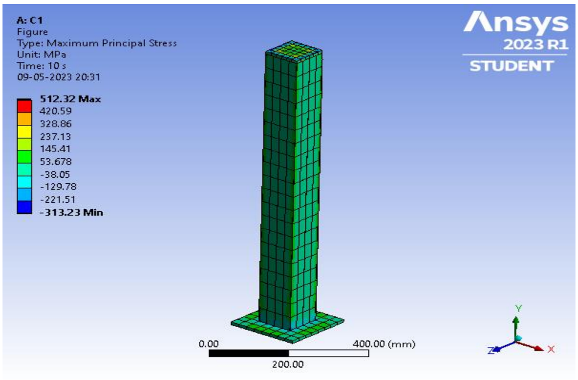

Fig. 13. Maximum principle stress simulation result

A full understanding of the material's unpredictable response as it interacts with gradually increasing axial loads is provided by the complex relationship that exists between axial load and axial strain.

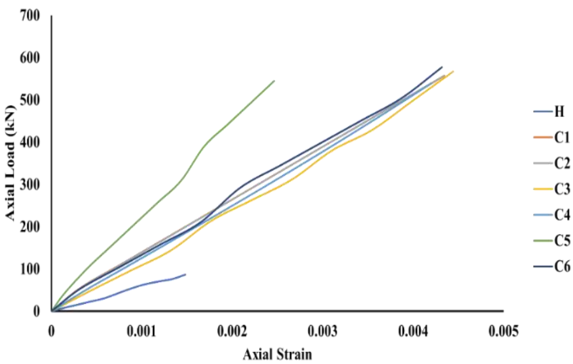

Fig. 14. Axial load vs axial strain experimental analysis result curve

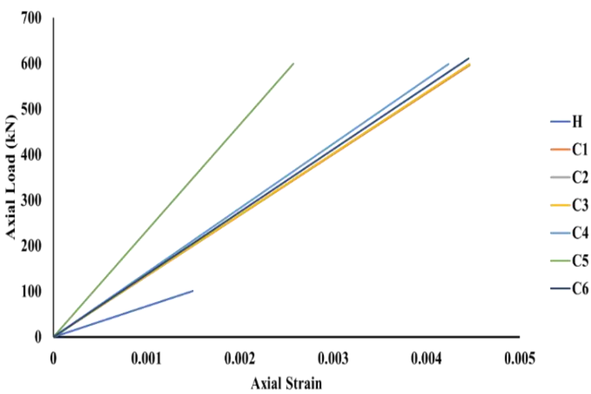

Fig. 15. Axial load vs axial strain numerical analysis result curve

This thorough research offers essential information that go beyond the surface, exploring the material's stiffness, yielding behavior, and ultimate strength when subjected to various axial loading levels. This in-depth knowledge of the material's mechanical behavior, which represents every stage from early elasticity to the point of yielding and final structural capacity, serves as essential for well-informed design and engineering considerations.

Considering the context of numerical analysis, the result of the numerical analysis, which described the relationship between axial load and axial strain in the column, showed a remarkable agreement with the experimental curve. This uniformity, a demonstration of the numerical model's accuracy, serves as a clear validation of its reliability. The simulation's capacity to accurately represent the structural integrity of the column in all of its details was demonstrated as its virtual environment consistently reflected the reality of the actual world.

4.5. Axial Stress – Axial strain relationship

The axial stress and axial strain relationship curve for the analyzed column, subjected to a 10 mm displacement, was assessed through experimental and numerical analysis. The connection between stress and strain is shown in Figure 17 and Figure 18 providing insights into the column's behavior under load. The experimental curve displayed three phases: elastic, yielding, and failure.

During the elastic phase, the curve exhibited a linear stress-strain relationship, indicating elastic deformation. As the load increased, the curve transitioned into the yielding phase, characterized by significant plastic deformation and a nonlinear stress-strain relationship. The maximum strain in column C3 was 0.004442 (experimental) and 0.004465 (numerical), while in column C1, it was 0.004442 (experimental) and 0.004465 (numerical). Peak stress values varied among columns based on the size of the recycled coarse materials, highlighting the impact of aggregate size on the column's response to axial stress.

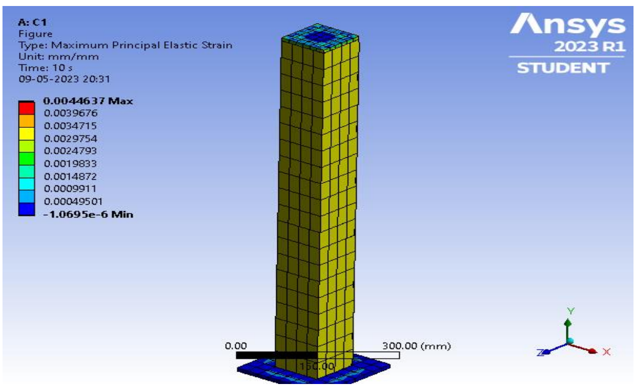

Fig. 16. Maximum principle strain simulation result

As the experimental curve effectively coincided with the results obtained from detailed numerical analysis, its accuracy was certainly confirmed. This complete agreement strengthened our confidence in the experimental results and enhanced our understanding of the complex details guiding the column's complex behavior to the continuous force of axial stress.

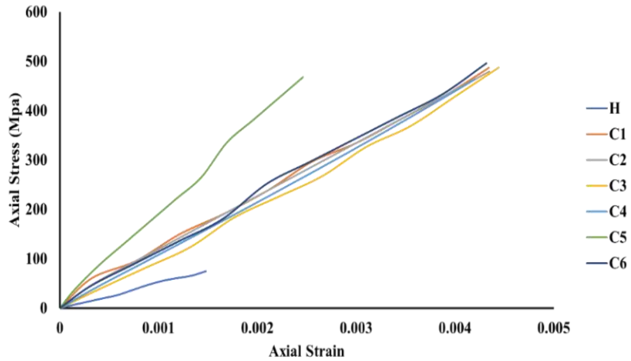

Fig. 17. Axial stress vs axial strain experimental analysis result curve

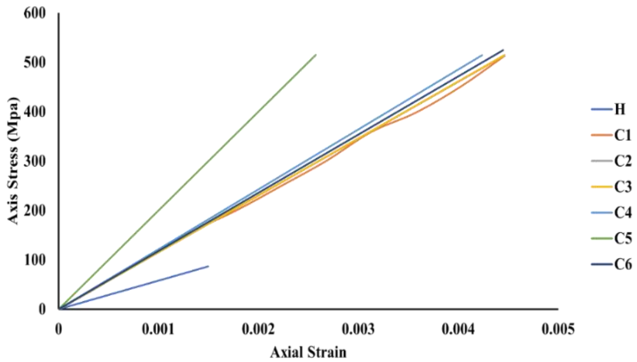

Fig. 18. Axial stress vs axial strain numerical analysis result curve

5. Critical Review and Discussions

The conclusions drawn from the experimental analysis and numerical simulations provide valuable insights into the performance of Steel Recycled Aggregate Concrete Composite (SRACC) columns. The axial compression tests on six specimens, featuring variations in the size of coarse aggregates, allowed for a comprehensive understanding of the effects of these modifications on stress, strain, ultimate strength, and load-bearing capacity.

The study highlighted a noteworthy finding concerning the strength of recycled aggregate concrete, indicating a 5% decrease compared to concrete with natural aggregates. This decline is attributed to the complete substitution of natural aggregates with recycled resources for both coarse and fine aggregates. However, the inclusion of recycled fine aggregate, containing fine cementitious substances, demonstrated an improvement in the strength properties of recycled fine aggregate concrete.

The experimental results showcased the superior compressive strength of the C6 column, while numerical analysis indicated a slightly lower strength. Discrepancies in strain values between experimental and numerical analyses for the C1 and C3 columns were observed, underscoring the need for precision in both methods.

The successful validation of experimental results by numerical analysis, with differences ranging from 2% to 5% across samples, substantiates the accuracy and dependability of the numerical simulation. However, the study identified a consistent compression failure in the uppermost portion of each specimen, suggesting irregular load distribution along their length. To address this, better load distribution methods are recommended for achieving a more uniform stress distribution.

the study emphasized the superior performance of composite columns C2 and C3 in terms of load, stress, strain, and displacement. Both experimental and numerical analyses supported the recommendation to implement these columns in practical applications. The concrete mixture with recycled aggregates ranging from 20 mm to 22.4 mm for C2 and 22.4 mm to 25 mm for C3 contributed to their enhanced performance characteristics. This practical recommendation aligns with the broader objective of promoting environmentally sustainable construction practices within the framework of a circular economy.

For the future studies that will forward the study of composite steel columns made using recycled aggregates. First off, more research into the long-term robustness and structural integrity of composite columns using recycled aggregates in different sizes might prove to be beneficial. A thorough grasp of the sustainability of these composite columns would also benefit from evaluation of their life cycle analysis and environmental effect. Enhancing the mix proportions of recycled aggregates to improve mechanical characteristics and reduce environmental impact might be the subject of future study. It would also be beneficial to look at how these columns might work in various structural arrangements and real-world building situations. Finally, working together with industry stakeholders might make it easier to translate research findings into real construction procedures, encouraging the broad use of environmentally friendly building methods.

6. Conclusions

A detailed and in-depth investigation was carefully performed for the purpose of this deep research study. The primary objective of this study was to gain insight into the complex mechanics of axial load-carrying capacity and the complex behavior demonstrated by columns that represent the core characteristics of Axial Compressive behavior of Recycled Aggregate Concrete Steel Composite Columns (RACSCC).The results shown have emerged like a thoroughly made pattern, generated by the comprehensive evaluation of facts and information, and have been guided by the priceless knowledge gathered from real-world experiments and numerical simulation. The experimental investigation involved axial compression tests on six specimens of recycled aggregate concrete square steel columns, with designed variations in the size of coarse aggregates. The analysis of stress, strain, ultimate strength, and load-bearing capacity of the specimens revealed the effects of these modifications. The study demonstrated that the strength of recycled aggregate concrete was approximately 5% lower compared to concrete made with natural aggregates. This decrease can be attributed to the complete substitution of natural aggregates with recycled resources, both for coarse and fine aggregates. Additionally, it was observed that the inclusion of recycled fine aggregate, containing fine cementitious substances, in the concrete mixture improved the strength properties of recycled fine aggregate concrete.

The experimental study revealed that the C6 column exhibited a significantly higher compressive strength of 610.28 kN, while the numerical analysis indicated a slightly lower strength of 576.72 kN. Furthermore, the numerical analysis showed that the C1 column had a higher strain value of 0.004465, whereas the experimental analysis showed a slightly higher strain of 0.0044424 for the C3 column. The numerical analysis using ANSYS software successfully validated the experimental analysis results, with a slight difference ranging from 2% to 5% across each of the samples. This confirms the accuracy and dependability of the numerical simulation. The analysis of each specimen indicated that the uppermost portion consistently experienced compression failure, suggesting irregular load distribution along the length of the specimens. To achieve a more uniform stress distribution, better load distribution methods should be employed. In conclusion, the study found that composite columns C2 and C3 outperformed all other columns in terms of load, stress, strain, and displacement, as supported by both experimental and numerical analyses. The use of concrete mixed with recycled aggregates ranging from 20 mm to 22.4 mm for C2 and 22.4 mm to 25 mm for C3 resulted in these superior performances. Consequently, it is recommended to implement composite columns C2 and C3 as the preferred choice for practical applications, considering their enhanced performance characteristics.

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