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The Use of Reinforced Concrete for Durable and Aesthetic Sports and Recreational Sports

Nwanneka Mmonwuba [a*], Emmanuel Ifeanyi Ogunjiofor [b], Ogudebe Chukwuebuka Samuel [b], Okafor Odinaka Kindness [b] and Dominic Machi Chiagozie [b]

[a] Chukwuemeka Odumegwu Ojukwu University, Nigeria.
[b] Department of Civil Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study focuses on the design and construction of durable recreational seating using reinforced concrete, addressing the limitations of traditional materials such as wood and metal, which are prone to environmental degradation and high maintenance costs. Reinforced concrete is known for its durability, strength, and resistance to harsh weather conditions, making it an ideal material for public seating in outdoor environments. Several key tests were conducted to assess the performance of the concrete mix used in this project. Sieve analysis confirmed that the fine and

**Corresponding author: Email: nc.mmonwuba@coou.edu.ng;*

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coarse aggregates were well-graded, ensuring optimal compaction and strength. The slump test,conducted with a water-cement ratio of 0.6, produced a slump value of 150 mm, indicating medium workability. This level of workability is suitable for concrete that requires easy placement and proper compaction without segregation or excessive bleeding. The compressive strength test at 7 days yielded a compressive strength of 15.81 MPa, demonstrating the early strength development of the concrete. However, compressive strength results for the 14-day and 28-day tests are still pending, as the remaining cubes are currently in the curing tank. These results will provide further insights into the long-term strength and performance of the concrete once the curing process is completed. Preliminary findings suggest that reinforced concrete is an excellent choice for recreational seating due to its ability to provide long-lasting durability and reduced maintenance. The combination of well-graded aggregates, an optimal water-cement ratio, and promising early compressive strength indicates that this material will perform well under both static and dynamic loads typically encountered in public seating.

Keywords: Reinforced concrete; compressive strength; sieve analysis; slump test; workability.

1. INTRODUCTION

The role of recreational seating in public spaces cannot be understated, especially when considering its function in providing comfort, encouraging social interactions, and enhancing the aesthetic value of an environment. This chapter reviews the literature related to the design, construction, and material selection for reinforced concrete recreational seating, focusing on the challenges, advantages, and disadvantages of using various materials. Special emphasis is placed on reinforced concrete due to its widespread use in outdoor seating applications, where durability and minimal maintenance are key concerns. (Ogunjiofor and Ayodele 2023)

Previous studies have explored the materials and construction techniques used in creating durable and sustainable seating structures, with recent innovations focusing on improved reinforcement techniques, fiber-reinforced concrete (FRC), and high-performance concrete (HPC) (Ogunjiofor, et al, 2024; Feizbahr and Pourzanjani, 2024; Nervi, 2018). This chapter also highlights the environmental considerations surrounding material sourcing and green concrete technologies that are becoming increasingly relevant in modern construction practices (Ogunjiofor, et al, 2023a).

In recent years, the design of recreational seating has undergone significant changes, with a shift towards modular, sustainable, and ergonomic designs (Ogunjiofor, 2020). The use of materials such as fiber-reinforced concrete (FRC) and self-compacting concrete (SCC) has provided new possibilities for creating seating that is both durable and easy to maintain (Ogunjiofor, et al, 2023b; Li & Xing, 2017). Modular seating designs allow for greater flexibility in terms of placement and configuration, making them ideal for public spaces that require adaptable furniture (Patel & Rao, 2020).

2. MATERIALS AND METHODS

2.1 Constituent Materials of Concrete

The materials used in this study were carefully selected based on their availability, cost-effectiveness, and performance characteristics. The following are the primary materials used:

1. Cement:
2. Fine Aggregate:
3. Coarse Aggregate:
4. Portable Water

2.1.1 Sample collection

The materials for this study were sourced from Uli and Ihiala, ensuring they met the required quality standards for concrete production. Fine aggregate (sand) was obtained from a supplier in Uli, while BUA Cement, reinforcement bars, and coarse aggregate (chippings) were sourced from reputable suppliers in Ihiala. All materials were carefully collected and transported to the Civil Engineering Laboratory of Chukwuemeka Odumegwu Ojukwu University, Uli Campus, where preliminary tests and concrete production were conducted under controlled conditions to ensure material integrity and quality.

2.1.1.1 Cement (BUA Cement)

The cement used in this study was BUA Cement, sourced from a local distributor in Uli. BUA

Cement is known for its high compressive strength and consistent performance in various construction applications. To ensure the quality of the cement, it was stored in a dry environment, protecting it from moisture and preventing any degradation that might affect its binding properties. The cement was tested for consistency and setting time before use to ensure it met the required standards for durable concrete production.

2.1.1.2 Fine aggregate

The fine aggregate used in this study was sourced from a local supplier in Uli. The aggregate, composed primarily of clean, well-graded sand, had a maximum particle size of 4.75mm. The fine aggregate was chosen based on its quality and suitability for concrete production, ensuring compliance with standard specifications. To ensure that it would not negatively affect the strength or durability of the concrete, the sand was thoroughly washed to remove any impurities such as silt, clay, or organic matter. After washing, the sand was air-dried and subjected to sieve analysis to verify its particle size distribution. This process confirmed that the fine aggregate met the necessary grading requirements for use in concrete, contributing to the overall workability and strength of the mix.

2.1.1.3 Coarse aggregate (Chipping)

The coarse aggregate used in this study consisted of chippings sourced from a well-established supplier in Ihiala. The aggregate, with particle sizes ranging from 10mm to 20mm, was selected based on its angular shape, which enhances interlocking within the concrete matrix and contributes to the overall structural integrity. The coarse aggregate was thoroughly washed to remove dust, fine particles, and any contaminants that could affect the quality of the concrete. After cleaning, the aggregate was stored in a dry environment to prevent moisture absorption before being used in the concrete mix. The combination of angular chippings and proper handling ensured that the coarse aggregate would enhance the strength and durability of the concrete, in line with standard construction practices.

2.1.1.4 Portable water

The water used for mixing and curing the concrete was sourced from the Civil Engineering Laboratory at Chukwuemeka Odumegwu Ojukwu University, Uli Campus. Portable water is crucial in concrete production as it directly affects the chemical reactions between the cement and aggregates. The water was free from any impurities such as salts, oils, or organic matter, which could interfere with the hydration process and reduce the strength of the concrete. The water quality was tested to ensure it met the standards for potable water as prescribed by relevant engineering codes. The use of portable water from a controlled laboratory environment ensured that the concrete mix achieved the desired consistency and strength.

This methodology and materials section offers a comprehensive overview of the materials used in the study and the procedures followed to ensure the quality and reliability of the concrete produced. Each material was selected with careful consideration of its properties, and the entire process was conducted under strict quality control measures to ensure that the final product met the desired standards of strength and durability.

2.1.1.5 Reinforcement bar

Reinforcement bars, commonly known as rebar, were used to enhance the tensile strength of the concrete. The rebar used in this study was sourced from a reputable supplier in Uli, ensuring that it met the required standards for construction purposes. The rebar was carefully selected based on its grade, diameter, and surface characteristics to ensure optimal bonding with the concrete. The reinforcement bars were cleaned to remove any rust or contaminants that could affect their performance within the concrete matrix.

The use of 10mm reinforcement as the main bar and 8mm as the distribution bar align with standard codes of practice, such as BS 8110 or Eurocode 2. These standards provide guidelines on the minimum diameter of reinforcement bars required for different structural elements, ensuring adequate strength and durability.

- 10mm Main Bars: These are typically used in elements where higher tensile stresses are expected, such as in the tension zone of beams or slabs. The choice of 10mm bars is common for moderately loaded structures, ensuring sufficient tensile strength.
- 8mm Distribution Bars: Distribution bars are used to hold the main bars in position

and to distribute loads evenly across the concrete. The 8mm diameter is often used in slabs, where it helps prevent cracking and ensures that the load is spread out over the structure.

These standards ensure that the selected bar sizes will provide the necessary strength and stability for the reinforced concrete structure.

2.2 Tests on Fresh Concrete

Test on fresh concrete are conducted immediately after the concrete mix is prepared. These tests assess the workability, consistency, and other properties of fresh concrete, ensuring that it can be easily placed and compacted without segregation or excessive bleeding.

2.2.1 Slump test

Slump test is a simple and widely used method to measure the workability or consistency of fresh concrete. It provides an indication of how easily the concrete can be mixed, transported, placed, and compacted. The test is particularly important because it helps ensure that the concrete has the right balance of fluidity and stiffness for the intended application.

Apparatus:

1. Slump cone
2. Tamping rod
3. Base plate
4. Measuring scale
5. Fresh concrete sample

2.3 Tests on Hardened Concrete

Tests on hardened concrete are conducted after the concrete has cured to assess its structural properties, such as compressive strength, durability, and resistance to environmental factors. These tests are crucial for ensuring that the concrete meets the design specifications and can with stand the loads and conditions it will encounter in service.

2.3.1 Compressive strength test

Compressive strength test is one of the most fundamental tests performed on hardened concrete to determine its ability to withstand loads that tend to compress it. The compressive strength is a critical parameter that indicates the materials structural capacity and durability. It is essential in ensuring that the concrete used in construction can bear the loads and stresses it will encounter in service.

Apparatus:

1. Compressive testing machine
2. Cured concrete cube or cylinder specimens.
3. Caliper for measuring dimensions.
4. Weighing balance
5. Recording device for load measurements.

Fig. 1. Slump test apparatus

2.4 Concrete Mix Design

The concrete mix design was developed with the goal of producing durable and workable concrete mixture suitable for the projects structural requirements. The chosen mix ratio of 1:3:6 was carefully determined to balance the cement, fine aggregate, and coarse aggregate, ensuring the desired properties in the final concrete.

2.4.1 Understanding the 1:3:6 mix ratio in the 1:3:6 mix ratio

1 part cement: cement was used as a primary binding material. It provided the necessary adhesive properties that held the concrete mix together once it hardened. The choice of cement was crucial in achieving the required strength and durability.

3 part fine aggregate: The fine aggregate or sand was utilized to fill the voids between the coarse aggregates, ensuring a dense and compact mix. The sand contributed to the workability of the concrete, making it easier to handle and place.

6 parts coarse aggregate: coarse aggregate, such as gravel or crushed stone, was incorporated as the bulk materials in the concrete. It provides the structural integrity and strength required for the fine concrete product. The selection of the appropriate size and grading of the coarse aggregate was essential to achieve a strong and durable concrete mix.

2.4.2 Mix design process

This section details the process of creating the concrete mix according to the selected ratio.

2.4.2.1 Batching

Batching involved measuring the materials accurately according to the mix ratio of 1:3:6. The cement, sand and coarse aggregate were weighed and proportioned separately to ensure that the mix met the designed specifications. Precision in batching was essential to maintain consistency in concrete quality.

2.4.2.2 Mixing

The materials were then thoroughly mixed to create a homogeneous concrete mixture. The mixing process was conducted either by hand or a mechanical mixer, depending on the batch size. The goal was to ensure even distribution of the cement paste around the aggregate, leading to a consistent mix that would see and harden uniformly.

2.4.2.3 Testing and adjustment

After the initial mixing, the fresh concrete was tested for workability using a slump test. Based on the test results, minor adjustments to the water content were made to achieve the desired consistency. This step was crucial to ensuring that the concrete could be placed and compacted effectively without compromising its strength.

2.4.2.4 Placement and curing

Once the mix was deemed satisfactory, the concrete was placed in the prepared forms and compacted to eliminate air voids. Proper curing techniques such as keeping the concrete moist and protected, were employed to allow the concrete to gain strength gradually. The curing process was monitored to ensure that the concrete achieved it intended properties over time.

2.4.3 Mix proportions and adjustment

2.4.3.1 Monitoring mix proportions

During the mixing process, the proportions of the materials were closely monitored to ensure consistency across all batches of concrete. Regular checks were performed to conform that the cement, sand, and coarse aggregate were being added according to the 1:3:6 ratios. This attention to detail was crucial in preventing deviations that could affect the strength and durability of the concrete.

2.4.3.2 Adjustments for consistency

If the initial test results indicated that the concrete was either too stiff or too fluid, adjustments were made to the mix. For example, if the concrete showed signs of excessive workability (too wet), the water content was reduced slightly to bring it back within the desired range. Conversely, if the mix was too dry, a small amount of water was added to improve its workability. These adjustments ensured that the concrete would perform well during placement and curing.

2.4.4 Application of the design mix

2.4.4.1 Concrete placement

After the final mix design was confirmed, the concrete was placed into the forms prepared for the structure.

The placement was done with care to avoid segregation of the mix components. The concrete was poured steadily and uniformly, ensuring that it filled all areas of the formwork without creating voids or air pockets.

2.4.4.2 Compaction

To achieve a dense and durable concrete structure the mix was thoroughly compacted using vibrators or manual tamping. Compaction was essential in eliminating trapped air and ensuring that the concrete fully surrounded the reinforcement bars. Proper compaction was also key to achieving the desired surface finish and structural integrity.

2.4.4.3 Finishing and curing

Once the concrete was placed and compacted, the surface was finished according to the project specifications. The concrete was then cured by keeping it moist for a specific period, usually by covering it with wet burlap, plastic sheeting, or by pounding water on the surface. This curing process was vital to prevent premature drying and to allow the concrete to reach its full strength.

2.4.5 Performing evaluation

2.4.5.1 Strength testing

Samples of the concrete were taken during the placement process and subjected to compressive strength tests at various intervals, such as 7days, 14days, 21 days and 28 days after casting. These tests were conducted to verify that the concrete met the required strength specification.

2.4.5.2 Durability assessment

In addition to strength tests, the durability of the concrete was assessed through visual inspections. These assessments help determine whether the concrete would withstand environmental conditions over its intended lifespan.

2.4.6 Workability review

The workability of the concrete was reviewed throughout the construction process to ensure that it could be easily placed and finished without segregation to excessive bleeding. The feedback from the construction team was used to refine the mix design if necessary for future applications.

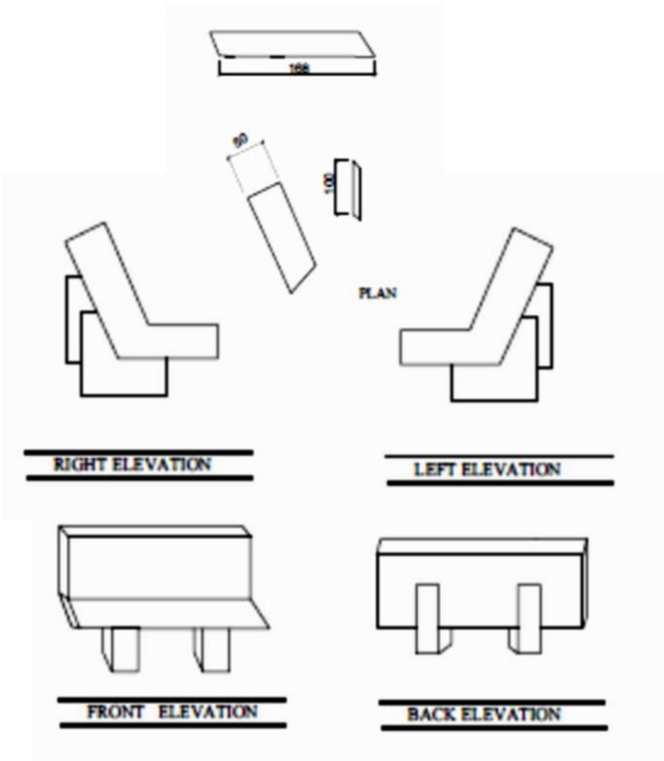

Fig. 2. Architectural drawing of the recreational seat

2.5 Design and Detailing

The design of the reinforced concrete recreational seat was developed with a focus on achieving both aesthetic appeal and structural integrity. The seat was designed for outdoor recreational use, intended to withstand varying loads from public usage and environmental exposure. The design process took into account the proper placement of reinforcement bars and the necessary dimensions to ensure durability and comfort.

2.5.1 Architectural design

The architectural design illustrates the dimensions, form, and structure of the seat, ensuring that the concrete mix, reinforcement bars, and overall shape work together to provide maximum strength and durability. The design allows for even distribution of loads through the concrete and reinforced structure. The seat's shape and surface were also designed with ergonomics in mind, ensuring user comfort while maintaining a simple and functional aesthetic suitable for public spaces.

2.5.2 Reinforcement detailing

The reinforcement detailing includes the use of 10 mm bars as the main reinforcement, which are placed to handle the primary tensile forces. 8mm bars were used as distribution bars, ensuring that the load was evenly spread across the seat, minimizing the risk of cracking or structural failure. The bars were placed in both horizontal and vertical grids, following standard practices for reinforced concrete, ensuring maximum structural support.

To further enhance the durability, the design also considered adequate concrete cover for the reinforcement, protecting it from environmental degradation, including moisture and potential corrosion. This detailing ensures the long-term performance of the recreational seat in an outdoor environment.

Below is the architectural drawing and reinforcement detailing of the recreational seat, showing the dimensions, arrangement of the reinforcement bars, and overall structure.

3. RESULTS

This chapter presents and discusses the results from the three key tests conducted during the study on the design and construction of durable recreational seating using reinforced concrete: sieve analysis, slump test, and compressive strength test. Each test was critical in evaluating the material properties and workability of the concrete mix, ensuring that it met the necessary standards for strength, durability, and performance.

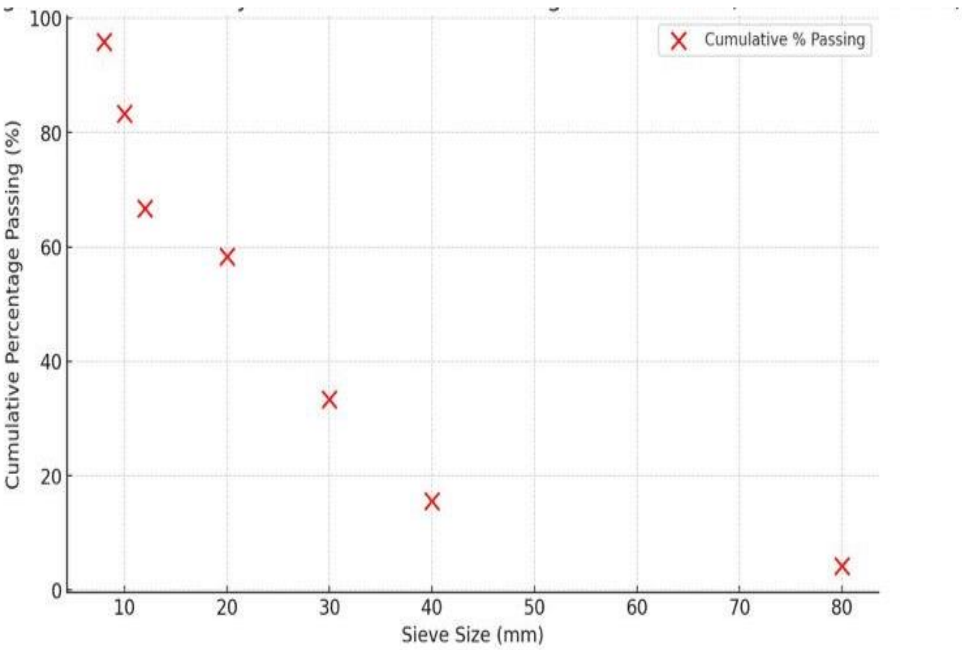

Fig. 3. Sieve Analysis - Cumulative percentage passing vs sieve size (Scatter plot in Red)

Table 1. Sieve analysis results (Fine Aggregate)

Sample: Fine aggregate
Total weight of sample: 1.2kg

Sieve Size (mm)	Weight of Sieve and Sand (kg)	Weight of Sieve (kg)	Weight of Sand (kg)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Cumulative Percentage Passing (%)
S	0.35	0.30	0,05	4.17	4.17	95.83
10	0.45	0.30	0.15	12.50	16.67	83.33
12	0,50	0,30	0.20	16,67	33.34	66.66
20	0.40	0.30	0,10	8.33	41.67	58.33
30	0.60	0.30	0.30	25.00	66.67	33.33
40	0.55	0.30	0.25	20.83	87.50	12.50
SO	0.40	0.30	0.10	8.33	95.83	4.17
Pan	0.30	0.30	0.00	0.00	95.83	4.17

Table 2. Slump test results

S/N	Water-Cement Ratio	Height of Cone (mm)	Height of Slump Concrete (mm)	Slump Value (mm)	Trial
1	0.6	300	150	150	1

Table 3. Compressive strength test results

S/N	Area (mm^2)	Compressive load (KN)	Design Compressive Strength (N/mm^2)			
			7 days	14 days	21 days	28 days
1	22500	356.20	15.81	Pending	Pending	Pending

3.1 Sieve Analysis

Sieve analysis is an essential test to determine the particle size distribution of aggregates, which plays a crucial role in the workability, strength, and durability of concrete. In this study, sieve analysis was conducted to assess the suitability of fine aggregates for the production of reinforced concrete seating. The particle size distribution of the fine aggregates directly impacts the compaction, void content, and bonding of the concrete mix. Well-graded aggregates reduce voids and improve the density of the concrete, contributing to higher strength and durability.

The results of the sieve analysis are shown in Table 1, which presents the amount of material retained on each sieve and the corresponding cumulative percentage passing. This test ensures that the fine aggregates meet the required gradation for concrete production.

3.2 Slump Test

The slump test is a critical procedure used to assess the workability of fresh concrete. It provides insights into the fluidity and consistency of the concrete mix, ensuring that it can be easily placed and compacted without compromising structural integrity. In this study, the slump test was conducted to evaluate the suitability of the concrete mix used for reinforced concrete seating, with a water-cement ratio of 0.6.

3.3 Compressive Strength Test

The compressive strength test is one of the most important tests for assessing the strength of concrete. It measures the concrete's ability to withstand axial loads, which is crucial for understanding how the material will perform under real-life structural conditions. For this study, the compressive strength test was conducted to determine the strength development of the concrete used for the reinforced concrete seating.

4. DISCUSSION

The results presented in Table 3 and the bar chart in Fig. 5 show that the initial compressive strength of the concrete mix was 15.81 N/mm², achieved under a load of 356.20 kN. This value represents the compressive strength obtained from the first test, while the results for the 7, 14, 21, and 28-day compressive strength tests are still pending.

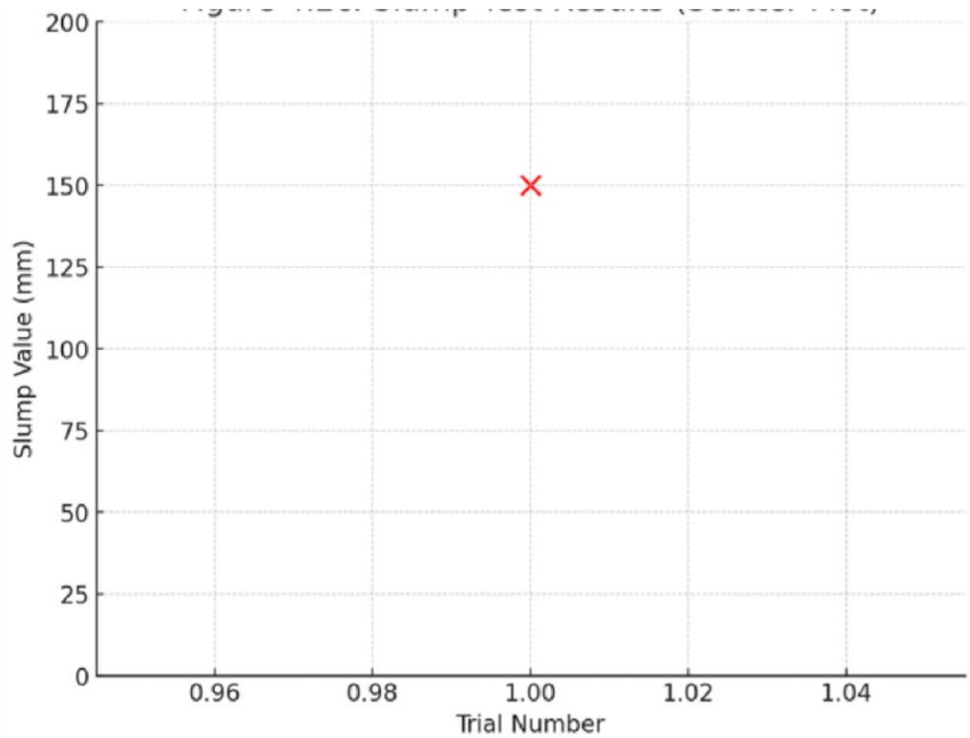

Fig. 4. Slump test results (scatter plot)

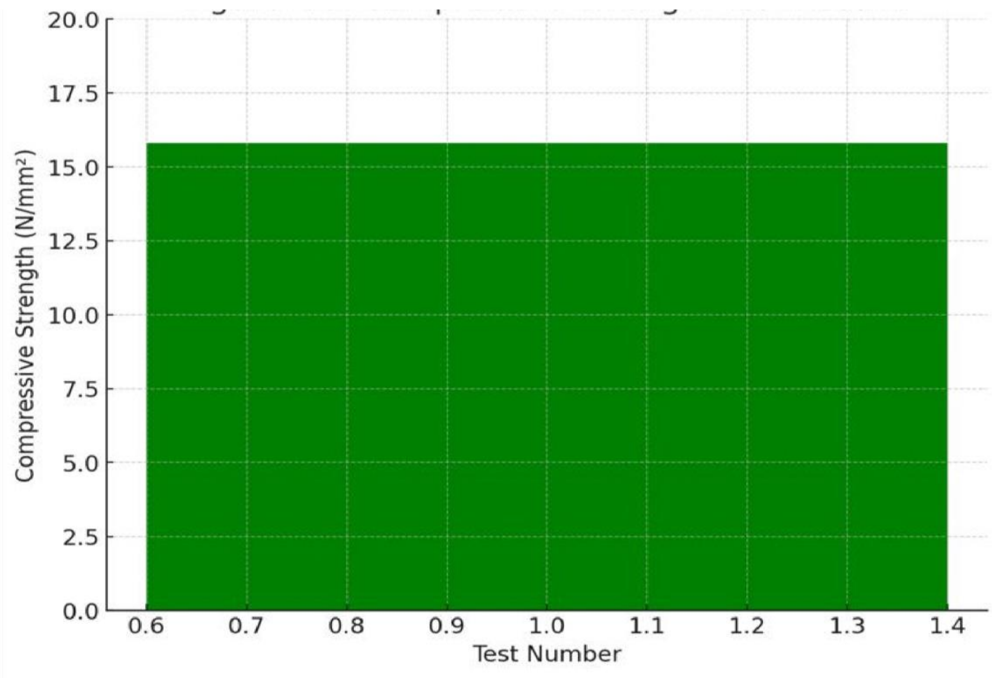

Fig. 5. Compressive strength test results

The compressive strength recorded at this stage is indicative of the early strength development of the concrete. At 15.81 N/mm², the concrete is within the expected strength range for early-age concrete, which typically gains strength rapidly in the first few days of curing. The results suggest that the concrete is on track to reach its designed compressive strength after 28 days of curing.

Concrete continues to gain strength as it cures, particularly within the first 28 days. By 7 days, concrete typically achieves about 65-70% of its design strength, with continued strength gains until it reaches full design strength at 28 days. Based on the initial test result of 15.81 N/mm², it is expected that the concrete will achieve higher compressive strength as the curing process progresses.

5. RECOMMENDATION

Based on the results obtained from this study, the following recommendations are made to enhance the design, construction, and performance of reinforced concrete seating:

5.1 Improved Concrete Mix Design

Consider the use of supplementary cementitious materials (SCMs), such as fly ash, silica fume, or slag, to improve long-term strength and durability. These materials can reduce permeability and enhance the concrete's resistance to environmental factors such as freeze-thaw cycles and chemical attacks.

5.2 Optimized Aggregate Gradation

Although the aggregates were well-graded, further optimization can improve compaction and strength. Using blended aggregates with a wider range of particle sizes can help reduce voids, improving the concrete's density and compressive strength.

5.3 Comprehensive Curing Process

Proper curing is essential to achieve the desired strength and durability. Use methods such as water curing or curing compounds to ensure consistent moisture retention. Curing should be maintained for at least 28 days to allow the concrete to reach its full design strength.

5.4 Consideration of Environmental Impact

Future designs should consider using recycled aggregates or low-carbon cement alternatives to minimize the environmental impact. These sustainable materials can reduce the carbon footprint of the construction process while maintaining performance.

5.5 Design for User Comfort

Future designs should prioritize user comfort in addition to structural durability. Factors such as seat height, backrest angle, and armrest positioning can enhance the user experience, making the seating more functional and comfortable for extended use.

5.6 Collaboration with Urban Planners

It is recommended that engineers collaborate with urban planners and architects to integrate reinforced concrete seating into public spaces in a way that enhances aesthetics and functionality. Using decorative finishes, color pigments, and textured surfaces can make the seating visually appealing while maintaining structural integrity.

6. CONCLUSION

This study focused on the design and construction of durable recreational seating using reinforced concrete. The primary objective was to assess the performance of the concrete mix in terms of workability, strength, and suitability for the intended application.

In conclusion, the findings from this study suggest that reinforced concrete is a suitable material for the construction of durable recreational seating. The concrete mix provided the necessary workability for proper placement and compaction, as well as the strength required for long-term performance. When designed and constructed properly, reinforced concrete seating can withstand the loads and environmental conditions it is subjected to, offering a durable and cost-effective solution for public spaces.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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