Project Report

Compressive strength of concrete using (LC3 + Nano-bubble)

CP302 Project

Civil

Department

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INTRODUCTION

Concrete is one of the most widely used construction materials globally due to its versatility, strength, and durability. The compressive strength of concrete is a key performance parameter that determines its ability to withstand axial loads, making it essential for structural applications. Recent advancements in materials science have led to the development of innovative components like LC3 cement (Limestone Calcined Clay Cement) and nanobubble water, which offer promising benefits for enhancing concrete properties. LC3 cement, with its reduced clinker content, not only improves the environmental sustainability of concrete but also enhances its mechanical performance. Similarly, nanobubble water, characterized by its high surface energy and unique hydration-promoting properties, has the potential to improve particle interaction and hydration kinetics, thereby boosting the compressive strength of concrete. This study focuses on evaluating the compressive strength of concrete prepared using LC3 cement and nanobubble water, compared to conventional mixes prepared with distilled water, to explore the synergistic effects of these innovative materials on concrete performance.

OBJECTIVE

The primary objective of this study is to evaluate the compressive strength of concrete made with LC3 (Limestone Calcined Clay Cement) using nanobubble water. Additionally, the study aims to compare the compressive strength of concrete prepared with LC3 and distilled water to assess the influence of nanobubble water on the material's performance.

Mechanical Properties: Compressive Strength of Specimens for Comparison

The compressive strength of concrete specimens will be evaluated as the primary mechanical property in this study. Concrete mixtures will be prepared using LC3 (Limestone Calcined Clay Cement) with two different types of water: nanobubble water and distilled water. The compressive strength of these specimens will be measured at various curing ages, and the results will be compared to determine the influence of nanobubble water on the overall strength development of the LC3-based concrete. This comparison will provide insights into how nanobubble water affects the hydration process and the mechanical performance of concrete when compared to traditional distilled water.

Microstructural Properties:-

1) **X-ray Diffraction (XRD):** XRD will be used to analyze the crystalline phases in LC3-based concrete specimens. This technique will identify key minerals and hydration products, helping to understand how nanobubble water affects the concrete's microstructure. Fourier-transform Infrared

2) **Fourier-transform Infrared Spectroscopy (FTIR):** FTIR will identify chemical bonds and functional groups within the concrete. It will help compare the chemical structure and bonding in samples made with nanobubble water versus distilled water, revealing any differences in the material's composition.

LC3 Cement

LC3 cement is composed of 50% clinker, 30% calcined clay, 15% crushed limestone, and 5% gypsum. In this study, a combination of LC2 (25%) and Ordinary Portland Cement (OPC) (75%) is used to form LC3. This blend aims to mimic the composition and properties of traditional LC3 while potentially offering improved sustainability and performance characteristics.

Here are some key advantages:

1. Reduced CO2 Emissions: LC3 can cut CO2 emissions by up to 40% compared to Ordinary Portland Cement (OPC). This makes it a more environmentally friendly option.

2. Enhanced Durability: LC3 exhibits improved resistance to aggressive environments, such as marine areas or sulfate-rich soils. This means structures made with LC3 may require fewer repairs and less maintenance over time.

3. Cost-Effectiveness: By utilizing locally available materials like limestone and calcined clay, LC3 can reduce overall cement costs.

4. Versatility: LC3 is suitable for a wide range of applications, from residential buildings to infrastructure projects.

5. Compliance with Regulations: LC3 aligns with global sustainability goals and can help meet future regulations aimed at reducing carbon emissions in the construction industry.

NanoBubble

Nanobubbles are tiny air bubbles, typically ranging from 70 to 120 nanometers in diameter, which possess unique properties due to their small size. When introduced into concrete, these bubbles penetrate the material and increase the available water for cement hydration at the microscopic level, promoting a chemical reaction between water and cement particles. The key benefits of nanobubbles include enhanced oxygen transfer efficiency, improved water quality through oxidation and contaminant degradation, increased energy efficiency in filtration and flotation processes, and agricultural benefits such as promoting plant growth by improving water absorption. Additionally, nanobubbles are eco-friendly, as they reduce the need for chemical treatments and lower energy consumption. In LC3 cement, nanobubbles enhance the reaction between kaolinite and lime, facilitating the formation of calcium silicate hydrates (C-S-H), resulting in a denser, stronger, and more durable concrete microstructure.

Methodology

Consistency Test

This test determines the amount of water required to be added to the cement to achieve a paste with a specific consistency. The goal is to ensure that the cement paste has the right fluidity for proper mixing and workability, which is crucial for ensuring the strength and durability of the final concrete. In this study, the consistency of the cement paste was found to be **36%**, indicating the proportion of water required to achieve the desired fluidity for effective mixing and hydration.

Initial & Final Setting Time

- **Initial Setting Time:** This is the time that elapses from when water is added to the cement until the paste begins to lose its plasticity and starts hardening. It marks the point when the cement transitions from a workable paste to a semi-solid state.
- **Final Setting Time:** The final setting time refers to the period it takes for the cement to completely lose its plasticity and achieve its final hardened form, indicating that the cement has fully set and is no longer workable.

Both initial and final setting times are calculated after determining the consistency of the cement paste. These times are critical in assessing the workability and curing process of the concrete.

For the specific tests conducted in this study:

- **Distilled Water:**
  - Initial Setting Time: 1 hour 31 minutes
  - Final Setting Time: 4 hours 25 minutes
- **Nanobubble Water:**
  - Initial Setting Time: 1 hour 28 minutes
  - Final Setting Time: 4 hours 46 minutes

These results highlight the effect of nanobubble water on the setting time, with nanobubble water resulting in a slightly quicker initial setting time but a longer final setting time compared to distilled water.

 # <u>Compressive Strength Test</u>

1) **Material Selection:**

   For this study, nanobubble water was collected from the chemical department to be used in the concrete mix. This water, with its unique properties, is expected to influence the hydration process and enhance the mechanical performance of the concrete.

2) **Mix Design:**

The concrete mix for this study was meticulously designed with a composition ratio of 1:3, where one part comprised cement, and three parts consisted of sand. A total of 200 g of cement was used, divided into 150 g of Ordinary Portland Cement (OPC) and 50 g of LC-2 cement, which were selected to enhance the mix's strength and durability properties. The sand portion totaled 600 g, split into three equal parts of 200 g each. Standard graded sand sizes were used to ensure uniform particle distribution, optimal packing density, and consistent workability. Two types of water were used in this study to prepare the concrete mixes: distilled water and nanobubble water. Nanobubble water, known for its unique properties that enhance the hydration process and improve particle interaction, was sourced from the chemical department. Its performance was compared to the traditional distilled water to evaluate its influence on the mechanical properties of concrete.

3) **Preparation and Mixing:**

The concrete mix was prepared by thoroughly blending the components to ensure uniform dispersion of particles. This step is crucial to avoid clustering of materials, as uneven mixing can negatively impact the concrete's properties and overall performance.

4) **Casting:**

The prepared concrete was then cast into moulds under controlled conditions to ensure proper hydration and strength development. The curing process is vital for achieving the desired mechanical properties in the concrete.

5) **Testing:**

Compressive strength tests were conducted on the cured concrete specimens at various curing ages: 7, 14, 28, and 56 days. Three samples of concrete made with distilled water and three samples made with nanobubble water were tested at each curing age to compare the performance of the two mixes.

Expected Outcome

1. **Enhanced Compressive Strength**

The incorporation of LC3 cement which combines limestone and calcined clay is anticipated to improve the compressive strength of the concrete due to the synergistic hydration process. The addition of nanobubble water is expected to further enhance this strength by promoting better hydration and reducing voids within the concrete matrix.

2. **Better Durability**

The use of Nanobubble Water is likely to make the concrete more resistant to environmental factors like freeze-thaw cycles and chemical attacks. This should make our concrete last longer under harsh conditions.

3. **Enviornmental Benefits**

LC3 cement has a smaller carbon footprint compared to regular portland cement which is a big plus point for sustainability combining this with nanobubble water should make the production process more eco friendly.

Observation

what result concluded by using LC3 ?

1.) Cost

2.) environmentally sustainable {*low c emissions)

what result concluded by using Nano Bubble Water ?

1.) The compressive strength results showed no significant improvement over distilled water, and further long-term studies are needed like 56 days testing .

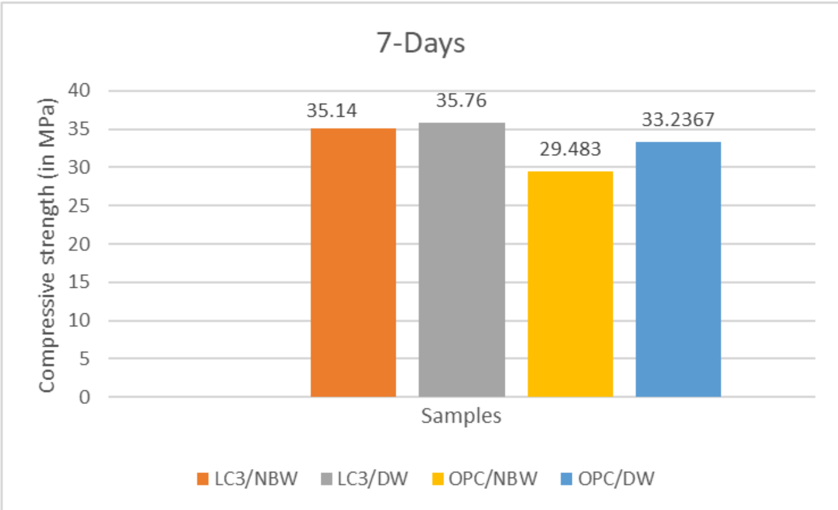
The combination of LC3 cement and nanobubble water could represent a promising solution as this is cost-effective also provided that further research confirms the long-term performance.

** The main objective of determining whether compressive strength would increase with these innovations was achieved, while the immediate results did not show an increase, long-term gains with nanobubble water still warrants further investigation.

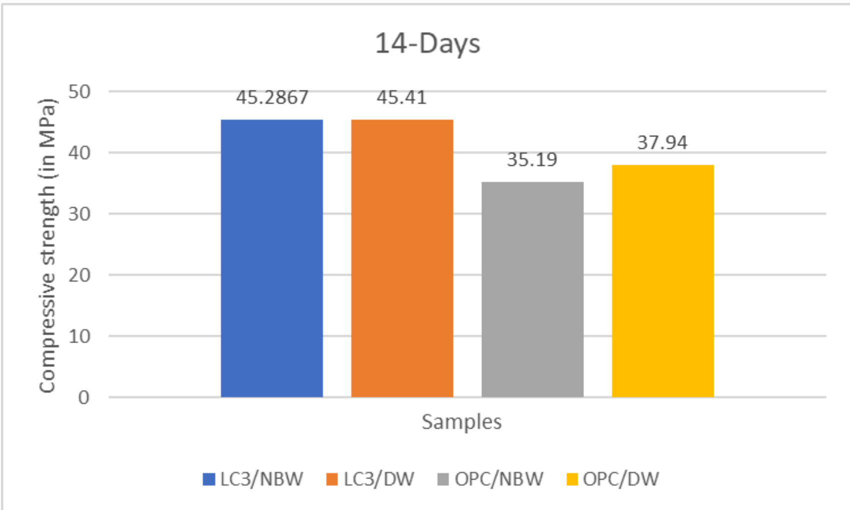
Data of Compressive Strength

Days	Sample	S-1	S-2	S-3
7	DW	32.91	40.05	34.32
	NBW	37.09	34.37	33.97
14	DW	44	46.51	45.72
	NBW	43.48	47.25	45.13
28	DW	46.10	49.12	38.59
	NBW	46.04	45.48	47.99

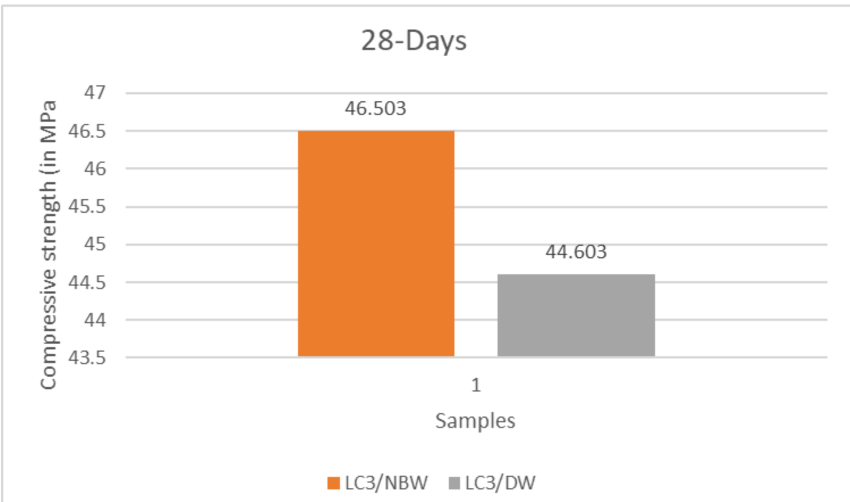
Graphs



7-Days
Compressive strength (in MPa)
40
35
30
25
20
15
10
5
0
35.14
35.76
29.483
33.2367
Samples
LC3/NBW
LC3/DW
OPC/NBW
OPC/DW

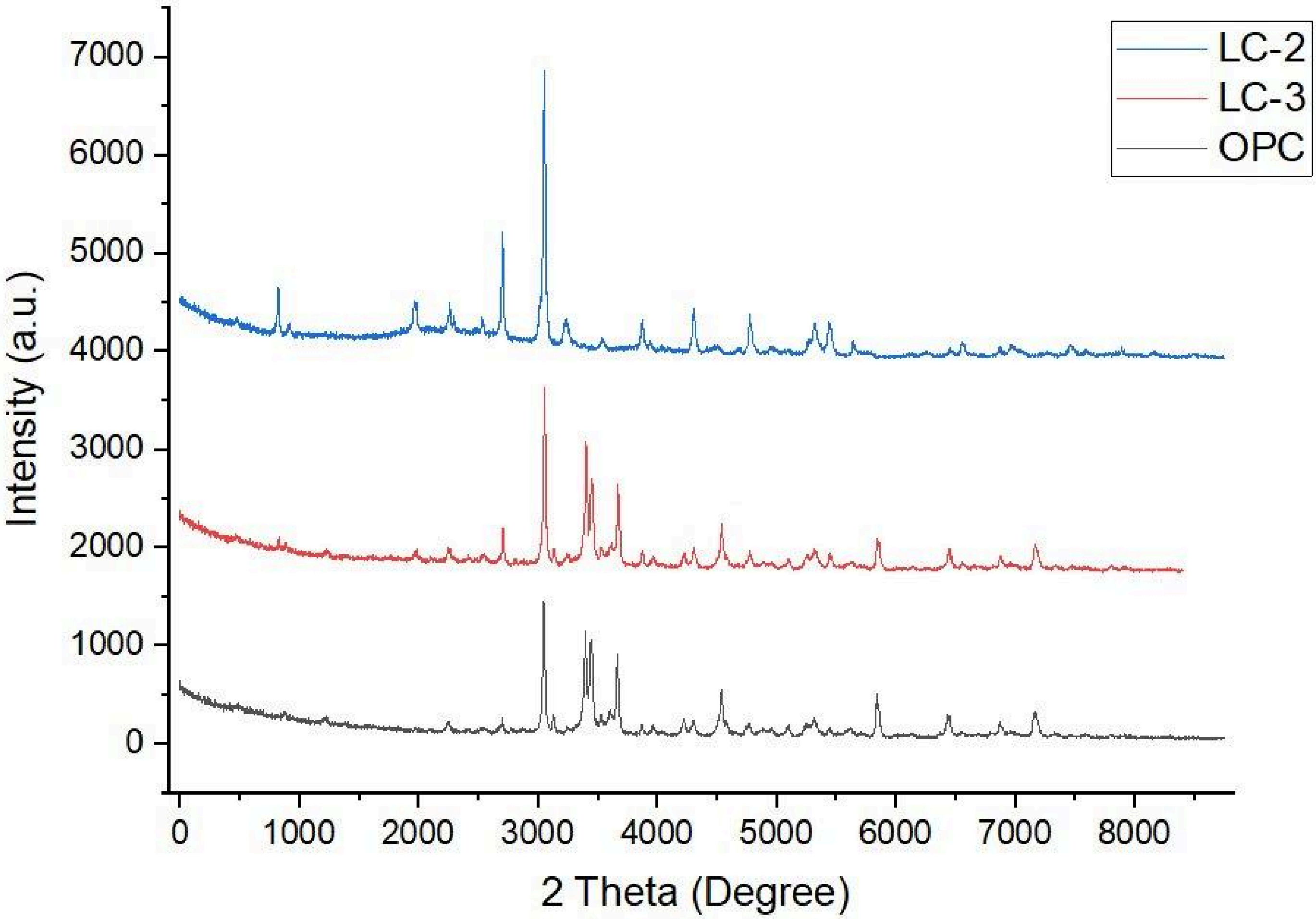


14-Days
Compressive strength (in MPa)
50
40
30
20
10
0
45.2867
45.41
35.19
37.94
Samples
LC3/NBW
LC3/DW
OPC/NBW
OPC/DW

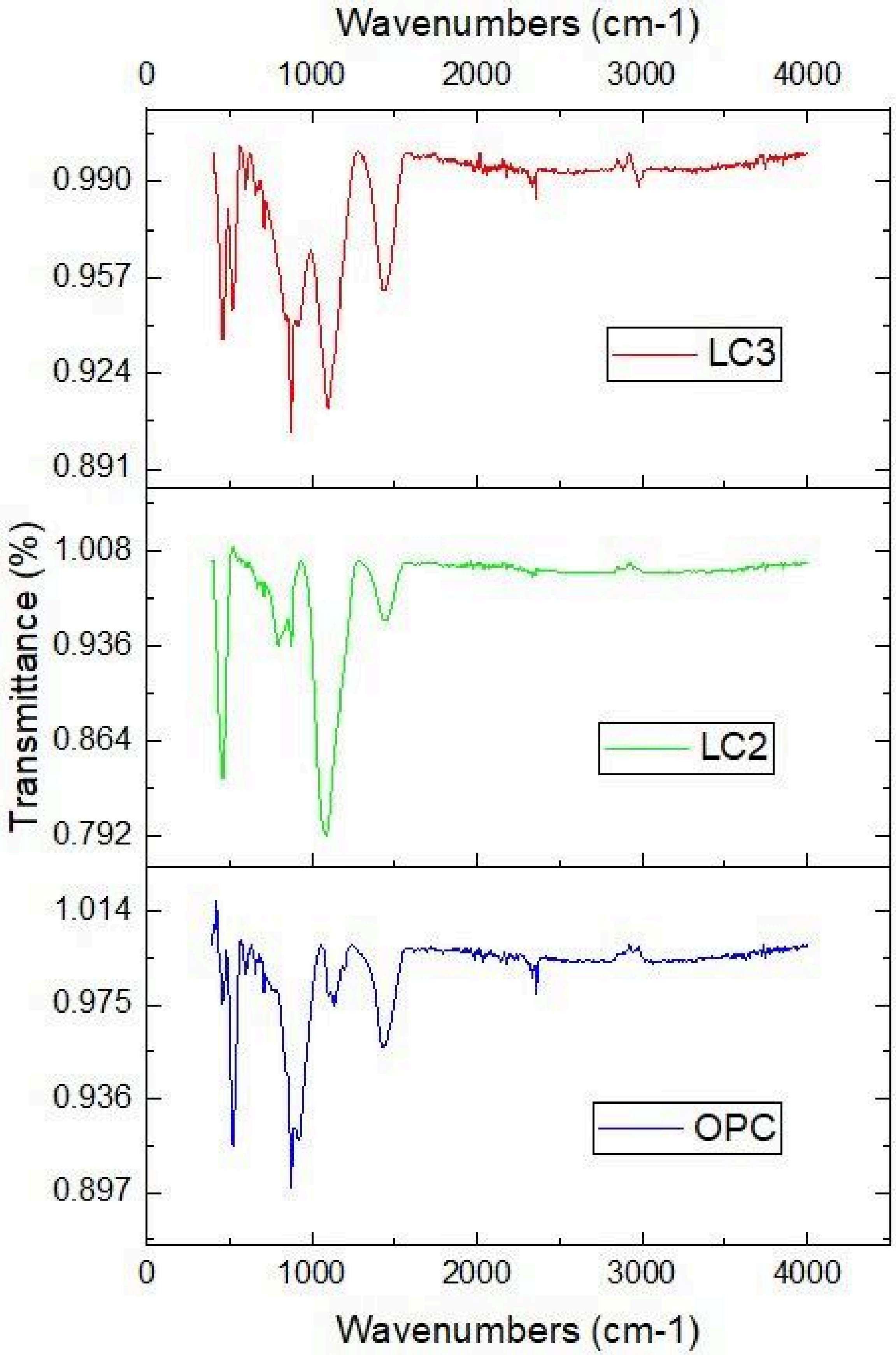


28-Days
Compressive strength (in MPa
47
46.5
46
45.5
45
44.5
44
43.5
46.503
44.603
1
Samples
LC3/NBW
LC3/DW

XRD Graph


LC-2
LC-3
OPC
Intensity (a.u.)
7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000
6000
7000
8000
2 Theta (Degree)

FTIR Graph



Wavenumbers (cm-1)
0
1000
2000
3000
4000
0.990
0.957
0.924
0.891
LC3
Transmittance (%)
1.008
0.936
0.864
0.792
LC2
1.014
0.975
0.936
0.897
OPC
0
1000
2000
3000
4000
Wavenumbers (cm-1)

Conclusions

Standard Consistency:

1. The standard consistency of the mix prepared using Nano-Bubble Water is observed to be 36%.

Settling Time:

1. Initial Setting Time:
   - Using Distilled Water: 1 hour 31 minutes.
   - Using Nano-Bubble Water: 88 minutes (slightly increased).
2. Final Setting Time:
   - Using Distilled Water: 4 hours 27 minutes.
   - Using Nano-Bubble Water: 4 hours 46 minutes (slightly delayed).

Compressive Strength:

1. The compressive strength is nearly similar in both cases (Distilled Water and Nano-Bubble Water) during early-age testing.
2. After 56 days, a significant improvement in strength is observed in the Nano-Bubble Water case. This is attributed to enhanced

reaction between kaolinite and the nanobubble water, which improves pozzolanic activity and hydration.

Overall Observation:

- Nano-bubble water positively impacts setting time and long-term strength due to its interaction with kaolinite and improved microstructure of LC3 cement.