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Curewise an Application for Automated Curing in Construction

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Abstract
Concrete curing plays a crucial role in determining its long-term strength and durability. This study focuses on the development and evaluation of CureWise, an automated concrete curing system designed to monitor and regulate moisture levels effectively. Two sets of concrete cubes were prepared using M20 grade concrete, with one set embedded with moisture sensors for real-time monitoring. The cubes were subjected to traditional immersion curing and smart curing using a sensor-based automated system controlled by NodeMCU. The smart curing system utilized embedded sensors to track internal moisture variations and automatically adjusted the water supply to maintain optimal hydration. Additionally, the CureWise mobile application provided remote monitoring and real-time alerts, ensuring better control over the curing process. Compressive strength tests were conducted at different curing ages to compare the effectiveness of both methods. The findings demonstrated that smart curing enhanced strength development while significantly reducing water consumption. This study highlights the potential of intelligent curing systems in optimizing construction efficiency and sustainability. By integrating automation and real-time monitoring, the CureWise system offers a more efficient, resource-conscious, and technologically advanced approach to concrete curing, paving the way for smart construction practices.

Keywords: Concrete curing, Automated curing system, Real-time monitoring,Moisture sensors, Node MCU, Durability, Sustainability, Construction efficiency, Smart construction.

1. INTRODUCTION

Concrete's durability and strength rely on proper curing, which ensures optimal moisture, temperature, and humidity for hydration. Without adequate curing, concrete becomes prone to cracking, surface defects, and premature deterioration, reducing its lifespan and structural integrity. Traditional curing methods, such as manual irrigation, spray applications, and coverings, often lack precision, requiring constant oversight and labor-intensive efforts. These methods can be inconsistent, leading to inefficiencies, increased water waste, and the risk of human error compromising construction quality.

CureWise is an innovative application designed to modernize curing and irrigation management in construction. By integrating real-time monitoring and data-driven insights, the app helps construction professionals ensure optimal curing conditions. It connects with advanced sensors that track key environmental parameters, including temperature, humidity, and moisture levels, which directly affect the hydration and strength development of concrete. When these parameters fall outside optimal ranges, CureWise instantly notifies users, enabling quick corrective actions, such as adjusting irrigation schedules or implementing protective measures.

This smart approach minimizes the risk of curing-related issues, such as uneven hydration, cracking, and reduced strength. By ensuring consistent curing conditions, CureWise enhances the structural performance and longevity of concrete, making construction projects more durable and reliable. Additionally, the app optimizes water usage, reducing unnecessary consumption and supporting
sustainable construction practices. In an industry increasingly focused on resource conservation and environmental responsibility, CureWise helps minimize water waste while maintaining high-quality standards.

Designed with accessibility in mind, CureWise features a user-friendly interface that allows construction teams, from field workers to project managers, to visualize real-time data, monitor historical trends, and evaluate curing effectiveness. The app's built-in alert system reduces human error by ensuring timely interventions without requiring constant on-site supervision. Furthermore, CureWise provides a valuable record-keeping tool, enabling teams to document curing conditions, track performance over time, and maintain quality assurance for audits or legal compliance.

By combining digital technology with practical construction needs, CureWise transforms the curing process, ensuring concrete structures achieve their full strength potential. As the construction industry continues to prioritize efficiency, quality, and sustainability, CureWise stands out as an indispensable tool for modern construction management. Through precise monitoring, improved resource management, and enhanced documentation, CureWise not only improves curing outcomes but also advances the broader goals of resilience and environmental responsibility in infrastructure development.

2. METHODOLOGY

This project aims to develop an application, Curewise, for monitoring the curing process of concrete. The study involved preparing two sets of concrete cubes—one with embedded moisture sensors and the other without. Each set consisted of standard 150 mm × 150 mm × 150 mm concrete cubes, prepared using M20 grade concrete with a mix ratio of 1:1.5:3 (Cement: Fine Aggregate: Coarse Aggregate).

The primary objective was to analyze and compare the curing efficiency of traditional immersion curing and smart curing using an automated system controlled by NodeMCU. The methodology was carried out in five key steps:

2.1 Concrete Cube Preparation

The preparation of concrete cubes was conducted systematically to ensure consistency and accuracy in testing. M20 grade concrete was used with a mix ratio of 1:1.5:3 (Cement: Fine Aggregate: Coarse Aggregate). The dry materials were thoroughly mixed to create a homogeneous blend, ensuring uniform distribution of cement and aggregates. Water was gradually added while mixing to maintain proper workability and hydration, achieving a mix that was neither too dry nor overly wet.

Once the concrete mix was prepared, it was poured into lubricated 150 mm × 150 mm × 150 mm cube molds in three layers. Each layer was compacted using a tamping rod, following standard procedures, to eliminate air voids and achieve maximum density. Proper compaction was essential for preventing honeycombing and ensuring uniform strength development. In one set of cubes, three moisture sensors were embedded at different depths—7.5 cm, 5 cm, and 2.5 cm—to monitor internal moisture variations during curing. These sensors allowed real-time tracking of hydration levels and moisture retention.

After casting, the cubes were left undisturbed for 24 hours at ambient conditions to allow the initial setting process to occur. This period was crucial for early-stage strength gain, as premature movement or exposure to harsh environmental conditions could affect the integrity of the specimens. After 24 hours, the cubes were carefully demolded to avoid any structural damage. They were then prepared for two different curing methods—traditional immersion curing and smart curing using an automated moisture monitoring system.

2.2 Implementation Of Different Curing Methods

Two different curing methods were implemented to compare their effectiveness in maintaining moisture levels and enhancing concrete strength:

a. Traditional Immersion Curing

In this widely used method, the concrete cubes were fully submerged in a water tank for 7, 14, and 28 days. The water level was regularly monitored and maintained to ensure complete immersion, preventing moisture loss. This method facilitated continuous hydration, which is essential for strength development. However, it required a significant amount of water and constant manual supervision. Additionally, water wastage was a major concern, making this method less sustainable.

b. CureWise Automated Curing System

The CureWise automated curing system employed embedded moisture sensors at depths of 7.5 cm, 5 cm, and 2.5 cm to monitor internal moisture levels. These sensors were connected to a NodeMCU microcontroller, which processed real-time data. When the moisture content dropped below 60.9%, an automated water pump activated to restore optimal hydration. Once the moisture level reached the desired range, the pump automatically turned off, preventing excess water use.

The system was integrated with the Curewise mobile application, allowing remote monitoring and real-time alerts. This ensured efficient curing while minimizing manual intervention.

2.3 Integration with NodeMCU and Pumping System

For the smart curing system, the moisture sensors embedded in the concrete cubes were connected to a NodeMCU microcontroller, which acted as the central processing unit for moisture monitoring. The system was programmed to:

Continuously monitor real-time moisture content in the concrete. Control an automated water pumping system to maintain the required moisture levels. Operate based on a threshold value of 400, ensuring that if the moisture content dropped below 60.9%, the motor automatically switched off to prevent excessive water loss. Additionally, the Curewise mobile application was developed and integrated with the system. The app allowed users to:

Remotely monitor the curing process in real-time.

Receive alerts on moisture fluctuations.
Ensure controlled hydration for improved strength development.

2.4 Compressive Strength Testing

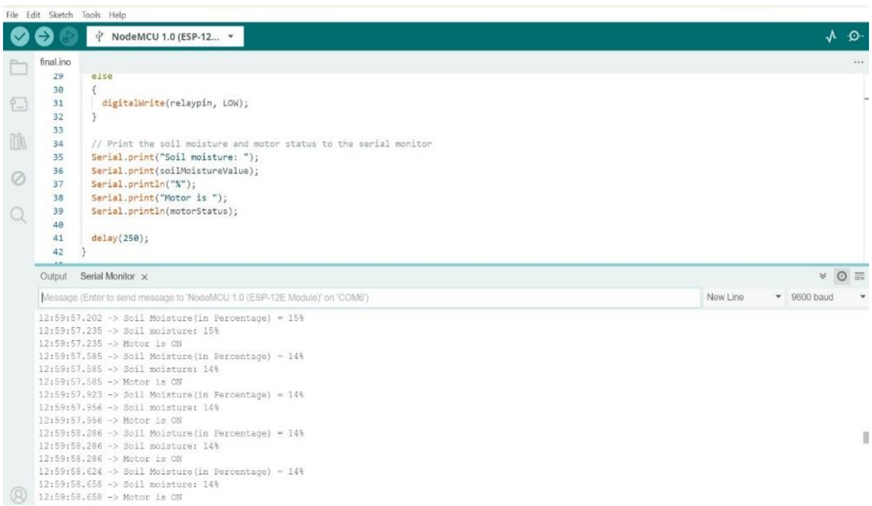
To evaluate the effectiveness of each curing method, compressive strength tests were conducted after 28 days in accordance with IS 516:1959.
The testing process involved:

1. Removing the cubes from their respective curing conditions.
2. Surface drying before testing.
3. Placing the cubes in a Compressive Testing Machine (CTM).
4. Applying a gradual load at a rate of 140 kg/cm² per minute until failure.
5. Recording the maximum load at failure and calculating compressive strength using the formula:

Compressive Strength= Load at Failure/Area of Cube
Load at Failure in Newton (N)
Area of cube (mm²)
The compressive strength values obtained from smart-cured and immersion-cured cubes were recorded and compared to assess the efficiency of automated moisture monitoring in improving concrete strength.

2.5 Data Analysis

The data analysis involved evaluating the recorded compressive strength values after 28 days to compare the effectiveness of traditional immersion curing and smart curing. Statistical analysis, including mean strength calculations, standard deviation, and coefficient of variation, was performed to assess consistency in strength development. Graphical representations, such as bar charts and line graphs, were used to illustrate strength progression over time. Additionally, moisture retention data from the embedded sensors in smart-cured cubes were analyzed to determine hydration efficiency, while water consumption in both methods was compared to highlight the sustainability benefits of smart curing. The findings demonstrated that smart curing maintained optimal moisture levels, enhancing strength development while significantly reducing water usage. These insights support the adoption of automated curing technology for improving concrete durability and resource efficiency in construction.



3. RESULTS AND ANALYSIS

Curing Type	Compressive Force	Area of cube	Compressive strength
Automated curing	564kN	22500	25.06 N/mm²
Immersion curing	556kN	22500	24.71 N/mm²

At 28 days, concrete is expected to achieve 99% of its characteristic strength. The concrete cube cured using the CureWise automated curing system attained a compressive strength of 25.06 N/mm², while the cube under traditional immersion curing reached 24.71 N/mm². This slight but notable increase in strength demonstrates the effectiveness of the smart curing system in optimizing concrete hydration. The superior performance of CureWise can be attributed to optimized moisture retention, as the system continuously monitored and maintained adequate hydration levels, preventing moisture loss that could weaken the concrete. Additionally, uniform curing conditions ensured consistent moisture distribution throughout the cube, reducing internal cracks and enhancing overall durability. In contrast, immersion curing, though effective, lacks precise moisture control, potentially leading to material leaching and uneven hydration. Another key factor was the controlled water supply in smart curing, which prevented excessive exposure to water, ensuring the proper development of calcium silicate hydrate (C-S-H) gel, the primary strength-giving compound in concrete. By improving hydration efficiency, CureWise not only enhanced concrete strength but also reduced water wastage, making it a more sustainable and efficient alternative to traditional curing methods. These findings highlight the potential of smart curing systems in advancing modern construction practices.

4. CONCLUSION

This project successfully developed and implemented CureWise, a automated curing system designed to enhance the concrete hydration process through real-time monitoring and automated water control. By comparing traditional immersion curing with IoT-based smart curing, the study demonstrated that the smart curing system effectively maintained optimal moisture levels, resulting in improved compressive strength and reduced water consumption.

The integration of NodeMCU-controlled moisture sensors and an automated water supply ensured that concrete hydration was consistently maintained, preventing over- or under-curing. The compressive strength tests after 28 days confirmed that smart curing yielded superior strength development compared to conventional methods, proving its effectiveness in enhancing concrete durability.

Furthermore, the CureWise mobile application provided a user-friendly interface for real-time monitoring, allowing for remote control and efficiency in curing management. This approach not only optimized curing but also contributed to sustainability by minimizing water wastage, aligning with modern eco-friendly construction practices.

In conclusion, the implementation of IoT-based smart curing systems like CureWise represents a significant advancement in construction technology, offering a more efficient, reliable, and sustainable approach to concrete curing. Future research can further refine this system by integrating additional sensors, optimizing automation, and exploring its application on larger construction projects.

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