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Original Article

A Study of An Iot Enabled Concrete Curing and Monitoring System

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Abstract: *The Implementation of Embedded Sensors for In-Situ Concrete Curing Monitoring System satisfies the critical need for accurate, real-time assessment of concrete curing processes in modern construction. Traditional methods are labor-intensive, time-consuming, and often fail to provide timely insights regarding curing conditions since they rely on routine sampling and laboratory testing. This project introduces an innovative Internet of Things-based embedded sensor system designed to monitor critical curing parameters, including temperature, humidity, and compressive strength, inside the concrete structure.Wireless sensors incorporated into the concrete matrix are used in this technique. For continuous monitoring and analysis, these sensors transmit data in real time to a centralized cloud platforms. By employing maturity methodologies and predictive algorithms, the system accurately evaluates early-age strength development, enabling informed decisions regarding formwork removal and construction timeline. Experimental validation confirms the system's accuracy and reliability by demonstrating a strong correlation between sensor-derived predictions and conventional destructive test results.*

Keywords : *Cloud Data Analytics, Concrete Curing,Embedded Systems , Internet of Things (IoT), Real-time Monitoring,Structural Health Monitoring (SHM),Wireless Sensor Networks (WSN).*

I. INTRODUCTION

The most popular building material in the world, concrete is used for everything from large-scale infrastructure projects like dams and bridges to residential homes. The curing phase, which is the time after placement when temperature and moisture are controlled to promote the chemical reaction known as hydration, is largely responsible for a concrete structure's long-term durability and load-bearing capacity. Despite its significance, traditional curing monitoring is still mostly done by hand and depends on visual inspections or "field-cured" test cylinders, which frequently don't adequately reflect the internal thermal conditions of a huge, monolithic pour.When it comes to concrete strength development, the conventional "wait-and-see" method often results in major construction schedule inefficiencies. An innovative way to address these long-standing issues is to include the Internet of Things (IoT) into construction management. The building site is transformed into a data-driven environment by integrating wireless, low-power sensors right into the concrete during the pour. Microcontrollers (such the ESP32) and specialized sensors are used by an Internet of Things-enabled concrete curing and monitoring system to continuously record temperature and moisture data. By sending this data to a cloud-based platform, engineers can use the Maturity Method (ASTM C1074) to accurately anticipate strength development in real time.In the end, the sector moves from reactive monitoring to proactive management when such a system is put into place.

II. LITERATURE REVIEW

The extensive collection of studies carried out between 2021 and 2026 reveals a revolutionary period in civil engineering, where data-driven, IoT-enabled frameworks are gradually replacing conventional building techniques. According to the literature, digital technology integration is now a basic requirement for maintaining structural integrity and efficiency in contemporary "Smart Cities," rather than an optional luxury. Wireless protocols like LoRaWAN and LPWAN, which effectively address the issue of transmitting data through dense, reinforced concrete over long distances without depleting battery life, are the foundation of this movement, as demonstrated by early foundational research like the studies by Chen & Liu (2021) and Barot & Pandey (2021). Additionally, the literature investigates specific uses for large-scale infrastructure. According to studies by Zhu et al. (2022) and MDPI Applied Sciences (2025), fiber-optic sensors and ZigBee mesh networks are essential for controlling heat gradients in large structures like bridge piers and dams to avoid catastrophic cracking. Although Zhang (2025) examines how quickly the field is moving toward "self-sensing" concrete, the examined publications frequently point out persistent issues, such as the need for improved sensor durability in severe alkaline conditions and the reduction of high initial setup costs. In the end, our assessment affirms that an IoT-integrated strategy offers a safer, quicker, and more transparent framework for building, guaranteeing that the infrastructure of the future is intelligent and robot.

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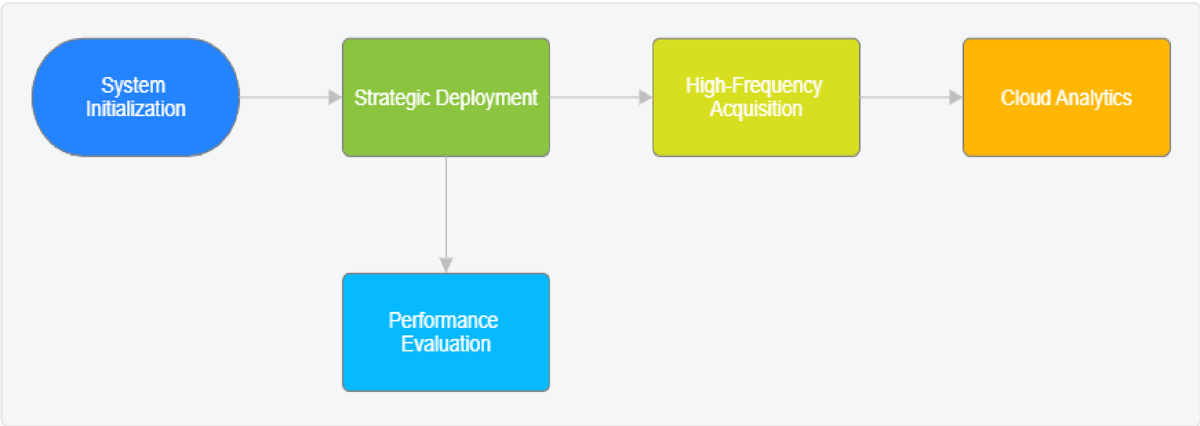
III. METHODOLOGY

The construction of a synchronized hardware-software interface intended for the independent hygro-thermal surveillance of concrete structures is the technological implementation of this work. The approach is based on a modular structure designed to bridge the gap between digital telemetry and physical material science.

Flowchart



IV. MATERIALS USED

Table 1: Comprehensive List of Materials and System Components

Category	Component / Material	Primary Function
Electronic Hardware	**ESP32 Microcontroller**	Acts as the central processing unit and IoT gateway for data transmission.
	DS18B20 Sensor	Measures the internal temperature (Heat of Hydration) within the concrete.
	Moisture Sensor	Monitors the volumetric water content to determine curing requirements.
	5V Relay Module	Acts as an automated interface between the ESP32 and the high-voltage water pump.
	Submersible Pump	Facilitates the physical application of water for automated curing.
	Power Supply	Provides regulated power to the microcontroller and integrated sensors.
Civil Materials	**Cement**	Acts as the primary binding agent in the concrete mix design.
	Aggregates	Provides structural bulk and compressive strength to the specimen.
	Water	Essential for the hydration process and automated curing spray.
	Concrete Molds	Used for casting standardized cubes for validation and UTM testing.
Software Stack	**Arduino IDE**	Used for writing, debugging, and uploading the firmware to the ESP32.
	MQTT Protocol	Facilitates low-latency telemetry between the site and the cloud server.

V. RESULT AND DISCUSSION

A. Empirical Data Acquisition and Analysis

Over the course of a 28-day curing cycle, the integrated IoT framework's performance was carefully assessed. The system recorded data points at intervals of fifteen minutes, maintaining a high-frequency sampling rate. The hygro-thermal behavior and strength development of the concrete specimens under observation are critically analyzed in the following sections.

B. Maturity Index and Predictive Modeling

For non-destructive strength estimation, the main computational technique was the Nurse-Saul Maturity Index. A real-time strength development curve was produced by the system by combining the temperature-time history.

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