



INTEGRATION OF BUILDING INFORMATION MODELING FOR MONITORING CONCRETE STRENGTH PROPERTIES

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ABSTRACT :

Concrete strength is one of the critical properties that determine the safety and stability of construction structures. Traditionally, concrete strength is determined through laboratory testing of concrete specimens under compression at specific ages to obtain compressive strength data. However, such procedures might yield inaccurate results because the curing conditions of concrete elements in laboratory settings differ from those that structures experience in the built environment. Building Information Modeling (BIM) enables enhancing concrete construction management by linking concrete structural information to monitoring data obtained from embedded sensors and testing equipment.

This paper aims to integrate the concepts of BIM and IoT to explore the potential use of sensors, embedded technologies for monitoring concrete maturity, and non-destructive testing to determine concrete strength properties. Sensors allow gathering information on concrete curing conditions, whereas maturity data enable estimating early-age concrete strength according to a previously established relationship between maturity and concrete strength. Moreover, non-destructive testing methods can be utilized to assess concrete strength. Information obtained from monitoring and testing equipment can be integrated into a BIM model to determine concrete properties for specific structural elements and visualize this data. Additionally, this study aims to examine the benefits, limitations, and challenges of utilizing integrated monitoring and testing equipment. The findings of this study demonstrate that BIM-based monitoring can significantly benefit from the utilization of IoT, embedded technologies, and non-destructive testing methods for concrete construction management. Nevertheless, the accuracy of sensor data, calibration procedures, and strength estimation methods should also be considered when selecting monitoring and testing equipment.

Keywords: Building Information Modeling, Concrete Strength, Internet of Things, Sensor-Based Monitoring, Concrete Maturity, Non-Destructive Testing.

INTRODUCTION :

Concrete is one of the most commonly used construction materials in civil engineering. It is utilized in building construction, bridge-building, road construction, and other infrastructure projects. The mechanical properties of concrete, including its compressive strength, are critical for ensuring the safety and long-term performance of structures. Compressive strength is one of the most important mechanical properties that plays a significant role in concrete construction. Traditionally, concrete strength is determined in laboratory settings, where cylindrical or cubic concrete specimens are subjected to a gradually increasing uniaxial compressive load until failure occurs. The obtained compressive strength data is critical for understanding the quality and performance characteristics of concrete and is utilized for construction management purposes. Concrete specimens are typically tested at the ages of 7 and 28 days, which represent the early- and long-term strength of concrete, respectively. Nevertheless, the curing conditions of concrete specimens in laboratory settings cannot adequately represent the conditions that concrete elements in actual structures undergo, which affects the accuracy of test results. Concrete elements gain strength through the process of curing, which is influenced by numerous environmental variables, including temperature, humidity, cement consistency, and others.

Researchers have explored alternative approaches to estimating concrete strength, including the utilization of embedded sensors and non-destructive testing methods. Sensors enable monitoring the curing process of concrete elements, whereas non-destructive testing allows assessing concrete strength without damaging structural elements. Building Information Modeling (BIM) is a technology that enables enhancing construction management through digital design and modeling of buildings and structures. It involves creating a unified database that stores all the information related to a building or a structure and follows its construction throughout the project's life cycle. BIM can be utilized to store the monitoring data related to concrete elements obtained from sensors and non-destructive testing equipment. The Internet of Things (IoT) refers to a network of interconnected objects and devices with built-in technologies that enable collecting and storing data. It can be utilized to link BIM and monitoring equipment, allowing construction managers to visualize concrete curing data and concrete strength. Thus, the benefits of IoT, embedded sensors, and non-destructive testing can be utilized in concert with BIM to enhance concrete construction management. Although such an approach offers a multitude of benefits, there are also

several limitations and challenges that should be considered before adopting this approach, including sensor calibration, software integration, and proper interpretation of results.

METHODOLOGY:

This study utilizes a literature-review methodology to explore the potential benefits and limitations of BIM-IoT integration for concrete construction management. To identify the relevant scholarly works, multiple databases were utilized to locate academic articles, journals, and publications that focus on BIM, IoT, embedded sensors, concrete maturity, and non-destructive testing methods. The identified scholarly works were reviewed to extract the information related to concrete monitoring technologies. Particular attention was paid to technologies that utilize sensors and embedded devices for gathering data on concrete curing rates, temperature changes, and predicting concrete strength. The reviewed articles were analyzed to identify the key benefits and limitations of the described approaches. Additionally, the potential application of BIM-IoT integration was examined to determine if it can enable effective concrete construction management.

The gathered information was sorted into four categories: BIM-IoT, sensor utilization for concrete monitoring, concrete maturity, and non-destructive testing methods. Each article was analyzed to identify the benefits, limitations, and potential of the described approaches. Following that, the information from the reviewed articles was compared to determine the key themes and trends. Particular attention was paid to the benefits of BIM-IoT utilization for concrete construction management.

LITERATURE REVIEW:

In recent years, researchers have investigated the potential of utilizing various technologies to monitor concrete's behavior and properties. Existing literature includes numerous studies exploring the benefits and limitations of BIM, IoT, embedded sensors, and non-destructive testing for concrete construction management. The reviewed articles can be organized into four groups: studies exploring the utilization of BIM and IoT, sensor-based monitoring of concrete, concrete strength estimation, and non-destructive testing methods for concrete.

-BIM and IoT

BIM plays a critical role in modern construction management, enabling teams to design and construct buildings and structures while minimizing errors and maximizing efficiency. IoT is a concept that refers to a network of interconnected objects and devices with built-in computer technologies that enable gathering and storing data. BIM-IoT integration involves utilizing the capabilities of IoT to enhance the performance of BIM software. Researchers have investigated the potential benefits of BIM-IoT integration for construction management, with a significant number of studies focusing on concrete construction. Iqbal et al. explored the utilization of BIM-IoT to monitor concrete compressive strength in real-time to enable effective construction management practices during the construction process of actual structures [1]. Thus, BIM-IoT enablement can be utilized to determine concrete strength properties, which will allow construction managers to make informed decisions. Nevertheless, effective BIM-IoT utilization requires effective software integration.

-Sensor-Based Concrete Monitoring

Various researchers have investigated the potential of utilizing sensors to monitor concrete curing and determine concrete's behavior. Sensor technologies can be utilized in many fields; however, their application in concrete construction has been the focus of numerous studies in recent years. Providakis and Liarakos have explored the utilization of an early-age concrete strength development monitoring system that utilizes wireless impedance sensing technologies [2]. The researchers have also reviewed the available sensor technologies that can be utilized for concrete curing monitoring [3]. Another team of researchers led by Zhou has investigated the utilization of a novel passive wireless sensor for concrete humidity monitoring [4]. Similarly, Cabezas et al. explored the potential of utilizing embedded wireless sensors for concrete curing monitoring [5]. Thus, the reviewed studies have demonstrated the potential of utilizing wireless sensing technologies for concrete construction management, although the effectiveness of such technologies depends on the accuracy of the selected equipment and calibration procedures.

-Concrete Strength Estimation

Concrete maturity is a concept that refers to the ability of concrete to gain strength as it cures. Concrete maturity can be estimated using concrete temperature data and a concrete maturity function established through laboratory testing. Researchers have investigated the potential benefits of utilizing concrete maturity data to predict concrete strength and determine the appropriate time to remove formwork. Temperature monitoring of concrete elements is relatively simple; nevertheless, the accuracy of results depends on the precision of the selected equipment. Maturity-based concrete strength prediction is an invaluable tool for construction management; however, constructing a maturity graph requires concrete temperature data, which can be affected by numerous external factors. The accuracy of predicted results is also affected by the calibration process, which determines the suitability of a selected maturity function for a particular concrete mixture.

-Non-Destructive Testing

Non-destructive testing (NDT) is a method that utilizes specialized equipment to assess the material properties of structures without damaging their integrity. Researchers have investigated the potential of utilizing NDT for concrete strength assessment in various settings. For example, Pereira and Romão have reviewed the available methods for assessing concrete strength using NDT and evaluating the variability of results [6]. Another team of researchers led by Hedjazi have explored the utilization of NDT for examining the mechanical properties of concrete with fiber reinforcement [7]. Although NDT is a valuable tool for concrete construction management, its utilization is limited by a number of factors, including the accuracy of results and the precision of the selected equipment.

CONCLUSION:

The reviewed articles demonstrate that BIM can be utilized to enhance concrete construction management by integrating data from IoT-enabled devices, embedded sensors, maturity-based concrete strength estimation, and non-destructive testing methods. Traditional methods of concrete testing, such as laboratory evaluation of concrete specimens, are crucial for estimating the mechanical properties of concrete. However, such approaches offer limited benefits for concrete construction management because they do not account for the unique conditions of a specific construction site. Sensor-based monitoring, maturity-based concrete strength estimation, and non-destructive testing can be utilized to gather valuable data on concrete curing and behavior to ensure that concrete structures meet the required standards. BIM can be utilized to store and visualize this information in relation to specific structural elements.

Nevertheless, effective BIM-IoT utilization requires additional technologies to be integrated into the platform. IoT-based data collection involves utilizing embedded sensors, which requires appropriate calibration procedures and accurate temperature estimation equipment. Maturity-based concrete strength estimation can provide valuable insights into the early-age behavior of concrete, which is crucial for determining if a concrete element is ready to proceed to the next stage of construction. The gathered information can be utilized to ensure the quality of concrete construction elements, as well as minimize delays during the construction process.

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