





Utilizing the Concrete Maturity Method for In-Situ and Real-Time Monitoring Using Portable Devices in the Construction Industry

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Abstract. As the Concrete Maturity Method is a widely recognized approach for estimating the strength development of freshly cast concrete. In the construction industry, Hutama Karya has advanced this method by developing a portable device equipped with sensors capable of real-time monitoring of concrete strength under actual site conditions. This portable system facilitates daily monitoring of temperature and strength development, offering an alternative to the traditional Universal Compressive Strength (UCS) test, which typically requires laboratory analysis to determine early-age concrete strength and maturity. The maturity method supports timely decisions on whether structural elements, such as formwork or other components, are ready for subsequent construction stages. By reducing reliance on conventional testing methods, the portable tool minimizes resource demands for quality control and monitoring. The device has been deployed across several company projects and tested on various structural elements, including formwork, columns, and girders. Comparative analysis between data from the portable tool and traditional methods has shown a high correlation, with R-values approaching 1.0—one instance reaching 0.899—demonstrating the tool's accuracy and reliability. Overall, this innovation contributes to more efficient and sustainable construction practices by streamlining the concrete maturity assessment Process.

Keywords: Concrete Maturity Method, In-situ Monitoring, Temperature, Non-Destructive Test (NDT), Real time Detection

1 Introduction

1.1 Brief Introduction

Green construction is an essential component of Goal 9 from the Sustainable Development Goals (SDGs), aligning with the broader objectives of sustainable development by ensuring that infrastructure development is environmentally responsible, economically viable, and socially beneficial. As Promoting green construction practices is crucial for achieving a sustainable future, addressing climate change, and improving the quality of life for all as from the Indonesian National Standard (SNI 1974:2011), the compressive strength of concrete is tested by applying axial load to cylindrical test specimens. These specimens, moulded either in the lab or on-site, are subjected to loading within set limits until they fail. The compressive strength is determined by dividing the maximum load the specimen can withstand by its cross-sectional area (Enishtalouis et al., 2019). This testing provides a basis for quality control of the concrete mix, mixing process, and pouring activities, ensuring the outcomes meet specifications. Many new technologies have emerged in the construction industry, especially for concrete. Among these is the concrete quality prediction tool available in various brands. However, this tool often fails to meet the Indonesian market's need for user-friendliness in regional projects. In response, PT Hutama Karya (Persero) has developed the Concrete Maturity Test (ConMT). This innovation offers a cost-effective and superior solution tailored to the needs of construction projects in Indonesia. PT Hutama Karya (Persero), a state-owned enterprise specializing in construction and infrastructure, is advancing the ConMT product through its System Development and Technology Research Division (Bstieler & Noble, 2023). This initiative aims to satisfy the demands of the Indonesian construction market and enhance the company's value.

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2 Literature Review

2.1 Maturity Concept

Concrete maturity is a technique used to predict the strength development of concrete over time, based on the idea that the strength is closely linked to the temperature-dependent hydration of cement. This approach offers a straightforward way to estimate the compressive strength of concrete, particularly within the first 14 days. For example, a specific concrete mix can achieve the same compressive strength after curing for 7 days at 10°C as it does after curing for 3 days at 23°C. The maturity function, which is related to the initial temperature, is derived from measurements of variations in constant values based on curing temperature.

The Nurse- Saul equation mathematically is represented as followed:

$$M = \sum(T_a - T_d)\Delta t \quad (1)$$

$M(t)$: Maturity at Age t (°hrs)

T_a : Average Temperature (°C)

T_d : Datum Temperature (°C)

Δt : Time Interval (hrs)

$$1^\circ C_{hrs} = 1.8^\circ F_{hrs} \quad (2)$$

2.2 Concrete Maturity Test (ConMT)

Concrete maturity test is a non-destructive approach to testing concrete by estimating the initial age and compressive strength of concrete in real-time, on-site. This method has advantages over traditional concrete testing in terms of time and cost efficiency, and the ease of developing and using its device, known as the Concrete Maturity Test (Concrete Maturity, Giatec, 2010). The Concrete Maturity Test (ConMT) was developed by PT Hutama Karya (Persero) as an effort to improve the performance of construction projects, one of the company's core businesses. Additionally, the company saw opportunities for enhancement over similar tools already available on the market, in terms of the formulas/functions used and the design aspects. The ConMT developed by Hutama Karya & UNS offers advantages over existing competitors, including affordable components available on the market and local assembly.

The development of this tool by ConMT has been ongoing for two years, initiated in 2021 and followed by a collaboration with Universitas Sebelas Maret (UNS) in 2022. By 2023, it was implemented on a limited basis in construction projects managed by the company. The ConMT developed comes in two types: portable and wireless, based on field requirements. The portable type can be used flexibly and mobile at all concrete casting locations on project sites, and is particularly useful in project locations with poor internet connectivity. Meanwhile, the wireless type is designed for use in locations with good internet connectivity, allowing for integrated Concrete maturity monitoring based on the Internet of Things (IoT). These two types are expected to complement each other and provide a real-time concrete maturity monitoring solution, aiding in decision-making on projects.

For the physical design, including the user interface and tools, an application on a mobile phone is used, as shown in the following image. The user interface is designed to be as simple as possible for ease of use and understanding by operators and users in the field, even in extreme conditions. The design is also made to be more rigid and durable against impacts and extreme weather, and easy to carry and mobilize in the field.

Table 1. Comparison Between Break Test and Maturity Test using Portable Tools (ASTM, 2021)

Aspect	Break Test	Maturity Test Portable Tool
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Guidelines	ASTM C39	ASTM C1074
Quality Information	Quality Information from the Concrete Test	Strength Information from the concrete temperature which is inputted from the Function
Output	The output depends on how the preparation and Sample making the best or not	Only depends on the concrete temperature, not depend to how the sample is produced
Testing	Needs time in production, logistic, and sample testing	50% of Sample Testing is cut off for Insite test

3 ConMT Implementation in Construction

Installment of Portable ConMT can be situated in specimen and in the part of structure. The method for installing sensor points ini this implementation involves first installing the sensors according to the planned quantity (Ary et al., 2021). Once the sensors are in place, the concrete is poured for the structure. The sensors are embedded in the concrete at a depth of 15 cm as shown in Figure.

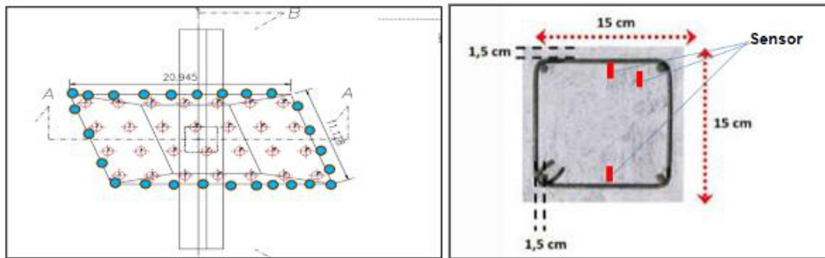


Fig. 1 Sensor Installation Positions on Pierhead and Thickness Depth

During the data collecting process, the initial temperature data collection is closely related to the prediction data of compressive strength (Nandhini & Kartikeyen, 2021). The initial temperature data can be obtained after concrete casting. Embedded sensors obtain and record the temperature of concrete pour at construction site. After obtaining the initial temperature data, recording is done for each installed sensor and calculate the temperature data and the pre-established strength-maturity curve, to estimate the concrete’s in-situ strength in real-time. This process mimic the strength developmental progress of cast *in-situ* concrete compared to the conventional cylinder test.

4 Methodology

This study employs a qualitative approach to the implementation of ConMT as a portable tool of the non-destructive test for concrete maturity. The research focused on qualitative analysis of concrete maturity test implementation in PT Hutama Karya (Persero) projects.

4.1 Portable tool Installation

The installation of the portable tool will be done by attaching the sensor inside of the materials, then the end point of the other side can be plugged in the portable tools. As shown in Figure 2, the sensor cable can be plugged directly to the portable tools. As the sensor will be attached in the concrete, the connecting cable which is outside the cast outside in the structure should be plugged in a system. Then, the monitoring can be done by plugging in to the portable tools.

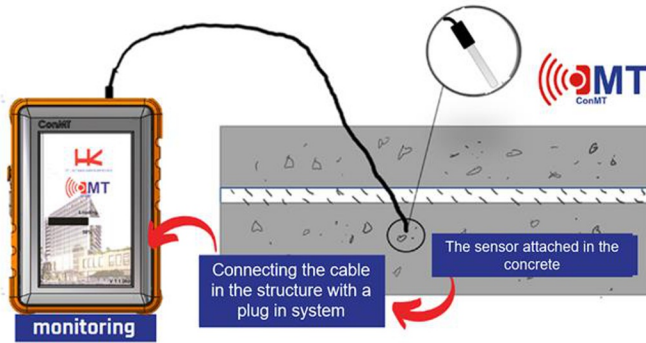


Fig. 2. Concrete Maturity Test Portable Type Instalment

4.2 Data Flow Analysis

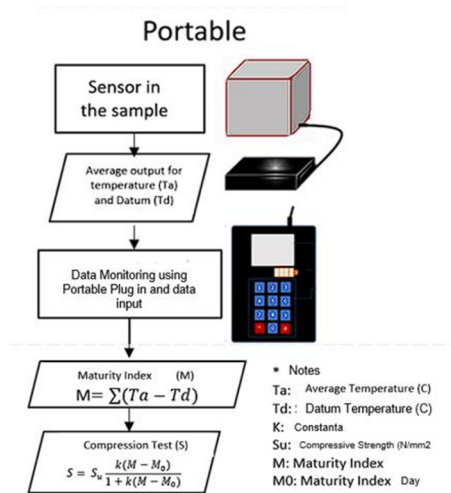


Fig. 3. Concrete Maturity Test Flow

The methodology flow of Portable ConMT starts from to install on the sample, sensor in the sample, then the average output for temperature (Ta) and Datum (Td). The data monitoring using portable Plug in and Data Input are received in the display of the tool. The data input then will be processed and the output to the counting will be the temperature and the maturity index. In this case, the maturity Index will be the real time data processed (Ary et al., 2022).

4.3 Installation

The Portable Concrete Maturity is a non-destructive approach to testing concrete by estimating its early age and compressive strength in real-time, on-site. This method offers advantages over traditional concrete testing in terms of time and cost efficiency, and the ease of developing and using the tool known as the Concrete Maturity Test (Concrete Maturity, Giatec, 2010).

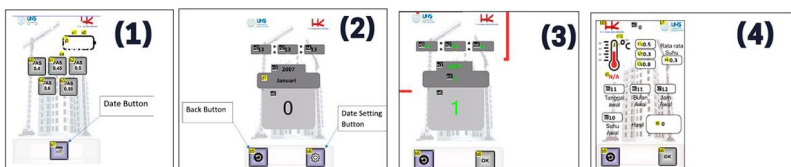


Fig. 4. Steps and Introduction to the User Interface of Concrete Maturity Test Tool: Portable Type Instalment

From Figure 4, the steps of measurement are applied. Step 1 is turning on the Device Press the power button to turn on the device. Wait a few moments until the loading page on the device transitions to the setting mode. Check the date and time before testing the device by pressing the date button on the setting page. Make sure the date and time match the current date.

Step 2 is confirming If the date and time are correct, the user only needs to press the back button to return to the setting page. If the date and time need adjustment, the user must press the date setting button to be directed to the date setting page.

Step 3 is selecting Active Sensors. Select the active sensor. If all three sensor ports are used and you want to take the average value, then activate the calculation in the average temperature box. Inactive sensor ports will be marked in red, while active sensor ports will be marked in green.

Step 4: Setting Initial Casting Time and Date. The initial casting time and date can be set manually or using the memory feature. The write memory button means the device will save the initial parameters to the specified partition number. The read memory button means the device will read the memory according to the partition number. After following the above steps, the user only needs to press the OK button on the screen, and the device will automatically display the concrete hardness in the result column.

5 Discussion

5.1 The Development of the Tool

The Concrete Maturity Test (ConMT) has been developed by PT Hutama Karya (Persero) as part of their effort to enhance construction project performance, one of the company's core businesses. The company identified opportunities for improvement in existing market tools, specifically in the application of formulas/functions and design aspects. The ConMT developed by Hutama Karya & UNS offers advantages over existing competitors, including affordable components available in the market and domestic assembly.

The development of this tool began in 2021, with a partnership with Universitas Sebelas Maret (UNS) starting in 2022. By 2023, the tool was implemented in a limited capacity on company-managed construction projects. The ConMT comes in two types: portable and wireless, catering to field requirements. The portable type is flexible and mobile, suitable for use across various concrete pouring locations, especially where internet connectivity is poor. The wireless type is designed for locations with good internet connectivity, enabling integrated monitoring of concrete maturity based on the Internet of Things (IoT). These two types are expected to complement each other and provide a real-time solution for monitoring concrete maturity, aiding decision-making on projects.

The physical design, including the user interface and tools, can be accessed via a mobile application, as shown in the accompanying image. The user interface is designed to be as simple as possible for easy use and understanding by operators and users in the field, even under extreme conditions. The design is also made to be rigid and durable against impacts and extreme weather, as well as easy to carry and mobilize in the field.

5.2 Implementation Process

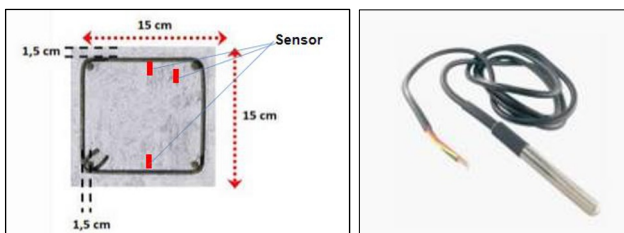


Figure 5: Installation of the Concrete and Temperature Sensor Visualisation

The method of installing sensor points in this implementation involves first casting the concrete according to the planned volume. Once the concrete has been poured and the initial finishing of

the slab and beam structure has been completed, the sensors are embedded in the concrete at a depth of 15 cm for the beams and 6 cm for the floor slabs. During the casting process, parallel work is also carried out by creating test specimens embedded with temperature sensors. With cylinder dimensions of 15x30 cm, the sensor is embedded at a depth of 15 cm within the cylinder



Fig. 6: Concrete Maturity Test Portable Type Instalment and the sensor attached

The minimum to the sensor instalment should be placed minimum above to the 4cm depth. As shown in the figure 6. Meanwhile, the sensor should be put inside the supporting sample. Both either for sample and structure.

Conclusion

Based on research and innovation, the portable concrete maturity test can be the best option as a solution for the real estimation testing method in the concrete maturity test or determining concrete strength (Poole, 1946). The design is minimalist and robust enough to be used in field construction. Besides, the portable tool as one of the Non-Destructive test that can be the best solution in estimating the strength and temperature of the concrete.

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