DETERMINING IN-PLACE CONCRETE STRENGTH

How the measuring method you choose can affect productivity

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1. EXECUTIVE SUMMARY

Knowing in-place concrete strength can be a key indicator for making decisions on a construction site. This paper provides an overview of what the challenges are when working with concrete, what parameters may influence concrete strength development and what methods are available to measure concrete strength.

2. CONCRETE CONSTRUCTION CHALLENGES

Over the past century reinforced concrete has proven to be a versatile material for construction projects with a high structural complexity. With its ability to resist tension and compressive loads, and the fact that it can be poured into a wide variety of shapes and forms, it's clear why reinforced concrete is widely used in construction projects. In addition, the ingredients for concrete are easily available and the concrete mix can be adjusted to cater to the specific demands of the construction project.

However, using concrete on construction sites can also pose certain challenges in the design and execution phase:

- Concrete members and steel reinforcement need to be designed for the structure's load and construction workflow
- The appropriate concrete mix design, and most importantly the final compressive strength, need to be defined
- Jobsite conditions like ambient temperature, exposure classes, formwork and method of concreting need to be taken into consideration
- The structural integrity of all concrete members needs to be checked during and after the construction process
- Concreting workflows need to be aligned in the construction process, which are often challenged by tight schedules
- Impromptu changes on the construction site affect quality and schedule
- It is necessary to document data and decisions on the construction processes

3. CONCRETE STRENGTH DEVELOPMENT

In order to remove formwork and shoring or to tension slabs, it is important that the in-place concrete has achieved a certain compressive strength. The development of concrete strength may differ greatly depending on the concrete mix, the conditions on the jobsite, or specifically the in-place concrete temperature. Concrete at high temperature will develop strength faster than the same concrete at lower temperature. In fact, below a certain temperature threshold (typically 5°C) the concrete will not cure properly at all.

Understanding the in-place compressive strength of concrete at a given time can help to make timely decisions on the construction project. There are various methods to measure in-place concrete strength (i.e., compressive strength of concrete), all of which are accepted by the European Standard EN 206 (Concrete - Specification, performance, production and conformity) given the structural engineer and producer agree for the use in a project.

3.1 Methods of measuring concrete strength

3.1.1 Concrete cylinder / cube tests

Cube breaks by the traditional method

Samples are cast during the concrete pouring process on the construction site.
After 24 hours on the construction site, the samples are transported to a local concrete laboratory for testing at certain time intervals (typically at 1, 3, 7, 14 and 28 days).
Results are used to determine whether a certain strength has been reached.

Advantages:

- Guarantees the concrete mix used on the construction project is laboratory-tested
- Indicates the specified mix was delivered to the jobsite

Disadvantages:

- Concrete cylinders/cubes are typically stored at room temperature, while the in-place concrete on the construction site will typically be warmer and therefore develop concrete strength quicker
- The results are not available in "real-time." If the compressive strength was not reached at a certain test, the construction site must wait until the next test interval to make a decision

3.1.2 Maturity meters

Maturity meters utilize in-place temperature data to calculate concrete maturity through the calibration data of the concrete mix inputted by the user beforehand.

The concrete mix is calibrated beforehand at a concrete laboratory.

The sensors are wired probes attached to rebar before the concrete is poured.

External maturity meters are attached to the wires to collect temperature data and calculate the in-place concrete strength. There are wired and wireless data collection meters available.

Wired sensors with probes attached to rebar

Advantages:

- In-place temperature and strength can be measured on the construction site
- Non-destructive method

Disadvantages:

- Wires protruding from the concrete member can be a hazard
- The project needs to ensure that the same concrete mix used on the construction site is calibrated beforehand Impromptu changes of concrete mix need to be reported and may lead to need for recalibration

3.1.3 Rebound hammer or Schmidt hammer

Schmidt hammer test

The plunger of the test hammer hits the concrete surface and the elastic mass within the hammer will rebound depending on the hardness of the concrete surface. The rebound number that can be read off the hammer is correlated with the compressive strength.

Advantages:

- Easy-to-use method
- Non-destructive method

Disadvantages:

- Calibration of rebound hammer necessary. A wrongly calibrated tool may result in incorrect results
- Multiple samples (ca. 12) are necessary due to local variations in the concrete testing
- It is important that the hammer is held in the right angle to the surface when testing the concrete

3.1.4 Sensors Monitoring maturity

Sensors are fully embedded wireless devices to monitor temperature and concrete strength

The concrete mix is calibrated beforehand at a concrete laboratory

Sensors are activated by the software app by scanning the QR code before installation. Sensors are then attached to rebar before concrete is poured.

Data collection is done wirelessly either via Bluetooth or long-range technology

Hilti Concrete Sensor

Advantages:

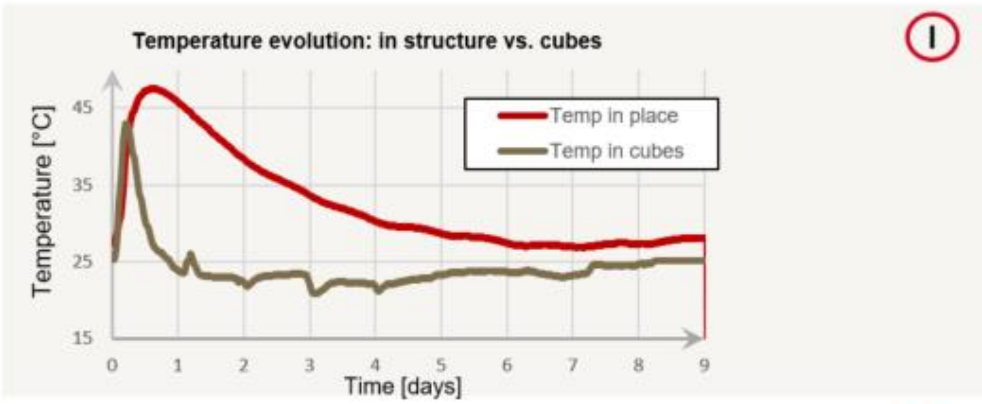
- In-place concrete temperature and strength measurements can be easily retrieved from sensors using either Bluetooth or long-range technology
- Alerts can be set to notify construction site when a certain concrete strength has been reached
- Sensor readings can be easily documented and shared with collaborators using the App or the data export function
- Easy installation and activation of the sensors directly on the rebar

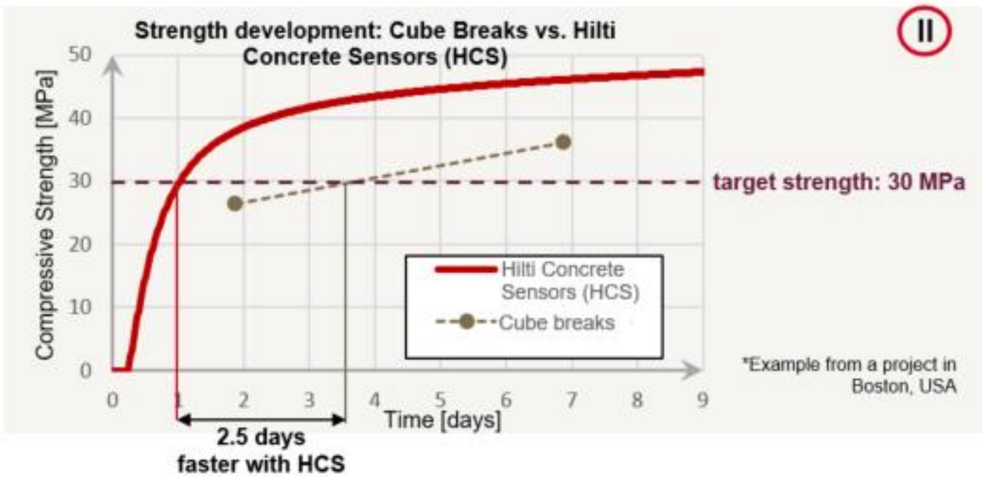
Disadvantage:

- The project requires that the same concrete mix used on the construction site is calibrated beforehand. Impromptu changes of concrete mix need to be reported and may lead to need for recalibration

4. CASE STUDY: SAVING TIME IN BOSTON

In the MIT Kendall Square Initiative SoMa project in Cambridge, USA, the structural engineer had determined that the compressive strength of the concrete would have to reach a minimum of 30 MPa in order to tension PT decks. Traditionally, the construction site used concrete cubes tests to determine the concrete strength. The concrete samples were taken from the concrete truck on the construction site and stored in the concrete laboratory at room temperature of ca. 22°C. After two days and again at seven days the laboratory performed crush tests and reported the results, plotted on a graph, back to the construction site (see gray line in graph II). Following this method, the concrete had reached a compressive strength of 30 MPa after 3.5 days.





As the average ambient temperature on the construction site was well above 25°C and the project schedule faced a lot of pressure, the project manager looked for a method that would provide a more accurate concrete strength reading. Subsequently, the use of concrete sensors was decided.

The concrete mix was calibrated in the concrete laboratory and the specific strength development data entered in the software. On the construction site, concrete sensors were installed in the four corners and the center of the slab. Based on the reading of the sensors in the slabs, it was clear that the in-place temperature was significantly higher than 25°C, meaning that the slab had reached a compressive strength of 30 MPa after just one day.

5. FINAL THOUGHTS

Contractors have many options for determining the strength of curing concrete, each providing its own advantages and disadvantages. As the Boston case study demonstrates, embedded concrete sensors allow stakeholders to monitor their slab's maturity in real time rather than relying on lab data, which doesn't always reflect what's happening onsite. As a result, they can make scheduling decisions, like removing formwork sooner or stressing PT cables, earlier and with more confidence.

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