A LOW-COST MATURITY METHOD IMPLEMENTATION BASED ON OPEN-SOURCE DEVELOPMENTS

Thomas Russo[1], Miguel Azenha[2], José Granja[3], José Terra[4] and Carlos Gomes[5]

[1] Civil engineering department; University of Minho; thomas.russo@civil.uminho.pt
[2] Civil engineering department; University of Minho; miguel.azenha@civil.uminho.pt
[3] Civil engineering department; University of Minho; granja@civil.uminho.pt
[4] Structural engineering department; Shay Murtagh; jose.terra@shaymurtagh.ie
[5] Structural engineering department; Shay Murtagh; carlos.gomes@shaymurtagh.ie

Abstract. Even though the maturity method [1] is well known in the civil engineering area, it can still be complicated to implement for small to middle size companies. Indeed, the commercial devices found on the market can represent a non-negligible investment for these companies both in terms of equipment acquisition and services. Moreover, there are frequent subscription models, for software and hardware services, bringing the user to the verge of vendor lock-in. Another issue is the dissemination of the data into the supplier's servers, which can create data security problems.
In order to get independent from any supplier, a fully open-source solution was developed, using relatively low-cost electronics (~250€ for a full setup). The solution offers the possibility to collect data from a structure, and to have samples aging in a climatic chamber at the same conditions as the structure, to verify the maturity level of concrete and make predictions of the compressive strength. A user-friendly interface was integrated and the database together with the webpage displaying the results are hosted on the company servers. This maturity system was demonstrated in a prefabrication plant, and the documentation will be publicly shared on GitHub. This paper will present the maturity system developed, as well as its advantages and limits.

Keywords: open-source, custom design, maturity method, concrete.

1.PRESENTATION OF THE SYSTEM DEVELOPED

In this part, the maturity system developed will be detailed. The presentation will be divided in two parts: the hardware aspects and the software explanation.

The presented maturity system was designed with relatively low-cost electronics. The computing device, a Raspberry Pi 4 model B with 8GB of RAM, was selected for its multitask abilities and because it offers the possibility to develop a graphical user interface. The Raspberry Pi can also be used as a server to host the online database and the webpage to display the results. All these features are not proposed by cheaper development boards such as Arduino Uno for example. For the temperature acquisition, platinum resistance temperature detectors (RTD PT100) were selected for their precision, which is significantly better than cheaper sensors such as NTC/PTC thermistors [2]. For the measurement of the structure temperature, the RTD PT100 sensor has to be covered not to be damaged when embedded in the material. However, the sensor measuring the temperature inside the climatic chamber should be uncovered in order to detect temperature changes faster. As the Raspberry Pi does not possess any analog to digital converter (ADC), it is necessary to use an external one. A RTD PT100 specific ADC was used in this project, the MAX31865 from Adafruit. The total resolution of the temperature acquisition system is 0,03°C, and the precision is ±0,5°C. The temperature inside the climatic chamber is controlled with an industrial heater of 1000W. The box constituting the climatic chamber doesn't need to be insulated, and vents need to be added, to prevent the temperature from rising above the targeted temperature for too long.

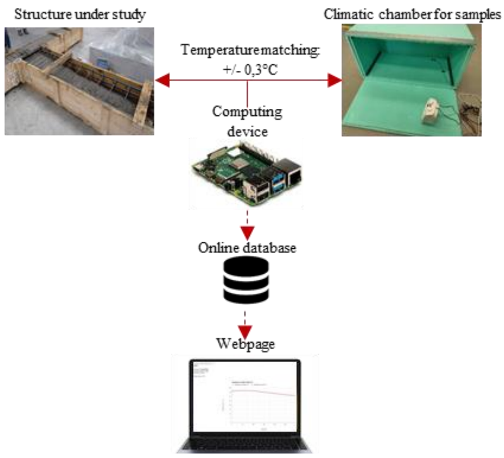

Figure 1. Graphical representation of the system.

The software part can be divided in two subparts: the temperature control algorithm and the online database. The temperature control algorithm is inspired from proportional integrative derivative (PID) method but was simplified into a combination of ON-OFF and PID method [3]. The temperature of both the structure and the climatic chamber is measured every half second, as well as the trend of the climatic chamber temperature curve. According to these parameters, it is decided whether to turn the heater ON or OFF, and for which duration. The data are stored locally on the SD card of the Raspberry Pi, as well as on an online database. The webpage displays the data contained in the online database in real time, as well as plots and strength prediction curve. On the webpage it is possible for the user to enter a safety limit temperature, that would stop the system if reached. The activation coefficient of the mix tested can also be entered on the webpage. Thanks to the online database and to the webpage, it is possible to access the test results from anywhere in the world in real time.

2. RESULTS

The maturity system was tested in laboratory and will be deployed in the near future on a prefabrication plant of prestressed concrete units. The figure 1 shows the temperature pot obtained during a constant temperature maintaining test over 8 hours. For this test, the algorithm was set to maintain the temperature of 32°C inside the climatic chamber. The average temperature obtained on the 8 hours was 31,98°C. Further various tests of temperature matching, target temperature changes, and temperature matching tests with a sample of hardening cement paste were conducted. All gave satisfying results as the constant temperature maintaining test presented above. In such conditions, we can assume that samples aging in the climatic chamber age at the same temperature as the tested structure. Thus, we can apply the maturity method calculations and verify the prediction with compressive strength tests on the samples.

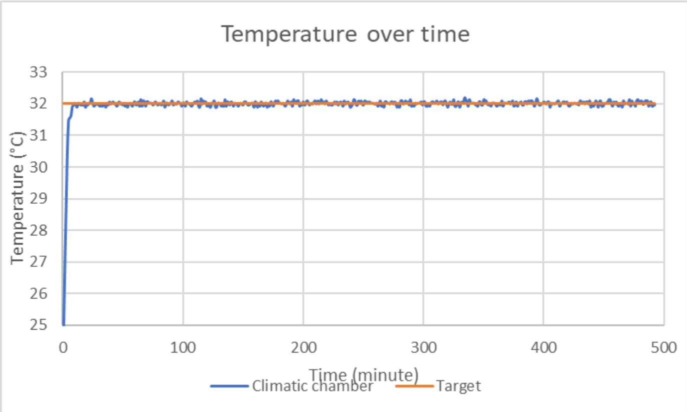

Figure 2. Temperature plot during constant temperature maintaining test.

3. CONCLUSION

To conclude, a low-cost open-source maturity system was developed and tested in laboratory. The system allows the calculation of the equivalent age of the tested structure through maturity method calculations. In addition to these calculations, and because maturity predictions shouldn't be used alone for safety reasons, the device offers the possibilities to have samples aging at the same temperature as the tested structure, in order to process compressive strength tests on the samples to verify the maturity predictions. Complete documentation of the system will be publicly shared on GitHub

The device was designed with relatively low-cost electronics, but could have been achieved with cheaper components. Indeed, the graphical user interface together with the database and webpage hosted on the server from the Raspberry Pi are not needed to apply the maturity method. Moreover, cheaper temperature sensors could have been used, since the maturity method doesn't absolutely require such laboratory grade measurements.

ACKNOWLEDGMENTS

This work was partly financed by FCT / MCTES through national funds (PIDDAC) under the R&D Unit Institute for Sustainability and Innovation in Structural Engineering (ISISE), under reference UIDB / 04029/2020.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Marie Sklodowska-Curie project SUBLime [Grant Agreement n. 955986].

REFERENCES

[1] ASTM C1074-19e1, "Standard Practice for Estimating Concrete Strength by the Maturity Method maturity index and maturity method," *ASTM Int.*, 2019, doi: 10.1520/C1074-19.2.

[2] "RTDs, PTCs, and NTCs: Temperature Sensors | DigiKey." https://www.digikey.com/en/articles/rtds-ptcs-and-ntcs-how-to-effectively-decipher-this-alphabet-soup-of-temperature-sensors.

[3] A. Marisiensis, S. Technologica, and M. Dulău, "ON-OFF ALGORITHM COMBINED WITH PID ALGORITHM," vol. 16, no. 1, pp. 5–9, 2019.