Determining Concrete Maturity with Temperature Monitoring

Thermocouple Data Loggers Save Time & Improve Safety

Concrete maturity is a measure of how much a batch of freshly poured concrete has cured. It is a quick indicator of the in-place strength at that point in time relative to the ultimate strength when the concrete is fully cured. Traditional measurements of concrete strength rely on compression tests such as made in a lab on field cured sample cylinders of concrete made during the pour or pullout or penetration tests made on site. The maturity method calculates an index based on time-temperature data which provides a relative indicator of strength.

This technique is attractive because it can be done quickly on-site with a temperature data logger and thermocouple sensors embedded in the pour. Using the maturity index is attractive because it can save time and improve safety by allowing form removal, post-tensioning, joint sawing or putting structures in service knowing that required strength has been obtained.

What is the Maturity Index?

The maturity method is based on idea that strength of concrete is based on the hydration of cement in the mix. This hydration is an exothermic reaction which give off heat. By recording the temperature profile at regular time intervals during the curing process you can estimate the strength of the concrete on-site in real-time.

The American Society for Testing Methods (ASTM) had created a standard procedure for estimating concrete strength using the maturing method, ASTM standard C 1074. This method requires an initial calibration process which requires evaluation of the maturity index in parallel with more traditional compressive strength test to develop the maturity index vs. strength curve. Once this curve is established it is assumed to be valid for any pours that use the same mix recipe.
The maturity index is calculated from the raw time temperature data using one of 2 expressions:

1. **The temperature-time factor:**

   \[ M(t) = \sum (Ta - To) \Delta t \]

   Where:
   - \( M(t) \) = Maturity temperature-time factor
   - \( Ta \) = Average temperature during time interval \( \Delta t \)
   - \( To \) = Datum temperature below which no hydration occurs
   - \( \Delta t \) = time interval between measurements

2. **Equivalent age using an Arrhenius function:**

   \[ t_e = \sum e^{-\frac{Q}{T_a - T_s}} \Delta t \]

   Where:
   - \( t_e \) = Equivalent age
   - \( Q \) = Activation energy divided by gas constant \( K \)
   - \( T_a \) = Average temperature during time interval \( \Delta t \)
   - \( T_s \) = Datum temperature below which no hydration occurs
   - \( \Delta t \) = time interval between measurements

Of these 2 methods, the second is more accurate, but the first is considered good enough for most applications.

**How to Measure Maturity Index**

The use of the maturity method in real applications requires 3 pieces. First, temperature sensors need to be imbedded in the pour. The simplest way to accomplish this is to obtain a spool of thermocouple wire, commonly 20 to 24 gauge solid wire K or T type. The actual sensor is created by stripping a short length of wire, 1/2”, and then twisting the two conductors together. The sensor is placed in a convenient location in the pour, either before or immediately afterwards. It’s important that the sensor be in good physical contact with the concrete. The thermocouple wire is extended out to a spot where the data logger can be placed out of harm’s way.
For the data logger, a simple battery powered stand-alone unit like the Grant Squirrel OQ610 or VersaLog VL-TC allows temperature data for multiple locations to be recorded. There are also wireless units like the VersaLog VL-WF-TC or TandD RTR-505-TC which allow streaming the data back to a computer in real-time.

The last piece is the software for analysis and calculation of the Maturity time-temperature factor or equivalent age. The equations above can be quickly created in Microsoft Excel. All of the previously mentioned data loggers allow recorded data to be exported as a .CSV text file that can be easily imported into Excel. An example template for the Grant OQ610 can be downloaded here.

**Conclusion**

The Maturity Index provides a convenient way to estimate the in-place strength of concrete during curing. It is based on the principle that the strength is determined based on the temperature-time history during the curing process. Using a thermocouple data logger with simple thermocouple temperature sensors embedded in the concrete allows the data to be recorded. This data can then be quickly analyzed using a tool like Excel to calculate the maturity index.

For more information on concrete temperature monitoring, or to find the ideal solution for your specific needs, contact a CAS Data Logger Applications Specialist at (800) 956-4437 or visit our website at www.DataLoggerInc.com.