Using Maturity Systems to Evaluate Concrete Strength

by John Gnaedinger, Con-Cure, and Danielle Shultz, CTL Engineering

Many people in the bridge-building community may be surprised to learn that the maturity method, introduced 20 years ago as ASTM C1074 *Standard Practice for Estimating Concrete Strength by the Maturity Method,*[1] can be incredibly beneficial for every stakeholder in the building process, including contractors, departments of transportation (DOTs), concrete producers, and testing agencies. The maturity method (often just called "maturity") is a vital supplement to traditional methods of testing concrete that are required by codes and specifications.

Applications in Bridges

Maturity is recognized by many state DOTs as an alternative to field-cured sample testing for determining in-place concrete strength for low-risk applications such as slab-on-grade fast-patch pavement repairs and mainline paving,[2] but its use in bridge construction is not nearly as universal. Using maturity can have substantial benefits for all aspects of concrete bridge construction, especially for high-risk projects where post-tensioning and cold-weather operations are commonplace.

Estimating concrete strength using maturity has been in place for more than 60 years and is based on the fact that concrete gains strength at a rate that is generally proportional to the temperature history of the concrete during the curing process. Maturity/strength relationships are mixture-specific (relationships must be determined for each mixture's proportions), but as long as the mixture constituents and proportions do not change, maturity estimates are remarkably accurate.[3,4]

There are several different ways to collect the field data needed to estimate concrete strength using maturity. Traditionally, sensors embedded in the fresh concrete record concrete temperatures over time via a data-logging device; then, at various ages, the data are "read"; and an assessment of the strength is made with software using the procedures of ASTM C1074. Today, the most innovative maturity-collection systems provide data to the user in real time via the internet.

Regardless of the type of maturity data-logging device used, the results are the same: in-place concrete strength estimates that are far more accurate than traditional field-cured samples could ever be.

Stakeholder Benefits

Each stakeholder in any bridge project has unique criteria to monitor, record, and achieve. The contractor wants to build quickly and safely while turning a profit. The owner (usually a DOT) wants the project done correctly to maximize the service life of the bridge while minimizing disruption to the traveling public. The engineer wants to ensure that the entire structure meets the minimum design requirements. The concrete producer wants to ensure consistent quality and eliminate cylinder breaks that come back too low (often due to improper curing and handling of the cylinders in the field). The regular use of the maturity method on any concrete project can help all stakeholders achieve their goals simultaneously, easily, and reliably, and this is especially true for time-sensitive and high-risk endeavors.

Contractors have reported many benefits from routine use of maturity on their projects. They experience lower project costs because construction schedules can be dramatically shortened. They can use knowledge obtained during other projects to estimate their time and staffing requirements more efficiently, which allows for more competitive bids. Their energy costs are significantly lower in cold weather, and their reliance on third-party testing is reduced. Finally, they can earn early-completion bonuses, if available, when they finish work ahead of schedules.

Black Ankle Valley Bridge for Interstate 69 in southern Indiana. Maturity and temperature were wirelessly monitored for the cast-in-place piers, saving the contractor the costly process of using a lift to collect recorded data. All data were sent wirelessly to the contractor's job-site trailer. All Photos: John Gnaedinger.

Sensors at the Black Ankle Valley Bridge were also used to monitor test cylinders for curing compliance and verification of strengths.

Conclusion

As more contractors become aware of the value of the data generated by a maturity system and the benefits that accrue almost immediately, we predict that maturity will soon earn the position it deserves as a vital quality control and process improvement tool for the entire construction community. Despite being around for decades, maturity is not yet used by the entire concrete industry. However, those who have embraced the methodology are reaping its benefits.

References

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John Gnaedinger is the founder of and engineering services director for Con-Cure, in Pioneer, Ohio. Danielle Shultz, is project manager for CTL Engineering, in Columbus, Ohio.

Firsthand Account

Danielle Shultz, coauthor of this article, began using maturity systems in 2012. The following recounts a few of her notable experiences using maturity systems on large projects.

My employer was the testing agency for the Interstate 75 rebuild near Lima, Ohio, and we were responsible for all the fresh concrete testing. Initially, we relied exclusively on field-cured cylinders, and it was taking between 10 and 14 days for those test cylinders to reach sufficient compressive strength for the contractor to begin stripping forms and backfilling against the structures. In order for the contractor to backfill, the cylinders had to reach 85% of the design concrete compressive strength (f'_c) per Ohio Department of Transportation (ODOT) specification 511.14-1A. This time-consuming process of waiting for test cylinders to indicate sufficient strength was one reason that the project fell six months behind schedule.

I promoted a maturity system to the contractor, who was unfamiliar with the concept but soon began to appreciate what it could do. Once the maturity curve was established and the sensors were being used on site to estimate in-place concrete strength, we were able to prove that the in-place concrete was achieving 85% of f'_c within 48 hours of placement. Every stakeholder for this important project realized immediately what a huge difference this new approach would make. By using the maturity system to monitor field-cured results and in-place strength data, we were able to get back the six months that the contractor had lost and shorten the project timeline by another three months, which allowed the contractor to receive a $1 million incentive from ODOT for finishing ahead of schedule.

Another instance in which maturity highly benefited a contractor was during winter construction season. The winter prior to implementing maturity, the contractor was required to blanket, tent, cover, and heat concrete until it reached sufficient strength. However, because the contractor was using an excessive amount of heat and covering the freshly placed concrete during the winter months to retain as much moisture as possible, the concrete was often being overheated, which was found to be the root cause of excessive shrinkage cracking and other problems that only appeared much later.

Once maturity was implemented, we were able to demonstrate that extra heat did not need to be added to the tented area because the concrete itself was generating sufficient heat to cure on its own. By reducing the amount of waiting time for the concrete to cure, not having to tent the entire structure, and not using a gas-powered salamander to heat under the tent, the contractor saved more than $50,000 in the first month. The contractor was also able to get ahead of potential problems with the concrete because the maturity system would provide the data to the project manager, technician, contractor, engineer, and owner on how the in-place concrete was behaving and how well it was curing.

We have also used a maturity system to assess the temperature differential and the overall strength for mass concrete placements. Using an innovative wireless maturity system and reusable sensors has allowed us to provide accurate and real-time in-place concrete information for our clients and project owners. Maturity has proven useful on projects that have a tight schedule or strict specifications.

EDITOR'S NOTE

The opinions expressed in this article are those of the authors. Some engineers that reviewed this article stated that using maturity as the only source of strength verification for critical operations is not always advised.

Example of mass concrete temperature and maturity monitoring of a structure in cold weather. Sensors embedded at the core and the surface record temperatures and differentials. All data from the devices are viewable on the internet in real time, saving the contractor valuable time that would have been required to collect and report this information to the engineers.