Florida Department of Transportation Research

Development of a Failure Theory for Concrete

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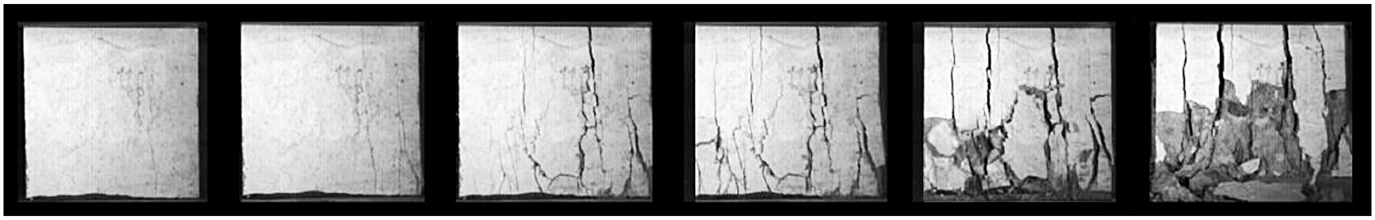

In a sequence of images spanning 0.7 seconds, high speed video reveals crucial cracking phenomena.

Concrete has been in use for over 2,000 years, yet the behavior of this common, but complex, substance is not fully understood. This gap affects standard compressive strength testing (ASTM C 39), which does not account for structural effects caused by sample geometry, size of contact surface, and intensity of surface friction at the compression interface. To assess the true compressive strength of concrete and to study the natural crack propagation within concrete materials, the conventional test method must be modified to reduce or eliminate structural effects.

In this project, the Florida Department of Transportation contracted researchers from Florida A&M University/Florida State University College of Engineering to investigate failure mechanisms in concrete under compression and to determine how accurately standard compressive testing assesses concrete strength.

The researchers' experimental program studied strength performance, crack initiation, crack propagation, and fracture patterns of concrete in uniaxial compression. Experiments employed four typical specimen types under varying boundary conditions, achieved by altering the friction at the interface of sample and bearing plates. Cylindrical and prismatic samples with squared cross-sections were evaluated for influence of sample shape. End confinement effects were assessed by using different bearing plates. Controls were tested with conventional compression plates; low friction materials were applied at the compression interface to assess test group samples. Ultimate strength and final fracture patterns were evaluated according to ASTM C 39, while high-speed video (2,000 frames per second) was used to monitor crack initiation and propagation.

Data analysis revealed consistently lower "ultimate" strength when surface friction at compression interfaces was reduced, regardless of sample shape. However, the extent of reduction differed with sample shape. Clear differences in crack initiation and propagation were found for different boundary conditions. Broadly, low friction interfaces produced more slender fragments, and high friction, typical of conventional testing, gave stockier fragments.

Stress analyses based on continuum mechanics explained observed crack orientations, but not rupture stresses for unconfined uniaxial testing or strength reduction. These effects were explained by observations using high speed video, which clearly documented local buckling (instability), a phenomenon that was facilitated as buckling loads decreased with more slender fragments.

Researchers concluded that current test methods do not reflect "true" uniaxial compressive strength and that specimen response differs from behavior in concrete structures, as strength measurement is affected by both specimen shape and compression interface. This research showed that concrete failure is strain driven; the stress domain does not suffice to explain cracking. Regardless of end confinement and specimen shape, ultimate collapse of concrete resulted from local buckling of concrete fragments that were formed throughout the unstable cracking phase.

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For more information, visit http://www.dot.state.fl.us/research-center