

## **Proper Procedures for Evaluating Low Strengths**

In the concrete industry, there may be some cases of reported low compressive strength test results from various projects. If faced with this situation, before replacing the concrete, verify that it is actually deficient in strength.

### ***Test Report Validation***

The first step is to verify that the procedures used to make and cure the strength specimens were performed according to ASTM C 31 specifications. Also, the procedures followed for the compressive strength testing must meet the criteria of ASTM C 39. Please note the following items from these standards.

- ❖ All strength specimens must have accompanying slump, air content, yield, and temperature data. This data is essential in determining possible causes for the low strengths.
- ❖ Immediately after molding and finishing, the specimens shall be stored in a temperature range from 60 to 80 °F [16 and 27°C]. ASTM C 31 lists the reporting requirements related to curing of the specimens. For standard curing methods, the initial curing method with maximum and minimum temperatures and final curing method are to be reported. The National Ready Mixed Concrete Association (NRMCA) Publication 53 includes the results of a study on the effects of initial non-standard curing. In the study, the effects of non-standard initial curing resulted in strength loss from 10 to more than 30 percent compared to standard cured cylinders. In addition, numerous industry studies have shown that elevated initial curing ambient temperatures result in decreased or lowered 28-day compressive strengths compared to standard curing.
- ❖ ASTM C 31 requires the initial curing to be a period of up to 48 hours maximum. Often times, cylinders are left in the field longer than the standard allows.
- ❖ ASTM C 39 states that two cylinders made from the same batch should not differ by more than 8% more often than 1 in 20 tests for field conditions.
  - For example, two cylinders should not differ more than 320 psi (pounds per square inch) for a 4000 psi test. If this is occurring more frequent than 1 in 20 tests, this may be an indication of improper testing procedures somewhere along the line.
- ❖ ASTM C 39 states that the fracture type should be listed (if other than the usual cone).
  - The specification states that when testing with unbonded (steel) caps, a corner fracture similar to a Type 6 pattern may occur before the ultimate capacity of the specimen has been attained. The specification then goes on to require the continued compressing of the specimen until the user is certain that the ultimate capacity has been attained. If the measured strength is lower than expected, it is also required of

the testing laboratory with a Type 6 fracture type to examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify that the end preparations were in accordance with Practice C 617 or Practice C 1231.

If these procedures were not followed the reports do not represent legitimate information and the strengths must now be determined from either cores or an alternative form of non-destructive testing that may be allowed.

### ***The strength reports are validated, now what?***

The ACI Manual of Concrete Practice (Section 318) provides guidelines for procedures that are helpful at this juncture.

- ❖ First, ACI states that the strength level of an individual class of concrete shall be considered satisfactory if both of the following requirements are met:
  - “Every arithmetic average of any three consecutive strength tests equals or exceeds “ $f'_c$ ” (Required Strength).
  - “No individual strength test falls below  $f'_c$  by more than 500 psi when  $f'_c$  is 5000 psi or less; or by more than 10% of  $f'_c$  when  $f'_c$  is more than 5000 psi.”
- ❖ ACI then states that if the likelihood of low-strength concrete is confirmed (the testing procedures appear to be consistent with current ASTM procedures) and calculations indicate that the load-carrying capacity is significantly reduced, cores shall be taken in accordance with ASTM C 42.
  - Three cores shall be taken for each strength test that falls below the criteria listed above.

### ***Proper procedures for cores***

Cores shall be wiped clean and placed in watertight bags or containers immediately after drilling and tested no earlier than 48 hrs and no later than 7 days.

- ❖ Commentary in ACI suggests the use of some non-destructive testing may be useful in determining whether a portion of a concrete structure contains low-strength concrete.
- ❖ Concrete in an area represented by a core shall be considered structurally adequate if the average of the three cores is at least 85% of  $f'_c$  and no single core is less than 75% of  $f'_c$ .
- ❖ If these results do not meet the above criteria then a detailed strength analysis as outlined by ACI 318 Chapter 20 is required in order to establish structural adequacy. The criteria for possible load testing of a structure are addressed in Chapter 20 of ACI 318.
- ❖ Something to note here is that in some cases the  $f'_c$  may not have been met but there is still enough strength to be structurally safe. Some owners/engineers/DOT agencies will allow the concrete to remain in place and assess a penalty due to the lower strengths.

### ***Finally***

If these procedures have been followed and the structural safety of the structure is compromised, then the concrete must be replaced.

## ***In Summary***

It is important to follow the proper steps when investigating low compressive strength test results on a project. Follow the NRMCA Publication No. 133 guideline which includes the following actions:

1. Verify testing accuracy and ensure that standard procedures were followed when making, curing, capping and testing strength specimens.
2. Compare the structural requirements with the measured strength. Often the portion of the structure represented by a low-strength test may not require the specified strength.
3. Try nondestructive tests to make an evaluation of the strength of the in-place concrete. These tests may not provide direct strength values, but can be used to compare characteristics with acceptable concrete.
4. Tests of cores removed from the structure.
5. Perform load tests on the structure to see if its strength is deficient for the anticipated loading.
6. If all fails, corrective actions are required and this might mean retrofitting the structure or removal and replacement.

### *References:*

*ASTM C 31-06, "Standard Practice for Making and Curing Concrete Test Specimens in the Field", American Society for Testing and Materials, West Conshohocken, PA*

*ASTM C 39-05, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", American Society for Testing and Materials, West Conshohocken, PA*

*NRMCA Publication No. 53, National Ready Mixed Concrete Association, Silver Spring, MD*

*ACI Committee 318, "Building Code Requirements for Structural Concrete" (ACI 318-05) and "Commentary" (ACI 318R-05), American Concrete Institute, Farmington Hills, MI*

*NRMCA Publication No. 133, National Ready Mixed Concrete Association, Silver Spring, MD*

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