Colorado Procedure 65-19

Standard Practice for

Evaluating Low Concrete Strength Test Results

1. SCOPE

1.1 Field test procedures and strength test results for standard molded and cured cylinders and beams shall be evaluated separately for each class of concrete. Such evaluation shall be conducted to determine if tests have been conducted in accordance with the ASTM, AASHTO and/or approved CDOT procedures and specifications.

1.1.1 The evaluation process will include investigation to ensure that proper procedures were followed in the following areas:

-Molding
-Curing methods and temperatures
-Initial curing period
-Laboratory curing period
-Testing procedure
-Personnel qualifications

NOTE: Contact the Central Laboratory at (303) 398-6545 at least 48 hours before coring so that additional instruction can be given.

1.2 This practice is comprised of two methods. Method A for evaluation of low concrete compressive strength and Method B for the evaluation of low concrete flexural strength.

2. EVALUATION

2.1 Should cylinders or beams fall below the specified strength, a field investigation will be conducted as follows:

2.1.1 If test procedures outlined in Subsection 1.1 were not followed, results will be considered to be invalid and the tests shall be discarded. If cores are required, they will be at the expense of CDOT to replace acceptance cylinders and at the expense of the Contractor to replace PC beams.

2.1.2 The concrete supplier will furnish concrete batch tickets of the suspected low strength concrete for comparison against approved mix design.

2.1.3 Batch tickets will be checked to determine job site water addition.

2.1.4 Evaluation of the concrete in question will be made based on Subsections 2.1.1, 2.1.2 and 2.1.3.

3. Section Deleted

4. CORING

4.1 This procedure describes the method used to obtain and evaluate cores from in-place concrete. This will be performed in accordance with the latest revision of AASHTO T 24 (ASTM C 42), with the exception that immediately after removal from the structure, cores will be cured at a temperature between 60° - 80°F (15° - 27°C) and at a relative humidity below 60% for the first 24 hours.

4.2 Cores taken for the determination of strength shall be of a standard size and within appropriate tolerance.

NOTE 1: Bits cut approximately 1/4" smaller than nominal OD (outside diameter). The 4 1/4" and 6 1/4" OD bits produce 4" and 6".

5. APPARATUS

5.1 The apparatus shall be as described in AASHTO T 24 (ASTM C 42).

Method A Compressive Strength

6. PROCEDURE

6.1 Within 45 days after placement, cores with a diameter at least 3 times the nominal maximum size of the coarse aggregate used in the concrete shall be obtained in accordance with AASHTO T 24 (ASTM C 42). The cores shall be conditioned in accordance with Subsection 4.1. The cores will then be tested for compressive strength between 24 and 48 hours after removal.

6.2 At least 3 representative cores shall be taken from the concrete represented by each out-of-specification cylinder set.

6.3 Coring location shall be in locations directed by the Engineer. .

6.4 Core holes shall be filled with low slump concrete or mortar.

6.5 If the compressive strength of any one core differs from the average by more than 10% that core will be discarded and the average will be determined using the compressive strengths of the remaining two cores. If more than one core's compressive strength differs from the average by more than 10%, the average will be determined using all three cores.

6.6 Pay factors for strength of structural concrete shall be according to Table 601-3 of the CDOT Standard Specifications, and will be used to price reduce the cores or standard test cylinders, whichever are higher in strength. Pay factors for concrete pavement will be evaluated according to Subsection 105.06 of the CDOT Standard Specifications.

6.7 The following examples are for structural concrete in accordance with Subsection 601.17 of the CDOT Standard Specifications:

Example 1:

Given: f '$_c$ = 3000 psi
Concrete test cylinders averaged 2820 psi.

	PSI
Core 1	2908
Core 2	2821
Core 3	2433

Average compressive strength of 3 cores = 2720 psi.

Find: Is the concrete in the structure adequate under CDOT specifications?

Solution:

Test Evaluation:

f '$_c$ = 3000 psi

Average compressive strength of 3 cores - 2720 psi

Do any compressive strengths differ from the average by more than 10%?

10% of Average compressive strength = 272 psi
Core 1: 2908 - 2720 = 188 psi, < 272 therefore OK

Core 2: 2821 - 2720 = 101 psi, < 272 therefore OK

Core 3: 2720 - 2433 = 287 psi, > 272 therefore - discard core and re-compute average compressive strength using two remaining cores.

New average compressive strength = 2860 psi

Use Table 601-3 to compute appropriate price reduction based on 2860 psi, since core strengths were higher than the cylinders strengths.

Example 2:
Price Reduction of Concrete

In this example calculation, a certain project has a pay item for 720 cubic yards of Concrete Class D (bridge). The contractor bid $700 per cubic yards. To cover this quantity 8 sets of cylinders were molded and tested for compressive strength at 28 days. Some of the test results showed the concrete had less than the required 28-day compressive strength of 4500 psi. The project engineer has used all eight sets of cylinders to calculate the appropriate price reduction.

Test Number	Cylinder Strength psi	Cylinder Strength psi	Cylinder Strength psi	Average Cylinder Strength Psi
1	4527	4273	4583	4460
2	6213	6057	6222	6160
3	3775	4302	3831	3970
4	4163	4388	4057	4200
5	4039	3833	3786	3890
6	4111	4017	3929	4020
7	4702	4678	4784	4720
8	4959	5141	5232	5110

TABLE 65-1

The average strength of three 28-day cylinders is used to determine the acceptability of concrete placed in a structure. The break results of test numbers 1, 3, 4, 5 & 6 are below the required 28-day strength of 4500 psi for bridge decks. According to Section 601.17(c) of the *CDOT Standard Specification for Road and Bridge Construction* "The concrete will be considered acceptable when the running average of three consecutive strength tests is equal to or greater than the specified strength and no single test falls below the specified strength by more than 3.5 MPa (500 psi)."

Test Number	Average Cylinder Strength psi	Average of Three Consecutive Tests (psi)	Strength Below f_c' psi
1	4460	---	---
2	6160	---	---
3	3970	4863	530
4	4200	4777	300
5	3890	4020	610
6	4020	4037	480
7	4720	4210	---
8	5110	4617	---

TABLE 65-2

The table above shows that the running average of three consecutive tests fall below the required strength of 4500 psi, and the concrete placed will be price reduced according to the pay factors in Table 601-3 in Subsection 601.17. Test numbers 3, 4, 5, & 6 are represented in the low consecutive averages and will be price reduced. Test number 1 is considered acceptable and will not be price reduced because its running average with the next two tests is greater than the required strength, and it is not more than 500 psi below the required strength.

To price reduce the low strength results you need to know the bid price for the concrete, and the quantity represented by each test. As stated above, the concrete was bid at $700.00 per cubic yard. The contractor placed 720 cubic yards of Concrete Class D (bridge). The 720 cubic yards are represented by 8 sets of cylinders. Therefore, on this project the Engineer determined that each test represents 90 cubic yards. This is only an example and the quantity represented per test shall be determined by the Project Engineer. The formula for price reduction is:

$$PR = P \times (1 - PF) \times CY$$

Where:

PR = Price Reduction,
P = Bid Price of Concrete,
PF = Pay Factor from Table 601-3 of Subsection 601.17,
CY = Cubic Yards represented by the test.

Test Number	Average Strength Psi	Average of Three Consecutive Tests (psi)	Strength Below f_c' psi	Pay Factor Table 601-2E	Price Reduction
1	4460	---	---	---	---
2	6160	---	---	---	---
3	3970	4863	530	0.65	$22,050.00
4	4200	4777	300	0.92	$ 5,040.00
5	3890	4020	610	0.54	$28,980.00
6	4020	4037	480	0.75	$15,750.00
7	4720	4210	---	---	---
8	5110	4617	---	---	---
				Total Price Reduction	$71,820.00

TABLE 65-3

The Contractor has the option to obtain cores from the areas represented by tests 3, 4, 5 & 6 before the concrete is 45 days old. Coring will be in accordance to CP 65. In this case the contractor elected to obtain cores from the bridge deck. The following is a summary of the core break results:

Test Area	Core Strength psi	Core Strength psi	Core Strength psi	Average Core Strength psi
3	4221	4002	4106	4110
4	4638	4566	4517	4570
5	3711	3737	3708	3720
6	4266	4504	4411	4390

TABLE 65-4

The core strength results will replace the cylinder strength results if the core strengths are higher. In this case, cores from areas 3, 4 & 6 will replace the cylinder strength results for tests 3, 4 & 6. The following table shows the new price reductions:

Test Number	Average Cylinder Strength psi	Average Core Strength psi	Strength Below f_c' psi	Pay Factor Table 601-2E	Price Reduction
1	4450	---	---	---	---
2	6180	---	---	---	---
3	~~3980~~	4110	390	0.84	$ 10,080.00
4	~~4220~~	4570	---	---	---
5	3890	~~3710~~	610	0.54	$28,980.00
6	~~4030~~	4390	110	0.96	$ 2,520.00
7	4720	---	---	---	---
8	5110	---	---	---	---
		Total Adjusted Price Reduction			$41,580.00

TABLE 65-5

Method B Flexural Strength

7. PROCEDURE

7.1 After 28 days, but within 45 days following placement, cores of the same size as the splitting tensile cylinders used in the trial mix shall be obtained in accordance with AASHTO T 24 (ASTM C 42). The cores shall be conditioned in accordance with Subsection 4.1. The cores will then be tested for splitting tensile strength between 24 and 48 hours after removal at a Department Lab in accordance with AASHTO T 198 (ASTM C 496).

7.2 At least 3 representative cores shall be taken from a single slab represented by each low flexural strength. A core containing rebar or dowel bars shall be discarded and a new core shall be taken.

7.3 Coring location shall be in locations directed by the Engineer. .

7.4 Core holes shall be filled with low slump concrete or mortar.

7.5 If the splitting tensile strength of any one core differs from the average by more than 10% that core will be discarded and the average will be determined using the splitting tensile of the remaining two cores. If more than one core's splitting tensile strength differs from the average by more than 10%, the average will be determined using all three cores.

7.6 The flexural strength of the concrete will be determined by using a correlation of the concrete's flexural strength to its splitting tensile strength.

7.6.1 Using the flexural strength and splitting tensile strengths from the concrete's correlation curve samples, for each age, plot the flexural strength on one axis and the splitting tensile strength on the second axis. Determine a linear equation relating the two strengths.

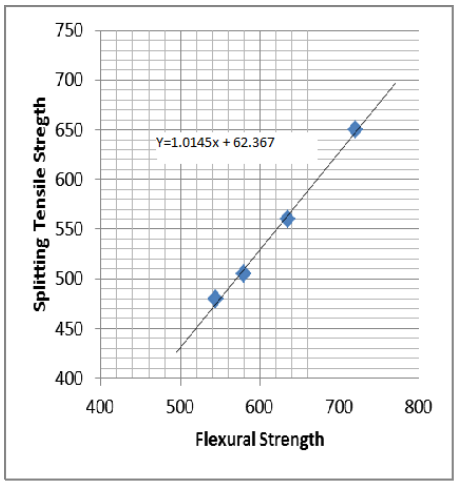
7.6.2 Using the average splitting tensile strength from a set of cores, and the equation in Subsection 7.6.1, determine the corresponding flexural strength.

7.7 Pay factors for concrete pavement will be evaluated according to Subsection 105.06 of the CDOT Standard Specifications.

Example 3:

The following example shows a plot of flexural strength and splitting tensile strength.

Age	Average Flexural Strength (psi)	Average Splitting Tensile Strength (psi)
3	545	480
7	580	505
14	635	560
28	720	650



Using this example plot, a contractor's flexural strength result from a set of beams is below 570 psi, and chooses to core the pavement to replace the low flexural strength results. If the splitting tensile results from the cores is 535 psi the corresponding flexural strength would be 605 psi. Since the core flexural strength is greater than the cast beam flexural strength, the core flexural strength will be used for determining the incentive/disincentive in SMM.