

Title: Acceptance of concrete test results according to the American Concrete Institute's, ACI 318-05, *Building Code Requirements for Structural Concrete*.

Problem: You are the Field Engineer on a project that is currently underway. The project specification states that the concrete strength is 3500 psi in twenty-eight (28) days. The following data contains the two (2) twenty eight (28) day cylinder test data that was sent to you by the testing laboratory. You need to evaluate this data and determine if the concrete is acceptable.

Test #	Cylinder #1 (psi)	Cylinder #2 (psi)
1	4100	4320
2	4320	4190
3	4310	4310
4	4420	4380
5	4200	4160
6	4250	3810
7	3880	4040
8	3570	3680
9	3570	3210
10	3780	3780
11	3680	2980
12	3300	3740
13	3470	3210
14	2770	2750
15	3200	3480

Assumptions

1. Sampling frequency is adequate; the minimal frequency is:
 - a. Once a day for a given class
 - b. Once every 150 yards³
 - c. Once each 5000 feet² of surface area for slabs or walls
(ACI 318.5.6.2.1)
2. Samples are taken on a random basis – concrete was not to be sampled due to appearance, convenience, or other biased criteria.
(ACI 318.5.6.2.2 and ACI 318R. 5.6.2.2)
3. Each set of cylinders come from a different batch of concrete.
(ACI 318.5.6.2.2 and ACI 318R 5.6.2.2)
4. No water was added to the concrete after the samples were taken.
(ACI 318R. 5.6.2.2)
5. Qualified field testing technicians performed the test on the fresh concrete.
(ACI 318.5.6.1)
6. Qualified laboratory technician performed all required laboratory tests.
(ACI 318.5.6.1)

Solution

1. Determine the strength test results (average strength of two tests cylinders from the same batch and tested at 28 days or at test age designed for determination of f'_c . (ACI 318.5.6.2.4)

$$\frac{\text{Cylinder 1} + \text{Cylinder 2}}{2} = \text{strength test results}$$

On our project:

For strength test #1:

$$\frac{4100 + 4320}{2} = 4210 \text{ psi}$$

Thus the strength test results are:

Test #	Strength Test Results (psi)
1	4210
2	4255
3	4310
4	4400
5	4180
6	4030
7	3960
8	3625
9	3390
10	3780
11	3330
12	3520
13	3340
14	2760
15	3340

2. Determine the arithmetic average of any three (3) consecutive strength test results. (ACI 318.5.6.3.3a)

For the first three (3) strength test results –

$$\frac{ST_1 + ST_2 + ST_3}{3} = \text{Arithmetic Average}$$

On our project

$$\frac{4210 + 4255 + 4310}{3} = 4258 \text{ psi}$$

Thus, the arithmetic averages are:

Test #	Arithmetic Average (psi)
1	-----
2	-----
3	4258
4	4322
5	4297
6	4203
7	4057
8	3872
9	3658
10	3598
11	3500
12	3543
13	3397
14	3207
15	3147

3. Determine if any strength test results are below $f'_c - 500$ or by more than $0.10f'_c$ when f'_c is more than 5000 psi.
(ACI 318.5.6.3.3b)

Since $f'_c = 3500$ psi, inspect the strength test results for:

$$f'_c - 500 \text{ or } 3500 - 500 = 3000 \text{ psi}$$

On our project:

Strength test result # 14 is the only strength test result below 3000 psi.

Notes:

- Only the strength test results (average of 2 cylinders) are to be used **not** the individual cylinders results.
- Test # 9 has one cylinder test result below 3500 psi (3210 psi). This does not indicate a problem since the strength test result is 3390 psi; this is above 3000 psi, thus, the concrete is acceptable.
- Test # 11 has a cylinder test result of 2980 psi. The strength test result is 3330 psi; this is above 3000 psi, thus the concrete is acceptable.

4. Determine if either the arithmetic average (calculated in Step 2) is below f'_c or if the strength test result is $f'_c - 500$ psi (calculated in 3), steps must be taken to improve the strength of future concrete placements.
(ACI 318.5.6.3.4)

On our project:

- a. The arithmetic average of three (3) are below f'_c (3500 psi) on test numbers 13, 14, and 15.
- b. Strength test results below $f'_c - 500$ or 3000 psi occurs at test number 14.

Thus on our project, we must improve future concrete placement.

5. Options of what needs to be done:
- a. An increase in cementitious materials content
 - b. Change in mixture proportions
 - c. Reductions in or better control of levels of slump supplied
 - d. A reduction in delivery time
 - e. Closer control of air content
 - f. An improvement in the quality of the testing, including strict compliance with standard test procedures

(ACI 318R. 5.6.3.4)

On our project

Changes need to be made so that we do not continue to make questionable concrete. One or more of the above needs to be implemented once the problem(s) of why we are having low strength tests is identified.

6. If the strength test result is below $f'_c - 500$, steps must be taken to assure that the load carrying capacity of the structure is not jeopardized
(ACI 318.5.6.5.1)

On our project:

Concrete placed at the location identified by test number 14 is below $f'_c - 500$ or 3000 psi. The concrete in this area does not meet the strength criteria and needs to be evaluated.

7. How to determine what needs to be done to assure that the load carrying capacity is not jeopardized.
 - a. Apply judgment as to the significance of the low test result (ACI 318R.5.6.5)
 - c. If further investigation is deemed necessary, consider non-destructive testing (ACI 318R.5.6.5)
 - d. Core area(s) of the concrete where load carrying capacity is significantly reduced in accordance with ASTM C 42 (ACI 318.5.6.5.2)

8. How to determine if cores indicate that the concrete is acceptable

Concrete is considered structurally adequate if the average of the three (3) cores equals or exceeds 85% of f'_c and no single core is less than 75% of f'_c . (ACI 318.5.6.5.4)

On our Project:

If we take three (3) cores in the area where the concrete at test location number 14 was placed,

- a. The average strength of the cores must exceed 85% of 3500 psi or 2975 psi and
- b. No single core strength is below 75% of 3500 psi or 2625 psi.

Note:

Additional core testing is permitted if the core test results are considered erratic. (ACI.5.6.5.4)

9. If these test cores fail, and structural adequacy remains in doubt, consider the test procedures outlined in Chapter 20. (ACI 318.5.6.5.3)

10. Are there other documents other than ACI 318 that can help me with additional analysis on testing data?

ACI have several documents which may be used. These include:

- ACI 214 – Evaluation of Strength Test Results of Concrete
- ACI 228.1R – In Place Methods to Estimate Concrete Strength
- ACI 228.2R – Nondestructive Test Methods for Evaluation of Concrete Structures
- ACI 301 – Specifications for Structural Concrete
- ACI 437 – Strength Evaluation of Existing Concrete Buildings