Assessing Concrete Strength Results

Computer program compares test data against established quality standards

BY LUKE M. SNELL

When the test results for a concrete's strength are low, an argument will usually follow as to where the fault lies: the people at the batch plant blame the testing company; the people at the testing company blame the batch plant. We assume, of course, that the contractor did not alter the said concrete mixture by adding more water than that allowed by ACI 301/ASTM C 94. Also assumed is that the mixture proportions in question were submitted and approved in accordance with the procedures outlined in ACI 318-02.

But once concrete production has started, there are only two groups of people that can be at fault for low-strength-test results. First, the batch plant may have delivered the wrong mixture, misbatched the concrete, or used the wrong materials. If this has occurred, the batch plant would likely be responsible for the resulting low-strength concrete. Then again, the testing laboratory is responsible for the sampling, handling, and testing of the concrete samples. If lab personnel performed the work without attention to standard testing procedures, the testing laboratory would likely be responsible for the poor strength results.

A simple computer program, described as follows, can assist the user in assessing concrete strength data. It is grounded in procedures outlined in "Evaluation of Strength Test Results of Concrete (ACI 214R-02)" from ACI Committee 214, Evaluation of Results of Tests Used to Determine the Strength of Concrete. The program employs a Microsoft Excel spreadsheet and guides its user through the process of entering data, while the software performs analyses and comparisons against established standards of concrete quality.

SCREEN 1—INPUT

Starting at Screen 1 as shown, the program user must enter the design strength, which, for the purpose of this example, is 4000 psi (28 MPa). Next, the user inputs the 28-day strength results for the two cylinders that are part of a typical quality control program. The program will permit information input on up to 500 sets of cylinders for each project.

In addition, a user of the program can enter the names, initials, or identification numbers designating the technicians who performed the field tests. This information, however, is not necessary to run the program. If there is no need to assess the performance of each technician, the respective cells can be left blank. In this fictitious example, two technicians worked on the project—Anne B. and James G.—and are identified by their initials.

SCREEN 2—ANALYSIS

The part of the program involving Screen 2 performs an analysis of the concrete data as described in "Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (318R-02)," Section 5.6. In the example given, problems were detected in Tests 14 and 15 and required action in two separate steps.

As required by the Code, the average strength of concrete for future placements must be improved when the arithmetic average of any three consecutive strength tests falls below specified strength and/or any test result is below $f'_c - 500$ (in psi). ACI 318R-02, Section R5.6.3.4, offers suggestions that include the following:

- An increase of cementitious material content;
- Changes in mixture proportions;
- Reduction in or better control of levels of slump supplied;
- A reduction in delivery time;

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- Closer control of air content; and
- An improvement in the quality of the testing, including strict compliance with standard test procedures.

This list is not exhaustive; however, it does include most of the suggestions that should be considered when attempting to improve concrete strengths for the remaining placements.

Evaluation of strength test results

What is the design strength called for in the specifications (f'_c)? 4000

Test no.	Cylinder One C1 (psi)	Cylinder Two C2 (psi)	Technician	
1	4750	4720	AB	
2	4530	4800	AB	
3	4620	4660	AB	
4	4580	4720	AB	
5	4590	4460	AB	
6	4500	4620	AB	
7	4620	4590	AB	
8	4700	4630	AB	
9	4720	4680	AB	
10	4810	4460	AB	
11	4250	3810	JG	
12	4400	4040	JG	
13	3990	4200	JG	
14	3750	3210	JG	
15	4440	4020	JG	
16	4700	4180	JG	
17	4610	3880	JG	
18	3470	3990	JG	
19	4220	4710	JG	
20	3990	4670	JG	
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Screen 1—Input

Required Strength 4000

Test no.	Cylinder One C_1 (psi)	Cylinder Two C_2 (psi)	Range R (psi)	Average	Arithmetic	Comments
1	4750	4720	30	4735		
2	4530	4800	270	4665		
3	4620	4660	40	4640	4680	No problem
4	4580	4720	140	4650	4652	No problem
5	4590	4460	130	4525	4605	No problem
6	4500	4620	120	4560	4578	No problem
7	4620	4590	30	4605	4563	No problem
8	4700	4630	70	4665	4610	No problem
9	4720	4680	40	4700	4657	No problem
10	4810	4460	350	4635	4667	No problem
11	4250	3810	440	4030	4455	No problem
12	4400	4040	360	4220	4295	No problem
13	3990	4200	210	4095	4115	No problem
14	3750	3210	540	3480	3932	Concrete placed in this area must be investigated and quality of future concrete placement must be improved
15	4440	4020	420	4230	3836	Quality of future concrete placement must be improved
16	4700	4180	520	4440	4050	No problem
17	4610	3880	730	4245	4305	No problem
18	3470	3990	520	3730	4138	No problem
19	4220	4710	490	4465	4147	No problem
20	3990	4670	680	4330	4175	No problem
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Screen 2—Analysis

As shown in Screen 2, the concrete strength ascertained in Test 14 is below the required $f'_c - 500$ (in psi) or 3500 psi (24 MPa) value. The concrete mixture represented by this test sample must be investigated further. The ACI 318-02 Commentary suggests that nondestructive tests of in-place concrete may be useful in determining whether or not a portion of the structure actually contains low-strength concrete. In extreme cases, further investigation may also include strength tests of cores. When the core tests fail to provide assurance of structural adequacy, it may be practical, particularly in the case of floor or roof systems, for the building official to require a load test. Care and sound engineering judgment must be exercised in deciding on the tests needed. Coring, and even certain nondestructive testing, can damage the concrete structure in question or mar its aesthetics. Such testing then must be carefully planned with input from all involved parties.

SCREEN 3—RESULTS

"Evaluation of Strength Test Results of Concrete (ACI 214R-02)" provides a procedure for analyzing the test results on a project. Accordingly, for this example project, Screen 3 displays an average concrete strength of 4380 psi (30 MPa) with a standard deviation of 340 psi (2.3 MPa). Comparing this value to the "Standard of Concrete Control" (Table 3.2) in ACI 214R-02, and also displayed within Screen 3, the overall variation is rated as "Excellent." While this indicates that the batch plant has been quite consistent in batching the concrete, it does not necessarily mean that the mixtureis adequate.

Screen 3 also displays further results of the analysis. The coefficient of variation of the testing, or the within-test variation, is 6.20. When compared with the previously mentioned Table 3.2, the testing is rated as "Poor." This indicates that there is a problem at the testing

laboratory that must be solved. The program user can thus conclude that at least part of the cause for low-strength results may be poor testing procedures.

SCREEN 4—TECHNICIAN ASSESSMENT

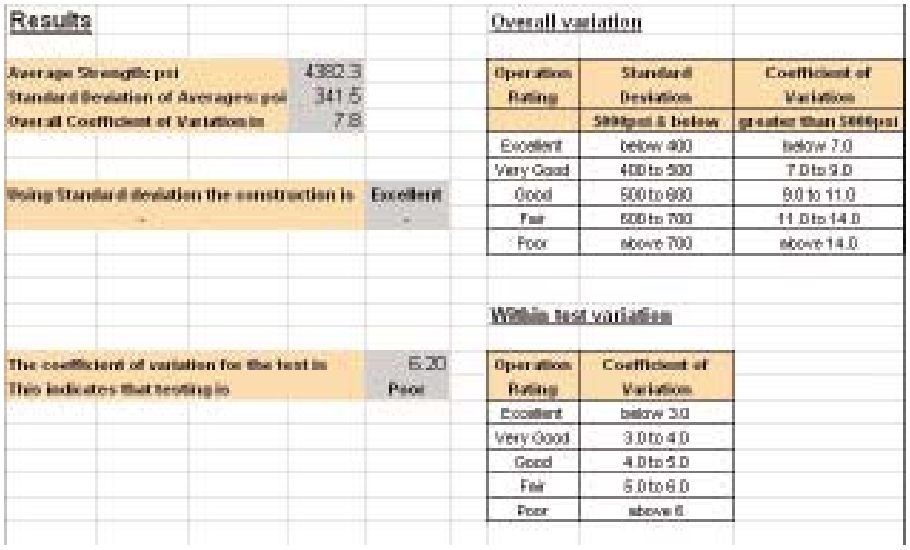
The user can then assess the performance of technicians by entering their names or identification codes. In our example on Screen 4, the assessment of technician AB (Anne B.) shows her work to have a coefficient of variation of 2.3—an excellent testing control. The user can, therefore, conclude that the performance of this technician is not the source of any of the testing problems.

But when Anne was on vacation, technician James G. tested the concrete. To analyze his work, the user enters in the initials JG (for James G.) and, as shown in Screen 5, his coefficient of variation turns out to be 10.5. His testing control is rated as poor. The user can thus conclude that the problem with the testing laboratory is probably a result of James' work, and that he requires additional training.

By checking with ACI about technicians' certifications (**www.concrete.org**, click on Certification, Personnel directory), the program user might also find that Anne B. was listed as a Field Grade I technician and James G. was not listed as certified. The latter technician could then be trained and certified before being allowed to return to the project.

This program, as well as two examples (one using 4000 psi [28 MPa] and another with 6000 psi [41 MPa]) can be downloaded from the website at **www.siue.edu/CCRU**, under Research. Readers may contact the author at lsnell@siue.edu if there are questions about using the program.

Selected for reader interest by the editors after independent expert evaluation and recommendation.



Screen 3—Results

Screen 4—Technician assessment

Screen 5—Technician assessment

Luke M. Snell, FACI, is the Director of the Concrete Construction Resource Unit and a professor of construction management at SIUE. He is Chair of ACI's Chapter Activities Committee and Committee 120, History of Concrete, and is a current and former member of several technical and educational committees. He has been on the faculty at SIUE for more than 20 years.