

Chapter News

Options for Mixture Design Criteria Development

A review of ACI 318 requirements when there is not enough data available to establish a standard deviation.

By Bill Meek and Jim Turici, CEMEX USA

If you are a concrete producer, chances are you have had to provide documentation that your mixtures will yield the necessary required average strength. However, in many instances, coming up with enough data to establish a standard deviation can be a challenge.

In a perfect world, we would always have field strength test records for the specified class (or within 1000 psi of the specified class of concrete). We would have 30 or greater consecutive test results. Or, maybe we would have two groups of consecutive tests totaling greater than or equal to 30 in number. Then we could calculate our standard deviation and determine the required strength based on the American Concrete Institute (ACI) 318-08 Table 5.3.2.1. At the very least, we would hope to have 15 to 29 consecutive tests and could still calculate our standard deviation and apply a multiplier from Table 5.3.1.2 and then determine the required average strength.

Unfortunately, we are not in a perfect world.... However, ACI recognizes that fact and provides some options we can follow for determining the required average strength and submitting supporting documentation of mixture proportions to meet the requirements. ACI 318 states that your mixture design submittal information provided must indicate the ability of being able to achieve an average strength meeting the requirements in Table 5.3.2.2. This is defined as the required strength or (f'cr).

TABLE 5.3.2.2—REQUIRED AVERAGE COMPRESSIVE STRENGTH WHEN DATA ARE NOT AVAILABLE TO ESTABLISH A SAMPLE STANDARD DEVIATION

Specified compressive strength, psi	Required average compressive strength, psi
f _C < 3000	$f_{Cr} = f_{C} + 1000$
$3000 \le f'_{C} \le 5000$	$f'_{Cr} = f'_{C} + 1200$
f _C > 5000	$f'_{Cr} = 1.10 f'_{C} + 700$

Figure 1 – Table 5.3.2.2 from ACI 318-08

At this point, there are two paths that you may take. You may possibly have field records of at least ten consecutive test results using similar materials and under similar conditions. Or, you may make trial mixtures using at least three different watercementitious materials ratios or cementitious materials contents according to section 5.3.3.2.

Field Records Option

(For clarification purposes, a strength record consists of series of consecutive compressive strength test results.)

Field strength records can be used as documentation as long as they meet the following conditions:

- Less than 30 consecutive tests
- Not less than 10 consecutive tests
- Encompassing a period of 45 days

Also, concrete proportions can be determined and documented with two sets of strength records by interpolating their strengths and proportions. These strength records must meet the criteria of "similar materials and conditions."

.....Article continued on page 2 🕨

Congratulations!

Congratulations to the Penn State Student Chapter! Their university has been named by ACI International as an Outstanding University for 2013. The ACI Award for University Student Activities was initiated to recognize universities that have participated in ACI-related activities. Penn State University can take exceptional pride

in having reached this level since only 13 universities are receiving this award for 2013.



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Example 1

ABC Concrete strength records from Project XYZ in Anywhere, USA:

Mixture Design 1; 500 lbs of total cementitious, water reducer, & air-entrained Mixture Design 2; 600 lbs of total cementitious, water reducer, & air-entrained

Table 1

Consecutive strength records (average of 2 cylinders):

Mixtur	e Design 1	Mixture I	Design 2
9/15	4150 psi	4/9	4910 psi
9/17	3910 psi	4/11	5270 psi
9/18	4020 psi	4/12	5300 psi
9/22	3750 psi	4/15	4830 psi
9/23	4500 psi	4/16	4890 psi
9/24	4370 psi	4/24	5080 psi
9/30	3900 psi	4/25	4690psi
10/1	4050 psi	4/26	5500 psi
10/3	3880 psi	5/5	5410psi
10/5	4360 psi	5/6	4970 psi
10/8	3790 psi		
Average	4060 psi	Average	5090 psi

ABC Concrete would like to submit a mixture design identified as Mixture 3 with a specified strength (f'c) of 3000 psi and is air-entrained.

From Table 5.3.2.2 the f'cr = (3000 + 1200) = 4200 psi. We can then use the two strength records from project XYZ to interpolate a mixture proportion for total cementitious from the strength data the following way:

Mixture 3 =	(4200 - 4060)(600 - 500)	+ 500
	(5090 - 4060)	
=	13.6 + 500	
=	514 lbs (after rounding)	

Mixture 3 would therefore have 514 pounds of total cementitious materials plus the use of a water reducing admixture and would be air-entrained.

Trial Mixtures

If there are no acceptable field test records available, mix design proportioning can be done from trial mixtures with the following requirements:

- Materials shall be the same as for the proposed work
- You must perform mixture designs at 3 different water-cement ratios (or cementitious contents) that will produce a range of strengths that encompass the required strength (f'cr).
- Trial mixture slumps must be within + .75" of the maximum permitted and air percentages within + .5%.
- You must make and test 3 cylinders (according to ASTM C 192) for each age and at 28 days or at the age of determination of the required strength.
- You must plot a curve that shows the relationship between water-cement ratios (or cementitious contents) and compressive strength at the designated age (for most projects this is 28 days).
- Your proposed mixture design average strength (f'cr) from the curve generated in the previous step must meet the requirements in Table 5.3.2.2. ...Continued on page 3

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Find out more about EPDs

Presented By Jim Turici, CEMEX USA Director of Technical Services

Find out how LEED v. 4 is changing how and what you may be reporting on green building projects in the very near future. Environmental Product Declarations (aka EPDs) are now the main way that the impacts of the use of concrete are measured on a LEED project. EPDs are expensive to produce and contribute very little (fractions of a point) to the total points desirable to achieve a LEED certified goal. Come find out more about EPDs and the potential impact on your bottom line. We hope to have Jim

present this topic at an upcoming member dinner meeting.



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Example 2

ABC Concrete would like to submit a mixture design identified as Mixture 4 with a specified strength (f^{*}c) of 4000 psi for a non-air-entrained concrete application.

A 3 point plot of 28 day compressive strength vs. total cementitious for each trial mix is contained in Figure 2.



Figure 2 – Example 2 Three point curve of 28 day compressive strength results

By plotting the resulting value of $f'_{cr} = (4000 + 1200)$, or 5200 psi, on the curve, the corresponding total cementitious content for Mixture 4 can then be determined. Please refer to Figure 3.



Figure 3 – Example 2 Example 2 Three pt. curve with indicated total cementitious content for 5200 psi compressive strength

Therefore, Mixture 4 would consist of a minimum of 525 pounds total cementitious content to achieve the required average strength.

In Summary

It is very common to not have the necessary data meeting the requirements of ACI 318 to determine the standard deviation for a targeted mixture design. ACI recognizes this problem and provides alternatives for development of submittal information to represent a mixture that meets the overdesign criteria required.

The use of field records and interpolation of average strength vs. proportions for determination of required average strength when the results represent two or more mixtures is an option, providing the data meets the required conditions.

The alternative to make three point curves from trial mixtures is sometimes misunderstood. However, the process is rather straightforward and well defined in ACI 318. Caution should be exercised in performing the trials to make sure the mixture slumps and air contents meet the uniformity requirements and the trials are performed in general accordance with ASTM C 192.

It is not always a perfect world, and it is good to have options....

References

ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-08)", American Concrete Institute, Farmington Hills, MI, 2008, pp. 63-69

ASTM C 192-07, "Standard Practice for Making and Curing Concrete Specimens in the Laboratory", ASTM, West Conshohocken, PA, 2007



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"Progress Through Knowledge"

TINK BRYAN AWARD ~ TRIBUTE TO: THOMAS "TINK" BRYAN

The Tink Bryan Award was created in honor of an outstanding individual who dedicated himself to his family, business and the concrete industry. For several years now, the Chapter has honored one individual each year with this award. The Pittsburgh Chapter Board of Directors is requesting nominations for the 2014 recipient. If a candidate is selected, they will be announced at the Awards Banquet in April. The candidate should demonstrate an exceptional commitment and achievement of service to the concrete industry.

Please forward a letter with your candidate(s) name and reasons for nomination to:

ACI, Pittsburgh Area Chapter PO Box 86 Zelienople, PA 16063 or email to: bethaci@verizon.net

Pittsburgh Area Chapter 2014 Upcoming Events

Wednesday - March 12th Member Dinner Meeting

Domenico's Restaurant, Cranberry

- Featuring a presentation - **"Petrographic Solutions to Concrete Forensics and Evaluations"** by April Snyder, Construction Materials Lab Manager at R J Lee, Inc.

> Friday - April 11th Awards Banquet Rivers Casino

Saturday - July 19th Social Night PNC Park