ACI Committee 348 –STRUCTURAL RELIABILITY AND SAFETY

ACI FALL 2021 CONVENTION

Monday, October 18, 2021

1:30 PM – 3:00 PM (EDT)

ONLINE VIRTUAL MEETING

AGENDA

1) Call to order

2) Welcome and self-introduction of members

3) Acceptance of minutes from the Spring 2021 online virtual meeting

4) TAC update / Announcements

5) Committee Membership Roster Review

6) Current action

   a) Tech Note 1: “Evaluation of Existing Concrete Strength?” Update by Dr. Nakin Suksawang and Dr. Hani Nassif. This was balloted in August and the ballot results are provided in Appendix C (in a separate file)

   b) Tech Note 2: “Risk based procedure for sampling and assessment of structural deficiencies” status update by Dr. Jeremiah Fasl.

   c) ACI 348 Document: “Guide to Reliability and Safety of Concrete Structures” Update by Dr. Mahmoud Maamouri, Dr. Ming Liu, and Dr. Georgios Balomenos. See Appendix A for proposed content.

7) Future Sessions
   a) Spring Convention 2022 in Orlando, FL “Reliability and Safety of Existing Concrete Structures”. Dr Suksawang submitted the request and TAC granted Preliminary Approval to proceed with a (1) - Two-Hour Session. See Appendix B for preliminary program.

8) New Business
   a) Effects of Climate Change on Reliability and Safety of Concrete Structures

9) Next Committee meeting: Monday, March 28, 2022, in Orlando, FL

10) Adjournment.

Appendix A

GUIDE TO RELIABILITY BASICS OF CONCRETE STRUCTURES

(ACI 348.YR.XX)

Report by ACI Committee 348

Objective

Develop a brief document aimed at introducing the fundamental concepts of structural reliability to practicing structural concrete engineers who had little to no exposure to this topic during their schooling and practical work experience.

CONTENTS

Part Three – Practical Considerations

1. $R = R_n$ MFP
    a. Nominal Strength
    b. Uncertainties Statistical Parameters

Future Topics that could be added later

1. How to define failure
2. Component vs. Systems Reliability
3. Benchmarking of Reliability (Historic Practice)
4. Seismic vs Non-Seismic
5. Anchoring to Concrete (Sensitivity)

Appendix B

Session for Spring Convention 2022

Reliability and Safety of Existing Concrete Structures

1. Hani Nassif and Dan Su “Reliability of Reinforced Concrete Bridges”

2. Andy Nowak and Victor Vidal “Reliability of Reinforced Concrete Bridge Beams in Shear – Strut and Tie”

3. Ming Liu and Andy Nowak “Reliability of Concrete Structures – Loads, Load Factors, and Load Combinations”

4. Jeremiah Fasl “Sampling & Assessment of Concrete Structures”

5. Any others?

Moderators: Nakin Suksawang / Mahmoud Maamouri

Revised Technote 1 Ballot		
LastName	FirstName	Item 1
Balomenos	Georgios	Y
Bazant	Zdenek	A
Diniz	Sofia Maria	Y/C
Fasl	Jeremiah	N
Frangopol	Dan	Y
Heo	YeongAe	-
Klein	Joseph	Y/C
Liu	Ming	Y/C
Maamouri	Mahmoud	Y
Nassif	Hani	-
Nowak	Andrzej	Y
Paczkowski	Piotr	-
Suksawang	Nakin	Y

Legend: Y = Yes, Y/C = Comments, N = No, A = Abstaining, A/C = Abstaining with comments, "-" = Not Returned

APPENDIX -C-

Revised Technote 1 Ballot							
Ballot Item	Yes	Y/C	No	Abstaining	Not Returned	The 1/2 Rule	The 2/3 Rule
1	5	3	1	1	3	Item Meets	Item Meets

Document Title: Evaluation of Existing Concrete Strength

Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
1.	Sofia Diniz		1	14-15	A	"*What is the statistical implication of using various methods to calculate the equivalent design strength for existing concrete structures?*" **Suggestion**: What is the statistical implication of using DIFFERENT methods to calculate the equivalent SPECIFIED strength for existing concrete structures? Note: Use "SPECIFIED" instead of "DESIGN" for consistent use of terminology (see for instance Table 2.
2.	Sofia Diniz		1	16	E	Instead of "OR", please use "AND".
3.	Sofia Diniz		1	17	A	"*What is the deviation that cause the discrepancy between the results using different codes?*" **Suggestion**: What is the cause of the discrepancy between the estimates of the concrete strength in existing structures according to different documents? Note: ACI 214.4R-10 is NOT a code, but rather a guide, i.e. it is not written in mandatory language.
4.	Sofia Diniz		1	19-20	E	"*The discrepancy between different codes is caused by the way in which each method assumed the confidence level and coefficient of variations (COV)*." **Suggestion**: The discrepancy in the estimates of the concrete strength in existing structures according to different documents is due to the assumed confidence level and coefficient of variation (COV). Larger discrepancies are observed when the COV of core strengths exceeds 15%.
5.	Sofia Diniz		1	20-21		"*The discrepancy becomes higher if the deviations of core sample for any test exceeds 15%.*" This statement is not clear; please revise. From the previous sentence, it was expected that a comment would follow on the COV of core strengths. Care should be exercized with the use of the word "sample". In statistical terms, a sample is a collection of results.

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: **Evaluation of Existing Concrete Strength**
Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
6.	Sofia Diniz		4	110-115		"*This is due to the large deviation of core samples (particularly sample 5 with approximately 20% deviated from the mean) used in this example. If the deviation was lower, the probability of exceedance using ACI 562-13 would be similar to ACI 214.4R-10. It is recommended that when using ACI 562-13, the engineer should continue to perform core sampling until the deviation of any test from the mean value does not exceed 15% using a minimum of 6 cores*." The above statement it is not clear! Please revise. What is the measure for deviation? Are we talking about coefficient of variation of the sample of size n, or the deviation of a single result with respect to the sample mean? Please note that in Lines 19-20 it is said "The discrepancy … is caused by the way in which each method assumed the … coefficient of variation (COV)." However, in the above statement it is not clear what the recommendation in terms of COVs is.
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: **Evaluation of Existing Concrete Strength**
Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
1.	Fasl		1	7	N	"One of the most important factors" is too strong. Could modify sentence to "A parameter often evaluated in existing structures is in-place concrete strength."
2.	Fasl		1	10-11	E	Should the references be updated? I don't think it changes anything technical. Also, ACI 214.4 is not a code.
3.	Fasl		1	14	E	I think the first question is better than the second question
4.	Fasl		1	19	N	Is the 214.4 alternate method different than the ACI 562 method? It seems like a difference in methodology rather than confidence level and COV.
5.	Fasl		1	21	N	No justification is provided for the 15% value.
6.	Fasl		2	48-51	N	Why are these equations presented? Can we make any comparison without knowing the sample standard deviation?
7.	Fasl		2	53	N	Can the target compressive strength (f_{cr}') be less than the design compressive strength (f_c')? The value of 9.01% seems overly precise.
8.	Fasl		2	59-61	E	I don't follow this sentence. Why are we trying to say?
9.	Fasl		3	63	N	Why don't we present both the tolerance factor and the alternate method in 214.4? 214.4 (9.4) states that both methods estimate the 10% fractile of the in-place strength. 214.4 (9.4.2) also states the tolerance factor may be unduly conservative in practice.
10.	Fasl		3	88-90	N	I don't think the 562 approach discusses modifying the tested values by 1.06.
11.	Fasl		4	96	N	~6% higher than the tolerance factor, but what about the alternate method in 214.4? Is probability of exceedance the correct term (also in the next section of the TechNote)?
12.	Fasl		4	113-115	N	Recommending more cores seems to beyond the intent of this tech note. Who will pay for the cores? Can something below 15% be achieved? Where did 15% come from?
13.	Fasl			117	N	I think we should be presenting both options in 214.4
14.						
15.						
16.						
17.						

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: Evaluation of Existing Concrete Strength

Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
1.	Joseph Klein		1	7	E	"structure" should be "structures" or "concrete structures"
2.	Joseph Klein		1	11	E	"However, there are discrepancy between the equivalent design strength" should be "However, there is a discrepancy between the equivalent design strengths"
3.	Joseph Klein		1	11	A	We should update ACI 562 references throughout to the 2019 version
4.	Joseph Klein		1	17	E	"cause" should be "causes"
5.	Joseph Klein		1	19	E	"assumed" should be "assumes"
6.	Joseph Klein		1-2	23-36	E	Suggested rewording of these lines: "For new structures, ACI 318-19 specifies a required average concrete compressive strength, f'_{cr}, and a design compressive strength, f'_c. All design calculations use f'_c, and f'_{cr} is used for proportioning concrete mixtures. Calculation of f'_{cr} is performed according to Section 4.2.3 of ACI 301-16. For existing structures, ACI 214.4R-10 and ACI 562-13 specify different methods for calculating an equivalent design strength, $f'_{c,eq}$, based on measured core strengths, f_{core}. Each of the three codes provide intrinsic structural safety by requiring that the actual concrete strength (f'_{cr} or f_{core}) is greater than the design compressive strength (f'_c or $f'_{c,eq}$) This technical note compares the intrinsic structural safety of ACI 318-19, ACI 214.4R-10, and ACI 562-19 by comparing the probability of non-exceedance of f'_c (ACI 214.4R-10) with the probability of non-exceedance of $f'_{c,eq}$. This technical note uses the five core strengths given in the example problem in Appendix A.3 of ACI 214.4R-10. Table 1 lists the unadjusted individual compressive strengths, f_{core}, of the five concrete cores. These cores were 4" (102 mm) in diameter by 8" (203 mm) in length and were air dried for seven days at 60° to 70°F (16° to 21°C), with a relative humidity of less than 60%, prior to laboratory testing. As discussed below, Section 9.1 of ACI 214.4R-10 provides core strength correction factors for converting core strengths to equivalent in-place strengths, f_c. Table 1 also presents f_c."
7.	Joseph Klein		2	53	A	"…the probability that f'cr is less than f'c is only 9.01%..." should be "…the probability that **a measured cylinder strength** is less than f'c is only 9.01%..." because f'cr is always greater than f'c

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: Evaluation of Existing Concrete Strength

Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
8.	Joseph Klein		2	59-61	E	Suggested rewording: "In general, these acceptance criteria are not applicable to safety evaluation of existing concrete structures unless evidence can be obtained to prove that the untested areas of the concrete structure are at least 500 psi stronger that the tested area." Might also suggest including the following: "ACI 318-19 allows for core strengths to fall below f'c because core strengths are expected to be lower than comparable cylinder strengths, as discussed in ACI 214.4R-10."
9.	Joseph Klein		3	64	A	I believe that the core strength correction factors apply to both the tolerance-factor method and the alternate method presented in Chapter 9 of ACI 214.4R-10. Accordingly, this sentence should read: "According to Section 9.4.1 of ACI 214.4R-10, the unadjusted core strength, f_{core}, may be corrected using core strength correction factors as follows:"
10.	Joseph Klein		3	65	E	ACI 214.4R-10 does not capitalize "f_c"
11.	Joseph Klein		3	84	E	Include ACI 562-19 table number
12.	Joseph Klein		-	-	A	In general, "probability of exceedance" should probably be "probability of non-exceedance" throughout the document
13.	Joseph Klein		-	-	A	Is it worth also including the alternate method presented in Section 9.4.2 of ACI 214.4R-10? Or explicitly saying this tech note uses the tolerance factor method only?
14.	Joseph Klein		-	-	A	In my experience, the comparison between 214.4R-10 and 562-19 is highly dependent on what kind of data you have. For example, if you have a core that has been soaked in water (correction factor = 1.09), ACI 214.4R will pretty much always result in a higher estimated strength than 562, because your net correction factor is on the order of 1.16, versus the 1.0 for 562. The document currently gives the impression that the 562 methodology is inherently less conservative than 214.4R-10, which is not always the case. In addition, while I tend to agree with the ultimate recommendation of the tech note ("when using ACI 562-13, the engineer should continue to perform core sampling until

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: **Evaluation of Existing Concrete Strength**
Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
						the deviation of any test from the mean value does not exceed 15% using a minimum of 6 cores"), I'm not sure this recommendation is always achievable due to the large amount of variability in core tests. Also, I would expect more instances where the core strength deviates from the mean strength as more tests are performed.
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: Evaluation of Existing Concrete Strength

Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
1.	Ming Liu		1	9	A	Suggest adding “from the individual core sample” after “results”.
2.	Ming Liu		1	14 - 16	A	Suggest deleting these lines.
3.	Ming Liu		1	19	A	Suggest deleting “the way in which each method assumed”
4.	Ming Liu		1	20	A	Suggest adding “of the core samples” after “(COV)”
5.	Ming Liu		1	33 - 34	A	Suggest deleting “For example, … … 5000 psi” (note: this is identical to Eq. (1b))
6.	Ming Liu		2	40	A	Suggest deleting “As stated ……fc’”
7.	Ming Liu		2	48	A	Replace “Table 5.3.2.2 ……as” with “fcr’ should be determined as”
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: **Evaluation of Existing Concrete Strength**
Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
1.	Bartlett		1	0		I am not a Voting Member of 348 so can only comment on the content of this draft
2.	Bartlett		1	6		N – actually the reliability of a well-designed concrete structure is rather insensitive to the concrete strength. Coring to get a compressive strength for determining a flexural capacity would be wasting a client's money. The presence of ties or spirals in columns confines the concrete and so makes the capacity less sensitive to the unconfined strength
3.	Bartlett		1	10		E – ACI 214.R4-10 is not a code. A more current version of this guide has recently been published (though the additions do not impact the content of this Tech Note)
4.	Bartlett		1	19		N – "The discrepancy between different codes is caused by the way in which each method assumed the confidence level and coefficient of variations (COV)." This is untrue. The difference is that the methodology reported as being from ACI 214.R4-10 is the Tolerance Factor Approach, which uses a non-central t-distribution to estimate one-sided tolerance limits on lower fractile values. As stated in the first paragraph of Section 9.4.2, "the tolerance factor approach may be unduly conservative in practice because core tests tend to overestimate the variability of the in-place strengths". (The tolerance factor approach gives severely low values if there are undetected low outliers in the data set – but that's another story.) The method given in ACI 562-19 is a simplification of the "Alternate Approach" given in ACI 214.R4-10, although this fact is nowhere stated in the Tech Note. It is based on determining a lower-bound estimate on the in-place mean strength and the estimating the corresponding 10% fractile strength using generic coefficients of variation for the within-structure strength variation given in Table 3.1 of ACI 214.R4-10.
5.	Bartlett		1	20		N – "The discrepancy becomes higher if the deviations of core sample for any test exceeds 15%." Whether this is accurate or not – there seems to be no justification in the Tech Note to support the "15%" value.

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: **Evaluation of Existing Concrete Strength**
Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
6.	Bartlett		2	46		N – Data from real projects do not show any particular correlation between the difference between mean and specified strengths and standard deviations. Please see for example Figure 3 of Bartlett, F.M. & MacGregor, J.G. (1996): "Statistical Analysis of the Compressive Strength of Concrete in Structures". *ACI Materials Journal*, **93** (2): 158-168. Typically the overdesign is greater than these "mix design equations" would suggest. But then again – cylinder strengths are not the same as in-place strengths due to curing inconsistent compaction and other factors.
7.	Bartlett		2	48		N – What is the value of including Equations 1(a), 1(b) and 1(c) here? If the standard deviation is not known how can any statement about the lower fractile represented by f'_{cr} be made?
8.	Bartlett		2	53		N – please review the statement "the probability that fcr' is less than fc' is only 9.01%". How is it possible that the required target average strength f'_{cr}, be less than the specified strength, f'_c? (and isn't expressing differences to hundredths of a percent a little precise for concrete strengths?) There is a 9% probability that the mean cylinder strength is less than f'c according to these equations (though again, Comment 6, these equations are not to be trusted!)
9.	Bartlett		2	57		A/C – the criteria for accepting suspect concrete based on core tests is correctly described (though the meaning of the sentence starting on line 59 "In general, it is not clear…" seems elusive). Why is this Tech Note not making apples vs. apples comparisons, comparing the specified strength one is allowed to use following the ACI 318 core test acceptance rules with the equivalent specified strengths obtained from core tests using the ACI 214.4R and ACI 562 procedures?
10.	Bartlett		3	63		E – the various core strength correction factors have at most three significant figures but the overall correction factor in Eq. (2) has five significant figures? There seems to be unwarranted precision throughout the Tech Note.
11.	Bartlett		3	83		E – it should be made clear in Eq. (6) by changing the symbol and providing a definition that F_c is the average in-place strength. This also applies to the equation for V in line 88. And elsewhere.

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: **Evaluation of Existing Concrete Strength**
Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
12.	Bartlett		3	88		N – "ACI 562-13 does not account for coring damage". This statement is incorrect. Please see Item 2 under "Basis of ACI 562 Procedure" in Bartlett, F. M. (2016): "Evolution of ACI 562 Code – Part 6. Quantification of in-place concrete strengths using core tests". *Concrete International*, **38** (7): 36-39.
13.	Bartlett		3	89		N – it is moot given the previous comment but the F_c value is obtained from cores that have sustained reduced strength due to drilling damage. So to account for the drilling damage the F_c value should be increased by a factor of 1.06 not reduced by a factor of 1.06? As noted in the previous comment, the effect of drilling damage is included in the 0.9 factor in the ACI 562 (and ACI 214.4R) procedure. Similarly S_s should be increased by 6% on Line 90.
14.	Bartlett		3	95		N – "which is about 5.75% higher than the ACI 214.4R-10 value = 3,458 psi". As has been noted above – and expressed many times in commenting on previous editions of this document, there are **<u>two</u>** methods presented in ACI 214.4R. The value computed using the ACI 562 approach is greater than that using the Tolerance Factor Approach in ACI 214.4R, but the authors of this Tech Note nowhere state that the ACI 562 method and the Alternative Approach given in ACI 214.4R give essentially the same results. We have been over this territory many times before. The authors of this Tech Note seem to rather arbitrarily assume that the Tolerance Factor Method is the gold standard when most practitioners believe it is unduly conservative in practice. This is particularly true for the case where undetected low outliers may be present in the data – see Bartlett, F.M. (2008): Discussion of Hanson, J. M. (2007): "Survey of Practice to Determine Strength of In Situ Concrete from Core Tests", *Journal of the Performance of Constructed Facilities* **22**(5): 348.
15.	Bartlett		4	102		N – "thus, the probability of exceedance of $f_{c,\,eq}$ = 3,657 psi is estimated to be 17.88%." First, the statement is factually incorrect: The probability **<u>of exceedance</u>** of this strength value is (100-17.9 =) 82.1%. Second, this is not a measure of the unconservatism of the ACI 562 procedure but a clear indication of the conservatism of the Tolerance Factor Approach in ACI 424.4R.

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.

Document Title: **Evaluation of Existing Concrete Strength**
Ballot Date: 8-1-2021 / Description: Tech Note - Form #1

No.	Commenter Name	Ballot Item #	Page #	Line #	A, N, E	Comment
16.	Bartlett		4	105		The conclusions are simply unwarranted and incorrect for the various reasons given above. This document is described as having a new title and being more focused, but it promulgates the same incorrect theories as in previous versions. It does not recognize that ACI 214.4R presents two approaches for estimating the 10% fractile of the in-place strengths.
17.	Bartlett		4	13		N - "It is recommended that when using ACI 114 562-13, the engineer should continue to perform core sampling until the deviation of any test from the mean value does not exceed 15% using a minimum of 6 cores." First, as a Voting Member of ACI Committee 562, I find it quite astonishing and grossly inappropriate that ACI 348 is trying to tell engineers how to use our standard. This statement is beyond ACI 348's terms of reference. Second, the recommended procedure is ill-conceived and will often in practice be impossible to implement. If two of the test results are 4000 and 6000 psi, it will be impossible to find a mean value with a deviation of a maximum of 15 % from these values irrespective of how many tests are taken.
18.	Bartlett		4	117		N – Table 2. To make this table fair, it should be changed as follows: 1. For the ACI 318-19 entry, show the lower bound fractile represented by f'_c when the criteria for accepting concrete based on core tests in accordance with ACI 318-19 Article 26.12.6.1 is used. 2. For the ACI 214.4R-10 entry, show two entries with two values, one obtained when the Tolerance Factor Approach is adopted and the other where the Alternative Approach is adopted. They should be labelled as such.

A = Affirmative vote with comment.
N = Negative vote with comment.
E = Editorial.