ESSAYS 2021
Volume 35, No. 1

TENNESSEE CONCRETE MAGAZINE

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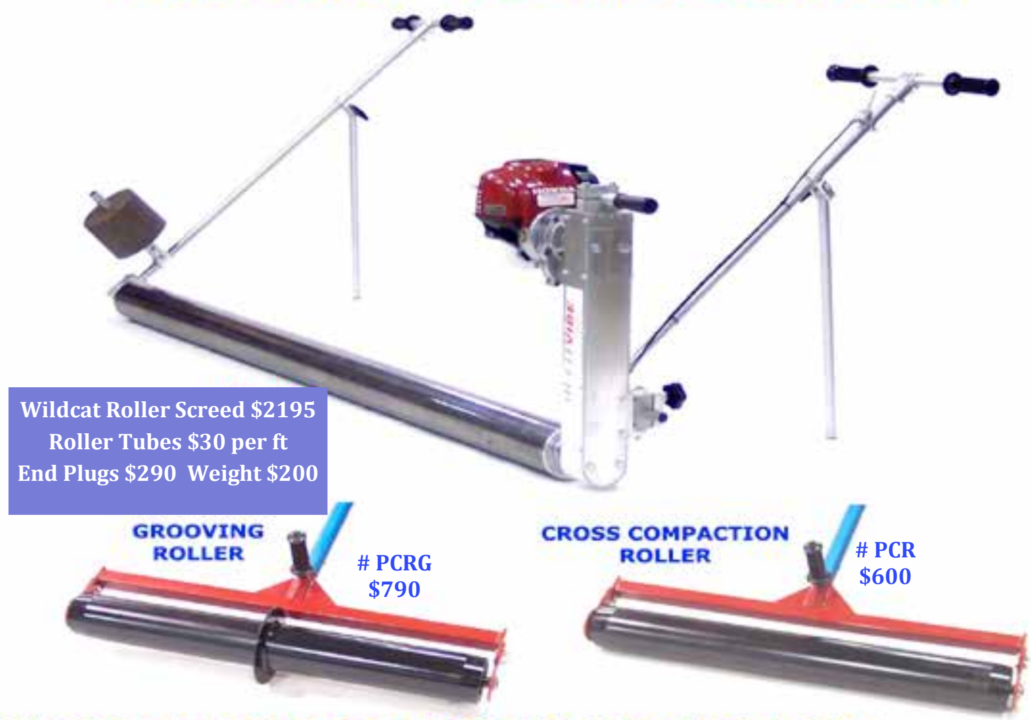

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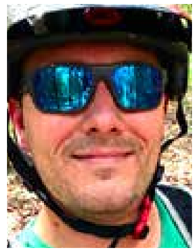


THE VIEW FORWARD REMAINS CLOUDY

Wes Blalock
TCA President

The strength of TCA starts with the support of every individual member company

....

[Thanks to] the many TCA members who have promptly renewed their dues

....

A special thanks to TCA's Annual Sponsors

Most of us couldn't wait for the calendar to flip from 2020 to 2021 but the view forward still remains cloudy for many of us. Construction has remained strong, even record-breaking for some, across Tennessee and many ready mix producers have little time left over to think about what the future may hold for our industry in 2021 and beyond.

That's where TCA brings such value to our industry. Associations like our Tennessee Concrete Association provide all of us TCA members with a place to address strategic issues like workforce development, professional education & training, sustainable construction, product innovation, customer education and marketing. I know that these issues are important—even critical—for the ongoing success of my business but they are often crowded out by the daily demands of producing concrete. Having a professional staff focused on the long run success of our industry is not a luxury, it is a necessity.

The strength of TCA starts with the support of every individual member company, so I want to thank the many TCA members who have promptly renewed their dues for the year ahead. I want to say a special thanks to TCA's Annual Sponsors who go above and beyond to financially support our association.

I would also like to urge each of you to make plans to attend our re-scheduled Annual Convention, now set for May 12–13, 2021. There is great value in seeing each other face to face, and I look forward to seeing you there in person.

—Wes Blalock

EXECUTIVE DIRECTOR'S MESSAGE—ALAN SPARKMAN

SPRING ISSUE—NOW FEATURES TCA'S CONCRETE ESSAYS

Welcome to our spring edition of Tennessee Concrete magazine. In years past, this has been our Awards issue, but we decided last year to move our Awards issue to the summer magazine so it could serve as an encouragement for everyone to enter their best projects in our annual awards competition. At the time, we did not anticipate that we would have to reschedule our Annual Convention from February to May. Since we announce our Awards winners at our Annual Convention that actually worked in our favor!

Our spring issue will continue to feature the winners from TCA's Concrete Essay Contest, open to high school students all across Tennessee every year. Be sure to check out this year's winning essays that are featured in this issue. This contest continues to be a great tool in educating our high school students about the concrete possibilities provided by the best building material on the planet.

This issue also continues TCA's long tradition of bringing useful research findings directly from the laboratory to our members. If you browse back through past editions of Tennessee Concrete magazine (you can do so easily by visiting our online archive at www.tnconcrete.org) you will find a wealth of research that TCA has produced for (literally) decades. This research benefits both ready mix producers and concrete customers by providing sound technical information that can be utilized to produce better concrete. To make this research even more accessible, we have added a new section to the TCA website focused on research past and present. Be sure to check out this valuable new resource that focuses on research specific not only to concrete but also to the great state of Tennessee.

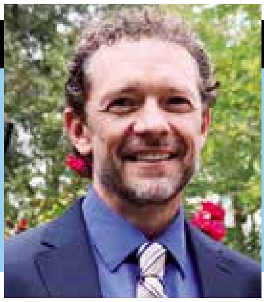
The pandemic that began early in 2020 appears poised to continue for much of 2021. The construction industry, especially here in Tennessee, has avoided much of the disruption that has so devastated other portions of our economy and our communities. In fact, when you look at the production numbers for ready mix concrete in Tennessee, you find that Tennessee has outperformed most other states in terms of the growth in concrete production for the past few years. The average annual growth nationally in year-over-year concrete production since 2015 is a little over 2 percent, assuming that 2020 annual production equals 2019 production—as appears to be the case by looking at the November 2020 totals. Tennessee's average annual growth over the same period is over 9 percent, with the past three years showing an average of over 10 percent growth. In fact, if the production trends hold for the last quarter of 2020 Tennessee may set a new annual production record in 2020 at about 8.4 million cubic yards, a whopping 17 percent increase over 2019.

While we are grateful for that it can cause us to lose focus on just how much has changed over the past year, and it makes it easy to not think about the kinds of changes we may see moving forward. What has not changed, especially in light of the strong increase in annual yardage, is that workforce remains the preeminent challenge for TCA members, both for ready mix producers as well as contractors.

While the pandemic has dramatically accelerated the shift to remote work in some sectors of the economy that is not an option for ready mix delivery professionals nor for the professionals who install our product every day. How we handle the challenge of re-making these critical jobs into real careers that more people will choose (voluntarily!) is perhaps the biggest challenge we face as we head deeper into this new decade. There are other challenges to be sure - competing with wood and steel for market share, understanding where concrete fits in the embodied carbon debate, and using technology to improve both operations and products are also critical.

In all of these, TCA will continue to seek information and answers on behalf of our industry and our members. Your support is what makes it possible, and your input is even more important as we chart our course into the future. Thanks to the many TCA members who promptly renewed their membership for 2021 and let me add my thanks to those of President Wes Blalock for our TCA Annual Sponsors who do more than what is required to support your association. And I join President Blalock in inviting you to attend our 2021 Annual Convention on May 12–13 in Cool Springs, Tenn.

—Alan Sparkman



TECHNICAL DIRECTOR'S MESSAGE—JOHN B. PEARSON, P.E.

IN SEARCH OF A BETTER MOUSETRAP
TCA PRACTICAL CURING STUDY

Maintaining the proper curing environment at the jobsite for standard cure concrete test cylinders can be a challenge, to say the least, especially in hot summer conditions. For concrete with design strengths below 6000 psi, ASTM C31 requires that standard cure cylinders be maintained between 60ºF and 80ºF during the initial curing period (for up to 48 hours after casting). Curing test specimens submerged in water inside an electrically powered, thermostatically controlled curing box is considered by some to be the gold standard of initial curing. Unfortunately, these boxes are not used on the majority of projects due to cost and logistical concerns. Practical initial curing solutions are needed. Many such methods have been suggested or attempted, but do any of them actually work?

Many of these practical curing methods do not require electricity, but primarily rely on a water-filled container to maintain moisture and temperature conditions. Container options vary in size and construction from small uninsulated buckets to traditional coolers or even high-end rotomolded coolers (think YETI and RTIC). The potential options seem endless and many questions quickly come to mind. What size container and temperature of water are needed? Is there a way to provide additional cooling without electricity? Are insulated containers better or will they trap the heat generated from the hydration process? Does the color of the container have an impact? This past summer TCA decided to put some these methods to the test to see how they actually perform in real world conditions.

In our initial round of testing, concrete cylinders were subjected to 7 different curing environments as shown in Table 1. Curing containers (or exposed cylinders) were stored on a concrete sidewalk unshaded during the majority of the daytime hours. Four 4x8 inch concrete cylinders and a temperature logger were placed in each environment and temperatures recorded over a 48-hour period. Water at approximately 64 degrees was placed in the containers just prior to concrete being mixed. Logging was started after the cast cylinders were placed in the test environment. The outside ambient temperature during the 48-hour initial cure period ranged from a low of 66ºF to a high of 98ºF.

As expected, when no protection was provided temperatures quickly surpassed the allowable maximum, reaching temperatures well in excess of 100ºF. Although better than no protection, the water-filled 5-gallon buckets were also ineffective at maintaining the required initial curing temperatures. The insulated coolers used in the study actually showed more promise. The two smaller coolers were able to keep temperatures in the required range for nearly 24 hours while the large volume cooler was able to maintain the required temperature range for the full 48-hour duration.

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TABLE 1. MAXIMUM OBSERVED CONCRETE TEMPERATURE

CURING CONDITION	MAX TEMPERATURE OVER 24 HRS (°F)	MAX TEMPERATURE OVER 48 HRS (°F)
No Protection	131	136
Blue 5-gallon bucket	117	117
White 5-gallon bucket	105	105
White 5-gallon bucket with ice*	92	98
Low-cost standard cooler (50 qt.)	80	87
Low-cost extended ice retention cooler (40 qt.)	81	86
Marine cooler (165 qt.)	71	75
ASTM C31 requirement <6000 psi	80	
ASTM C31 requirement ≥6000 psi	78	

*For this condition, the bottom container of a white 5-gallon bucket with holes drilled in the lid. A second bucket was stacked on top with 20 lbs. of ice inside. Holes were drilled in the bottom of the bucket to allow cool water to fall into the bottom bucket as the ice melted.

by L. K. Crouch, Robert Tyler Hughes, Samuel Mathews, Daniel Badoe, Alan Sparkman and John Pearson

A BRIEF LOOK AT THE EFFECTS OF ADDING Water and/or Lack of Curing of Residential/Commercial Concrete

INTRODUCTION AND BACKGROUND

The primary focus of the Going beyond ACI 332: Commercial / Residential Enhanced Durability Concrete study is the resistance to degradation of concrete in the presence of commercial magnesium chloride deicing salts. However, the Tennessee Concrete Association (TCA) Executive Director inquired if Tennessee Technological University (TTU) researchers could show a general loss of durability (not just due to magnesium chloride deicing salt) resulting from water added at the jobsite and/or the lack of proper curing. This brief paper is an effort to comply.

There are a wide variety of concrete durability concerns. However, this brief look will focus on only three of these: freeze-thaw resistance, corrosion of reinforcement, and cracking. Freeze-thaw resistance decreases with increasing absorption and decreasing tensile strength. ACI 332-14 specifies a 28-day compressive strength of 4000-psi in the presence of deicing salts as well as an air content range based on coarse aggregate size and limitations on supplementary cementing materials replacement percentages to ensure adequate freeze-thaw resistance. Corrosion of reinforcement becomes more likely as chloride permeability increases (surface resistivity of concrete decreases). ACI 332-14 specifies a 28-day compressive strength of 4000-psi in the presence of deicing salts to minimize corrosion of reinforcement. ACI 332-14 does not specify a maximum water-to-cementing-materials (w/cm) ratio for freeze-thaw or corrosion protection. However, the commentary accompanying the code recommends a w/cm ratio less than 0.45.

Concrete with more water (a higher w/cm) typically experiences more shrinkage than lower water content concrete mixtures. In addition, concrete with lower static modulus of elasticity is likely to deform more due to load-associated or thermal stresses. Concrete with a lower tensile strength is more likely to crack due to stresses resulting from shrinkage, load-associated stress, or thermal stresses.

MATERIALS

The same materials were used for Phase 1 and Phase 2 of the project.

PROCEDURE

The control mixtures used in Phase 2 of the study are from Phase 1 of this TCA study (Tennessee Concrete Winter 2019/20). Table 1 shows characteristics of the control mixtures. Table 2 shows water-cementing materials ratios from the control and variable mixtures used in Phase 2.

Unfortunately, only one batch of each mixture / variable was produced due to limited space in the 125º F drying oven. Nine batches were produced for Phase 2. Twelve 4x8-inch cylinders and 9 3x6-inch cylinders were fabricated from each batch. Four 4x8-inch cylinders and 3 3x6-inch cylinders (for absorption after boiling) were tested at 28-days to produce the results shown in Table 3. The remainder of the cylinders will be used to measure the effect of commercial deicing salt containing magnesium chloride on concrete properties.

RESULTS

Table 3 shows 28-day properties for the three control mixtures (from Phase 1) and the three variables applied to each control mixture used in Phase 2. None of the mixtures (control or variable) had been subjected to deicing salts prior to testing. Testing procedures were the same as those used in Phase 1 of the study (Tennessee Concrete Winter 2019/20).

ANALYSIS

General

Table 3 also includes some analysis such as percent gain or loss compared to properties of the control mixture. The surface resistivity section of Table 3 also shows the chloride permeability

TABLE 1. CHARACTERISTICS OF CONTROL MIXTURES FOR PHASE 2 OF THE TCA STUDY

CONTROL MIXTURE	TOTAL CEMENTING MATERIALS (PCY)	WATER-CEMENTING MATERIALS RATIO	SUPPLEMENTARY CEMENTING MATERIALS (PERCENT OF TOTAL CEMENTING MATERIALS)	CHEMICAL ADMIXTURES
3500-psi Commercial	480	0.521	22 Class C Fly Ash	Air + MRWR
ACI 332 Commercial	564	0.443	20 Class C Fly Ash	Air + MRWR
CRED 1 36F/4MK	520	0.390	36 Class F Fly Ash + 4 Metakaolin	Air + MRWR + HRWR

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TABLE 2: WATER-CEMENTING MATERIALS RATIOS FOR CONTROL AND VARIABLE MIXTURES

MIXTURE	CONTROL	+2 GAL/CY	NO CURE	BOTH
3500-psi Commercial	0.521	0.555 (+6)	0.521	0.555 (+6)
ACI 332 Commercial	0.443	0.473 (+7)	0.443	0.473 (+7)
CRED 1 36F/4MK	0.390	0.422 (+8)	0.390	0.422 (+8)
<ACI 332-14 Commentary Recommended Maximum?			Yes	No

TABLE 3. EFFECT OF ADDING WATER AND/OR NO CURING ON 28-DAY CONCRETE PROPERTIES

MIXTURE	CONTROL	+2 GAL/CY	NO CURE	BOTH
Surface Resistivity in kilohm-cm (% change from control)				
3500-psi Commercial	12.3	11.2 (-9)	8.3 (-33)	7.1 (-42)
ACI 332 Commercial	12.4	11.5 (-7)	10.5 (-15)	8.3 (-33)
CRED 1 36F/4MK	30.3 33.6 (+11)		25.8 (-15)	22.8 (-25)
Chloride Permeability Category		Low	Moderate	High
Compressive Strength in psi (% change from control)				
3500-psi Commercial	5200	3860 (-26)	2980 (-43)	2790 (-46)
ACI 332 Commercial	6610	5370 (-19)	4060 (-39)	3890 (-41)
CRED 1 36F/4MK	8770	7110 (-19)	5980 (-32)	5610 (-36)
Meets Comp. Strength Specification/Expectation?			Yes	No
Split Tensile Strength in psi (% change from control)				
3500-psi Commercial	440	350 (-21)	295 (-33)	260 (-41)
ACI 332 Commercial	530	550 (+4)	375 (-29)	350 (-34)
CRED 1 36F/4MK	565	605 (+7)	495 (-12)	455 (-20)
Static Modulus of Elasticity in million psi (% change from control)				
3500-psi Commercial	3.95	4.10 (+4)	3.65 (-8)	3.45 (-13)
ACI 332 Commercial	4.30	4.20 (-2)	3.95 (-8)	3.95 (-8)
CRED 1 36F/4MK	4.65	4.60 (-1)	4.90 (+5)	4.85 (+4)
Absorption after Boiling (% change from control)				
3500-psi Commercial	5.28	5.66 (+7)	4.99 (-6)	6.11 (+16)
ACI 332 Commercial	4.96	5.07 (+2)	5.11 (+3)	5.51 (+11)
CRED 1 36F/4MK	4.28	3.95 (-8)	4.05 (-5)	4.72 (+10)
High Performance Concrete Level Absorption (<5%)?			Yes	No

category at 28-days. The compressive strength section of Table 3 shows whether the mixture / variable met specifications / expectations for 28-day compressive strength. The expected compressive strengths for the three mixtures are 3500, 4000, and 4500-psi, respectively. The absorption after boiling section of Table 3 shows whether the mixture / variable was able to achieve high performance concrete (HPC) level absorption (< 5%) at 28-days.

Damage

Statistical analysis are not possible with only one batch per mixture / variable. Therefore, the damage level assumptions in Table 4 will be used to characterize the change in 28-day properties. An unfavorable change in properties will be considered an increase in absorption or a decrease in surface resistivity, strength and/or modulus.

Damage Level by Mixture

Table 5 shows relative damage by mixture. The 3500-psi commercial mixture had the highest mean damage level (2.33) and the highest number of catastrophic level damages (4). The higher level of damage is probably due to the several factors: highest w/cm of any mixture tested, lowest cementing materials content of any mixture tested, and least desirable properties of the control mixture. The ACI 332 commercial mixture fared much better with a lower mean damage level (1.67) and lower number of catastrophic level damages (1). The CRED 1 mixture fared the best with the lowest mean damage level (1.33) and lowest number of catastrophic level damages (0). Water addition and lack of curing had a greater effect on the higher w/cm mixtures and a lesser effect on the lower w/cm mixtures.

Damage Level by Phase 2 Variable

Table 6 shows relative damage by Phase 2 variable. Addition of water generated the lowest mean damage level (0.93) and the lowest number of severe damage levels (2) and the lowest number of catastrophic damage levels (0). That is not to say that addition of water did not cause damage to 28-day properties. Addition of water significantly damaged properties related to concrete durability in 8 of 15 cases. Lack of curing generated much greater change than the addition of +2-Gallon/CY. Lack of curing had a higher mean damage level (1.80) and generated a higher number of severe damage levels (5) and catastrophic damage levels (1). Lack of curing significantly damaged properties related to concrete durability in 11 of 15 cases. As expected the combination of water addition and lack of curing produced the maximum damage to 28-day concrete properties. The combination of variables had the highest mean damage level (2.67) and generated the highest number of severe damage levels (5) and catastrophic damage levels (4). The combination of variables significantly damaged properties related to concrete durability in 14 of 15 cases.

Damage Level by Engineering Property

Table 7 shows relative damage by measured 28-day property. Compressive strength suffered the greatest mean damage (3.11) and the highest number of severe damage levels (4) and catastrophic damage levels (3) combined. Compressive strength suffered significant damage in all cases. Split tensile strength and surface resistivity were second and third in damage, respectively. Split tensile strength suffered the second greatest mean damage (2.33) and the second highest number of severe damage levels (5) and catastrophic damage levels (1) combined. Split tensile strength suffered significant damage in 7 of 9 cases. Surface resistivity suffered the third greatest mean damage (2.11) and the third highest number of severe damage levels (3) and catastrophic damage levels (1) combined. Surface resistivity suffered significant damage in 8 of 9 cases. Static modulus of elasticity and absorption after boiling suffered relatively little mean damage, 0.56 and 0.47, respectively. Neither static modulus of elasticity or absorption after boiling suffered a single severe or catastrophic damage. That is not to say neither suffered any damage. Both of these properties suffered significant damage in 4 of 9 cases.

Freezing and Thawing Potential

Table 8 shows properties and parameters related to the potential for freeze-thaw damage. The potential for freeze-thaw damage greatly increased in the 3500-psi commercial mixture due a decrease in tensile strength and an increase in absorption after boiling resulting from Phase 2 variables. In addition, the Phase 2 variables forced the 3500-psi commercial mixture to never meet the ACI 332 specification for compressive strength or the ACI 332 commentary recommendation for w/cm ratio.

The CRED 1 mixture is a totally different story. The potential for freeze-thaw damage only slightly increased in the CRED 1 mixture due to a decrease in tensile strength or an increase in absorption after boiling resulting from Phase 2 variables. The addition of two gallons of water per cubic yard seemed to have no harmful effect on absorption after boiling or split tensile strength. In addition, the Phase 2 variables did not stop the CRED 1 mixture from maintaining HPC level absorption or meeting the ACI 332 specification for compressive strength and the ACI 332 commentary recommendation for w/cm ratio. The CRED 1 mixture appeared to have the strongest resistance to Phase 2 variables. A fail-safe or invulnerable concrete mixture is not possible but CRED 1 withstood the damage far better than the other mixtures.

The potential for freeze-thaw damage increased substantially in the ACI 332 commercial mixture due to a decrease in tensile strength and an increase in absorption after boiling resulting from Phase 2 variables. The addition of two gallons of water per cubic

TABLE 4: DAMAGE LEVEL ASSUMPTIONS AND DEFINITIONS

DAMAGE LEVEL	DESCRIPTION	EFFECT ON 28-DAY PROPERTY
0	None or Insignificant	<5% unfavorable change in property
1	Significant	≥ 5 to <10% unfavorable change in property
2	Minor	≥ 10 to <20% unfavorable change in property
3	Severe	≥ to <40% unfavorable change in property
4	Catastrophic	≥ 40% unfavorable change in property

TABLE 5. DAMAGE LEVEL BY MIXTURE

MIXTURE	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	MEAN DAMAGE LEVEL
3500-psi Commercial	2	3	2	4	4	2.33
ACI 332 Commercial	4	3	3	4	1	1.67
CRED 1 36F/4MK	7	0	4	4	0	1.33

TABLE 6. DAMAGE LEVEL BY PHASE 2 VARIABLE

MIXTURE	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	MEAN DAMAGE LEVEL
+2 Gallans/CY	7	4	2	2	0	0.93
No Cure	4	2	3	5	1	1.80
Both	1	1	4	5	4	2.67

TABLE 7. DAMAGE LEVEL BY 28-DAY MEASURED PROPERTY

MIXTURE	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	MEAN DAMAGE LEVEL
Surface Resistivity	1	2	2	3	1	2.11
Compressive Strength	0	0	2	4	3	3.11
Split Tensile Strength	2	0	1	5	1	2.33
Static Modulus of Elasticity	5	3	1	0	0	0.56
Absorption after Boiling	5	1	3	0	0	0.47

yard seemed to have only a small harmful effect on absorption after boiling or split tensile strength. The lack of curing greatly reduced the split tensile strength and increased the absorption after boiling of the ACI 332 commercial mixture. The lack of curing variables also caused the compressive strength to either fail ACI 332 specifications of come uncomfortably close to failing. ACI 332 commercial mixture performance was intermediate between the other two mixtures.

Reinforcement Corrosion Potential

Table 9 shows properties and parameters related to the potential for reinforcement corrosion damage. The chloride permeability category is probably the most important factor for reinforcement corrosion damage. In 8 of 9 cases, the Phase 2 variables caused an increase in the permeability category. This increase in permeability category increases the likelihood of reinforcement corrosion, especially in cases where the permeability is in the high category. All Phase 2 variables caused the chloride permeability of the 3500-psi and ACI 332 commercial mixtures to be categorized as high. A high chloride permeability category greatly reduces the expected service life of the concrete. Again, the CRED 1 mixture suffered some damage but fared far better than the other mixtures.

Cracking Potential

Table 9 shows properties and parameters related to the potential for cracking. A higher w/cm ratio increases the amount of drying shrinkage expected in concrete. The stresses generated from drying shrinkage must be resisted by tensile strength in concrete elements not free to move. Most residential and commercial concrete elements are restrained by the base, subgrade or other concrete elements. The combination of an increase in shrinkage potential and a decrease in tensile strength makes cracking far more likely.

Load-associated and thermal changes can cause stresses and deformations in concrete elements. The magnitude of these stresses and deformations is dependent on the modulus of elasticity among other factors. Lower modulus of elasticity leads to larger deformations and possibly cracking. However, the decreases in modulus of elasticity due to Phase 2 variables were relatively small and therefore did not seem as great a problem as shrinkage.

The 3500-psi commercial mixture fared the worst and the CRED 1 fared the best. As expected, the ACI 332 commercial mixture was intermediate in performance.

A commercial mixture with a w/cm ratio above the ACI 332-14 commentary recommended (<0.45) is likely to suffer severe to catastrophic damage to 28-day compressive and tensile strength as well as chloride permeability when subjected to water addition or lack of curing. The probable damage experienced by the mixture greatly increases the likelihood of freeze-thaw, reinforcement corrosion, and cracking durability problems.

A TTU commercial and residential enhanced durability (CRED) mixture with a w/cm ratio well below the ACI 332-14 commentary recommended (<0.45) is likely to suffer minor to severe damage to 28-day compressive and tensile strength as well as chloride permeability when subjected to water addition or lack of curing. The probable damage is not only less than that of a high w/cm mixture but the damaged properties are still in excess of ACI 332-14 specification and commentary requirements / recommendations. Therefore, the probable damage experienced by the mixture only slightly to moderately increases the likelihood of freeze-thaw, reinforcement corrosion, and cracking durability problems.

As expected, an intermediate w/cm mixture was much more likely to have durability problems than the CRED mixture and less likely than the high w/cm ratio commercial mixture when subjected to addition of water or lack of curing. An intermediate w/cm commercial mixture just meeting the ACI 332-14 commentary recommended (<0.45) is likely to suffer severe damage to 28-day compressive and tensile strength as well as chloride permeability when subjected to water addition or lack of curing.

The addition of 2-gallons/CY of water typically results in much lower damage to 28-day properties and consequently the probability of durability problems than lack of curing. As expected, the combination of both variables produces devastating damage (always severe or catastrophic) to 28-day compressive and tensile strengths as well as chloride permeability. Therefore, the combination of both variables makes durability problems much more likely.

Static modulus of elasticity and absorption after boiling suffered relatively little damage compared to compressive strength, tensile strength and chloride permeability due to the addition of water or lack of curing. Neither static modulus of elasticity or absorption after boiling suffered a single severe or catastrophic damage due to either variable or the combination of variables. That is not to say neither suffered any damage. Both of these properties suffered significant damage in 4 of 9 cases.

OBSERVATIONS

Conclusions seem inappropriate for a study with only one batch of each mixture / variable. Therefore, the authors have decided to offer some observations and recommend that these observations be verified with further research and literature examination. The following observations are based on the limited data available in this brief look.

WHAT'S NEXT?

The variable mixtures began cycling between 7 days of drying at 125º F and 7-days of soaking in a 15% (by weight) solution of commercially-available deicing salt containing magnesium chloride in July of 2020. Testing of properties (strength, modulus, and absorption) is planned for January and March of 2021. Results

—Continued on page 22

TABLE 8. FREEZE-THAW DAMAGE POTENTIAL

MIXTURE/VARIABLE	ABSORPTION AFTER BOILING IN PERCENT	SPLIT TENSILE STRENGTH IN PSI	MEETS ACI CODE COMPRESSIVE STRENGTH (≥ 4000-PSI)?	MEETS ACI COMMENTARY W/CM (<0.45)?
3500-psi Commercial Control	5.28	440	Yes 5200	No 0.521
3500-psi Commercial + 2 Gallons/CY	5.66	350	No 3860	No 0.555
3500-psi Commercial No Cure	4.99	295	No 2980	No 0.521
3500-psi Commercial Both	6.11	260	No 2790	No 0.555
ACI 332 Commercial Control	4.96	530	Yes 6610	Yes 0.443
ACI 332 Commercial + 2 Gallons/CY	5.07	550	Yes 5370	No 0.473
ACI 332 Commercial No Cure	5.11	375	Yes 4060	Yes 0.443
ACI 332 Commercial Both	5.51	350	No 3890	No 0.473
CRED 1 36F/4MK Control	4.28	565	Yes 8770	Yes 0.390
CRED 1 36F/4MK + 2 Gallons/CY	3.95	605	Yes 7110	Yes 0.422
CRED 1 36F/4MK No Cure	4.05	495	Yes 5980	Yes 0.390
CRED 1 36F/4MK Both	4.72	455	Yes 5610	Yes 0.422

TABLE 9. REINFORCEMENT CORROSION DAMAGE POTENTIAL

MIXTURE/VARIABLE	CHLORIDE PERMEABILITY CATEGORY	MEETS ACI CODE COMPRESSIVE STRENGTH (≥ 4000-PSI)?	MEETS ACI COMMENTARY W/CM (<0.45)?
3500-psi Commercial Control	Moderate	Yes 5200	No 0.521
3500-psi Commercial + 2 Gallons/CY	High	No 3860	No 0.555
3500-psi Commercial No Cure	High	No 2980	No 0.521
3500-psi Commercial Both	High	No 2790	No 0.555
ACI 332 Commercial Control	Moderate	Yes 6610	Yes 0.443
ACI 332 Commercial + 2 Gallons/CY	High	Yes 5370	No 0.473
ACI 332 Commercial No Cure	High	Yes 4060	Yes 0.443
ACI 332 Commercial Both	High	No 3890	No 0.473
CRED 1 36F/4MK Control	Low	Yes 8770	Yes 0.390
CRED 1 36F/4MK + 2 Gallons/CY	Low	Yes 7110	Yes 0.422
CRED 1 36F/4MK No Cure	Moderate	Yes 5980	Yes 0.390
CRED 1 36F/4MK Both	Moderate	Yes 5610	Yes 0.422

and analysis of these tests should be available in the summer of 2021.

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REFERENCES

Detailed references are shown in Tennessee Concrete Winter 2019/20.

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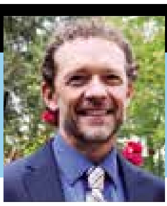
TABLE 10. CRACKING DAMAGE POTENTIAL

MIXTURE/VARIABLE	STATIC MODULUS OF ELASTICITY IN MILLION PSI	SPLIT TENSILE STRENGTH IN PSI	MEETS ACI COMMENTARY W/CM (<0.45)?
3500-psi Commercial Control	3.95	440	No 0.521
3500-psi Commercial + 2 Gallons/CY	4.10	350	No 0.555
3500-psi Commercial No Cure	3.65	295	No 0.521
3500-psi Commercial Both	3.45	260	No 0.555
ACI 332 Commercial Control	4.30	530	Yes 0.443
ACI 332 Commercial + 2 Gallons/CY	4.20	550	No 0.473
ACI 332 Commercial No Cure	3.95	375	Yes 0.443
ACI 332 Commercial Both	3.95	350	No 0.473
CRED 1 36F/4MK Control	4.65	565	Yes 0.390
CRED 1 36F/4MK + 2 Gallons/CY	4.60	605	Yes 0.422
CRED 1 36F/4MK No Cure	4.90	495	Yes 0.390
CRED 1 36F/4MK Both	4.85	455	Yes 0.422

Continued from page 14—



TECHNICAL DIRECTOR'S MESSAGE—JOHN B. PEARSON, P.E.

IN SEARCH OF A BETTER MOUSETRAP
TCA PRACTICAL CURING STUDY

Although this study just scratches the surface, a few initial observations can be made. Even without electricity, acceptable initial curing conditions can be maintained in hot summer conditions using a large, but not unreasonable, volume of cool water. This may require having ice available at the jobsite to initially acclimate the water to the desired temperature. Smaller coolers may be effective when cylinders will be picked up the day after casting, or for longer durations when the coolers can be stored in a shaded area of the site. If additional cooling measures, such as incorporating melting ice above the samples, are used to combat temperature rise, precautions may need to be taken to make sure the temperatures do not fall below the low end of the allowable range. Lastly, and not surprisingly, container color can have a noticeable impact on curing temperature when containers are stored in direct sunlight.

TCA plans to perform additional curing trials under varying conditions using various curing methods in both hot and cold weather. We would love to hear your ideas or find out what has worked for you. If you would like to share your ideas or participate in one of these trials, please reach out to me at jpearson@tnconcrete.org.

—John Pearson

TENNESSEE CONCRETE ASSOCIATION

1ST

THE REMARKABLE LEGACY OF CONCRETE
by CLAIRE SANBORN

When will your legacy end? Some argue that it is when you die; others would say that it is when you are forgotten. The main way we have remembered artists and innovators is through their works: Alexander Graham Bell and his revolutionary light bulb, Mary Shelley and her fantastic characters in Frankenstein, and Leonardo Davinci's intriguing Mona Lisa. But imagine if there was someone who did it all, walked the streets of Rome, supported buildings with ease, delivered the troops to Normandy, while also making millions all over the world feel safe. This person would be renowned as a hero and plastered all over history textbooks. What if I were to tell you that it is not a man, but concrete!

Humans have always wanted to build structures that last, and this drive has earned concrete a dominant role in history. Infrastructure strength has been a consistent need throughout the past, from the old limestone temples to massive draw-bridged castles. There's a reason why in the Bible the wise man built his house on the rock, but the foolish man lost everything by building on the sand. Humanity has thrived off of stability and concrete has been there to meet that need.

Roman architects used enough concrete for historians to nickname the Roman Architectural Revolution the Concrete Revolution. The imperishable bases held up magnificent structures, such as the grand Colosseum artfully crafted by Vespasian. Roman architecture is considered to be some of the finest in the world, from its tremendous domes to its immaculate detail. By ensuring long-term stability, concrete prolonged Rome and Vespasian's legacies that continue to captivate many to this day.

America today would look significantly different if it weren't for concrete.

Transportation became easier and more efficient because concrete roads provided much faster transportation routes for vehicles than the obsolete dirt road provided. In World War II, Ferro Cement Barges, also known as Concrete Ships, were used on D-Day during the storming of Normandy to transport our troops and ensure our victory. We might have lost the war if it weren't for concrete! The threat of war carried on into the sixties when families invested in concrete bomb shelters. For these Americans, concrete was a sign of strength and security, whether it was on the battlefield or within their homes. The American legacy today would have not risen to such heights if it weren't for innovations with concrete.

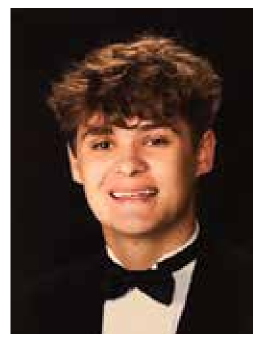
Today, concrete has not only taken center stage but has rewritten the whole story! Skyscrapers, tunnels, and bridges all rely on this trusty material. Concrete stabilizes skyscrapers with industrial innovation and security that wouldn't have been conceivable centuries ago.

Concrete also aids suburban families through its storm-resistant structures and new sidewalks.

So how will concrete be remembered? Will it be recalled for leading soldiers to war or keeping millions protected within their homes? Maybe it will be praised for raising up temples and monuments. It will certainly be remembered for preserving the historic foundations of nations. Whatever concrete's legacy may be, I know it won't be forgotten anytime soon!

2ND

FOUNDATIONS BUILD SUCCESS
by Eli Ferguson



This simple phrase was the "mission" Fall Branch School, a school that I attended for nine years. Each morning, after saying the Pledge of Allegiance, the principal would recite that saying over the intercom. I heard these words each day for the majority of nine years, but never truly understood the meaning until later on. Now, I realize that foundations truly are the most important part of any process. Without a strong starting point, whatever the task at hand is bound to fail.

In construction, a foundation gives the building strength. Without this, many buildings would simply crumble with the constant pressure on them or even with the slightest gust of wind. Fall Branch is an old building, built prior to the Civil War. As is the case with many older structures, it has many cosmetic blemishes. However, for a building to stand that long, it must have a strong foundation. I never thought about what was in those cold, hard floors I used to walk down every day, but now I realize that the foundation of Fall Branch School relies on one important material: concrete.

Concrete's first uses can be traced back to around 6500 B.C. It seems that something that old would be extinct by now, especially considering the architectural and technological advances since then. However, concrete is different. Its amazing properties have allowed it to withstand these changes, much as it is able to withstand the forces of nature and humanity. Even the most destructive natural disasters do not seem to affect concrete. For example, after Hurricane

Matthew in 2016, many structures in North and South Carolina were completely demolished except for their foundations. These foundations, made mainly of concrete, withstood the 150 mile per hour plus winds. Impressive displays of strength such as these have caused concrete to stay an important factor in architecture for thousands of years.

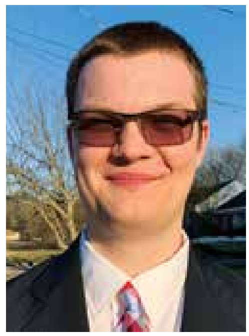
Concrete plays much more of a role in our daily lives than we are led to believe. As previously mentioned, concrete sets the foundations for most homes. It also plays an important role in the construction of many other types of buildings, ranging from hospitals to parking garages. Parking garages show the sheer strength of concrete, as each level is able to support thousands of pounds without the need for extensive support. Other uses of concrete that we often go without noticing are the roads and highways that we drive each day. Although asphalt is sometimes used as well, many roads are still concrete. These roads hold up well in comparison with asphalt and tend to require much less maintenance.

In conclusion, concrete plays a very important role in the building process and has for thousands of years. Its strength and durability allow it to be useful in a multitude of different ways, including as a foundation or even as a road. Concrete is a vital part of our everyday lives and will continue to be for many years.

3RD

HUMBLENESS

by Tobias Bokcom



I like high school, but the best part of education is hands-on learning. My school allows its students to go on job shadow days. I chose to go with my dad to one of his construction sites. He is a contractor, and I was excited to go to the house he had been working on the last few months to see the final project.

The latest house he built was almost completely made of concrete. Dad and I had been talking a lot about it. From his first descriptions, I thought the house would end up looking like a giant cinder block. Boy was my mental picture wrong!

His crew began the project by laying the foundation. They dug the footer and had the concrete company bring mix with extra fiber to pour the footing Next, the crew spent hours framing the basement walls and getting the forms ready to pour. When they were ready for the concrete company to send out the concrete truck, Dad ordered the concrete, and had it colored a dark gray. The truck brought the concrete to the building site. The mix was just right. Dad and his crew poured the walls and waited for them to cure. Then, the construction team was ready to pour the basement floor. Dad had the floor concrete tinted a medium gray color. The color looked great with the dark gray walls. Next, the crew formed and poured the main floor the same color as the basement floor. The main floor walls were formed and poured. Dad choose a light gray color for the walls. The colors all blended together nicely.

The construction crew did the interior walls and put in the doors and windows. They got the house in the dry with a durable metal roof. Dad choose black. The front porch was formed and poured with the dark gray concrete. They put black shutters on the windows to bring everything together. Then, it was time for the team to do the inside work.

The floors were polished to give them a brilliant shine. The main floor walls were washed to a light grey, almost white color. With beautiful gray concrete countertops, the kitchen was breath-taking. Elegant white stairs extended out of the wall and down into the basement. The steps created the illusion that they were floating. The downstairs walls were sealed and the floors were polished. The contrast was stunning!

Dad and the construction team also poured a driveway leading up to this amazing home. The concrete was the medium gray color to match the house and was stamped to look like marble. It was impressive!

Dad and I walked outside on the stamped concrete patio and sat down on the outside furniture, which was also made of concrete. After seeing everything inside the house and all the angles of the outside of it, I realized how my initial image of a giant brick was extremely off. This house gave off a futuristic vibe, and with everything so elegant, it looked like a mansion. I was inspired by the beauty and durability of the concrete. Dad and I even discussed the cost of the home. The most amazing part for me was not the splendor of the house, it was the value. After the tour and our talk, I have decided that I want to build a house for myself out of concrete. ✷

CIM UPDATE

CIM FALL FUNDRAISING

The School of CCM had a backlog of events from the spring covid shutdown and hosted three industry fundraisers as we began the fall semester to catch up.

- The CIM Jim Speakman Golf Tournament delayed from May was played on September 2. Even with half capacity to allow for safe distances, one flight was full with 34 teams and the program raised nearly $70,000 in one event.
- Always a great fall homecoming event, the CIM Skeet Shoot went off with a literal "bang!" on Friday, October 2. This year had great weather and with 10 teams of five shooters as well as a silent auction online another $17,000 was raised

Garrott Brothers Team at the Fall Trap Shoot

Clark Gates, Boral and Autumn Gates, CIM senior played on a team together.

Ward Poston and Jim Brandon on the course

CIM 3050 PRACTICES FLATWORK TECHNIQUES

Professor Huddleston's CIM 3050 class still took advantage of the weather and practiced their flatwork skills while pouring several small pads on campus last fall. Tables with solar charging stations will be on the pads.

CIM junior Jack Sandifer steps back for a quick look at his work

Professor Huddleston steps in to show them how it's done

They picked a good day to get in some practice.

NEW SCHOOL OF CCM BUILDING READIES FOR CONSTRUCTION

There is exciting action on campus with a fence and job trailer arriving on the site of the new CCM Building. Here are several architect renderings of the new building on campus that will house the CIM program. Classes are expected to start in the new building in Fall of 2022.

MUSIC CITY GRAND PRIX

Concrete Industry Management students in Dr. Heather Brown's CIM 4200 Senior Lab course have had the opportunity last fall and this spring to work on a unique project for the inaugural Music City Grand Prix in Nashville. Seniors are developing sustainable concrete mixes to use in new barriers for the race, to be held in August. Through industry partnership with Jarrett Concrete Products, 2400 of the first precast barrier walls are built. CIM Alumni Travis Jarrett and CIM MBA Alumni Frank Bowen are leading the project.

JARRETT CONCRETE

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