Spring 2019
VOL. 33, NO. 1

TENNESSEE CONCRETE MAGAZINE

GRAND CHAMPION
BLUEGRASS UNDERGROUND
IMI, Irving Materials, Inc.
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BLUEGRASS UNDERGROUND

See page 8

BEST FINISHING — COMMERCIAL

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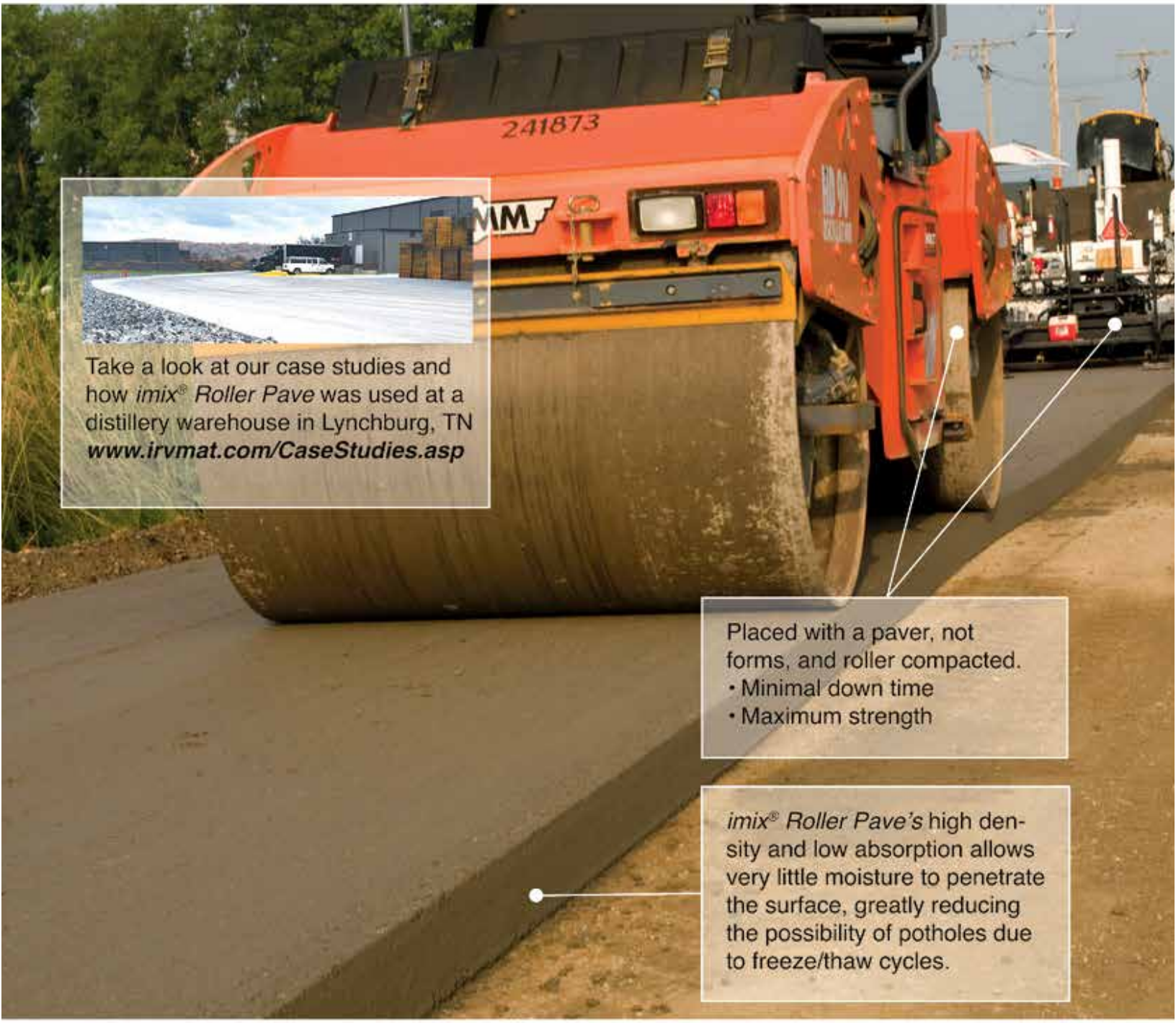

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TENNESSEE CONCRETE MAGAZINE

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WORKFORCE DEVELOPMENT

Alan Sparkman
Executive Director

You are competing for employees …

The balace of power has shifted …

What people want and expect from a job has changed …

Workforce Development – it's the phrase that everyone is using and its not just the construction industry who is consumed with the difficulty of finding and keeping good people. All sectors of the economy are faced with the same burning issue – where can we find qualified people to recruit and how do we keep them once we find them?

All indications are that this is not just a blip or a temporary condition of a robust economy. This condition of employee scarcity is the new normal across our economy and it may even be worse for construction and manufacturing than it is for other sectors. Statistics reveal that in the manufacturing sector there are far more people (Baby-boomers) retiring than can be replaced, let alone hiring enough talent to grow capacity. Add to this the fact that most new work-force entrants (that's code for young people like Millennials and Gen Z) don't even consider careers in the traditional blue-collar realms and you have a perfect storm of persistent employee scarcity. All of this has a number of important implications for the concrete industry to consider, including the three listed below:

FIRST, You are competing for employees with all types of jobs not just concrete or construction opportunities. There is only one manufacturing company in Fortune's Top 100 Best Companies to work for list (Mars Wrigley Confectionery). So not only are you competing across the full spectrum of the economy, your concrete or construction business is at the very bottom of the list for most folks looking for their first opportunity. The standard image of a construction job for new job seekers is not 'cool' and seems more like a last-resort job rather than a first-choice career. Some of that disdain isn't deserved and the truth is that many concrete/construction positions have a lot to offer – the task for us is to do a much better job communicating the 'cool' opportunities and benefits that a construction career offers.

SECOND, the balance of power has shifted – dramatically. Employees, not employers have the upper hand in today's economy. Employees, not jobs, are the scarce commodity so employers have nowhere near the leverage they once had. In today's world employees are doing you a favor by just considering your open position. Add to this the fact that there is dramatically more transparency today about what various jobs pay and what they offer as benefits. Job seekers can get publicly available information about the culture of your workplace, your safety record (especially true for companies that operate trucks), and your environmental record before they even apply for your position. In most cases it's easy for potential employees to know more about your organization than you know about them, even after reviewing their job application. All of this leads to…

THIRD, what people want and expect from a job – any job (including yours) – has changed. Work/life balance, opportunities to build skills, prospects for advancement, connection to purpose and passion are all important and part of the decision-making process for many potential employees. In case some of these terms are not familiar, let me translate. Work/life balance means regular schedules and limited overtime that provides the ability for your employees to attend their children's school activities or participate in their own softball league (even during the summer). Skill building means regular training that builds the employee's personal resume and expands their capabilities. And yes, that means they are more valuable not only to you but other employers so the competition to keep them with your organization DOES NOT END after you hire them. Those new skills also need to provide a path for advancement within your organization that should include higher compensation as well

as new challenges and opportunities. Finally, potential employees today care a lot about whether or not your organization is making your local community a better place to live. Allowing employees to pursue a personal cause or passion as part of their work (or while on the clock) can be a powerful motivator for both recruitment and retention.

This landscape for employment seems completely alien to many of us who started our careers in the last century but the time for looking backward is long over. Focus your energy forward and think in terms of making your organization the very best place to work, period. Who knows – you might even find yourself on a Best Place to Work list with the other cool kids in the room!

Congratulations

TENNESSEE CONCRETE ASSOCIATION'S Class of 2019

LIFETIME HALL OF FAME INDUCTEES —

Steve Lambert
Lambcon

Reece Thomas
Sequatchie Concrete

Fellow Hall of Fame inductee Reece Thomas, of Sequatchie Concrete, has also served as a adjunct professor for the CIM program.

Dr. Heather Brown
MTSU School of Concrete and Construction Management

Dr. Heather Brown, Director of the School of Concrete and Construction Management at MTSU, was inducted to the TCA Lifetime Hall of Fame at the 2019 TCA Annual Convention on February 7. Honoring Dr. Brown were former graduates of the CIM program including Christopher Davenport of Southern Concrete Machinery. All CIM program graduates were asked to join Dr. Brown on stage for a photo. Dr. Brown spoke to give her thanks and also say that while she does not build buildings, she builds people. Congratulations to Dr. Brown on this well-deserved honor!

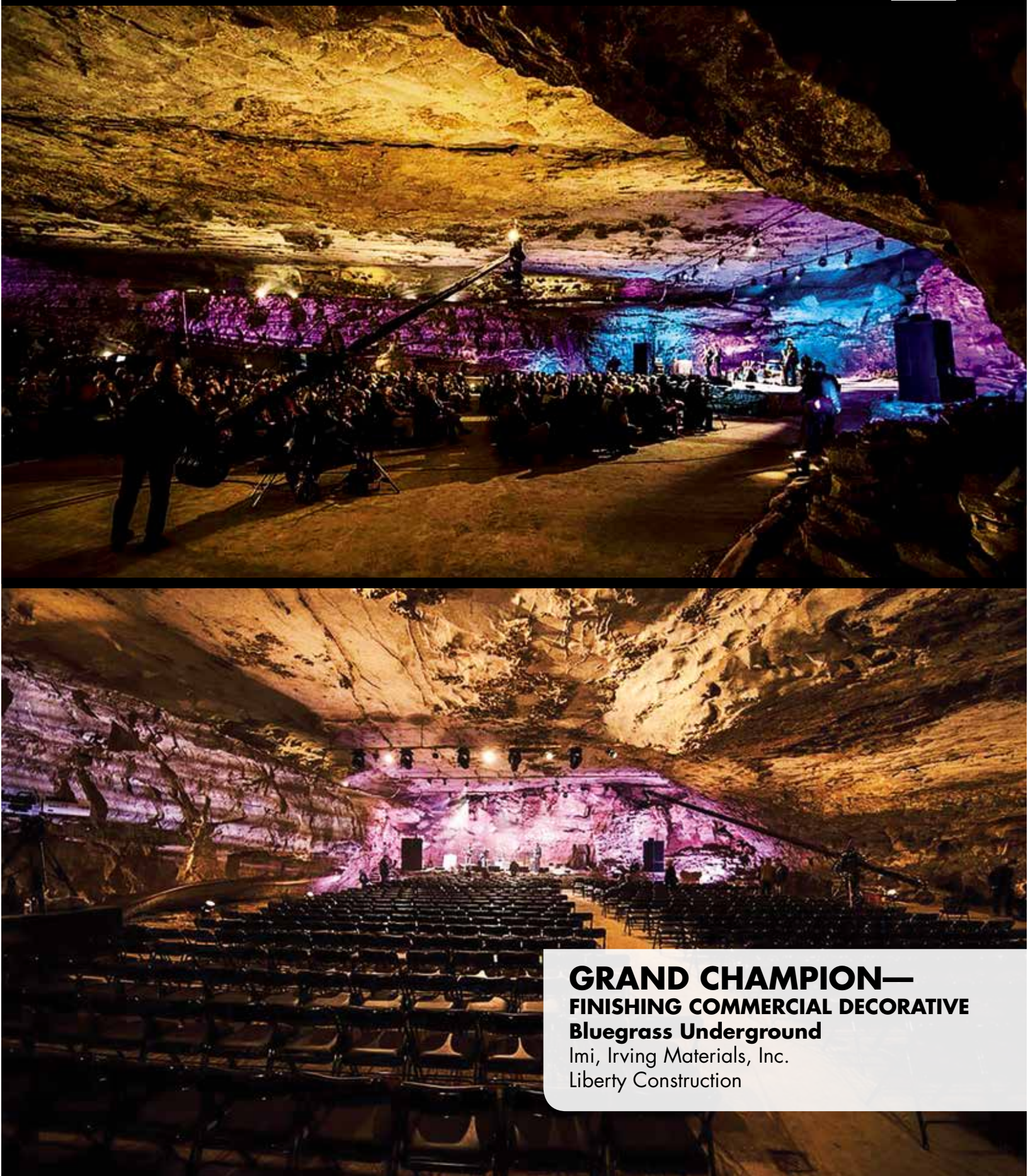

Oh yes, it's time to start signing up for the 2019 Tri-State Summer Meeting with AL, MS, & TN in Sandestin, FL
June 27-30th!

2019 CONCRETE AWARD WINNERS

Congratulations

This project is located at 555 Charlie Roberts Road, Pelham, Tenn. This was the site for the new Blue Grass Underground The Caverns venue. The work was all performed by Liberty Construction under the guidance of Temple Bowling. To start the project the cave entrance had to be excavated using only machines with no blasting. After excavation 35,000 yards of material had been removed from the cave. The ceilings and walls remained natural and uncut.This is an active cave so 24 inches of clean rock had to be placed under the 200 plus yards of Yosemite Sand Concrete for the stage and floors to allow the water from the cave system to drain to an underground pumping system. The Color was chosen to mimic the surrounding atmosphere. The walls for the entrance into the cave are 3 feet thick and 11 feet tall to hold back any water that might potentially flood the cave as there is a dry creek that runs down the side of the cave and in front of the entrance. Concrete was then used to create a road from the entrance to the top of the cave. Up top, two slab buildings were built: one to accommodate the singer-songwriter bands called the Green Room and the other for a gift shop. All-in-all, there were 615 yards of Concrete utilized on this project.

2019 CONCRETE AWARD WINNERS



GRAND CHAMPION—
FINISHING COMMERCIAL DECORATIVE
Bluegrass Underground
Imi, Irving Materials, Inc.
Liberty Construction

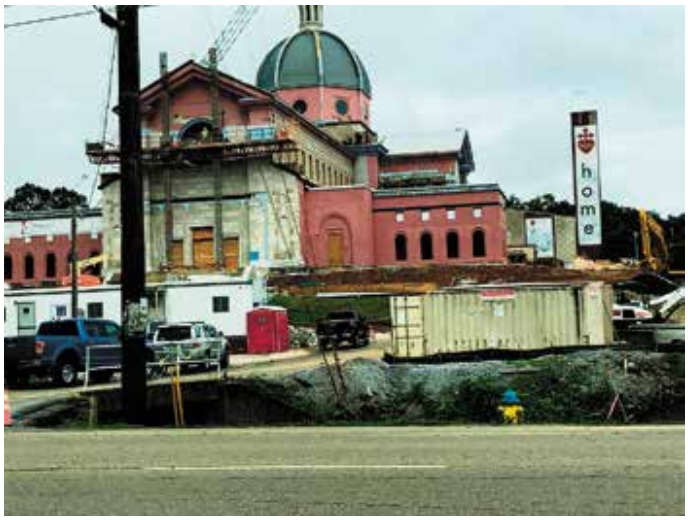
2019 CONCRETE AWARD WINNERS

BEST ARCHITECT/ENGINEER-NON-BUILDING STRUCTURE
CNR 048
Imi, Irving Materials, Inc.
Project Owner: TDOT
Bell & Associates Construction

The Tennessee Department of Transportation (TDOT) used the accelerated bridge construction (ABC) process for replacing Interstate 24 bridges in downtown Nashville. More than 148,000 vehicles travel on this section of I-24 daily. The $28.5 million dollar project included replacement of the bridges over Oldham Street and Spring Street on the eastern loop of downtown, deck repairs to the Silliman Evans Bridge and resurfacing of the entire area. The 4 bridges were replaced in 4 weekends. Construction on each bridge started on a Friday night and would be finished before Monday morning rush hour traffic. Bell & Associates crews worked non-stop during the closures, they removed the old bridge superstructures, placed new components, and placed over 650 cubic yards of the TDOT Class X concrete mix supplied by imi. This special Class X mix reaches high early strength in only a few hours which allowed the crews to finish placing barriers and striping within hours. This ABC process allowed construction to be finished in months instead of years.

CO-WINNER BEST BUILDING
Sacred Heart Cathedral
Glenn E. Mitchell
Ready Mix USA
Barber McMurry & James McCrery

Groundbreaking for the New Sacred Heart Cathedral was held on April 19, 2015, with dedication of the nearly $40 million structure being held on March 3, 2018. Seating capacity was increased from 580 in the old cathedral to 1,358 and it increased the worship space from 7,500 square feet to 28,000 square feet. The central dome, inspired by the Florence Cathedral, rises to a height of 144 feet. The exterior of the cruciform structure is clad in Indiana limestone and Roman-style bricks from Ohio. Seventeen types of marble were used in the interior, much being set in or on concrete. Over 3,500 CY of concrete (including color concrete) Color was used on the project. In addition to tight time constraints (the dedication ceremony was "set in concrete" since a team of Catholic officials were flying in from around the world), primary challenges for this project were forming concrete to exact specs so as to accept marble overlays and adjacent materials; casting concrete for the rose windows on the ground to tight specs since it was lifted into position by crane; and overcoming tight site conditions to achieve elevation changes that were both aesthetically pleasing and that met ADA requirements.



2019 CONCRETE AWARD WINNERS

CO-WINNER BEST BUILDING
Vanderbilt E. Bronson Ingram Dorm
Imi, Irving Materials, Inc.
R.C. Mathews Contractor
EMC Structural Engineers
Hastings Architecture Associates

The new residential college will replace the existing 65-year-old Vanderbilt and Barnard Halls and will be located on the same site. It will provide housing for 340 sophomores, juniors and seniors. It will include apartments for a faculty member and a residential area coordinator, a large dining space, a new kitchen and additional space for academic and programming needs.

BEST CONCRETE HOME
Strkyer Place
Imi, Irving Materials, Inc.
Dusty & Sons Concrete

Dusty and Sons Concrete, LLC was contacted by a home builder to pour all of the concrete for a home in Brentwood, Tennessee. This basement lot was on the side of a hill. IMI supplied all of the concrete and Dusty and Sons Concrete, LLC poured all of the concrete from the footings, cast in place poured walls, porches, retaining walls, driveway, and city sidewalks. Over 400 yards went in the footings, cast in place poured walls, and basement slab. Another 100 yards went in the back patio retaining wall footings and cast in place retaining walls. The micro wash

exposed aggregate driveway had 165 yards placed with broom finish boarder on it. Finally, another 65 yards was placed in the city sidewalk and porches.

A big problem to overcome on this job was the access. We were constantly using a pump truck, using a skid steer to carry concrete, or waiting until it was dry enough to get a concrete truck down the slope of the site. Another thing that was unique about this project was that the homeowner wanted to have his main level garage suspended, so he could drive under it also to drive in the basement. Wall heights where critical with some of them being almost 20 feet high. Another challenge was keeping the driveway within code by not getting it steeper than 20 percent.

BEST CONCRETE STREET

Honey Farms

Imi, Irving Materials, Inc.

CT Concrete

Charles Raines Construction LLC is the developer of a subdivision called Honey Farms located on Highway 31 south in Springhill TN. Charles decided to use concrete for his roadways. In doing so he realized the saving of maintenance and sustainability to his roads along with less lighting. Phase 3 of the Honey Farm began in April 20 2018. Charles Raines hired CT Concrete for his concrete finishing and IMI as his concrete producer. CT Concrete along with IMI masterfully completed 1620 yards of 4000 psi in phase 3 in 5 pours. Each pours of roughly 200 to 400 yards completing this project by September 14 2018. During this process IMI was able to deliver a average between a 100 to 120 yards per hour, out of two concrete plants. There were concrete cylinders taken and broken exceeding concrete specified strength. IMI as a leader in the ready mix business in middle Tennessee, IMI along with CT concrete was able to complete this task with a high standard of quality and delivery for our customer. In doing so Charles Raines Construction decided to use IMI as his concrete suppler on all of his projects.

BEST FINISHING - ARTISAN

Christian Brothers High School Logo

Baltz & Sons Concrete

Memphis Ready Mix

Linkous

As part of a large campus expansion at Christian Brothers High School in Memphis, Linkous Construction turned to Baltz & Sons Concrete to help develop and implement a decorative feature in front of the courtyard entry to the newly constructed Athletic Development Center. The plans indicated nothing definitive other than that there was to be a "decorative element" implemented into a central focal-point in front of the new buildings commanding facade. President and owner of Baltz & Sons concrete Kevin Baltz, an alum of CBHS, relished the creative opportunity, and presented a variety of options to the school. Ultimately it was decided to reproduce the school's athletics team logo, the Purple Wave, into the courtyard terrace. Baltz first installed a concrete "canvas" opting for a cement-rich mix-design that would lend to subsequent steps. After adequate cure time, their team designed a large multi-paneled vinyl template of the logo. This was applied and secure with temporary adhesives, then the pattern was carefully and intricately cut into the surface

of the concrete by hand using 4" angle grinders. Baltz's decorative team devised and blended custom pigments to use for the logo, and four colors were hand-painted onto the scored surface. As a special final touch, Baltz infused a metallic gold agent into the shining band that encircles the logo. The logo was then sealed with an ultra-hard UV stable acrithane sealer to protect it from foot traffic and the sun. The logo has quickly become a prominent feature of the campus, loved by students, visitors, and alumni alike.

BEST FINISHING - COMMERCIAL
Jack Daniels Bottling Facility
Imi, Irving Materials, Inc.
Fiberforce by ABC Polymer
Lithko Contracting

This project is located in Lynchburg, Tn at Jack Daniels Bottling Facility. This project was ran through Lithko Contracting under Kendel Kitchens supervision. In total there was 10,500 yards of concrete on this project. Floor slabs were over 250,000 square feet and the walls had just over 55,600 square feet. The interior concrete floors and exterior slabs for the loading docks utilized Macro Synthetic Fibers utilizing its ease of placement while keeping the schedule ahead of schedule. SCC concrete was used for the elevator shafts and Penetron was added to waterproof water tight slabs. The Jack Daniels Logos were added to both walls each spanning 9 feet in diameter using Mevalite forms. With this expansion it made it possible for Jack Daniels to now bottle 3,000 bottles a minute while adding Cafeteria space for their staff and a much larger loading dock.

BEST FINISHING - RESIDENTIAL DECORATIVE INTERIOR
Honed Wood Project
Dusty & Sons Concrete
Imi, Irving Materials, Inc.

A homeowner in Spring Hill, Tennessee contacted Dusty and Sons Concrete, LLC about pouring a unique but timeless stamped concrete patio to build a sun room on top of it. After looking at many patterns, they decided on a honed wood beam pattern. These planks are 16 inches wide by 10 feet long. The color that they decided on was a pecan tan color hardener with a deep charcoal release. IMI was the supplier of the 4,000psi concrete mix. This patio had one side that was build up about 18 inches high, so that wall was poured first, and then the stamped patio was poured next. They were both poured with the use of a Georgia buggy.

2019 CONCRETE AWARD WINNERS

BEST FINISHING - RESIDENTIAL DECORATIVE EXTERIOR

Jerkins Residence

Memphis Ready Mix

Baltz & Sons Concrete

Summit Landscapes

This spectacular residential project features a variety of concrete applications–from the gunite pool itself , the stamped concrete pool decking, to the outdoor kitchen counter-top surfaces, concrete met a wide array of building material needs. The initial phase of the project was a installation of a large custom shaped gunite, or shotcrete pool. The elaborate design featured various shelves and ledges to house subsequent stone features, including a masonry fire-pit, several patio areas, a large natural waterfall and built-in slide. Adjacent to the pool, an expansive pavilion cabana features an outdoor kitchen with cast-in-place concrete counter-tops and as well as a slate-textured stamped concrete bench along the entire length of the outdoor entertaining space. The customer was so impressed with the concrete installations in the first part of the project, he sought to incorporate its use into subsequent stages as well. For this reason, concrete was cast into caps for the multiple brick columns, and also cast into a winding staircase atop natural stone, leading to the pool slide that threads thru the natural stone water feature. Baltz & Sons Concrete formed and cast each of these applications, carefully texturing and pigmenting each portion so that it would blend seamlessly with the natural stone elements.

2019 CONCRETE AWARD WINNERS

BEST CONCRETE PARKING LOT
Johnson Electric
Imi, Irving Materials
Dennis Concrete Services

Dennis Concrete Services started this job in September of 2018. They poured this job in 5 different pours using a mix 4000 with air. Dennis Concrete Services poured 1150 yards for this parking lot. Dennis Concrete Services done an exceptional job on this parking lot project. Johnson Electric was very pleased with the job.

BEST PERVIOUS CONCRETE
Hamilton Springs Train Station
Imi, Irving Materials, Inc.
EOA Architects of Nashville
Lose & Associates

A new transit train station was built and pervious concrete was used in the parking lot to help with water runoff. A total of 183 yards of pervious concrete were used on this project.

BEST SPECIALTY
Hillwood Smyrna
Imi, Irving Materials, Inc.
Lampley Construction, Inc.
MacGregor Associates Architects
Haines, Gipson, & Associates

Construction of the Hillwood ABP Building 1 started in November of 2016 and was to be completed in one year. This was the beginning of what would soon become a new 963,000 sf warehouse facility in the heart of Smyrna's Airport Business Park. The high-volume, tilt-up warehouse features the use of over 25,000 cy of concrete.

Diligent coordination and teamwork highlights the success of the Hillwood ABP Building. Through this coordination, T.W. Frierson Construction, Inc. and Lampley Construction, Inc. successfully worked together with their ready-mix supplier, Irving Materials, Inc. to erect the immense Hillwood ABP Building 1.

by L. K. Crouch, James Locum, Daniel Badoe and Heather P. Hall

Going Past TDOT Specifications to Lower Concrete Permeability

Part 2: Already Gone

SERIES OVERVIEW

This four-part series of papers is an investigation of going past current Tennessee Department of Transportation (TDOT) Class D concrete specifications (1) to increase surface resistivity (SR). The investigation explores both exceeding limitations on currently approved TDOT supplementary cementing materials (SCMs) and using SCMs not currently approved by TDOT. All concrete mixtures used in the investigation met TDOT's Class D concrete plastic and hardened property requirements. Further, all concrete mixtures used in the investigation were constrained to meet the following criteria:

- Water-cementing materials-ratio (w/cm) = 0.37
- Design air content of 7%
- Total cementing materials = 620-lbs/CY
- Same brand and type of Portland cement
- Same source and size of coarse aggregate
- Same source of fine aggregate
- Fine aggregate as a percentage of total aggregate by volume (FA/TA) of approximately 38%
- Same three TDOT-approved chemical admixtures

These additional constraints should facilitate easier comparison of the concrete mixtures used. It is important to note that w/cm = 0.37 and FA/TA ~ 38% are not considered optimal, but rather these values met TDOT Class D concrete specifications and have worked well for the authors. The authors hope that mixture designers and concrete professionals find the information useful.

In Part 2, the effect of increasing the Grade 120 slag replacement dosage on SR is examined. Subsequent articles in the series will examine:

3. Life in the Fast Lane – SCM Dosages for Rapidly Reaching the SR "Very Low" Category
4. New Kid in Town – Ground Pumice as an SCM

INTRODUCTION

The Slag Cement Association recommends slag substitution levels of 25 to 65% to lower concrete permeability (2). Lowering SR by "going past" current TDOT specifications for slag substitution, was the purpose of this paper. Therefore, the research team decided to start with a 35% slag substitution since it is the highest substitution currently allowed by TDOT Class D concrete specifications (1).

MATERIALS AND PROCEDURE

TDOT-approved materials used in the study are shown in Table 1, column 1. The proportions of the seven mixtures used in the study (see Table 1) were determined through trial batching. After trialing, all seven mixtures met TDOT Class D concrete plastic and hardened property requirements. Table 2 shows TDOT requirements for minimum cementing materials, w/cm ratio, fine aggregate percentage by total aggregate volume, and allowable SCM replacement percentages. The first mixture, 35% Slag, met all Table 2 criteria, whereas mixtures 40% through 65% (indicated in red) met all criteria except maximum SCM replacement percentage. Six batches of each mixture were made and tested as per Table 3 criteria.

Figure 1 below shows two cylinders tested in compression from this series. The cylinder on the right is a fly ash specimen from the aforementioned portion of this series "Take It to the Limit." The cylinder on the left is from this portion of the series on slag substitutions. Notice the green/blue color of the paste in the slag cylinder shown on the left. This paste color change is caused by the slag's oxidation state of the sulfide sulphur compounds during its hydration with Portland cement (2). This brief effect often disappears when the PCC is exposed to the air and environment and leaves the PCC often whiter than ordinary PCC (2). However, the authors do not recommend the PCC to be used for aesthetic applications where the slag PCC will continuously be exposed to moist conditions since the greening has been known to return even after the forms have been removed (2).

Figure 1: Compressive Specimens - Slag (left), Fly Ash (right)

—Continued on page 10

TABLE 1. MIXTURES USED TO EVALUATE SLAG REPLACEMENT PERCENTAGE EFFECT

	35% SLAG	40% SLAG	45% SLAG	50% SLAG	55% SLAG	60% SLAG	65% SLAG
Type I PC, (lbs/CY)	403	372	341	310	279	248	217
Grade 120 Slag, (lbs/CY)	217	248	279	310	341	372	403
No. 57 Stone, (SSD lbs/CY)	1867	1870	1867	1865	1865	1866	1865
River Sand, (SSD lbs/CY)	1128	1127	1126	1125	1124	1125	1125
Water, (lbs/CY)	229.5	229.5	229.5	229.5	229.5	229.5	229.5
Design Percent Air	7	7	7	7	7	7	7
Air Entrainer, (oz/cwt)	0.35	0.60	0.60	0.60	0.60	0.60	0.75
Mid-Range Water Reducer, (oz/cwt)	3.00	4.00	3.70	4.00	4.00	4.00	4.00
High-Range Water Reducer, (oz/cwt)	4.00	3.85	3.10	3.40	3.70	3.85	4.00

TABLE 2: SLAG REPLACEMENT EFFECT WITH TDOT CLASS D PCC REQUIREMENTS

MIXTURE ID	CEMENTING MATERIALS CONTENT, (LBS/CY)	W/CM RATIO	PERCENT FINE AGGREGATE BY TOTAL AGGREGATE VOLUME	PERCENT GRADE 120 SLAG SUBSTITUTION (BY WEIGHT) FOR PC
35	620	0.37	38	35
40	620	0.37	38	40
45	620	0.37	38	45
50	620	0.37	38	50
55	620	0.37	38	55
60	620	0.37	38	60
65	620	0.37	38	65
TDOT 604.03 Class D PCC Requirements	620 minimum	0.40 maximum	44 maximum	35 maximum for Grade 100 or Grade 120 Slag

TABLE 3. COMPARISON OF AASHTO ALLOWABLE COEFFICIENTS OF VARIATION

TEST METHOD	FREQUENCY	SPECIMENS
Compressive Strength, AASHTO T22 (3)	3 @ 28 and 56 days	4 x 8 cylinders
Surface Resistivity, AASHTO T 95-11 (4)	3 @ 7, 14, 21, 28, 42 and 56 days	56-day compressive strength 4 x 8 cylinders
Hardened Concrete Absorption, ASTM C642 (5)	3 @ 56 days	3 x 6 cylinders

TABLE 4. 28-DAY COMPRESSIVE STRENGTH RESULTS AND DATA QUALITY (PSI)

% SLAG	BATCH 1	BATCH 2	BATCH 3	BATCH 4	BATCH 5	BATCH 6	MEAN	RANGE	ALLOWABLE RANGE
35	8150	8020	7730	8130	7860	7680	7928	470	1015
40	7010	7600	7190	7370	6950	7480	7267	650	930
45	7690	7730	7540	7710	7420	8000	7682	580	983
50	8940	8890	8040	8850	7370	7920	8335	1570	1067
55	7820	7690	7680	7590	7480	7900	7693	420	985
60	7270	7970	8100	7720	8150	8340	7925	1070	1014
65	7690	8250	8650	8540	8140	8060	8222	960	1052

by L. K. Crouch, James Locum, Daniel Badoe and Heather P. Hall

Going Past TDOT Specification to Lower Concrete Permeability

Part 2: Already Gone

RESULTS AND DATA QUALITY

Tables 4 and 5 show 28-day compressive strength and 56-day absorption results, respectively. The SR results are shown in Table 6 for 7, 14, 21, 28, 42 and 56 days. The acceptable range of the hardened properties results was determined by obtaining the standard deviation or coefficient of variation from the appropriate test method and multiplying by an ASTM C 670 factor for the number of test results (6). The multi-laboratory precision was used for the 4x8-inch cylinder results, since AASHTO T 22 states that the preparation of cylinders by different operators would probably increase the variation above multi-laboratory precision criteria (3). All hardened property test results met the acceptable precision criteria except the 50 and 60 percent slag compressive strengths (indicated in red in Table 4). Unfortunately, no precision criteria are available for hardened concrete absorptions after boiling.

ANALYSIS OF RESULTS

Statistical Comparison of SR Results

The hypothesis test results of SR equality are represented in Tables 7 and 8 for the various mixtures at a given curing time and for the same mixture over various curing times, respectively. A statistical t-test with the assumption of unequal variances was performed. The estimated t-value was observed to be less than the critical t-value at the corresponding degree of freedom with a 5 percent significance level. The compared mixes that were deemed to have statistically equal SR values were denoted as NSD in Tables 7 and 8. When the estimated t-value exceeded the critical t-value at the corresponding degree of freedom with 5 percent significance level, the compared mixes were deemed to have significantly different SR values. Significantly different SR values were denoted as SD in Tables 7 and 8. The green shaded cells in Tables 7 and 8 indicate a statistically significant difference between SR values. Red shaded cells indicate there was not a statistically significant difference between compared SR values.

Graphical Comparison of SR Results

A graphical comparison of SR results for all slag percentages and curing times are shown in Figure 1, with the exception of those for 21 and 42 days. The 21 and 42-day results were not included in the plot in an attempt to reduce congestion. Further, there were not significant differences between the 42-day SR results and the 56-day SR results in four out of the seven cases in Table 8. Figure 2 appears to show an increase in SR for all substitution percentages for every curing time increment increase. The coded results of the statistical analysis shown in Table 8 supports this observation in the vast majority of cases (99 of 105 comparisons) with only six exceptions. All six cases in which the difference between compared SR values were not statistically significant involved comparisons with the 21 or 42-day time increments.

Figure 2 appears to show an increase in SR for most of the substitution percentages for increases in percent slag replacement. The coded results of the statistical analysis shown in Table 7 supports this observation in the vast majority of cases (121 of 126 comparisons) with only five exceptions. All five exceptions involved either 40 or 45% slag substitutions. Further, three of the five exceptions involved comparisons between the 40 and 45% slag substitutions alone.

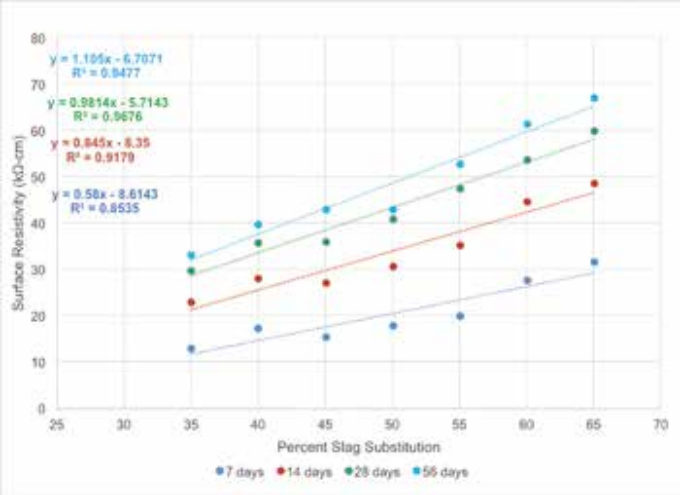


Figure 2: Effect of Slag Substitution on Surface Resistivity

TABLE 5. 56-DAY ABSORPTION AFTER BOILING RESULTS AND RANGES (%)

% SLAG	BATCH 1	BATCH 2	BATCH 3	BATCH 4	BATCH 5	BATCH 6	MEAN	RANGE
35	Not Available							
40	5.46	5.43	5.45	5.21	5.30	5.13	5.33	0.33
45	5.01	5.03	5.11	5.02	5.08	4.95	5.03	0.16
50	4.87	4.89	5.13	5.06	5.10	5.15	5.03	0.28
55	4.64	4.58	4.54	4.54	4.46	4.61	4.56	0.18
60	5.56	5.30	5.24	5.58	5.08	5.15	5.32	0.50
65	5.84	5.63	5.47	5.52	5.63	5.59	5.61	0.37

TABLE 6. SURFACE RESISTIVITY RESULTS AND DATA QUALITY

SLAG SUBSTITUTION (%)	TEST AGE (DAYS)	MEAN RESULT (KΩ-CM)	RANGE OF RESULTS (KΩ-CM)	ALLOWABLE RANGE OF RESULTS (KΩ-CM)
35	7	13.0	1.5	6.5
35	14	23.0	1.4	11.5
35	21	24.8	3.7	12.4
35	28	29.8	1.4	14.9
35	42	32.9	4.2	46.4
35	56	33.1	1.9	16.5
40	7	17.3	0.8	8.6
40	14	28.0	2.7	14.0
40	21	32.4	4.9	16.2
40	28	35.8	3.0	17.9
40	42	36.6	2.7	18.3
40	56	39.8	2.8	19.9
45	7	15.4	1.1	7.7
45	14	27.1	1.5	13.6
45	21	32.6	2.5	16.3
45	28	36.0	2.0	18.0
45	42	40.1	2.8	20.0
45	56	42.9	2.2	21.5
50	7	17.8	1.7	8.9
50	14	30.7	2.0	15.4
50	21	36.6	4.4	18.3
50	28	40.9	3.3	20.58
50	42	42.9	1.6	21.5
50	56	42.9	1.8	21.4
55	7	19.9	2.3	10.0
55	14	35.2	3.2	17.6
55	21	44.1	2.1	22.1
55	28	47.5	2.8	23.7
55	42	51.2	1.8	25.6
55	56	52.7	6.8	26.4
60	7	27.6	3.1	13.8
60	14	44.7	3.9	22.3
60	21	50.6	3.8	25.3
60	28	53.6	5.5	26.8
60	42	59.3	5.1	29.7
60	56	61.4	4.8	30.7
65	7	31.7	1.7	15.8
65	14	48.6	2.7	24.3
65	21	58.4	4.3	29.2
65	28	59.9	4.4	30.0
65	42	64.0	2.9	32.0
65	56	67.0	2.6	33.5

by L. K. Crouch, James Locum, Daniel Badoe and Heather P. Hall

Going Past TDOT Specification to Lower Concrete Permeability

Part 2: Already Gone

Rate of Increase of SR Results

The curing time required to reach various SR chloride permeability categories for all seven slag mixtures in the study are shown in Table 9. Class F fly ash mixtures from Part 1 of the study are shown as a comparison. By 56 days, all slag mixtures, except 35%, achieved the "Very Low" SR chloride permeability category. Meanwhile, no Class F fly ash mixture reached the "Very Low" SR category within the allotted time (56 days). Further, the slag mixtures reached the "Moderate" and "Low" SR chloride permeability categories sooner than the Class F fly ash mixtures.

Figure 3 shows 28-day mean SR results expressed as a percentage of 56-day mean SR results. The slag mixtures achieved a very high percentage (83-96%) of their 56-day SR by 28 days. However, Class F fly ash substitution mixtures achieved a much lower percentage (50-72%) of their 56-day SR by 28 days. It appears that in the short term (0-56 days) in which most state DOTs are interested in, slag mixtures are superior to Class F fly ash mixtures in SR for the given parameters. Slag mixtures achieve much lower chloride permeability levels (higher SR results) overall and much sooner when compared to Class F fly ash mixtures.

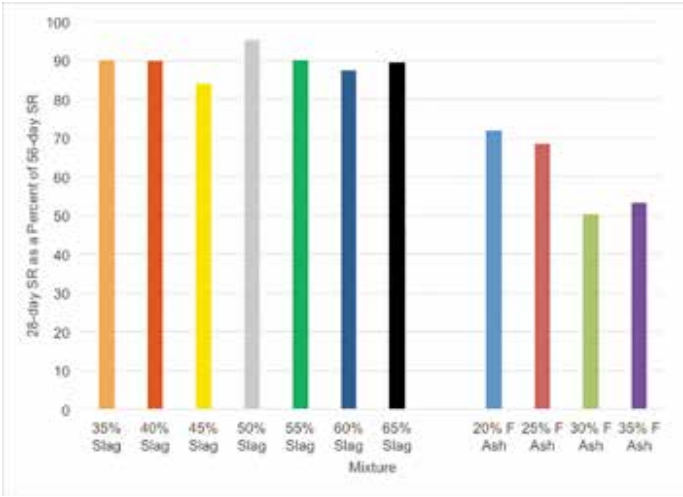


Figure 3: 28-day Surface Resistivity as a Percentage of 56-day Surface Resistivity

Compressive Strength Analysis

The 28-day compressive strength results that are shown in Table 4 all exceed the TDOT Class D concrete specification requirement by at least 3200-psi. The results for the seven mixtures in the study appear to have no discernable trend as percent slag substitution increases.

Absorption Analysis

The hardened concrete absorption after boiling results shown in Table 5 are adequate but not excellent. The mean absorption after boiling result for the 55% slag mixture meets high performance concrete criteria. High performance concrete has absorption after boiling requirements of less than 5.0% (7). The results for the other five mixtures range from 5.03 to 5.61% and appear to have no discernable trend as percent slag substitution increases.

Material Cost Analysis

Table 10 shows material cost assumptions for concrete materials except water. Calculations using Table 1 mixture proportions and Table 10 cost assumptions were used to generate Figure 4. Class F fly ash mixtures costs from Part 1 of the study are shown for comparison. The slag mixtures all have a higher cost than the Class F fly ash mixtures. However, using the TDOT-approved 25% Class F fly ash mixture as a reference, slag mixtures ranged from 3.3 to 8.1% higher in cost. Therefore, material cost would not be a major factor in mixture choice.

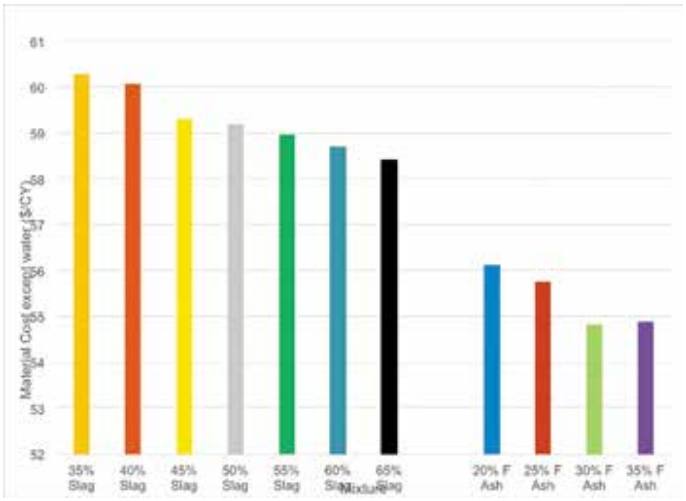


Figure 4: Material Cost Comparisons

Cautionary Statement

Some of the mixtures are close to current TDOT mixtures. However, some of the mixtures with very high slag substitution are considerably diverse when compared to current TDOT Class D mixtures. Caution should be taken with these higher substitution mixtures by thorough verification in the laboratory prior to use. If the laboratory investigations are deemed acceptable, an experimental field placement should be placed and monitored for further verification.

TABLE 7: STATISTICAL ANALYSIS COMPARING DIFFERENT MIXTURES AT A GIVEN CURING TIME

	7 DAYS	14 DAYS	21 DAYS	28 DAYS	42 DAYS	56 DAYS
35 vs. 40	SD	SD	SD	SD	SD	SD
35 vs. 45	SD	SD	SD	SD	SD	SD
35 vs. 50	SD	SD	SD	SD	SD	SD
35 vs. 55	SD	SD	SD	SD	SD	SD
35 vs. 60	SD	SD	SD	SD	SD	SD
35 vs. 65	SD	SD	SD	SD	SD	SD
40 vs. 45	SD	NSD	NSD	NSD	SD	SD
40 vs. 50	NSD	SD	SD	SD	SD	SD
40 vs. 55	SD	SD	SD	SD	SD	SD
40 vs. 60	SD	SD	SD	SD	SD	SD
40 vs. 65	SD	SD	SD	SD	SD	SD
45 vs. 50	SD	SD	SD	SD	SD	NSD
45 vs. 55	SD	SD	SD	SD	SD	SD
45 vs. 60	SD	SD	SD	SD	SD	SD
45 vs. 65	SD	SD	SD	SD	SD	SD
50 vs. 55	SD	SD	SD	SD	SD	SD
50 vs. 60	SD	SD	SD	SD	SD	SD
50 vs. 65	SD	SD	SD	SD	SD	SD
55 vs. 60	SD	SD	SD	SD	SD	SD
55 vs. 65	SD	SD	SD	SD	SD	SD
60 vs. 65	SD	SD	SD	SD	SD	SD

TABLE 8: STATISTICAL ANALYSIS COMPARING SR RESULTS OF THE SAME MIXTURE OVER VARIOUS CURING TIMES

	35%	40%	45%	50%	55%	60%	65%
7 vs. 14 days	SD	SD	SD	SD	SD	SD	SD
7 vs. 21 days	SD	SD	SD	SD	SD	SD	SD
7 vs. 28 days	SD	SD	SD	SD	SD	SD	SD
7 vs. 42 days	SD	SD	SD	SD	SD	SD	SD
7 vs. 56 days	SD	SD	SD	SD	SD	SD	SD
14 vs. 21 days	SD	SD	SD	SD	SD	SD	SD
14 vs. 28 days	SD	SD	SD	SD	SD	SD	SD
14 vs. 42 days	SD	SD	SD	SD	SD	SD	SD
14 vs. 56 days	SD	SD	SD	SD	SD	SD	SD
21 vs. 28 days	SD	SD	SD	SD	SD	SD	NSD
21 vs. 42 days	SD	SD	SD	SD	SD	SD	SD
21 vs. 56 days	SD	SD	SD	SD	SD	SD	SD
28 vs. 42 days	SD	NSD	SD	SD	SD	SD	SD
28 vs. 56 days	SD	SD	SD	SD	SD	SD	SD
42 vs. 56 days	NSD	SD	SD	NSD	NSD	NSD	SD

Going Past TDOT Specification to Lower Concrete Permeability

Part 2: Already Gone

CONCLUSIONS

Compared to Class F fly ash mixtures, slag mixtures achieve much lower chloride permeability levels (higher SR) and achieve them much sooner. If this were a race, the slag mixtures are already gone.

DISCLAIMER

The opinions expressed herein are those of the authors and not necessarily the opinions of the Tennessee Department of Transportation or the Tennessee Concrete Association (TCA).

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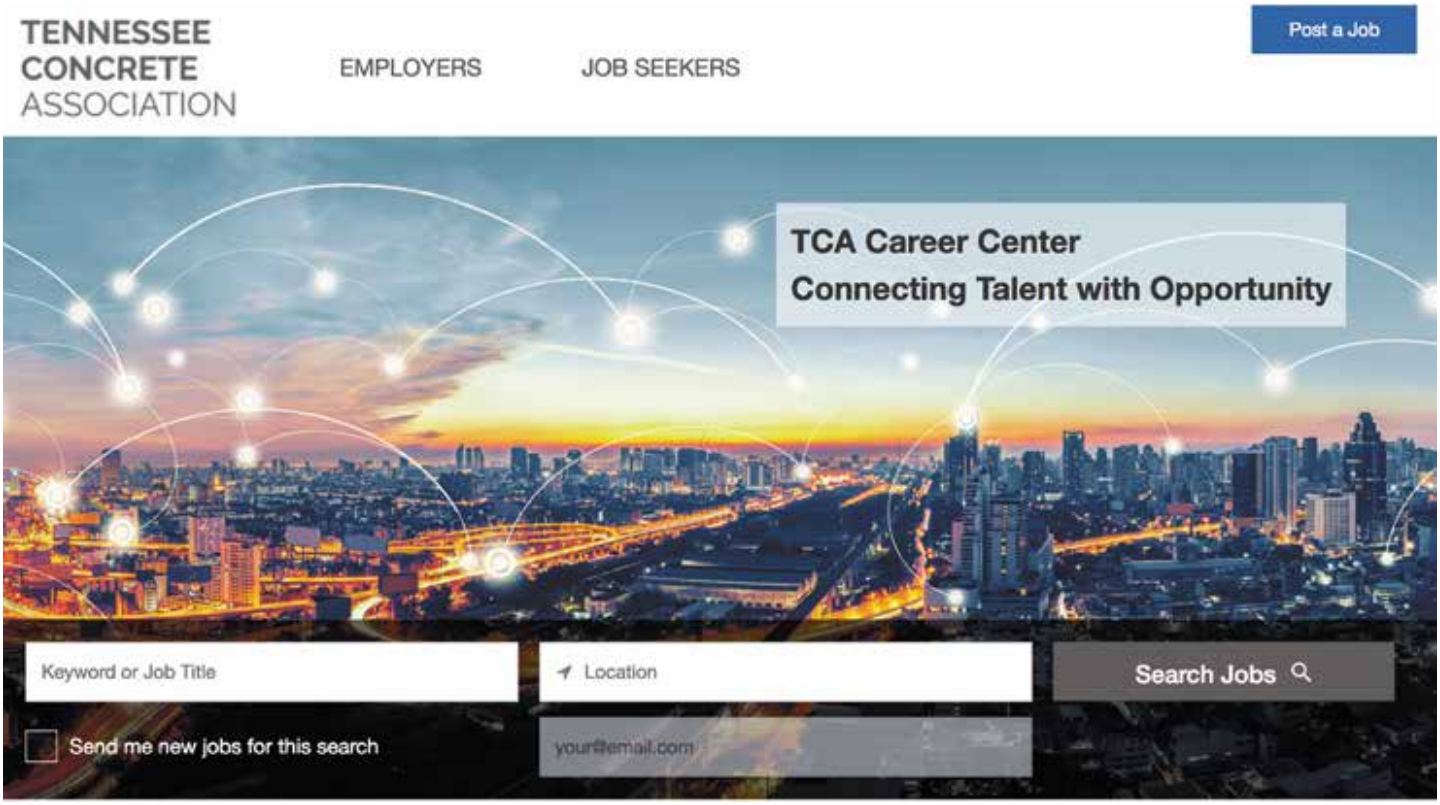
TABLE 9: CURING TIMES REQUIRED TO REACH SURFACE RESISTIVITY CHLORIDE PERMEABILITY CATEGORIES

MIXTURE	MODERATE (SR≥12) (2000≤RCP≤4000)	LOW (SR≥21) (1000≤RCP≤2000)	VERY LOW (SR≥37) (100≤RCP≤1000)
35% Grade 120 Slag	7 days	14 days	Did not reach
40% Grade 120 Slag	7 days	14 days	56 days
45% Grade 120 Slag	7 days	14 days	42 days
50% Grade 120 Slag	7 days	14 days	28 days
55% Grade 120 Slag	7 days	14 days	21 days
60% Grade 120 Slag	< 7 days	7 days	14 days
65% Grade 120 Slag	< 7 days	7 days	14 days
20% Class F Fly Ash	28 days	Did not reach	Did not reach
25% Class F Fly Ash	28 days	Did not reach	Did not reach
30% Class F Fly Ash	28 days	42 days	Did not reach
35% Class F Fly Ash	28 days	42 days	Did not reach

TABLE 10: COST ASSUMPTIONS

COMPONENT	ASSUMED COST DELIVERED TO READY MIX PRODUCER
Type I PC, ($/ton)	110.00
Class F Fly Ash, ($/ton)	30.00
Grade 120 Slag, ($/ton)	85.00*
No. 57 Limestone, ($/ton)	18.00
River Sand, ($/ton)	15.00
Air Entrainer, ($/gallon)	4.50
Mid-Range Water Reducer, ($/gallon)	8.50
High-Range Water Reducer, ($/gallon)	12.00

*plus freight



TCA CAREER CENTER

Visit at: http://tca.careerwebsite.com/

TCA has launched an online Career Center focused on the concrete industry in 2018. A link to the TCA Career Center is included here on the right. TCA members can post jobs at discounted rates and concrete industry personnel can post resumes here to stay in touch with the latest opportunities in the concrete industry in Tennessee and beyond.

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CIM UPDATE • • • • by Dr. Heather J. Brown • • • • • • • • • • • • • • • • • •

The School hosted the annual Networking Event on 10/10/18 with the largest turnout in its eight-year history. With 71 companies and over a 50% increase from last year's event, students were encouraged to attend workshops in advance to plan their attack and to make the best use of the three-hour event. The event, essentially a career fair with a focus on career exploration, is the best for companies to get to know the School, the unique majors, faculty and students. 25 of the 71 companies were new to recruiting from the school and at least another 30 had alumni working with them and were back to find more talent.

Over 60 resume critiques were requested prior by students to arm themselves with flawless documents to deliver to companies of interest. Now, just a month out from the event, students are already hearing from companies to move on to the next step of the hiring process and, even some, with offers. With just 3x the number of students per company at the event, and a record number of company socials this semester, it's a good time to be a student or graduate in concrete and construction.

Alumnus Jaclyn Streeter (5/2018), Sales Representative with BASF, at her table at the Networking Event talking with current CIM student, Cody Gange.

BUSY RECRUITING

MIDDLE TENNESSEE STATE UNIVERSITY

The School of CCM is busy with employers recruiting . . .

A packed house at the School of CCM Networking Event with 71 employers and 188 student attendees.

THE SCHOOL OF CCM IS BUSY WITH INDUSTRY ON CAMPUS...

The Mid-South Chapter of the International Concrete Repair Institute came to MTSU this month to host their biannual meeting. The group is hoping to raise funds to help furnish a scholarship next year for CIM students. About 20 members of the local group came to campus to learn more, interact with students, and hear an industry speaker.

Current CIM students, Autumn Gates, Brandon Beers, and Gary Dietz attending the ICRI meeting on campus in the Honors College

THE SCHOOL OF CCM IS BUSY RECRUITING STUDENTS...

Through connections on campus, approximately 15 Smyrna High School Interior Design students were able to visit campus and the School of CCM. The group, which was joined by MTSU Campus Planning staff, learned about some concrete basics, got to tour our labs and see our Residential Materials course work on their model homes as well as some exciting research, they had great questions and were able to make concrete coasters to take home before moving on to the Interior Design program on campus.

Interior design students discuss the cylinder break fragments with Lab Manager, Kevin Overall

Smyrna High Interior Design students successfully make concrete coasters

THE SCHOOL OF CCM IS BUSY WITH ALUMNI EVENTS...

Each fall, the CIM Program hosts the annual Skeet Shoot for industry and alumni the Friday of homecoming. This year was a particularly good year as our teams and sponsorships at the event were filled quickly and the weather was beautiful and warm at Big Springs in Christiana. This year also marks three years of a silent auction in conjunction with the event, the bidding was fierce and fruitful. The auction alone raised over $7,500 for a total of over $13,000 for this year's event.

The teams and helpers for this year's CIM Alumni Skeet at Big Springs in Christiana, TN

Info Link

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