Transportation Consortium of South-Central States

Tran-SET

Solving Emerging Transportation Resiliency, Sustainability, and Economic Challenges through the Use of Innovative Materials and Construction Methods: From Research to Implementation

Workforce Development Symposiums for UHPC

Project No. 18TTNMS02

Lead University: New Mexico State University

Final Report
August 2019

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16. Abstract

Ultra-high performance concrete (UHPC) is a cementitious material with a dense microstructure that contributes to high compressive strengths as well as enhanced durability properties. UHPC also possesses significant post-cracking strength and ductility due to the addition of fibers. These characteristics produce a material that provides advantages over conventional concrete; however, high costs attributed to materials and production, lack of industry familiarity and knowledge, and the absence of standardized design procedures have impeded its widespread use. To help disseminate knowledge on UHPC, two workforce development symposiums on UHPC were held in Las Cruces, New Mexico. The symposiums consisted of presentations and hands-on demonstrations to introduce UHPC and distribute the findings of almost a decade of research conducted in New Mexico to a diverse audience including members of the New Mexico Department of Transportation, contractors, designers, researchers, and concrete suppliers. Through the symposiums, a more knowledgeable workforce was created, guidance on the mixing, placing, and curing of UHPC was provided, concerns were addressed, collaborations were developed, and increased interest in UHPC was generated.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

HPC	High Strength Concrete
HRWRA	High-Range Water Reducing Admixture
NMDOT	New Mexico Department of Transportation
NMSU	New Mexico State University
NSC	Normal Strength Concrete
RDM	Relative Dynamic Modulus
SCM	Supplementary Cementitious Material
SSMTL	Structural Systems and Materials Testing Laboratory
Tran-SET	Transportation Consortium of South-Central States
UHPC	Ultra-High Performance Concrete

EXECUTIVE SUMMARY

This project provided two workforce development symposiums for New Mexico Department of Transportation (NMDOT) personnel, practicing engineers, contractors, and other transportation-related organizations and practitioners. The topic addressed in these symposiums was ultra-high performance concrete (UHPC). The major objectives of the symposiums were to provide the necessary information to implement UHPC into infrastructure projects. UHPC has the potential to extend the service life of transportation infrastructure.

Since 2009, funding has been provided from the NMDOT for research activities that have included mixture development, parametric studies of bridge designs, assessment of mechanical properties, durability testing that has included testing for frost resistance and alkali-silica reaction susceptibility, structural design, and ultimately, the design, construction, and monitoring of a bridge completed in 2017 that contains girders made using a UHPC mixture produced with local materials. Additionally, Tran-SET recently funded a project on the use of locally developed UHPC for concrete bridge deck overlays. These studies have led to several projects within New Mexico that will incorporate UHPC.

NMDOT currently has two bridges that they are planning to rehabilitate with thin bonded UHPC overlays. They are also in the planning stages for projects where they would like to use UHPC to repair deteriorated shear keys and other joints between bridge superstructure elements. The NMDOT personnel working on projects related to these bridges and other potential implementation projects for UHPC requested multiple training sessions to prepare them for working with this new material. Additionally, NMDOT requested training or other workforce development opportunities for engineers and contractors that might want to compete for work on these projects. The two workforce development symposiums offered through this project helped to address these needs.

The symposiums provided extensive coverage of UHPC topics including: (1) a review of past and current UHPC projects in the United States, (2) UHPC materials and mixture development including coverage of testing methods and procedures, (3) potential modifications to testing procedures, (4) engineering design with UHPC, (5) experiences of batch plant and precast plant operators in batching, mixing, and placing UHPC, and (6) a hands-on demonstration of batching, mixing, and placing UHPC produced with local materials.

The workforce development symposiums helped to provide engineers and construction personnel with a knowledge base related to UHPC that prepares them for work on projects that might specify the use of UHPC. Attendees were provided information on the development of UHPC mixtures using local materials, practical production techniques that include batching, mixing, and placing methods, testing methods for assessing UHPC, and design methods that can be used to design new UHPC structures. Furthermore, concerns from the community were addressed to ensure NMDOT projects incorporating UHPC are successful and new collaborations were developed (e.g., new cement/admixtures partners) and ideas were shared that could lead to new applications of UHPC or improved methods for implementing UHPC in structural applications.

1. INTRODUCTION

Ultra-high performance concrete (UHPC) is a cementitious material with a dense microstructure resulting in very high compressive strengths and, due to its impervious nature, improved durability properties. Due to the addition of high strength steel fibers, UHPC also possesses higher ductility and post-cracking strength than normal strength or high strength concretes. These properties provide several advantages for use in transportation infrastructure projects because it has superior strength and exceptional durability properties that can substantially reduce maintenance activities, maintenance costs, and life-cycle costs of concrete structures. These properties also provide the potential to greatly extend the service lives of concrete structures *(1–3)*. Throughout the last few decades, significant effort has been focused on the development of UHPC and its introduction into bridge applications; however, lack of industry familiarity and knowledge and the lack of design procedures and tools have hindered its extensive use in practice.

It is important to distinguish between prepackaged, commercially available UHPC mixtures and non-proprietary mixtures produced with local materials. Commercially available UHPC mixtures require less effort by an agency to develop the mixture. However, commercial mixtures have greater material costs than non-proprietary mixtures and are often shipped long distances for use on a specific project. The sustainability of higher material and shipping costs is questionable, but non-proprietary mixtures also have drawbacks. Research at New Mexico State University (NMSU) has shown that when UHPC is produced with local materials, excellent durability is still achieved and materials costs can be decreased by as much as 70 percent *(4–6)*. However, there is a small reduction (10 to 15 percent) in compressive strength of UHPC when using local materials in comparison to strengths obtained with commercially available UHPC mixtures.

Since 2009, funding from the New Mexico Department of Transportation (NMDOT) has allowed for research on mixture development, parametric studies of bridge designs, assessment of mechanical properties, durability testing that has included testing for frost resistance and alkali-silica reaction susceptibility, structural design, and ultimately, the design, construction, and monitoring of a bridge completed in 2017 that contains girders made using a UHPC mixture produced with local materials *(7–9)*. Additional funding through Tran-SET resulted in the successful completion of a project investigating the use of locally developed UHPC for concrete bridge deck overlays *(10)*. Currently, a project investigating locally developed UHPC for shear keys is underway *(11)*. These studies have led to several projects within New Mexico that will incorporate UHPC.

To bridge the gap between research and practice, two workforce development symposiums on UHPC were held. Through these symposiums the tools, knowledge, and techniques to implement UHPC into infrastructure projects were disseminated. Presentations provided information on the development of UHPC mixtures using local materials, practical production techniques that include batching, mixing, and placing methods, testing methods for assessing UHPC, and design methods that can be used to design new UHPC structures. This report presents the major objectives of the symposiums, topics covered, and successes of the two symposiums.

2. OBJECTIVES

The major objectives of this project were to prepare and host two workforce development symposiums on UHPC to provide the necessary information for the NMDOT continue to implement UHPC into infrastructure projects. As new technologies emerge through research, it is necessary to disseminate knowledge through different platforms. Through technology innovation such as UHPC, there is the potential for major advancement and transformation on the state of the nation’s infrastructure. However, without a form of technology transfer, the stakeholders (e.g., state departments of transportation, contractors, concrete industries, etc.) are not equipped to optimize and implement the technology solutions available to them. The two workforce development symposiums provided a forum for the dissemination of information, best practices, and lessons learned through over a decade of research. Specifically, the workforce development symposiums objectives were to:

1. Create a more knowledgeable workforce through the dissemination of research, best practices, lessons learned, etc. for UHPC.
2. Provide guidance on the mixing, placing, and curing of UHPC.
3. Address concerns from the community to ensure NMDOT projects incorporating UHPC are successful.
4. Increase interest in UHPC from multiple entities (e.g., contractors, concrete suppliers).
5. Develop collaboration and share ideas that could lead to other novel applications of UHPC or improved methods for implementing UHPC.

3. LITERATURE REVIEW

3.1. Ultra-High Performance Concrete

Ultra-high performance concrete (UHPC) is a fiber reinforced composite concrete material that is known for having greater compressive strengths, tensile strengths, durability, corrosion resistance, post-cracking capacity than conventional concrete. UHPC is made using a high content of cementitious materials, a low water-to-cement ratio, silica fume, high-range water reducing admixtures (HRWRA), and steel fibers *(1)*. The materials used in the production of this material typically result in a high-cost product, however, by using local materials, the cost can be reduced significantly. Additionally, the superior durability and corrosion resistance provided by UHPC provides a means to increase service life and lower maintenance costs in concrete structures.

Basic constituents of UHPC include cement, fine sand, silica fume, steel fibers, water, and HRWRA. A common guideline for producing UHPC is summarized in Cheyrezy and Richard's *(11)* recommendations:

- Removing coarse aggregate to enhance homogeneity of concrete.
- Steel fibers improve the ductility of UHPC.
- Heat treatment after initial setting improves mechanical properties and microstructure.
- Using silica fume improves density and produces secondary calcium silicate hydrates.
- HRWRA's facilitate a very low w/cm ratio with enough workability for placement and consolidation.

The use of mineral admixtures and HRWRA are two methods to produce concrete mixtures with a dense microstructure that improves mechanical and durability properties *(13)*. Additionally, Dili and Santhanam *(14)* suggested that the coarse aggregate should be replaced by fine sand, reducing the largest aggregate particle size to 0.0236 in (600 µm) to improve homogeneity of the mixture. Cheyrezy and Richard *(11)* also suggested avoiding particles smaller than 0.0059 in (150 µm) to prevent interference with the cement particles that range from 0.00315 to 0.00394 in (80 to 100 µm).

In North America, the use of silica fume as the main supplementary cementitious material (SCM) in UHPC mixtures results in a high cost compared to other SCMs since it is usually imported *(5)*. To reduce the cost of UHPC, it is desirable to use class F fly ash, which is cheaper because it is produced domestically *(15)*. Although slower to react and produce strength gains than silica fume, fly ash provides long term strength gains and aids in controlling alkalis that contribute to alkali-silica reaction *(16)*.

Previous research at NMSU has demonstrated that UHPC produced with local materials and SCMs that include both silica fume and class F fly ash have excellent strength and durability properties *(6, 15, 17)*. Figure 1 shows freeze-thaw testing results for UHPC mixtures with varying fly ash content from Muro Villanueva *(17)*. The two mixtures that finished testing with relative dynamic modulus (RDM) values less than 100 used only silica fume as a SCM. Mixtures that maintained an RDM greater than 100 after 300 cycles used class F fly ash as either 37.5 or 50 percent of the total SCM content.

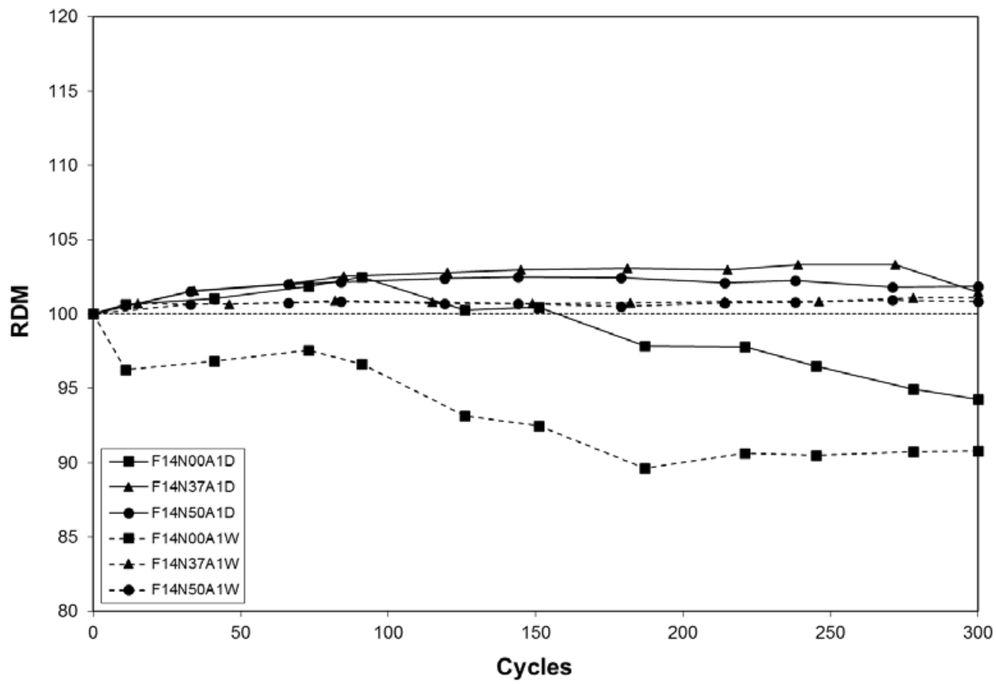

Figure 1. RDM versus cycles of freezing and thawing for mixtures with varying fly ash content *(17)*.

Figure 2 presents some expansion measurements from Tahat et al. *(6)* that demonstrate that UHPC produced with local materials is not susceptible to alkali-silica reaction. The four specimens represented in this plot used fly ash to make up 37.5% of the SCM content. The expansion results were less than 0.01% expansion at the end of testing which is much less than the 0.08% expansion that would be indicative of alkali-silica reaction susceptibility.

Ongoing research at NMSU is focused on monitoring of a two-span, channel girder bridge constructed in 2017 with one span containing high performance concrete channel girders and the second span containing channel girders produced with UHPC made from local materials. Another ongoing project is investigating the potential of using UHPC produced with local materials as an overlay material for rehabilitation of existing concrete bridge decks. As part of the overlay project, UHPC mixtures have been identified that are capable of attaining compressive strengths greater than 18,000 psi (124.1 MPa) at 28 days with no elevated temperature curing *(10)*.

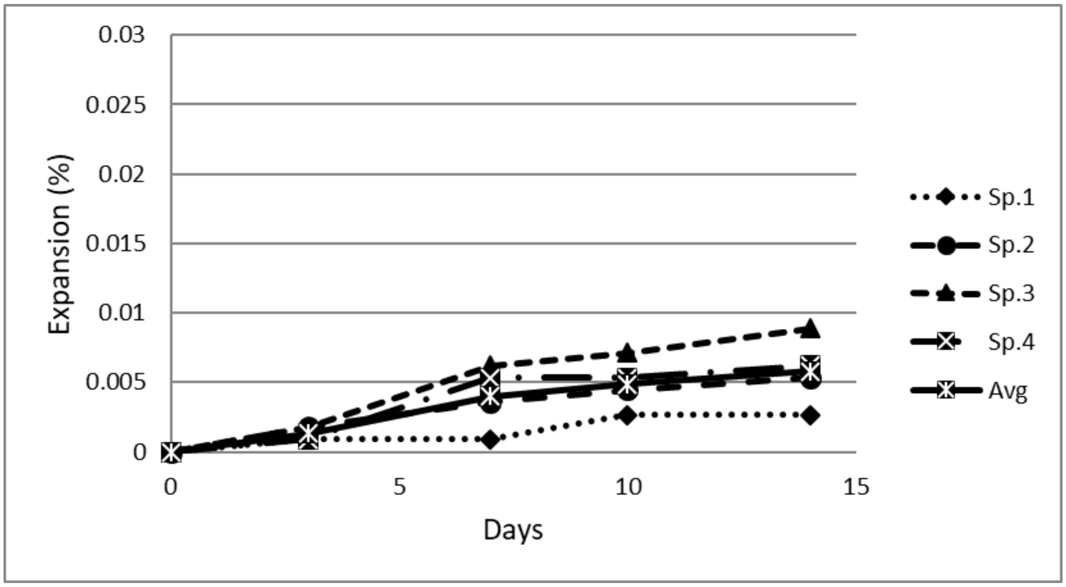

Figure 2. Expansion versus time for mixture 4-37-19 *(6)*.

The first full-scale demonstration project for UHPC use in the United States was a bridge in Wapello County, Iowa constructed in 2006. The Wapello County/Mars Hill Bridge is a simple, single span with three 110 ft (33.53 m) UHPC girders with no shear stirrups. This bridge validated a design without mild steel reinforcement. Additionally, the deck was made from Ductal® without rebar. This UHPC achieved 30 ksi (207 MPa) after steam curing at 195 °F (90 °C) for 40 hours *(18)*. The Wapello County/Mars Hill Bridge was the culmination of decades of mixture development by Lafarge and several years of mixture characterization and design development funded by the Federal Highway Administration.

Since the construction of the Wapello County bridge there have been several other bridge projects that have utilized UHPC in precast superstructure elements. More recently, UHPC has been proposed, and in many cases implemented, for use in field placement applications such as filling fill shear keys in bridge superstructures *(19–21)*.

3.2. Workforce Development

Over the last several years, a research project in collaboration with the New Mexico Department of Transportation (NMDOT) has investigated the feasibility of incorporating UHPC into bridge design in the State. Through the findings of a comprehensive literature and historical application review, trial designs, and cost analyses on typical prestressed concrete bridges using UHPC, it was determined that UHPC could potentially benefit design, construction, maintenance, and the lifespan of structures *(7)*. Optimized mixture proportions and a curing regimen for an UHPC that uses materials local to New Mexico were developed that meet the strength and durability design requirements of the NMDOT *(8)*. The creep and shrinkage behavior of the local UHPC has been investigated and Special Provisions have been developed for the implementation of UHPC in bridge design. To verify the design and behavior of UHPC girders, large scale flexural tests were conducted *(9)*. Using the results of the research Bridge 9706, a two simple-span structure, was designed and constructed as the first UHPC bridge in New Mexico. One span of the bridge used UHPC and the other used high performance concrete (HPC). Bridge 9706 is currently being tested and monitored to investigate the performance of UHPC compared to HPC. Using the data gathered from the bridge, analytical models are being developed to further investigate the behavior Bridge 9706 and improve design methods for UHPC.

UHPC offers many advantages as its improved material and durability properties allow for smaller structural members to be used in designs, longer spans on bridges, and greatly increase the lifespans of structures *(22)*. It also reduces maintenance activities, maintenance costs, and life-cycle costs of concrete structures. With UHPC being a relatively new material, there are not many working professionals with experience or significant knowledge of the mixing, casting, curing, and testing of UHPC. Furthermore, many of the projects incorporating UHPC in their design have been in collaboration with researchers. Recently, testing standards became available for UHPC, however, there are currently no design codes that incorporate the material properties of UHPC. These issues have created a lack-of-knowledge in regards to the incorporation of UHPC with other materials in projects. As has been noted, emerging technologies are often difficult to get adopted due to a lack of dissemination, even when the technology offers many advantages *(23)*. While there are several international and domestic conferences that provide information, there are very limited local workforce development activities that focus on disseminating local research to a broad audience. Therefore, to disseminate the results of almost a decade of research and encourage the use of UHPC, workforce development and training seminars were necessary. Collaborating with the NMDOT, two workforce development symposiums were planned and held in early 2018 and 2019. A broad range of applications for UHPC was introduced in the workforce development symposiums so that the attendees have a better understanding of potential applications that are possible for this promising material.

4. METHODOLOGY

The objectives of the project were to hold two workforce development symposiums on UHPC. It was important to ensure that the needs of the NMDOT were met through the two workforce development symposiums. Therefore, numerous meetings with the NMDOT were held to identify key needs and concerns. Additionally, representatives from the NMDOT were involved in all aspects of the planning of the symposiums as well as involved in several presentations at both symposiums. While there was not a formal planning committee established, representatives from the research technical panel and bridge bureau, personnel involved in the upcoming NMDOT UHPC projects, and the research team were involved in the planning. To encourage a more diverse audience, the symposiums were offered free of charge and held the day prior to NM TransCon, New Mexico's Premier Transportation and Construction Conference. This conference is sponsored by NMSU College of Engineering, the NMSU Department of Civil Engineering, NMDOT, Associated Contractors of New Mexico, the American Planning Association – New Mexico Chapter, and the American Council of Engineering Companies – New Mexico.

4.1. Planning and Timeline

Meetings and/or conference calls were held approximately on a monthly basis, typically in conjunction with research meetings. Initially, meetings focused on location, date, and general topics to be covered based on the objectives of the symposium. As the date neared, the meetings identified specific speakers and finalized the agenda. Once the date and location were finalized, a save-the-date was created and sent approximately two months prior to the symposium through different networks including, but not limited to, the NMDOT newsletter, NMSU Engineering Resource Network, and the Associated Contractors of New Mexico. A general timeline of the planning of the symposiums is shown in Table 1. However, due to changes in scheduling and funding of NMDOT projects, there was some flexibility in the timeline to ensure the needs of the NMDOT were met.

Table 1. Symposium planning timeline.

Months Prior to Symposium	Milestone
6	Date, location, general topics covered
5	Date, location, general topics covered
4	Preliminary agenda and topic identified
3	Speakers identified and invited
2	Save-the-dates e-mailed via different networks
1	Agenda finalized
0.5	Reminder and confirmation of speakers; last minute changes

5. ANALYSIS AND FINDINGS

Through this project, the first steps to develop an informed workforce on the potential of UHPC was provided. The diverse audience including representatives from the NMDOT, contractors, other regional DOT's, contractors, suppliers, researchers, and students provided an opportunity for ideas to be shared, concerns to be addressed, and new opportunities to be created. As UHPC continues to emerge and new applications are introduced, there will continue to be a need for a platform to disseminate the knowledge and provide training to ensure successful implementation of UHPC. Furthermore, it is necessary that training is provided on the proper mixing, placement, curing, and testing techniques for this material.

5.1. First Workforce Development Symposium on UHPC

The First Workforce Development Symposium on UHPC was hosted by New Mexico State University (NMSU) on April 17 - 18, 2018 at the Las Cruces Convention Center in Las Cruces, New Mexico. The Symposium focused on defining UHPC, identifying benefits of UHPC, and sharing experiences with mixing, casting, and curing UHPC. Through the knowledge gained through the research program, presentations helped to demonstrate how UHPC can be incorporated into precast facilities with little to no changes made to the facility or typical casting procedures. Furthermore, through the design of test specimens and the girders for Bridge 9706, engineers were exposed to how the improved properties of UHPC were incorporated into the designs. Results of small and large scale testing were also presented to demonstrate the difference in behavior typical high performance concrete and UHPC. Finally, hands-on demonstrations were provided to allow individuals to see the difference in the material from traditional concretes.

The symposium was tailored for the needs of the NMDOT; however, contractors, designers, and suppliers were also encouraged to attend. Attendance to the UHPC Symposium was requested through the use of personal invitations, as well as, a save-the-date announcement. These invitations and announcements were sent to contractors, designers, suppliers, ready-mix companies, and researchers throughout the state of New Mexico and the surrounding regions. Professors and graduate students at NMSU were also invited and encouraged to attend the Symposium since it was going to be a great learning experience for everyone involved. The save-the-date announcement that was sent out can be seen in Figure 3.

Figure 3. First UHPC Symposium save-the-date announcement.

At the UHPC Symposium there were 11 presentations given over two days by professors, graduate students, and working professionals that discussed what UHPC is, its benefits, research that is currently in progress, how to test the material, and how engineers can use UHPC in their future designs. The list of presentations and speakers is provided in Table 2. Pictures from the presentations given at the First Symposium can be found in Figures 4 and 5.

Table 2. First UHPC Symposium agenda.

Day One: April 17, 2018		
Presentation Title	**Presenter**	**Affiliation**
Introduction	Lakshmi Reddi, David Jauregui	NMSU
What is UHPC?	Brad Weldon	NMSU
Upcoming NMDOT UHPC Projects	Kathy Crowell	NMDOT
Research at NMSU – Feasibility to Implementation	Craig Newtson	NMSU
Large Scale Testing	Michael McGinnis	University of Texas at Tyler
Designing with UHPC	Danton Bean; Ben Najera	HDR, NMDOT
Implementation in Precast Plant	Marking Manning	NMSU
Construction and Load Testing of Bridge 9706	Marking Manning, Chris Kennedy, and Alain Cuaron	NMSU
UHPC Projects in New Mexico	Kathy Crowell	NMDOT
Day Two: April 18, 2018		
Introduction	Brad Weldon	NMSU
Overlay Project – Tran-SET	Craig Newtson, Kathy Crowell	NMSU, NMDOT
Hands-on Demonstration at the Structural Systems and Material Testing Laboratories at NMSU	Graduate Students	NMSU

Figure 4. First UHPC Symposium presentation (C. Newtson).

Figure 5. First UHPC Symposium presentation (K. Crowell).

One the second day of the UHPC Symposium, graduate students at NMSU assisted in demonstrating the mixing, casting, and testing procedures of UHPC to the attendees at the Structural Systems and Material Testing Laboratory (SSMTL) at the conclusion of the presentations. Pictures of these demonstrations can be found in Figures 6 and 7.

Figure 6. Demonstration of mixing UHPC.

Figure 7. Demonstration of testing UHPC.

At the UHPC Symposium, there were over 40 attendees including representatives of the NMDOT – materials sections, bridge bureau, district offices, regional contractors, design engineers, researchers (including international colleagues from Mexico), suppliers, and ready-mix companies. The demographics of the attendees was approximately 50% minorities (including Hispanics/Latinos, American Indians or Alaska Natives, and two or more races), 17% were female, and 83% were males. The professional demographics of the attendees was approximately 68% government affiliations (NMDOT / FHWA), 19% practitioner affiliations (design engineers, contractors, and concrete industry), and 13% academic affiliations. Figures 8 – 10 show the demographics for the symposium.

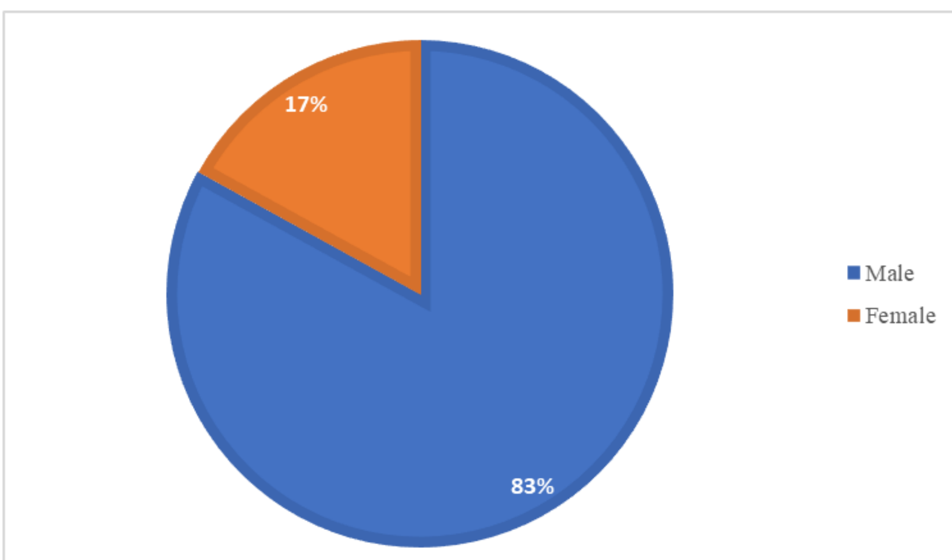

Figure 8. First UHPC Symposium gender demographics.

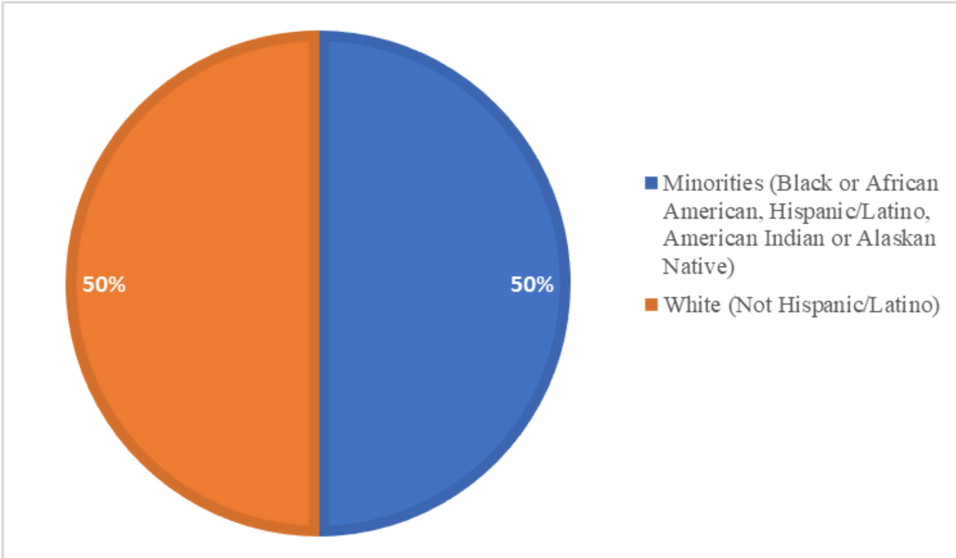

Figure 9. First UHPC Symposium ethnic demographics.

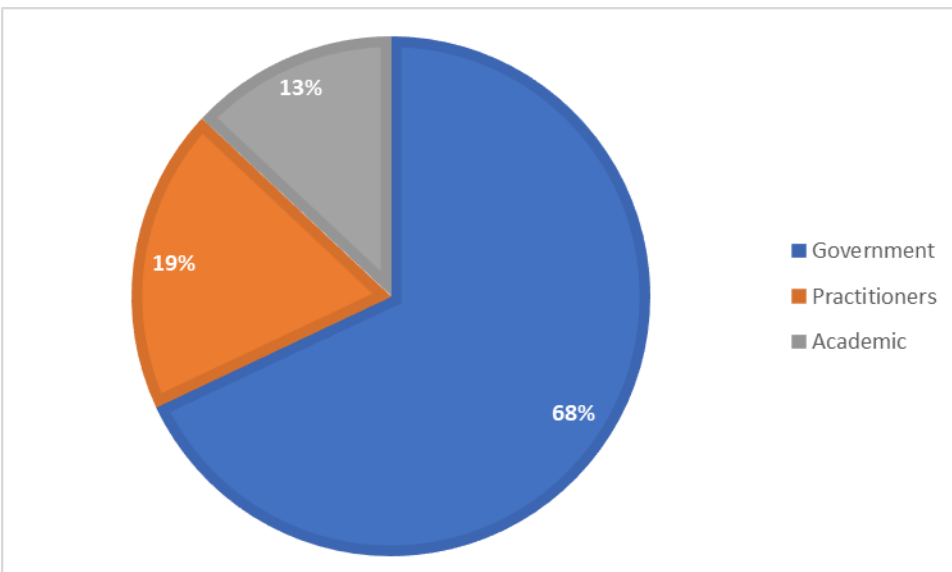

Figure 10. First UHPC Symposium professional demographics.

Following the successful completion of the workforce development symposium on UHPC, meetings were held with NMDOT and regional contractors to identify additional needs. Further training was requested by the NMDOT and contractors to provide guidance on how to mix, place, and cure UHPC for different applications, many focused on upcoming NMDOT projects. These considerations were incorporated into the second symposium.

5.2. Second Workforce Development Symposium on UHPC

The Second Workforce Development Symposium on UHPC was hosted by New Mexico State University (NMSU) on April 23, 2019 at the Las Cruces Convention Center in Las Cruces, New

Mexico. The Symposium was focused on an upcoming UHPC overlay project that will be constructed in Spring 2020. Through several meetings with the NMDOT, key items for the symposium were identified including: substrate surface preparation, UHPC overlay mixing, casting, and placing, and a hands-on demonstration for mixing and placing the material. These topics were addressed in the second symposium, which is based on a recent Tran-SET project *(11)*. Additionally, the NMDOT asked for the research team to provide a short presentation during the required pre-bid meeting for the UHPC overlay project.

Similar to the first symposium, the second symposium was tailored for the needs of the NMDOT; however, contractors, designers, and suppliers are also encouraged to attend. Attendance to the UHPC Symposium was requested through the use of personal invitations, as well as, a save-the-date announcement (Figure 11). These invitations and announcements were sent to contractors, designers, suppliers, ready-mix companies, and researchers throughout the state of New Mexico and the surrounding regions.

Figure 11. Second UHPC Symposium save-the-date announcement.

At the Second UHPC Symposium there were five presentations given by professors, graduate students, and the State Bridge Engineer and State Concrete Engineer from the NMDOT. The presentations discussed the work that has been done on UHPC in New Mexico, its benefits, current research that is currently in progress, and how to mix, place, and test the material, the newly developed NM Specifications for UHPC overlays, and upcoming project in New Mexico that will incorporate UHPC. The list of presentations and speakers for the second symposium is provided in Table 3. Pictures from the welcome reception and presentations given at the symposium can be found in Figures 12 – 16.

Table 3. Second UHPC Symposium agenda.

April 23, 2019		
Presentation Title	**Presenter**	**Affiliation**
Introduction and Welcome	David Jauregui	NMSU
UHPC Overview and Research at NMSU	Brad Weldon	NMSU
Implementation of UHPC into Precast Plant	Mark Manning	NMSU
Tran-SET Overlay Project	Craig Newtson	NMSU
Specifications and Testing	Sean Brady	NMDOT
NMDOT and UHPC	Shane Kulman	NMDOT
Question and Answer		
UHPC Mixing and Placing Demonstration at the Structural Systems and Material Testing Laboratories at NMSU	Graduate Students	NMSU

Figure 12. Second UHPC Symposium welcome reception.

Figure 13. Second UHPC Symposium presentation (M. Manning).

Figure 14. Second UHPC Symposium presentation (C. Newtson).

Figure 15. Second UHPC Symposium mixing demonstration.

Figure 16. Second UHPC Symposium mixing and placing demonstration.

At the Second UHPC Symposium, there were over 70 attendees including representatives of the NMDOT – materials sections, bridge bureau, and district offices, regional contractors, design engineers, researchers (including international colleagues from Mexico), suppliers, ready-mix companies, and NMSU students. Additional information was collected during the second symposium to have more information on the attendees and their background. The demographics of the attendees was approximately 81% minorities (including Hispanics/Latinos, American Indians, and Black or African American), 22% were female, and 78% were males. The professional demographics of the attendees was approximately 73% government affiliations (NMDOT / FHWA), 15% practitioner affiliations (design engineers, contractors, and concrete industry), and

12% academic affiliations. Figures 17 – 19 present the gender, ethnic, and professional demographics for the Second UHPC Symposium, respectively.

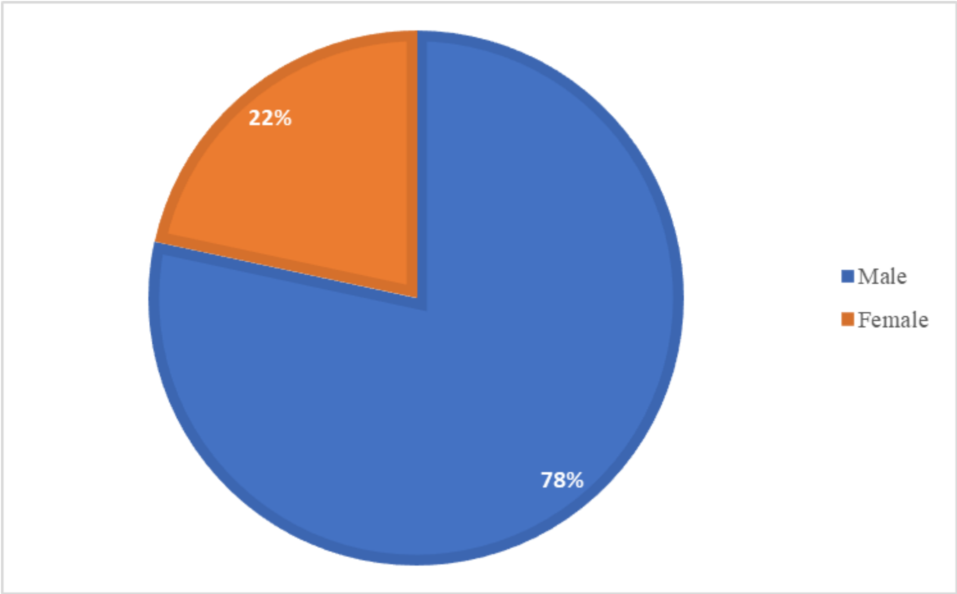

Figure 17. Second UHPC Symposium gender demographics.

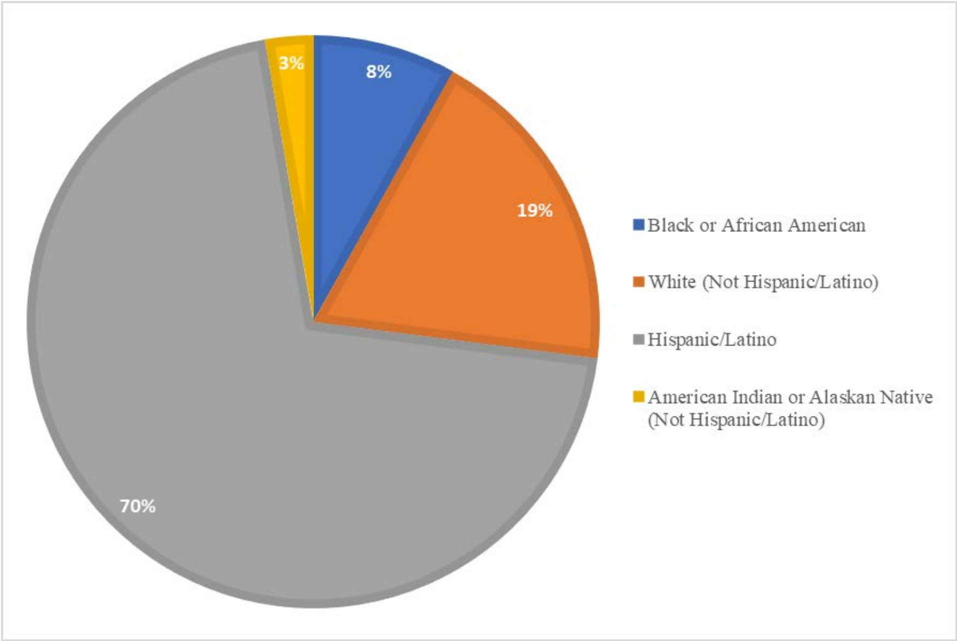

Figure 18. Second UHPC Symposium ethnic demographics.

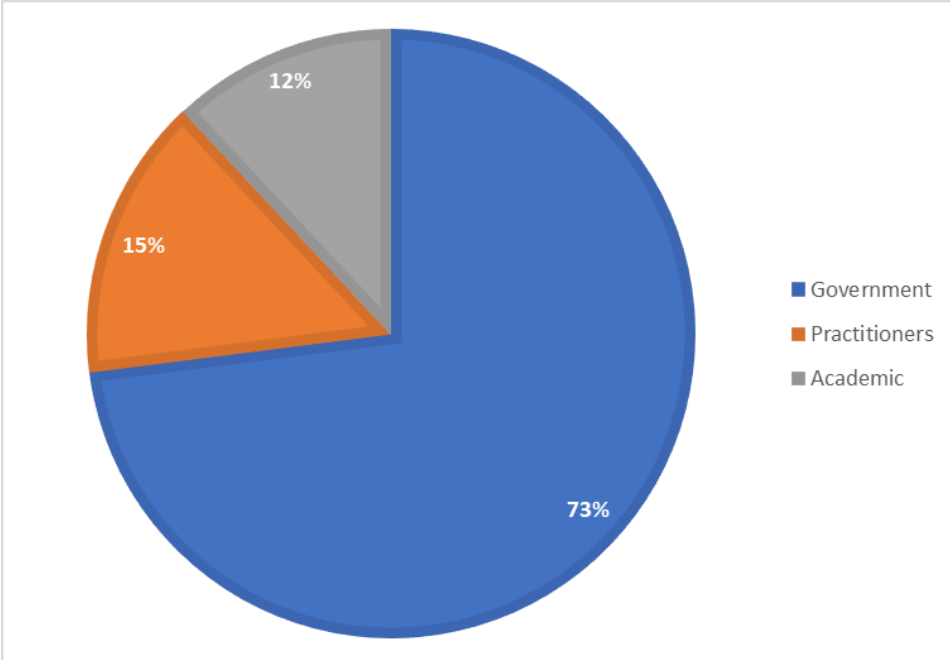

Figure 19. Second UHPC Symposium professional demographics.

Following the second workforce development symposium on UHPC, additional meetings and discussions were held with NMDOT and regional contractors to identify additional needs. To help provide additional guidance and support to the NMDOT, the NMSU research team presented findings from the Tran-SET Project 17-NM-6 (17CNMS01) at the mandatory pre-bid meeting for the upcoming UHPC overlay project scheduled to begin in Spring 2020 (initially Fall 2019). At the pre-bid, a demonstration of mixing and placing of the UHPC was also provided.

Additionally, a short survey was sent to attendees of the Second Workforce Development Symposium to identify strengths, weaknesses, potential improvements, and what other topics on UHPC and/or other areas should be addressed in similar technology transfer symposiums. Limited responses were received. The survey questions can be found in Appendix A.

Responses from the survey scored the second symposium at 4.25/5. The collaboration between NMSU and NMDOT was a positive point mentioned by the attendees. Additionally, the openness of questions and conversation between people from different aspects of the profession was mentioned as a positive aspect. Most responses indicated that people would be willing to implement UHPC into their projects. Finally, attendees mentioned that additional symposiums such as these are needed to continue to facilitate and build an informed workforce, not only on UHPC, but in additional areas as well.

6. CONCLUSIONS

The two workforce development symposiums on UHPC were successfully held in April 2018 and April 2019. The objectives of the symposiums were to provide a platform for state DOTs, regional engineers, contractors, and concrete suppliers to learn about UHPC and provide feedback on ongoing studies, identify limitations for implementation, and new practices or improved methods. Information on UHPC was provided through presentations, hands-on demonstrations, and question and answer periods. Additionally, the symposiums provided an opportunity to ask questions, learn, share knowledge, and gain guidance on how to successfully implement UHPC in different applications. Through the hands-on demonstration, attendees were able to learn what specific changes (if any) are needed for the mixing, placing, curing, and testing of UHPC. By observing the mixing and placing process, the difference between normal/high strength concretes and UHPC could be observed.

Collaborating with the New Mexico Department of Transportation was essential to adequately address the needs of the infrastructure community and to provide the tools, information, and knowledge necessary to implement UHPC into standard practice. This collaboration also ensured that the local contract community was able to provide feedback and identify concerns and limitations on projects incorporating UHPC and provided a mechanism for these issues to be addressed. The result of this collaboration should greatly facilitate the adoption of the new technology and practices.

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APPENDIX A: SECOND SYMPOSIUM SURVEY

1. What did you find the most helpful at this symposium?
2. What could be improved on?
3. Did you find the information presented at the symposium useful to your area of work?
4. Did you find the UHPC mixing demonstration useful?
5. Would you be willing to implement UHPC into future designs?
6. Are there any topics you would like to see covered through symposiums?

Overall, how would you rank this symposium (1 to 5)? (With 5 being the best)