UHPC: REDEFINED AND REVOLUTIONIZED

RICHARD FIRST - PRODUCT MANAGER, MORTARS

MARCH 5, 2024

BUILDING TRUST

SIKACRETE®-930 UHPC

OVERVIEW

- What is UHPC?
- Benefits and limitations
- Applications
- SikaCrete®-930 UHPC
  - Properties, UVP

Shawnessy Light Rail Station Canopy Roof
Calgary AB

SIKACRETE®-930 UHPC

WHAT IS UHPC?

- Ultra High-Performance Concrete
  - **No coarse aggregate**
  - Very low water content
  - Contains steel fibers
  - Self-consolidating
  - f’(c) ≥ 20,000 psi
  - Post-cracking tensile strengths ~750 psi
  - Excellent durability

UHPC is a cementitious composite material composed of an optimized gradation of granular constituents, a water-to-cementitious materials ratio less than 0.25, and a high percentage of discontinuous internal fiber reinforcement. The mechanical properties of UHPC include compressive strength greater than 17,500 psi (120 MPa) and sustained post-cracking tensile strength greater than 750 psi (5.2 MPa).

Ultra high-performance concrete has a discontinuous pore structure that reduces liquid ingress, significantly enhancing durability compared to conventional and high-performance concretes.

Ref: Federal Highway Administration

The mechanical properties of UHPC include compressive strength greater than 21.7 ksi (150 MPa) and sustained post-cracking tensile strength greater than 0.72 ksi (5 MPa)

Ref: Ben Graybeal, HRDI-40

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    - **very low w/cm ratio; SCM content**

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SIKACRETE®-930 UHPC

WHY UHPC?

- Complex, intricate shapes
- High strength
- Fast-track construction
- Excellent post-crack toughening
- Excellent wear resistance
- Excellent impact resistance

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- Complex, intricate shapes
- High strength
- Fast-track construction
- Excellent post-crack toughening
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- Excellent impact resistance
- **Longer service life – 80 years!**

Hossain, A. & Chang, C. M., (2023) "Life-Cycle Cost Analysis of Ultra High-Performance Concrete (UHPC) in Retrofitting Applications", *International Interactive Symposium on Ultra-High Performance Concrete* 3(1): 82.
doi: https://doi.org/10.21838/uhpc.16694 Florida International University

SIKACRETE®-930 UHPC

WHERE IS UHPC USED?

- Bridges
  - Precast bridge panel connections
  - Modular superstructural elements
  - Substructure connections
    - caps / columns / abutment walls
    - columns / footers
  - Shear keys
  - Header joints
  - Overlays

Pre-fabricated bridge deck panel connections
Ref: FHWA

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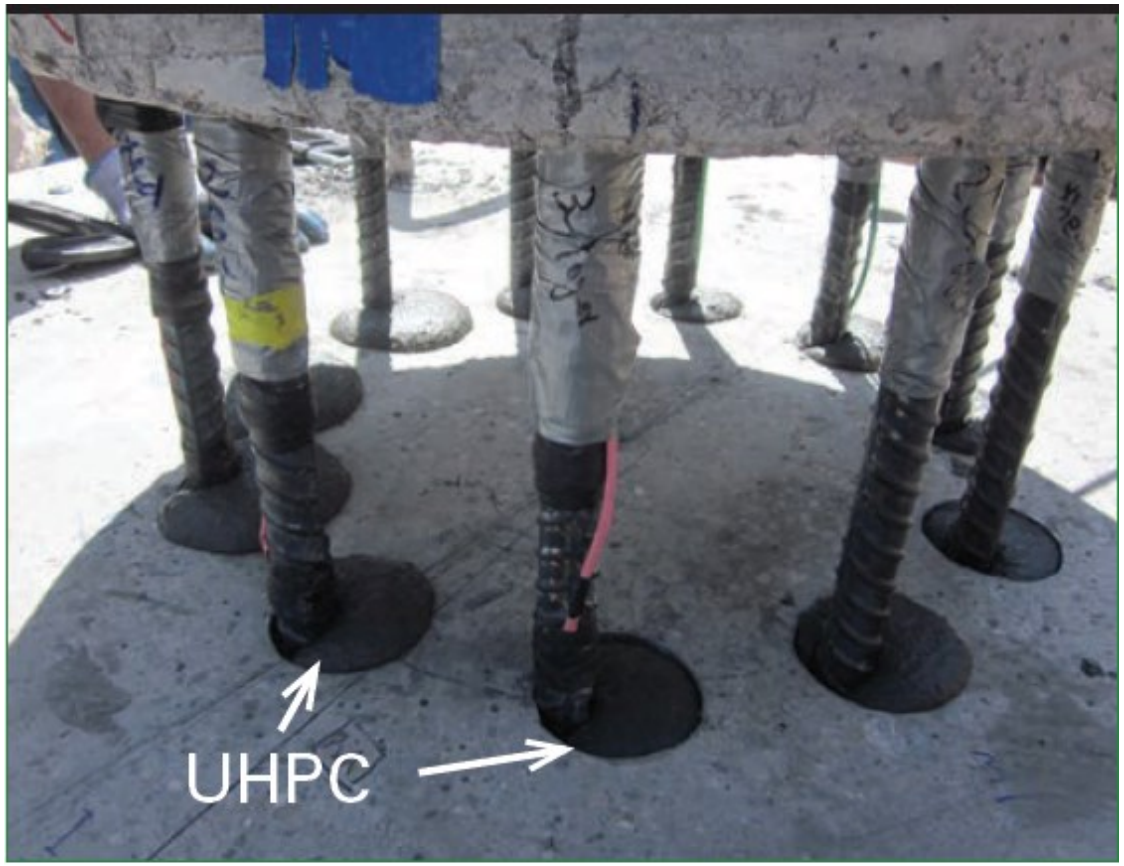
WHERE IS UHPC USED?

Lap-spliced substructure. Hooper Rd. Bridge Union, NY Ref: FHWA



Ducted UHPC substructure. Ref: FHWA

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WHERE IS UHPC USED?

Semi-integral abutment wall with vertical and horizontal connections.
I-81 at Prebble Rd. Syracuse, NY. Ref: FHWA

Longitudinal connections between double tee girders
Route 31 Bridge, Lyons, NY Ref: FHWA

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WHERE IS UHPC USED?

- Bridges
  - > 600,000 bridges in US (2013. AAMP)
  - 200,000 are steel
  - 235,000 are conventional, reinforced concrete
  - 108,000 are precast concrete elements
  - As of 2021, 150 bridges have used UHPC

* AAMP – Association for Materials Protection and Performance
NACE and SSPC have merged

Ref: Integral Engineering company

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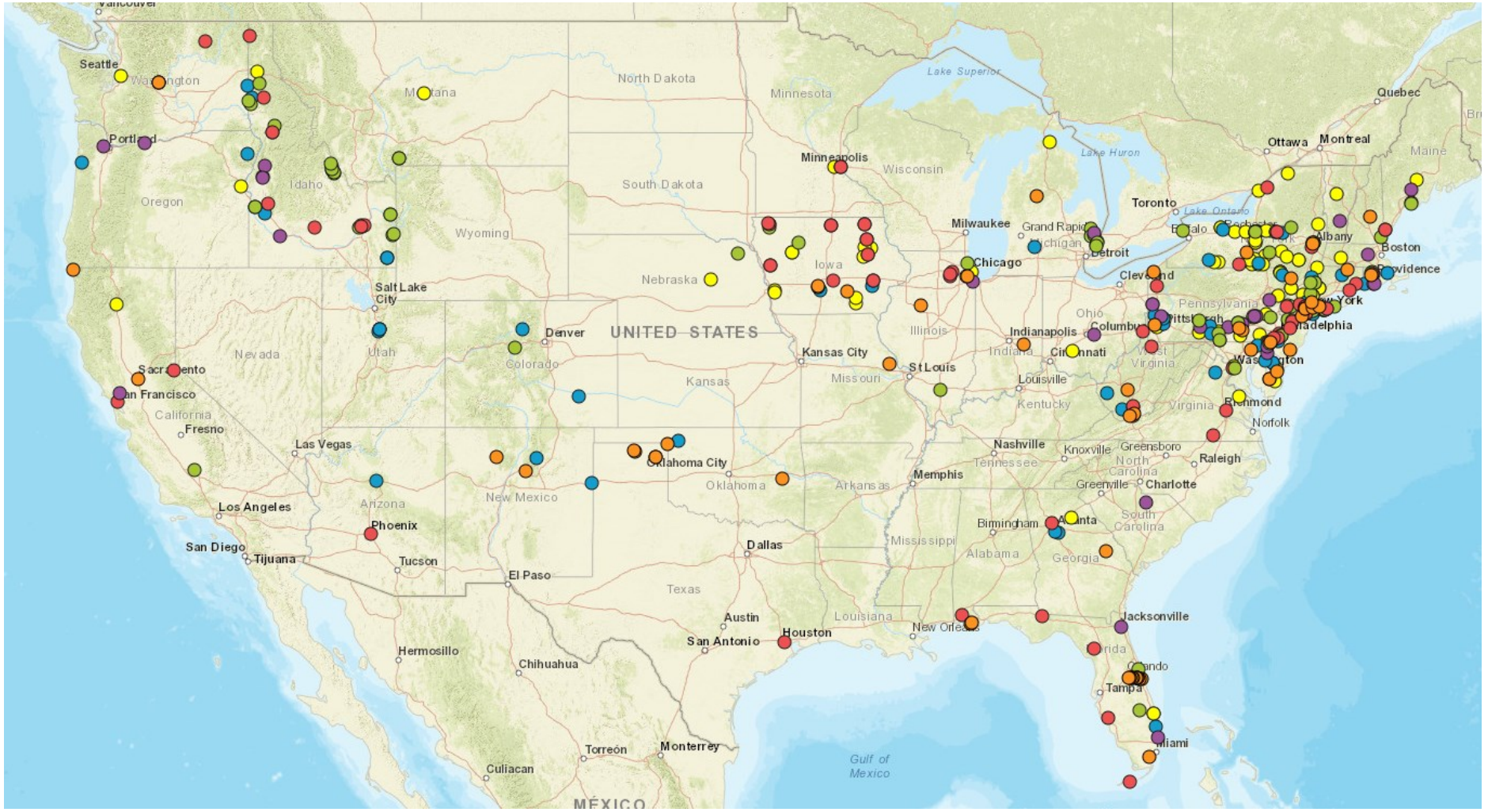
WHERE IS UHPC USED?



https://usdot.maps.arcgis.com/apps/webappviewer/index.html?id=41929767ce164eba934d70883d775582

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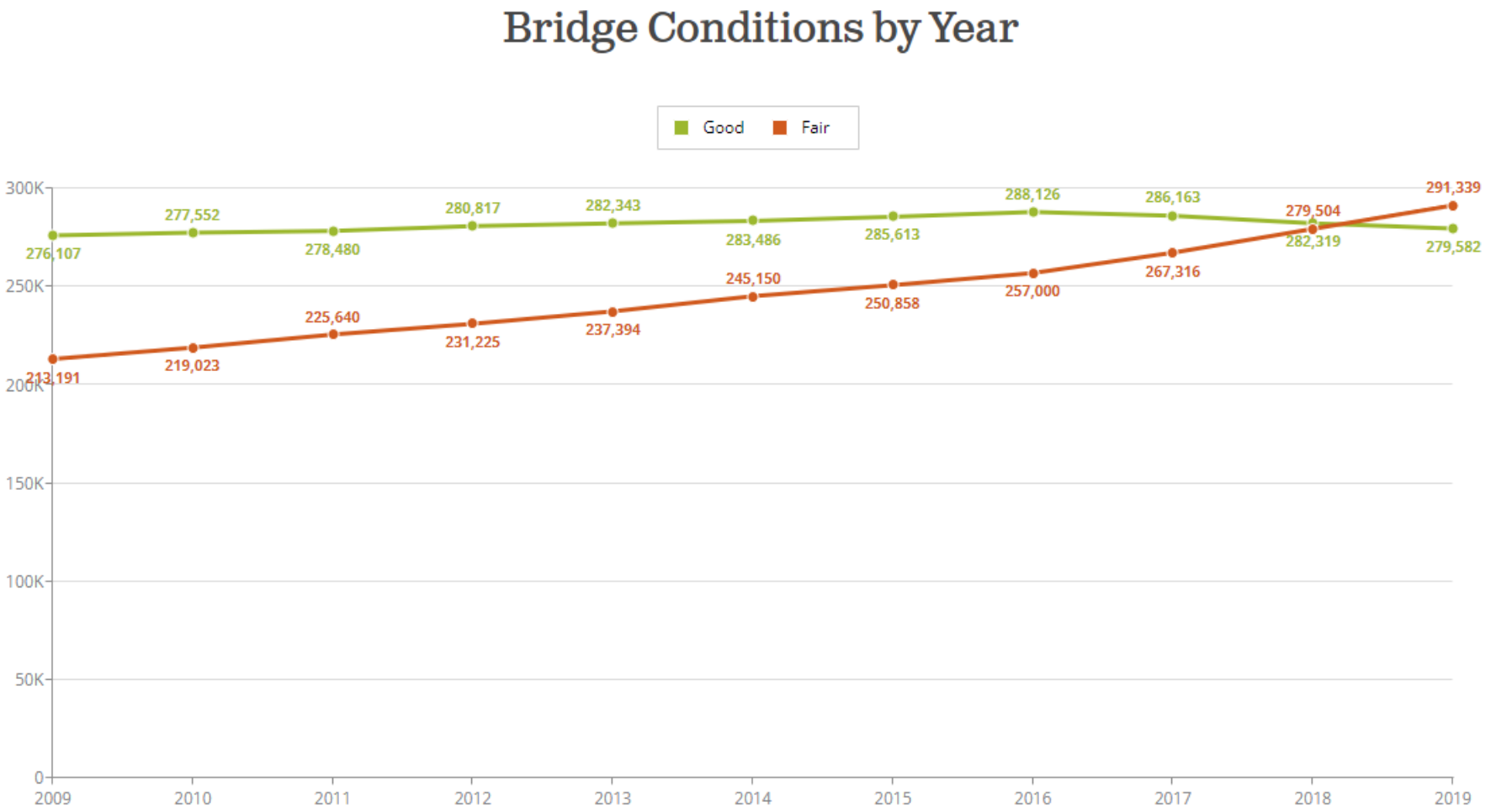
WHERE IS UHPC USED?



Source: U.S. Department of Transportation, Federal Highway Administration, InfoBridge: Data: https://infobridge.fhwa.dot.gov/Data/Dashboard

SIKACRETE®-930 UHPC

LIMITATIONS

- ***Environmental impacts:***

- Cement : silica fume : supplemental material =
  - 1.0 : 0.25 : 0.25 (ref)
- w/cm ratio = 0.2 – 0.3
- Aggregate : cement ratio = 1 – 2
- Fiber content (by volume) = 1 – 2%

- Typical UHPC mixes use ~ 40% cement
  - 266% greater CO_2 footprint than conventional concrete!

Ref: Ben Graybeal, FHWA-HRT-13-100

SIKACRETE®-930 UHPC

LIMITATIONS

- ***Cost:***
  - UHPC cost is ~ $2,000 / yd^3
  - Material cost only

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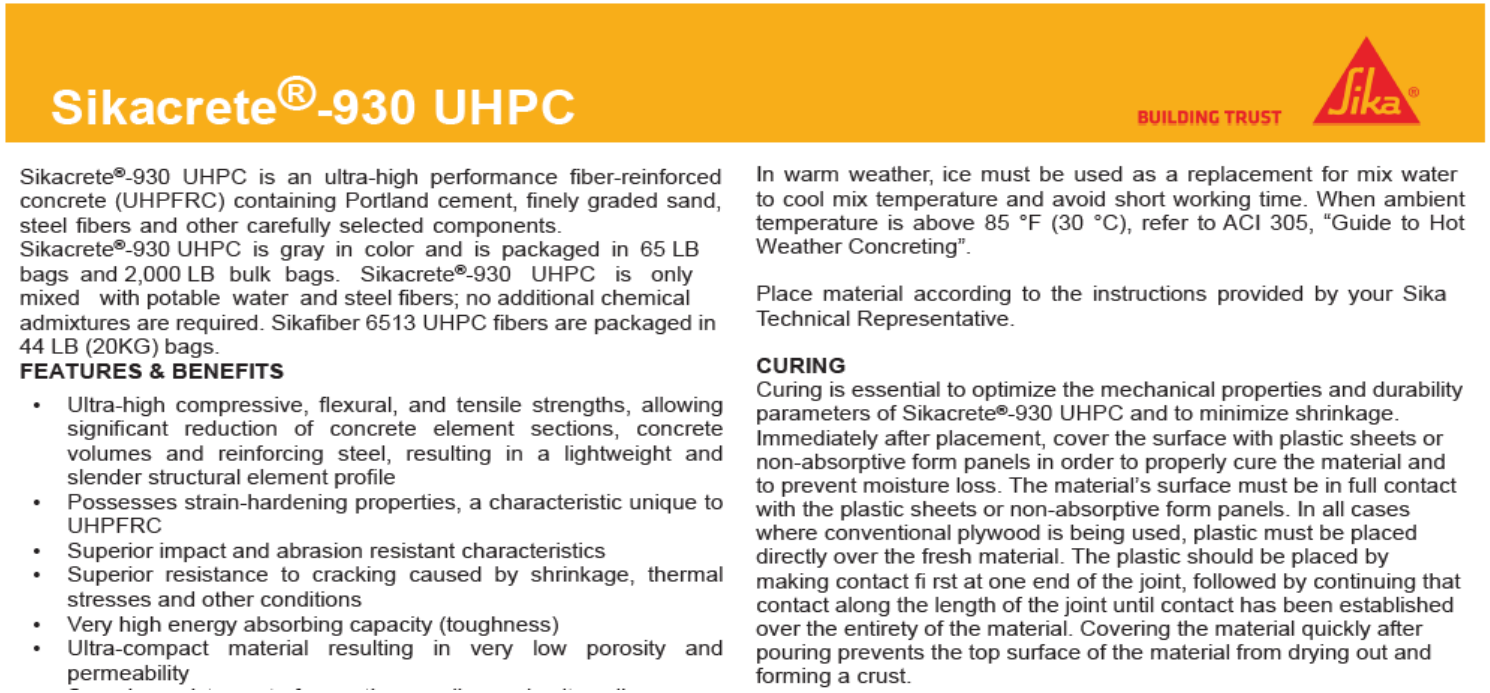
LIMITATIONS

- ***Cost:***
  - Labor cost
    - typical, on-site batching is a very inefficient process
    - lengthy mixing time
      - ~20 minutes per batch

SIKACRETE®-930 UHPC

- **Performance**
  - f’(c) > 10,000 psi at 24 hours
  - f’(c) > 22,000 psi at 28 days
  - > 1,400 psi tensile strength
- SCC consistency
- Able to hold slopes
- Freeze/thaw – 100% RDM @ 300 cycles
- RCP - < 200 Coulombs



Sikacrete®-930 UHPC

BUILDING TRUST

Sikacrete®-930 UHPC is an ultra-high performance fiber-reinforced concrete (UHPFRC) containing Portland cement, finely graded sand, steel fibers and other carefully selected components.
Sikacrete®-930 UHPC is gray in color and is packaged in 65 LB bags and 2,000 LB bulk bags. Sikacrete®-930 UHPC is only mixed with potable water and steel fibers; no additional chemical admixtures are required. Sikafiber 6513 UHPC fibers are packaged in 44 LB (20KG) bags.

FEATURES & BENEFITS

- Ultra-high compressive, flexural, and tensile strengths, allowing significant reduction of concrete element sections, concrete volumes and reinforcing steel, resulting in a lightweight and slender structural element profile
- Possesses strain-hardening properties, a characteristic unique to UHPFRC
- Superior impact and abrasion resistant characteristics
- Superior resistance to cracking caused by shrinkage, thermal stresses and other conditions
- Very high energy absorbing capacity (toughness)
- Ultra-compact material resulting in very low porosity and permeability

In warm weather, ice must be used as a replacement for mix water to cool mix temperature and avoid short working time. When ambient temperature is above 85 °F (30 °C), refer to ACI 305, “Guide to Hot Weather Concreting”.

Place material according to the instructions provided by your Sika Technical Representative.

CURING

Curing is essential to optimize the mechanical properties and durability parameters of Sikacrete®-930 UHPC and to minimize shrinkage. Immediately after placement, cover the surface with plastic sheets or non-absorptive form panels in order to properly cure the material and to prevent moisture loss. The material’s surface must be in full contact with the plastic sheets or non-absorptive form panels. In all cases where conventional plywood is being used, plastic must be placed directly over the fresh material. The plastic should be placed by making contact first at one end of the joint, followed by continuing that contact along the length of the joint until contact has been established over the entirety of the material. Covering the material quickly after pouring prevents the top surface of the material from drying out and forming a crust.

SIKACRETE®-930 UHPC

WHAT IS OUR UVP?

- **Quality Assurance**
  - Current solutions are batched on site
  - *Errors can occur*
    - weighing powders
    - measuring admixtures
  - **Sikacrete®-930 UHPC provides confidence of installed product performance.**

SIKACRETE®-930 UHPC

- Independent performance validation
- ISO 9001

NELSON TESTING LABORATORIES®

EXPERIENCED | INNOVATIVE | AUTHENTIC

December 6, 2023
Sika – Sikacrete 930 UHPC
NTL Project: 22-1402
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TEST RESULTS

ASTM C39 – Compressive Strength

Material: **Sikacrete 930 UHPC**
Cast Date: November 2023
Specimens: Average of three 3 x 6-inch cylindrical specimens
Curing: Air Cure

Results:

Compressive Strength @ 1 day **10,220 psi**

Specimen 1 10,250 psi
Specimen 2 10,390 psi
Specimen 3 10,010 psi

ASTM C469 – Compressive Modulus of Elasticity

Material: **Sikacrete 930 UHPC**
Cast Date: November 2023
Specimens: Average of three 4 x 8-in readings
Curing: Air Cure

Results:

Compressive Modulus @ 28 days **7.04×10^6 psi**

Specimen 1 6.91×10^6 psi
Specimen 2 7.07×10^6 psi
Specimen 3 7.14×10^6 psi

ASTM C1202 – Rapid Chloride Permeability

Material: **Sikacrete 930 UHPC (cast without steel fibers)**
Cast Date: November 2023
Specimens: Average of two 4 x 2-in cylindrical specimens cured 28 days
Curing: Air Cure

Results:

Rapid Chloride Permeability @ 28 days **131 coulombs**

Specimen 1 124 coulombs
Specimen 2 138 coulombs

SIKACRETE®-930 UHPC

WHAT IS OUR UVP?

- **Labor Savings**
  - Current solutions are batched on site
  - *Requires time*
    - weighing powders
    - measuring admixtures
  - **> 100% improvement in efficiency**
  - **Sikacrete®-930 UHPC results in lower installed cost**

SIKACRETE®-930 UHPC

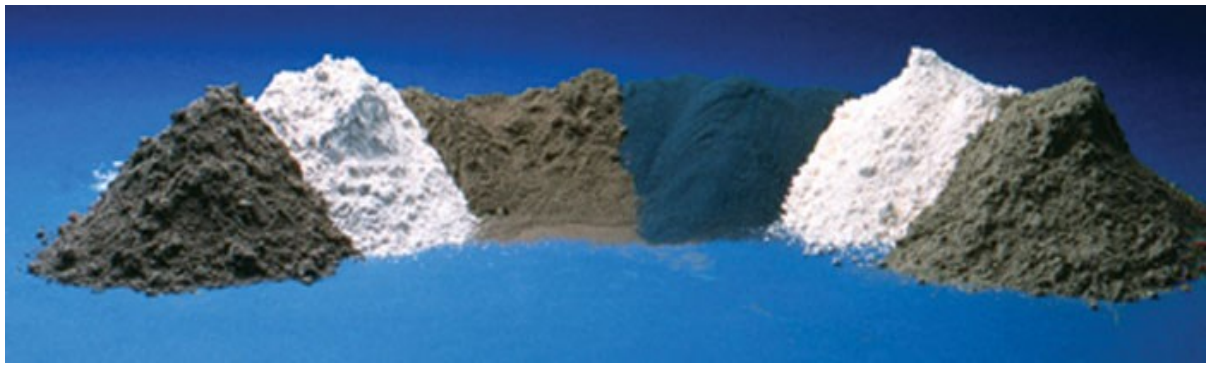
WHAT IS OUR UVP?

- **Safety**
  - Current solutions are batched on site
  - *Dust generation*
  - OSHA repsirable quartz considerations
  - **Sikacrete®-930 UHPC incorporates low dust technology**

SIKACRETE®-930 UHPC

WHAT IS OUR UVP?

- **Reduced environmental impact**
  - Increased use of supplemental cementing materials through proprietary technology
  - Reduced use of Portland cement
  - **Sikacrete®-930 UHPC**
    - **CO_2 footprint ~ 25% lower**

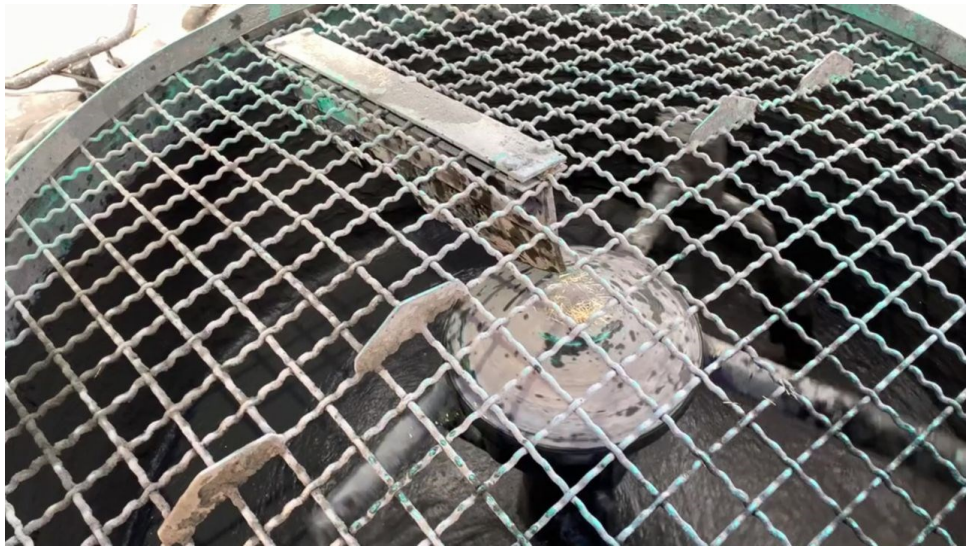


Ref: Portland Cement Association

SIKACRETE®-930 UHPC

MIXING & PLACEMENT OF SIKACRETE®-930 UHPC

- **Mixing**
  - Pan mixers commonly used
    - modifications may be required
  - Drill & paddle recommended for small projects
    - Collomix XO-55 Duo
  - 7-10 minute mix time



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SIKACRETE®-930 UHPC

PACKAGING & YIELD OF SIKACRETE®-930 UHPC

- 65 LB bag of SikaCrete®-930 UHPC
- 44 LB bag of SikaFiber®-6513 UHPC
- One “batch” of SikaCrete®-930 UHPC consists of:
  - 4 bags of SikaCrete®-930 UHPC
  - ½ bag of SikaFiber®-6513 UHPC
  - Yield = 2 cubic feet

SIKACRETE®-930 UHPC

SUMMARY

- UHPC use is rapidly growing in infrastructure applications
- Long-term durability is key benefit
- Current approaches use site-batched designs
- Pre-packaged solutions offer many benefits, including
  - worker safety
  - guaranteed quality
  - reduced environmental impact
  - significant labor savings through faster installation
    - lower installed cost vs typical, site-batched UHPC

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