Ultra High Performance Concrete
Material, Design and Application

**UHPC India Pvt. Ltd.**

India’s First Commercial Manufacturer:
Since 2020

(W): https://uhpcindia.com
(E): info@uhpcindia.com
(M): +91 91674 24144 +91 77100 04517

Dr. Satish Jain, Ph.D, PE, SE (USA)
Managing Director, UHPC India Pvt. Ltd
ISKCON School – off Mumbai: Feb 2021

India’s First Project
Concrete is the Wrong Choice of Word

Fibrous Composite

- Ultra High Performance Fiber Reinforced Composite (UHPFRC)
- Ultra High Performance Concrete (UHPC)
- Ultra High Performance Fiber Reinforced Concrete (UHPFRC)
- Reactive Powder Concrete (RPC)
UHPC – The Material

Ultra Green !!
Ultra Strong !!
Ultra Durable!!

Steel Fibers: 2% by Vol
0.2 mm (d) x 13 mm (L)
Tensile Strength ~ 2800 MPa
AR: 60 to 70
Ultra High Mechanical Properties

- **Direct Tensile Strength:** ~10 MPa
- **Compressive Strength:** 140 MPa to 220 MPa
- **Elastic Modulus:** ~50,000 MPa
- **Low Creep Coefficient:** ~1.0 (Normal Curing)

Flexural Design of Beams
Courtesy: Aaleti & Sritharan (2013)
Robust Durability Performance

Longevity: 100 Year Maintenance Free Life

Performance

Strategy A

Strategy B

Limit state

Service Life

t₀ t₁ t₂

time

Report: Samaris
WP14 D22
Concrete

- 50% Weight reduction of structural elements
- Negligible/Low Reinforcing Steel
- 100 Year **maintenance free** service life
- Sleek and elegant Looks
- Ultra High wear and impact resistance
- Rapid development of strength:
  - > 60 MPa in 24 hours
  - > 100 MPa in 3 days

Structural Steel
At a **Fraction of Steel Cost**, you get **Steel Behavior**

<table>
<thead>
<tr>
<th></th>
<th>Concrete</th>
<th>UHPC</th>
<th>Struc. Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu.m. Rate</td>
<td>Rs 7000</td>
<td>Rs 80,000 to 1,00,000</td>
<td>Rs 7,00,000</td>
</tr>
<tr>
<td>Ratio</td>
<td>1</td>
<td>11 to 15</td>
<td>100</td>
</tr>
</tbody>
</table>
Few of our Projects
84 Hollow UHPC Beams

GCC Mumbai
GCC Namaste, Mumbai

- Addition of a floor at the 13th Level in an existing hotel tower.
- The floor needed to be as light as possible.

13m Span

19m Span

Section AA

1200mm deep Light weight cast-in-place UHPC Girder

RC Slab

Floor Plan
Bungalow Project– Tirupati
Extension of Existing Slab

1200 mm extension of slab using UHPC

• The cantilever extension must be lighter in weight

(UHPC Curtain wall and Parapet to keep the building elevation uniform)

(SDC Dev Aangan, Mumbai)
Column Splicing on existing building

- Required Development length in UHPC < 15 × bar dia.
RC-UHPC Composite Columns

- Currently tested for predominantly Gravity Loaded Columns.
- First Set of Tests Successful

Tested at IIT Hyderabad
Retrofit for Additional Parking – Mumbai

• Existing Beams strengthened to support 3 Level Steel Parking Structure.
Motibaug C2, Mumbai

- Proposed precast UHPC girder (800 mm deep)

Floor Plan

15m Span

- Longer Spans – Flexible space option at retail levels.
Upcoming Jewellery Store, Vellore

- Longer Spans – Flexible space option.
- Super fast construction – Pre-casting.
- Floor-to-Floor height remains the same.
Dry Mix Jumbo Bags
UHPC Dry Premix in Jumbo bags

Ready-Mix UHPC
UHPC wet-mix in ready-mix concrete trucks

Precast Long Span UHPC Girders
Composite girders for bridges and buildings
Busting Myths
**Myth 1: UHPC Elements Needs to be Precast in a Facility**

UHPC Premix manufactured in factory controlled condition

+ Batched Ice or Iced water

+ Weighed Steel Fibers

Mixing with High Energy mixer

Wet UHPC mixed at site
Myth 2: UHPC Cannot be Cast-in-Place

Shuttering for UHPC girders (19.0 m span) at 13th floor level supported over props

UHPC poured in place through bucket
Myth 3: UHPC Cannot be Pumped

UHPC Pumping

UHPC Pumping at 13th floor of an existing Hotel building in Mira road, Mumbai
Myth 4: UHPC has to be Steam Cured

Normal water curing
Site mixing
Strength achieved (28 days) = 186 MPa
with a standard deviation of 8 MPa

Curing using curing compound
Site mixing
Strength achieved (3 days) = 117 MPa
Myth 5: UHPC has to be poured within 30 minutes

A Good UHPC is workable for long hours
Myth 6: Flexural Strength is Sufficient to Define Tensile Property of UHPC.

Two most important parameters to define tensile strength of UHPC.

Credits: FHWA
Myth 7: Only French Code Can be Used for Design

SWISS STANDARD – SIA 2052 - 2016

ASTM C1856-17

ACI 239C - Upcoming
Shear Strength of UHPC Beams/Girders

As per French Code of Practice, NF P-18 710 (2016)

Shear Strength = UHPC Concrete + Fibrous UHPC + Shear Rebar

As per Swiss recommendations (2016)

Shear Strength = UHPC Concrete + Fibrous UHPC + Shear Rebar

El-Helou and Graybeal (2022) experimental observations on pre-stressed UHPC girders

Shear Strength = UHPC Concrete + Fibrous UHPC + Shear Rebar


- UHPC has a fine granular structure. Hence, no significant aggregate interlocking.
- Negligible advantage from Concrete/Prestressing

Credits: FHWA
**Shear Strength of UHPC**

- UHPFRC depicts extraordinarily high Shear Strength
- For most common applications, Shear rebar is not Required

\[
V_{Rd} = V_{Rd,U} + V_{Rd,s}
\]

with:

\[
V_{Rd,U} = \frac{b_w \cdot z \cdot 0.5(f_{Ule} + f_{Uld})}{\tan \alpha}
\]

\[
V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{sd} \cdot (\cot \alpha + \cot \beta) \sin \beta
\]

**Approximate Shear Strength of UHPFRC:**
For \( \alpha = 30 \) degrees,
Design Elastic Strength = 5 MPa
Design Ultimate Strength = 6 MPa

Shear Strength of UHPC = 9.5 MPa

Courtesy: Swiss Code
Shrinkage

*French Code*

- Graph showing shrinkage strain ($\varepsilon_{sh}$) as a function of time (t) in days.
- RH = 60%
- Points at specific time intervals: 28, 0.015; 28, 0.0076; 1825, 0.0361

*Swiss Code*

- Graph showing shrinkage strain ($\varepsilon_{sh}$) as a function of time (t) in days.
- Points at specific time intervals: 28, 0.047; 1825, 0.071

Creep

*French Code*

- Graph showing creep coefficient ($\phi$) as a function of time (t) in days.
- Points at specific time intervals: 28, 0.85; 1825, 1.48

*Swiss Code*

- Graph showing creep coefficient ($\phi$) as a function of time (t) in days.
- Points at specific time intervals: 28, 0.81; 1825, 1.16
Minimum Clear Cover to Post Tensioning Ducts

IRC 112-2020

75mm
Considering durability, bond and crack width requirements, irrespective of the exposure conditions and duct dia.

French Code

Duct Dia
Clear cover ~ Duct Dia
Upcoming Bridge Projects
Bridge Girder Size Comparison
## Bridge Girder, 15m Span vs 15m Span

<table>
<thead>
<tr>
<th></th>
<th>RC Girder</th>
<th>PS UHPC I Girder</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>With SPV Loading</strong></td>
<td><img src="image" alt="RC Girder Diagram" /></td>
<td><img src="image" alt="PS UHPC I Girder Diagram" /></td>
<td>~72% reduction in the Girder Self-weight.</td>
</tr>
<tr>
<td><strong>Span</strong></td>
<td>15m</td>
<td>15m</td>
<td>Similar</td>
</tr>
<tr>
<td><strong>Girder Self-Weight</strong></td>
<td>28.5 MT</td>
<td>7.9 MT</td>
<td>~72% reduction in depth</td>
</tr>
</tbody>
</table>

~72% reduction in the Girder Self-weight.
# Bridge Girder, 30m Span vs 30m Span

<table>
<thead>
<tr>
<th></th>
<th>PSC Girder</th>
<th>PS UHPC I Girder</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>With SPV Loading</strong></td>
<td><img src="image" alt="PSC Girder Diagram" /></td>
<td><img src="image" alt="PS UHPC I Girder Diagram" /></td>
<td><strong>750mm reduction in depth</strong></td>
</tr>
<tr>
<td><strong>Span</strong></td>
<td>30m</td>
<td>30m</td>
<td>Similar</td>
</tr>
<tr>
<td><strong>Girder Self-Weight</strong></td>
<td>81 MT</td>
<td>32 MT</td>
<td><strong>~60%</strong></td>
</tr>
</tbody>
</table>

~60% reduction in the Girder Self-weight.
**Bridge Girder, 30m Span vs 42m Span**

<table>
<thead>
<tr>
<th></th>
<th>PSC Girder</th>
<th>PS UHPC I Girder</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>With SPV Loading</strong></td>
<td>![Diagram PSC Girder]</td>
<td>![Diagram PS UHPC I Girder]</td>
<td>100mm reduction in depth</td>
</tr>
<tr>
<td><strong>Span</strong></td>
<td>30m</td>
<td>42m</td>
<td>~40%↑</td>
</tr>
<tr>
<td><strong>Girder Self-Weight</strong></td>
<td>81 MT</td>
<td>67 MT</td>
<td>~17%↓</td>
</tr>
</tbody>
</table>

~17% reduction in the Girder Self-weight even with 40% increased span.
~32% reduction in the number of piers in a major bridge (780m).
**Bridge Girder, 30m Span vs 60m Span**

<table>
<thead>
<tr>
<th></th>
<th>PSC Girder</th>
<th>PS UHPC I Girder</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>With SPV Loading</strong></td>
<td><img src="image1.png" alt="PSC Girder Diagram" /></td>
<td><img src="image2.png" alt="PS UHPC I Girder Diagram" /></td>
<td>500mm increase in depth</td>
</tr>
<tr>
<td><strong>Span</strong></td>
<td>30m</td>
<td>60m</td>
<td>~100%↑</td>
</tr>
<tr>
<td><strong>Girder Self-Weight</strong></td>
<td>81 MT</td>
<td>122 MT</td>
<td>~50%↑</td>
</tr>
</tbody>
</table>

~50% increase in the Girder Self-weight even with double span.

~50% reduction in the number of piers in a major bridge (780m).
### Bridge Girder, 30m Span vs 70m Span

<table>
<thead>
<tr>
<th></th>
<th>PSC Girder</th>
<th>PS UHPC I Girder</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>With SPV Loading</strong></td>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
<td>1000mm increase in depth</td>
</tr>
<tr>
<td>Span</td>
<td>30m</td>
<td>70m</td>
<td>~133%↑</td>
</tr>
<tr>
<td>Girder Self-Weight</td>
<td>81 MT</td>
<td>164 MT</td>
<td>~102%↑</td>
</tr>
</tbody>
</table>

~43% reduction in the number of piers in a major bridge (420m).
Now Possible to **Eliminate Concrete Box Girders for Longer Spans (60 to 70m)**

*If Structural Steel I-Girders are Possible*

**UHPC I-Girders are Possible as well**

<table>
<thead>
<tr>
<th></th>
<th>Steel Plate Girder</th>
<th>UHPC I Girder</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span</td>
<td>60m</td>
<td>60m</td>
<td></td>
</tr>
<tr>
<td>Girder Self-Weight</td>
<td>120 MT</td>
<td>120 MT</td>
<td>Similar</td>
</tr>
<tr>
<td>Girder Span-to-Depth Ratio</td>
<td>22.2</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Erected Cost</td>
<td>1.4 Cr.</td>
<td>0.8 Cr.</td>
<td>43% Savings</td>
</tr>
</tbody>
</table>
Misc. Infrastructure Application around the World
Other Applications in Bridge Engineering

Enhancing **Strength and Durability of a Deteriorated Pier with UHPC Cover**

Expansion Joints at Deck Replaced with UHPC Link Slab

Longitudinal Joints Repair / Filling with field cast UHPC

UHPC wearing coat over Bridge deck

Credits: FHWA
Precast Circular - MORTH

UHPC India Pvt. Ltd. is expanding with

25 to 30 Micro UHPC Precast Facilities around India

2022-23

With Precasting and Infra Channel Partners

Build with your OWN UHPC!!
THANK YOU !!
We Look Forward to create Value for You!!

MADE IN INDIA UHPC