Revolutionizing Road Infra with Modern Equipment, Technologies, Sustainable Materials and Policy Guidelines

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UHPFRC Technology for Sustainable Development

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M/s LONGSPAN STRUCTURES PVT LTD.

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Quick Background on Concrete Technology

EVOLUTION OF CONCRETE TECHNOLOGY

- **1824** – Portland Cement First Developed (Joseph Aspdin)
- **1849** – Reinforced Concrete Evolved With Addition of Metallic Reinforcement
- **1980s** – High Performance Concrete Improves the Compressive Strength of Concrete
- **1994** – The Term 'Ultra-High Performance Concrete' is Coined
- **1997** – UHPC is first used in Pedestrian Bridge in Canada

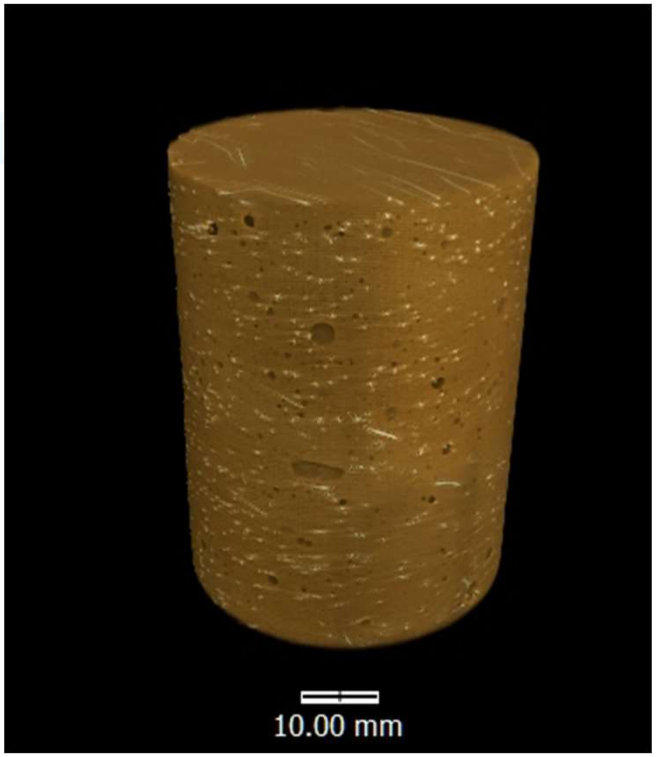
Sherbrooke Pedestrian Bridge, Quebec, Canada

Introduction

UHPFRC is a new generation of cement-based construction material tailored for very High Compressive Strength, High Ductility, Durability and Sustainability based on:

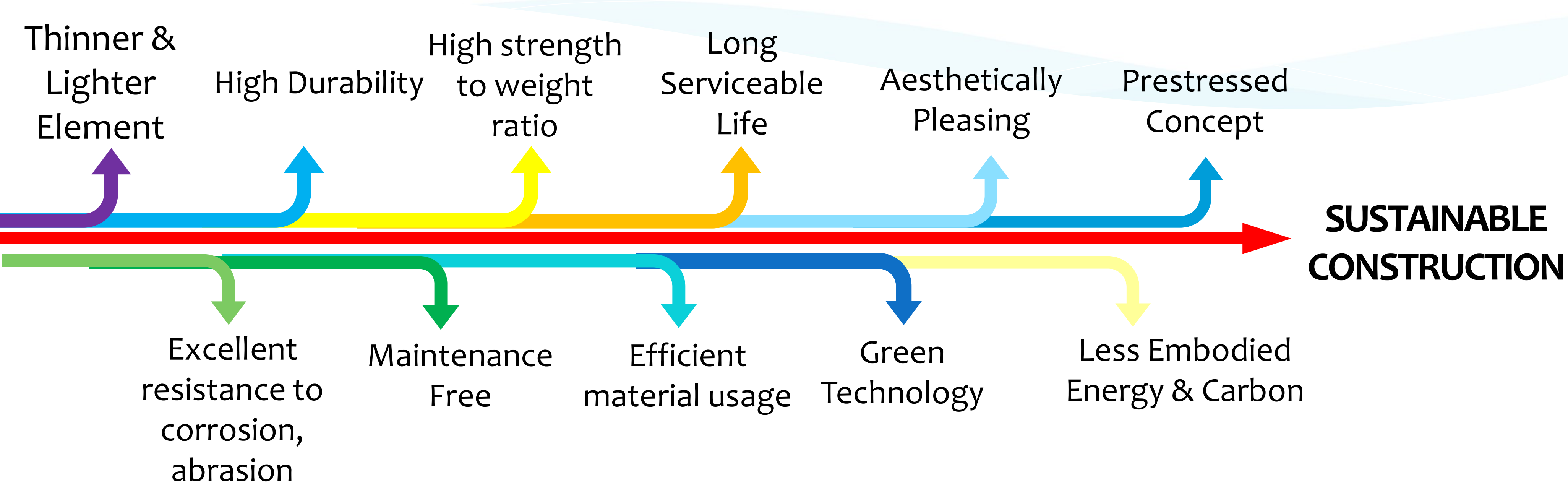
- ❑ Micro-scale optimization of fine and ultrafine aggregates (silica fume and sand),
- ❑ Lower content of water to cement ratio
- ❑ Added superplasticizer and reinforcement with high-strength steel fibers.

- Concrete Grade 150/165 & above.
- With usable structural ultimate tensile strength (> 8 MPa) and ultimate flexural strength more than 30 MPa.
- at least 4-6 times stronger than normal concrete (in compressive strength)
- 10 times more fatigue Strenght as comparad to Normal Concrete
- Better Impact Resistance due to high Strenght



Steel Fiber distribution in UHPFRC

Advantages of UHPFRC Bridge Construction



Areas of Application

- Currently most promising Field of Application of UHPFRC is Infrastructure Bridge girders, Sheet Piles, Wearing coat, etc.
- Building & industrial Infrastucture
- Offshore Structures
- Defence Structures.
- Thermal and Nuclear Power Plants
- Architectural Facades and finishes.

UHPFRC technology in India

LIST OF UHPFRC Project Executed and Under Progress

Bridge No.	Bridge Name	Authority	Span Arrangement (m)	Total Length (m)	Total Width (m)	Status	GIRDER Type
1	Latur Br.	MORTH Through MSRDC	2 x 55.5	111	16	Completed	BBG2400-55.5m
2	Mahad Br. CH161+400	PWD NHAI Division	1 x 33.9	33.9	16	Completed	BT1500-33.9m
3	Kharwandi CH.18+889	PWD NHAI Division	2 x 30	60	16	Completed	BT1500-30m
4, 5	Samruddhi Br1. CH531+068 &107	MSRDC	1 x 52	52	35	Completed	UBG2250-51.8m
5 ,6	Samruddhi Br2. CH531+968	MSRDC	1 x 52	52	35	Completed	UBG2250-51.8m
7	Taloja Creek Br.	PWD Maharashtra	2 x 33	66	8.25	Completed	BT1500 - 32.6 m
8	Dharmapuri- 145+635	NHAI	1 x 102.6	102.6	16	Completed	UBG4000-102.6m
9	Dharampuri- 137+979	NHAI	1 x 60	60	32	Completed	UBG3000-57.5M
10, 11	Dharmapuri- 142+465 (MCW)	NHAI	3 x 35	105	21	Completed	BT1500-34m
	Dharmapuri- 142+465 (SR)	NHAI	3 x 35	105	21.6	Completed	BT1500-34m
12	Dharmapuri- 138+875	NHAI	1 x 60	60	16		UBG3000-57.5M
13	TNT - RTO Flyover Span 1	PWD NHAI Division	1 x 65	65	17.2	Completed - Erection Pending	UBG3000-65M
14	TNT - RTO Flyover Span 2	PWD NHAI Division	1 x 65	65	17.2	Completed - Erection Pending	UBG3000-65M
15, 16, 17	TURBHE ROB - Flyover	PWD Maharashtra	38 x 30	1140	11.6289	In Progress	BT1500 -30m
18, 19	Vehicular Overpass Chandni Chowk (Main span)	NHAI	1 x 57	57	38.6	Completed	UBG2250 - 57m
	Vehicular Overpass Chandni Chowk (Ramp)	NHAI	6 x 23 - 35m	193	16		BT1500 -30m
20	Pandoh Nerchwok 206+650	MoRTH	1 x 32	32	25	In Progress	BT1500 -32m
21	Pandoh Nerchwok 207+270	MoRTH	1 x 20	20	25	In Progress	BT1500 -20m
22	Pandoh Nerchwok 209+510	MoRTH	1 x 39	39	25	In Progress	BT1500 -39m
23	Raipur, Chhattisgarh 155+340	MoRTH	2 x 35	70	12.9	In Progress	BT1500 -35m
24	Raipur, Chhattisgarh 147+970	MoRTH	4 x 35	140	12.9	In Progress	BT1500 -35m
25	Raipur, Chhattisgarh 133+090	MoRTH	3 x 47	141	12.9	In Progress	UBG2250-47m
			1 x 35	35	12.9	In Progress	BT1500-35m
26	DHARAMPURI - 145+902	NHAI	1 x 34	34	32	In Progress	BT1500-34m
27,28	DHARAMPURI - 124+630 (MCW)	NHAI	2 x 30	60	21	In Progress	BT1500-30m
	DHARAMPURI - 124+630 (SR)		2 x 30	60	21.6	In Progress	BT1500-30m
29	DHARAMPURI - 127+538	NHAI	2 x 29	58	32	In Progress	BT1500-29m
30	DHARAMPURI - 129+506	NHAI	1 x 35	35	32	In Progress	BT1500-35m
31	DHARAMPURI - 141+350 - Flyover	NHAI	2 x 32.5	65	22	In Progress	BT1500-32.5m

LIST OF UHPFRC Project Executed and Under Progress

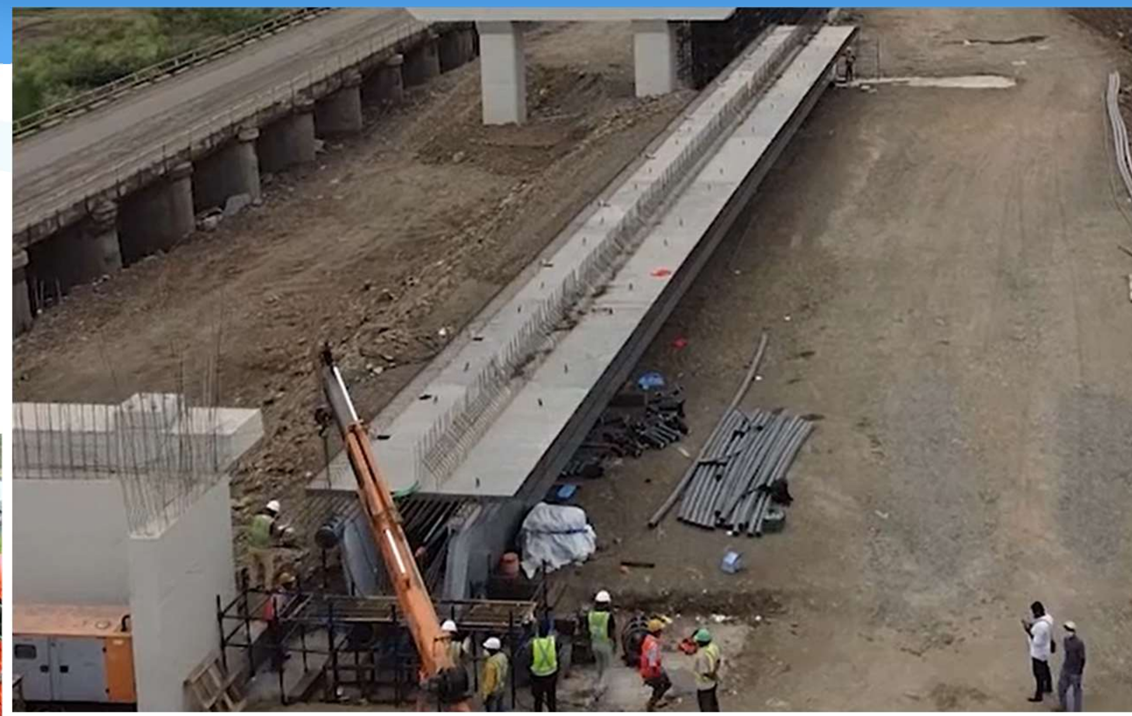
Bridge No.	Bridge Name	Authority	Span Arrangement (m)	Total Length (m)	Total Width (m)	Status	GIRDER Type
	DHARAMPURI - VUP Projects						
32	Ch. 119+160	NHAI	2 x 10.5	22	21.5	In Progress	IB850 - 21.5 m
33	Ch. 136+400	NHAI	2 x 10.5	22	21.5	In Progress	IB850 - 21.5 m
34	Ch. 152+700	NHAI	2 x 10.5	22	21.5	In Progress	IB850 - 21.5 m
35	Ch. 131+300	NHAI	2 x 10.5	22	21.5	In Progress	IB850 - 21.5 m
36	Mumbra Bridge overlay	PWD Maharashtra	50 x 30	1500	15	Completed	-
37	INDORA FLYOVER - NAGPUR	NHAI	VARIOUS spans of 60 m, 80m and 90 m with total bridge length of 5950 m			In Progress	Various
38	Thirunavaya Bridge, Kerala	RBDCK, Govt of Kerala	13 x 62	806	11	In Progress	mUBG3000
39	VUP on Solapur Hydrabad Highway (302+050)	NHAI	2 x 20	40	2 x 16	Completed	BT1500 - 20m
40	Extension to Major Bridge on Solapur Hydrabad Highway (322+450)	NHAI	2 x 32.24	64.48	3.5	Completed	BT1500-30m
41,42	Bridge at Ch. 175+075	TIPL - NHAI	1 x 55	55	2 x 16	In Progress	UBG2250
43,44,45,46,47,48,49,50	8 Nos of Major Bridges on Kolhapur-Ratnagiri 4 Lane Highway	NHAI				In Progress	BT1500-37.5
51,52,53,54	Missing Link Project on Mumbai Pune Expressway.	Navyuga - MSRDC	16 x 25 + 35	435	24.95 x 2	In Progress	BT1500-25m
55,56	2 Bridgs on Mumbai Goa Highway	MoRT&H	3 x 37.5	112.5	16 x 2	In Progress	BT1500-37.5
57	Taloja Creek Br. (New Reconstruction)	PWD, Maharashtra	2 x 67.06	134.12	13.55	In Progress	UBG3000 - 66.06
58	Taloja Creek Br.	PWD Maharashtra	2 x 33	66	8.25	In Progress	BT1500 - 32.6 m
59	Bhoj Morbe Pkg. 17 Major Bridge	NHAI	2 x 21.25	95	3 x 31.76	In Progress	BT1500 - 32.6 m
60	FORMULA 3 Race track Building	Private					
61	Marwah Towers Arches	Private					
62, 63	Firodia Township Bridges	Private					

UHPFRC PROJECTS IN INDIA AS ON DATE = 63 NOS
COMPLETED PROJECT TILL DATE = 18 NOS

India's First UHPFRC Bridge – May 2021

Transportation

Transportation via trailers



Alignment and Post-tensioning

India’s First UHPFRC Bridge – May 2021

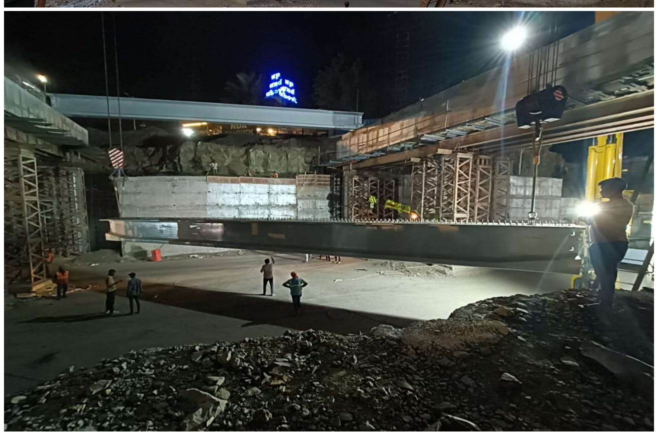
Alignment and Post-tensioning

Completed Photo of Bridge

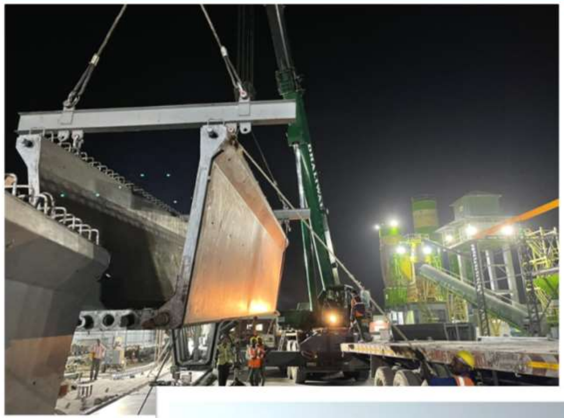
Interchange Structure - Chandni Chowk (Pune)

UHPFRC is Cost Effective, Speedy Construction & Sustainable solution for Structures in Urban Environment

Interchange Structure - Chandni Chowk (Pune)



Bridges on Samruddhi Mahamarg



DURING CASTING PROCESS

GIRDER LAUNCHING IN PROGRESS @ Ch. 531+968

LONGSPAN STRUCTURES
LONGSPAN STRUCTURES PVT LTD
The UHPFRC Company

Sustainability with UHPFRC Technology

- Sustainability is a concept that has gained significant importance within the construction industry and is here to stay. In a time of increased focus on environmental challenges and the need to create a more sustainable future, it is crucial to recognize the significance of sustainability in construction. Particularly, it is important to focus on the materials used, their durability, and production processes.

HOW UHPFRC help in Sustainability?

- **Higher strength parameters of UHPFRC enables sleek and slender components resulting**
  - **30 to 40% less consumption of concrete**
  - **Less carbon footprint with 25% less CO_2 emissions**
- **Higher Durability results into service life of 100+ years.**
- **Minimal maintenance is required.**
- **Lightweight precast component**

CEPP fib Model Code 2020

fib CEB-FIP

***fib* Model Code**
for Concrete Structures
2020

Final draft

May 2023

Presented at the fib Technical Council and General Assembly 2023 in Istanbul

In order to provide the designer with a indicator to evaluate whether the concrete under consideration has a high potential to build a sustainable structure, the so-called Concrete Environmental Performance Potential (*CEPP*) can be considered. Concrete Environmental Performance Potential (*CEPP*) is defined in Eq. (14.5-2):

$$CEPP = \frac{f_{ck}\, t_{SL}}{EIC} \qquad (14.5\text{-}2)$$

with:

f_{ck} the characteristic strength of the concrete according to section 14.2 in [MPa] representing the possible performance of the material;

t_{SL} the potential service life of the concrete under the specific environmental actions to be expected in the lifetime of the building member in years

EIC the environmental impact calculation, expressed as the CO_2-eq. for 1 m^3 of concrete.

The *CEPP*-index recognizes the fact that high strength concretes may have high emissions for producing 1 m^3 of concrete, but that their strongly improved structural behaviour and durability allow to produce highly sustainable structures. It also acknowledges that eco-concretes will only be deemed sustainable if they meet the required structural performance and durability criteria. Note that the dimension of the *CEPP*-index (i.e. [MPa · year/(kg CO_2-eq)] does not hold a physical interpretation, but rather represents the impact of crucial input values on the concrete's environmental performance.

Minimizing the environmental impact by choosing a low CO2-concrete might potentially affect the properties of the concrete. Because in this Model Code, all concrete properties related to structural performance are expressed as a function of the characteristic compressive strength f_{ck}, which is a key parameter for quantifying structural performance and well-known to the designer, f_{ck} is incorporated in the *CEPP* definition. Reducing the environmental impact by choosing a low CO_2-concrete should neither lead to a reduction in durability. In recognition of the significance of durability, the potential service life t_{sl} of the concrete under a given environmental impact is also introduced in the *CEPP* definition. For concrete production, the most dominant environmental impact results from the greenhouse gas (GHG) emission, including CO_2 For this reason the CO_2-equivalent is here chosen as the lead environmental impact parameter in the *CEPP* definition. The CO_2-equivalent can be calculated by summing up the CO_2-equivalent contribution of the different concrete constituents. The individual CO_2-equivalent of each constituent material must be obtained from the specific producer. Further, emissions e.g. resulting from the transport of the raw materials to the concrete plant and emissions resulting from the mixing process etc. should be considered. For more details see Haist et al. [14-yy].

De Passivation of steel start

FIB Model Code 2020

Calculation for Durability For Exposure to Marine Environment

Assumption
1. Non cracked section
2. Diffusuion coefficient Dc constant

$$C_{x,t} = C_s\left[1 - erf\left(\frac{x}{2\sqrt{D_c\,t}}\right)\right]$$

Y

		Grade130/145 UHPC				**Grade50/60 NSC**	
Exposure Class		XS3				XS3	
Cement Content		850	kg/m^3	**Cement Content**		485	kg/m^3
Chloride Conc. at Splashing Surface	C_s	19.25	kg/m^3		C_s	19.25	kg/m^3
Chloride Threshold Concentration	$C_{x,\ 0.3\%}$	2.55	kg/m^3		$C_{x,\ 0.3\%}$	1.46	kg/m^3
	C_x/C_s	0.1324675			C_x/C_s	0.075584	
	$1-C_x/C_s$	0.8675325			$1-C_x/C_s$	0.924416	
Mean Comp. Cly. Strength	f_{cm}	138	MPa		f_{cm}	58	MPa
Concrete Cover	X	75	mm		X	75	mm
Chloride Diffusion Coeff.	D_c	1.00E-13	m^2/s		D_c	2.00E-12	m^2/s
Chloride Diffusion Coeff.	D_c	1.00E-07	mm^2/s		D_c	2.00E-06	mm^2/s
Error Function	erf(Y)	0.8675			erf(Y)	0.9244	
Error Function Calculated	erf(Y) cal	0.8675			erf(Y) cal	0.9244	
	difference	0.0			difference	0.0	
	Y	1.0638			Y	1.2565	
Time (sec)	t	12,426,285,178			t	445,384,084	
	De Passivation of steel start	**394**	**years**		De Passivation of steel start	**14.12**	**years**
		27	times Higher				

Higher CTL

Higher Impermeability

Solve for 0

Solve for 0

Conclusion UHPC is very much more durable and superior than NSC.

Case Study 1 : Bridge with 102.5 m Span (STEEL Vs UHPFRC)

EC – Embodied Carbon
EE – Embodied Energy

	Dura 1.5 SF					NSC 32/40			
Density	2420	kg/m3			Density	2350	kg/m3		
EE	3.83354262	MJ/kg	9.278	GJ/m3	EE	0.880	MJ/kg	2.068	GJ/m3
EC	0.46844106	kg/kg	1133.674	kg/m3	EC	0.123	kg/kg	289.050	kg/m3
	NSC 50/60					Steel bar/structure			
Density	2373.9860000	kg/m3			Density	7850	kg/m3		
EE	1.0471890	MJ/kg	2.486	GJ/m3	EE	29.200	MJ/kg	229.220	GJ/m3
EC	0.1704154	kg/kg	404.564	kg/m3	EC	2.590	kg/kg	20331.500	kg/m3
	Deck width	16	m	Length	102.6	m			
Steel I Beam Composite RC Deck Bridge									
		Remark	**Nos. of Pile**	**Length (m)**	**Concrete (m3)**	**Steel (kg)**	**Mass (ton)**	**EE (GJ)**	**EC (ton)**
1	RC Deck (125 kg/m3)	Grade 50/60			**410**	**51300**	**1026**	2518	299
2	End-diaphragm (125 kg/m3)	Grade 32/40			**19**	**2400**	**48**	110	12
3	RC parapet (120kg/m3)	Grade 32/40		205.2	**66**	**7880**	**162**	366	39
4	Bow String Girder	Steel		102.6	**0**	**1442000**	**1442**	42106	3735
4.1	Cross Bracing (5% of Steel I Beam)	Steel			**0**	**72100**	**72**	2105	187
4.2	Other component (bolt and nut, assume 3%)	Steel			**0**	**43260**	**43**	1263	112
							2793	**48469**	**4384**
	Deck width	16	m	Length (m)	102.6	m			
DURA UHPC Composite RC Deck Bridge									
		Remark	**Nos. of Pile**	**Length (m)**	**Concrete (m3)**	**Steel (kg)**	**Mass (ton)**	**EE (GJ)**	**EC (ton)**
1	RC Deck (125 kg/m3)	Grade 50/60			**410**	**82080**	**1056**	3417	379
2	End-diaphragm (125 kg/m3)	Grade 32/40			**19**	**3610**	**49**	145	15
3	RC parapet (120kg/m3)	Grade 32/40		205.2	**66**	**7880**	**162**	366	39
4	3 pcs Dura UHPFRC UBG4000 girder (188.82 m3/beam)	Dura 1.5 SF		102.6	**566**	**0**	**1371**	5255	642
4.1	Strands (31.11t/beam)	Steel			**0**	**279990**	**280**	8176	725
4.2	Rebar (6.352t/beam)	Steel			**0**	**57168**	**57.17**	1669	148
							2975	**19028**	**1948**

EC Reduction

$$= \frac{(4384 - 1948)}{(4384)} \times 100$$

= 55. 56 %

EE Reduction

$$= \frac{(48469 - 19028)}{(48469)} \times 100$$

=60.74 %

Case Study 2 : Bridge with 102.5 m Span (Conventional Vs UHPFRC)

	Dura 1.5 SF					NSC 32/40			
Density	2420	kg/m3			Density	2350	kg/m3		
EE	3.83354262	MJ/kg	9.278	GJ/m3	EE	0.880	MJ/kg	2.068	GJ/m3
EC	0.46844106	kg/kg	1133.674	kg/m3	EC	0.123	kg/kg	289.050	kg/m3
	NSC 50/60					Steel bar/structure			
Density	2373.9860000	kg/m3			Density	7850	kg/m3		
EE	1.0471890	MJ/kg	2.486	GJ/m3	EE	29.200	MJ/kg	229.220	GJ/m3
EC	0.1704154	kg/kg	404.564	kg/m3	EC	2.590	kg/kg	20331.500	kg/m3

EC – Embodied Carbon

EE – Embodied Energy

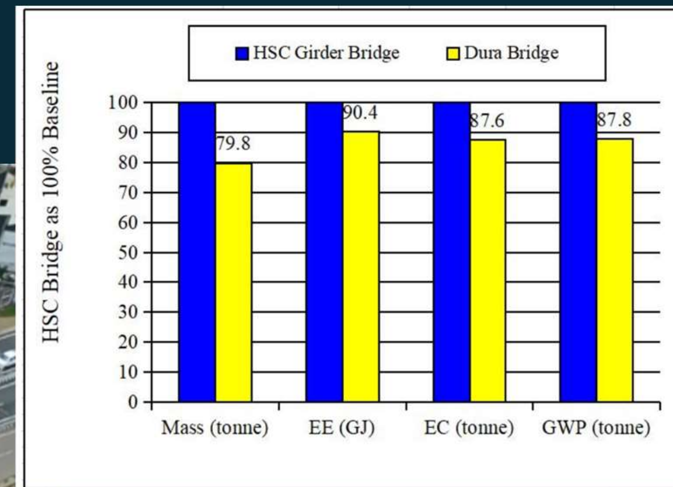
	Deck width	16	m	Length	60	m			
	PSC Girder + RC Deck Bridge								
		Remark	Nos. of Pile	Length (m)	Concrete (m3)	Steel (kg)	Mass (ton)	EE (GJ)	EC (ton)
1	RC Deck (125 kg/m3)	Grade 50/60			240	30000	600	1473	175
2	End-diaphragm (125 kg/m3)	Grade 32/40			19	2400	48	110	12
3	RC parapet (120kg/m3)	Grade 32/40		120	38	4608	95	214	23
4	Precast T beam - 5 x 30 m (2 Spans)	Grade 50/60		60	305	0	1442	759	124
4.1	Strands	Steel			0.00	22899	23	669	59
4.2	Rebar	Steel			0.00	25953	26	758	67
5	Substructure (Centeral Pier - 150kg / cum)				200.00	30000	505	1373	159
							2233	3982	618
	Deck width	16	m	Length (m)	60	m			
	DURA UHPC Composite RC Deck Bridge								
		Remark	Nos. of Pile	Length (m)	Concrete (m3)	Steel (kg)	Mass (ton)	EE (GJ)	EC (ton)
1	RC Deck (120 kg/m3)	Grade 50/60			192	23040	479	1150	137
2	End-diaphragm (100 kg/m3)	Grade 32/40			19	1920	47	96	11
3	RC parapet (120kg/m3)	Grade 32/40		120	38	4608	95	214	23
4	3 pcs Dura UHPFRC UBG3000 girder (74 m3/beam)	Dura 1.5 SF		60	216	0	523	2004	245
4.1	Strands (11.40 t/beam)	Steel			0	34200	34	999	89
4.2	Rebar (3.7 t/beam)	Steel			0	11100	11.10	324	29
							1189	4787	533

EC Reduction

$$= \frac{(618 - 533)}{(618)} \times 100$$

=13.86 %

UHPFRC's **Sustainability** for Interchange at Pune



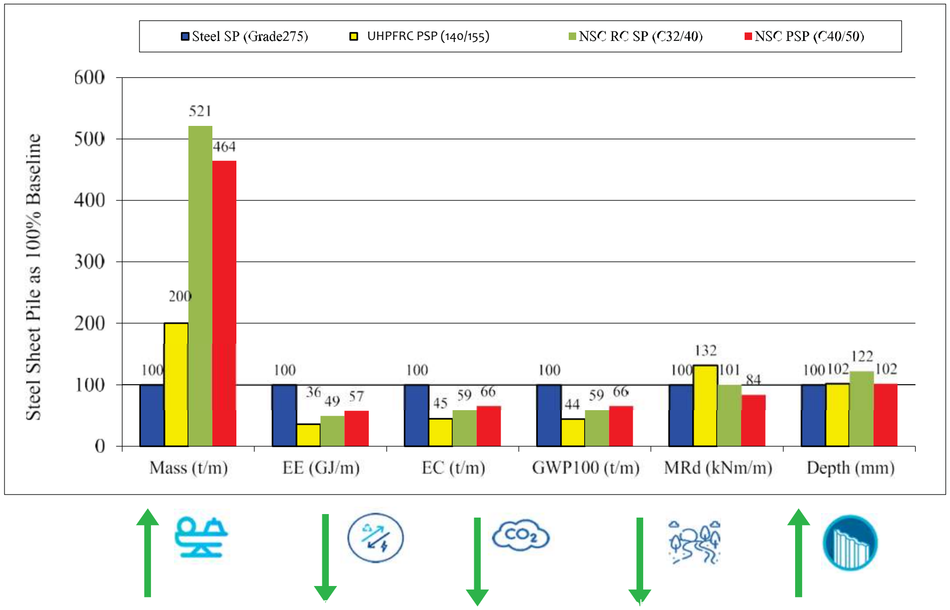
60m span (UHPC vs HSC)

- 20% lighter ↓
- 10% less EE ↓
- 12% less CO_2 ↓
- 12% less GWP ↓
- **CEPP Ratio = 97**

PRESTRESSED UHPFRC SHEET PILES

Recently, developed new application from UHPFRC is Prestressed Sheet Pile. Which offer superior strength and high durability, enhanced life span. It is an alternative to Steel Sheet Piles.

- Made from grade above 130/145 UHPFRC.
- Thinner and lighter elements
- Superior strength and durability
- Enhance in load-carrying capacity and resistance to bending and deformation
- High structural integrity and load-bearing capabilities



UHPFRC APPLICATION IN DEVELOPMENT STAGE FLOATING BRIDGES

Bridge are constantly being constructed across India. Construction of Permanent bridges in certain cases may be impractical based on objectives, cost & terrain and limitation of construction time.

Examples, where alternative to conventional bridges is required.

Based on Objectives	Based on Cost	Based on Terrain
Military Bridges	Where deep water locations are present, such as backwaters of Dams, Pile or well foundations are impractical to construct.	Over Lakes and Dam Backwaters
Bridges for carrying utilities.		Perennial Rivers
Bridges in Emergency conditions		River or water bodies with very large depth
Bridges for site access.		

The current alternative is floating Bridges which are constructed using structural Steel, which have disadvantages such as corrosion, high cost, low service life and periodic maintenance.

The Bergsøysund Bridge

Nordhordland Bridge

The Evergreen Point Floating Bridge

Thank You