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LONG SPAN BRIDGE DESIGN TREATED WITH UHPC IMPLEMENTATION

Naveenkumar Swamy
Department of Civil Engineering
University of Bologna, Bologna, Italy, Tongji University, Shanghai, China

Abstract— In the last several years great progression has been created in the investigation and development of a brand-new kind of concrete called ultra-high-performance concrete (UHPC). This high-tech material has excellent material attributes as compared to traditional concrete and has the potential to create slender and lighter structures. Nevertheless, the content is still really costly and requires designers to reduce material use to make an economic structure. The application of UHPC is able to enhance the box shaped cross section in a number of ways. Very slender beams could be created by using a higher amount of prestress. Also, wider beams with very slim webs can be made because of the high shear capacity. For this particular master thesis 5 different kinds of UHPC box beams are actually developed. These optimized box beams are actually created for bridges spanning 60m, 80m, 70m, 85m and 90m. The most crucial benefits of these UHPC box beams over box beams made of standard concrete are:

- *The beams are actually slenderer*
- *The beams are actually wider: o Less beams must be produced, transported and assembled, lessening the amount of time and labor necessary to construct the bridge.*
- *The beams are actually lighter: o the total loading of the bridge is actually reduced by the lower self-weight. o They're easier in order to transport as well as to hoist. o Longer beams up to 90m may be made without exceeding the 170t weight limit for transport by road.*

These benefits enable the UHPC box beams to be a fit solution for spans which are way too long for conventional box beam strategies, without having to create an intermediate pier or even to shift to segmented or even cast in situ solutions. Additionally, they are able to change old bridges with a stronger one without having to change the substructure. Consequently, it could be concluded that UHPC beams provide build brand new bridges and replace older bridges with little traffic hindrance.

I. INTRODUCTION

The Increasing demand of highways. Additionally, many existing bridges reach their service life and/or don't have the capability to carry the improved traffic intensities and many of them may have to be replaced or perhaps strengthened. When a new bridge must cross a highway with higher traffic intensity, there's usually a need for a bridge which may be constructed with minimum traffic hindrance. The exact same holds for old bridges that should be changed. It's ideal that these may be replaced with minimum traffic hindrance. By taking away the demand for an intermediate pier the traffic hindrance can be cut down considerably. Nevertheless, at the exact same time the span increases with a significant amount. Therefore, to minimize traffic hindrance, road bridges that can easily span longer distances are actually needed. Furthermore, it's also appealing that when a bridge is actually replaced, the current substructure would still have the ability to withstand the increased traffic loading. This could just be accomplished if the replacing superstructure is substantially lighter.

II. PROBLEM DESCRIPTION

In the previous years a new information, referred to as Ultra-High-Performance Concrete (UHPC), is actually being created and has shown results that are promising in the two tests and in training. This substance which is characterized by extremely substantial compressive toughness, shear capacity and advantageous cracking conduct, has the possibility to make extremely durable bridges which have the chance to span long distances with no intermediate piers. Additionally, these bridges may additionally be substantially lighter. Thus, this content appears to be the perfect choice to be used in road bridges that will need minimum site traffic hindrance during building. Nevertheless, the high expenses of the content, which is much more than 8 times the expense of typical concrete, poses a major struggle for the custom of the bridge. To make an economic style, the material use must be held to a bare minimum. This may be accomplished by locating a structural idea which uses the excellent information qualities of UHPC almost as possibleDWT Decomposition model.

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III. OBJECTIVES OF RESEARCH

The goal of this article is actually finding an economic look for UHPC in span that is long (≥60m) street bridges. design concepts that are Different will be examined to find the one that's most appropriate. This idea will be enhanced and eventually a look of an enhanced UHPC bridge is going to be offered.

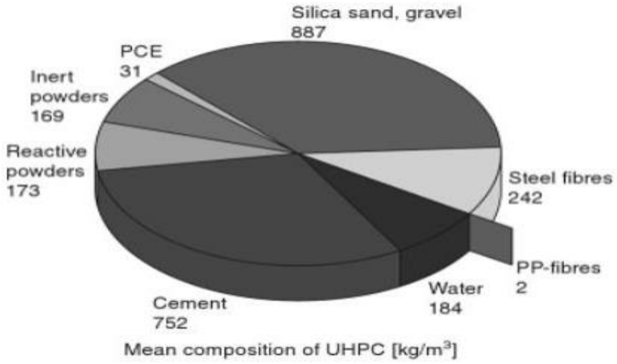
IV. BRIDGE PROPERTIES

To figure out when it is better to put on UHPC and how you can use it to the fullest potential of its, a great comprehension of the material as well as its action is actually needed. Consequently, in this particular chapter the mechanical and physical properties of UHPC are actually summarized. To be able to have the ability to design with the content, recommendations regarding distinctive and design values are usually provided. These're taken using the Recommendations on Ultra High-Performance Fiber Reinforced Concretes created by the AFGC. This's generally the French style code for UHPC

Density	ρ	2.500	kg/m³
Characteristic compressive strength	f_{ck}	150	N/mm²
Characteristic elastic tensile strength	$f_{ctk,el}$	9	N/mm²
Characteristic post-cracking tensile strength	f_{ctfk}	9	N/mm²
Mean modulus of elasticity	E_{cm}	50.000	N/mm²
Fiber orientation factor for global effects	K_{global}	1,25	-
Fiber orientation factor for local effects	K_{local}	1,75	-
Material factor UHPC	γ_c	1,5	-
Shrinkage - heat treatment hardened concrete	$\varepsilon_{cs,hht}$	550	µm/m
Shrinkage - heat treatment during curing	$\varepsilon_{cs,cht}$	550	µm/m
Shrinkage - no heat treatment	$\varepsilon_{cs,nht}$	700	µm/m
Creep factor heat treatment hardened concrete	Φ_{hht}	0,2	-
Creep factor heat treatment during curing	Φ_{cht}	0,4	-
Creep factor no heat treatment	Φ_{nht}	0,8	-

V. UHPC PROPERTIES

Material	lbs/yd³	% by wt.
Portland Cement (15 µm)	1200	28.7
Silica Fume (~1 µm)	390	9.3
Quartz Flour (10 µm)	355	8.4
Sand (150 to 600 µm)	1720	40.8
Steel Fibers (0.5" long, 8 mm Ø)	263	6.2
High-Range Water Reducer	51.8	1.2
Accelerator/Corrosion Inhibitor	50.5	1.2
Water	184	4.4



VI. UHPC BEAM BRIDGE DESIGN(>60M)

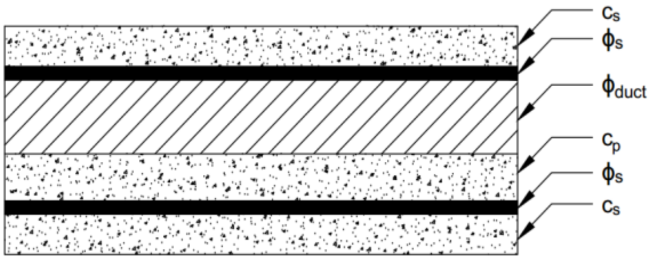


Figure 1 c/s of top flanges

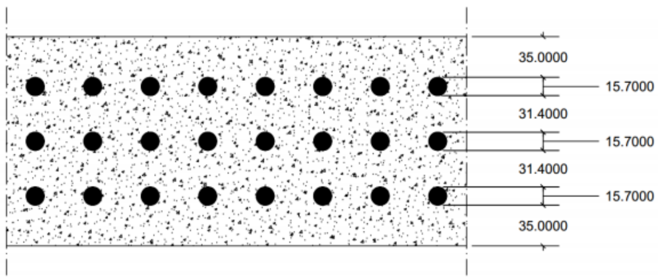


Figure 2 c/s of bottom flanges

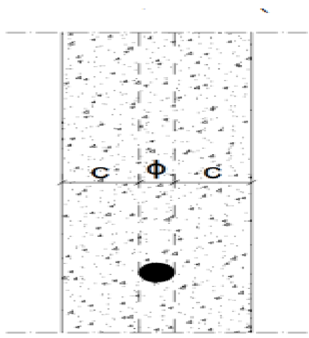


Figure 3 c/s of web

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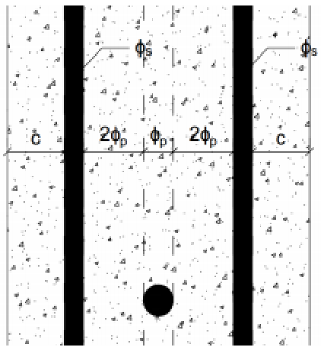

Figure 4 c/s of web with stirrup installed

Height	h		1300	mm
Width	b		1500	mm
Top flange thickness	d_{top}		170	mm
Bottom flange thickness	d_{bot}		225	mm
Web thickness	d_w		90	mm
Cross-section area	A_c		0,755 x 10^6	mm^2
Top fiber distance to neutral axis	z_t		693	mm
Bottom fiber distance to neutral axis	z_b		607	mm
Moment of inertia	I_c		1,908 x 10^{11}	mm^4
Section modulus top fiber	W_t		2,75 x 10^8	mm^3
Section modulus bottom fiber	W_b		3,15 x 10^8	mm^3
Amount of prestressing steel	A_p		156000	mm^2
Drape of prestressing strands	f_p		493	mm
Mass	G		115,5	t

Figure 5 Properties of 60m Box Beam

				6.10a[6]		6.10b[6]	
	m_x (kNm/m)	M_k (kNm)	q_k (kN/m)	γ	ψ	γ	M_d (kNm)
Self-weight beam	-	8498	18,9	1,4	1,0	1,25	11898
Asphalt	1620	2430	5,40	1,4	1,0	1,25	3402
Edge Loads	222	333	0,74	1,4	1,0	1,25	466,2
LM1	3142	4713	10,5	1,5	0,8	1,5	5656

Figure 6 Permanent and Variable Loads

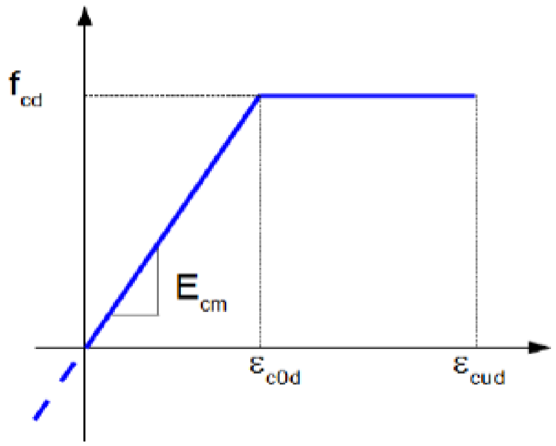

Figure 7 Compressive Stress - Strain Curve

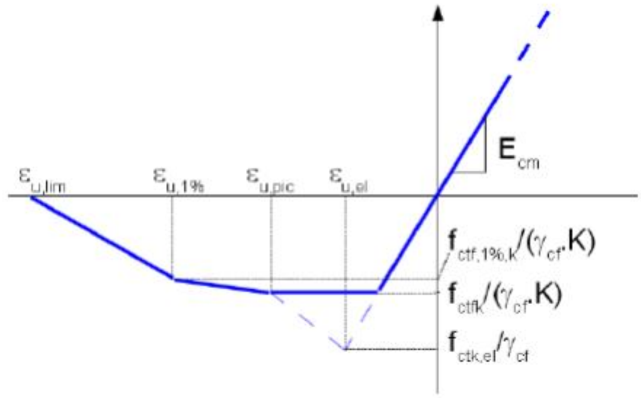

Figure 8 Stress - Strain Curve of Tensile Force

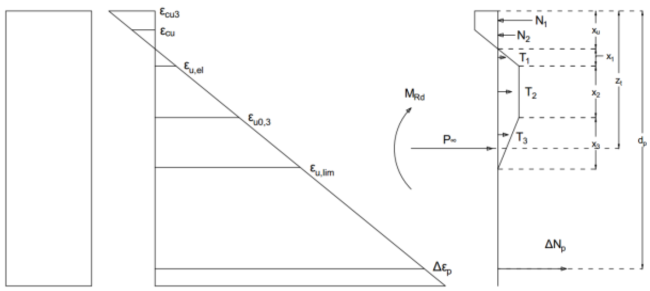

Figure 9 Bending Moment Capacity of Internal Forces

Moment	0,66
Shear	0,97
Transverse moment top flange (cracking)	0,44
Transverse moment web (cracking)	0,84
Deflection (traffic)	0,34
Deflection (camber)	0,16
Cracking	0,46
Concrete fatigue	0,28
Steel fatigue	0,10

Figure 10 Unity Check Performed For 60m Long Box Beam

VII. UHPC BOX BEAM (>70M)

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Height	h	1600	mm
Width	b	1500	mm
Top flange thickness	d_{top}	170	mm
Bottom flange thickness	d_{bot}	225	mm
Web thickness	d_w	85	mm
Cross-section area	A_c	$0{,}797 \times 10^6$	mm^2
Top fiber distance to neutral axis	z_t	855	mm
Bottom fiber distance to neutral axis	z_b	745	mm
Moment of inertia	I_c	$3{,}144 \times 10^{11}$	mm^4
Section modulus top fiber	W_t	$3{,}68 \times 10^8$	mm^3
Section modulus bottom fiber	W_b	$4{,}22 \times 10^8$	mm^3
Amount of prestressing steel	A_p	174000	mm^2
Drape of prestressing strands	f_p	631	mm
Mass	G	142,2	t

Figure 13 Properties of Box Beam (>70m)

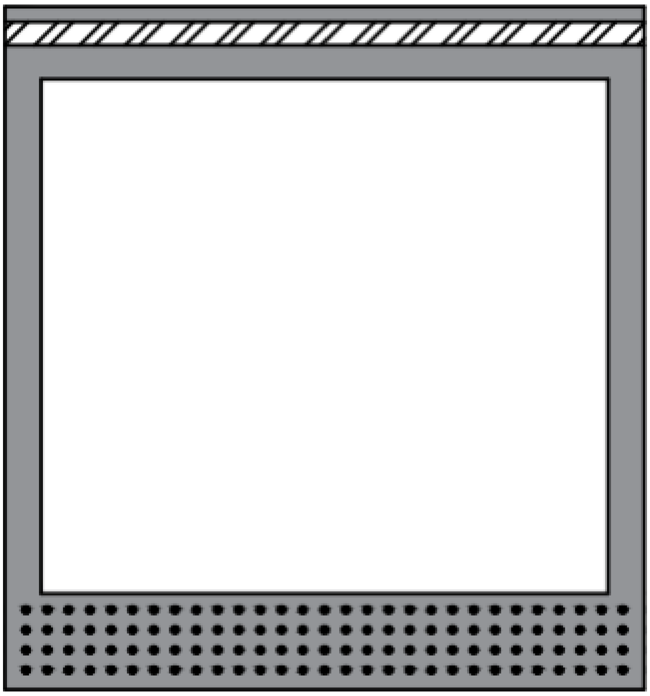

Figure 22 c/s of transverse post tensioning and pre tensioning

Moment	0,58
Shear	0,95
Transverse moment top flange (cracking)	0,47
Transverse moment web (cracking)	0,74
Deflection (traffic)	0,31
Deflection (camber)	0,17
Cracking	0,43
Concrete fatigue	0,42
Steel fatigue	0,17

Figure 11 Unity Check Performed on 70m Box Beam

VIII. UHPC BOX BEAM (>80M)

Height	h	2000	mm
Width	b	1250	mm
Top flange thickness	d_{top}	170	mm
Bottom flange thickness	d_{bot}	225	mm
Web thickness	d_w	85	mm
Cross-section area	A_c	$0{,}77 \times 10^6$	mm^2
Top fiber distance to neutral axis	z_t	1062	mm
Bottom fiber distance to neutral axis	z_b	938	mm
Moment of inertia	I_c	$4{,}570 \times 10^{11}$	mm^4
Section modulus top fiber	W_t	$4{,}30 \times 10^8$	mm^3
Section modulus bottom fiber	W_b	$4{,}87 \times 10^8$	mm^3
Amount of prestressing steel	A_p	180000	mm^2
Drape of prestressing strands	f_p	824	mm
Mass	G	156,3	t

Figure 14 Properties of Box Beam(>80m)

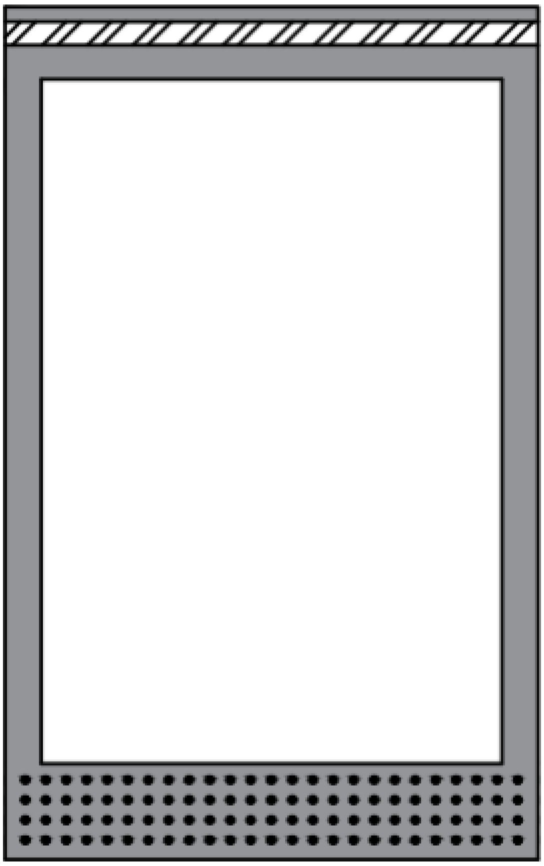

Figure 15 C/s of Transverse Post and Pre-Tensioning

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Moment	0,64
Shear	0,74
Transverse moment top flange (cracking)	0,41
Transverse moment web (cracking)	0,46
Deflection (traffic)	0,23
Deflection (camber)	0,28
Cracking	0,50
Concrete fatigue	0,04
Steel fatigue	0,22

Figure 17 Unity Check Performed on 80m Long Box Beam

IX. UHPC BOX BEAM (>85M)

Height	h	2200	mm
Width	b	1000	mm
Top flange thickness	d_{top}	170	mm
Bottom flange thickness	d_{bot}	270	mm
Web thickness	d_w	85	mm
Cross-section area	A_c	$0{,}74 \times 10^6$	mm^2
Top fiber distance to neutral axis	z_t	1199	mm
Bottom fiber distance to neutral axis	z_b	1001	mm
Moment of inertia	I_c	$4{,}99 \times 10^{11}$	mm^4
Section modulus top fiber	W_t	$4{,}17 \times 10^8$	mm^3
Section modulus bottom fiber	W_b	$4{,}99 \times 10^8$	mm^3
Amount of prestressing steel	A_p	225000	mm^2
Drape of prestressing strands	f_p	864	mm
Mass	G	160,1	t

Figure 18 Properties Of 80m Long Box Beam

Moment	0,57
Shear	0,61
Transverse moment top flange (cracking)	0,33
Transverse moment web (cracking)	0,30
Deflection (traffic)	0,22
Deflection (camber)	0,34
Cracking	0,45
Concrete fatigue	0,15
Steel fatigue	0,22

Figure18 Unity Check Performed On 85m Long Box Beam

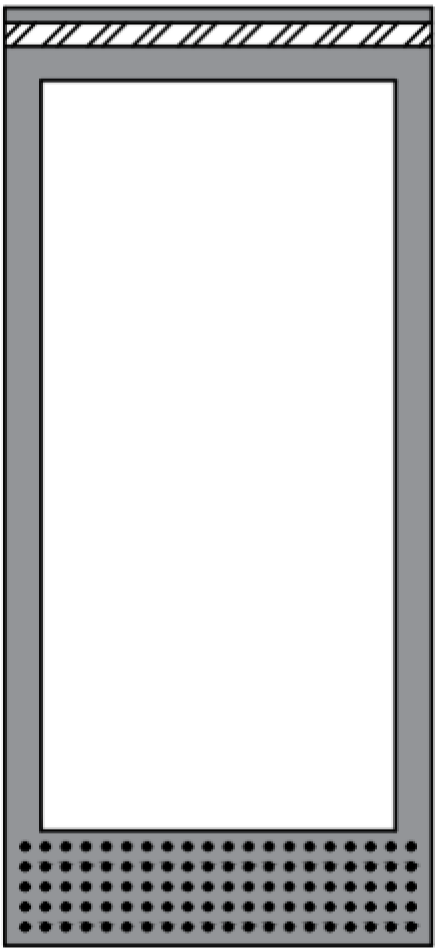

Figure 6 C/s of Transverse Post and Pre-Tensioning

X. UHPC BOX BEAM (>90M)

Height	h	2450	mm
Width	b	1000	mm
Top flange thickness	d_{top}	170	mm
Bottom flange thickness	d_{bot}	270	mm
Web thickness	d_w	85	mm
Cross-section area	A_c	$0{,}78 \times 10^6$	mm^2
Top fiber distance to neutral axis	z_t	1332	mm
Bottom fiber distance to neutral axis	z_b	1118	mm
Moment of inertia	I_c	$6{,}51 \times 10^{11}$	mm^4
Section modulus top fiber	W_t	$4{,}89 \times 10^8$	mm^3
Section modulus bottom fiber	W_b	$5{,}82 \times 10^8$	mm^3
Amount of prestressing steel	A_p	225000	mm^2
Drape of prestressing strands	f_p	981	mm
Mass	G	179,3	t

Figure 20 Properties of 90m Long Box Beam

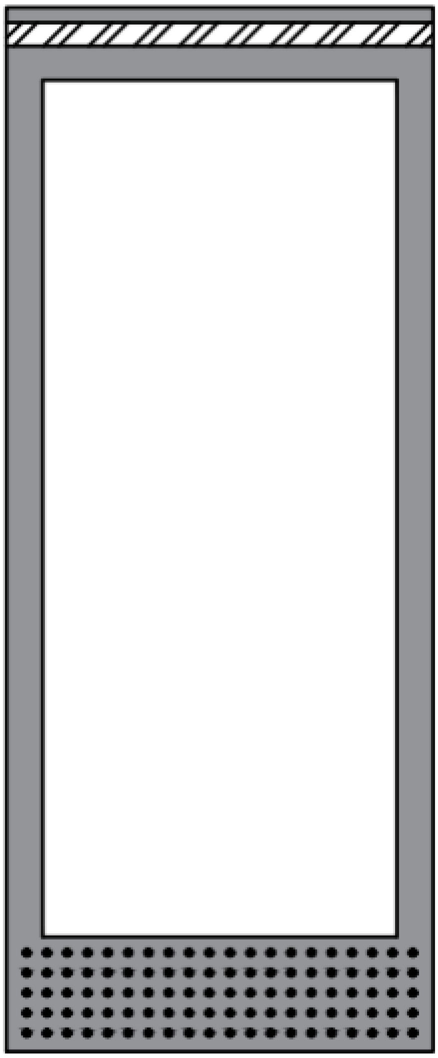

Figure 21 C/s of Transverse Post and Pre-Tensioning

Moment	0,60
Shear	0,59
Transverse moment top flange (cracking)	0,34
Transverse moment web (cracking)	0,27
Deflection (traffic)	0,21
Deflection (camber)	0,49
Cracking	0,48
Concrete fatigue	0,03
Steel fatigue	0,27

Figure 22 Unity Check Performed on 90m Long Box Beam

Beam and Bridge Properties					
Span	60	70	80	85	90
Concrete Class	C170	C170	C170	C170	C170
Slenderness ratio	46,2	43,8	40,0	38,6	36,7
Height	1300	1600	2000	2200	2450
Width	1500	1500	1250	1000	1000
Top flange thickness	170	170	170	170	170
Bottom flange thickness	225	225	225	270	270
Web thickness	90	85	85	85	85
Beam mass	115,5	142,2	156,3	160,1	179,3
Total cross-section area	7,55	7,97	9,20	11,09	11,73
Total amount of p-steel	156000	174000	180000	225000	225000
Unity Checks					
Moment	0,66	0,58	0,64	0,57	0,60
Shear	0,97	0,95	0,74	0,61	0,59
Transverse moment top flange (cracking)	0,44	0,47	0,41	0,33	0,34
Transverse moment web (cracking)	0,84	0,74	0,46	0,30	0,27
Deflection (traffic)	0,34	0,31	0,23	0,22	0,21
Deflection (camber)	0,16	0,17	0,28	0,34	0,49
Cracking	0,46	0,43	0,50	0,45	0,48
Concrete fatigue	0,28	0,42	0,04	0,15	0,03
Steel fatigue	0,10	0,17	0,22	0,22	0,27

Figure 23 Overall Comparison of Long Box Beam

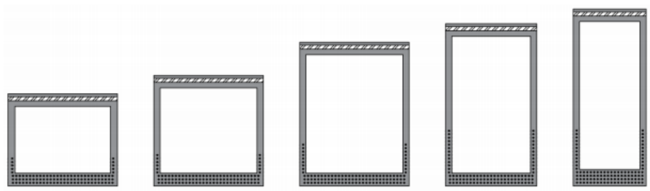

Figure 24 Diagram Representing Long Box Beam

XI. CONCLUSION

A total of 5 models for UHPC package beam bridges with spans of 60m, 80m, 70m, 85m as well as 90m were put together to help this theory. The styles are actually enhanced to minimalize material consumption and discover by far the slenderest as well as mild bridge attainable. This may be done with the next optimization strategies:

• Omit transverse reinforcement almost as possible

• Minimizing beam level until the optimum amount of prestress or maybe deformation capacity is actually reached

• Maximizing minimizing web and beam width thickness until shear capacity is actually reached

• Minimizing bottom flange thickness by using as a lot of strands as you can per level the layouts for spans of 60m as well as 70m may be enhanced with the technique above. The style for 80m was constrained through the pounds cap of 170t for commuter routes by street. In order to keep this cap, the beam width is actually decreased. The breadth of 1500mm would result in an exceedance, as a result the 80m style has a breadth of 1250mm. For the exact same explanation, the 85m beam has a reduced width of 1000mm. The style for 90m couldn't be maintained below 170t without lessening the breadth to below 1000mm. Nevertheless, a 90m layout was even now made with 1000mm breadth to exhibit the feasibility and productivity the UHPC beam. Ultimately the optimized designs had been compared with current box beam strategies that make use of a lot of more traditional concrete sessions like C60. This comparison study proved that the UHPC beams hold the following benefits:

• More slender beams having a slenderness ratio of up to 46,2 may be made to satisfy strict slenderness needs as well as to reduce needed elevation height of this bridge. SKK-beams possess a slenderness ratio which range from thirty to thirty-two.

• Lighter bridges with fat reductions up to thirty-six % compared to SKK beam bridges could be made to greatly reduce loading on the bridge as well as improve the simplicity of transportation. Additionally, greater beams of 85m may be made, while even now being in the position to carry these by road. Conclusions 114

• Wider beams of 1500 rather than 1200mm may be made decreasing the entire mass of webs and cutting back on the number of beams which should be produced and sent.

• Beams which don't involve transverse reinforcement aside from transverse posttensioning could be made. This could bring down the needed quantity of labor and steel.

Besides the UHPC package beams with kinked hair strands in the webs an additional variant with straight locks in the webs is actually developed. This enables a reduction in the selection of strands in the bottom part flange and more locks in the net. As a result, a lot more slender and lighter beams could be turned around comparison to the UHPC package beams with kinked hair strands. The slenderness of the beams reaches up to forty-eight and the weight reduction gets to up to forty-one %. This variant becomes just light that they are able to be moved by road while for 90m longer beams. To further enhance this particular variant the strands in the strands and the web in the bottom part flange positioned below the net could be kinked. As an outcome, the sheer power grows. This's advantageous for smaller spans, permitting lighter bridges, by raising both beam width of minimizing web thickness. For large spans the beams can't be made any wider as a result of the 170t industry limit, therefore this approach just succeeds for shorter bridges. Nevertheless, in case these longer beams could be moved by water, subsequently the pounds limit no longer can be applied. In this particular situation these beams may be built wider and the method gets much more fascinating.

This very last most optimized variant called KSIW beams (Kinked Strands within Web) offer loads of potential programs since they're both slender and light very. Initially, they present a fit option for fresh bridges with spans which are way too long for typical package beam strategies, without having to create an intermediate pier or maybe switch to segmented or even cast in situ solutions. Next, they permit us to upgrade older bridges with a much stronger one without needing to change the current substructure. Both these apps have the benefit of lowering traffic hindrance. For the 2nd program it's also examined whether it's feasible to omit the current intermediate pier. Slenderness smart this's possible, since the KSIW beams only require almost no level for long spans. Nevertheless, they're not lightweight enough, to stop the reaction power at the abutment to remain the same with no intermediate pier.

Thus, the substructure should have adequate overcapacity, or maybe the substructure needs to be strengthened to create this possible. To conclude UHPC box beams are actually a fit option for both brand-new bridges and swapping old bridges, since they are able to result in much less traffic hindrance, because of their superb slenderness and lightness.

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