

Contents

	Editorial	IX
1	Introduction.....	1
2	Principles for the production of UHPC.....	5
2.1	Development.....	5
2.2	Basic material concepts.....	6
2.2.1	Microstructure properties.....	6
2.2.2	Grading optimization.....	8
2.3	Raw materials.....	12
2.3.1	Cement.....	12
2.3.2	Reactive admixtures.....	12
2.3.2.1	Silica fume.....	12
2.3.2.2	Ground granulated blast furnace slag.....	13
2.3.3	Inert admixtures.....	14
2.3.4	Superplasticizers.....	14
2.3.5	Steel fibres.....	14
2.4	Mix composition.....	15
2.5	Mixing.....	15
2.6	Curing and heat treatment.....	17
2.7	Testing.....	18
2.7.1	Fresh concrete.....	18
2.7.2	Compressive and flexural tensile strengths.....	20
3	Mechanical properties of the hardened concrete	23
3.1	General.....	23
3.2	Behaviour in compression.....	23
3.2.1	UHPC without fibres.....	23
3.2.2	UHPC with steel fibres.....	24
3.2.3	Further factors affecting the compressive strength.....	27
3.2.3.1	Geometry of test specimen and test setup.....	27
3.2.3.2	Heat treatment.....	27
3.3	Behaviour in tension.....	27
3.3.1	Axial (concentric) tension loads.....	27
3.3.2	Flexural tensile strength.....	32
3.3.3	Derivation of axial tensile strength from compressive strength.....	34
3.3.4	Derivation of axial tensile strength from bending tests.....	35
3.3.5	Splitting tensile strength.....	36
3.3.6	How fibre geometry and orientation influence the behaviour of UHPC in tension.....	36
3.3.7	Converting the stress–crack width relationship into a stress–strain diagram.....	39
3.3.8	Interaction of fibres and bar reinforcement.....	41
3.4	Shrinkage.....	42
3.5	Creep.....	43

3.6	Multi-axial stresses	44
3.7	Fatigue behaviour.....	44
3.8	Dynamic actions.....	51
3.9	Fire resistance	53
3.10	UHPC with combinations of fibres ('fibre cocktails').....	53
4	Durability	59
4.1	Microstructure.....	59
4.2	Resistance to aggressive media.....	59
4.3	Classification in exposure classes	63
5	Design principles	65
5.1	Influence of fibre distribution and fibre orientation.....	65
5.2	Analyses for the ultimate limit state.....	66
5.2.1	Safety concept.....	66
5.2.2	Simplified stress–strain curve for design.....	67
5.2.2.1	Compression actions	67
5.2.2.2	Tension actions	70
5.2.3	Design for bending and normal force.....	72
5.2.4	Design for shear	75
5.2.4.1	Tests at the University of Kassel.....	75
5.2.4.2	Tests at RWTH Aachen University.....	79
5.2.4.3	Tests at Delft University of Technology	81
5.2.5	Punching shear.....	84
5.2.6	Strut-and-tie models.....	85
5.2.6.1	Load-carrying capacity of struts.....	86
5.2.6.2	Load-carrying capacity of ties.....	87
5.2.6.3	Load-carrying capacity of nodes.....	87
5.2.7	Partially loaded areas	88
5.2.8	Fatigue	88
5.3	Analyses for the serviceability limit state.....	89
5.3.1	Limiting crack widths	89
5.3.2	Minimum reinforcement	97
5.3.3	Calculating deformations	99
6	Connections.....	105
6.1	General.....	105
6.2	Dry joints	105
6.3	Glued joints.....	105
6.4	Wet joints.....	108
6.5	Grouted joints	111
6.6	Adding UHPC layers to existing components to upgrade structures ..	113
7	Projects completed	117
7.1	Bridges.....	117
7.1.1	Canada	117

7.1.1.1	Bridge for pedestrians/cyclists, Sherbrooke (1997)	117
7.1.1.2	Glenmore/Legsby footbridge, Calgary (2007)	117
7.1.2	France	118
7.1.2.1	Road bridge, Bourg-lès-Valence	118
7.1.2.2	Pont du Diable footbridge (2005)	119
7.1.2.3	Pont de la Chabotte road bridge	120
7.1.2.4	Pont Pinel road bridge (2007)	121
7.1.2.5	Strengthening the Pont sur l’Huisne, Mans	124
7.1.3	Japan	124
7.1.3.1	Sakata-Mirai footbridge (2003).....	124
7.1.3.2	GSE Bridge, Tokyo Airport (2010)	126
7.1.3.3	Tokyo Monorail, Haneda Airport line.....	128
7.1.4	South Korea	129
7.1.4.1	Seonyu ‘Bridge of Peace’, Seoul.....	129
7.1.4.2	KICT cable-stayed footbridge (2009)	131
7.1.4.3	Design for Jobal Bridge (KICT).....	132
7.1.5	Germany	133
7.1.5.1	Bridges over River Nieste near Kassel	133
7.1.5.2	Gärtnerplatz Bridge over River Fulda, Kassel (2007).....	134
7.1.5.3	HSLV pilot project.....	137
7.1.5.4	Bridge for pedestrians/cyclists over River Pleiße, Markkleeberg (2012).....	140
7.1.6	Austria.....	141
7.1.6.1	Wild Bridge near Völkermarkt.....	141
7.1.6.2	Bridge for pedestrians/cyclists, Lienz	143
7.1.6.3	Modular temporary bridge for high-speed rail lines.....	144
7.1.7	Switzerland	146
7.1.8	The Netherlands	147
7.2	Applications in buildings	149
7.2.1	Columns	149
7.2.2	Façades	151
7.2.3	Stairs and balconies.....	152
7.2.4	Roofs.....	155
7.3	Other applications	157
7.3.1	Runway, Haneda Airport, Tokyo, Japan	157
7.3.2	Jean Bouin Stadium, Paris	160
8	Acknowledgements	163
	References	165
	Index	183

