

Contents

Editorial	IX
1 Introduction	1
1.1 The reason behind this book	1
1.2 Strengthening with adhesively bonded reinforcement	1
2 DAfStb guideline	3
2.1 The reasons for drawing up a guideline	3
2.2 Preparatory work.....	3
2.3 Work on the guideline	4
2.4 The structure and content of the guideline	4
2.4.1 General.....	4
2.4.2 Design and detailing	4
2.4.3 Products and systems	4
2.4.4 Execution	5
2.4.5 Planning	5
2.5 Safety concept.....	5
2.6 Applications.....	6
2.6.1 Member to be strengthened.....	6
2.6.2 Strengthening systems	7
2.6.3 Ambient conditions.....	7
2.6.4 Fire protection	8
2.7 Relationship with other regulations.....	9
2.8 Documents and assistance for practical applications.....	10
3 Design of strengthening measures with externally bonded CFRP strips	11
3.1 Principles	11
3.2 Verification of flexural strength	13
3.3 Bond analysis.....	15
3.3.1 Principles	15
3.3.2 Simplified method.....	16
3.3.3 More accurate method.....	17
3.3.3.1 General.....	17
3.3.3.2 Determining the crack spacing.....	19
3.3.3.3 Accurate analysis of concrete element between cracks	20
3.3.3.4 Simplified analysis of element between cracks	23
3.3.4 End anchorage analysis.....	24
3.3.4.1 General.....	24
3.3.4.2 End anchorage analysis at flexural crack nearest to point of contraflexure.....	24
3.3.4.3 Anchorage analysis at an arbitrary concrete element between cracks	26

3.3.4.4	End anchorage analysis with shear wrapping.....	27
3.4	Shear force analyses.....	29
3.4.1	Shear strength.....	29
3.4.2	Shear strengthening.....	30
3.4.2.1	Full wrapping in steel.....	31
3.4.2.2	Full wrapping in fibre-reinforced material	32
3.4.2.3	U-wrapping	32
3.4.3	End strap to prevent concrete cover separation failure.....	33
3.5	Fatigue analysis.....	35
3.6	Analyses for the serviceability limit state.....	36
3.7	Detailing.....	36
3.7.1	Strip spacing	36
3.7.2	Provision of shear straps	37
3.7.3	Steel shear straps	37
4	Example 1: Strengthening a slab with externally bonded CFRP strips	39
4.1	System.....	39
4.1.1	General.....	39
4.1.2	Loading	39
4.1.3	Construction materials	40
4.1.3.1	Near-surface tensile strength	40
4.1.3.2	Concrete compressive strength	41
4.1.3.3	Type and quantity of existing reinforcement.....	41
4.1.3.4	Position of existing reinforcement	41
4.1.3.5	Strengthening system	41
4.2	Internal forces	42
4.3	Determining the prestrain.....	42
4.4	Simplified analysis	44
4.5	Accurate analysis	46
4.5.1	General.....	46
4.5.2	Verification of flexural strength	46
4.5.3	Determining the crack spacing.....	48
4.5.4	Accurate analysis of concrete element between cracks	48
4.5.4.1	Determining the strip forces.....	49
4.5.4.2	Determining the bond strength.....	52
4.5.5	End anchorage analysis.....	55
4.6	Analysis of shear capacity.....	58
4.7	Serviceability limit state.....	59
5	Design of strengthening with near-surface-mounted CFRP strips	61
5.1	Principles	61
5.2	Verification of flexural strength	61
5.3	Bond analysis.....	63
5.4	Shear Force Analyses.....	65

5.5	Fatigue analysis.....	66
5.6	Analyses for the serviceability limit state.....	67
5.7	Detailing.....	67
6	Example 2: Strengthening a beam with near-surface-mounted CFRP strips.....	69
6.1	System.....	69
6.1.1	General.....	69
6.1.2	Loading	69
6.1.3	Construction materials	71
6.1.3.1	Concrete compressive strength	71
6.1.3.2	Type and quantity of existing reinforcement.....	71
6.1.3.3	Position of existing reinforcement	71
6.1.3.4	Strengthening system	71
6.2	Internal forces	72
6.3	Determining the prestrain.....	72
6.4	Verification of flexural strength	74
6.5	Bond analysis.....	76
6.5.1	Analysis point	76
6.5.2	Acting strip force	78
6.5.3	Bond resistance	79
6.5.4	Bond analysis.....	80
6.6	Shear analyses.....	80
6.6.1	Shear capacity	80
6.6.2	Shear strengthening.....	81
6.6.3	Check for concrete cover separation failure.....	82
6.7	Analyses for the serviceability limit state.....	84
7	Design of column strengthening with CF sheets.....	87
7.1	Principles	87
7.2	Properties of CF sheets relevant to design	91
7.3	Load-carrying capacity of cross-section.....	93
7.4	Load-carrying capacity of member	98
7.5	Creep.....	102
7.6	Analysis at ultimate limit state	105
7.7	Analysis at serviceability limit state.....	111
8	Example 3: Column strengthening.....	115
8.1	System.....	115
8.1.1	General.....	115
8.1.2	Loading	115
8.1.3	Construction materials	116
8.1.3.1	Concrete.....	116
8.1.3.2	Type and quantity of existing reinforcement.....	116
8.1.3.3	Strengthening system	117
8.2	Internal forces	118

8.3	Determining the cross-sectional values	118
8.4	Boundary conditions	119
8.5	Verification of column load-carrying capacity	120
8.5.1	Creep of confined concrete.....	120
8.5.2	Properties of the CF sheet	121
8.5.3	Distribution of transverse compression	122
8.5.4	Multi-axial stress state in concrete	122
8.5.5	Calculation of column load-carrying capacity	123
8.6	Serviceability limit state.....	127
9	Summary and outlook.....	129
	References.....	131
	Index	145