List of Figures

Figure No.	Title	Page No.
1.1	Phases in a typical composite	1
1.2	Classification of composites	1
1.3	Structural composites	3
1.4	Schematic of fiber reinforced composites	4
1.5	Hand layup process	5
1.6	Pultrusion process for manufacturing of FRP profiles	6
1.7	Types of fibers	7
1.8	Buckling of beams	10
1.9	Crippling of I-beam	10
2.1	Shear test apparatus for composite specimens	24
2.2	Failure of web-flange junction	30
2.3	Tensile testing of web-flange junction specimen	31
2.4	Illustration of loading conditions	33
2.5	Formation of plastic hinges at the corner of the opening	36
2.6	Beam with fillet corner web opening	38
3.1	Dimensions and layup of I-beams	40
3.2	Coordinate system of FRP I-beam	45
3.3	Ignition of samples in a muffle furnace for removal of resin	48
3.4	Tensile testing of coupon	48
3.5	Stress vs strain curves obtained from tensile testing of coupons	49
3.6	Compression testing of specimen	50
3.7	Three-point bending test of coupon	52
3.8	Load versus deflection curves obtained from 3-point bending test of coupons of beams	52
3.9	Response of short span coupon under flexural loading	54
3.10	Flexural testing of beams	55
3.11	Regression analysis of beams for measurement of Young’s and shear moduli	57
3.12	Load-deflection responses of beams under four-point loading	58

3.13	Comparison of load-deflection responses obtained from experimental investigation and analytical Eq. (3.26)	60
4.1	Experimental set-up for 3-point bending test of GFRP I-beam	66
4.2	Deformation of the beams under different lengths of bearing plates	67
4.3	Flexural responses of beams with different lengths of bearing plates	68
4.4	Failure mode of FRP I-beam (7B-TS-F-B beam) with T-shaped stiffener	70
4.5	Dimensions and layup of stiffeners	70
4.6	Load vs deflection responses of the beams with and without imperfection	71
4.7	Failure mode of the beam with bonded and bolted stiffener under three-point loading (7B-TS-F)	72
4.8	Load vs deflection responses of beams with bonded and bolted connection	72
4.9	Failure mode of the beams having bearing stiffeners under the loading and over supports	73
4.10	Load vs deflection curves of beams with different sizes of stiffener	74
4.11	Flexural behavior of the FRP I-beam with cover plate (7C-CP beam)	75
4.12	Load vs deflection responses of beams with and without cover plate	75
4.13	Local failure of the compression flange of beam stiffened with FRP web plate (7C-WP-AS beam)	76
4.14	Load vs deflection responses of beams with and without web plate	77
4.15	Deformation of the beam with cover angle under the loading	78
4.16	Load vs deflection responses of beams with GFRP cover angle and carbon fiber layers	79
4.17	Flexural deformation of the beams having L/d ratio 5	80
4.18	Load vs deflection responses of PULT-B beams with and without bearing stiffener	80
4.19	Crushing of compression flange of the beam 5C-TS-AS under three-point bending	81
4.20	Plot of load vs deflection responses of beams 5C-BP125 and 5C-TS-AS	81
4.21	Failure of beams under three-point bending test having L/d ratio 3	82

4.22	Load vs deflection responses of the PULT-C beams with and without bearing stiffener	82
4.23	Flexural behavior of beams having L/d ratio 3	83
4.24	Load vs deflection plot of the beams 'PULT-C' with and without bearing stiffener having L/d ratio 3	83
4.25	Comparison of load vs deflection responses of beams with different stiffening element	85
4.26	Fabrication process of FRP castellated beam	86
4.27	Flexural deformation of the castellated beam under 3-point loading	87
4.28	Flexural responses of FRP castellated and parent (7C-BP) beams	87
5.1	Flow chart of the computational model of FRP I-beam	90
5.2	Cordination system of I-beam	91
5.3	Shear deformation of I-beam	92
5.4	Typical cross-section of I-beam	94
5.5	Schematic of beams with stiffening elements	97
5.6	Modes of failure of I-section	103
5.7	Distribution of bearing stress in beam	107
5.8	Bearing area of beam with different stiffening elements (Top view of I-beam without flanges)	107
6.1	Discrete rigid shell bearing plate	109
6.2	Half part of castellated beam	110
6.3	ABAQUS model of I-beam having concentrated load on the center of bearing plate and have simply supported boundary conditions	112
6.4	Failure mode of the beam with bearing plate	114
6.5	Comparison of flexural responses of beams having different L/d ratios	115
6.6	Load-deflection responses of beams with bearing plate and bearing stiffeners	119
6.7	Stress profile in beams of different length-to-depth (L/d) ratios	119
6.8	Beam stiffened with cover angle at compression web-flange junction	121
6.9	Beam stiffened with carbon fiber layers at compression web-flange junction	122
6.10	Beam stiffened with web plate at mid-span	123
6.11	Beam stiffened with cover plate at mid-span	124

6.12	Effect of length of bearing plate on the service and failure loads of beams	127
6.13	Effect of variation in transverse modulus on failure and service loads of beams	129
6.14	Buckling of beam having h_w/t ratio 40, b/t ratio 5 and L/d ratio 7, with size of bearing plate 210 mm (a/L=0.2)	129
6.15	Effect of variation in shear modulus on failure and service loads of beams	130
6.16	Influence of length of bearing plate/flange width of bearing stiffener on failure and service loads of beams	132
6.17	Local buckling of beam having bearing plate of size $0.7b_{tf}$ and h_w/t ratio 40	132
6.18	Influence of length of cover angle on failure and service loads of beams	134
6.19	Variation of service and failure loads of beams w.r.t. ratio of length of carbon fiber layer/ length of the beams	136
6.20	Local buckling of beams having carbon fiber layer	137
6.21	Variation of service and failure loads of beams	139
6.22	Variation of stresses near the bolted connection	140
6.23	Flexural deformation of castellated beam under three-point loading	141
6.24	Comparison of experimental and numerical flexural response of beams having hexagonal cutout	142
6.25	Castellated beam with hexagonal openings	142
6.26	Stress variation in beams having different shape of openings	144