List of Figures

Figure 1.1 Design truck (HS-20), design tandem load (a pair of 25 kip axles 4 ft apart), and design lane load (0.64 kips/ft longitudinally distributed) 8

Figure 1.2 Fatigue live loading 9

Figure 1.3 Shear and moment diagrams for controlling design truck (HS-20) live load position 14

Figure 1.4 Shear and moment diagrams for the design truck (HS-20) center axle at midspan 15

Figure 2.1 T-beam design example 18

Figure 2.2 Interior T-beam section 20

Figure 2.3a Influence lines for moment at midspan 21

Figure 2.3b Influence lines for shear at support 21

Figure 2.4 Design truck (HS-20) position for moment at midspan 22

Figure 2.5 Design tandem load position for moment at midspan 22

Figure 2.6 Design truck (HS-20) position for shear at support 22

Figure 2.7 Design tandem load position for shear at support 22

Figure 2.8 Lever rule for determination of distribution factor for moment in exterior beam, one lane loaded 25

Figure 2.9 Moment distribution for deck slab and wearing surface loads .. 32

Figure 2.10 Moment distribution for curb and parapet loads for exterior girder 33

Figure 2.11 T-beam section and reinforcement in T-beam stem 36

Figure 2.12 Critical shear section at support 41

Figure 2.13 Lane load position for maximum shear at critical shear section 43

Figure 2.14 Fatigue truck loading and maximum moment at 32 kips position per lane due to fatigue loading 51

Figure 2.15 Cracked section determination of T-beam 54

Figure 2.16 T-beam bridge cross section 62

Figure 2.17 T-beam section 62

Figure 2.18 Interior T-beam section for determination of flexural resistance 67

Figure 2.19 Critical section for shear at support 69

Figure 2.20 Live load shear at critical shear section due to lane load 70

Figure 2.21 Composite steel–concrete bridge example 75

Figure 2.22 Steel section 75

Figure 2.23 Composite steel section 76

Figure 2.24 Composite section for stiffness parameter, K_g 79

Figure 2.25 Lever rule for determination of distribution factor for moment in exterior beam, one lane loaded 81

Figure 2.26 Load position for moment at midspan for design truck load (HS-20) 83

Figure 2.27 Load position for moment at midspan for design tandem load 84

Figure 2.28 Load position for moment at midspan for design lane load 84

Figure 2.29 Load position for shear at support for design truck load (HS-20) 85

Figure 2.30 Load position for shear at support design tandem load 85

Figure 2.31 Load position for shear at support for design lane load 86

Figure 2.32 Composite steel–concrete section for shear and moment capacity calculation 88

Figure 2.33 Section and cross section of interior girder for plastic moment capacity 91

Figure 2.34 Composite cross section for exterior beam 92

Figure 2.35 Section and cross section of exterior girder for plastic moment capacity 95

Figure 2.36 Interior girder section prior to transformed area 100

Figure 2.37 Interior girder section after transformed area 101

Figure 2.38 Dimensions for transformed interior beam section 101

Figure 2.39 Exterior girder section prior to transformed area 106

Figure 2.40 Exterior girder section after transformed area 106

Figure 2.41 Dimensions for transformed exterior beam section 107

Figure 2.42 Single lane fatigue load placement with one design truck load for maximum moment at midspan 112

Figure 2.43 Single lane fatigue load placement with one design truck load for maximum shear at support 116

Figure 2.44 Steel girder bridge, 40 ft span 118

Figure 2.45a Influence line for maximum moment at midspan 121

Figure 2.45b Controlling load position for moment at midspan for design truck load (HS-20) 121

Figure 2.45c Controlling load position for moment at midspan for design tandem load 121

Figure 2.45d Controlling load position for moment at midspan for design lane load 121

Figure 2.45e Single lane fatigue load placement with one design truck load for maximum moment at midspan 122

Figure 2.46 Noncomposite steel section at midspan 123

Figure 2.47 Lever rule for determination of distribution factor for moment in exterior beam, one lane loaded 125

Figure 2.48a Maximum live load shears; influence line for maximum shear at support 127

Figure 2.48b Controlling load position for shear at support for design truck load (HS-20) 127

Figure 2.48c Controlling load position for shear at support for design tandem load 127

Figure 2.48d Controlling load position for shear at support for design lane load 127

Figure 2.48e Single lane fatigue load placement with one design truck load for maximum shear at support 128

Figure 2.49 Position of design truck loading (HS-20) for deflection at midspan 137

Figure 2.50 Concrete deck slab design example 145

Figure 2.51 Locations in slab strips for maximum reactions and moments due to dead loads 146

Figure 2.52 Moments and reactions for deck slab dead load excluding deck cantilever 147

Figure 2.53 Moments and reaction for deck slab dead load in deck cantilever 147

Figure 2.54 Moments and reaction for curb and parapet loads 148

Figure 2.55 Moments and reaction for wearing surface loads..... 148

Figure 2.56 Live load placement for maximum negative moment..... 149

Figure 2.57 Live load placement for maximum negative moment, one lane loaded..... 150

Figure 2.58 Live load placement for maximum positive moment in first interior span, one lane loaded 151

Figure 2.59 Live load placement for maximum positive moment, double lane loaded..... 152

Figure 2.60 Live load placement for maximum negative moment in first interior span, one lane loaded 153

Figure 2.61 Live load placement for maximum reaction at first support .. 154

Figure 2.62 Deck slab section for reinforcement placement..... 158

Figure 2.63 Prestressed concrete interior girder design example 165

Figure 2.64 Cross section of girder with composite deck..... 166

Figure 2.65 Area transformed section of girder section 168

Figure 2.66 Bending moments at midspan due to HL-93 loading 171

Figure 2.67 Girder I-beam section..... 176

Figure 2.68 Concrete stresses at midspan at release of prestress for girder I-beam 179

Figure 2.69 Final concrete stresses at midspan after losses 183

Figure 2.70 Reinforced concrete girder design example 184

Figure 2.71 Girder section with area transformed deck slab..... 186

Figure 2.72 Lever rule for distribution factor for exterior girder moment with one lane loaded..... 190

Figure 2.73 Design truck (HS-20) load position for the maximum moment at midspan..... 192

Figure 2.74 Design lane load moment at midspan 193

Figure 2.75 Design truck load (HS-20) load position for the maximum shear at support 193

Figure 2.76 Design lane load position for the maximum shear at support 194

Figure 2.77 Reinforcement details 196

Figure 2.78 Review of shear reinforcement 199

Figure 2.79 Abutment structure 16 ft in height and 29.5 ft in width 202

Figure 2.80 Two-lane bridge supported by seven W30 × 108 steel beams at 29.5 ft wide abutment 202

Figure 2.81 Steel beams at abutment and away from abutment 203

Figure 2.82 Wind loads on abutment transmitted from superstructure ... 205

Figure 2.83 Wind loads on abutments transmitted from vehicle live load 206

Figure 2.84 Forces on abutment from braking 208

Figure 2.85 Summary of forces on abutment due to wind loads, braking forces, temperature changes, and earthquake loads 214

Figure 3.1 Cross section of noncomposite steel beam bridge 216

Figure 3.2 W40 × 249 properties 216

Figure 3.3 Dead loads for interior girder 217

Figure 3.4 Dead loads for exterior girder 220

Figure 3.5 Section for longitudinal stiffness parameter, K_g 223

Figure 3.6 Lever rule for the distribution factor for moments for exterior girder 225

Figure 3.7 Design truck (HS-20) load moment at midspan 227

Figure 3.8 Design tandem load moment at midspan 227

Figure 3.9 Design lane load moment 228

Figure 3.10 Design truck (HS-20) shear at support 228

Figure 3.11 Design tandem load shear at support 229

Figure 3.12 Design lane load shear 229

Figure 3.13 Center of gravity of design truck loading (HS-20) 234

Figure 3.14 Fatigue load position for maximum moment 234

Figure 3.15 Fatigue load position for maximum shear 235

Figure 3.16 Design truck loading for maximum deflection at midspan ... 240

Figure 3.17 Design lane loading for maximum deflection at midspan 242

Figure 3.18 Steel I-beam with concrete slab 245

Figure 3.19 I-beam properties 246

Figure 3.20 Cross-section properties for shears and moments due to dead loads 246
Figure 3.21 Design truck load (HS-20) position for maximum shear 250
Figure 3.22 Design tandem load position for maximum shear 250
Figure 3.23 Design lane load position for maximum shear 251
Figure 3.24 Design truck load (HS-20) position for maximum moment ... 251
Figure 3.25 Design tandem load position for maximum moment 252
Figure 3.26 Design lane load position for maximum moment 252
Figure 3.27 Lever rule for the distribution factor for moments for exterior girder 255
Figure 3.28 Fatigue load position for maximum moment at midspan 260
Figure 3.29 Prestressed concrete I-beam 264
Figure 3.30 Deck and I-beam 264
Figure 3.31 Curb and parapet 265
Figure 3.32 Composite section 267
Figure 3.33 Influence line diagram for maximum moment at midspan ... 272
Figure 3.34 Design truck (HS-20) position for moment at midspan 272
Figure 3.35 Design tandem load position for moment at midspan 273
Figure 3.36 Design lane load for moment at midspan 273
Figure 3.37 Influence line diagram for maximum shear at support 274
Figure 3.38 Design truck position for shear at support 274
Figure 3.39 Design tandem load position for shear at support 274
Figure 3.40 Design lane load for shear at support 274
Figure 3.41 Prestressed I-beam with 30, ½ in strands 279