

# Table of Contents

|                                                    |          |
|----------------------------------------------------|----------|
| <b>Introduction</b> .....                          | <b>1</b> |
| <b>1 Tension and Compression in Bars</b>           |          |
| 1.1 Stress.....                                    | 7        |
| 1.2 Strain.....                                    | 13       |
| 1.3 Constitutive Law .....                         | 14       |
| 1.4 Single Bar under Tension or Compression.....   | 18       |
| 1.5 Statically Determinate Systems of Bars .....   | 29       |
| 1.6 Statically Indeterminate Systems of Bars ..... | 33       |
| 1.7 Supplementary Examples .....                   | 40       |
| 1.8 Summary .....                                  | 47       |
| <b>2 Stress</b>                                    |          |
| 2.1 Stress Vector and Stress Tensor .....          | 51       |
| 2.2 Plane Stress.....                              | 54       |
| 2.2.1 Coordinate Transformation.....               | 55       |
| 2.2.2 Principal Stresses .....                     | 58       |
| 2.2.3 Mohr's Circle .....                          | 64       |
| 2.2.4 The Thin-Walled Pressure Vessel .....        | 70       |
| 2.3 Equilibrium Conditions.....                    | 72       |
| 2.4 Supplementary Examples .....                   | 75       |
| 2.5 Summary .....                                  | 78       |
| <b>3 Strain, Hooke's Law</b>                       |          |
| 3.1 State of Strain.....                           | 81       |
| 3.2 Hooke's Law .....                              | 86       |
| 3.3 Strength Hypotheses .....                      | 92       |
| 3.4 Supplementary Examples .....                   | 94       |
| 3.5 Summary .....                                  | 98       |
| <b>4 Bending of Beams</b>                          |          |
| 4.1 Introduction.....                              | 101      |
| 4.2 Second Moments of Area .....                   | 103      |
| 4.2.1 Definitions.....                             | 103      |
| 4.2.2 Parallel-Axis Theorem.....                   | 110      |

|              |                                                                             |            |
|--------------|-----------------------------------------------------------------------------|------------|
| <b>4.2.3</b> | <b>Rotation of the Coordinate System, Principal Moments of Inertia.....</b> | <b>115</b> |
| <b>4.3</b>   | <b>Basic Equations of Ordinary Bending Theory .....</b>                     | <b>119</b> |
| <b>4.4</b>   | <b>Normal Stresses .....</b>                                                | <b>123</b> |
| <b>4.5</b>   | <b>Deflection Curve .....</b>                                               | <b>127</b> |
| <b>4.5.1</b> | <b>Differential Equation of the Deflection Curve .....</b>                  | <b>127</b> |
| <b>4.5.2</b> | <b>Beams with one Region of Integration.....</b>                            | <b>131</b> |
| <b>4.5.3</b> | <b>Beams with several Regions of Integration .....</b>                      | <b>140</b> |
| <b>4.5.4</b> | <b>Method of Superposition .....</b>                                        | <b>142</b> |
| <b>4.6</b>   | <b>Influence of Shear.....</b>                                              | <b>153</b> |
| <b>4.6.1</b> | <b>Shear Stresses .....</b>                                                 | <b>153</b> |
| <b>4.6.2</b> | <b>Deflection due to Shear.....</b>                                         | <b>163</b> |
| <b>4.7</b>   | <b>Unsymmetric Bending.....</b>                                             | <b>164</b> |
| <b>4.8</b>   | <b>Bending and Tension/Compression .....</b>                                | <b>173</b> |
| <b>4.9</b>   | <b>Core of the Cross Section .....</b>                                      | <b>176</b> |
| <b>4.10</b>  | <b>Thermal Bending .....</b>                                                | <b>178</b> |
| <b>4.11</b>  | <b>Supplementary Examples .....</b>                                         | <b>182</b> |
| <b>4.12</b>  | <b>Summary .....</b>                                                        | <b>190</b> |
| <b>5</b>     | <b>Torsion</b>                                                              |            |
| <b>5.1</b>   | <b>Introduction .....</b>                                                   | <b>193</b> |
| <b>5.2</b>   | <b>Circular Shaft.....</b>                                                  | <b>194</b> |
| <b>5.3</b>   | <b>Thin-Walled Tubes with Closed Cross Sections.....</b>                    | <b>205</b> |
| <b>5.4</b>   | <b>Thin-Walled Shafts with Open Cross Sections .....</b>                    | <b>214</b> |
| <b>5.5</b>   | <b>Supplementary Examples .....</b>                                         | <b>222</b> |
| <b>5.6</b>   | <b>Summary .....</b>                                                        | <b>230</b> |
| <b>6</b>     | <b>Energy Methods</b>                                                       |            |
| <b>6.1</b>   | <b>Introduction .....</b>                                                   | <b>233</b> |
| <b>6.2</b>   | <b>Strain Energy and Conservation of Energy.....</b>                        | <b>234</b> |
| <b>6.3</b>   | <b>Principle of Virtual Forces and Unit Load Method .....</b>               | <b>244</b> |
| <b>6.4</b>   | <b>Influence Coefficients and Reciprocal Displacement Theorem .....</b>     | <b>263</b> |
| <b>6.5</b>   | <b>Statically Indeterminate Systems .....</b>                               | <b>267</b> |
| <b>6.6</b>   | <b>Supplementary Examples .....</b>                                         | <b>281</b> |
| <b>6.7</b>   | <b>Summary .....</b>                                                        | <b>288</b> |

|              |                                              |            |
|--------------|----------------------------------------------|------------|
| <b>7</b>     | <b>Buckling of Bars</b>                      |            |
| <b>7.1</b>   | Bifurcation of an Equilibrium State .....    | <b>291</b> |
| <b>7.2</b>   | Critical Loads of Bars, Euler's Column ..... | <b>294</b> |
| <b>7.3</b>   | Supplementary Examples .....                 | <b>304</b> |
| <b>7.4</b>   | Summary .....                                | <b>308</b> |
| <b>Index</b> | .....                                        | <b>309</b> |