Uniaxial Material Testing
NORMAL STRESS

\[ \sigma = \frac{P}{A} \]
NORMAL STRAIN

\[ \epsilon = \frac{\delta}{L} \]
STRESS VS. STRAIN

SOFT ALLOY

σ

σ_U

σ_Y

0.2%

FAILURES

NOTE: NOT TO SCALE

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“ut tensio, sic vis”

-Robert Hooke, 1678
HOOKE’S LAW

CONSTITUTIVE RELATION
DERIVED FROM STRESS-STRAIN PLOT
Young’s Modulus

\[ E = \frac{\sigma}{\epsilon} \]

<table>
<thead>
<tr>
<th>Material</th>
<th>Young’s Modulus (10^9 N/m^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural steel</td>
<td>200</td>
</tr>
<tr>
<td>Aluminum</td>
<td>70</td>
</tr>
<tr>
<td>Glass</td>
<td>65</td>
</tr>
<tr>
<td>High-strength concrete</td>
<td>30</td>
</tr>
<tr>
<td>Douglas Fir</td>
<td>13</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>3</td>
</tr>
</tbody>
</table>

**Fig. 2.16** Stress-strain diagrams for iron and different grades of steel.
Stress vs. Strain

Low-Carbon Steel

Note: Not to Scale

σ

σ_U

σ_Y

Elastic

0.2%

Perfectly Plastic

Strain Hardening

Necking

Failure

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PLASTIC DEFORMATION

NOTE: NOT TO SCALE
DUCTILITY

ductility = \frac{A_o - A_f}{A_o}
Stress

Strain

1

\( E \)

(note - not to scale)
**Ultimate Tensile Strengths**

<table>
<thead>
<tr>
<th>Material</th>
<th>Tension (MPa)</th>
<th>Compression (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural Steel</strong></td>
<td>400</td>
<td>~400</td>
</tr>
<tr>
<td>ASTM-A36</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4.5% C Cast Iron</strong></td>
<td>170</td>
<td>655</td>
</tr>
<tr>
<td>ASTM-A48</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Douglas Fir</strong></td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td><strong>Concrete</strong></td>
<td>SMALL, VARIABLE</td>
<td>40</td>
</tr>
<tr>
<td><strong>Marble</strong></td>
<td>20</td>
<td>240</td>
</tr>
</tbody>
</table>

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CONCRETE

\[ \sigma \]

\[ \sigma_U, \text{tension} \rightarrow \times \text{Rupture, tension} \]

Linear elastic range

\[ \sigma_U, \text{compression} \]

Rupture, compression
ANISOTROPIC MATERIALS
TENSION TESTING
INSIDE A LOAD CELL
Strain Gauges

Strain sensitive pattern

Terminal

Tension: area narrows, resistance increases.

Higher resistance

Compression: area thickens, resistance decreases.

Lower resistance

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HARDNESS TESTING

RESISTANCE TO DEFORMATION
ROCKWELL HARDNESS TESTING

Depth to which indenter is forced by minor load

Depth to which indenter is forced by major load

Increment in depth due to increment in load is the linear measurement that forms the basis of Rockwell hardness tester readings
INDENTERS
# Common Rockwell Scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Materials</th>
<th>Indenter</th>
<th>Major Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Soft Metals</td>
<td>Hardened Steel Ball</td>
<td>100 kgf</td>
</tr>
<tr>
<td>C</td>
<td>Hard Metals</td>
<td>Brale</td>
<td>150 kgf</td>
</tr>
</tbody>
</table>

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