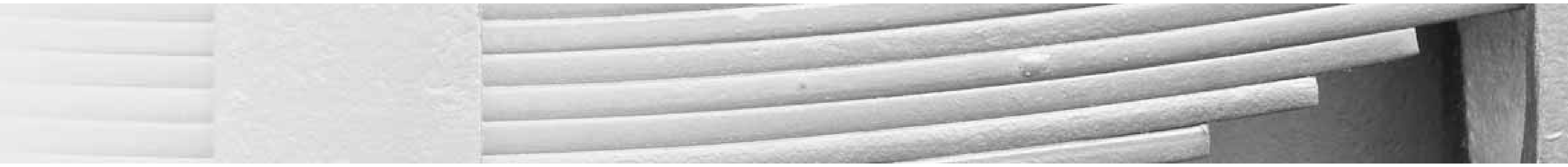


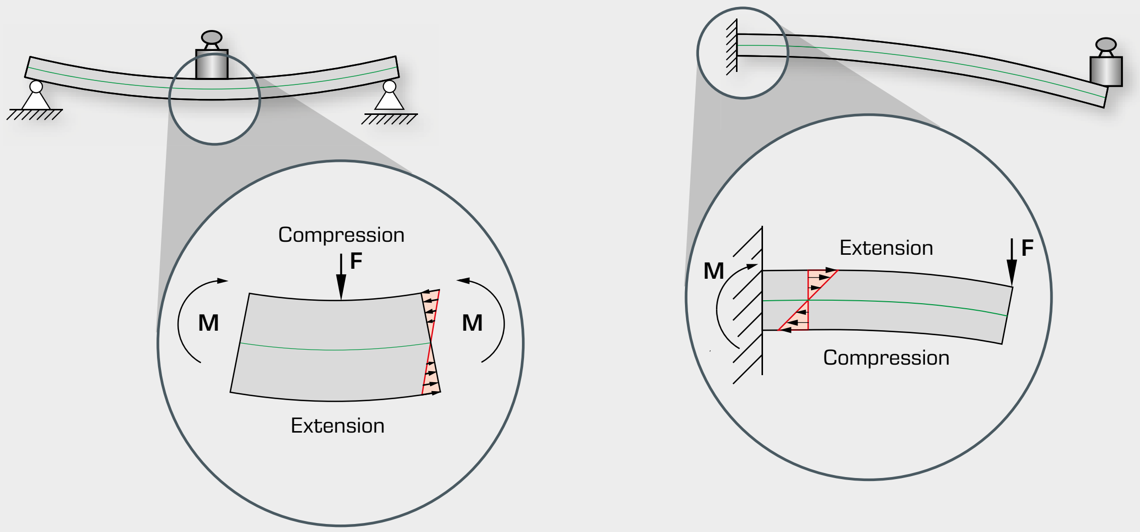
Basic knowledge

Elastic deformations

Components are differently stressed when subjected to load from external forces. Load causes stresses in the components. The mesh of the material is deformed under force action, e.g. compressed and stretched. This load leads to volume or shape deformation. Unlike plastic deformation, elastic deformation means that all atoms return to their original position once the force action ends. Different loads lead to typical component deformations.

Deformation of beams

Deflection and load-bearing capacity of beams are extremely important in practice, in structural engineering and bridge building as well as in mechanical and automotive engineering. Deflection depends on the dimensions, material properties and especially on how the beams are mounted at the ends.

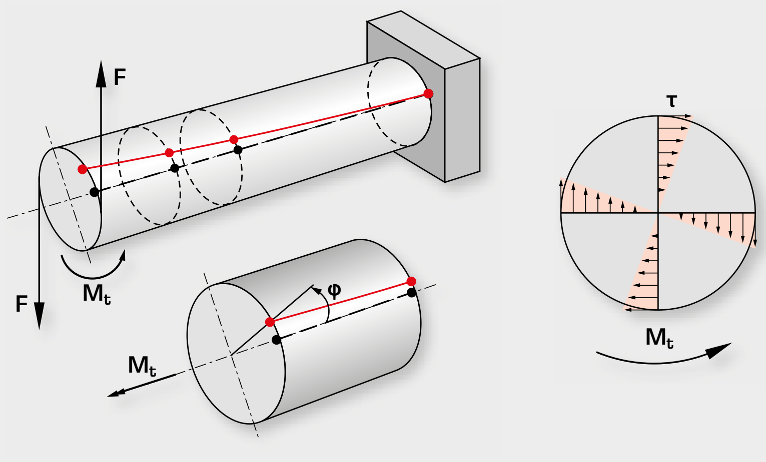


Tensile stress results in the extension of the outer strands, whereas compressive stress results in compression of the outer strands. The neutral strand (green) passes through the centroid and is neither compressed nor extended.

M moment, **F** force

Deformation of bars due to a twisting moment

When subject to a load due to a twisting moment, bars are twisted about their bar axis. The torsional deformation is described by the twisting angle **φ**. Hooke's law states that the twisting angle **φ** is proportional to the externally acting twisting moment.



Torsional stress leads to deformation of the bar.

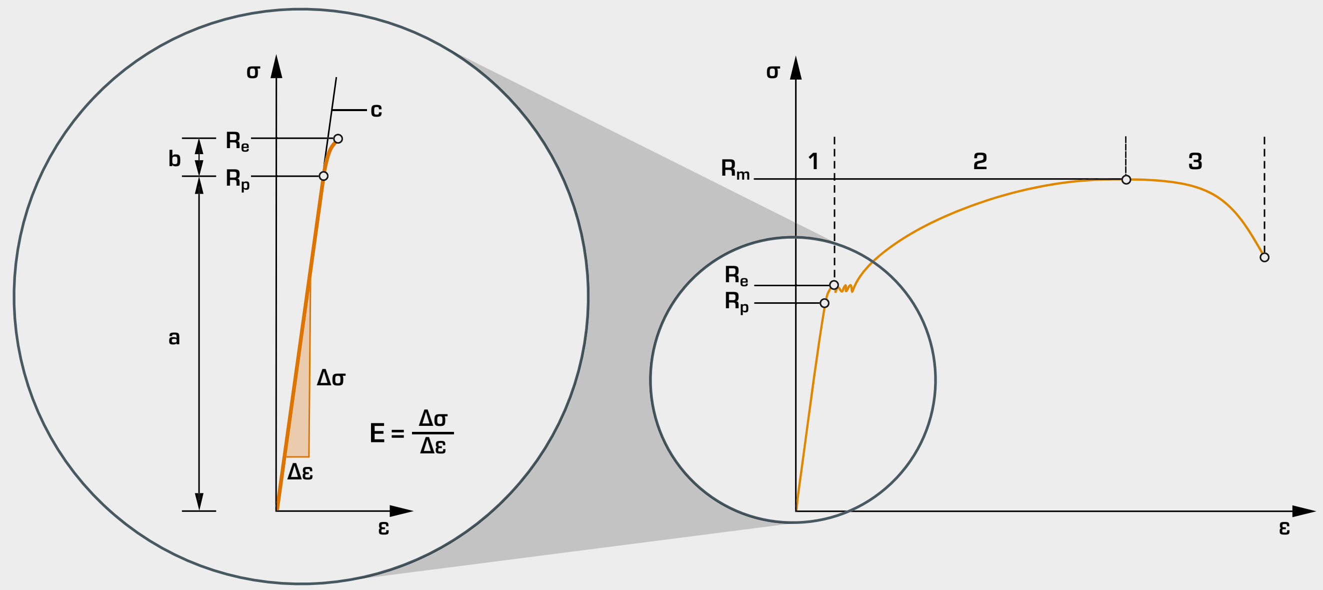
M_t twisting moment, **F** force, **φ** twisting angle, **τ** shear stress

Determination elastic behaviour

There is direct proportionality between deformation and applied force. Therefore, it is necessary to know the material properties as well as the stress to determine the strain or elastic deformation. These material properties, known as the modulus of elasticity, describe the relation between stress and strain in the deformation of a solid body with linear elastic behaviour. The elastic modulus can be calculated from the measured values of the tensile test or determined graphically from the stress-strain diagram (also see chapter 6 Materials testing).

In strength of materials, we consider the linear-elastic region, since the deformation of the material is reversible in this region. When designing beams or supporting structures, the linear-elastic region should not be exceeded.

Elastic region of the stress-strain diagram **Stress-strain diagram**



The elastic region is divided into a linear-elastic component a, where the strain is proportional to the stress and is reversible and a nonlinear-elastic component b, where the strain is not proportional to the stress but is still reversible. In the plastic region, the strain is not reversible and the deformation remains even after the force has been removed.

σ stress, **ε** strain, **E** elastic modulus, **R_p** proportional limit, **R_e** yield strength, **R_m** tensile strength, **1** elastic region, **2** plastic region, **3** constriction to fracture, **a** linear-elastic component, **b** nonlinear-elastic component, **c** Hooke's straight line

The calculation of deformations under load is described by Hooke's law of elasticity

$$\sigma = E \cdot \varepsilon = \frac{F}{A}$$

σ stress, **E** elastic modulus, **ε** strain, **F** force, **A** area

Elastic modulus for various materials

Material	E in N/mm²
steel	$2{,}1 \cdot 10^5$
aluminium	$0{,}7 \cdot 10^5$
concrete	$0{,}3 \cdot 10^5$
wood along the grain	$0{,}7...1{,}6 \cdot 10^4$
cast iron	$1{,}0 \cdot 10^5$
copper	$1{,}2 \cdot 10^5$
brass	$1{,}0 \cdot 10^5$