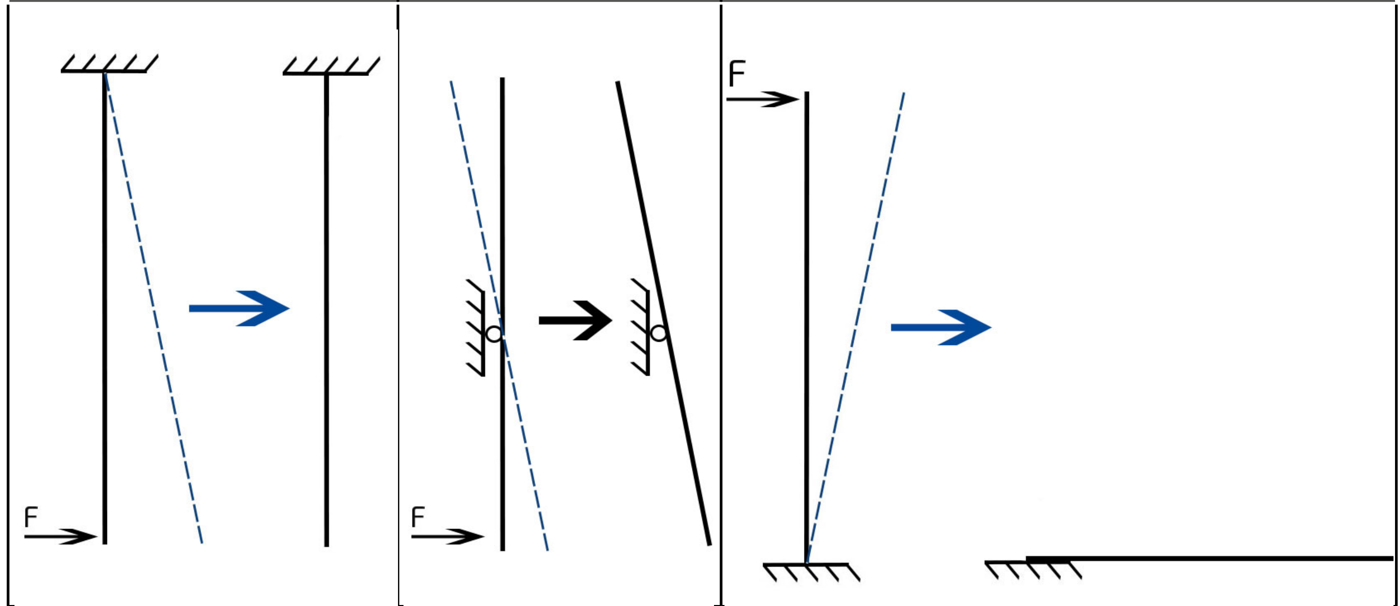
Basic knowledge

BUCKLING AND STABILITY

If slim and long components such as bars, beams and columns are subject to compressive stress owing to a force along the bar axis, these can end up in indifferent or unstable equilibrium positions. If the force F is less than the critical force F_K, also known as buckling force, the component is in a stable equilibrium position and there is a strength problem. If the force F reaches the buckling force F_K of the bar, the bar suddenly starts to buckle. The components, thus, lose their ability to function.
Buckling is usually a very sudden and abrupt process which causes large deformations.

Different equilibrium positions

Stable equilibrium	Indifferent equilibrium	Unstable equilibrium



F-Force

Different equilibrium positions

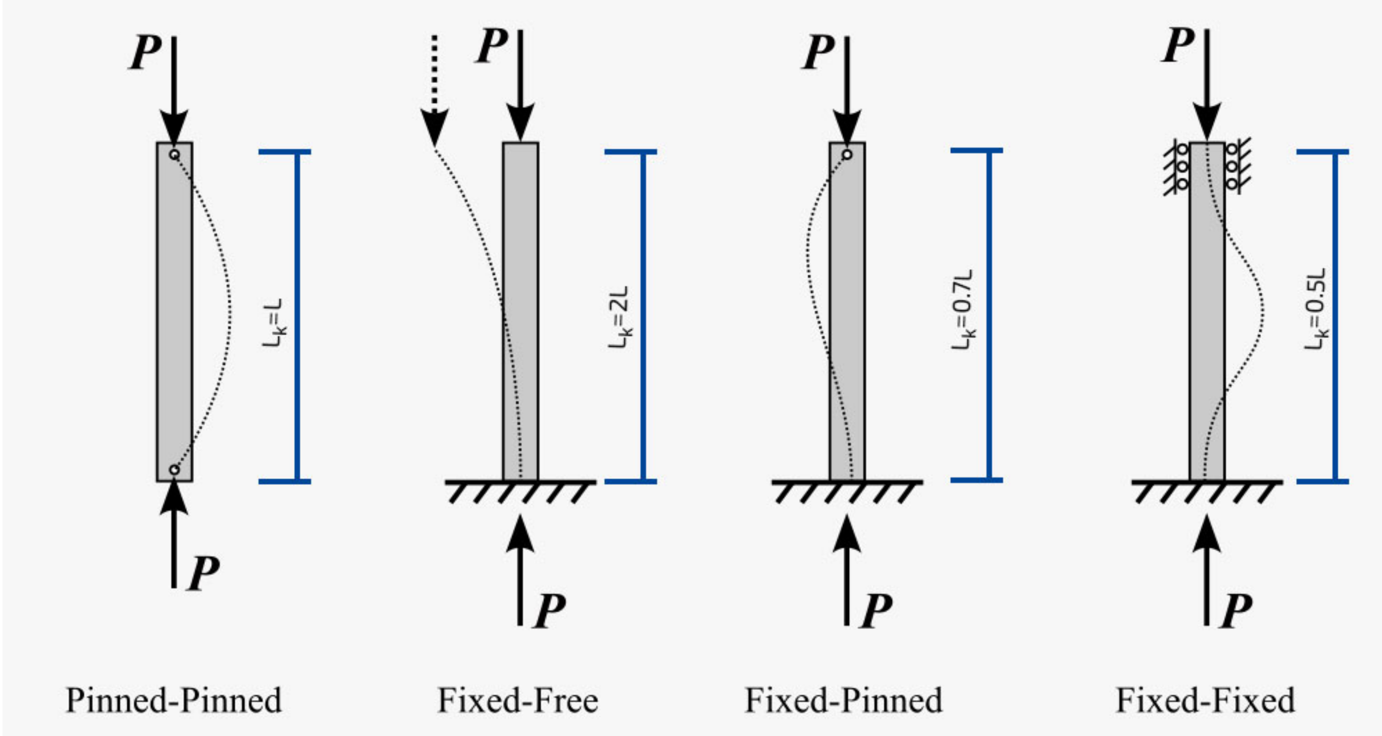
Bars under pressure are a typical stability problem. Here, we investigate when a straight bar collapses. The critical buckling force F_K describes the smallest possible compressive force under which the bar buckles. The critical buckling stress σ_K is the stress that occurs at the critical buckling force F_K.
The buckling force for pressure-loaded bars depends on the support conditions, bending stiffness and geometry of the shape of the bar cross-section. Euler's four buckling cases are taken as the basis for the study of the bending stability of bars with constant bending stiffness.

Basic knowledge

BUCKLING AND STABILITY

Euler's buckling cases

The mathematician and physicist Leonhard Euler defi ned four typical buckling cases to calculate the buckling force. For each of these cases, there is a buckling length coefficient β that is used to determine the buckling length L_K.



buckling length coefficient β = 2	buckling length coefficient β = 1	buckling length coefficient β = 0.7	buckling length coefficient β = 0.5
buckling length $L_k = L \cdot \beta$	buckling length $L_k = L \cdot \beta$	buckling length $L_k = L \cdot \beta$	buckling length $L_k = L \cdot \beta$

P force, L bar length, L_K buckling length, β buckling length coefficient

Determining the buckling force F_K

$$F_K = \frac{\pi^2 \cdot E \cdot I}{L_K^2}$$

F_K critical buckling force, L_K bar length, E elastic modulus I axial second moment of the cross-section area

Determining the buckling stress σ_K

To determine the buckling stress we use the degree of slenderness λ as a material parameter and the moment of area radius i.

$$\lambda = \frac{\beta \cdot L}{i} \qquad i = \sqrt{\frac{I}{A}} \qquad \sigma_K = \frac{\pi^2 \cdot E}{\lambda^2}$$

σ_K buckling stress, E elastic modulus, λ degree of slenderness, β buckling length coeffi cient, L bar length, i moment of area radius, A cross-section area of the buckled bar, I second moment of area