ENGINEERING MECHANICS

Volume 1

Equilibrium

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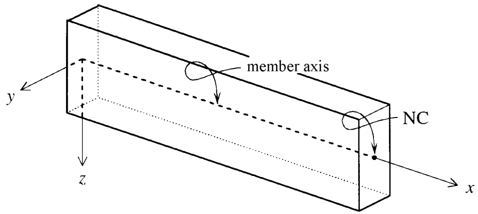
Springer

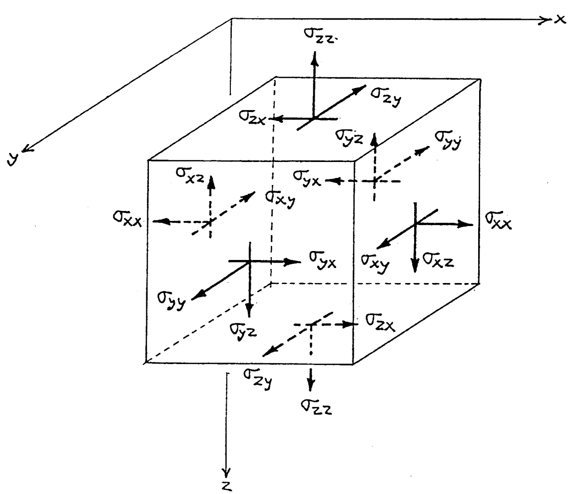
Coordinate system in a member (bar, beam, column, etc.)

The x axis is selected along the *member axis*, through the *normal (force) centre* NC of the consecutive cross-sections. The y and z axis are chosen parallel to the plane of a cross-section.



Normal and shear forces

σ_{ij} is the stress on a plane with the normal in the i direction ($i = x, y, z$), and acting in the j direction. σ_{ij} is a normal stress when $i = j$ and a shear stress when $i \neq j$. The positive directions are shown in the figure.



Relationship between section forces and stresses in the cross-section

Normal force

$$N = \int_A \sigma_{xx} \, \mathrm{d}A$$

Shear forces

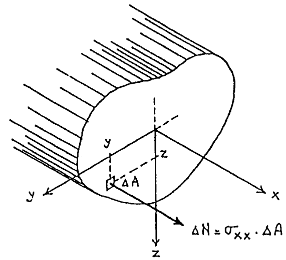
$$V_y = \int_A \sigma_{xy} \, \mathrm{d}A$$

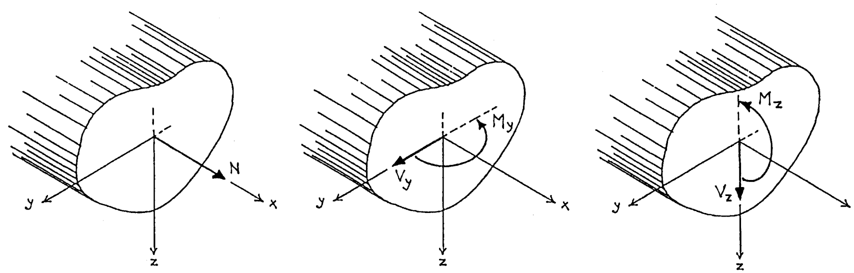
$$V_z = \int_A \sigma_{xz} \, \mathrm{d}A$$

Bending moments

$$M_y = \int_A y\sigma_{xx} \, \mathrm{d}A$$

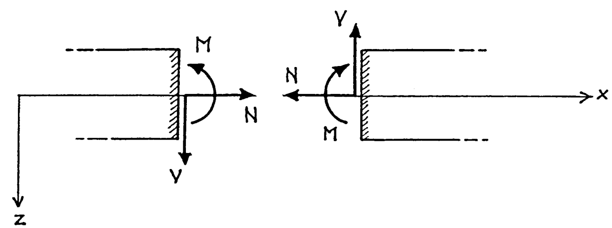
$$M_z = \int_A z\sigma_{xx} \, \mathrm{d}A$$





Positive directions of N, V_z and M_z

The figure below shows the positive directions of the normal force N, shear force $V_z = V$ and bending moment in the xz plane $M_z = M$.



Relationship between section forces and load

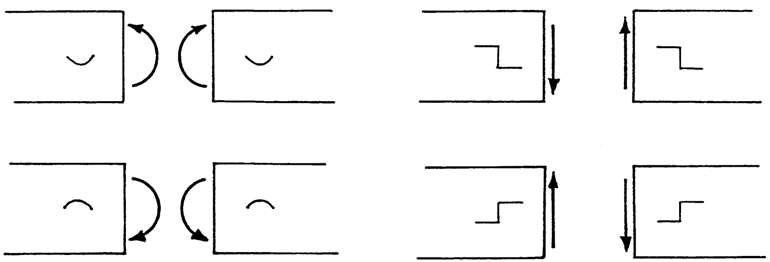
$$\frac{\mathrm{d}N}{\mathrm{d}x} + q_x = 0, \qquad N = -\int q_x \,\mathrm{d}x,$$

$$\frac{\mathrm{d}V_z}{\mathrm{d}x} + q_z = 0, \qquad V_z = -\int q_z \,\mathrm{d}x,$$

$$\frac{\mathrm{d}M_z}{\mathrm{d}x} - V_z = 0, \qquad M_z = \int V_z \,\mathrm{d}x = -\iint q_z \,\mathrm{d}x\,\mathrm{d}x.$$

Deformation symbols

The deformation symbols for bending are given in the left-hand figure, those for the shear forces are shown in the right-hand figure.

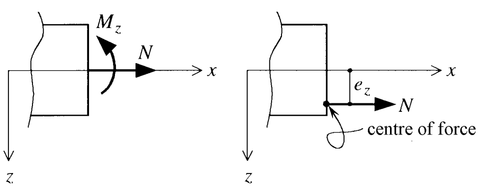


Cable equation

$$H\frac{\mathrm{d}^2 z}{\mathrm{d}x^2} = -q_z.$$

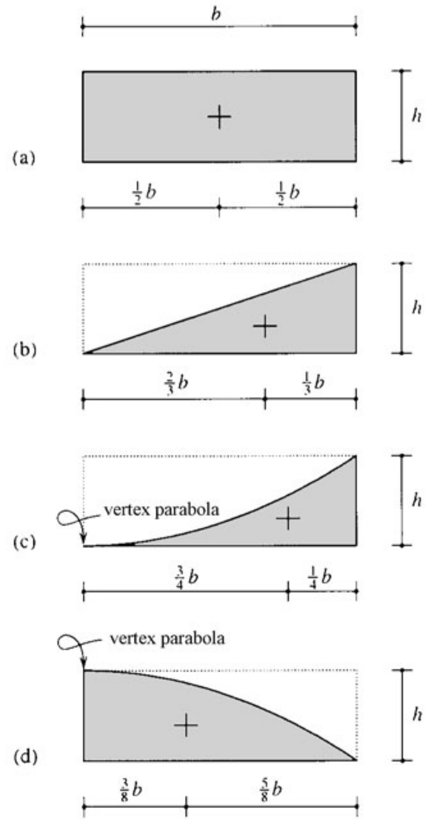
Centre of force

$e_z = \dfrac{M_z}{N}$, see figure below.



Area A and centroid (+) of a number of simple shapes

Shape	Area A	Figure
Rectangle	bh	a
Right-angles triangle	$\frac{1}{2}bh$	b
Parabola (concave)	$\frac{1}{3}bh$	c
Parabola (convex)	$\frac{2}{3}bh$	d



Engineering Mechanics

Volume 1: Equilibrium

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A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN-10 1-4020-4120-9 (HB)
ISBN-13 978-1-4020-4120-4 (HB)
ISBN-10 1-4020-5483-1 (e-book)
ISBN-13 978-1-4020-5483-9 (e-book)

Published by Springer,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

www.springer.com

This is a translation of the original Dutch work “Toegepaste Mechanica, Deel 1: Evenwicht”, 1999,
Academic Service, The Hague, The Netherlands.

Printed on acid-free paper

Table of Contents

Preface

This Volume is the first of a series of two:

- Volume 1 : Equilibrium
- Volume 2 : Stresses, deformations and displacements

Volume 1 introduces the fundamentals of structural and continuum mechanics in a comprehensive and consistent way. All theoretical developments are presented in the text and by means of an extensive set of figures. Numerous examples support the theory and provide a link to engineering practice. Combined with an extensive set of problems in each chapter, students are given ample opportunities to exercise.

The book consists of distinct modules, each divided into sections which are conveniently sized to be used as lectures. Both formal and intuitive (engineering) arguments are used in parallel to derive the important principles, for instance in bending moment diagrams and shear force diagrams. An important feature of the book is the straightforward and consistent sign convention, based on the stress definitions of continuum mechanics which will be used in Volume 2.

The modular content of the book shows a clear order of topics, starting with the introduction of forces and equilibrium of a particle followed by the extension to moments and the equilibrium of rigid bodies. An important aspect that is used throughout the series is the interaction between rigid bodies and the forces that act upon rigid bodies. These forces play an important role in Chapter 4, where structural elements and support conditions are introduced, followed by Chapter 5, which deals with the interaction forces and support reactions. A comprehensive chapter on loads gives an overview not only of the origin of loads, but also provides an introduction how to treat loads in engineering codes and in structural calculations. Examples of specific loads from gases, from liquids and from soils can be found in Chapters 7 and 8. These chapters can be regarded as an introduction in soil and fluid mechanics, and can be omitted when treating only structural mechanics.

After the basic theory of equilibrium of rigid bodies, boundary conditions and the method of calculating the reactions, the focus shifts to the section forces (internal forces) in trusses (Chapter 9), and beam and frame structures (Chapters 10 to 13). The formal treatment of the beam theory of Chapter 11 uses as little mathematics as possible and shows the fundamental relations between bending moments, shear forces and distributed loads. This fundamental approach is supported with an extensive intuitive approach based on the visual use of bending moment diagrams and shear force diagrams. Chapters 12 and 13 are therefore the most important chapters, and use all previously introduced definitions and sign conventions.

The last part of Volume 1 consists of some special topics like cables (Chapter 14), virtual work and influence lines (Chapters 15 and 16). Virtual work is introduced as an alternative to the ordinary equilibrium conditions as used in the first part of this book. Using the principle of virtual work proves to be a fast method to calculate sectional forces and reactions in statically determinate structures. The theory of virtual work is also needed to obtain influence lines. Chapter 16 can therefore only be used in combination with Chapter 15.

Although the books introduce the fundamentals of engineering mechanics, not much mathematical knowledge is required. Examples in which use is made of integral calculus or differential equations can be omitted, although they contribute to the mathematical explanation of the relations between bending moments, shear forces and distributed loads. The educational value is therefore not only fundamental knowledge. It is also a demonstration how to translate physical problems into abstract models, which can be solved with mathematical tools.

Finding the right balance between the abstract fundamentals and practical application should be the challenge for the lecturer.

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July 2006

Foreword

Structural or Engineering Mechanics is one of the core courses for new students in engineering studies. At Delft University of Technology a joint educational program for Statics and Strength of Materials has been developed by the Koiter Institute, and has subsequently been incorporated in the curricula of faculties like Civil Engineering, Aeronautical Engineering, Architectural Engineering, Mechanical Engineering, Maritime Engineering and Industrial Design.

In order for foreign students also to be able to benefit from this program an English version of the Dutch textbook series written by Coenraad Hartsuijker, which were already used in most faculties, appeared to be necessary. It is fortunate that in good cooperation between the writers, Springer and the Koiter Institute Delft, an English version of two text books could be realized, and it is believed that this series of books will greatly help the student to find his or her way into Engineering or Structural Mechanics.

Indeed, the volumes of this series offer some advantages not found elsewhere, at least not to this extent. Both formal and intuitive approaches are used, which is more important than ever. The books are modular and can also be used for self-study. Therefore, they can be used in a flexible manner and will fit almost any educational system. And finally, the SI system is used consistently. For these reasons it is believed that the books form a very valuable addition to the literature.

René de Borst
Scientific Director, Koiter Institute Delft