



Budapest University of Technology and Economics

Department of Mechanics, Materials and Structures

English courses

General course /2020

Fundamentals of Structures

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Lecture no. 4:

Forces, loads and effects

Forces, loads and effects

Definition of forces

2nd law of Newton:

$$F=ma$$

Where: F is (concentrated) force (Newton= kg·m/sec²)
 m stands for mass (kg)
 a means acceleration (m/sec²)

The most commonly known kind of acceleration is caused by the *attraction of the Earth on its surface*: the *gravitational acceleration*

$$g=9,81 \text{ m/sec}^2$$

The weight – or self-weight - of a unit (1kg) mass is:

$$G_1= ma=mg= 1\cdot 9.81 = 9,81 \text{ kgm/sec}^2 \approx 10 \text{ N}$$

The most commonly used *unit of forces* (loads) is 1 kN= 1000 N

A frequent case of occurrence of 1 kN is the appr. weight of 1 thick man:

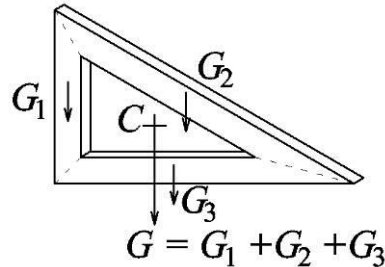
C: centre of gravity
(point of application)



$G \approx 1 \text{ kN}$

The vector character of forces and moments

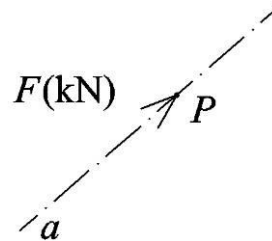
The self-weight G as a concentrated force is an idealization, the resultant of a distributed parallel force system: the sum of the weights of the elementary parts of a body (mass), acting in vertical direction and passing through the *centre of gravity* (C) of the body. The self-weight of a set-square for example:



The self-weight G as an idealized resultant force is called a *concentrated force*.

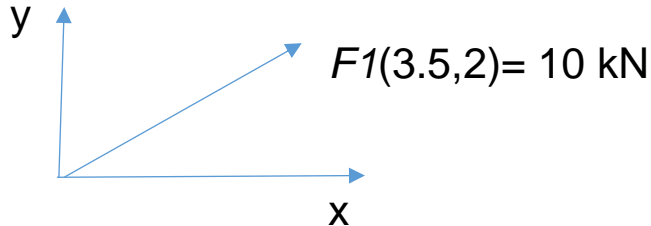
The vector character of concentrated forces means further idealization, that is a *generalized force in the space* can be defined by the following data:

1. point of application (P)
2. line of action (a)
3. direction (arrow head)
4. magnitude F (kN)

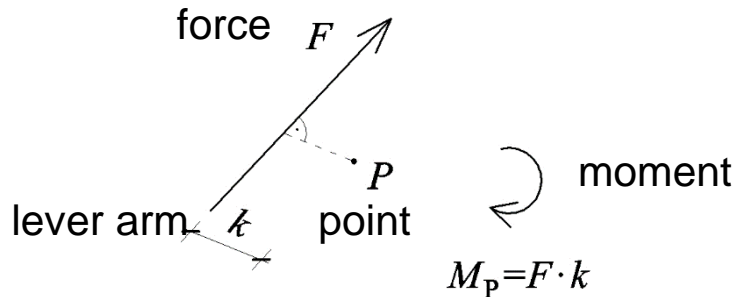


The vector character of forces will be exploited by determining the resultant of planar or spatial force systems and by equilibration problems, and will be practiced during this course and in the subject Statics. The effect of a force F will not change by shifting the force along its line of action.

The direction of a force can be given in a rectangular coordinate system by two points of the line of action, one of them being – in general – the origin of the coordinate system:



The moment of a force



The moment of a force F with respect to a point P is $M = Fk$ (kNm)
 This moment is acting in the plane determined by the point P and the line of action of the force F .

here k is the distance of point P from the line of action of the force F , called also *lever arm*.

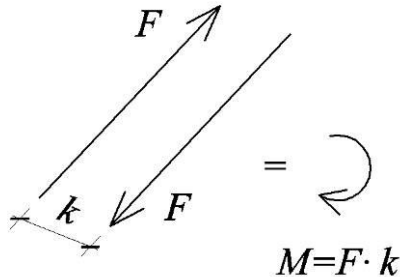
The *sense* (direction) of a *moment* is indicated by an arrowhead on the sign (semicircle) of the moment.

The effect of a moment M will not change by shifting the moment parallel to its plane in any position in the space.

The moment is a vector quantity too, that is given with its axis – which is perpendicular to its plane – supplied with a double-arrow head. When you look the moment vector against the double-arrow head parallel with the axis of the moment, you see the moment turning in clockwise (positive) direction.

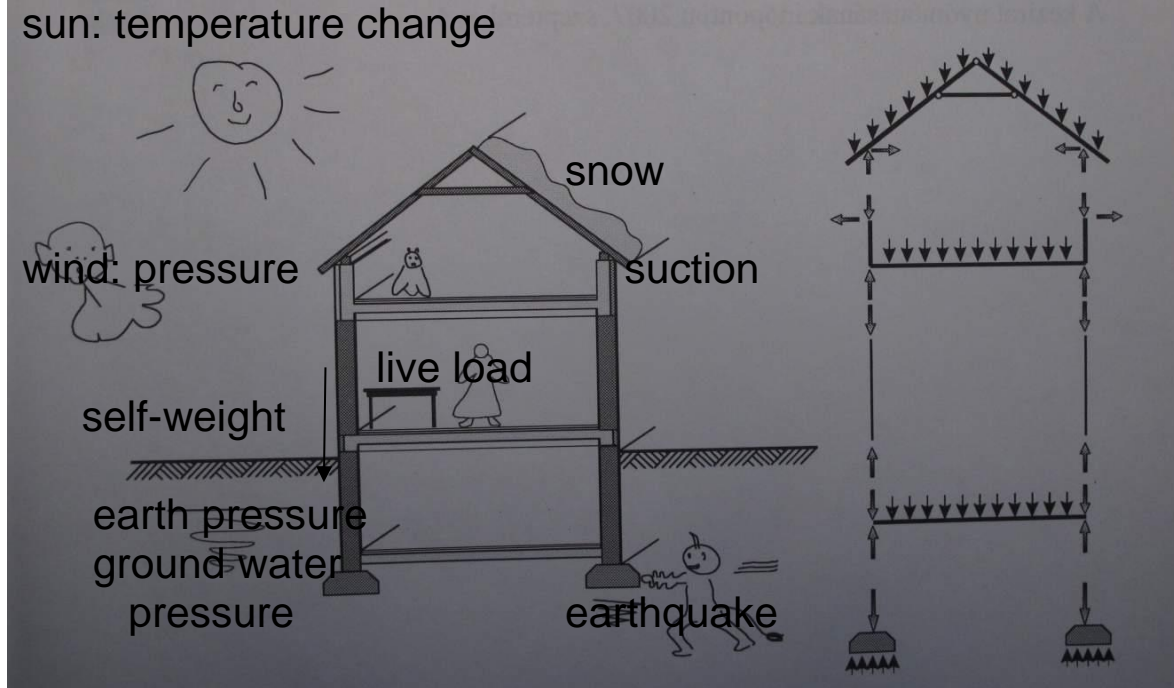
The couple

The resultant of two parallel forces F of equal magnitude, opposite direction and distance k is a moment $M=Fk$. The two forces are called a *couple* or *couple of forces*.



Buildings and loads

cross-section of a building, loads and effects static model and loads



Rem.: way of construction of the static model will be discussed later

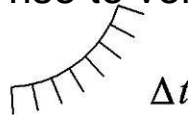
Loads and effects

According to present international terminology, loads are also regarded as effects.

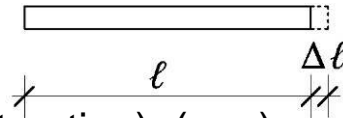
According to traditional terminology:

Examples for effects are:

- *temperature effects*: that give rise to volume (length) changes:



$$\Delta l = \alpha l \Delta t \text{ (mm)}$$



where Δl means elongation (contraction) (mm)

α : linear coefficient of thermal expansion of the material ($1/^\circ\text{C}$)

(For example for concrete: $\alpha_{\text{concrete}} = 10^{-5} 1/^\circ\text{C}$)

l : length of a linear member (mm)

Δt : temperature change ($^\circ\text{C}$)

- *corrosion effects*: for example oxidation of steel

- *aging*, for example plastics become more brittle with time

brittle behaviour: rigid rupture without previous deformation

-kinematic effects:

-uneven settlements

-dynamic effects:

-vibrations (due to traffic)

-earthquake

-shocking of vehicles

Static loads according to traditional meaning of the word are forces (force systems) applied with slowly increasing intensity onto the structure:

-permanent loads acting due to

self-weight of the structures, constructions

-variable loads acting due to

meteorological loads: snow and wind

live loads: weight of people and furniture according to function

To simplify calculations, dynamic character of the effects are often taken into consideration by use of dynamic coefficients >1 , and handled as static loads.

Classification of loads according to *distribution*

Concentrated load (a)

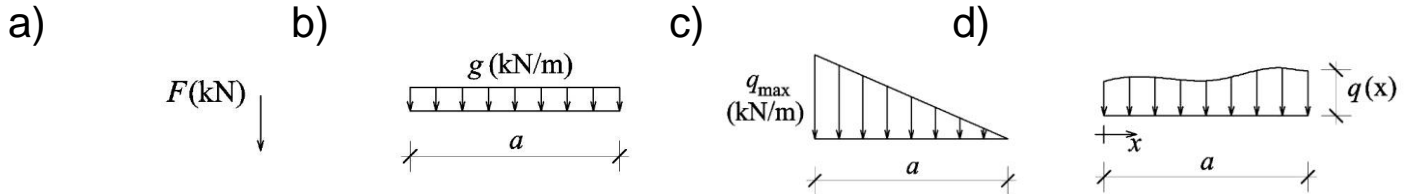
Distributed *planar* (or coplanar) loads

uniformly distributed load (b)

triangular (linearly variable) (c)

general (d)

Examples for planar loads:



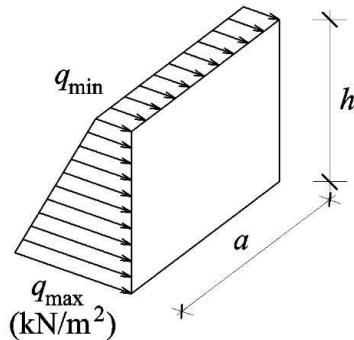
concentrated load uniformly distributed load triangular load general distributed load

Resultant of distributed loads

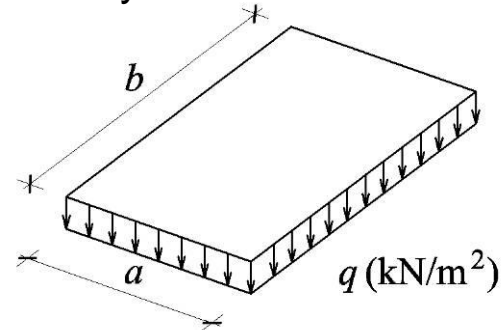
Spatial load systems

Examples:

earth pressure



uniformly distributed
gravity forces acting on a surface
(self-weight of a floor construction or
live load intensity on a two-dimensional
floor)



Loads acting on buildings

Loadbearing structural members of

- roofs

- vertical loadbearing members, like walls and columns

- horizontal load-bearing members of floors and

- foundations

of buildings are to be loaded by design by static loads originated by

- self-weight of the constructions (including that of the load-bearing structures) and installations

- live loads (weight of people and furniture)

- meteorological loads: snow and wind

Factors influencing the load intensity

Self-weight

- specific weights of the building materials (kN/m^3)
they are tabulated in design aids tables
- dimensions

Live loads

- depend on the function of space above the floor (kN/m^2)
they are tabulated in design aids tables

Snow load

- depends on the country, altitude (kN/m^2)

Wind load acts perpendicular to the surface (kN/m^2)

- depends on height above ground level, character of the neighbourhood, position of the surface with respect to the wind direction investigated
- tabulated in design aids tables

To increase the safety of load-bearing structures against rupture and collapse, tabulated (characteristic) values of permanent loads should be increased by 35%, variable loads by 50% by application of **safety factors**.

Examples for some characteristic and design load intensities

Specific weights of loadbearing structural materials were treated in lecture 3.

Square m load intensity of roof and floor constructions and of walls are to be determined by summing up the weight of their layers.

Some important characteristic live load intensities:

rooms in residential houses: 2 kN/m^2

corridors and stairs in residential houses: 3 kN/m^2

storage areas in industrial buildings: 5 kN/m^2

Approximate design values of the load intensities of a family house:

- High roof (timber roof construction with thermal insulation and ceramic tiles cover + meteorological loads): $2,5 \text{ to } 3,0 \text{ kN/m}^2$
- Intermediate floor construction + weight of partition walls: 15 kN/m^2
- Thermal insulated loadbearing wall (ceramic blocks of bricks): 4 kN/m^2