Budapest University of Technology and Economics

Department of Strength of Materials and Structures
English courses
General course /2014
Fundamentals of Structures

Lecture no. 1:

Introduction
Forces and loads

Introduction, general information, ways of communication

Our subject:

FUNDAMENTALS OF STRUCTURES

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Practical lessons: Mrs Rita Vajk

Department: DEPARTMENT OF MECHANICS, MATERIALS AND STRUCTURES

Building K 2nd floor 61.

Topics schedule and requirements are available on the website of the Department: www.szt.bme/english courses/fundamentals of structures/2014.hu

To get to informations of the subject, choose: English, Download, English courses, Fundamentals of Structures

Weekly reception hours are commumicated on the home page and at the entrance of the Department

András Draskóczy: Thursdays 14.00-15.00 pm

General aims of the course:

-acquire *general overview about problems of architectural and structural design and construction* through site visits at:

an existing building
a construction site
a material testing laboratory
a design buro and

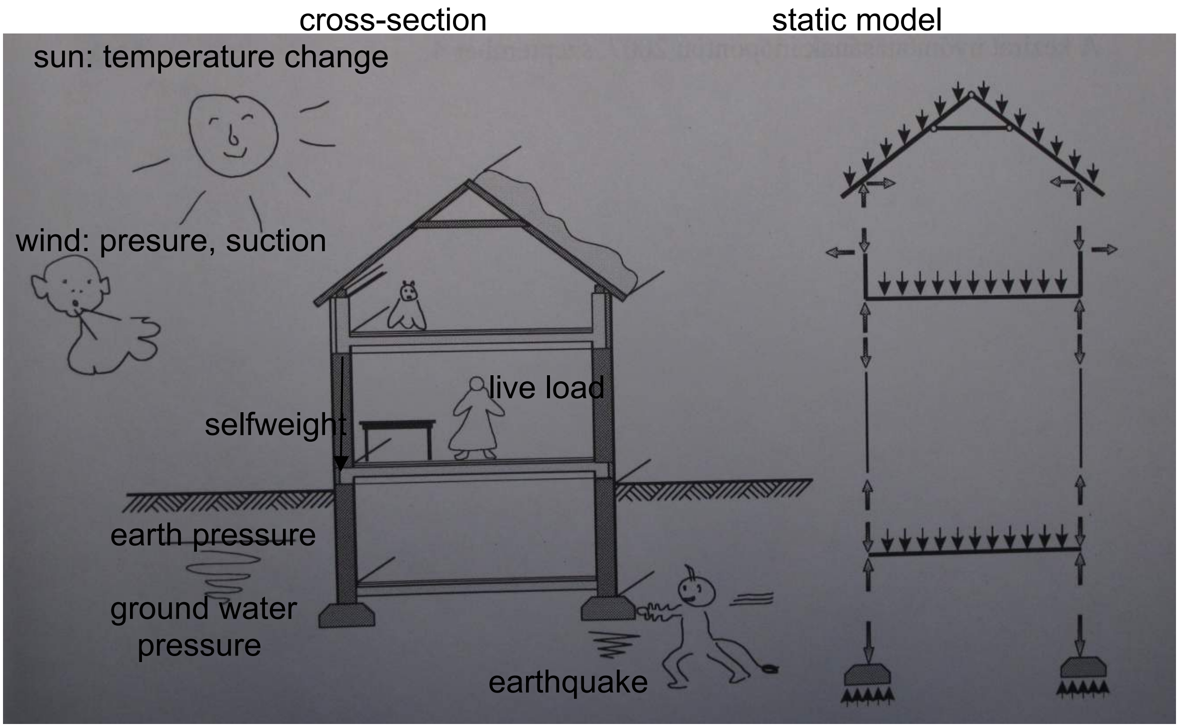
discussing the experiences gained at the above visits

-making *preparatory steps in numerical problem solution in the field of statics* (one of our basic subjects): determination of the resultant and equilibration of coplanar force systems.

-*help* the *students to decide definitively to continue studies in direction of architectural engineering*

<u>1st lecture</u>: **Forces and loads**

1. Buildings and loads



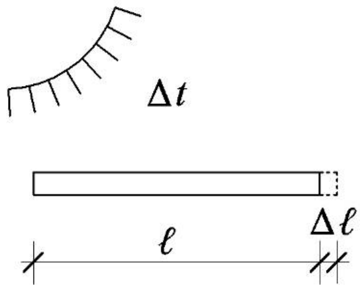
2. Loads and effects

According to present terminology, loads are also 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 alongation (contraction) (mm)

α: linear coefficient of thermal expansion of the material (1/°C)

(For axample for concrete: $\alpha_{concrete} = 10^{-5}$ 1/°C)

l: length of a linear member (mm)

Δt: temperature change (°C)

-*corrosion effects*: for example oxidation of steel

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

-*creep and shrinkage* of concrete (will be discussed in detail later)

Loads according to traditional meaning of the word are **forces** that are acting onto the structure

3. Forces

Definition of forces by the 2nd law of Newton:

$$F=ma$$

where: *m* stands for mass (kg)

a means acceleration (m/sec^2)

unit of forces: 1 kgm/sec^2= 1 N (Newton)

The most commonly known kind of acceleration is caused by the gravitational attraction of the Earth: $g = 9{,}81 \text{kgm} / \sec^2$

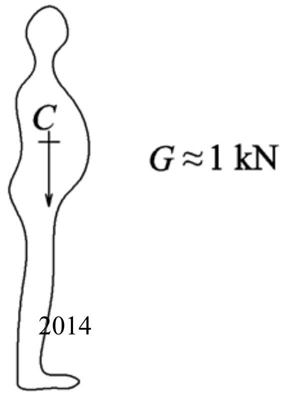
which produces the **(self)weight** of masses:

$$G = mg \quad (N)$$

The selfweight of 1 kg mass is: $G = 1 \cdot 9{,}81 \approx 10 \text{kgm} / \sec^2$ = 10 N

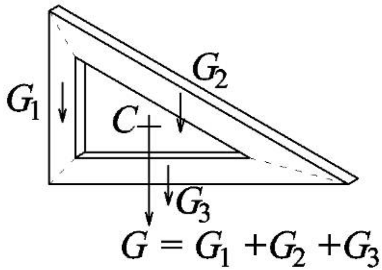
The most commonly used unit of forces (loads) is 1 kN= 1000 N

A frequent case of occurance of 1 kN is the weight of 1 thick man:



4. The vector character of forces

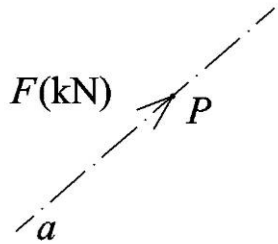
The selfweight *G* is an **idealization**, the resultant of a distributed (parallel) force system: the sum of the weights of the elementary parts of a body (mass), acting in vertical direction and passing through the centre of gravity (C) of the body. The selfweight of a set-square for example:



The selfweight G as an idealized resultant force is called a **concent-rated force**.

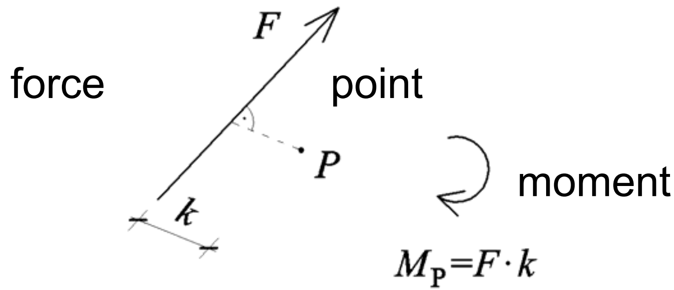
The **vector character of concentrated forces** means further idealization, that is a generalized force in the space can be defined by the following data:

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



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

5. The moment of a force

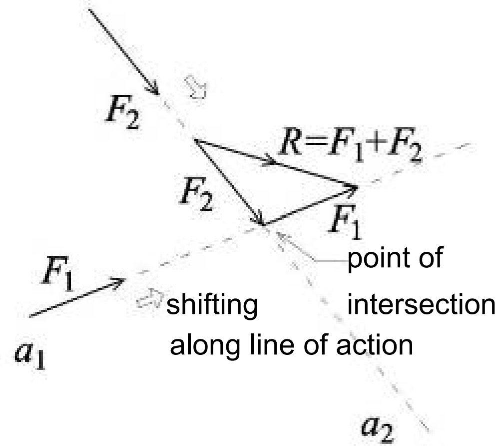


The moment of a force *F* with respect to a point *P* is $M = Fk$ (kNm) where *k* is the distance of point *P* from the line of action of the force *F*, called also *lever arm*.

The *sense* (direction) *of a moment* is indicated by an arrow head 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.

6. The summation of forces in the plane: the resultant force, the couple



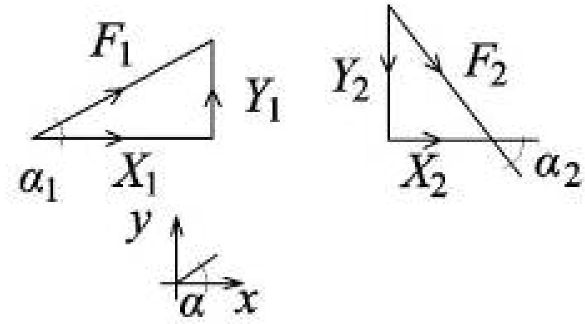
a) Geometrical (graphical) method:

Use of *force scale*:

1 kN ≡ 1 cm

F_1 and F_2 lie in the same plane

b) Analytical (numerical) method



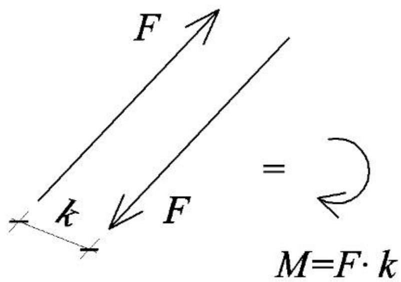
$R_x = X_1 + X_2$ $\quad$ $R_y = Y_1 + Y_2$ $\quad$ $R = \sqrt{R_x^2 + R_y^2}$ (kN)

$X_1 = F_1 \cos\alpha_1$ $\quad$ $X_2 = F_2 \cos\alpha_2$ $\quad$ $\alpha_R = \text{arctg}\dfrac{R_y}{R_x}$

Line of action of *R* passes through the point of intersection of the lines of action of F_1 and F_2.

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*.



6. Classification of loads

6.1 According to **mode of actuation**:

Static loads:
slowly increasing to the total intensity
example: snow load, imposed loads (live loads)
Dynamic loads:
rapidly increasing to the total intensity
example: earthquake loads, explosion, brake forces of cranes
Cinematic loads:
forced dislocations
example: uneven settlement, thermal expansion

6.2 According to **duration of application and variation**

Permanent loads	*Variable loads*
self weight	imposed loads (live loads)
weight of equipments	meteorological loads (snow, wind)

6.3 According to **distribution** of loads

Concentrated (a)

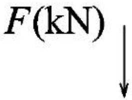
Distributed *coplanar* loads

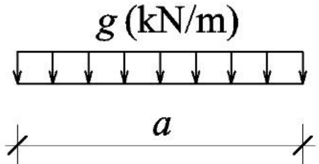
- uniformly distributed (b)
- triangular (linearly variable) (c)
- general (d)

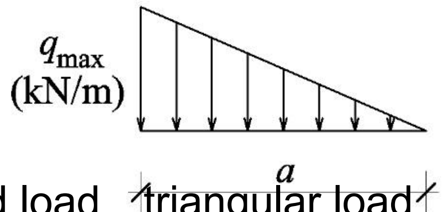
*Spatial l*oad system: gravity forces (e)

earth pressure (f)

Examples for planar loads:

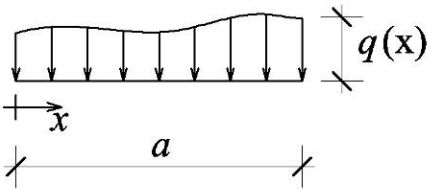




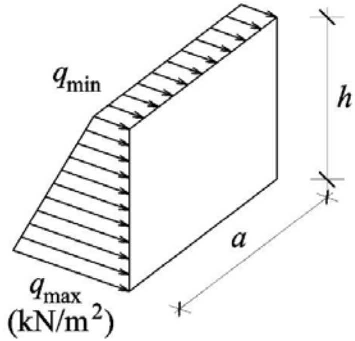


concentrated load uniformly distrubuted load triangular load

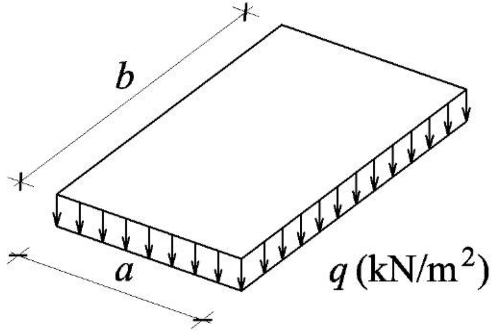
Examples for spatial loads:



general distributed load



earth pressure



uniformly distriubuted spatial load

7. Different values of loads

Due to safety considerations, in different investigations of the structure different values of the loads are to be used

Characteristic value: F_k, G_k, Q_k, g_k, q_k

Different characteristic values of variable loads are used in defferent loading situations:

Combination value:	$\psi_0 q_k$	
Frequent value	$\psi_1 q_k$	$\psi_2<\psi_1<\psi_0<1$
quasi permanent value	$\psi_2 q_k$	

Design value:

$G_d = \gamma_G G_k$ $\gamma_G = 1{,}35$ **partial safety factor** of permanent loads

$g_d = \gamma_G g_k$

$q_d = \gamma_Q q_k$ $\gamma_Q = 1{,}5$ partial safety factor of variable loads

The determination of the characteristic value of loads is made through **statistical evaluation** of measurement data.

8. Magnitude of loads

Permanent loads

Design tables contain **specific weights** of

- -building materials (kN/m^3)
- -stored materials
- -structures, building constructions (kN/m^2)

Variable loads

Imposed loads (**live loads**): varying according to the functions of buildings

	uniformly distributed vertical load intensity (kN/m^2)
Residential, hospitals, hostels:	2-4
Offices	3
Areas susceptible to overcrowding	5
Department stores	5

Meteorological loads

Snow load varying according to

Geographical location
Altitude
Slope of the roof
Exposure
s_k= 1,0 kN/m^2 uniformly distributed vertical load in Hungary acting on horizontal surfaces and altutudes≤400 m

Wind load

Wind pressure (kN/m^2) influenced by
- Reference mean velocity pressure
- Exposure
- Reference height
- External pressure coefficient
- Air density

w_k= 0,5 to 1,0 kN/m^2 uniformly distributed load acting in perpendicular (or parallel) direction to the surfaces of the building: wind pressure (+), wind suction (-) (friction)

9 Area and position of the **centre of gravity** of simple plane figures

- -rectangle: $A = ab$
- -triangle: $A = ah_a/2$
- -circle, semicircle: $A = r^2\pi$ and $A = r^2\pi/2$
- -area under and above a second degree parabola: $A = 2x_1y_1/3$ and $A = x_1y_1/3$