Loads affecting the structure

Theory:

Construction calculations are used to check that nothing exceeds the conditions of the **limit state**. A limit state means a situation where things break or are no longer fit for use in case of bigger loads. All possible calculation situations and their corresponding loads must be checked. A distinction is made between the ultimate limit state and serviceability limit states.

Ultimate limit states:

Bearing limit states are associated with the breaking of a structure (for example, a wall of a house or an electric pole) (something breaks), with loss of static balance (the house falls over, but does not break), loss of stability or other damages resulting in the loss of structural load-bearing capacity and danger to people.

Serviceability limit states:

They are based on the requirements of the regular use of the structure, the comfort of people and the appearance of the building (deformations, vibrations, damage to non-bearing elements). Depending on whether the consequences caused by the load remain even after the load's influence is removed or disappears, may the serviceability limit state be recoverable or non-recoverable. For example, cracks appear in the wall, the wall is ugly and no longer holds the wind, the ceiling panel is crooked, cracked and people are afraid of them.

Calculation situations:

Calculation situations are chosen based on the conditions under which the structure must fulfil its purpose. The following situations are differentiated:

- Permanent – Normal conditions of use.
- Temporary - Temporary conditions, such as during construction or renovation.
- Extraordinary– For example, the consequences of fire, collision or local rupture.

The calculation must show that the limit state is not exceeded in the time period corresponding to the calculation situation.

Terms used from now on:

Load variant - load with its position, magnitude and direction at some observed moment.
Load conductor – physically compatible, simultaneously acting load variants.
Load combination - a set of individual loads acting simultaneously.

Classification of loads:

Koormused liigitatakse:

- By duration:
  - **Permanent i.e. permanent loads (symbol: G)** – self-weight of structures (e.g. the weight of concrete slab or the weight of wall stones), a permanent technological installation (e.g. a rolling machine in a factory and generator in a hydroelectric plant) and the weight of the road surface.
  - **Variable loads (symbol: Q)** – payload on suspended ceilings (caused by use, usually acting through the floor, for example, the weight of people, chairs, cabinets, etc.), wind load (mostly affects walls and roof corners, sometimes it is also negative, i.e. it pushes wall elements away), snow load (snow on the roof), the load of moving transport equipment (e.g. driving and the weight of the truck, as well as the force caused by braking), loads on structures during transportation (e.g. the panel is usually lifted by crane at two or three points secured, these fasteners should not come off during lifting and the panel should not break in half during lifting), weather-dependent temperature load (the force caused by the temperature expansion and contraction of building parts, if extending and shortening is prevented).
  - **Extraordinary loads (symbol: A)** – explosions (e.g. gas explosion on the first floor in an apartment should not cause the whole house to collapse), the collision of vehicles (e.g. a truck drives into the corner post of the first floor and removes it completely, whether the second floor may or may not collapse in this situation), fire

- By mode of influence:
  - Static loads that do not cause significant accelerations in the structure
  - Dynamic loads that cause significant accelerations

Load values:

Each load has some expected value, hopefully, similar to the actual one, called standard value, this number is often chosen from the table.

We get the calculated value of the load by multiplying the standard value by the partial reserve factor. The partial reserve factor takes into account that perhaps we misjudge the normative value in an unfavourable direction.

In a load combination, the calculated value of the variable load is multiplied by the combination factor, which considers how likely it is that the most adverse effects will occur at the same time (for example, we hope that an accident with a truck does not happen on the windiest day).

The calculated value of the load F can be obtained by multiplying the standard value of the load by its combination factor and with load partial reserve factor:

$$F_d = \psi \cdot \gamma_f \cdot F_k$$

Where:

ψ is the load combination factor
γf is the load partial reserve factor
Fk is the standard value of the load

In the case of favourable and unfavourable effects of permanent loads, two different partial reserve factors are used (γG.inf AND γG.sup). The value of the combination factor ψ is either 1.00 or based on the table value ψ0;ψ1;ψ2.

Each load combination contains a permanent load and, in addition, at least one variable load or extraordinary load. In doing so, the dominant variable load whose influence is different from the others is distinguished as greater than variable loads.

Load combinations for the bearing limit state:

NB! More detailed explanation in the example at the end of the lecture!

Load combinations for permanent or temporary design situations

$$\Sigma\gamma_{G.j}G_{k.j} + \gamma_{Q.1}Q_{k.1} + \Sigma\gamma_{Q.i}\psi_{0.i}Q_{k.i}$$

Where "+" and "Σ" represent the effect of loads in one combination

$\Sigma\gamma_{G.j}G_{k.j}$ is the sum of the multiplication of self-weight loads and partial reserve factors

$\gamma_{Q.1}Q_{k.1}$ is the product of the dominant variable load and the partial reserve factor multiplication

$\Sigma\gamma_{Q.i}\psi_{0.i}Q_{k.i}$ is the sum of the multiplication of the secondary variable loads, partial reserve factors and combination factors

Emergency calculation situation load combinations

$$\Sigma G_{k.j} + A_d + \psi_{1.1}Q_{k.1} + \Sigma\psi_{2.i}Q_{k.i}$$

$\Sigma G_{k.j}$ is the sum of normative permanent loads

A_d is the calculated extraordinary load

$\psi_{1.1}Q_{k.1}$ is the multiplication of the dominant variable load and the combination factor

$\Sigma\psi_{2.i}Q_{k.i}$ is the sum of the multiplications of secondary variable loads and combination factors

Load combinations of service limit state:

NB! More detailed explanation in the example at the end of the lecture!

The load combinations considered in the respective calculation situations must be in accordance with the requirements and conditions of use. Three combinations of service limit states are distinguished:

Normative combination (normative load combination of service limit state, rare):

$$\Sigma G_{k.j} + Q_{k.1} + \Sigma\psi_{0.i}Q_{k.i}$$

$\Sigma Gk.j$ is the sum of self-weight loads
$Qk.1$ is the dominant variable load
$\Sigma\psi 0.iQk.i$ is the sum of the multiplications of secondary variable loads and combination factors

Generally applied to non-recoverable serviceability limit states.

Normal combination (usual load combination for the service limit state):

$$\Sigma G_{k.j} + \psi_{1.1}Q_{k.1} + \Sigma\psi_{2.i}Q_{k.i}$$

$\Sigma Gk.j$ is the sum of self-weight loads
$\psi 1.1Qk.1$ is the multiplication of the dominant variable load and combination factor
$\Sigma\psi 2.iQk.i$ is the sum of the multiplications of secondary variable loads and combination factors

Generally applied to renewable serviceability limit states.

Probable load combination:

$$\Sigma G_{k.j} + \Sigma\psi_{2.i}Q_{k.i}$$

$\Sigma Gk.j$ is the sum of self-weight loads
$\psi 1.1Qk.1$ is the multiplication of the dominant variable load and combination factor

$\Sigma\psi 2.iQk.i$ is the sum of the multiplications of secondary variable loads and combination factors

In general, a probable combination is applied in case of long-term effects of loads and serviceability limit states related to the structural appearance

Tables of partial reserve factors and combination factors:

Table 8.2. Partial reserve factors in the bearing limit state.

Types of loads:	fractional reserve notation	For calculations:	
		temporary/permanent	extraordinary
Permanent loads from the self-weight of structures, ground and soil water:			
Static weight loss (does not depend on the strength of the material): 1) adverse effect 2) favorable effect	 $\gamma_{G,sup}$ $\gamma_{G,inf}$	 1,10 0,90	 1,00 1,00
loss of carrying capacity (depends on the strength of the material): 1) adverse effect 2) favorable effect	 $\gamma_{G,sup}$ $\gamma_{G,inf}$	 1,35 1,00	 1,00 1,00
Loss of the load-bearing capacity of the structure due to the pressure of soil or groundwater; loss of bearing capacity depending on soil strength	γ_G	1,00	1,00
variable loads: (adverse effect) – All cases except the loss of bearing capacity depending on the strength of the soil	γ_Q	1,50	1,00
– loss of bearing capacity depending on soil strength	γ_Q	1,30	1,00
extraordinary loads	γ_A	–	1,00

Table 8.3. Values of the combination factors

Type of load	ψ_0	ψ_1	ψ_2
Payloads :			
Class A (living quarters)	0,7	0,5	0,3
Class B (Offices)	0,7	0,5	0,3
Class C (Rooms, where people are able to gather)	0,7	0,7	0,6
Class D (Shopping malls, stores)	0,7	0,7	0,6
Class E (Warehouses)	1,0	0,9	0,8
Traffic load in buildings:			
Class F (Carparks for light vehicles ≤30kN)	0,7	0,7	0,6
Class G (Carparks for vehicles 30...160kN)	0,7	0,5	0,3
Class H (Roofs)	0	0	0
Snow load	0,6*	0,2*	0*
Wind load	0,6*	0,5*	0*
Temperature (except fire)	0,6*	0,2*	0*

* – These are the commonly used values, in some geographical locations, other values may apply.