Film projection 23. 03. 2017

1st film: LOADS

Men-made disasters to study the effect of loads acting on structures, such like:
hurricanes, earthquakes, floods, fire, land slide, shocks of vehicles
For example airplane crash test to study the behaviour, safety, strength and reliability of such structures, and the danger of loss of human lives

Different loads:
Dead load: self-weight
Superimposed loads or live loads
Live loads can be
steadily applied or static loads like snow load or
rapidly or dynamically applied loads like hurricanes, earthquakes
and invisible effects like temperature changes, residual stresses and uneven settlements of the foundations

Demonstration of the difference between steadily or slowly applied loads and rapidly or dynamically applied loads:
When applying the same load dynamically, the response (elongation, displacement) of the structure can almost be the double

Oscillation of a vertical cantilever (metal strip) loaded by a horizontal impact load at the top extremity
The natural period of the structure is the duration of time necessary to one oscillation taking place (revival to the original position) after actuation of the impact load
The natural period of oscillation depends from various characteristics of the cantilever, such as the length, the weight of the body fixed to the free end of the cantilever:
The longer the cantilever, the longer the natural period of oscillation
The greater the weight, the longer the period
The natural period of oscillation is independent from the way of the load application that is static or dynamic character of the load
Steady load: applied during a period of time (much) longer than the natural period
Dynamic load is applied during shorter time than the natural period
Impact load is applied in one instant (very much shorter than the natural period)

Shocks that produce plastic (irreversible) deformations of the structure and are applied repeatedly, may cause the collapse of the structure

If the load revival period is the same as the natural period of the structure, the response of the structure will be gradually increasing (called cumulative effect).
This phenomenon is called resonance, and leads to ultimate failure (loss of stability, rupture) of the structure

Modes of vibration of structures (columns)
The first fundamental mode is that of the longest period of vibration
Steady pressure and suction caused by wind in a wind channel experiment
If the wind pressure revival coincides with the natural period of the structure, resonance effect can develop

Flatter of loose tents under steady wind pressure: aerodynamic resonance

In case of suspension bridges even steady wind pressure can be reason of rapid aerodynamic oscillation:

The case of the Tacoma Narrows bridge in the USA in 1940.

The three months earlier constructed bridge collapsed after three o´clock steady wind of 70 km/hour velocity, after formation of standing waves passing through the span between the pylons of the bridge

2nd film: DEFORMATIONS AND STRESSES

Behaviour of a sealing wax beam: the deformation remains unrecoverable after the removal of the load:

sealing wax is a creeping material. Creep: time dependent deformation under constant loading. (plastic deformation)

Plastics, rubbers are creeping materials

Temperature changes may influence the elastic, plastic, creeping behaviour of materials:

Metal bar shows elastic behaviour under room temperature, but behaves plastically when heated up

Metal bar becomes rigid after being emerged into fluid nitrogen (under very low temperature), whereas under normal temperature shows elastic-plastic behaviour

Speed of loading can also influence the way of behaviour of materials

Plasticine or kneaded soft part of bread is elastic when dropped down, but falls apart in a brittle manner when hit by dynamic load. When the load is applied slowly – by pulling it apart – it will creep. Pulling it apart rapidly, it is brittle

Sealing wax beam: plastic behaviour under slowly applied load, but brittle, when the load is applied rapidly

The behaviour is linear elastic, if doubling the load produces the double deformation. After reaching the yield limit, plastic – unrecoverable – deformations take place.

Plastic – unrecoverable – deformations indicate the danger of the structure being overloaded.

Repeated loads causing plastic deformations may destroy the structure (because plastic deformations are accumulated).

Application of brittle materials is dangerous, because the failure occurs suddenly, without previous plastic deformations, which otherwise represent the pre-sign of the danger of rupture. Only oversized structures can be made of brittle materials.

Repeated load can also cause rupture: the reason is called fatigue of the material.

Fatigue of plastic materials can occur after a few number of load revivals, whereas in case of metals fatigue failure takes place only after a very great number (some ten thousands) of load revivals (testing of airplane wings).

Stress is the load applied to each unit of the cross-sectional area , measured in N/mm^2

Tension stress tends to elongate the material

Compression stress causes shortening

Shear stress acts parallel to the cross-section investigated and causes distortion: change of angle between facets lying rectangular before deformation (that is: shear distorts a right angle)

Tension, compression and shear are the basic states of stress

The relation of stresses and deformations can be visualized id stress-strain curves

Strains are specific deformations (elongation, shortening and distortion), that is deformations per unit length

Example: linear elastic and plastic range of the stress-strain curve of metals. At junction of the two ranges yield (becoming plastic) of the material occurs

Initial tangent of the stress-strain curve is called (linear) modulus of elasticity of the material (unit: N/mm^2)

Comparison of the behaviour of steel and aluminium

Deformation perpendicular to the direction of the applied force is of opposite sign.
The ratio of specific deformations (strains) perpendicular to the direction of the applied force and in direction of the applied force is called te Poisson ratio, another mechanical characteristic of the material (for example 1/6 for the concrete)

Stress state corresponding to bending of linear members: originally straight lines parallel to the axis of the linear member become curved, lines perpendicular to the axis remain straight.
When bending produces curvature of the member convex from the top, top fibres become longer and are in tension, bottom fibres become shorter and are in compression. Length of the central fibre remains unchanged, this is called the neutral axis.
Shear produced by bending: separated layers of the beam tend to slide on each other, when the layers can deform independently:

A rectangle drawn on the side of the beam deform to a rhombus, distortion of rectangles proves the presence of shear.

Torsion (twisting) of one circular bar produces shear stresses in the cross-sections, acting perpendicular to the axis of the bar:
Longitudinal lines on the surface become a helice, tangential lines remain unchanged. Rectangles deform to rhombuses, representing the presence of shear. In cross-sections of the member pure shearing is acting. In directions 45 degrees to the cross-sections principle compression and tension stresses are acting: when drilling the swabber, the water splash in diagonal direction.
Another proof of that is, that drilling a piece of chalk produces breaking – in tension - along a diagonal facit.

Brittle materials such as chalk, stone, glass and cast iron and concrete are weak in tension and strong in compression. Break of concrete cylinder under compression occurs due to transverse tension.
Reinforcing of a rubber beam – of low modulus of elasticity – by sticking a strong fibre - of high modulus of elasticity – onto the tension side of the beam (on top side of the cantilever beam). Deflection will be less.

Principle of reinforced concrete: steel wires of high modulus of elasticity and strong in tension are embedded into concrete, which does not resist well to tension, but is strong in compression. After hardening of the concrete, the beam is supported at the extremities and tested by application of vertical load: tension stresses develop at the bottom and compression stresses at the top. The broken beam shows the concrete is weak in tension and strong in compression, because cracks develop at the lover part. After cracking the steel bars resist to tension. Near supports diagonal cracks develop, which is the sign of diagonal tension produced by intensive transverse shear.

The film demonstrated the influence of the environment on the behaviour of structural materials. The choice of the most suitable structural material is one of the most significant problem of structural design.

Questions

1. What was the reason of the collapse of the Tacoma Narrows Bridge in the USA in 1940?

2. Very high and very low temperature influence the mechanical behaviour of structures. How?
3. The speed of load application (slow, rapid, dynamic load application) can influence the mechanical behaviour of structures. Give an example for that!
4. What is self frequency (or natural period) of structures?
5. Why is it dangerous, if the natural period of the structure is equal to the load revival period?
6. Why is it dangerous to apply rigid materials to loadbearing structures?
7. You apply the same load slowly and then dynamically to the structure: Will the response (for example the deformation) of the structure be the same or different? If different, how much is approximately the difference?
8. What kind of deformation is caused by shear? Sketch an example!