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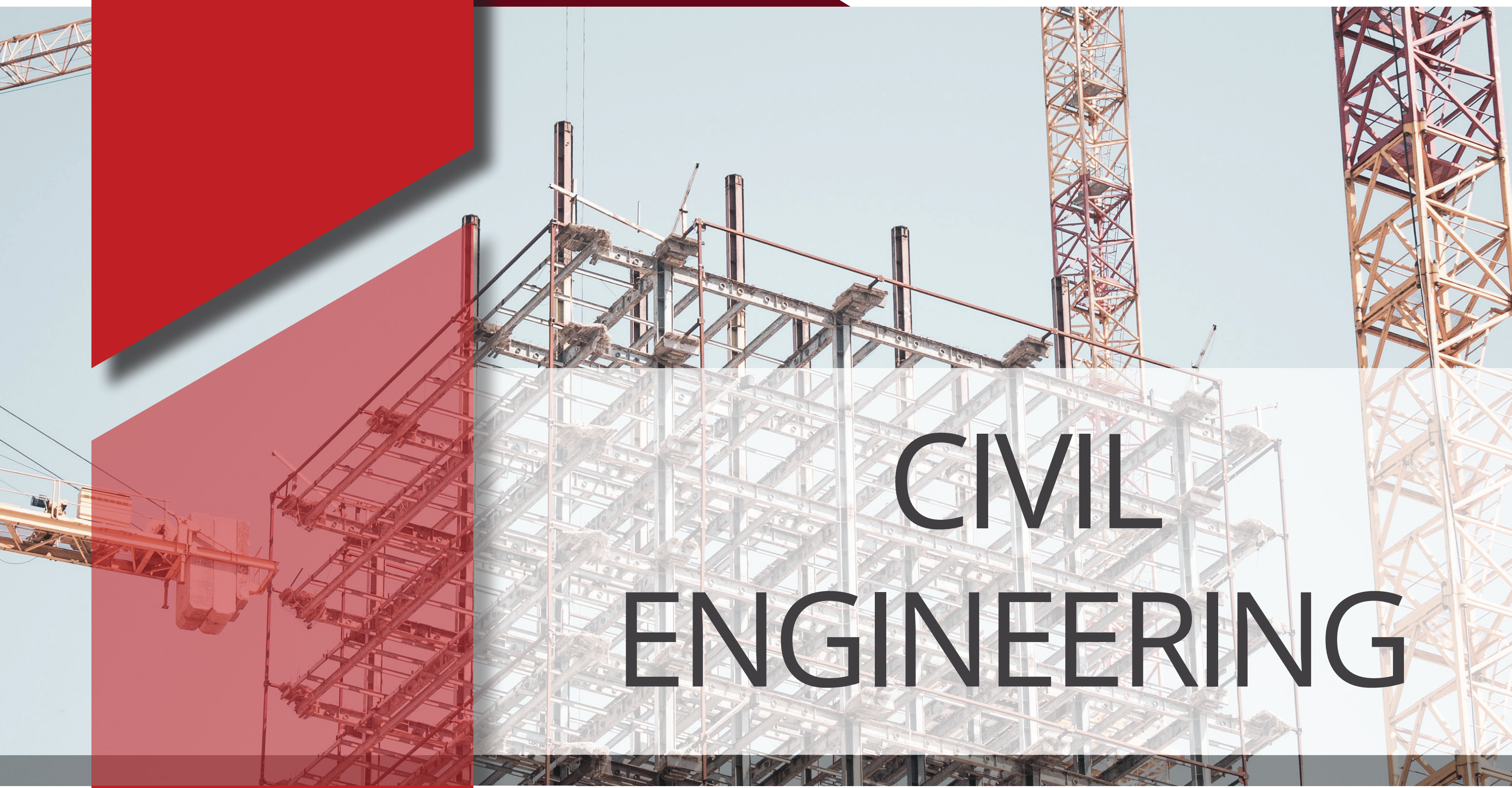

CIVIL ENGINEERING

Steel structures

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1. ADVANTAGES AND DISADVANTAGES OF STEEL STRUCTURES

Advantages:

- it is the best quality standard material
- used for large spans, tall buildings
- main advantages: slenderness, light construction, low weight, fast construction, recoverability, export option

Disadvantages:

- fire resistance (thermal conductivity)
- risk of corrosion
- high price

Volume of steel production:

- the Czech Republic is one of the largest manufacturers, producing 600 kg of steel per inhabitant per year, which is about 6 million tonnes of steel per year in the Czech Republic
- worldwide production is about 700 mil. tons / year
- Europe: Arcelor 42.8 mil. tons / year, Corus 19.1 mil. tons / year

Use of steel:

- in the Czech Republic, it is about 30 % for export, 55 % in mechanical engineering, 15 % in construction, 10 % for reinforcement, 5 % steel construction
- in Europe: 8% construction, 3% reinforcement, 5% steel construction
- steel structures in the building industry - buildings: skelets of buildings, halls (warehouses, production, sports, exhibition ...), pavilions, tribunes; Bridges; special constructions: stores and towers, energy, warehouses, silos, gasometer, mutal structures, buildings

1.1. Steel as a material

Steel = malleable iron (C ≤ 1,5%)

Mechanical properties:

- E = 210 000 MPa
- G = 81 000 MPa
- μ = 0,3
- α = 12x10-6
- K-1
- ρ = 7850 kg/m3

Effect of carbon:

- the iron alloy crystallizes in two modifications: γ dissolves carbon, α not
- melted iron cools and the γ iron is converted into α iron
- using carbon increases strength and hardness, while toughness, ductility decrease
- cast iron: 2.1% C
- steel = malleable iron alloy (<1.5% C), steel: <0.2% C
- weldability of steel (the higher the content of impurities, the worse the weldability)
- carbon equivalent - contains the content of other ingredients

1.2. Features, steel tests

- yield strength ⇐ pull test, strength limit, ductility, toughness ⇐ bending test
- weldability ⇐ weldability test - resistance to fatigue fracture ⇐ fatigue test (cyclic)
- hardness (~ linear dependence on strength)

Tension test:

- the yield strength, strength limit, ductility (Δ = ΔL / L0)

Impact bending test:

- test piece (10 × 10 × 55 mm prism)
- notch of the standard shape on the drawn side of the body; Impact is measured to break the sample
- notched toughness (KCU or KCV notch) and impact work relative to the cross-section area at the weakest point of the body
- transition temperature: thickness of steel decreases with temperature while notched toughness will decrease significantly

Hardness tests:

- by a known force the standard test body (indentor) is pressed into the polished surface of the material
- imprint / depth is measured
- Brinell, hardened steel ball (HB)
- Rockwell, diamond cone or steel ball (HR)
- Vickers, a diamond quadrangle (HV)
- Knoopova, a diamond elongated pyramid (HK)
- there is a correlation between hardness and strength of steel

Fatigue tests:

- they are used to identify resistance of steel to repeated stress
- Wohler curve
- the fatigue limit depends mainly on the adjustment of the test bar
- time strength is about 3,000,000 cycles

Weldability tests:

- the following tests are carried out: testing of weld metal - tensile test - Weldability tests
- method - by bending at bending with weld more labor consumed than with weld joint
- bending test by bending
- carbon equivalent (on a chromatograph)

1.3. Steel production

- essential is to remove excess carbon + remove Si, P, S. It is carried out in martin furnaces (not any longer), in oxygen converters, in electric furnaces
- raw materials: raw iron, scrap

Siemens – Martin furnaces:

- the ovens are gas-fired
- air is own into the bath, more recently oxygen
- the share of steel production from Siemens-Martin-ovens is decreasing

Oxygen convectors:

- thick-walled steel containers with lining. Pressurized oxygen is moved using water cooled nozzles. This is followed by carbon oxidation ⇒ carbon monoxide (mixes the bath and leaks). Silicon and phosphorus oxides are slagged as slag

Electric furnaces:

- there are two basic types: arched or inductive
- its disadvantages are high production costs
- they are used mainly for stainless (quality, alloyed) steels with additives (legury)
- it is not used for construction steel

Steel deoxidation:

- there are two basic types: into the conical metal vessels and continuous pouring
- the vessels: Cast steel is poured into conical vessels – mold, after surface hardening, the ingot can be removed, the head is faulty

Types of steel:

- carbon: with a carbon content of about 0.2%, other impurities up to 1%
- low-alloyed: the carbon content is about 0.2%, manganese up to 1,5%
- alloyed: with carbon content up to 0,2%, legumes of 3% or more

Steel products: they are mostly produced by hot rolling, cold forming, casting, fittings

2. HISTORY OF IRON AND STEEL

- the origins are about 3800 BC - Meteorites origin. About 1600 BC Fluxed iron from ores
- in China - used in around 280 for manufacturing chain bridges
- in Europe - younger history: 1400 Blast furnaces with charcoal
  1784 Welding steel (England - Cort - in dough status, fiber)
  1813 Coke (English Derby)
  1848 I beam (Franc. Zorès)
  1855 Floating steel (English Bessemer, Thomas) in liquid state

Cast iron and welded iron:

- 1779: Bridge of Coalbrookdale, England - Arc with a span of 30 m (Pritchard)
- 1826: Menai Chain Bridge, 177 m (Telford)
- 1836/1864: Clifton Chain Bridge, 191 m (Brunel)
- 1850: Britannia Chamber Bridge Bridge, Span 140 m (Stevenson)
- 1859: Saltash truss bridge, span 139 m (Brunel)
- Czech lands: 1822 Chain suspended bridge in Žatec, 1836 Chain Suspension Bridge in Lokti (Schnirch), 1848 Chain Bridge in Podolsko across the Vltava river

Floating steel:

- 1883 Brooklyn Bridge, 486 m (Roebling)
- 1889 Eiffel tower in Paris, height 300 m
- 1890 lattice Firth of Forth Bridge, 521 m (Baker)

Development and history:

- composite profiles change into solid profiles, lattice structures ⇒ full-body structures. The components are first joined by rivets, then by bolts, later by welds

2.1. Properties of structural steel

- ductility is up to 40%. Structural steel also has high elastic modulus of 210,000 MPa
- Elastic modulus (Young's) E = 210,000 MPa
- Bulk density ρ = 7,850 kg / m3
- the yield strength fy = 235 to 420 MPa
- strength limit fu = 360 to 490 MPa
- elongation δ = min. 15%

Steel marking:

- S235J2 (yield strength 235 MPa, KVC> 27 J at -20 ° C)
- examples of steels: S275, S355, S420, S460, S355

Production of structures. Most often, the following procedure of steel production is used: first a project is created, followed by production of steel components (bridgework). The components are then transported to the place of location and assembled.

Production regulations:

- ČSN 73 2601 Implementation of steel structures
- GROUP A: includes dynamically stressed and special design. Used for bridge structures, produced and assembled in factories (workshops)
- GROUP B: includes those not listed in Group A. Workshop assembly is not required.
- GROUP C: Includes substructures and supplementary structures. Used e.g. for production of stairs. In the CR, there is valid regulation since 2010 - ČSN EN 1090 European Standard.

Workshop production - bridge workshop, operations:

The following procedure is used: firstly, material is produced by means of roll cylinder. Material is then cut, sawed (thermal cutting is used). Subsequently, surface and edges are treated, and openings are made. Material then goes to welding shop (workshop preassembly), then to paint shop. Quality control is performed followed by expedition (into warehouse of finished products)

Heat cutting:

- by oxygen, using portable cutting machines, stable cutting machines
- copying head (Roller Magnetic, Optical) follows the shape of the template or drawing
- modern machines are controlled numerically
- there are also multi-burning automatic machines, plasma, and laser

Drilling:

Openings for rivet holes and screws are made using rack drills. The rim of the holes is screwed under the rivet head and screws. Drills are cooled by liquid or air.
Tools used:

- multi-spindle drills
- numerically controlled (NC)

Punching:

It refers to shearing in sheet metal, making angles, etc. The material around the hole is changed. Holes are usually up to 25 mm thick. Recessing the hole (2 mm), just as good.

Welding:

It is used for making welds using welding machines for melt welding or hand welding in a protective atmosphere.

- welding is performed by with short, at least 50 mm long welds
- we can select the order of welds and positioners

Authorization to manufacture:

The manufacturer shall demonstrate in advance the professional competence for the manufacture of steel structures.

- Czech Accreditation Institute (CIA) - Certification of Manufacturers in the Czech Republic
- small and Complex Welding Card
- some investors (especially state-owned companies such as Czech Railways or the Road and Motorway Directorate) do not purchase constructions from the manufacturer without certification

Transport:

- transport panels - up to 12 m by default

Assembly of steel structures on site:

- usually it is carried out by a specialized organization.
- procedure: first, assembly joints are planned and made. Design is made with a sketch of storage space. It is also necessary to plan the method of transport of parts to the site. Then we plan work on the pre-assembly platform - assembly - lifting of assembly units, etc.

Construction:

- preferably screw mounting connections, documentation, pre-assembly
- options: mounting parts = transport elements, assemblies from multiple transport elements

2.2. Project documentation

- Building Act 183/2006 Coll. (Since 1 January 2007)
- Decree of MMR 499/2006 Coll. On building documentation
- documentation for Territorial Decision (DUR) - Architectural Plan, building permit (DSP) - even design solution
- entering the building (DZS) - to select the contractor of the building
- schemes of steel structures, raw material report
- construction is provided by the contractor of the building
- detailed design of the steel structure
- main, essential details
- production (workshop) documentation
- detailed drawings, complete listing of material

Construction Documentation (RDS) for Steel Structures:

- static calculation
- technical report
- material report (approximate)
- clear drawings
- drawings of less common details
- anchorage drawings (delivery cost)

Static calculation:

- for static calculation, a list of standards and regulations used in the calculation is necessary, where it should be considered the following: type and quality of materials used (steel, screws, electrodes, etc.). a list of used aids and literature, program data (software)
- the author of the static calculation is always responsible for the results of the computational calculation. He has to shall take into account the diagram of the geometric shape and static action of the structure, the load considered, the calculation of internal forces, shall perform the design of the structure, the assessment of the structure (including joints) according to the relevant standards.
- the static calculation shall include the contents, date, signature of the processor and, where appropriate, of the controlling person
- schematic of geometric shape and static

3.RELIABILITY OF STRUCTURES

3.1. Suggestion from experience, intuition

Methods of safety factor:

- one safety factor derived from experience, method of permitted stress

Probabilistic methods of design:

- a special subject of the Engineering study program
- calculating the probability of failure in relation to time
- input variables are stochastic

Method of partial reliability factors:

- semi-probability method
- the basis of current design standards
- the limit state method

Probability:

- confidence index $\beta = \mu z / \sigma z$
- μz average
- the standard deviation of the random variable Z
- B = 3,8 for the ultimate limit state
- B = 1,5 for the usability limit state
- for the design life of the structure (typically 50 years)
- Z = R - S
- R bearing capacity
- S load

3.2. Limitations

- limit state of the structure - status criteria will no longer be met
- limiting states of load capacity: strength, bond strength, fatigue strength, fragile quarry, position stability

Limit states of usability (in the construction state):

- deformation
- oscillation
- aesthetics

Sub-factor of reliability:

- factor γ material, load factor γF, lLimit states of resistance - γM> 1, γF> 1, limit states of usability - γM = 1, γF = 1
- it includes the following: unfavorable deviations from characteristic values, load model inaccuracies, inaccuracies of the calculation model of the structure, inaccuracy of the conversion factors
- statistical analysis of experimental data or observations
- quantities: characteristic, design

The principle of reliability:

- Sd ≤ Rd
- Sd the largest possible design effect of the load
- Rd the smallest possible design load bearing capacity

Limit state of position stability:

- Ed, dst ≤ Ed, stb
- Ed, dst design effects of destabilizing loads
- Ed, stb design effects of stabilizing loads
- at the ultimate limit state
- extreme load (γF,> 1.0)
- Fd = Fk * γF
- minimum load capacity (γM> 1.0)
- Rd = Rk / μM

Limit state of load capacity:

- these are extreme situation. There is a very low probability of exceeding.
- design yield strength … fyd = fy / γM
- γM ≥ 1

- design load … FEd = Fk γF
- γF> 1
- it includes nominal dimensions of the structure, material stiffness characteristics (E, G), nominal value (average)

Limit state of usability:

- it is a usability in normal operation with operating load (γF = 1) and with nominal dimensions of the structure
- material characteristics (fy, E, G)
- nominal value (average)

Classification of load:

- the origin of the load is either gravitational (self-weight of the structure), climatic (snow, wind, rain, frost, temperature), useful (load of ceilings in buildings)
- according to certainty, they are divided into certain ones (the load is precisely determinable – e.g. load of bridges) or considerably indeterminate (e.g. wind)

Load size:

- it is determined by statistical characteristics - load size / frequency
- histogram
- it is possible to replace the theoretical curve, mean value, variance, Gaussian normal probability distribution

Load recurrence:

- 50 years

Division of loads in terms of limit states:

- characteristic - Fk x design (extreme - γF> 1, operational - γF = 1)
- design value: FEd = γF Fk

Combination of multiple loads:

- permanent load + simultaneous random loads:
- basic load combinations:
- simplified load combination

Dynamic loads:

- introduction of dynamic effects: dynamic calculation, dynamic factor δ. quasi-static calculation

Design resistance (Rd):

- Rd = Rk / μM
- Rk characteristic value
- γM material safety factor

Example of a drawn beam:

- Rk = A fy
- A - area
- fy - characteristic value of yield strength
- histogram of results

3.3. European standards

- mostly and product standards
- Design standards (Eurocodes): European standards since 1980 - European Standardization Commission (CEN) since 1990. Czech member since 1998
- Preliminary standards (ENV), National Application Document (NAD) - national differences, frame values - national differences in reliability
- Definitive European Standards (EN) - since 2005
- National Annex, very limited

European design standards:

- EN 1990 Eurocode 0 Design principles since 2004 ČSN
- EN 1991 Eurocode 1 Loading of structures since 2004 ČSN
- EN 1992 Eurocode 2 Design of concrete structures since 2005 ČSN
- EN 1993 Eurocode 3 Design of steel structures since 2005 ČSN
- EN 1994 Eurocode 4 Design of composite steel-reinforced concrete. from 2005 ČSN
- EN 1995 Eurocode 5 Design of timber structures since 2005 ČSN
- EN 1996 Eurocode 6 Design of masonry structures
- EN 1997 Eurocode 7 Geotechnical design
- EN 1998 Eurocode 8 Design of structures for earthquake effects
- EN 1999 Eurocode 9 Design of aluminium structures

Standards for proposals:

- are not respected by law x as evidence of recent knowledge of science and technology. The Czech harmonized system is used.
- ČSN 73 1401 Design of steel structures
- limit states since 1968
- in 1998 similar to the European preliminary standard
- European harmonized systems - ČSN P ENV, ČSN EN, ČSN EN 1993-1-1 Design of steel structures, ČSN EN 1994-1-1 Design of steel-concrete structures, ČSN EN 1990 Principles of design of structures, ČSN EN 1991 Loads of structures
- supplemented by a national annex

4. AFFIXED STEEL-CONCRETE STRUCTURES

- benefits / reasons for using: Increase stiffness. Concrete in compression and steel in tension, fire resistance, material saving ⇒ price
- elements: beams, pillars, steel-concrete slabs

Norms:

- European Standard EN 1994-1-1

Coupling elements:

- welded mandrels with head
- welded continuous perforated strip
- locked stops
- next

Coupling spines:

- the most common, cheap
- excellent working chart
- draw
- electric current for welding

Advantages of couplings spines:

- deformation of flexible spines

Perforated moldings:

- two types are used in the Czech Republic: Height 50 mm, Thickness 10 mm, Holes 32 mm and height 100 mm Thickness 12 mm, Holes 60 mm

Stoppers:

- galvanized sheet metal 2 mm, two nails
- height from 80 to 140 mm
- simple x expensive ⇒ reconstruction

4.1. Assessment

- we assess limit state of load capacity, bending capacity of critical cross sections, shear resistance, load capacity in longitudinal shear (coupling elements)
- limit state of usability - flexible behavior, deflections

Effective cross section:

- cooperative beff width
- effect of shear flap in plate

Bending capacity of cross section:

Cross section assessment - in plastic molding:

- positive plastic bending moment: neutral axis in the board, neutral axis in beam
- negative plastic bending moment x positive elastic bending moment

Shear connection:

- the coupling elements transmit longitudinal shear either plastically (Class 1 and 2) - spikes evenly placed, number of spikes placed on the shear stress section, or flexibly (Class 3 and 4) - spikes according to the moving force

Limit state of usability:

- assessed according to operating load (γG = γQ = 1,0; γM = 1,0), beam in elastic state
- deflections
- frame limitation in concrete - the width wk = 0.3 mm is tolerated
- board reinforcement design
- influence of installation procedure

Flexible action:

- the assumption of the cross-sectional plane
- ideal cross section

Static values of the ideal cross section:

- conversion of concrete cross-section to steel equivalent: the area of the ideal cross section
- location of center of gravity, moment of inertia

Mounting procedure:

- with and without formwork
- does not affect Mpl, Rd
- it affects flexible behavior
- no formwork - Verify the bearing capacity at the assembly stage

5.STOREY BUILDINGS

- their basic purpose is twofold: residential buildings and in industrial buildings
- for storey buildings, mainly steel is used due to the following advantages: speed of construction (assembly), large spans ⇒ freedom of disposition, high buildings, exact dimensions (small tolerances)
- small weight ⇒ cheaper foundations, cheaper transport, easier reconstruction and demolition ⇒ recycling
- disadvantage: risk of fire

5.1. Structure of the load-bearing structure

Columns, ceiling beams, vertical stiffeners. Ceilings consist of boards and beams.

Construction systems:

- with or without ceiling beams (panels, light ceiling construction). Requirements for ceiling boards: resilience, stiffness, stiffness in the plane, easy mounting, acoustic parameters

Reinforced concrete slabs:

- monolithic x prefabricated
- reinforced ceiling slabs - profiled sheet profile + concrete
- steel - sheet metal with projections, steel bead
- ceramic

Reinforced ceiling slabs:

- high sheet metal panels (height 150-300 mm), low sheet metal panels (height 40-150 mm)
- the following components are used: Self-supporting trapezoidal sheets, sheets as lost formwork of a reinforced concrete slab, cohesive (so-called reinforced concrete slabs)

Ceiling beams:

- thickness (L / 15 to L / 30): rolled (IPE, 6-9 m), broken (9-12 m)
- trusses (h = L / 10 to L / 20) - over 15 m - skyscrapers
- proposal for the usable limit state (total L / 250; utility L / 300) - skid is never a decisive factor

Drawings:

- the MSU decides ⇒ in the direction of a smaller span
- decides on SMEs ⇒ in the direction of longer range
- seful load can be reduced (for area> 18 m2)
- same structural types of beams as for ceilings

Connections:

- articulated, with the front plate, using angles, on the joint plate

Pillars:

- extruded rods, eventually pressure + bends

Cross sections of columns:

- rolled HEB, welded, steel concrete
- steel scaffolds

Mounting connections:

- production length - usually 2 to 4 floors, normally up to 12 m, max. About 15 m
- easy fitting: near the ceiling, simple contact. Up to a quarter of the floor height
- change the cross section - welded - preservation of external dimensions

Space rigidity:

- in the horizontal direction - secured by a ceiling (rigid ceiling board)
- in the vertical direction - trusses, frame stiffeners, concrete lining of the wall

Types of stiffeners:

- truss
- frame
- mixed
- wall

Placement of stiffeners:

- if possible symmetrical to the axis in the wind direction
- building stiffness - Allowed deflection
- transfer of horizontal loads
- avoiding pull in the columns
- placement inside the layout

6.HALLS

There are two basic types of halls:

- of smaller spans up to 60 m - typical thickness rail/frame
- halls of large spans: construction of rigid elements, plane structures, space structures, suspension structures: fiber structures, hybrid construction, membrane structures; suspended structures: suspended rigid structures, suspended suspension structures
  pneumatic structures with ropes

Load acting on halls:

- constant load
- crane loads
- snow loads
- wind load
- other loads: technological load, ventilation equipment on the roof, power distribution
- load temperature differences, boundary dimensions of the sections of the object
- the effects of undermining

6.1. Crane loads

- repeatedly dynamically
- vertical wheel pressures V from the weight of the crane, the cat and the load,
- horizontal transverse forces:
- transverse braking forces Bt from the start and braking of crane cats,
- the transverse forces Htp from the crane's crossing,
- the horizontal longitudinal braking forces B from the start and braking of the crane,
- the horizontal longitudinal forces H from the impact of the crane on the track bumpers.
- dynamic effects
- combination
- only one of the horizontal loads

6.2. Snow loads

Typically, two loading states are considered: even load caused by invasion of snow in the wind and unequal load caused by the snow

The uniform snow load on the roof is determined by the formula:

- S = µi Ce Ct sk
- where µ
- i shape coefficient
- Sk characteristic value of snow load on the ground kN/m 2
- Ce exposure factor, which typically has a value of 1.0
- Ct is a coefficient of heat that typically has a value of 1.0

The uneven snow load on the roof in an exceptional situation under exceptional snow conditions is determined by the relationship:

- s = µi Ce Ct sAd
- In the conditions of exceptional snowflakes from the relationship
- S = µ
- I sk
- where sAd is the design value of an exceptional snow load on the ground
- In the considered location given by the relationship
- SAd = Cesl sk
- Cesl is a factor for exceptional snow loads (the recommended value is 2)

6.3. Layout of the hall

- entered inner volume, external volume, casing, boom range L0, distance of trusses B0, distance of columns (B0)
- clearance H0
- in the past, a 300 mm module was typical

Layout solution:

- one-lane halls
- multiple halls with parallel boats
- halls with perpendicular boats

Design of spatially rigid halls - the main parts of the space:

- tight structure of the hall: roof structure, columns, crane tracks
- longitudinal bracing of the hall, the construction of perimeter walls

Elements:

- roofing
- purlin
- beam
- dies
- pillars
- crane tracks
- front walls
- joints (frame, foot, top)

Roofing:

- unbalanced, folded, sandwich
- the purlin pitch is determined by the load-bearing capacity of the roof sheath, (3.5 m)
- intermediate, gutter and ridge
- statically
- simple-walled, Cracked up to 6 m
- simple Arrows from 12 m
- articulated or continuous solids 6 to 9 m
- retractable and suspended 9 to 15 m

Bouncers:

- thin wall trusses
- beam trusses

Pillars:

- articulated (swinging)
- clamped columns - full body
- trusses

7.LARGE SPAN HALLS

Covering large areas:

- sports buildings
- exhibition purposes
- social and cultural centers
- large garage
- hangars
- tribunes of sports stadiums
- transportation construction

Engineering aesthetics:

- design systems with minimization of weight and minimal load
- example: roofing = functional part of the supporting structure - membrane
- segmentation according to viewpoints: static system, construction design, the shape of the roof area, the shape of the ground plan

Static effect:

- construction of rigid elements - plane structures, space structures
- hanging structures: fiber structures, hybrid construction, membrane structures
- suspended structures: suspended rigid structures, suspended suspension structures, pneumatic structures with ropes

7.1. Construction of rigid elements

Planar structures: beam, frames, arched, systems with rigid draw bars (from suspended structures)
Spatial structures: space arcs, the needles and the dome, shells, spatial beam structures

- shaped
- truss plates

Two-layer rod systems:

- significantly stiffer, constructively more complicated
- rods or shells
- computing
- rods: single-layered systems
- spatial system diagonal
- not affected by global or local stability

Gable:

- from planar parts, e.g. saw blades roofs, circular gable above the central plan view
- single-sided - side walls with truss beams
- two-layer - beam structures

Cupolas:

- lamels
- sectoral
- grates
- plates

End of a stick/bar: welded, ball joints - welded from hollow hemispheres of sheet metal, screwed

Hanging structures:

- great advantage is low material consumption, great shape diversity, great distortion
- large horizontal reactions
- fiber structures, hybrid structures, membrane structures

Hybrid structures:

- reinforced roofs - bending rigid casing - concrete layer
- construction of ropes and beams, direct wire design, structure with fibers over the roof
- fibers and beams

Membrane structures:

- sheet steel membranes
- non-metallic membranes

Pneumatic structures with ropes:

- overpressure
- a low-passive cloak
- steel wire rope stabilization
- rigid structures of the tribunes

Corrosion:

- it is an electrochemical reaction of oxygen and water - critical humidity 60 to 75%
- protection of structures
- separation from the atmosphere - coatings
- electrochemically - coated with zinc or aluminum
- alloying - Stainless steel, patting steel
- constructional solutions

Electrochemical corrosion:

- aluminium
- zinc
- carbon steel
- stainless steel
- copper
- silver
- gold

The metal positioned above acts as an anode; disappears and protects against corrosion.

7.2. Coatings

Main color components: it is necessary to apply it to the surface of the component, use layers, coating films
Pigment - color shade, water resistance, corrosion inhibitor
Thinner - for the correct consistency of the paint

Paint system:

- primer (primer) - Apply a coating to the surface of the protected element, two (three) layers
- coating layers - Color base, Coating layer - thickness 25 μm, three (four) layers
- cover coat - Aesthetic purpose, single-layered (two-layer); thickness of layer 25 to 100 μm