Wooden structures Calculation of wooden structures by the method of limit states EN RK 1995-1-1: 2008/2011 Design of wooden structures. Section 1-1. General rules and building regulations);

EN RK 1995-1-2: 2008/2011 Design of wooden structures. Section 1-2. General rules for the design of structures, taking into account the effects of fire;

EN RK 1995-2: 2008/2011 Design of wooden structures. Part 2: Bridges;

ST RK EN 14081-1 Wooden structures. Structural timber of rectangular cross-section, sorted by strength. Section 1. General requirements.

ST RK EN 14374 Wooden structures. Structural fibrous plywood wood material. Technical requirements.

ST RK EN 409 Wooden structures. Test methods. Determination of bending moments of pin-type fasteners;

Importance of wooden structures

Wood is loved not only by architects, but also by craftsmen, technicians and engineers, because when working with wood, they feel connected to nature.

Today, designers offer not only stone, concrete, steel, mixed structures, but also wooden structures, which are often used in construction. Due to the development of new methods and techniques in construction, the application of wooden structures has expanded. Formations Advantages of wooden structures:

- □ wood lightweight material;
- □wood is easily processed both at the plant and on the construction site;
- □wooden building parts can be combined in different ways;
- □ Forms that are not made of other materials or can be made of complex structures can be made of wooden structures;
- □ Some types of wood structures (eg shells) can be more efficient than concrete or other structures;
- □ Some of the structural and physical abilities of wood are very valuable (for example, heat capacity).

Disadvantages that limit the use of wooden structures:

- •Swelling;
- drying;
- Danger of extinguishing and combustion;
- curvature;
- •explosion;
- heterogeneity of structure;
- Defects of wood.

But the effect can be reduced, because modern technology uses a variety of methods to eliminate the disadvantages of natural wood - protection and beautification.

Areas of application of wooden structures:

Modern methods of wood preservation and gluing with waterproof adhesives allow the use of wooden structures in open ground and hydraulic structures (bridges, overpasses, towers, dams, etc.).

ADHESIVE CONSTRUCTIONS ARROW BACKS



ARCHES



FRAMEWORK STRUCTURES



DOME COVER



Design and calculation of elements of structures



Figure 1. Structural schemes and assemblies of two-story wooden roofs: a, b - suspended rafters (trusses) for single-storey single-storey buildings; c - sloping rafters for single-storey two-storey buildings; d - suspended rafters (trusses) for one-story attic buildings; e - such as broken roofs; e - for two-story attic buildings.



The use of wooden structures is limited:

- in multi-storey industrial buildings with large crane loads, on large span bridges;

- in rooms with high industrial humidity (due to the risk of rot).

The use of wooden structures in hot shops and in all cases where the use of wood is not allowed under fire safety conditions is prohibited

Wood structure

In temperate climates, trees grow by increasing the concentration layers in the trunk. In the cross section of the tree trunk, this process looks like a ring - they are called annual layers.

Annual layers are clearly visible in many species of trees: pine, pine, oak, etc. They consist of two stripes - light and closed. The light-colored inner strip is composed of flat-striped spring cells that form a low-strength young tree.

Closed inner band - consists of cells with thick-walled thin cavities that form a strong and dense old wood

The difference between young and old trees is insignificant in spruce, fir and some deciduous trees.

Radial section



A nine-year-old tree trunk wedge

1 Деревянный клин, вырезанный из деаятилетнего ствола



Tangential section

Features that characterize the structure of wood: fiber and porosity. The structure of the tree is well visible in the main sections of the trunk.

In the middle of the cross section is the weakest and most prone to rot - the core.

In many species of wood, the middle part, which surrounds the core, is solid and impermeable to liquids - the strongest part.

If the outside of this part is dark brown, it is called the core (pine, pine, oak).

If the color of this part is the same as the outside, and the humidity is low, it is called a mature tree (spruce, cedar, beech).

Chemical composition of wood

Cell membranes are composed mainly of cellulose, hemicellulose and lignin. As the tree grows, its lignin content increases and the bark hardens. The substance between the cells is mainly lignin.

- Chemical composition of wood, rounded up to 1%:
- \Box carbon 50%;
- □ oxygen 44%;
- \Box water only 6%.

Physical properties of wood

Wood has different properties in different directions, ie it belongs to anisotropic building materials.

- Because these properties make wood a fibrous material.
- Defines two main directions when considering the properties of wood:
- along the fibers usually corresponding to the longitudinal axis of the wood elements;
- The fibers are horizontal in a direction perpendicular to the longitudinal axis.

Physical properties of wood

Wood materials are divided into hard and soft wood materials according to the density of wood.

- Soft and hard wood seeds can also be used to make wooden structures.
- Soft seeds: spruce, pine, cedar, poplar, aspen Hard seeds - cedar, birch, oak, ash

All wood materials are divided into strength classes according to the values of strength and elastic characteristics of wood in accordance with the requirements of EN 338.

EN 338 has 18 strength classes: - 12 - for softwood seeds - C14, C16, C18, C20, C22, C24, C27, C30, C35, C40, C45, C50; - For 6 hardwood seeds - D30, D40, D50, D60 and D70.

Letters C and D belong to the coniferous and deciduous tree species, and the number indicates the characteristic strength at bending, N / mm2.

Mechanical properties of wood

- Strength and rigidity are the most important in building timber structures.
- The strength of wood is very well studied under the influence of short-term static load. The effects of long-term loads are currently being studied in detail, as such loads are very common in practice (own weight, snow, equipment weight, etc.).

Standard determination of the properties of wood is carried out in laboratories with the help of special equipment.

- Based on the testing of standard samples, the following indicators of the tree are determined:
- strength limit the voltage corresponding to the destructive short-term static load;
- proportional limit the voltage corresponding to the point of transition of the straight part of the curve to the curvilinear part (in some tests this indicator may not be);
- modulus of elasticity the index of rigidity of the material, equal to the tangent of the angle of inclination of the curve to the abscissa axis.
- The value of the modulus of elasticity is constant to the limit of proportionality, and in the general case it is variable.

The strength of wood is determined by a compression test along the fibers. Tests are performed on prisms of $2 \times 2 \times 3$ cm.

The strength limit of spruce is 400-500 kg / cm2. The development of elastic deformations is observed before destruction.

Wood works in the same way when the surface is compressed, ie wrinkled, along the fibers.

The compressive or creasing strength of wood in the horizontal direction to the fibers is much lower.

Tensile tests are performed on specimens with a cross-sectional area of 0.4×2 cm. The strength limit of a spruce is 800-1000 kg / cm2, which is twice as high as when the fibers are compressed.

However, due to the defects of the wood, the high tensile strength of wood is not used in structures.

When stretched, the wood breaks brittlely, that is, the elastic deformations do not develop suddenly.

Strength class. Characteristic values according to EN 338

			Терек және қылқан жапырақты ағаш тұқымдары							2	Жапырақты ағаш тұқымдары								
Tes Selen		C14	C16	C18	C20	C22	C24	C27	C30	C35	C40	C45	C50	D30	D35	D40	D50	D60	D70
Беріктік көрсеткішт	r <mark>epi</mark> , H/	MM ²																	
Иілу	$f_{\rm mk}$	14	16	18	20	22	24	27	30	35	40	45	50	30	35	40	50	60	70
Талшықтар бойы созылу	$f_{t,0,k}$	В	10	11	12	13	14	16	IS	21	<mark>24</mark>	27	30	IS	21	24	30	36	42
Талшықтарға көлденең созылу	<i>f</i> _{t,90,k}	0,4	0,5	0,5	0,5	0,5	0,5	0.6	0,6	0,6	0,6	0,6	0.6	0,6	0.6	0,6	0.6	0,7	0,9
Талшықтар бойы сығылу	$f_{\rm c,0,k}$	16	17	IS	19	20	21	22	23	25	26	27	29	23	25	26	29	32	34
Талшықтарға көлденең сығылу	$f_{\rm c,90,k}$	2.0	2,2	2,2	2,3	2.4	2,5	2.6	2,7	2,8	2,9	3.1	3,2	8;0	8.4	8,8	9,7	10,5	13,5
Ығысу	$f_{\mathrm{v,k}}$	1,7	1,8	2,0	2,2	2.4	2.5	2.S	3.0	3.4	3.8	3.S	3.S	3.0	3.4	3.8	4.6	5,3	6.0
Қатандық көрсеткі	штері	кН/мм2	2		22														
Талшықтар бойы серпімділік модулінің орташа мәні	$E_{0,\mathrm{mean}}$	7	S	9	9 <mark>,</mark> 5	10	11	11	12	13	14	15	16	10	10	11	14	17	20
Талшықтар бойы серпімділік модулінің 5%-дық квантилі	<i>E</i> _{0,0,5}	4,7	5,4	6,0	6,4	6,7	7,4	8.0	S;0	8,7	9,4	10,0	10,7	8,0	8,7	9,4	11,S	14,3	16,K
Талшықтарға көлденең серпімділік модулінің орташа мәні	$E_{90,\mathrm{mean}}$	0,23	0,27	0,30	0.32	0,33	0,37	<mark>0,3</mark> 3	0.40	<mark>0.4</mark> 3	0,47	0.50	0,53	0,64	0,69	0,75	0,93	1 1 3	1,33
Ығысу модулінің орташа мәні	$G_{ m mean}$	0,44	0.50	0,56	0.59	0,63	0,69	0,72	0,75	0.81	0,85	0.94	1,00	0,60	0,65	0,70	0,88	1,06	1,25
Тығыздық, кг/м ³																		a x	
Тығыздық	$\rho_{\rm k}$	290	310	320	330	340	350	370	380	400	420	440	460	530	560	590	650	700	900
Тығыздықтың орташа мәні	$ ho_{\rm mean}$	350	370	3S0	390	4 <mark>1</mark> 0	420	450	460	430	500	520	550	640	670	700	750	840	108 0

Примечание — 1 Указанные выше шэченпя прочности нрн растяжении, сжатии н ствиге. 5%-нын КБантнль модиля уорута-стн. среднее значение ко духа упругости поперек волокон н среднее шлченде модуля

едннга рдсситии с применением формул. указанных в ЕЫ 333 (Приложение А.).

Примечание — 2 Табличные значения распространяются на древесину с влагосолержаннем прп температуре 20 С н относительнон влажности воздуха 65"**.

Protection of wooden structures from rot

Wood rot is a biochemical process that leads to collapse. The causative agents of rot are fungi.

The most dangerous fungi for wooden structures are house mushrooms that grow on felled trees.

The wood is first protected by constructive methods, if they are not enough, then use chemical methods (antiseptics)

Materials

The main materials of timber structures are cut materials made of pine and spruce in accordance with EN 13986 *, delivered in sorted form.

For the manufacture of structures used in indoor buildings, the humidity of the wood should not exceed 20%.

The moisture content of wood should not exceed 25% for the manufacture of structures used in ventilated open buildings located on the ground.

The moisture content of cut materials for adhesive structures and elements should be 8-12% and they should meet the requirements of EN 14080

Calculation of tree structures

- 2011 Characteristics of the introduced RK STD 05-01-1.1-2011 are as follows:
- Table 1 for tree species depending on strength classes;
- Table 3 for homogeneously glued multilayer trees;
- Table 4 for composite glued multilayer trees;
- Table 8 for Finnish birch plywood (according to EN 12369-2);
- Tables 9-10 for Finnish composite plywood (according to EN 12369-2);
- Table 18 for OSB boards (according to EN 12369-1).

Elements extending from the middle Checks the strength of the elongated elements according to the following formula:

$$\sigma_{\rm t,0,d} \le f_{\rm t,0,d}$$

 σ t, 0, d - rated voltage extending along the fibers;

ft, 0, d is the design resistance of the wood to elongation along the fibers.

Determines the rated voltage σt , 0, d along the fibers by the following formula:



where Nd is the calculated longitudinal tensile force; Anet - the "net" area of the cross section of the element, taking into account the weakening of the cross section. ft, 0, d - the calculated resistance of wood to elongation along the fibers is determined by the following formula

$$f_{t,0,d} = \frac{k_{\text{mod}} \cdot k_{\text{sys}} \cdot k_{\text{h}} \cdot f_{t,0,\text{k}}}{\gamma_{\text{m}}}$$

ksys - a factor that takes into account the strength of the system, is used only if the system can redistribute the load; kh is the correction factor that takes into account the effect of the size of the element during elongation, to determine it should be used the maximum size of the cross section of the element:

$$k_h = \min\left\{ \left(\frac{150}{h}\right)^{0.2} \text{ или } 1.3 \right\}$$

ft,0,k is the characteristic value of tensile strength of an element made of wood or its base material (given in Tables 1-18).

□m - individual coefficient of material properties Table 25

Table 25 Individual coefficient of material properties, fM

Негізгі комбинациялар	$f_{\rm M}$
Біртұтас ағаш	1,3
Желімделген ағаш	1.25
LVL. фанера. OSB	1,2
дсп	1,3
ДВП (ұатты)	1,3
ДВП (орташа тығыздықты)	1,3
двп. мдф	1,3
ДВП (жұмсақ)	1,3
Қосылыстар	1,3
Перфорацияланған бекіткіш металл пластиналары	1.25
Кездейсоқ комбинациялар	1.0

Құрылыс құралымдары

Table 26 - The value of the coefficient kmod

		Dečeseva	Әрекет ету ұзақтығы класы								
Материал	Стандарт	класы	тұрақты	ұзақмерзімді	ортамерзімді	қысқамерзімді	жылдам				
Біртұтас ағаш		1	0,60	0,70	0.80	0,90	1.10				
	CT PK EN 14081	2	0,60	0,70	0.80	0,90	1.10				
	- 111 s	3	0,50	0,55	0,65	0,70	0,90				
Желімделген ағаш		1	0,60	0,70	0.80	0,90	1.10				
	EN 14080	2	0,60	0,70	0.80	0,90	1.10				
		3	0,50	0,55	0,65	0,70	0,90				
	CT PK EN 14374	1	0,60	0,70	0.80	0,90	1.10				
LVL	CT PK EN 14279	2	0,60	0,70	0.80	0,90	1.10				
		3	0,50	0,55	0,65	0,70	0,90				
Фанера	EN 636-1	1	0,60	0,70	0.80	0,90	1.10				
	EN 636-1	2	0,60	0,70	0.80	0,90	1.10				
	EN 636-1	3	0,50	0,55	0,65	0,70	0,90				
OSB	EN 300 OSB/2 OSB/3, OSB/4 OSB/3, OSB/4	1	0,30	0.45	0,65	0,85	1.10				
		1	0,40	0,50	0,70	0,90	1.10				
		3	0,30	0.40	0,55	0,70	0,90				
дсп	EN 312 P4, P5	1	0,30	0.45	0,65	0.55	1.10				
	EN 312 P5 EN 312 P6, P7 EN 312 P7	2	0,20	0,30	0,45	060	0,50				
		1	0,40	0,50	0,70	0,90	1.10				
		2	0,30	0.40	0,55	0,70	0,90				
ДВП (тығыз)	CT PK EN 622-2 HB1A. HB.HLA	1	0,30	0.45	0,65	0,55	1.10				
	1 или 2 HB.HLA 1 или 2	2	0,20	0,30	0,45	060	0,50				
ДВП (орташа тығыздықты)	СТ РК EN 622-3 MBH.LA1 или 2	1	0,20	0.40	0,60	050	1.10				
	MBH.HLS1 или 2	1	0,20	0.40	0.60	050	1.10				
	MBH.HLS1 или 2	2	-		8	0,45	0,50				
ДВП. МДФ	CT PK EN 622-5 MDF.LA.	1	0,20	0.40	0.60	050	1.10				
	MDF.HLS	1	0,20	0.40	0.60	050	1.10				
	MDF.HLS	2		123	2	0,45	0,50				
						-					



Compressed elements from the center **Курылыс қуралымдары**

Wood is well resistant to compression. The effect of wood defects on compressed elements is less than on elongated elements. Compressed elements from the center can be destroyed due to loss of strength or stability.

The strength of elements subject to axial compression depends on several factors:

- modulus of compressive strength and elasticity of wood;
- dimensions and length of the cross section;
- Terms of approval of the three;
- geometric defects (deviations from the nominal size, initial curvature, etc.);
- changes in the properties of the material and its disadvantages (density, elasticity of joints, moisture)

During axial loading, due to imperfections in the geometry of the element or changes in its properties, as well as a combination of two factors, the elasticity of the element increases and the displacement in the horizontal direction increases, which eventually leads to loss of stability as shown in the figure. The elasticity of the element should be determined by the formula: $\lambda = \text{Le} / \text{I}$

where Le is the calculated longitudinal tensile force;

i is the radius of inertia of the section $i = \sqrt{I/A}$ I is the moment of inertia of the cross section or the element. A is the cross-sectional area of the element.



$$\lambda_{\rm y} = \frac{L_{\rm e,y}}{i} = \frac{L_{\rm e,y}}{h/\sqrt{12}} \qquad \qquad \lambda_{\rm z} = \frac{L_{\rm e,z}}{i} = \frac{L_{\rm e,z}}{b/\sqrt{12}}$$

where Le, y and Le, z are the calculated lengths of the element relative to the y-y and z-z axes, respectively.

The loss of stability of the element is related to the axis with the highest

value of elasticity.

The calculated length of the element Le is determined: Le = $\mu 0^* L$

where L is the full length of the element;

Le is the calculated length of the element, depending on the scheme of load distribution and fastening of the ends along its length;

 μ 0 is a factor that takes into account the conditions of attachment of the element, which is equal to:

1) in the case of longitudinal loading on the ends of the element:

- if the ends are hinged, as well as when hinged at intermediate points of the element, $\mu 0 = 1$;
- if one side is hinged and the other side is rigidly fixed -0.8; μ 0 = 2.2 if one side is rigidly fixed and the other side is loose;
- $\mu 0 = 0.65$ if both sides are rigidly fixed;

2) in the case of uniform distribution along the length of the longitudinal load element:

- if both ends are hinged, $\mu 0 = 0.73$;
- μ 0 = 1,2 if one side is rigidly fixed and the other side is loose.

For a full-length idealized vertical element with homogeneous properties and two ends hinged, the critical force at which the loss of stability with respect to the y-y or z-z axis occurs within the elastic work of the element material can be defined as follows:

$$P_{\rm E,y} = \frac{\pi^2 E_{0,05} A}{\lambda_{\rm y}^2} \qquad P_{\rm E,z} = \frac{\pi^2 E_{0,05} A}{\lambda_{\rm z}^2}$$

where PE, y is the critical force with respect to the y-y axis; PE, z - critical force with respect to the z-z axis;

E0.05 - 5% quantile of the modulus of elasticity of the element material;

Cross-sectional area of the A-element;

 λy is the elasticity with respect to the y-y axis, $\lambda y = (1, 0 \times L) / iy$;

 λz is the elasticity with respect to the z-z axis, $\lambda z = (1, 0 \times L) / iz$.

Dividing A by the cross-sectional area of the corresponding critical strong element, we obtain the critical strength of the element with respect to the z-z and y-y axes.

$$\sigma_{\rm E,y} = \frac{\pi^2 E_{0,05}}{\lambda_y^2} \qquad \sigma_{\rm E,z} = \frac{\pi^2 E_{0,05}}{\lambda_z^2}$$

According to EN 1995-1-1: 2008/2011, the relative flexibility (ie the element oscillates along the z-z axis) corresponding to the bending relative to the λ rel, y -u-y axis and the relative flexibility corresponding to the bending relative to the λ rel, z-z-z axis (that is, the element oscillates along the y-y axis) is determined by:

$$\lambda_{\rm rel,y} = \frac{\lambda_{\rm y}}{\pi} \sqrt{\frac{f_{\rm c,0,k}}{E_{0,05}}}$$

$$\lambda_{\rm rel,z} = \frac{\lambda_{\rm z}}{\pi} \sqrt{\frac{f_{\rm c,0,k}}{E_{0,05}}}$$

Calculation for short and massive elements with relative flexibility λ rel, y and λ rel, z \leq 0,3 should be performed according to the following formula

$$\sigma_{c,0,d} \leq f_{c,0,d}$$

$$\sigma_{\rm c,0,d} = \frac{N_{\rm d}}{A}$$

σc, 0, d - rated stress along the compressed fibers;fc, 0, d is the design resistance of the wood to compression along the fibers.

The compressive stress along the fibers σc , 0, d is determined by the following formula:

$$\sigma_{\rm c,0,d} = \frac{N_{\rm d}}{A}$$

where Nd is the calculated longitudinal compressive strength;

A is the cross-sectional area of the element.

For compressed elements with relative flexibility λ rel, y> 0.3 and / or λ rel, z> 0.3, the following conditions must be met

kc, y and kc, z - longitudinal bending coefficients:

$$k_{\rm c,y} = \frac{1}{k_{\rm y} + \sqrt{k_{\rm y}^2 - \lambda_{\rm rel,y}^2}}, \qquad \qquad k_{\rm c,z} = \frac{1}{k_{\rm z} + \sqrt{k_{\rm z}^2 - \lambda_{\rm rel,z}^2}},$$

$$k_{\rm y} = 0,5(1 + \beta_{\rm c}(\lambda_{\rm rel,y} - 0,3) + \lambda_{\rm rel,y}^2),$$

 $k_{z} = 0,5(1 + \beta_{c}(\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^{2})$

fc, 0, d - the calculated resistance of the wood to compression along the fibers is determined by the following formula

$$f_{\rm c,0,d} = \frac{k_{\rm mod} k_{\rm sys} f_{\rm c,0,k}}{\gamma_{\rm M}}$$

where kmod - modification factor 26 table; ksys - a factor that takes into account the strength of the system, used only if the system can redistribute the load; fc, 0, k is the characteristic value of compressive strength along the fibers of an element made of wood or a material based on it (given in Tables 1-18). \Box m - individual coefficient of material properties Table 25

where βc is $\beta c = 0.2$ for solid cross-sectional elements made of wood, if the deviation from the vertical line measured in the middle of the length of the element is less than or equal to L / 300. For elements made of multilayer glued wood and LVL, the coefficient $\beta c =$ 0.1, if the deviation from the straight line measured in the middle of the length of the element is less than or equal to L / 500.