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ASSESSMENT OF THE TECHNICAL STATE OF TIMBER OUTLET ELEMENTS OF UNDERGROUND SUPERSTRUCTURES WHILE HOLDING THE MONITORING OF OPERATING UNDERGROUND RUNNING LINE TUNNELS IN MINSK

Timber elements computation methods are presented in the article including the endurance of load action and humidity for timber strength in accordance with statutory documents. The analysis of humidity and temperature conditions of the underground constructions is performed; defects and damages, timber outlet elements of underground superstructure of normal operating are described in details. An alternative method of timber elements underground superstructure longevity rising is proposed in obedience to the mentioned reasons of the decreasing longevity.

***Keywords:** transportation construction, longevity, reliability, defects, damages, sleepers, tunnels, monitoring, deformations.*

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ОЦІНЮВАННЯ ТЕХНІЧНОГО СТАНУ ДЕРЕВ'ЯНИХ ВИВІДНИХ ЕЛЕМЕНТІВ ПІДЗЕМНИХ НАДБУДОВ ПРИ МОНІТОРИНГУ ПРАЦЮЮЧОЇ ГІЛКИ МЕТРО У МІНСЬКУ

Наведено методи розрахунку елементів із деревини, в тому числі вплив дії навантаження та вологості на міцність деревини відповідно до нормативних документів. Проаналізовано вологість та температурні умови підземних споруд, дефекти та пошкодження, поверхневі деталі підземної надбудови з деревини з метою їх нормальної роботи. Запропоновано альтернативний спосіб підвищення витривалості елементів деревини підземної надбудови згідно зі згаданими причинами зменшення їх довговічності.

***Ключові слова:** транспортне спорудження, довговічність, надійність, дефекти, пошкодження, шпали, тунелі, моніторинг, деформації.*

Introduction. In the underground a rail-tracked and cross-tied lath is spread on the concrete base where the base is a granular sub base. The most important question while designing the running line tunnels is the reduction of destructive effect on the tunnel both with vibration and noise. In comparison with reinforced concrete sleepers, timber sleepers operate better. Another complicated task is fixing of a reinforced concrete sleeper with track concrete considering its possible change. The appliance of running line tunnel superstructure of treated timber sleepers in construction work is technically and economically reasonable as Belarus is a member of top 10 wooden European states upon key indications and the production of marketable timber in 2016 is 15,1 million cu.m. [8]. But the process of sleepers' change is a complicated and expensive operation that requires a lot of financial needs and hand-labour. For reliability and longevity resistance increase of track circuits there is a need of the investigation, elaboration, testing and implementation of constructions' production of constructions that meet modern requirements, improving vibration and noise insulation as well as protection from corrosion and as a consequence introduction of a new assessment of the status of the road.

Analysis of recent sources of research and publications. According to the analysis of recent research and publications, the research in specific areas of this subject can be highlighted [6, 7, 9, 15]. The research is conducted and improved type of the rails and the bases of substructure are implemented in constant research, while the question of sleepers structures modernization (the exception is their substitution with concrete and polymer) is not properly considered.

Identification of general problem parts unsolved before. The main characteristic of underground trains save movement the rail head level. In Minsk underground rail tracks are laid on the monolithic timber and at the stations - on the sleepers. Sleepers as an element of the upper line are disregarded in the calculations. Without switching the sleepers, it is impossible to build the actual analytical model corresponding to the actual operation of the structures and surrounding of the array. Therefore, determination of the underground surface line as a whole is impossible.

The **goal** is comprehensive study of buildings and constructions conditions, use of combined research based on the type of design, required social significance and conditions.

Basic material and results. Considering the fact that since 2015 a five-year period of transition to European standards of design and construction of the Eurocodes in the Republic of Belarus (order Mais No. 404 dated 10.12.2009 g) all calculations of wooden structures are produced according to TKP EN 1995-1-1-2009 "Design of timber structures. Part 1-1. General - Common rules and rules for buildings" [1, 12].

According to section 6.1.5 of TKP EN 1995-1-1-2009 [1] the calculation of the cross section on the first group of limit States direct solid wood in compression perpendicular to the fibers should be made as follows: (1) in case (2):

$$\sigma_{c,90,d} \le k_{c,90,d} \cdot f_{c,90,d} \; ; \tag{1}$$

$$\sigma_{c,90,d} = \frac{F_{c,90,d}}{A_d} \; , \tag{2}$$

where $\sigma_{c,90,d}$, $F_{c,90,d}$, $f_{c,90,d}$ – is a calculated compressing press, forcing and resistance are in the functional contact area perpendicular to fibers;

A_d – a functional land area perpendicular to fibers;

$k_{c,90}$ – coefficient that takes into account the load configuration, possibility of splitting and degree of deformation.

The functional contact area perpendicular to the fibers A_d should be determined taking into account an functional contact length parallel to the fibers, which is the actual length of contact l is increased by 30 mm in each direction, but no more than a, l or $l/2$ (Fig. 1).

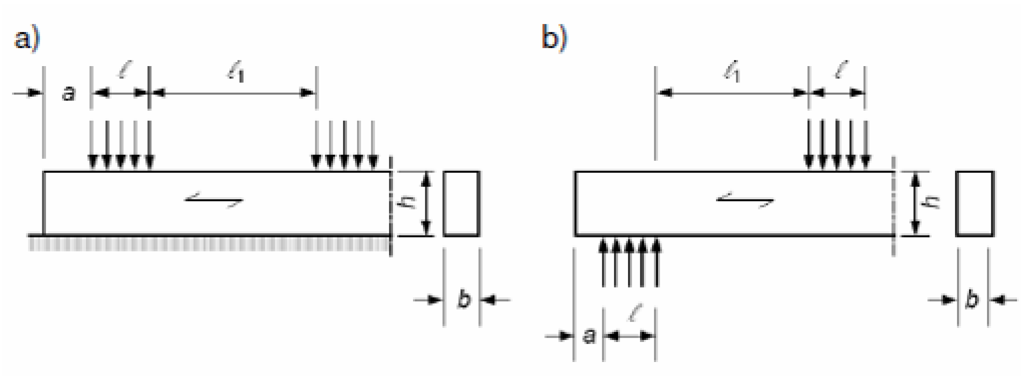

Figure 1 – continuous Element on (a) individual and (b) supports

The dimension $k_{c,90}$ is taken as 1.0 until the condition of this paragraph is done. In such cases, you should take the highest value $k_{c,90}$ but not more $k_{c,90}$ = 1,75.

For the object on the continuous support $l_1 \geq 2h$ (Fig. 1, a) value $k_{c,90}$ should be taken:

$k_{c,90}$ = 1,25 – for solid soft wood;

$k_{c,90}$ = 1,5 – for laminated soft wood;

where l is the length of the contact; h – the height of the element.

For the item in certain poles $l_1 \geq 2h$ (picture b), the value $k_{c,90}$ should be taken:

$k_{c,90}$ = 1,5 – for solid soft wood;

$k_{c,90}$ = 1,75 – for laminated soft wood with mm.

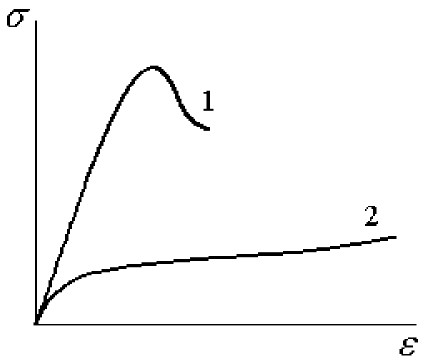

Figure 2 – Diagram of compression wood along fibres (1) and transverse (2)

According to curve 1 from the strain diagram (Fig. 2) the sample tested along the grain undergoes a small permanent deformation to failure. The destruction of the sample begins when the highest values of compressive force P_{max}, in the future there is a drop in load. A sample of the wood in the process of destruction of the fibers splits, then separation and breaking of the fibers, the formation of transverse folds and longitudinal cracks on the side surfaces of the sample happen.

Curve 2 shows that the diagram acquires a different character in the test sample in compression across the grain. To load P_{RG} curve chart looks like a sloped line, after overcoming this value, the sample is quickly deformed with a faint load change. This nature of the curve allows us to consider that the capacity of the test sample is exhausted. In this regard, the load corresponds to a tensile strength σ, P_{max} take such a load at which the sample is compressed to one third its original height.

When designing wooden structures, it should be considered the direction of the fibers in accordance with the diagrams of deformation, according to which the ratio of strength of wood in compression along and across the fibers is 1/8 – 1/10. Best option is the location of the compressive forces along the grain, i.e. in the direction of most resistance.

It is also necessary to calculate the increases and decreases in the temperature of rail lashes, allowable conditions of strength and stability.

Based on the studies of the stability of the path which includes directly considered in this article, sleepers, sets the permissible increase in temperature of rail lashes Δty. Calculation of the strength of the rail determines the allowable temperature drop.

Further investigation of the question of the computation of joint work of the concrete base, sleepers and thread rail is needed.

Important transport facilities safety depends on temperature and humidity conditions, operating conditions, nature of material and storage conditions. The speed of the aging process, in turn, determines the durability of any material.

In accordance with GOST 22830-77 [5], before placing in the path of the wooden sleepers, there is impregnated protective equipment on oily basis. For the sleepers made of pine plantations considering 50.1% of species composition of the Republic of Belarus [8], GOST [5] have additional requirements:

– prestressing humidity should not exceed an average of 18%;

– the depth of impregnation on a naked core should not be less than 10 mm;

– the average rate of antiseptic absorption should be 150 kg/m^3, with a minimum value of 125 kg/m^3.

The direct influence of the environment on the wooden structural elements in the form of metal dust, groundwater seepage can be reduced with constructive measures of protection or by the use of wood with high natural durability, or timber that has been previously protected against biological influences.

Temperature change leads to linear and volumetric deformations of structural elements, the nature of which depends on the nature of the materials.

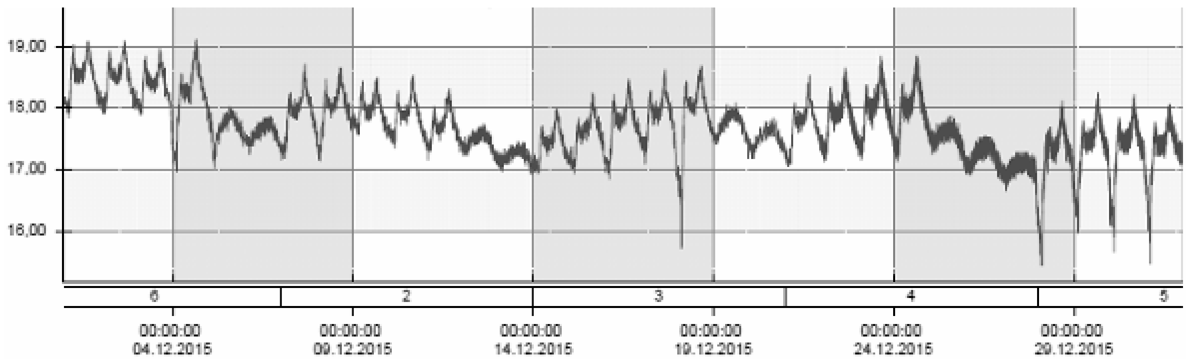

Figure 3 – Graph of temperature change in the running tunnel of the Minsk metro in winter

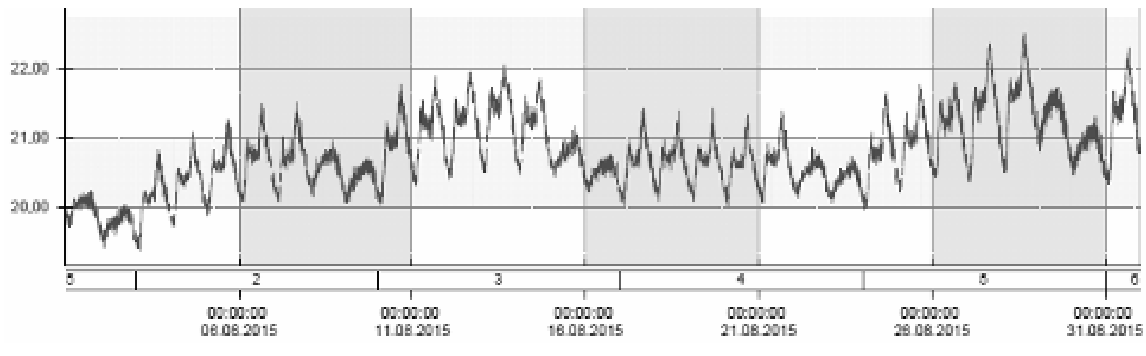

Figure 4 – Graph of temperature change in the running tunnel of the Minsk metro in the summer

Biological boundaries and intensity of damage is determined by the rate of chemical hydrolysis processes, gas and vapor permeability, and accelerated high humidity. The main cause of biological damage is the relative humidity exceeding 70%. Water change content causes a change in the volume of the material, which depends on the capillary movement of water in the material.

The change in moisture content of the air does not impact directly on the moisture content of the entire facility. Changes in relative humidity, which affect not immediately lead to different volumetric changes of connected materials, creating an invalid power of compression and extension.

The equilibrium moisture content in the material is established as a result of moisture exchange between him and air. The degree of absorption of moisture from the air (sorption) and return it back (desorption) determined by the temperature and relative humidity. Therefore, the main rule that must be respected, – the minimization of the absorption and desorption of moisture, that is, the achievement of thermal and humid dynamic equilibrium in the materials.

Occurring over a long period of time, alternate saturation with water and drying of structural materials leads to material fatigue and, as consequence, to decrease in strength.

The main causes of disruption of the normal operation of wood are rotting, cracking, mechanical wear of the wood under the pads and shoes develop holes from screws and crutches.

The whole rotting wooden sleepers is due to:

– the penetration rate of wood-destroying fungi through the cracks in the impregnated layer;
– improper storage and stacking, which directly affect the humidity conditions;
– damage to the impregnated surface.

The subway system is characterized by the decay in the upper third of the wooden sleeper's thickness.

There are two main reasons for the cracking (fracturing) wooden elements of the upper line:

– shrinkage of wood;
– rolling stock impact.

Timber sleepers are cracking - cracking of shrinkage of wood, developing mainly on the upper bed, and them falling into the water, particles of metal, dust and sand contribute to its decay.

The impact of train loads leading to tensile stresses from the lower bed, which in turn leads to developing over time, cracks as well as cracks with a length up to 30 cm in places of penetration of the main elements of rail fasteners.

The main causes of mechanical wear of the wood sleepers:

– vibration pads;
– infringement of sleepers installation technology;
– the way frequent remaking;
– the use of materials that do not meet these standards requirements.

Duration effect of load and moisture content on the timber strength in accordance with clause 2.3.2.1 EN 1995-1-1 [1] is calculated:

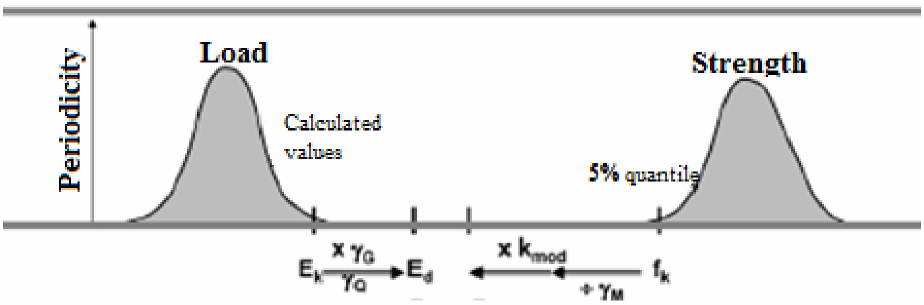

Figure 5 – Wooden structures safety

$$\sigma_d \le f_d \ ; \tag{3}$$

$$f_d = \frac{k_{mod} \cdot f_k}{\gamma_M} \ ; \tag{4}$$

$$E_d = \frac{k_{mod} \cdot R_k}{\gamma_M} \ . \tag{5}$$

Table 1 – Values of k_{mod}

Material	Standard	Operating class	Loadcase duration				
			Constant	Long -term	Medium -term	Short-term	Special
Solid wood	EN 14081	1	0.60	0.70	0.80	0.90	1.10
		2	0.60	0.70	0.80	0.90	1.10
		3	0.50	0.55	0.65	0.70	0.90

The equation of durability of wood [1] in accordance with the kinetic concept of solids strength can be written:

$$t = t_0 e^{\frac{U_o - \gamma f}{RT}} \ ; \tag{6}$$

$$lg\, t = lg\, A - \alpha f, \tag{7}$$

where

$$\alpha = \frac{\gamma}{2{,}3RT} \ ; \ \ lg\, A = \frac{U_0}{2{,}3RT} + lg\, \tau_0 \ , \tag{8}$$

U_0 – initial activation energy of fracture, kJ/mol;
t_0 – period of the thermal vibrations of the atoms.
f – stress, MPa;
t – time to failure (durability);
γ – structure-sensitive coefficient, kJ/(mol·MPa);
R – characteristic of the thermal motion (gas constant), kJ/(mol ·deg);
T – temperature, K.

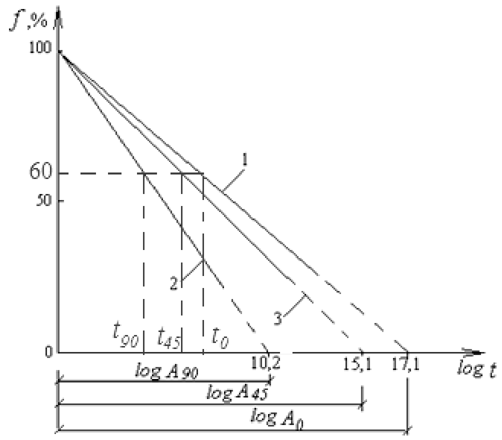

Figure 6 – The long-term strength dependence of wood for different types of the stress state:
1 – tension, compression and shear parallel to the grain (Adopted in EN 1995-1-1 regardless of SSS); 2 – tension across the grain; 3 – stretching at an angle of 45^0 to the fibers

An alternative to the traditional materials to increase durability and improve the operating conditions of the sleepers permanent way of the Metropolitan is the following composite system: working together wooden ties, concrete Foundation and GFPR-shell. This system better distributes the load from the temporary rolling stock between elements and at the same time is protected from corrosion, degradation of materials, because it is insensitive to environmental influences.

The modulus of elasticity of this material is twice the modulus of elasticity of concrete, its strength in tension, compression and bending exceeds the strength of steel more than doubled, and the resistance to the effects of lateral forces is only 2.5 times less than the strength of steel.

Durability for more than one hundred years (forecast), minimum operating costs, manufacturing plant - advantages of alternative composite material

Currently, this system is tested for spans in Canada, where it is built and successfully operated on roads (highways), and dozens of bridges with spans of 11 to 90 m.

Conclusions. For the analysis of structures it should be needed to consider all known science impact on design. Only comprehensive interpretation of the studies outcomes tests conducted by different specialists, enables the establishment of objective diagnosis and, as a consequence, development of the necessary activities as for the design and buildings restoration.

Accordingly, without considering the actual condition of the sleepers it is impossible to determine the surface structures of the metro as a whole.

When the timber outlet elements of underground superstructures are applied in the design, construction and monitoring of the metro tunnels structures, attention should be paid to:

– modeling and calculation of the above elements in accordance with applicable regulations;

– mounting technology, as the second stage, the possibility of defects and damages, leading out of normal operation;

– operation temperature and humidity conditions control, which directly affects the properties and the strength characteristics of the used materials.

For a better evaluation of the structure it is needed to study concrete base, sleepers and thread rail joint work calculation.

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