DESIGN RESULTS OF STRUCTURAL WOOD ELEMENTS ACCORDING TO EUROPEAN AND RUSSIAN BUILDING CODES
KOKA KONSTRUKCIJU ELEMENTU APRĒĶINA REZULTĀTI, PIELIETOJOT KRIEVIJAS UN EIROPAS BŪVNORMAS

T. Keskküla
Estonian Agricultural university
Igaunijas Lauksaimniecības universitāte
L. Ozola
Department of Structural Engineering, LLU
LLU Būvkonstrukciju katedra

Abstract. The article presents the comparison of design results of structural wood elements according to different building codes - Russian SNiP and European standards (ENV). For the analysis are chosen such subjects as design strength of wood, design snow load, timber connections. Significant differences are observed in the results of timber connection design.
Key words: wood structures, building codes, design.

1. Introduction

The reliability and effectiveness of wood constructions for the whole time of exploitation - that is a matter of current interest at any stage of branch development. Design rules being valid for building and civil engineering works guarantee the reliability of the structures designed, constructed and exploited as determined. Specialists therefore are responsible for a good selection to take Russian building codes SNiP or European standards Eurocode as a base for the Latvian building codes. Both SNiP and Eurocode (ENV 1991-1, 1994) are based on the same method - limit states method for the designing of building constructions. But there are some differences in the realization of the method and the determination of the parameters influencing the reliability. The article is devoted to the analysis of some design characteristics obtained using SNiP regulations and the same ones according to ENV codes of 1990 series.

2. Materials and methods

2.1. The design resistance of wood

The design resistance of material is a basic value in ultimate limit states calculations. Strength of wood in exploitation is influenced by different factors - such as loading time and moisture content most of all. By taking the equal mean value of the strength obtained in standard testing of structural wood elements, the design resistance values are calculated in two ways - according to SNiP and ENV.

Both SNiP (СНиП II-25-80, 1982) and ENV (ENV 1995-1-1, 1993) codes determine as a basic value characteristic strength of structural wood element with moisture content W=12 % in standard (short-term) loading, which has been modified by partial factors taking into account the real service conditions to obtain a design value of strength or design resistance.

Design resistance of structural wood element R in real service conditions according to SNiP is obtained by formula (Пособие, 1986):

$$R= R^{H} \cdot m_{дл} \cdot m_{B} \cdot m_{д} / \gamma_{M}, \quad (1)$$

where R^{H} - characteristic value of strength, $R^{H}=X(1-1.65\nu)$; X - the mean value of strength; ν - coefficient of variation $\nu=0.15...0.25$;

$m_{дл}$ - modification factor for load duration: $m_{дл}=0.66$ for simultaneous action of permanent and variable (snow) load;

$m_{д}$ - service factor for permanent loading in prevailing, $m_{д}=0.8$; in the case of short-term loading $m_{д}$ has been replaced by $m_{H}=1.2$;

m_{B} - service factor for moisture content, $m_{B}=0.75...1$ in relationship of moisture content;

γ_{M} - partial factor for material properties, $\gamma_{M}=(1-1.65\cdot\nu)/(1-2.33\cdot\nu)$.

Design resistance of structural wood element f_d (Table 1) in service conditions according to ENV 1995-1-1 codes is obtained by formula:

$$f_d = k_1 X \cdot k_{mod} / \gamma_M, \quad (2)$$

where k_{mod} - modification factor for load duration and moisture content; $k_{mod}= 0.5...1.1$;

γ_M - the same as mentioned above, $\gamma_M=1.3$;

k_1 - the statistical parameter calculated as $k_1 = \exp[-(2.645+1/\sqrt{n})\nu+0.15]$, n - sample size ($n\geq30$); X and ν - see above.

For example, there is presented the comparison of design resistance values based on the same mean value X=33 MPa (sample size n=50) in compression parallel to the grain for different coefficients of variation and service factors (Table 1). Design resistance values obtained according to SNiP are less then according to ENV codes and differences come to 40 %. Note that acoording to ENV codes design resistance determination procedure become considering now variation, now sample size.

2.2. Design snow load values on roofs

Both SNiP and ENV present the same formulae for snow load design value s_{cal} on the horizontal projection of the roof:

$$s_{cal} = \mu \cdot s_o \cdot \gamma_f, \quad (3)$$

where s_o - snow load value on the ground obtained by observations of many years standing for geographic region;

μ - shape coefficient for snow load on the roof;

γ_f - partial factor for snow load; $\gamma_f=1.5$ by ENV (ENV 1991-2-3, 1995); $\gamma_f=1.6$ for light roofs and $\gamma_f=1.4$ for heavy roofs by SNiP (СНиП 2.01.07-85, 1986). A roof is defined as "light", if it's self weight and snow load characteristic values ratio is less than 0.8 ($g/s_o<0.8$).

Adopt the same value of snow load on the ground, for example s_o= 1 kPa and estimate the design value of snow load by formula (3). There are differences in shape coefficient values determined by SNiP codes and the same determined by ENV as well as in safety factor γ_f values. Snow load design values in relationship of pitch angle for monopitch and double pitch roofs are given in Fig. 1. The SNiP codes determine considerably more snow load on the light roofs with the angle of pitch up to 30 degrees in comparison with ENV.

2.3. Simple beams in bending

Material consumption and safety of structural elements are in firmly relationship from design procedure limited by building codes. Consider design results of roof rafters behavioured as simple beams in elastic stage.

Table 1/1.tabula

Design resistance according to SNiP and ENV for the same mean value
Aprēķina pretestība pēc SNiP un ENV pie analoga vidējā lieluma

Coefficient of variation Variāciju koeficients	The mean strength value of wood X = 33 Mpa Koksnes vidējais stiprības lielums X = 33 MPa									
	Design values according to SniP Aprēķina lielumi pēc CNuN					Design values according to ENV Aprēķina lielumi pēc ENV				Relationship Attiecība
	characteristic strength normatīvā pretestība	partial factor drošuma koeficients	service factors darba apstākļu koeficienti		design resistance aprēķina pretestība	statistical parameter statistikas parametrs	characteristic strength stiprības raksturlielums	service factor darba apstākļu koeficients	design resistance aprēķina pretestība	
ν	R^n (MPa)	γ_M	m_B	$m_д$ (m_H)	R (MPa)	k_1	f_k (MPa)	k_{mod}	f_d (MPa)	R/f_d
0.15	21.86	1.14	1	1	12.70	0.76	25.24	0.8	15.53	0.82
0.15	21.86	1.14	1	0.8	10.16	0.76	25.24	0.6	11.65	0.87
0.15	21.86	1.14	1	1.2	15.24	0.76	25.24	0.9	17.48	0.87
0.15	21.86	1.14	0.9	1	11.43	0.76	25.24	0.65	12.62	0.91
0.15	21.86	1.14	0.9	0.8	9.15	0.76	25.24	0.5	9.71	0.94
0.15	21.86	1.14	0.9	1.2	13.72	0.76	25.24	0.7	13.59	1.01
0.2	18.15	1.22	1	1	9.83	0.67	21.96	0.8	13.51	0.73
0.2	18.15	1.22	1	0.8	7.87	0.67	21.96	0.6	10.14	0.78
0.2	18.15	1.22	1	1.2	11.80	0.67	21.96	0.9	15.20	0.78
0.2	18.15	1.22	0.9	1	8.85	0.67	21.96	0.65	10.98	0.81
0.2	18.15	1.22	0.9	0.8	7.08	0.67	21.96	0.5	8.45	0.84
0.2	18.15	1.22	0.9	1.2	10.62	0.67	21.96	0.7	11.82	0.90
0.25	14.44	1.34	1	1	7.10	0.58	19.10	0.8	11.76	0.60
0.25	14.44	1.34	1	0.8	5.68	0.58	19.10	0.6	8.82	0.64
0.25	14.44	1.34	1	1.2	8.52	0.58	19.10	0.9	13.23	0.64
0.25	14.44	1.34	0.9	1	6.39	0.58	19.10	0.65	9.55	0.67
0.25	14.44	1.34	0.9	0.8	5.11	0.58	19.10	0.5	7.35	0.70
0.25	14.44	1.34	0.9	1.2	7.66	0.58	19.10	0.7	10.29	0.74

The design section modulus W_{cal} of rafter is obtained from strength condition:

a) according to SNiP - $$W_{cal} = k_M L^2 \gamma_n (g_{cal} + s_{cal}) / R \quad (4)$$

b) according to ENV - $$W_{cal} = k_M L^2 \left(g_{cal}/f_{d,g} + s_{cal}/f_{d,s} \right) \quad (5)$$

where k_M - static factor for bending moment;
L - span of rafter;
g_{cal} - design permanent load;
s_{cal} - design snow load;
R - see in chapter 2.1;
$f_{d,g}$ and $f_{d,s}$ - design resistance of wood in permanent and medium-term loading respectively.

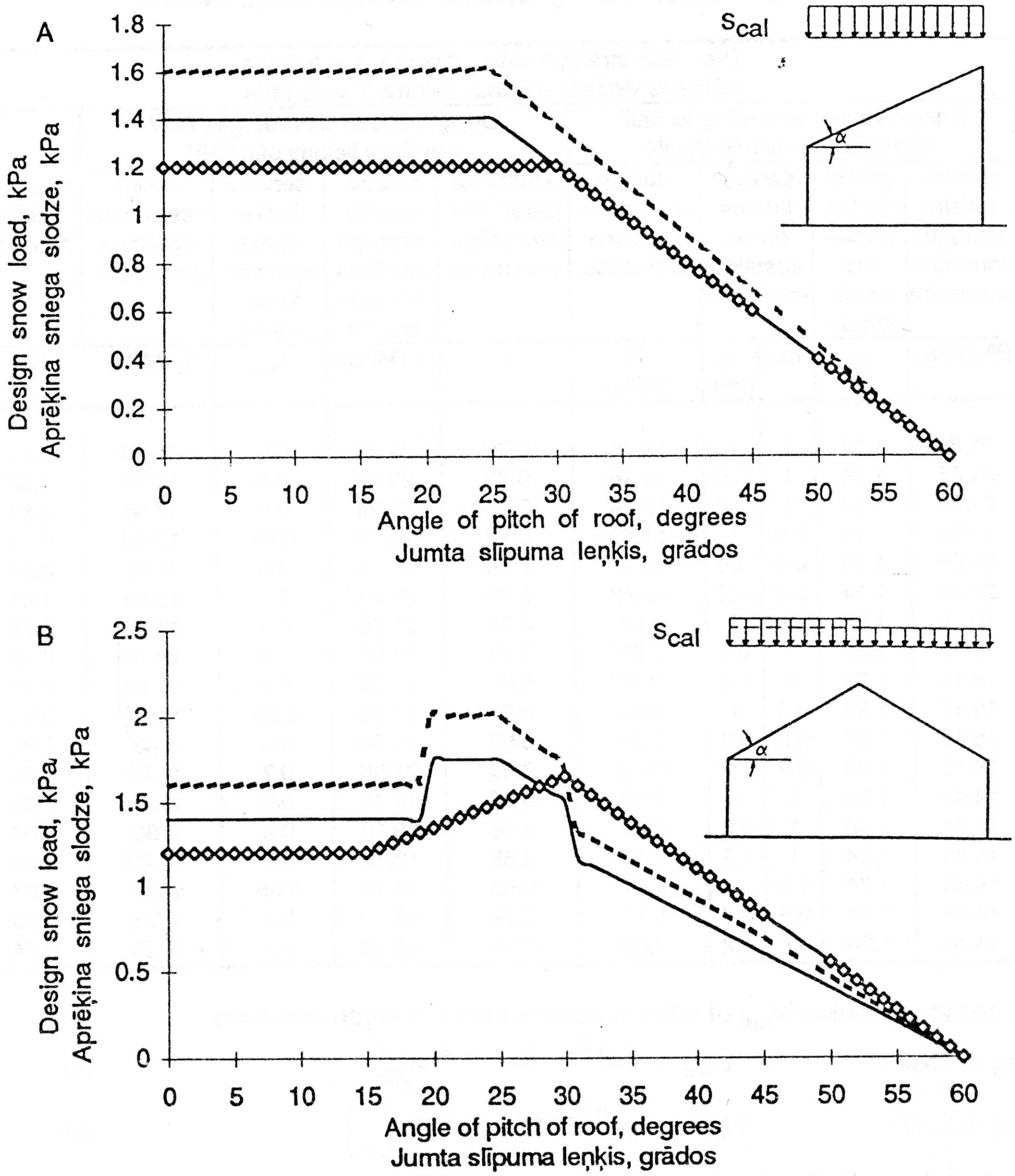
The design modulus of inertia J_{cal} of rafter section is obtained from serviceability condition:

a) according to SNiP - $$J_{cal} = n_o k_f (g + s) \gamma_n L^3 / E m_B m \quad (6)$$

b) according to ENV - $$J_{cal} = n_o k_f (g + s) L^3 / E \quad (7)$$

where n_o - serviceability factor for rafter deflection (n_o=200);
k_f - static factor for simple beam deflection (k_f=5/384);
γ_n - partial factor for building (γ_n=0.95 for dwelling houses);

g - characteristic (normative) permanent load;
s - characteristic (normative) snow load;
E - modulus of elasticity (E=10 000 MPa).



- - - on the light roof according to SNiP/ uz vieglu jumtu saskaņā ar SNiP

——— on the heavy roof according to SNiP/ uz smagu jumtu saskaņā ar SNiP

—◇— according to ENV/ saskaņā ar ENV

Fig. 1. Changes of design snow load: A – on monopitch roofs, B – on double pitch roofs.
1. att. Aprēķina sniega slodzes izmaiņas: A – uz vienslīpu jumtiem, B – uz divslīpu jumtiem.

Calculate the necessary cross section using (4), (5), (6), (7) for the same mean strength value of wood in bending (X=33 Mpa from strength values group with coefficient of variation c_v=0.15), characteristic snow load and permanent load values (s_o=1 kPa and g=0.5 kPa in the case of light roof, s_o=0.5 kPa and g=1 kPa in the case of heavy roof), span of rafter (L=3.6 m) and width of rafter section – 50 mm. Analysing the changes of cross section area of rafter for different pitch angle values we obtain insignificant differences (Fig. 2) in material consumption – up to 14 percents. The rafters sections of light roofs are with larger reserves designed according to SniP codes than ENV.

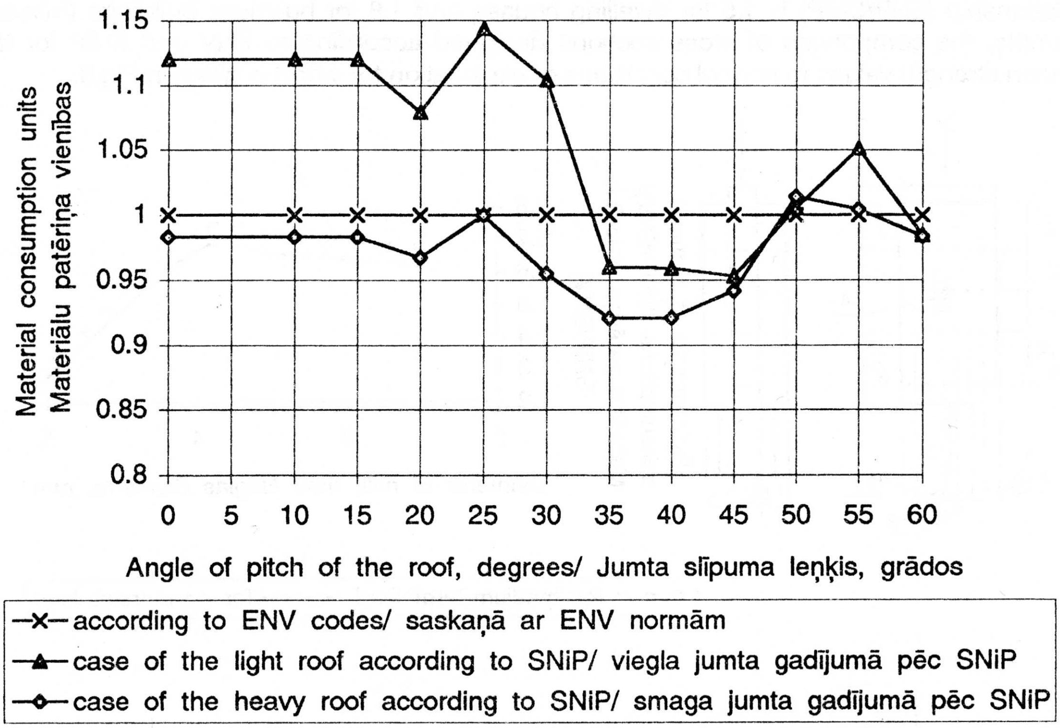


Fig. 2. Changes of material consumption of double pitch roof rafters designed according to SNiP and ENV for the same data.
2. att. Materiāla patēriņa atšķirības saskaņā ar SNiP un ENV projektētām divslīpu jumta spārēm pie vienādiem izejas datiem.

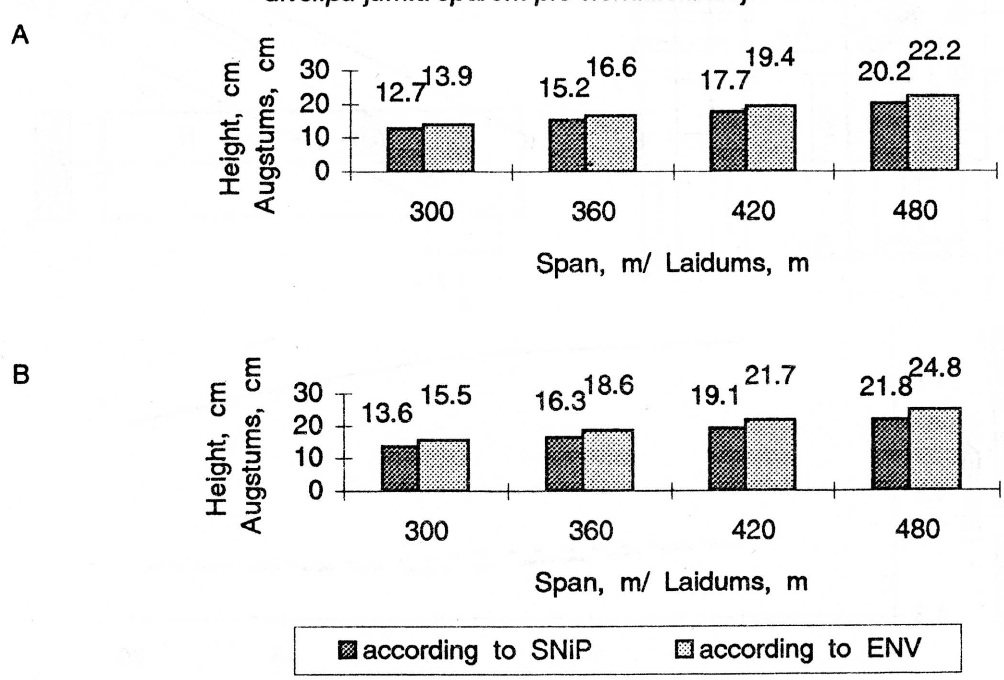


Fig. 3. Comparison of designed cross sections of joists (width 10 cm): A - in dwelling houses; B - in business buildings (offices).
3. att. Siju šķērsgriezuma augstumu salīdzinājums (platums 10 cm): A - dzīvojamās mājās, B - administratīvās ēkās.

Another results are obtained for floor joists. At first there are differences in characteristic values of imposed loads on floors as well in partial factors according ENV and SNiP codes- in result design load relationship (ENV/SNiP) is 1.5 for dwelling houses and 1.8 for business buildings (offices). For example, the comparison of cross sections designed according to ENV and SNiP for the same mean strength values in normal conditions of exploitation for wood is given in Fig.3.

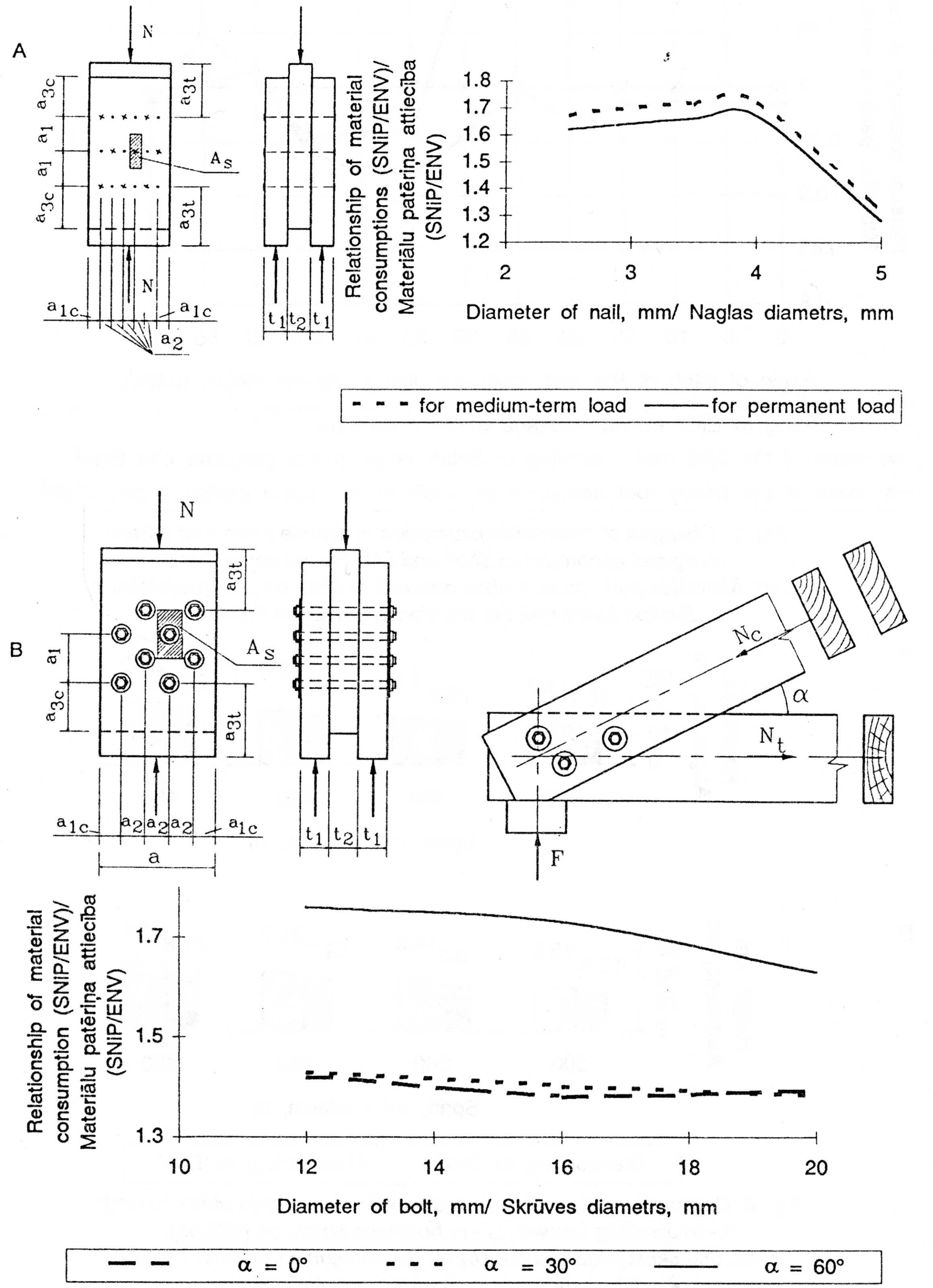


Fig. 4. Material consumption (per 1 unit of shear force) relatioships:
A - for nailed joints in double shear, B - for bolted joints in double shear.
4. att. Materiālu patēriņa (uz 1 bīdes spēka vienību) attiecības:
A - naglotiem simetriskiem savienojumiem, B - simetriskiem skrūvsavienojumiem.

2.4. Timber connections

There is a large variety of types and means of timber connections because of the reduction in shear strength of wood, which is 5-6 times lower than the compression or tensile strength. The main problem for the tens of years in wood engineering was to study and produce the most effective timber connector type - with a minimum of material consumption and sufficient reliability for the whole working life of the structure. It is a great loss for the branch development that one of the most rational type of timber connectors - nail plates were not included in SNiP II-25-80*.

There is presented analysis of load carrying capacity values and material consumption of nailed and bolted joints which are included both in SNiP and ENV (Fig. 4). SNiP regulations determine large unused reserves in load carrying capacity of nailed and bolted joints as well as excess material consumption. It is proved by the results of numerous nailed joint tests.

3. Conclusion

• The safety factor system for the determination of design strength value of wood in relationship of loading time, moisture content and temperature is based on the results of pure research both in European countries and Rusia. ENV codes present more detailed procedure for the determination of characteristic value from mean value.
• It is necessary to regulate the accuracy of characteristic values of imposed loads on the floors of dwelling and business buildings as well as to work out regulations for providing sufficient degree of fire resistance.
• It is more effective to be guided by ENV 1995-1-1 regulations for joint design.

References

1. EUROPEAN PRESTANDARD. ENV 1991-1. (1994). Eurocode 1: Basis of design and actions on structures. Part 1: Basis of design. CEN. Brussels. 85.
2. EUROPEAN PRESTANDARD. ENV 1991-2-3. (1995). Eurocode 1 - Basis of design and actions on structures. Part 2-3: Actions on structures - Snow loads. CEN. Brussels. 59.
3. EUROPEAN PRESTANDARD. ENV 1995-1-1. Eurocode 5 - Design of timber structures CEN. (1993). 110.
4. Пособие по проектированию деревянных конструкций (к СНиП II-25-80). ЦНИИСК им. Кучеренко. (1986). М.: Стройиздат. 216.
2. СНиП II-25-80. (1982). Деревянные конструкции. Госстрой СССР. М.: Стройиздат. 66.
6. СНиП 2.01.07-85. Нагрузки и воздействия. Госстрой СССР. (1986). М.: ЦИТП Госстроя СССР.

ANOTĀCIJA

Rakstā atspoguļoti koka konstrukciju elementu aprēķina rezultāti pēc Krievijas celtniecības normām un noteikumiem *SNiP* un Eiropas valstu normām *EUROCODE*. Salīdzināti koksnes aprēķina pretestības lielumi dažādiem ekspluatācijas apstākļiem pie vienāda koksnes stiprības vidējā lieluma, sniega slodzes aprēķina lielumi uz vienslīpu un divslīpņu jumtiem, kā arī materiālu patēriņš spārēm un pārseguma sijām pie vienādiem izejas datiem. Analizēts materiālu patēriņš naglotos un skrūvsavienojumos uz vienu bīdes spēka vienību.