State-of-the-art Report; Safety in Principles and Levels in the Nordic Countries

Nordic Wood: Safety in Timber Structures

Larsen, Hans Jörgen

2001

State-of-the-art Report
SAFETY PRINCIPLES AND LEVELS IN THE NORDIC COUNTRIES
Nordic Wood: Safety in Timber Structures

HANS JØRGEN LARSEN

Structural Mechanics

Structural Mechanics

ISRN LUTVDG/TVSM--01/3058--SE (1-10)
ISSN 0281-6679

State-of-the-art Report

SAFETY PRINCIPLES AND LEVELS IN THE NORDIC COUNTRIES

Nordic Wood: Safety in Timber Structures

HANS JØRGEN LARSEN

Printed by KFS I Lund AB, Lund, Sweden, August 2001.

For information, address:
Division of Structural Mechanics, LTH, Lund University, Box 118, SE-221 00 Lund, Sweden.
Homepage: http://www.byggmek.lth.se

Introduction
This report describes the safety principles and the safety levels in Denmark, Finland, Norway and Sweden. It is based on national reports prepared by the participants[i] in the project "Safety in Timber Structures" supported by the Nordic Industrial Fund under the special Nordic Wood programme, and national industries[ii].

Conclusions
Although they have a common basis, the safety rules in the Nordic design codes for timber structures are different on many points. Also the general safety levels differ.

Some of the differences are common to all materials, and a harmonisation requires decisions by the national standardisation bodies. A possibility is to adopt the Eurocode 1 with a common Nordic Application Document.

Other differences are due to decisions made by the timber committees. This applies e.g. to:

1. Assumptions regarding the coefficient of variation for material properties.
2. The influence of the duration of load.
3. The effect of (third party) control.

As for 1 and 2 the differences are to a large extent due to insufficient knowledge. The important factor k_{mod} is generally not fixed on a firm theoretical basis, and the knowledge about the distributions of the material properties is insufficient. For these items the results of this project can lead to harmonisation and a more rational design.

The differences mentioned under 3 are to some extent due to different national approval philosophies, and it should be possible to remove them the when The Construction Products Directive in near future becomes operational.

The general safety levels differ very much. The level is by far the highest in Denmark and lowest in Norway and Sweden. There are no experiences that can support the Danish level.

The Eurocode level is almost the same as the Danish and an uncritical adoption of Eurocode 5 will increase the required dimensions of many well functioning structures.

Notation
G permanent action
Q variable action
R resistance, strength
S action effect
k factor
k_{mod} modification factor for service and load-duration classes
γ partial coefficient
α $G_k/(G_k+Q_k)$

Subscripts

k characteristic

Load cases
Only the simple case with permanent action (G) and **1 variable action** (Q) is covered in the following, and it is assumed that permanent action is not dominating.

Safety format

All the codes (and also the European design codes: the Eurocodes) are based on the following format, where γ are partial coefficients:

$$S(\gamma_G G_k + \gamma_Q Q_k) = S_d \leq R_d = k_{mod} R_k / \gamma_m \qquad (1)$$

$$\gamma_m = \gamma_0\, \gamma_1\, \gamma_2\, \gamma_3\, \gamma_4\, \gamma_5 \qquad (2)$$

- γ_0 takes account of the **safety class**
- γ_1 takes account of the **type of failure**
- γ_2 depends on the coefficient of variation for the characteristic material properties which correspond to the **5-percentile for strength parameters and the mean values for stiffness parameters**
- γ_3 takes account of the **accuracy of the design model**
- γ_4 takes account of the **uncertainty** in the determination **of the material parameter in the structure** based on the controlled material parameter. It is assumed that $\boldsymbol{\gamma_4 = 1}$.
- γ_5 takes account of the extent of the **control of materials and at the building site.**

For limit states where (1) applies it is possible freely to transfer a factor from one side to the other, i.e. (1) is identical to:

$$S(k\, \gamma_G G_k + k\, \gamma_Q Q_k) = k\, S_d \leq k\, R_d = k_{mod} R_k / (\gamma_m / k) \qquad (3)$$

It is thus possible to choose γ_G =1. During the work with the Eurocodes the Nordic members of CEN in unison have advocated that this value should be used. It makes the calculations easier and makes it possible to use the same format and γ-values for the design of foundations. It is, therefore, surprising that the present Finnish and Norwegian codes are based on γ_G =1.2.

To make comparisons easier the Finnish and Norwegian partial coefficients are in accordance with (3) corrected to correspond to γ_G =1.0. The partial coefficient γ_2 is also corrected to correspond to γ_0 =1 for normal safety class, and γ_5 =1 for normal control class.

Actions

The characteristic permanent actions G_k are defined as the action values that with a probability of 50 % will not be exceeded.

The characteristic variable actions Q_k are with one exception defined as the action values that with a probability of p_{50} = 0.98 (return period 50 years) will not be exceeded in one year: The exception is snow load in Finland, where the annual probability of exceeding is p_{30} = 0.967 % (return period 30 years) for natural actions like snow and wind.

The ratio S_r/S_{50} between actions corresponding to two return periods (r and 50 years) can be calculated from:

$$S_r/S_{50} = (1 - k \ln(-\ln p_r)) / (1 - k \ln(-\ln p_{50})) \qquad (4)$$

where k is a parameter taking the values k ~ 0.20 for wind load and k ~ 0.30 for snow load. For snow load S_{30}/S_{50} = 0.93.

The return period for the characteristic snow load in Norway has till now been r = 5 years. In future a return period of 50 years will be prescribed. According to equation (4) this corresponds to an increase in the load by 50 %.

Partial coefficients for actions

The values given in table 1 correspond to γ_G =1 and a return period of 50 years.

Table 1 – Partial coefficients γ_Q for variable actions corresponding to γ_G =1.

	Denmark		**Finland**	**Norway**	**Sweden**	**Eurocodes**
	old	new				
imposed action	1.3	1.3	1.3	1.25	1.3	1.5/1.35 = 1.11
wind	1.3	1.5	1.3	1.25	1.3	1.11
snow	1.3	1.5	1.25	1.25	1.3	1.11

Partial coefficients γ_m

In all countries it is explicitly or implicitly assumed that the failure type is ductile without reserve and that $\gamma_1 = \gamma_3 = 1$.

The use of different safety classes is illustrated in table 2 together with examples on structures assigned to the classes. The factor γ_n is taken as 1.0 for normal safety class. In Sweden γ_n =1.1 for normal safety class, but the factor as mentioned has been transferred to γ_2.

Table 2 – Partial safety factor γ_n depending on safety class

Safety class	**Denmark**	**Finland**	**Norway***	**Sweden**
low	0.9 secondary buildings, storehouses, barns, many agricultural buildings	0.9 roof structures where failure does not cause damage to persons	–	1/1.1 = 0.91 floor structures on ground, roof covering, wall sheathing, light ceiling
normal	**1.0**	**1.0**	**1.0**	**1.0**
high	1.1 6 storey buildings, arenas for sports and concerts, large road bridges and high masts	–	–	1.2/1.1 = 1.09 structures including stabilising elements, substructures if failure leads to collapse of building.

* In Norway the importance of a structure is taken into account through the prescribed level of control of the design and of execution.

The influence of control is illustrated in table 3. At present only Norway takes into account the influence of third party control. In future the Construction Products Directive prescribes that all products shall be produced under a production control system under third party supervision.

The most important partial coefficient γ_2 is given in table 4.

Table 3 – Partial safety factor γ_5 depending on control class

Control class	**Denmark**	**Finland**	**Norway**	**Sweden**
reduced	–	–	–	–
normal	**1.0**	**1.0**	**1.0**	**1.0**
extended	(0.95)*	–	1.0/1.1 = 0.91 for extended control and for simple components (beams, joints, purlins) and pre-manufactured components when a precise installation instruction is available.	–

* This value was used in the old code. In the new code normal control class is assumed for all structures.

Table 4 – Partial safety factor γ_2 for timber and wood based materials and in ( ) the assumed coefficient of variation.

	Denmark		**Finland**	**Norway**	**Sweden**	**Eurocodes**
	old	new				
structural timber	1.5 (0.15)	1.64 (0.20)	1.55 (0.25)	1.58	1.38 (0.20)	1.76
glulam, plywood	1.35 (0.10)	1.5 (0.15)	1.55 (0.25)	1.32	1.27 (0.15)	1.76
other panels	1.35 (0.10)	1.5 (0.15)	1.55 (0.25)	1.32	1.38 (0.20)	1.76
components	1.35* (0.10)	1.64 (0.20)	1.55 (0.25)	1.32		
joints	1.5 (0.15)	1.64 (0.20)	1.55 (0.25)	1.58	1.38 (0.20)	1.76

* provided they are produced under third party control.

Modification factor k_{mod}

The modification factor k_{mod} is given in table 5 for structural timber and glulam for indoor climate (Service class 1-2 according to Eurocode 5).

Table 5 – Modification factor k_{mod} for structural timber and glulam and indoor/outdoor climate.

class	duration	**Denmark***	**Finland**	**Norway**	**Sweden***	**Eurocode 5**
permanent	> 10 years	0.60/0.50	0.62/0.50	0.70/0.60	0.70	0.60/0.50
long-term	0.5**-10 years	0.70/0.55 storage	0.62/0.50 storage	0.80/0.65 storage	0.70 storage mean snow	0.70/0.55 storage
medium	1-26** weeks	0.80/0.65 imposed	0.77/0.65 imposed, snow	0.90/0.70 imposed, snow	0.85 imposed char. snow mean wind	0.80/0.65 imposed
short-term	< 1 week	0.90/0.70 snow		1.0/0.80 wind	1.0 char. wind	0.90/0.70 snow, wind
instant		1.10/0.90 wind, accidental	1.0/0.77 wind, accidental	1.1/0.90 accidental		

* The values depend on the timber quality. The stated values apply for timber C24 (INSTA T2).
** In Finland 6 weeks.
*** New.

Global safety

To compare the safety variation between countries for different loads a "global safety factor" can de determined as $n = R_k/S_k$ provided $R_d/S_d = 1.0$.

$$n = \max \begin{cases} \dfrac{G_k}{G_k + Q_k} \dfrac{\gamma_2}{k_{\text{mod},G}} \\ \dfrac{G_k + \gamma_Q Q_k}{G_k + Q_k} \dfrac{\gamma_2}{k_{\text{mod},Q}} \end{cases} \qquad (5)$$

The variation of n is illustrated in figures 1 - 5, where $\alpha = G_k/(G_k + Q_k)$.

Other load cases

Another important case is the one where a variable action – often wind – is counteracted by dead load (uplift, overturning). The total safety for this case varies between the countries as follows: Denmark: 1.5/0.8 = 1.88 – Finland: 1.5/0.9 = 1.67 – Norway: 1.5/0.9 = 1.67 – Sweden: 1.3/0.85 = 1.53.

The Danish value corresponds to the new code DS 413:1999. According to the old code the safety was only 1.3/0.85 = 1.53. The old Danish value was the same as the present Swedish value, and lower than in Finland and Norway– maybe too low, although the number of failures due to overturning/uplift has been extremely low – but Denmark has now by far the "safest" structures.

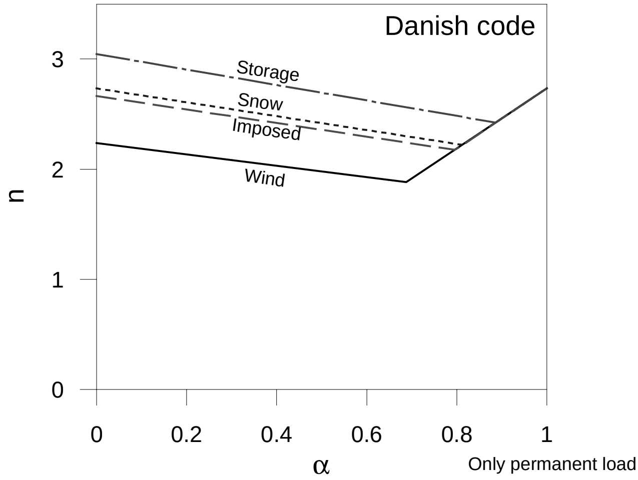

Figure 1 – Global safety, n, according to the Danish code. The dotted line corresponds to the case with 0.25G_k regarded as a free action.

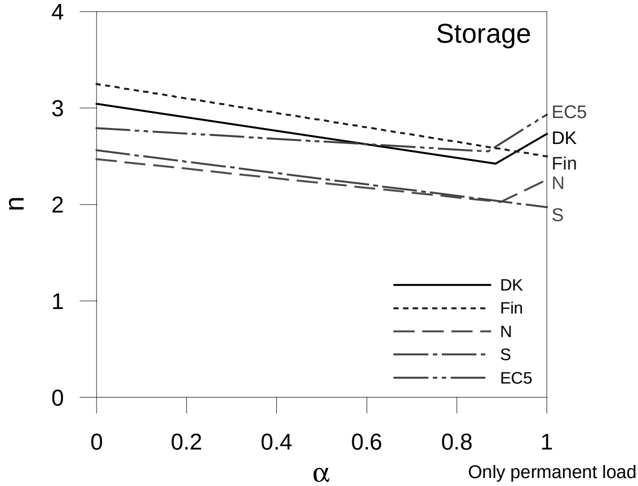

Figure 2 – Global safety, n, for stored load

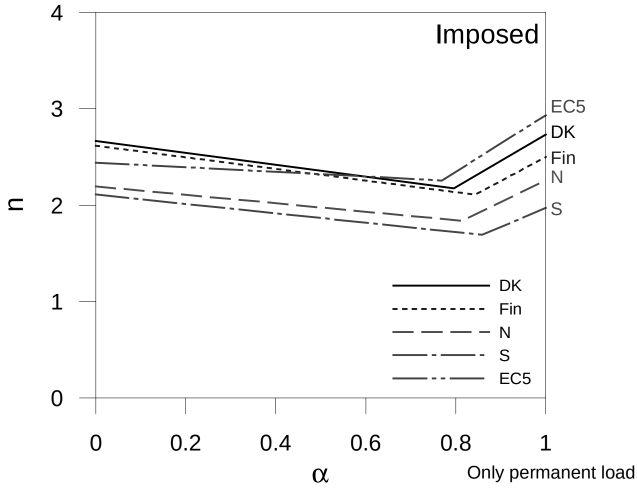

Figure 3 – Global safety, n, for imposed load

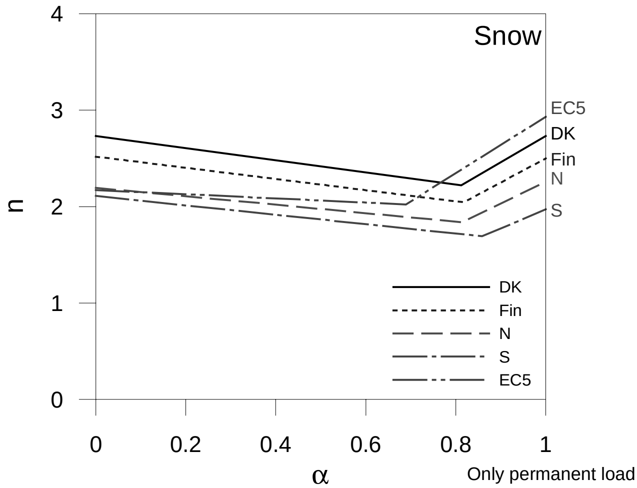

Figure 4 – Global safety, n, for snow load

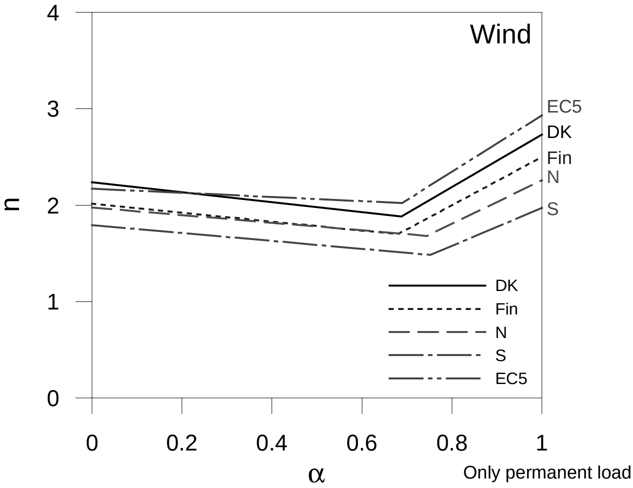

Figure 5 – Global safety, n, for wind load

Comparisons with steel structures

The material partial coefficient for steel is shown i table 6 together with the assumed coefficient of variation.

Table 6 – Partial safety factor α_2 and coefficient of variation for steel structures.

	Denmark		Finland	Norway	Sweden
	old	new			
yield stress	1.28	1.17		1.1*	1.00
ultimate tensile strength	1.42	1.43			1.20
coefficient of variation		< 0.05			(narrow tolerances)

- expected value (code under revision)

[i] Denmark: SBI, Norway: NTI, Finland: VTT, Sweden: LTH

[ii] Denmark: Danish Manufacturers of Wooden Rafters, Danish Manufacturers of Wooden Elements
Norway: Nordisk Kartro A/S, MOCON
Sweden: Södra Timber AB
Finland: Finnish Forest Industries Federation, Stora Enso