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NEW GDR TIMBER DESIGN CODE
STATE AND DEVELOPMENT

by

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1. State of the Research Work

Since 1985, in the GDR a new timber design code is being prepared and elaborated which shall be based on the method of limit states. Reports concerning the accomplished basic activities and the content of the individual draft codes are included in the papers mentioned under references /1/, /2/ and /3/. The future design and calculation code shall mainly consist of three parts (see the Table 1).

Part 1 shall be assimilated to the CIB Model Code and the Eurocode. It will comprise the definitions, symbols, units and bases for the calculation, design and construction of timber structures (see para 2 hereinafter).

In connection with the project of the new code, other existing codes and standard specifications must be modernized since their rules and regulations will then no longer comply with the latest state (see Table 2).

Both the new code and the revised codes shall correspond to the international trend being represented by the CIB Model Code /4/ and the Eurocode 5 /5/ (see also Tables 1 and 2).

The research work concerning the bases (fundamentals) for all three parts of the code has been continued.

2. Draft Code (1989)

2.1. Arrangement, Designations and Definitions

The arrangement, the designations and the definitions have been revised anew as compared with the reports indicated under /1/, /2/ and /3/ and are now corresponding to the Eurocode 5 /5/ (see Figure 1).

Merely in the chapters 3 and 5, structural timber and glued laminated timber only are being dealt with. Timber engineering mate-

rials, glues and mechanical connecting means (fasteners) are being dealt with in a separate Part 3 of the Draft Code. Chapter 6 will be modified according to the specifications included in the TGL 33 135/01 Code of the GDR.
The great number of tests performed with a view to achieving a scientific consolidation of the new timber design code has been accomplished in compliance with and on the model of the RILEM/CIB recommendations as to the testing of structural timber and connections (fasteners). Within the next years, the test codes in the GDR will be revised in accordance with the ISO Codes.

2.2. Bases for Design and Calculation

Exceptions to the Eurocode are existing with regard to the load factors. The GDR Code dated 1978 for the design loads is fixing load factors for the calculation by limit states /6/.
In compliance with /6/, the load factors as summarized in Table 3 are applicable.

The design values of the load are being determined by means of the following equation:

$$S = \gamma_n \left(\sum_{i=1}^{n} F_i^n \cdot \gamma_{f,i} + \sum_{j=1}^{m} \psi_j \cdot F_j^n \cdot \gamma_{f,j} \right.$$

where $i = 1 \ldots$ is the index for permanent and long-term actions

$j = 1 \ldots$ is the index for short-term and instantaneous actions

γ_n = according to Table 4 as per /7/

ψ = according to Table 5 as per /6/

γ_f = according to Table 3 as per /6/

In compliance with /7/, a valency factor ranging - subject to the reliability grade - between $0.9 < \gamma_n \leq 1.1$ is applicable (see Table 4). Thus, the different degree of reliability of the structure concerned as to the level of the design specification is being taken into consideration.

The combination factor ψ is considering the reduced probability of a simultaneous exceeding of several loads and is having - according to /6/ - the values as indicated in Table 5 .
In Table 6 , the partial safety coefficients for actions as applicable in the GDR are being compared with those values included in the Eurocode. In this connection, the valency factor has been taken into consideration.
The Eurocode 5 is fixing higher values for the partial safety coefficients concerning actions.
As between the previous proposal for the moisture grades indicated in /3/ and those values fixed in the Eurocode 5, there have been only slight differences which are now eliminated by an approximation to the Eurocode 5 (see Table 7).
Table 7 shows the allocation of different kinds of utilization to the modified moisture grades.
An analogous approach was adopted concerning the load action period grades. The GDR proposal from 1987 as compared with the Eurocode is illustrated in Figure 2 . Also the slight difference of the classification of the load action period as compared with the Eurocode 5 has been eliminated by means of the new GDR Draft Code of 1988 (see Figure 2).

The GDR Code for the design loads /6/ comprises a classification of the loads which are being allocated to the new grades of the load action period as shown in Table 8 .
Table 9 includes a comparison of different code proposals concerning the modification factor for considering the influence of the load action period.
A proposal for the grouping into a time grade is shown in Table 10b.

2.3. Building Materials Requirements

2.3.1. Sorting of the Timber

Hitherto, in the GDR structural timber has still exclusively been sorted according to visual criteria.
Said criteria were fixed by a code dated 1963 /8/. This code is corresponding in general to the DIN 4074 Code dated 1958 /10/.

The present sorting code specification has been revised in 1988 (see /9/) and is now considering also hardwood in addition to softwood. Moreover, now a mechanical sorting of the softwood and hardwood is possible as well.
The visual criteria have been revised in part. However, as before a grouping into quality grades is being accomplished.
The criteria for the mechanical sorting are based on the quality grades in combination with the modulus of elasticity in bending which mechanically can be determined in a fairly easy way (see Figure 3).
However, the sorting effects are different subject to defined grade limits for the moduli of elasticity which is being demonstrated by an initial investigation into the influence of different grade limits (see Figure 4).
With the variants 0 and 1, the values of the modulus of elasticity have been fixed so that they are within the range of the 5 % fractiles (quantiles) for strength grade III (variant 0) or of the minimum values for all strength grades, respectively.
With variant 0, the quantity of structural timber of quality grade II according to strength grade II is slightly increasing whereas with variant 1 the sorting effect is identical with a visual sorting by quality grades (see Figure 4). The quantity of structural timber of quality grade 1 according to strength grade I is decreasing with a simultaneous considerable increase in strength. The small percentage of sorted-out timber due to the low modulus of elasticity for the strength grade III must be purchased with a loss in strength as compared with the visual sorting. By means of the variants 2 and 3, the strength of the strength grades II and III can be improved as compared with the variant 0; however, this results in considerably increasing the percentage of sorted-out timber.
The connections and interdependencies must be taken into account with future economic studies and investigations. With a view to achieving a percentage of sorted-out timber being as small as possible, for the Draft Code the grade limits of the variant $0_{b)}$ have been fixed (see Figure 3).

2.3.2. Quality Control for the Production of Glued Laminated Timber

The technical conditions and specifications and the safeguarding of a constant quality for the production of glued laminated timber are being arranged in the GDR by means of separate codes (see /12/ and /13/). In compliance with said codes, regular checks of the tensile shear strength of the glued joint, the tensile strength of the key-dovetail connection and the flexural strength of glued laminated timber beams in structural timber dimensions must be performed.
Said codes will be revised within the next years, and in future they shall correspond to the testing specifications of the ISO Codes and to the international standard specifications for the production of glued laminated timber.

2.3.3. Investigations into the Strength of Structural Timber and Glued Laminated Timber

With a view to determining the characteristic material strengths, experimental studies and investigations have been accomplished. In this connection, issues of focal interest were investigations into the flexural and compressive strength of structural timber and glued laminated timber which has been sorted mechanically and visually.

Flexural strength of structural timber:

The studies and investigations have been performed by Apitz /20/ by using test specimens in structural timber dimensions. An interpretation (evaluation) of the tests is illustrated in Figure 5. The characteristic values were determined as a result of the three-parametric Weibull distribution according to the GDR Code No. 38791/03. The characteristic values of the visually and mechanically sorted quality grades of timber can be allocated to the strength grades of the Eurocode as indicated hereinafter (see also Figure 5).

	Quality grade acc. to GDR Code	Strength grade acc. to Eurocode grade	Strength grade acc. to Eurocode stress
Visually sorted timber	G I	C 6	28.5 N/mm^2
	G II	C 5	24.0 N/mm^2
	G III	C 3	19.0 N/mm^2
Mechanically sorted timber	F 1	C 7	38.0 N/mm^2
	F 2	C 6	28.5 N/mm^2
	F 3	C 3	19.0 N/mm^2

A remarkable feature is the insignificant scattering as to the strength with mechanically sorted timber (see Figure 6) which, however, is also dependent on the selection of the sorting criteria. The sorting criteria used in the revised sorting standard specification have been selected so that with the strength grade 3 the yield is as high as possible (no rejects, if possible). Thus, the strength and the scattering for the strength grade 3 are within the range of the visually sorted timber (see Figure 5).

Compression strength of structural timber:

The compression strength in parallel with the grain of visually sorted timber has been studied and investigated by Kiesel (see /26/). An interpretation of the authors reveals small differences between spruce and pine timber. The values were combined for the two kinds of timber in order to obtain data concerning softwood. The allocation to the grades according to the Eurocode 5 results in a conformance with the characteristic values for the compression strength in parallel with the grain (see Figure 7).

Quality grade (GKl) acc. to GDR Code	Failure strength N/mm^2	Number of specimens n	Strength grade acc. to Eurocode compression strength
GKl I	26.22	542	C 6
GKl II	24.03	124	C 5
GKl III	17.23	41	C 3

Bulk density of structural timber:

When performing the tests with regard to the compression strength in parallel with the grain, the bulk density was recorded as well. The values resulting from an interpretation (evaluation) are as follows:

pine timber	580 ... 577 ... 557 kg/m^3	(quality grade GKl I to III)
spruce timber •	433 ... 464 ... 481 kg/m^3	(quality grade GKl I to III)

In the case of spruce timber, the bulk density is increasing with a diminishing quality grade. This is not in contradiction with the practice of the visual sorting since the bulk density is not being measured.
The bulk density is being taken into consideration directly or indirectly only with the mechanical sorting. (Figure 8a, 8b)
Visually sorted pine timber and spruce timber can be allocated to the bulk density grade D 500 and D 400, respectively. Consequently, softwood is corresponding to grade 400 with the strengths squarely to the grain when allocated to said grade. The values are as follows:

tension 0.4 N/mm^2 ; compression 7.0 N/mm^2.

Tension strength of layers of boards for the production of glued laminated timber:

The tension strength of layers of boards with and without key-dovetail connection which previously have been sorted visually or mechanically is being illustrated in Figure 9. Figure 9 reveals a distinct influence of the method of sorting on the strength of layers of boards without key-dovetail connection.
In the case of layers of boards with key-dovetail connection, an influence can be found as well which, however, is not as distinct as that in the aforesaid instance. The characteristic values are within the range of those values indicated by Ehlbeck in /23/ for laminae with and without key-dovetail connection only with quality grade I and strength grade I.
The experimental values for the flexural and tensile strength are being classified in compliance with characteristic values according to Annex 2 of the Eurocode 5.

Key-dovetail connections are in part reducing the strength considerably.
As a rule, key-dovetailed timber must therefore be grouped into a category being inferior by one grade (see Figure 9).

Flexural strength of glued laminated timber:

Hitherto, 3 sorts of glued laminated timber are existing. The individual layers of boards are being sorted visually (see BSH 1 to BSH 3 in Table 11, with BSH meaning glued laminated timber). For the future, in the GDR there will be 3 additional sorts of glued laminated timber with which the layers of boards will be sorted mechanically.

The flexural strength of glued laminated timber is illustrated in Figure 10.
The increased characteristic strengths for mechanically sorted glued laminated timber must be attributed to the fairly insignificant scatterings with small quantities of test specimens. A distinct difference in strength can also be found as between glued laminated timber beams without key-dovetail connection in the external zone and those with key-dovetail connection in the external zone.
An allocation to the strength grades indicated in Table A 2.1 of the Eurocode is being accomplished in Figure 10 as well.

Flexural strength of glued laminated timber subject to the girder depth:

(a) mechanically sorted glued laminated timber girders

With regard to the still somewhat obscure connection between cross-sectional height and flexural strength with mechanically sorted glued laminated timber girders, experimental studies and investigations were carried out. For this purpose, 12 girders each of "M 3"-type glued laminated timber with a cross-sectional height of 192, 288 and 608 mm have been produced and tested.
All test specimens were provided with key-dovetail connections in the test zone since during the production glued laminated timber girders without key-dovetail connections in the outside layer are hardly being manufactured.

From the values according to Figure 11 one can see that up to a height (depth) of 608 mm the characteristic strength is not decreasing. Also the mean values for the modulus of elasticity which are required for the limit state of the usability are not decreasing up to depths of 608 mm.

(b) visually sorted glued laminated timber girders

In addition to the studies and investigations as mentioned in para (a) hereinbefore, previous investigations performed with visually sorted glued laminated timber girders have been evaluated. Up to a depth of 800 mm the characteristic value is not decreasing. Only at a depth of 992 mm the characteristic value will be diminished by 6 %. The mean value of the modulus of elasticity is not decreasing over the girder depth.

Schöne /21/ has accomplished investigations into the influence of the girder depth on the flexural strength of glued laminated timber beams. As a result of the tests using beams without key-dovetail connection, the power function which is taken as a basis in the Swiss Code SIA 164 was being verified as a tendency.
However, with key-dovetail connections existing in the test zone no influence can be determined. In the case of such girders, the strength of the key-dovetail connection is of a decisive significance for the maximum carrying capacity (bending strength) of the beam. The mean bending failure strength is only slightly larger than the mean value of the tensile strength of the key-dovetail connection which is statistically covered by a great number of tests /21/. From the point of view of the actual production with average board lengths of about 2 m, the application of a depth-dependent factors seems to be unjustified /21/.

Flexural strength of glued laminated timber subject to the moisture of timber:

The influence of the moisture on the flexural strength should be studied for a timber moisture of $\omega \geq 15$ %. The tests have been carried out by using mechanically sorted "M 3"-type glued laminated timber with key-dovetail connections in the test zone (cross section: h = 192 mm; b = 97 mm).

The investigations and tests covered the influence for $\omega \leq 15$ %, $\omega = 18$ % and $\omega = 24$ %. The timber moisture of $\omega \geq 18$ % has been achieved by storing the glued laminated timber girders in the humid room. A typical moisture distribution is illustrated in Figure 12. It can be seen that after 146 days of storage with a climate of T = 20° C. and $\varphi = 95$ % only the boundary zones are containing the required timber moisture of u = 24 %. As for the timber moisture of both 18 % and 24 %, 12 beams each have been tested.

However, in the heart the timber moisture is about 18 %. Figure illustrates that up to a timber moisture of $\omega \leq 18$ % no decrease of the characteristic strengths is occurring. Only with $\omega \geq 24$ %, the strength is being reduced by 7 %.

The mean values of the modulus of elasticity in bending are decreasing with an increasing timber moisture (see Figure 13).

2.3.4. Characteristic Strengths

Table 12 shows the characteristic strengths as well as the mean moduli of elasticity and shear moduli G for visually and mechanically sorted structural timber and glued laminated timber. The values are largely corresponding to the strength grades of the Eurocode 5.

2.3.5. Factor for Considering the Moisture Content and the Load Action Period

The factor being applied to take the moisture content and the load action period into consideration corresponds to the value included in the Eurocode 5 /5/ (see Table 13).

2.3.6. Factor for Considering the Action of Aggressive Media

Studies and investigations carried out in the GDR concerning the influence of aggressive media have demonstrated that many chemical agents and substances are exercising a strength-reducing influence and action only in the boundary zone of the timber cross sections (see also /24/). Timber structures are being used in the chemical industry and in agriculture due to their high resistance to che-

mical attacks.
It is recommended to take the action of aggressive substances on timber into consideration by applying a special factor. Said factor is being explained in /25/.
It is being indicated subject to 3 stress degrees and the cross-sectional size. The stress degrees are resulting from the classification or integration of available media (gases, solutions and solids) into ranges of aggressiveness.
With gases and solids, the moisture grade must be taken into consideration when performing the above-mentioned classification (see Tables 14a to 14j).

2.4. Limit States of the Serviceability

Timber has a distinct creep behaviour which must be considered with the calculation of the downward deflections. The magnitude of creep is mainly dependent on the kind of timber, the type of loading, the degree of loading and the environmental influences.

An evaluation of the creep tests and investigations from the publications and of our own test findings resulted in preparing initial proposals as to coefficients of creep of beams subjected to bending (see Table 15). The differences as compared with the Eurocode are insignificant, In the future code, the values of the Eurocode will be taken as a basis.

2.5. Calculation and Dimensioning (Design)

2.5.1. Individual Structural Components

The calculation and dimensioning (design) of individual components is largely corresponding to the proper chapter of the Eurocode 5 /5/. Since no specifications concerning biaxial bending are included in the Eurocode 5 and the CIB Code /4/, this part will be dealt with anew taking into account the applicable TGL 33 135/01 standard specification of the GDR.

(a) tension in the direction of grain, see Figure 14
(b) tension rectangularly to the direction of grain, see Figure 14

(c) compression in the direction of grain, see Figure 15
(d) compression at an angle to the direction of grain, see Figure 15
(e) bending, uniaxial, see Figure 16
(f) bending, biaxial, see Figure 16
(g) shear / solid timber girder, see Figure 17
(h) shear / glued laminated timber girder, see Figure 17
(i) combined stresses, see Figure 18
(j) compressed members, see Figure 19a, 19b, 19c

Since hitherto the creep influence of the timber has been left out of consideration in the stability check calculation for compression members (see Figure 19a), special tests and investigations were carried out at the Wismar College of Technology and a proposal for the calculation of compression members was elaborated.

The procedure (approach) comprises the stress calculation according to the second-order theory at the pre-deformed member with an increase in buckling due to flexural creep for a period of 50 years (see Figure 20).
Different stability checks have been compared with one another by plotting the stresses from the characteristic standard values of the loads $\sigma_{c,0,k}$ subject to the coefficient of slenderness λ (see Figure 21).

Results:

- Curve 1 comprises the ω-approach according to the GDR Code TGL 33 135/01 /19/
- Curve 2 comprises the second-order theory according to the Eurocode 5 /5/ or Figure 19a, respectively
- Curve 3 comprises the second-order theory according to the SNiP Code /16/
- Curve 4 comprises the second-order theory considering the creep influence according to the Wismar College of Technology /14/.

The investigations are being accomplished for sawn structural timber of the quality grade II or the strength grade C 5, respectively. The ratio of loading selected concerning the permanent load to the total load is 85 %. The mean load factor $\gamma_{G,Q}$ for this is 1.145. For the sawn structural timber, the related eccentricity of $\eta = 0.006$ and the material factor of $\gamma_m = 1.4$

have been selected.
For the load action period grade "long", the modification factor is $K_{mod} = 0.8$ /5/.
When looking at the developments as plotted in Figure 21, one will see that above $\lambda = 100$ the curves according to the Eurocode (curve 2) and according to the SNiP Code (curve 3) are almost coinciding with the ω-approach (curve 1).
Below $\lambda = 100$, the curves 2 and 3 are more considerably deviating or shifting towards the top which thus means that they are comprising a higher loadbearing capacity (stress acceptance) than the ω-approach according to curve 1.
Due to taking the creep influence into consideration, above $\lambda = 30$ the curve 4 is located below the ω-approach curve 1 and is consequently comprising a lower loadbearing capacity.
As compared with all other approaches, the design method with the creep influence (curve 4) is the most real one; however, it involves an increased material consumption as compared with the ω-approach (curve 1).

Since no failure cases have transpired from the construction practice in connection with the application of the ω-approach over longer periods of time, the exact method (curve 4) is being dispensed with and the stability check according to the Eurocode 5 (curve 2) is being accepted.

2.5.2. Composite Structural Components
(Figure 23 to 28)

Glued thin-webbed girders and stiffened sheets (plates) are being dealt with separately in Part 3 of the **Draft** Code.
Composite (i.e. built-up) compression members with a T, I or box section as well as frame and lattice members are being calculated and dimensioned according to the CIB Code /4/, pp. 55-65, taking into consideration the TGL 33 135/01 Code, pp. 14-18.

In the case of composite components with mechanical connecting means (fasteners), the calculation of the effective moment of inertia I_{ef} is being accomplished according to the CIB Code /4/, p. 57, whereas the proper modulus of displacement (translation) K is being calculated according to the Eurocode 5 /5/, p. 77 (see Figure 23).

The calculation of bracings and plane frames according to the Eurocode 5 /5/ is being prepared for the practical utilization. With regard to "bracings", see the Figure 28.

2.5.3. Connections

The check calculation of connecting means (fasteners) according to the Eurocode 5 is being improved taking into account the TGL 33 135/01 Code.
Figures 29 to 31 comprises an indication of the check for nails. Bolts, dowels, wood screws, hexagonal bolts, special dowels etc. are being dealt with analogously (see Figure 32 to 36)

3. Summary

To sum up, it can be stated that the calculation and design of strcutures made of structural timber and glued laminated timber are being accomplished to a great extent according to the Eurocode 5 taking into account the national particularities as included in the TGL 33 135/01 Code. With a view to facilitating the practical application of the check conditions and specifications, the formulae and factors extracted from the Eurocode 5 must still be handled and prepared to render them favourable for the application.

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Compression in the direction of grain
(without buckling risk)

$$\sigma_{c,o,d} \leqq f_{c,o,d}$$

Compression at an angle to the direction of grain

- $\alpha = 90^o$: $\sigma_{c,90,d} \leqq K_{c,90} \cdot f_{c,90,d}$

- α = at random:

$$\sigma_{c,\alpha,d} \leqq f_{c,o,d} - (f_{c,o,d} - f_{c,90,d}) \sin \alpha$$

- deformation:

$$u = K_{u,90} \cdot \frac{\sigma_{c,90,d}}{E_{90,mean}} \cdot h$$

Meanings:

$K_{c,90}$ factor taking into account the influence of the amount of loading l on the strength, acc. to /5/, table 5.1.5.

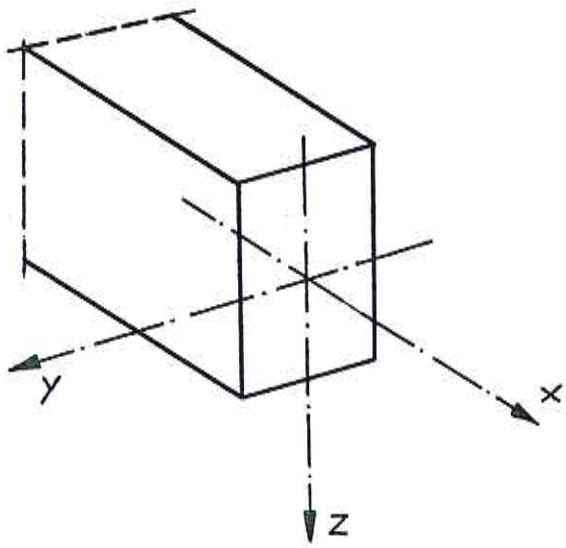
$K_{u,90}$ deformation coefficient acc. to /5/, (5.1.5. c and d)

Figure 15: Calculation of individual components, compression

Bending

- uniaxial: $\sigma_{m,d} \leqq K_{inst} \cdot f_{m,d}$

- biaxial: $\sigma_{m,d,y} + \sigma_{m,d,z} \leqq K_{inst} \cdot f_{m,d}$



Meanings:

K_{inst} factor taking into account the influence of the lateral deflection (tilting) on the loadbearing capacity, acc. to /5/, (5.1.6. c to e)

λ_m tilting slenderness degree acc. to /5/, (5.1.6. b and f)

Figure 16: Calculation of individual components; bending

Shear due to transverse force

- for solid timber girders and glued laminated timber girders with a volume of $V \leq 0.1\ m^3$:

$$\tau_d \leq K_V \cdot f_{V,d}$$

- for glued laminated timber girders with $V > 0.1\ m^3$:

$$Q_d \leq K_V \cdot K_{vd,V} \cdot K_{dis,V} \cdot K_l \frac{4}{3} \cdot b \cdot h \cdot f_{V,d}$$

Meanings:

K_V factor taking into account the influence of the stress concentration due to disengaging (notching) on the s trength, acc. to /5/, (5.1.7.1 c to e)

$K_{vd,V}$ factor taking into account the size of the stressed volume V on the strength, acc. to /5/, (5.1.7.2 c)

$K_{dis,V}$ factor taking into account the influence of the transverse force distribution on the strength, acc. to /5/, (5.1.7.2 d)

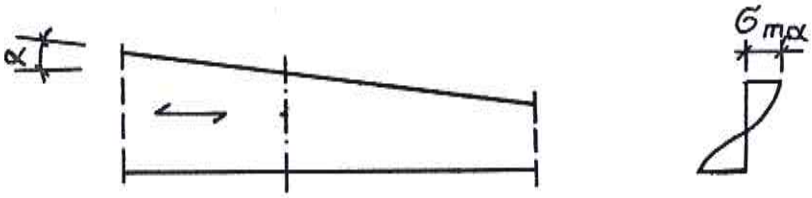
K_l factor taking into account the influence of the girder length l on the strength, acc. to /5/, (5.1.7.2 b)

Shear due to torsion

$$\tau_{tor,d} \leq 1.2 \cdot f_{V,d}$$

Figure 17: Calculation of individual components; shear

Girder with a variable depth



- tension at the angle α to the direction of grain:

$$\sigma_{m,\alpha,d} \leqq k_{t,\alpha} \cdot f_{m,d}$$

- compression at the angle α to the direction of grain:

$$\sigma_{m,\alpha,d} = k_{c,\alpha} \cdot f_{m,d}$$

Meanings:

$k_{t,\alpha}$ conversion factor in the case of a rectangular cross section, acc. to /5/, (5.1.9 a)

$k_{c,\alpha}$ conversion factor in the case of a rectangular cross section , acc. to /5/, (5.1.9 b)

Tension and bending

$$\frac{\sigma_{t,o,d}}{f_{t,o,d}} + \frac{\sigma_{m,d}}{f_{m,d}} \leqq 1$$

Compression and bending
(without buckling risk)

$$\frac{\sigma_{c,o,d}}{f_{c,o,d}} + \frac{\sigma_{m,d}}{f_{m,d}} = 1$$

Shear due to torsion and transverse force

$$\left(\frac{\tau_d}{f_{,d}}\right)^2 + \frac{\tau_{tor,d}}{1.2\ f_{v,d}} = 1$$

Figure 18 : Calculation of individual components; combined stresses

Stability check calculation

$$\frac{1}{K_c} \cdot \frac{\sigma_{c,o,d}}{f_{c,o,d}} + \frac{1}{K_m} \cdot \frac{\sigma_{m,d}}{f_{m,d}} \leq 1$$

Meanings:

K_c buckling coefficient acc. to /5/, (5.1.10 g)

K_m buckling coefficient acc. to /5/, (5.1.10 d)

Explanation concerning K_c, K_m

K_c and K_m are being calculated only for the strength class C 5!

In compliance with and by means of /5/, tables A 2.1 a and A 2.3 b it results as follows:

$f_{m,k} = 24 \frac{N}{mm^2}$ $\frac{E_{o,k}}{f_{c,o,k}} = 340$

$f_{c,o,k} = 21.5 \frac{N}{mm^2}$ $\eta = 0.006$

The following applies to the limit slenderness λ_G:

$$\sigma_{eu,k} = f_{c,o,k} = \frac{\pi^2 \cdot E_{o,k}}{\lambda_G^2}$$

thus resulting therefrom: $\lambda_G = \pi \cdot \sqrt{\frac{E_{o,k}}{f_{c,o,k}}} = 57.9 \sim 58.$

The following applies to the slenderness :

$$\sigma_{eu,k} = \frac{\pi^2 \cdot E_{o,k}}{\lambda^2}$$

$$K_{eu} = \frac{\sigma_{eu,k}}{f_{c,o,k}} = \left(\frac{\lambda_G}{\lambda}\right)^2 = \left(\frac{58}{\lambda}\right)^2$$

$$K_m = 1 - \frac{K_c}{K_{eu}} \cdot \frac{\sigma_{c,o,d}}{f_{c,o,d}} = 1 - K_c \left(\frac{\lambda}{58}\right)^2 \cdot \frac{\sigma_{c,o,d}}{f_{c,o,d}}$$

Figure 19a: Calculation of individual components; compressed members buckling length $l_{crit} = \beta \cdot l$

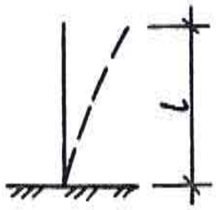
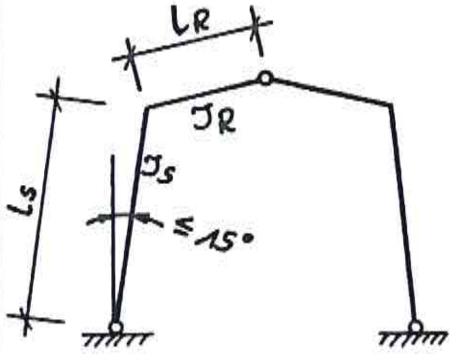
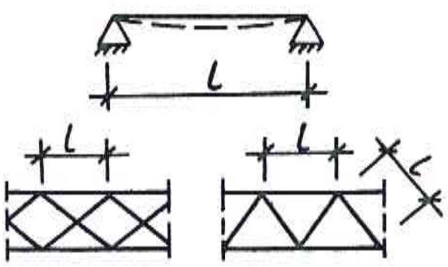
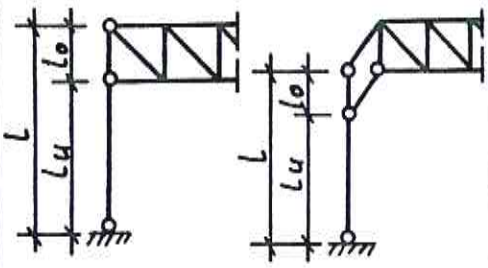
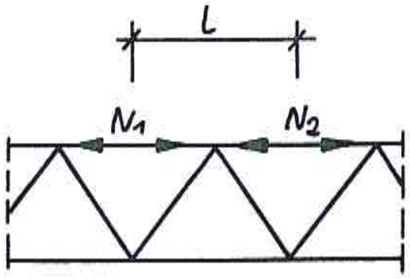
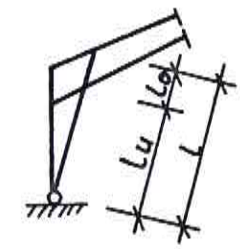
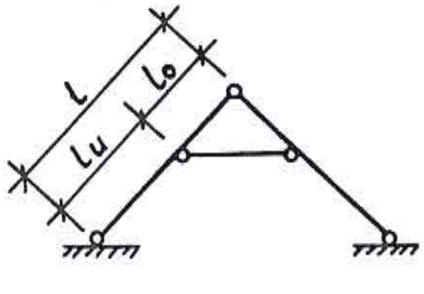
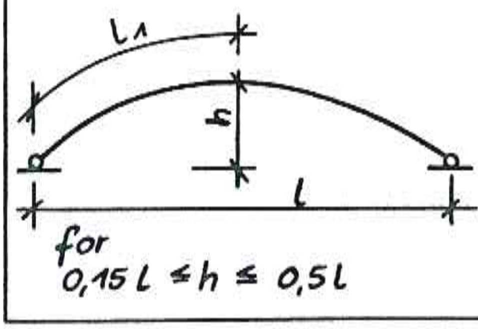
static (stability) system	β	static (stability) system	β
	2		$\sqrt{4 + 3{,}2 \frac{J_s}{J_R} \cdot \frac{l_R}{l_s}}$
	1	 for $l_o \le l_u$	$2 - 1{,}3 \frac{l_o}{l}$
	$0{,}75 + 0{,}25 \cdot \frac{N_2}{N_1}$	 Inner frame corner - laterally supported $l_{crit} = l_u, l_o$ - not laterally supported $l_{crit} = l$	
 $l_u < 0{,}7\,l$: $l_u \ge 0{,}7\,l$:	0,8 1	 for $0{,}15\,l \le h \le 0{,}5\,l$	1,25

Figure 19b: Calculation of individual components; buckling length coefficients β acc. to /13/

Compression

$$\sigma_{c,o,d} \leq K_{c,1} \cdot f_{c,o,d}$$

Compression with bending

$$\frac{\sigma_{c,o,d}}{K_{c,1} \cdot f_{c,o,d}} + \frac{\sigma_{m,d}}{f_{m,d}} \leq 1$$

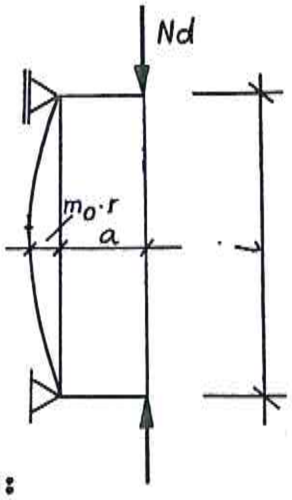
Meanings:

$K_{c,1}$ compression factor acc. to /22/ (5.1.7 b-c)

Figure 19c: Calculation of individual components; columns

Stability check calculation:

$$\left(1 + m \cdot \eta_{crit} \cdot K_{\varphi} \right) \cdot \frac{N}{A} \leq f_{c,o,d}$$



Meanings:

m amount of eccentricity $m = m_o + \frac{M \cdot A}{N \cdot W}$

m_o · random eccentricity $m_o = 0.1 + \frac{\lambda}{K_o}$

K_o factor, K_o = 140 for structural timber of the strength class C 5 with a rectangular or square cross section

M moment increasing the random eccentricity
$M = N \cdot a$

η_{crit} enlargement factor $\eta_{crit} = \eta_{crit} \left(\frac{\sigma_{eu,d} \cdot A}{N_d} \right)$

$\sigma_{eu,d}$ Euler's stress $\sigma_{eu,d} = \frac{\pi^2 \cdot E_{o,d}}{\lambda^2}$

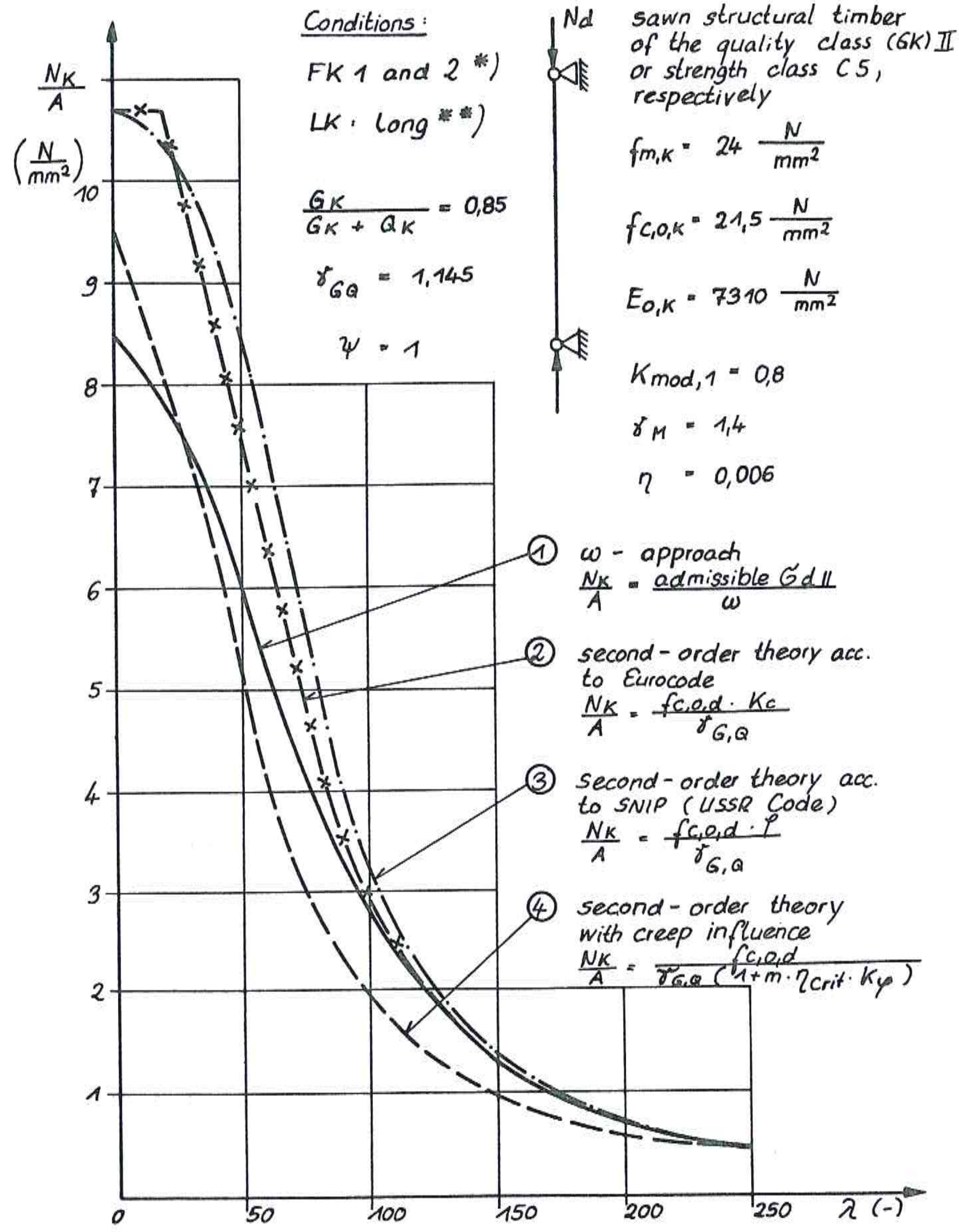
K_{φ} long-term factor $K_{\varphi} = K_{\varphi} \left(\frac{\sigma_{eu,d} \cdot A}{N_{G,d}} \right)$

$N_{G,d}$ pemanent compressive force (stress)

r heart (core) dimension

$E_{o,d}$ design value $E_{o,d} = \frac{E_{o,k} \cdot K_{mod,1}}{\gamma_M}$

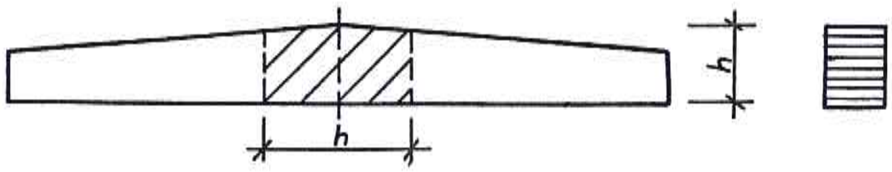
Figure 20 : Method for the design of compressed members being exposed to a buckling risk by adopting the second-order theory with creep influence acc. to / 13 /



*) FK = moisture class **) LK = Load action period class

Figure 21: Comparison of different stability check calculations

Saddle roof girder



Bending: $\sigma_{m,d} \leq f_{m,d}$

Tension perpendicular to the grain:

$$\sigma_{t,90,d} \leq K_{vol} \cdot K_{dis} \cdot f_{t,90,d}$$

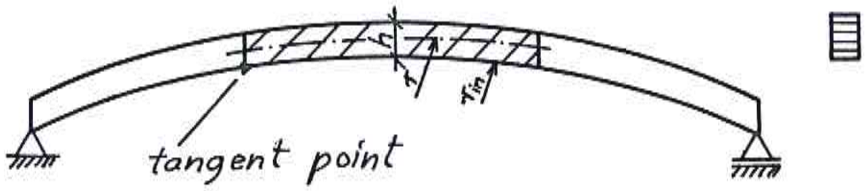
Meanings:

K_{vol} volume factor acc. to /5/, (5.1.11 g)

K_{dis} distribution factor acc. to /5/, (5.1.11 h and i)

σ_m, $\sigma_{t,90}$ stresses acc. to /5/, (5.1.11 e and f)

Arched girder



Bending: $\sigma_{m,in,d} \leq K_r \cdot f_{m,d}$

Tension perpendicular to the grain:

$$\sigma_{t,90,d} \leq K_{vol} \cdot K_{dis} \cdot f_{t,90,d}$$

Meanings:

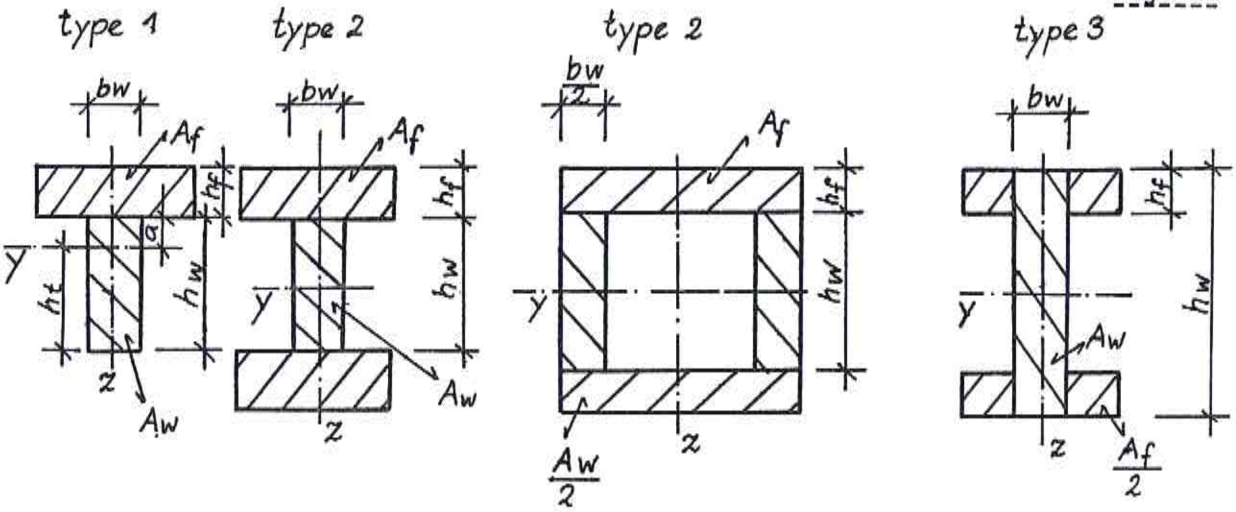
K_r factor of curvature acc. to /5/, (5.1.12 b and e)

K_{vol} volume factor acc. to /5/, (5.1.12 i)

K_{dis} distribution factor acc. to /5/, (5.1.12 j and k)

$\sigma_{m,in,d}$; $\sigma_{t,90,d}$ stresses acc. to /5/, (5.1.12 d and h)

Figure 22: Calculation of individual components; saddle roof girder and arched girder



$$\mathfrak{J}_{ef} = \mathfrak{J}_o + \gamma(\mathfrak{J}_{tot} - \mathfrak{J}_o)$$

Meanings:

$\mathfrak{J}_{ef}$	effective moment of inertia about the Y-axis
$\mathfrak{J}_o$	sum of the inherent moments of inertia
$\mathfrak{J}_{tot}$	total moment of inertia
γ	efficiency factor $\gamma = \dfrac{1}{1 + \dfrac{\pi^2 A_f \cdot E}{l^2 \cdot K} \cdot s}$
A_f	flange cross-sectional area
E	modulus of elasticity
l	effective span
s	spacing of the timber fasteners pushed into one row
K	modulus of displacement acc. to /5/, page 77

Figure 23 : Calculation of built-up (composite) components; cross sections with mechanical timber fasteners

Bending:

In this connection,
- the check calculation conditions acc. to Figure 16, and
- the cross section values acc. to Figure 23
are applicable.

Meanings:

$\sigma_{m,d}$ design value of the stress
For cross sections of the types 1 to 3 acc. to /4/, (71.5 - 13)

For type 1: $\sigma_{m,d} = |\sigma_{w,ult,d}| = \frac{M_d}{J_{ef}} \cdot h_t$

For types 2 and 3: $\sigma_{m,d} = |\sigma_{w,ult,d}| = \frac{M_d}{J_{ef}} \cdot \frac{h_w}{2}$

$f_{m,d}$ design value of the strength

$$f_{m,d} = \frac{f_{m,K} \cdot K_{mod,i}}{\gamma_M} \; ; \quad i = 1 \; / \; 2$$

$f_{m,K}$ characteristic value of the strength acc. to /5/, table A 2.1 a

$K_{mod,1}$ modification factor acc. to /5/, table 3.1.3.

γ_M material factor acc. to /5/, table 2.3.3.

Figure 24 : Calculation of built-up components; bending

Maximum shear

In this connection,
- the check calculation conditions acc. to Figure 17, and
- the cross section values acc. to Figure 23

are applicable.

Meanings:

τ_d design value of the stress

For type 1 cross section:

$$\tau_d = \max \tau_d = \frac{V_d \, h_t^2}{2 \cdot J_{ef}}$$

For type 2 cross section:

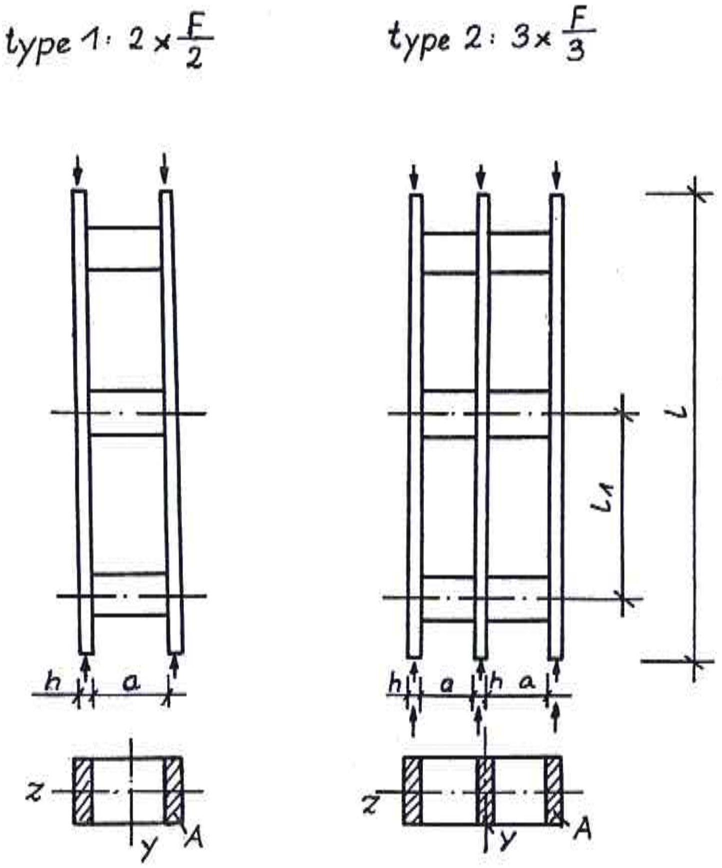
$$\tau_d = \max \tau_d = \frac{V_d}{J_{ef} \cdot bw} \left(\gamma \cdot A_f \frac{(h_w + h_f)}{2} + \frac{1}{8} A_w h_w \right)$$

For type 3 cross section:

$$\tau_d = \max \tau_d = \frac{V_d}{J_{ef} \cdot bw} \left(\gamma \cdot A_f \frac{(h_w - h_f)}{2} + \frac{1}{8} A_w h_w \right)$$

acc. to /4/ (71.14 - 16)

Figure 25: Calculation of built-up components; shear



$$F_d \leq F_{crit,d}$$

Meanings:

F_d design value of the total compressive load at the spread compressed member

$F_{crit,d}$ design value of the buckling load of the spread compressed member

$$F_{crit,d} = \frac{F_{crit,K}}{\gamma_M} \cdot K_{mod,1}$$

$F_{crit,K}$ characteristic buckling load

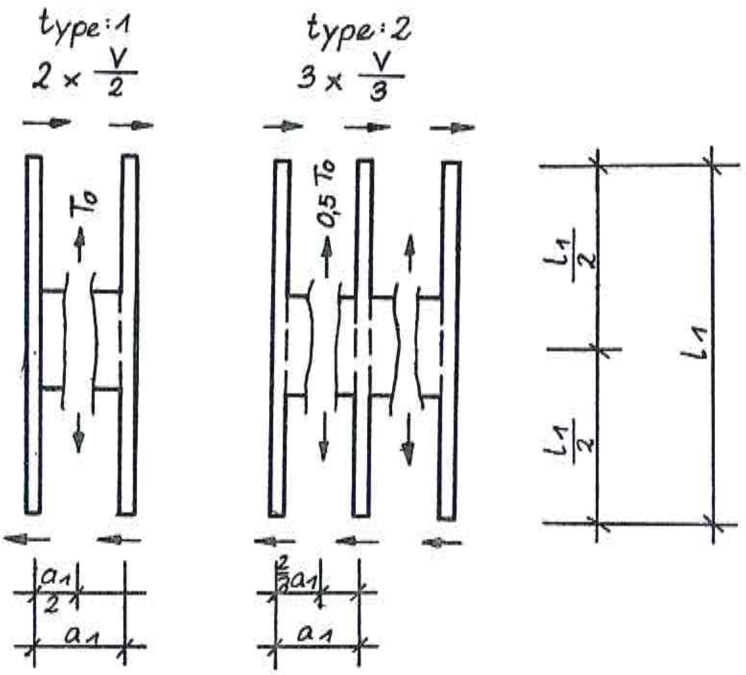
$$F_{crit,K} = K_c \cdot f_{c,o,k} \cdot A_{tot}$$

$$A_{tot} = n \cdot A$$

K_c buckling coefficient acc. to /5/, (5.1.10 g) for λ_{ef}

λ_{ef} effective degree of slenderness acc. to / 4/ (72.3)

Figure 26: Calculation of built-up components; spread compressed members



The shear braces must be checked for the following shear forces T according to Figure 16 and Figure 17:

- type 1: $T_d = T_{o,d}$

- type 2: $T_d = 0.5\ T_{o,d}$

Meanings:

$T_{o,d}$ design value of the shear force

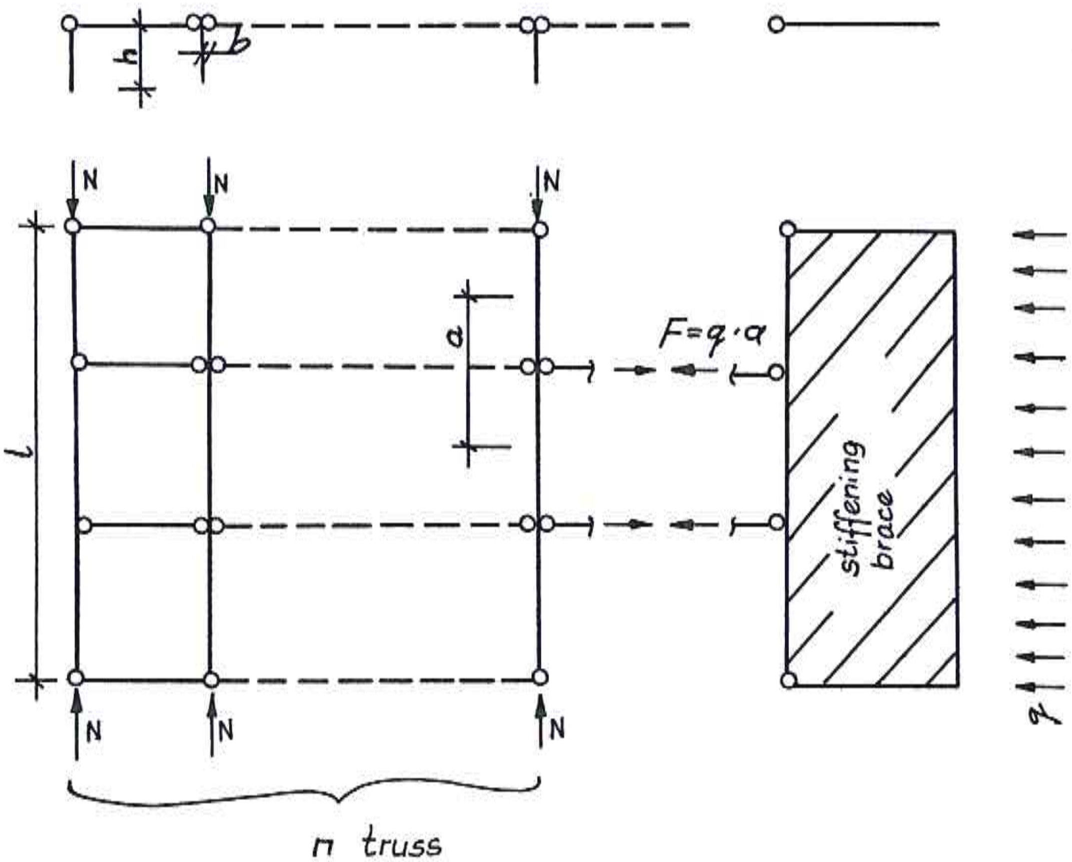
$$T_{o,d} = \frac{V_d \cdot l_1}{a_1}$$

V_d design value of the transverse force

$$V_d = \frac{V_K \cdot K_{mod,1}}{\gamma_M}$$

V_K characteristic value of the transverse force acc. to /4/ (72.5)

Figure 27:
Calculation of built-up components; spread compressed members



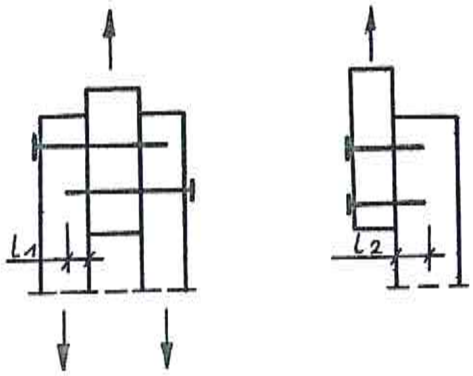
$$q = \frac{n \cdot N}{l \cdot K_{b,r,c} \cdot K_{b,r,m}}$$

Meanings:

q	distributed lateral load per unit of length due to stabilization; it is acting in addition to the external loads (e.g. wind)
$K_{b,r,c}$	acc. to /5/, (5.2.6 b)
$K_{b,r,m}$	acc. to /5/, (5.2.6 g)

Figure 28: Calculation of built-up components; stiffening braces

Nails being stressed perpendicularly to their axis



For each nail:

$F_{la,d} \leqq R_{la,d}$ for connections of timber with timber

$F_{la,d} \leqq 1.25\ R_{la,d}$ for connections of sheet steel with timber

Meanings:

$F_{la,d}$ design value of the loading perpendicular to the nail axis

$R_{la,d}$ design value of the loadbearing capacity perpendicular to the nail axis

$$R_{la,d} = \frac{l_i}{\min l_i} \cdot \frac{R_{la,K}}{\gamma_M} \cdot K_{mod,1}$$

γ_M material factor acc. to /17/

l_i depth of penetration

$\min l_i$ minimum depth of penetration
- for round nails: $\min l_2 = 6\ d$
- for grooved and threaded nails: $\min l_2 = 4\ d$

$K_{mod,1}$ modification factor acc. to /5/, table 3.1.3.

$R_{la,K}$ characteristic loadbearing capacity perpendicular to the nail axis

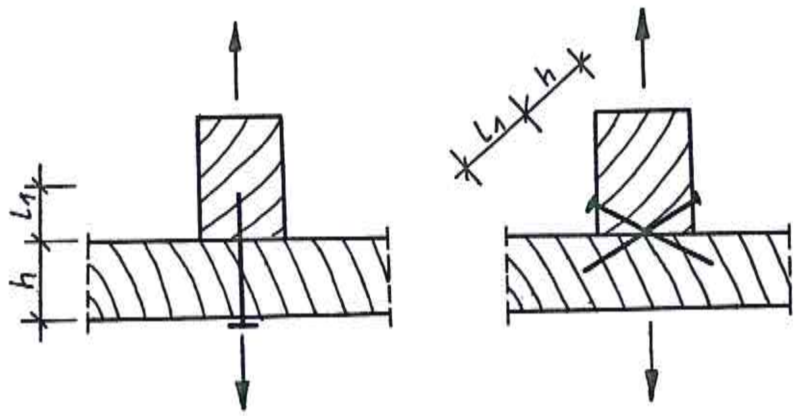
$R_{la,K} = K \cdot d^{\beta}$

d nail diameter

K, β parameters acc. to /5/, (5.3.2. b and c)

Figure 29: Calculation of timber fasteners; nails

Nails being stressed in the direction of their shank



For each nail: $F_{ax,d} \leq R_{ax,d}$

Meanings:

$F_{ax,d}$ design value of the loading in the direction of shank

$R_{ax,d}$ design value of the loadbearing capacity in the direction of shank

$R_{ax,d} = R_{ax,K}$ for round nails.

Round nails must not be subjected to a long-term loading!

$R_{ax,d} = \frac{R_{ax,K}}{\gamma_M} \cdot K_{mod,1}$ for nails being not round, grooved and threaded nails.

$R_{ax,K}$ characteristic loadbearing capacity in the direction of shank

$$R_{ax,K} = 18 \cdot 10^{-6} \cdot \rho^2 \cdot d \cdot h + 300 \cdot 10^{-6} \cdot \rho^2 \cdot d^2$$

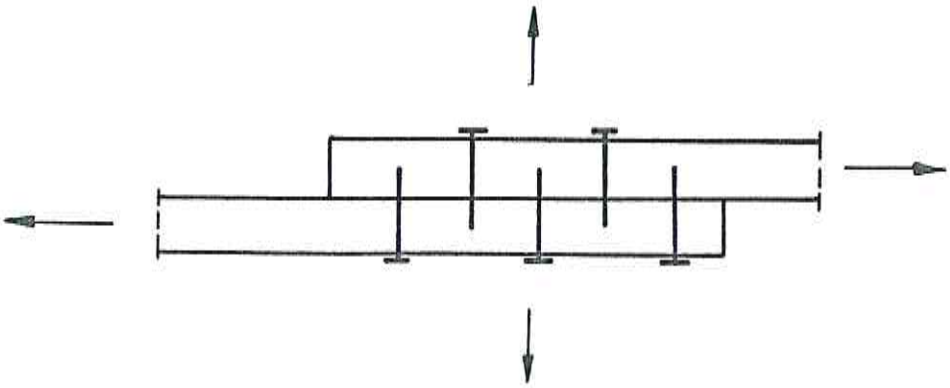
for round nails;

otherwise acc. to /5/, (5.3.3. a,c)

ρ characteristic bulk density (5 %-quantile), kg/m^3

Figure 30 : Calculation of timber fasteners; nails

Combined stressing



For round nails:

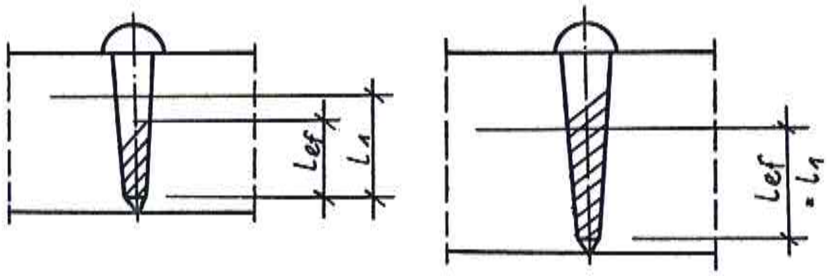
$$\frac{F_{ax,d}}{R_{ax,d}} + \frac{F_{la,d}}{R_{la,d}} \leqq 1$$

For grooved and threaded nails:

$$\left(\frac{F_{ax,d}}{R_{ax,d}}\right)^2 + \left(\frac{F_{la,d}}{R_{la,d}}\right)^2 \leqq 1$$

Figure 37 : Calculation of timber fasteners; nails

Wood screws being stressed perpendicularly to their axis



For each wood screw: $F_{1a,d} \leq R_{1a,d}$

Meanings:

$F_{1a,d}$ design value of the loading perpendicular to the wood screw axis

$R_{1a,d}$ design value of the loadbearing capacity perpendicular to the wood screw axis

$$R_{1a,d} = \frac{l_1}{\min l_1} \cdot \frac{R_{1a,K}}{\gamma_M} \cdot K_{mod,1}$$

$R_{1a,K}$ characteristic loadbearing capacity perpendicular to the wood screw axis

- acc. to /5/ (5.3.7. a,b) for connections of timber with timber
- acc. to /5/ (5.3.7. d) for connections of sheet steel to timber

l_1 depth of penetration

$\min l_1$ minimum depth of penetration; $\min l_1 = 4\ d_1$

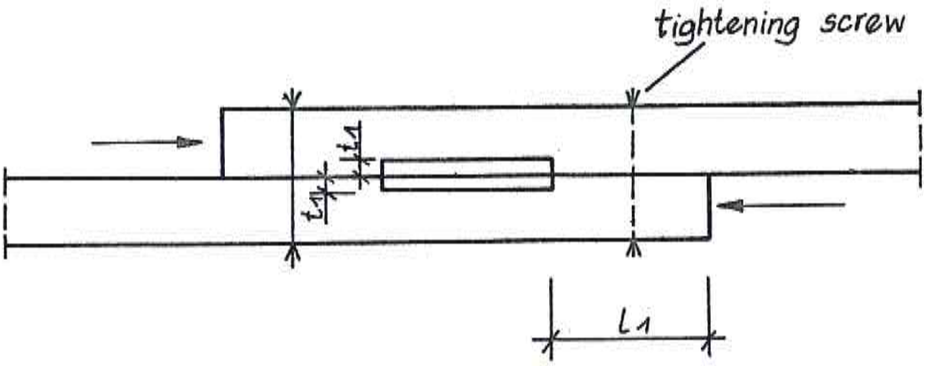
d_1 external thread diameter of the wood screw

γ_M material factor acc. to /17/

$K_{mod,1}$ modification factor acc. to /5/, table 3.1.3.

Figure 32 : Calculation of timber fasteners; wood screws

Stressing in parallel with the flat connector (dowel)



For each flat connector: $F_d \leq R_d$

Meanings:

F_d design value of the loading in parallel with the flat connector

R_d design value of the loadbearing capacity in parallel with the flat connector

$$R_{c,o,d} = \frac{R_{c,o,K}}{\gamma_M} \cdot K_{mod,1} \cdot t_1 \cdot b \qquad (1)$$

$$R_{V,o,d} = \frac{R_{V,o,K}}{\gamma_M} \cdot K_{mod,1} \cdot l_1 \cdot b \qquad (2)$$

$R_{c,o,K}$ characteristic compression strength of the timber acc. to /17/

$R_{V,o,K}$ characteristic shear strength of the timber acc. to /17/

t_1 depth of penetration of the connector; t_1 = 15 mm

l_1 fore-timber length; $l_1 = 8\ t_1$

γ_M material factor acc. to /5/

$K_{mod,1}$ modification factor acc. to /5/, table 3.1.3.

Figure 33 : Calculation of timber fasteners; flat connectors

Bolts (studs) and connectors (dowels) being stressed perpendicularly to their axis

(continued)

ρ_K characteristic bulk density (5 %-quantile), kg/m^3

t_1 ; t_2 timber thicknesses, mm

d bolt (stud) diameter, mm

$K_{\alpha,1}$; $K_{\alpha,2}$ factors taking into account the influence of the angle as between force and direction of timber grain

$$K_{\alpha,1} ; K_{\alpha,2} = \frac{K_{90}}{K_{90} \cos^2\alpha + \sin^2\alpha}$$

$$K_{90} = 0.32 + 10 \cdot d^{-1.5}$$

γ_M material factor acc. to /17/

$K_{mod,1}$ modification factor acc. to /5/, table 3.1.3.

(b) Connections of sheet steel with timber

Lateral steel butt straps:

R_K is to be calculated with $t_1 = t_2$ = timber thickness

Central steel butt strap:

R_K is to be calculated acc. to /5/ (5.3.5. d-f), (5.3.5. f) to be multiplied by 1.4

Figure 34 : Calculation of timber fasteners; bolts (studs) and connectors (dowels)

Wood screws being stressed in the direction of their shank

For each wood screw:

$$F_{ax,d} \leq R_{ax,d}$$

Meanings:

$F_{ax,d}$ design value of the loading in the direction of shank

$R_{ax,d}$ design value of the loadbearing capacity in the direction of shank

$$R_{ax,d} = \frac{R_{ax,K}}{\gamma_M} \cdot K_{mod,1}$$

$R_{ax,K}$ characteristic loadbearing capacity in the direction of shank

$$R_{ax,K} = (1.5 + 0.6\ d) \sqrt{\rho_K}\ (l_{ef} - d)$$

l_{ef} effective length of thread (within the timber component to be attached)

d screw shank diameter, mm

ρ_K characteristic bulk density (5 %-quantile), kg/m^3

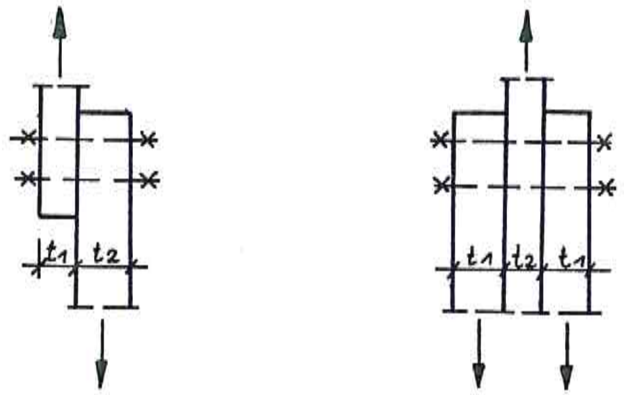
γ_M material factor acc. to /17/

$K_{mod,1}$ modification factor acc. to /5/, table 3.1.3.

Figure 35 : Calculation of timber fasteners; wood screws

Bolts (studs) and connectors (dowels) being stressed perpendicularly to their axis

(a) Connections of timber with timber



For each bolt and/or connector: $F_d \leqq R_d$

Meanings:

F_d design value of the loading perpendicular to the bolt (stud) axis

R_d design value of the loadbearing capacity perpendicular to the bolt (stud) axis

$$R_d = \frac{R_K}{\gamma_M} \cdot K_{mod,1}$$

R_K characteristic loadbearing capacity perpendicular to the bolt (stud) axis acc. to /5/, (5.3.5. b-f)

For single-shear timber fasteners:

$$R_K = 0.2 \cdot f_{b,K} \; (K_{\alpha,1} \, t_1 + K_{\alpha,2} \, t_2) \; d$$

$f_{b,K}$ bolt-bearing property (pressure):

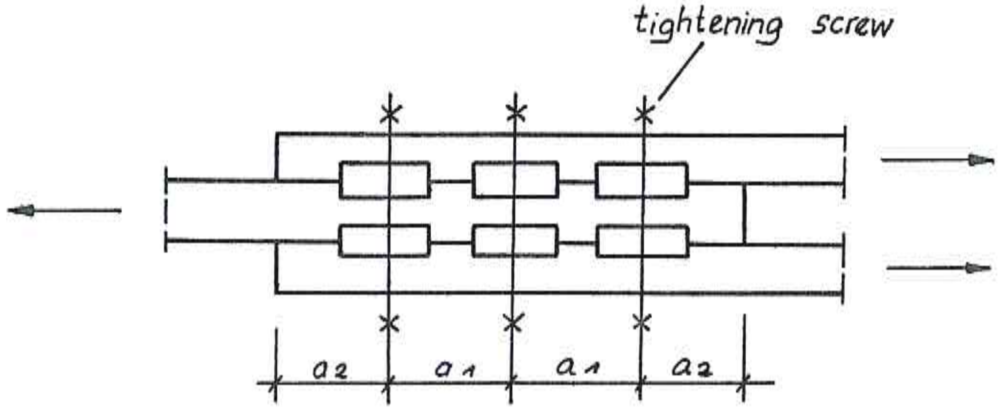
$$f_{b,K} = 0.075 \; \rho_K \text{ (MPa)}$$

connector-bearing property (pressure):

$$f_{b,K} = 0.09 \; \rho_K \text{ (MPa)}$$

(to be cont'd.)

Special connectors being stressed perpendicularly to their axis



For each special connector: $F_d \leqq R_d$

in connection with structural requirements concerning the amount of $_{min}A$, d, a_1, a_2

Meanings:

F_d design value of the loading perpendicular to the axis of the special connector

R_d design value of the loadbearing capacity perpendicular to the axis of the special connector

$$R_d = \frac{R_K}{\gamma_M} \cdot K_{mod,1}$$

R_K characteristic loadbearing capacity perpendicular to the axis of the special connector, acc. to /5/

γ_M material factor acc. to /17/

$K_{mod,1}$ modification factor acc. to /5/, table 3.1.

$_{min}A$ minimum cross section of the timber components to be connected, acc. to /15/

d tightening screw diameter acc. to /15/

a_1 ; a_2 spacings of the special connectors acc. to /15/

Figure 36 : Calculation of timber fasteners; special connectors (lay-in connectors, bolted connectors)

Table 1 : Parts of the Future GDR Timber Design Code

Part	Title	Objective	Date of completion (year)
1	Timber construction; Loadbearing systems; Calculation and structural design	Establishment of wide conformity with the CIB Model Code and the Eurocode	1990
2	Timber construction; Analysis of the structural state of repair and reconstruction of existing (historic) timber structures	Generalization of the experience prevailing in this field for many years	1991
3	Timber construction; Wood-based engineering materials and constructions consisting of these materials	Establishment of wide conformity with the CIB Model Code and the Eurocode	1992

Table 2 : GDR Standard Specifications related to the new GDR Timber Design Code which must be revised within the next years

GDR Standard Specification (TGL)	Draft dated (year)	Title	Completion of the planned revision(year)	Objective of the revision
33136/01	1987	Timber construction; Building components of glued laminated timber; Technical specifications	1992	Approach to the international trend in the testing of finger joints and beams
33136/02	1978	Timber construction; Building components of glued laminated timber; Quality control in the production	1993	Approach to the international trend
42704	1986	Bridges in traffic construction; Timber bridges; Calculation and structural design	1995	Design based on limit states
117-0767	1963	Structural timber; Sorting by quality grades and strength classes	1992	Establishment of a wide conformity with the ECE Code

Table 3 : Load factors acc. to /6/

Kind of load	Load factors [1]
Dead load	0.8 ... 0.9 [2] 1.1 ... 1.3 0.82 ... 0.935 [2] 1.065 ... 1.18
Live loads in residential and public/community buildings and structures [3]	1.2 ... 1.4
Live loads in industrial and agricultural buildings and structures [3]	1.2 ... 1.4
Loads of liquids in pipings	1.0 ... 1.1
Wind loads [3]	1.2 ... 1.3
Snow loads	1.4

1) They apply only to the limit state of the loadbearing capacity (GZT); as for the limit state of the usability (GZN), γ_f = 1.0 is applicable if no particular specifications are fixed.

2) To be applied if the reduction of the loading should have an unfavourable effect.

3) Additional values are indicated in /6/.

Table 4 : Reliability classes and valency factors for the limit state of the load-bearing capacity (GZT) acc. to /7/

Reliability class	Consequences in the case of failure	Kind of utilization of the building/structure	Valency factor
1	2	3	4
I	- very high risks for the population	- safety-relevant structures of nuclear plants and systems - embankment-type dams and barrages of hydro dams with a capacity of $\geqq 10^7 m^3$ - industrial and storage buildings and structures with a very high risk potential - buildings and structures in which crowds totalling as from 3,000 people may gather	1.1 [1)]
II	- high risks for crowds of people - high economic losses - high cultural losses	- buildings and structures with frequent crowds totalling $\geqq$ 500 people . sports stadiums as far as they do not fall under the reliability class I . theatres, cinemas, concert halls, churches . schools, auditoriums . passenger terminal buildings of railway stations, airports . high-rise buildings of hotels and ward blocks as well as of boarding-schools . hospitals - department stores and indoor markets with a sales floor area of $\geqq$ 10,000 m^2 - bridges in the construction of traffic facilities - buildings and structures with a considerable national-economic importance . main buildings of power plants . selected stacks with a height of $\geqq$ 50m . dams/barrages of hydro dams with a capacity of $\geqq 10^5$ and $< 10^7 m^3$	1.05

Table 4 (cont'd.), page 2

1	2	3	4
(reliab. class II, cont'd.)		- buildings and structures of a great public importance and with a particular representative character . buildings/structures of central state organs, parties and mass organizations . museums containing irretrievable treasures - buildings and structures for disaster control and civil defence purposes	
III	- risks for groups of people - considerable economic consequences	- residential buildings - office buildings as far as they do not fall under the reliability class II - industrial, public/social and agricultural buildings and structures as far as they do not fall under other reliability classes - central storage buildings and structures for the population's supply and provision; storage facilities for technical equipment of great value - building constructions in the erection state and in case of fire - loadbearing structures of systems for the transmission and distribution of electrical energy	1.0
IV	- insignificant risks for people - insignificant economic consequences	- smaller, single-storey production (service) buildings and workshops of the locally controlled industry and of agriculture - greenhouses with roof frame spans of $\geqq$ 12 m - buildings/structures for the storage of agricultural products, fertilizers and innocuous chemicals - objects of the site facilities with service periods of $\geqq$ 8 years - bungalows and arbours	

Table 4 (cont'd.), page 3

1	2	3	4
V	- very insignificant risks for people - very insignificant economic consequences	- smaller, single-storey buildings of an insignificant economic importance in which people are not staying permanently . greenhouses with roof frame spans of <12 m . barns, sheds . individual garages . smaller storage buildings of a secondary importance	0.90

1) To be fixed by agreement with the State Building Supervision Authority.

Table 5: Combination factor acc. to /6/

Load combination	Number of the short-term loads	ψ
Basic combination[1]	1	1.0
	2 or 3	0.9
	> 3	0.8
Special combination[2]	≧ 1	0.8

1) maximum load, without instantaneous load

2) maximum load, including instantaneous load

Table 6: Comparison of the partial safety values for actions as applicable in the GDR and acc. to Eurocode 5 /5/

Permanent actions γ_G	Partial safety values in the GDR by reliability classes acc. to /6/					Partial safety values in the Eurocode 5 acc. to /5/	
	I	II	III	IV	V	+)	++)
- smallest effect	1.0	1.0	1.0	1.0	1.0	1.0	1.0
- unfavourable effect	>1.20	1.16	1.10	1.05	1.0	1.35	1.2
Variable actions γ_Q							
- one with its characteristic value	>1.54	1.47	1.40	1.33	1.26	1.5	1.35
- one with its accompanying value						1.5	1.35

+) normal partial safety values

++) reduced partial safety values 1)

1) For single-storey structures with a medium span and only occasional utilization. This corresponds to the reliability class V in the GDR.

Table 7 : Proposal as to moisture classes and allocated climatic conditions

Moisture class	Classification of the category of building/structure and climatic conditions	Timber moisture	Relative air humidity at 20°C	Remarks
1	2	3	4	5
1	- Enclosed buildings/structures with heating (well ventilated; no rooms with moisture sources) - Enclosed buildings/structures, slightly heated (well ventilated; no rooms with moisture sources)	$\omega \leqq 12\ \%$	$\varphi \leqq 65\ \%$	
2	- Enclosed buildings/structures without heating (well ventilated; with rooms having weak moisture sources) 1) - Glued laminated timber and square timber components being exposed to the utilization conditions of the moisture class 3 which, however, are provided with a hydrophobic protective coat	$12 < \omega \leqq 18\ \%$	$65 \leqq \varphi \leqq 85\ \%$	1) Grain storage facilities, works halls and assembly halls of the metalworking industry

(cont'd.)

Table 7 (cont'd.), page 2

1	2	3	4	5
3	- Enclosed buildings/structures with rooms having moisture sources [2)] - Free-standing building/structures made of medium- to large-sized timber cross sections such as square timber members and glued laminated timber components - Components made of boards and laths being exposed to a utilization according to moisture class 2 - Roofed buildings/structures being open on all sides, with unprotected components - Small-sized components of free-standing buildings/structures such as laths, boards, planks - Glued laminated timber and square timber components being exposed to utilization conditions of moisture class 2 which, however, serve for roofing over halls for the storage of fertilizers, in particular of urea	$18 < \omega \leqq 26$ %		2) e.g. baths, swimming pool halls, weaving mills, foodstuffs enterprises, industrial and water-supply wet rooms such as tanneries, laundries etc. In case of doubt, the allocation will be accomplished according to the magnitude of the permanently acting air humidity by agreement with the State Building Supervision Authority.
	- Buildings/structures with wet rooms which have a permanent air humidity of $\varphi \geqq 95$ %		$\varphi \geqq 85$ %	
	- Building components being located in water	$\omega > 30$ %		

T a b l e 8 : Classes [1] of the load action period acc. to Eurocode and allocation, load classes acc. to GDR Code /6/

Load action period		Classification of the loads acc. to GDR Code
class/permanent load	magnitude as to time	
1	2	3
A long	10 years	Permanent loads such as the dead load of the building/structure, the actions due to soil (earth) and/or water permanently surrounding the building/structure concerned, as well as the tensioning forces at the time $t = \infty$ long-term loads such as dead loads of dismountable partitions, loads from stationary equipment including its filling or surcharges such as the material to be conveyed on conveyor belts, internal pressure, e.g. of tanks, silos, loads in rooms serving for storage purposes, e.g. warehouses (stores), libraries, technologically conditioned temperature actions lasting for a long period, actions resulting from surrounding soil (earth) or water as far as they do not fall under the permanent loads, load resulting from deposits, e.g. dust, actions resulting from the shrinkage of the building materials, actions resulting from the rheological behaviour, actions resulting from movable conveying and lifting equipment as far as they fall under the long-term loads, such as foundry cranes etc.

(cont'd.)

Table 8 (cont'd.), page 2

1	2	3
B medium	6 months	Short-term loads, such as loads in zones located near stationary equipment, e.g. service, handling and attendance zones, loads acting at the stage of erection, assembly and/or dismantling, loads occurring at switch-in and switch-off (i.e. starting and stopping) stages and with the trial operation, loads resulting from movable conveying and lifting equipment, including material to be conveyed, live loads in residential and public/community buildings as far as they are not resulting from technological equipment, snow loads, ice loads
C short	1 week	Short-term loads, such as wind climatically conditioned temperature actions
D impulsive		Instantaneous loads, such as forces due to operating troubles (breakdowns), e.g. short circuit, rupture (failure), impact, explosion pressures, forces due to inertia ("mass forces") as a result of earthquake, actions due to mining subsidence and other special loads squalls (gusts)

1) They are characterized by the effect of a constant load.

Table [illegible]

No.	Kind of loading		$K_{mod.}$ acc. to standard code or proposal, respectively								US, UK, Kanada	tests of Madsen (evaluated by Steck)	SIA-165 of Switzerland	GDR proposal (1985)	GDR proposal (1976)	Eurocode 5 acc. to /17/		DIN 1052 (84)	TGL 33135 (84)	Eurocode 5 for moisture classes 1 and 2		GDR proposal (1988)		USSR Code SNiP (1981)	
			$f_m, f_{c,0}$ $f_{t,0}, f_v$	$f_{t,90}$	E, G (check of deflection)	high-quality timber and glued laminated timber $f_m, f_{t,0}$ $f_{c,0}$, E	low-quality timber $f_m, f_{t,0}$ $f_{c,0}$, E	for all quality classes + glued laminated timber $f_{c,90}$ f_v	$f_{t,90}$	for all quality + glued laminated timber E, G						f_m $f_{c,0}$ $f_{c,90}$ $f_{t,90}$	$f_{t,0}$, f_v			f_m $f_{c,0}$ $f_{c,90}$ f_v $f_{t,0}$ E	$f_{c,90}$	structural timber	glued laminated timber		$f_{c,90}$
1.	impulsive	3 sec	1,1	1,1	–	1,1	1,1	1,1	1,1	–	1,2	–	1,08 [2)]	–	1,2	1,2	1,2	2,0 [3)] 1,25 1,50 [4)]	1,15	–	–	1,3	1,3	1,2	1,4
2.	short-term test	3..5 min	(1,0)	(1,0)	(1,0)	(1,0)	(1,0)	(1,0)	(1,0)	(1,0)	1,0	1,0 [1)]	1,0	–	1,0	(1,0)	(1,0)	1,0	1,0	–	–	–	–	–	–
3.	very short-term	< 10 h	0,95	0,90	1,0	0,95	1,0	0,95	0,90	1,0	0,83	0,98	–	1,0	–	1,0	1,0	–	–	1,2	1,2	1,2	1,2	–	–
4.	short-term										0,80	0,56													
5.	short-term	100 h (1 week)	0,80	0,70	1,0	0,80	0,95	0,80	0,70	1,0	[illegible]	0,85		0,83		0,95	0,90			1,0	0,85				
6.	short-term (long-term)	1 month									0,70	0,575			0,70							1,0	1,0		
7.	medium-term	10000 h (1 year)	0,70	0,50	1,0	0,70	0,90	0,70	0,50	0,80	0,65	0,75				0,90	0,75			0,90	0,70				
8.	long-term (normal)	< 10 years	0,55	0,35	0,70	0,55	0,85	0,55	0,85	0,60	0,60	0,655	0,77			0,85	0,60			0,80	0,55				0,8
9.	long-term (permanent)	50 years									0,55	0,60			0,60			0,59	0,59				0,85	0,80	

1) related to 1 hour

2) related to 10 seconds

3) horizontal impact loads and earthquake loads

4) conditions of transport and assembly

Table 10a: Time classes

Time class	Duration of the load action
A	Permanently and/or for a long period (e.g. dead load, live load)
B	For a short period (e.g. live load, snow)
C	For a very short period (e.g. wind)
D	Suddenly (e.g. impact, earthquake)

Table 10b: Load combinations; grouping into time classes

Load combination	Time class A	Time class B	Time class C	Time class D
A + B	LA ≧ 85 %	LA < 85 %	–	–
A + C	LA ≧ 85 %	–	LA < 85 %	–
A + B + C	LA ≧ 85 %	LC ≦ 15 %	LC < 15 %	–
A + B + C + D	LA ≧ 85 %	LD ≦ 15 % LA ≦ 85 %	– –	LD > 15 % –

LA (etc.) means load component (percentage) of time class A (etc.) of the total load

e.g. $LA = \frac{A}{A + B}$

Table 11: Design of the new grades of glued laminated timber

Sort		BSH 1	BSH 2	BSH 3	BSH M1	BSH M2	BSH M3
Sorting of the layers of boards		visually	visually	visually	mechanically	mechanically	mechanically
Exterior layers	kind of timber	NSH GK I,II	NSH GK II	NSH GK I,II	NSH F I	NSH F II	NSH F II
	KZV (mm)	≧ 250	≧ 250	≧ 0	≧ 250	≧ 250	≧ 250
Interior layers	kind of timber	NSH GK I,II	NSH GK III	NSH GK I,II	NSH F III	NSH F III	NSH F II
	KZV (mm)	≧ 250	≧ 0	≧ 0	≧ 0	≧ 0	≧ 0

Meaning of the abbreviations:

BSH = glued laminated timber

NSH = sawn coniferous timber (pine, spruce or larch)

GK = quality class (grade) ; F = strength class

KZV = staggering of key-dovetail connections ("finger joints")

Table 12: Strength classes, characteristic values and mean moduli of elasticity and shear moduli

		sawn structural timber						glued laminated timber						round timber	GK II hardwood
		quality class (GK)			strength class (F)			grade							
		I	II	III	I	II	III	1	2	3	M1	M2	M3		
strength class acc to Eurocode 5 10/87		C6	C5	C3	C7	C6	C3	C6	C5	C4	C6/7	C6	C5	C5/6	C5
bending	R^n_m	28,5	24	19	38	28,5	19	28,5	24	21,5	33,3	28,5	24	26,5	24
tension	$R^n_{t,0}$	17	14,5	7,1	24	17	11,5	14,4	4,8	14,4	14,6	15,7	13,6	15,8	17
	$R^n_{t,90}$	0,5	0,45	0,35	0,6	0,5	0,35	0,45	0,35	0,45	0,35	0,5	0,35	0,5	0,5
compression	$R^n_{c,0}$	26	21,5	17,5	30	26	17,5	26	21,5	19	21,7	26	21,5	26	26
	$R^n_{c,90}$	8	7,5	6,8	11	8	6,8	7,5	6,8	7,5	6,8	8	6,8	7,8	11,3
shearing off ‖ to grain	$R^n_{a,0}$	2,0	1,7	1,5	2,9	2,0	1,5	1,7	1,5	1,7	1,5	2,0	1,5	1,5	3
shear from transverse force	R^n_τ	2,7	2,3	2,0	3,8	2,7	2,0	2,7	2,0	2,1	2,0	2,7	2,3	2,7	2,7
moduli	E^n_0	12000	11000	9000	13500	12000	9000	12000	11000	10000	12500	12000	11000	12000	12500
	E^n_{90}	400	350	300	450	400	300	400	350	300	400	400	350	400	600
	G^n	750	700	550	850	750	550	750	700	600	800	750	700	750	1000
	$E_{0\ 5\%}$	8500	7500	6500	9500	8500	6500	8500	7500	8500	9000	8500	7500	8000	9000
	$G_{5\%}$	550	500	400	600	550	400	500	500	500	600	550	500	550	600

Table 13: Modification factor $\gamma_{d,1}$ as to "long-term behaviour" for the limit state of the loadbearing capacity (GZT)

Time class	Moisture class (FK) FK 1 + FK 2 BH	BSH	FK 3 BH	BSH
A	0.85	0.8	0.65	0.4
B	1.0	1.0	0.75	0.5
C	1.2	1.2	0.9	0.6
D	1.3	1.3	1.0	0.65

Meaning of the abbreviations:

BH = structural timber

BSH = glued laminated timber

For air temperatures of $35^\circ C \leq T \leq 50^\circ C$ and moisture class FK 1, $\gamma_{d,1}$ shall be multiplied by 0.85.

Table 14a: Modification factor $\gamma_{d,4}$ as to aggressive media" for the GZT and GZN limit states for structural timber (BH) and glued laminated timber (BSH)	
The kinds of the media are grouped into gases, solutions and solids. By considering the criteria as to concentration of the medium concerned and the moisture class, the stress degrees (BG) I, II, III are obtained:	
Stress degree (BG)	Explanation
BG I	Not or slightly aggressive
BG II	Moderately aggressive
BG III	Highly aggressive

Table 14f: Modification factors $\gamma_{d,4}$ for aggressive media subject to the timber cross-sectional size		
Note: Minimum dimension of the timber component with stress degrees BG II and BG III: 40 mm Minimum cross-sectional area: 4,000 mm^2 Approved timber preservatives do not exercise any aggressive influence (action) on the timber. The value of the modification factor is equal to $\gamma_{d,4} = 1$ when using efficient linings or coatings.		
Stress degree (BG)	Cross-sectional size (10^3 mm^2)	Factor $\gamma_{d,4}$
BG I		1.0
BG II	< 9	0.75
	< 30	0.85
	≧ 30	0.95
BG III	< 9	0.65
	< 30	0.75
	≧ 30	0.85

Ranges of aggressivity and stress degrees for gases

Table 14b: Ranges of aggressivity for gases

Gas, increasing aggressivity	Gas group with a concentration (mg/m^3) amounting to: A 1	A 2	A 3
1. CH_2O (formaldehyde)	1 ... 200	-	-
2. NH_3 (ammonia)	0.5 ... 20	-	-
3. SO_2 (sulphur dioxide)	0.2 ... 10	10 ... 200	-
4. NO_2 (nitric oxide)	0.1 ... 5	5 ... 25	above 25
5. HCl (hydrogen chloride)	0.05 ... 1	1 ... 10	above 10
6. Cl_2 (chlorine)	0.02 ... 1	1 ... 5	above 5

Table 14c: Stress degrees for gases

Range of aggressivity	Moisture class FK 1	FK 2	FK 3
A 1	I	I	I
A 2	I	II	II
A 3	II	II	II

T a b l e 14d: Stress degrees for solutions

Group	Solution	pH-value	Concentration of the solution	Degree of dissociation	Stress degree
Acids	nitric acid HNO_3	below 2	up to 5 above 5	high	III III
	hydrochloric acid HCl		up to 5 above 5	high	III III
	sulphuric acid H_2SO_4		up to 5 above 5 / above 15	medium	I II / III
	acetic acid $C_2H_4O_2$	4	above 15	low	I
Bases	soda lye $NaOH$	above 13	up to 2 above 2	high	II III
	potash lye KOH		up to 2 above 2	high	II III
	ammonium hydroxide NH_4OH		up to 5 above 5	low	I II
Salt solutions	chloride solutions: KCl, NaCl	7	up to 10 above 10	medium	I II
	sulphate solutions: Na_2SO_4 (Glauber's salt)		up to 10 above 10	medium	I II
	$(NH_4)_2SO_4$ (ammonium sulphate)	5	up to 40		I
(Organic compound)	urea $CO(NH_2)_2$	2	up to 40		II

Table 14a Stress degrees for solid media

Solid medium	pH-value	Solubility in water	Hygroscopicity	Stress degree (BG) with FK 1	FK 2	FK 3
Potash fertilizer	8	good (up to 20 %)	good	I	II	II
Urea	9	good (up to 40 %)	high	I	II	II
Superphosphate	3	(up to 5%)	good	I	I	II
Sodium chloride	7	good	good	I	I	II
Ammonium sulphate	5	good (up to 40 %)	low	I	I	I

Table 15: Creep factor K_{creep}

No.	Kind of loading	time (period)	Eurocode 5 1987 moisture class			Eurocode 5 1985 acc. to // moisture class			GDR proposal (1987) moisture class acc. to Eurocode		
			1	2	3	1	2	3	1	2	3
1	impulsive	< 3sec	–	–	–	1,0	1,25	1,5	–	–	–
2	short-term test	3-5 min	–	–	–				–	–	–
3	very short-term	< 10h	1,0	1,1	1,5				–	–	–
4	short-term	1 day									
5	short-term	100 h (1 week)	1,2	1,3	2,0	1,2	1,5	2,0	1,0 <1,65> [1,0]		1,6 <1,3> [3,3]
6	short-term (long-term)	1 month									
7	medium-term	10 000 h (1 year)				1,5	2,0	3,0			
8	long-term (normal)	< 10 years	1,5	1,8	3,0						
9	long-term	50 years							1,5 [2,5] <1,0>		2,5 <2,0> [5,0]

( ) applies to glued laminated timber

< > applies when using timber which is too wet and was dried back; e.g. $\omega_a \geq 30\%$ $\omega_e \leq 10\%$

[ ] ω_a = initial moisture
ω_e = final moisture

Figure 1a: Moisture classes (proposal of 1987) in comparison with Eurocode 5

Moisture class (FK)	Relative air humidity φ (%) (T = 20 ± 2°C)	Moisture of timber ω (%) (T = 20 ± 2°C)	Moisture class acc. to Euro-c ode 5	Relative air humidity 1) φ (%)	Moisture content ω (%)
FK 1	< 80	$\leqq 18$	1	< 65	$\leqq 12$
FK 2	$80 \leqq \varphi \leqq 95$	>18 to 24	2	$65 \leqq \varphi \leqq 80$	$\leqq 18$
FK 3	>95	> 24	3	> 80	$\geqq 18$

1) Value is being exceeded only for some weeks a year.

Industrial Code Specification — December, 1989

G D R	Timber Construction Loadbearing Structures Calculation — Structural Design	TGL 33 135/04 E89

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   (Purpose and scope, assumptions, units, symbols, definitions, reference documents)

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4. Limit state of the usability
   (Deflections, vibrations)

5. Calculation and design
   (Individual components, built-up components, fasteners)

6. Execution and supervision
   (General assembly, transport and erection)

Figure 1 : Arrangement of the Code

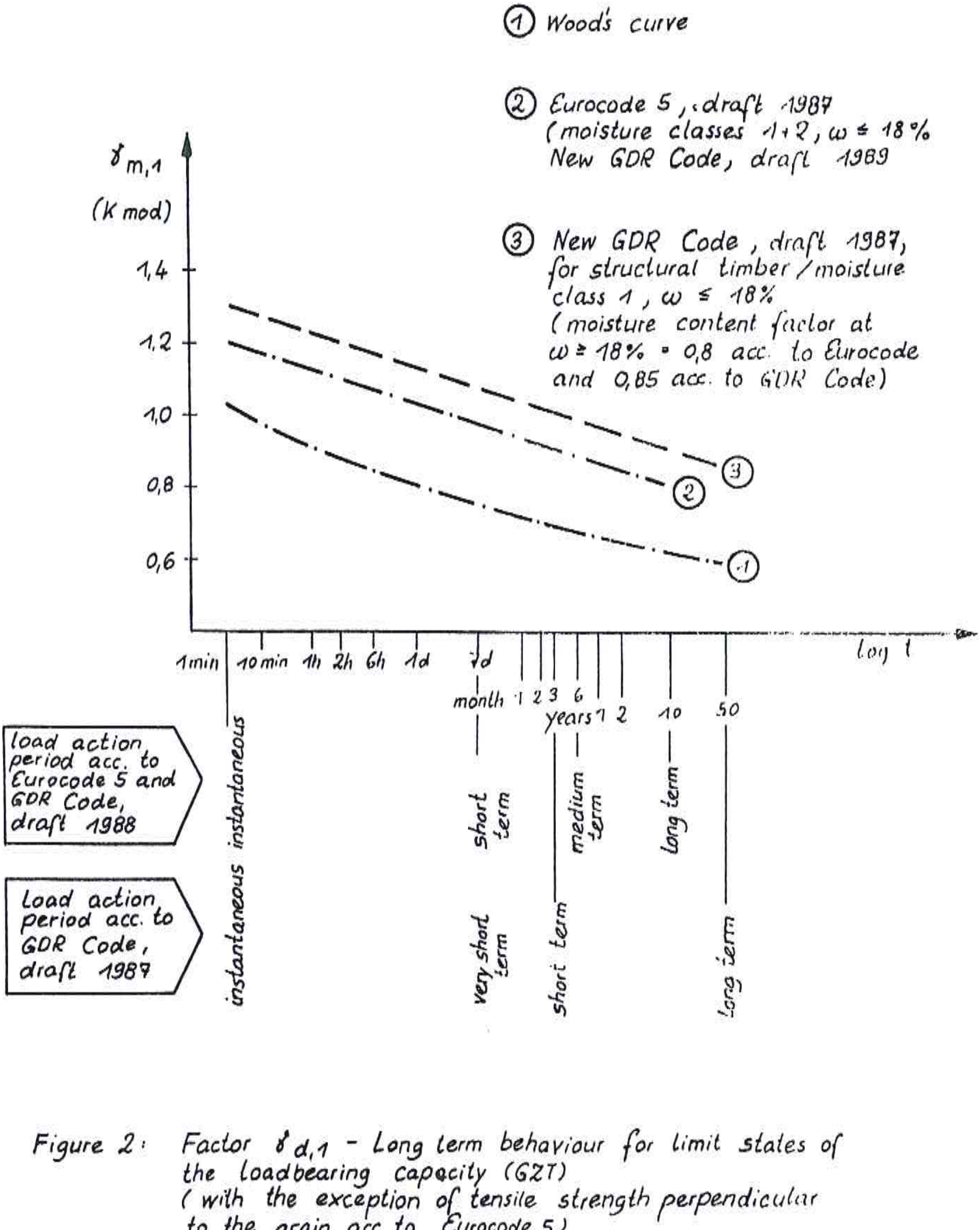
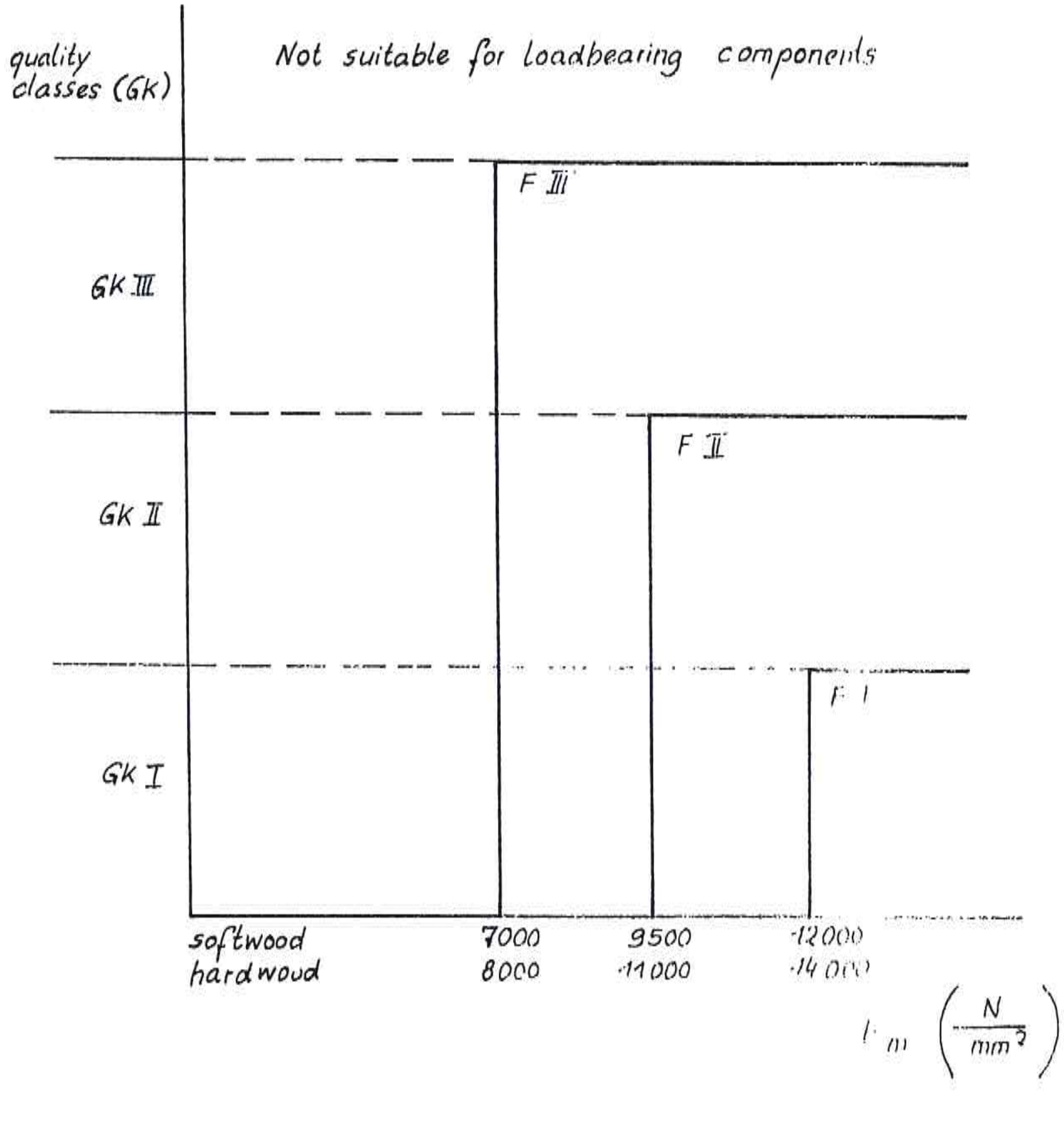


Figure 2: Factor $\gamma_{d,1}$ - Long term behaviour for limit states of the loadbearing capacity (GZT) (with the exception of tensile strength perpendicular to the grain acc. to Eurocode 5.)

Figure 3 : Strength classes (F) of sawn structural timber or layers of glued laminated timber



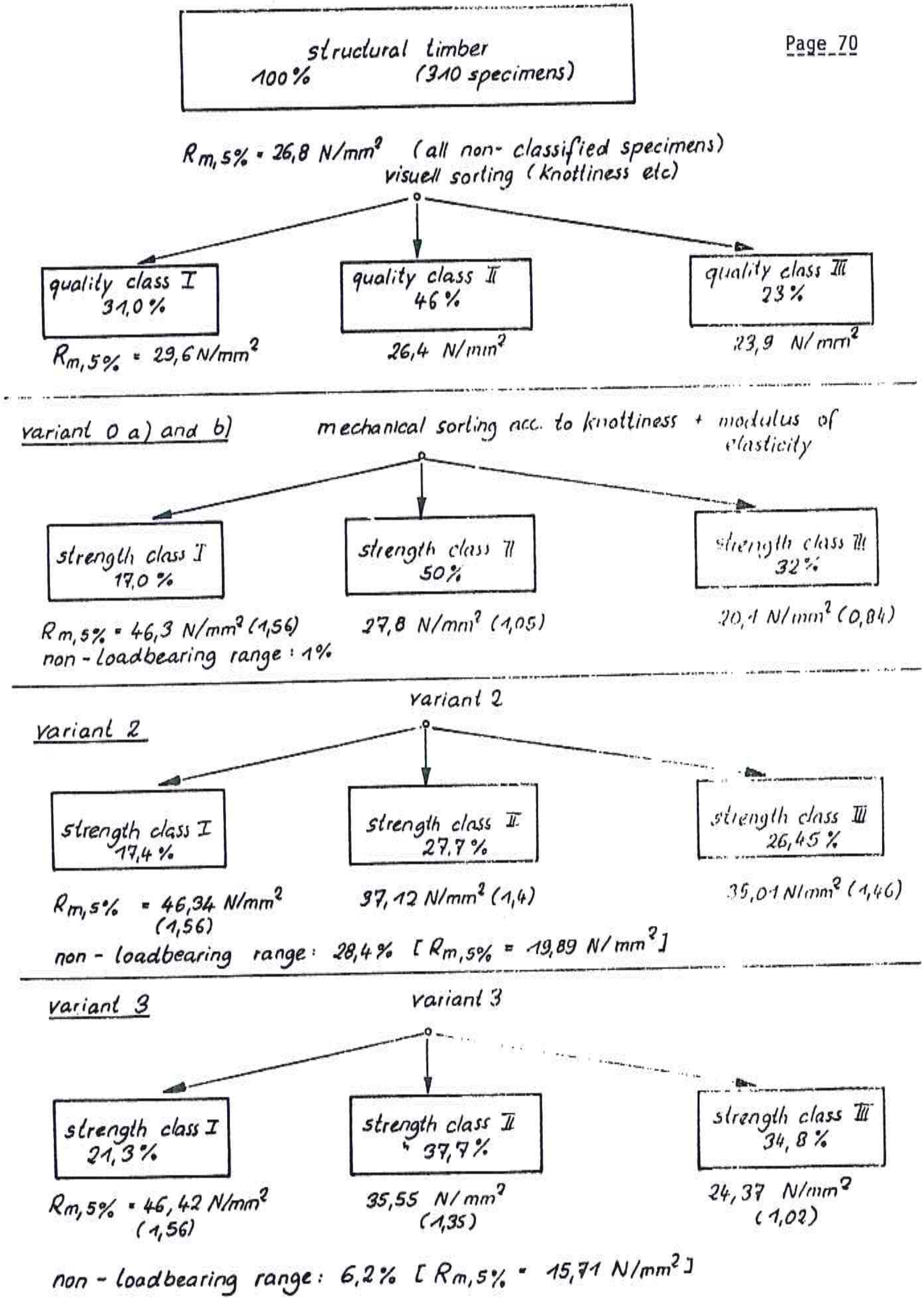
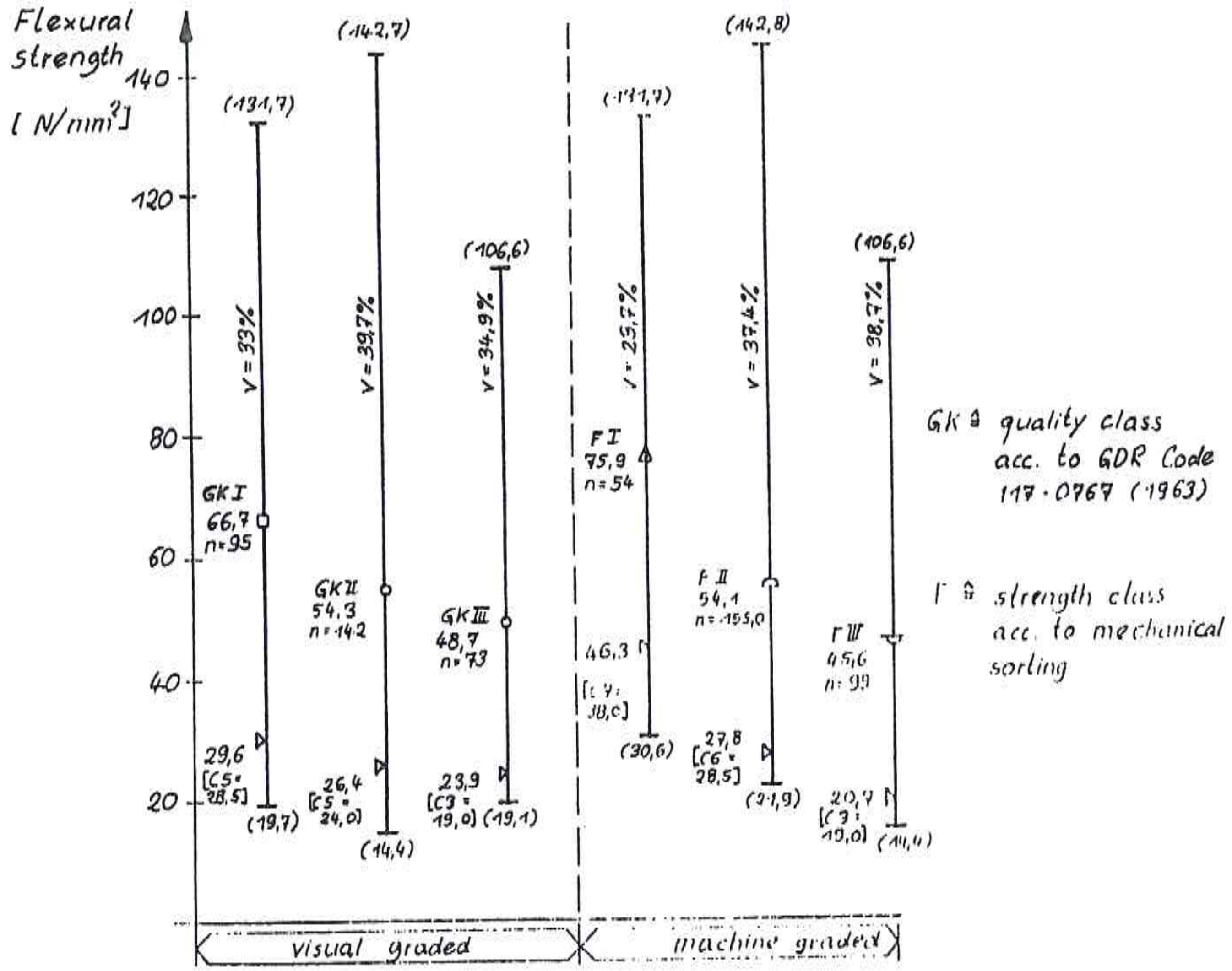


Figure 4: Sorting effect with structural timber (bending stress) depending on the selected class limits
( )-value = ratio to the $R_{m,5\%}$-value of the quality class



n - number of girders

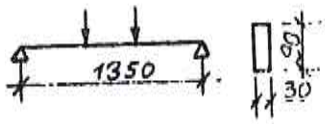
▷ - 5 % - quantiles of the 3 - parametric Weibull distribution acc. to GDR Code TGL 38734/03

v - variation coefficient, %

( ) - maximum / minimum value

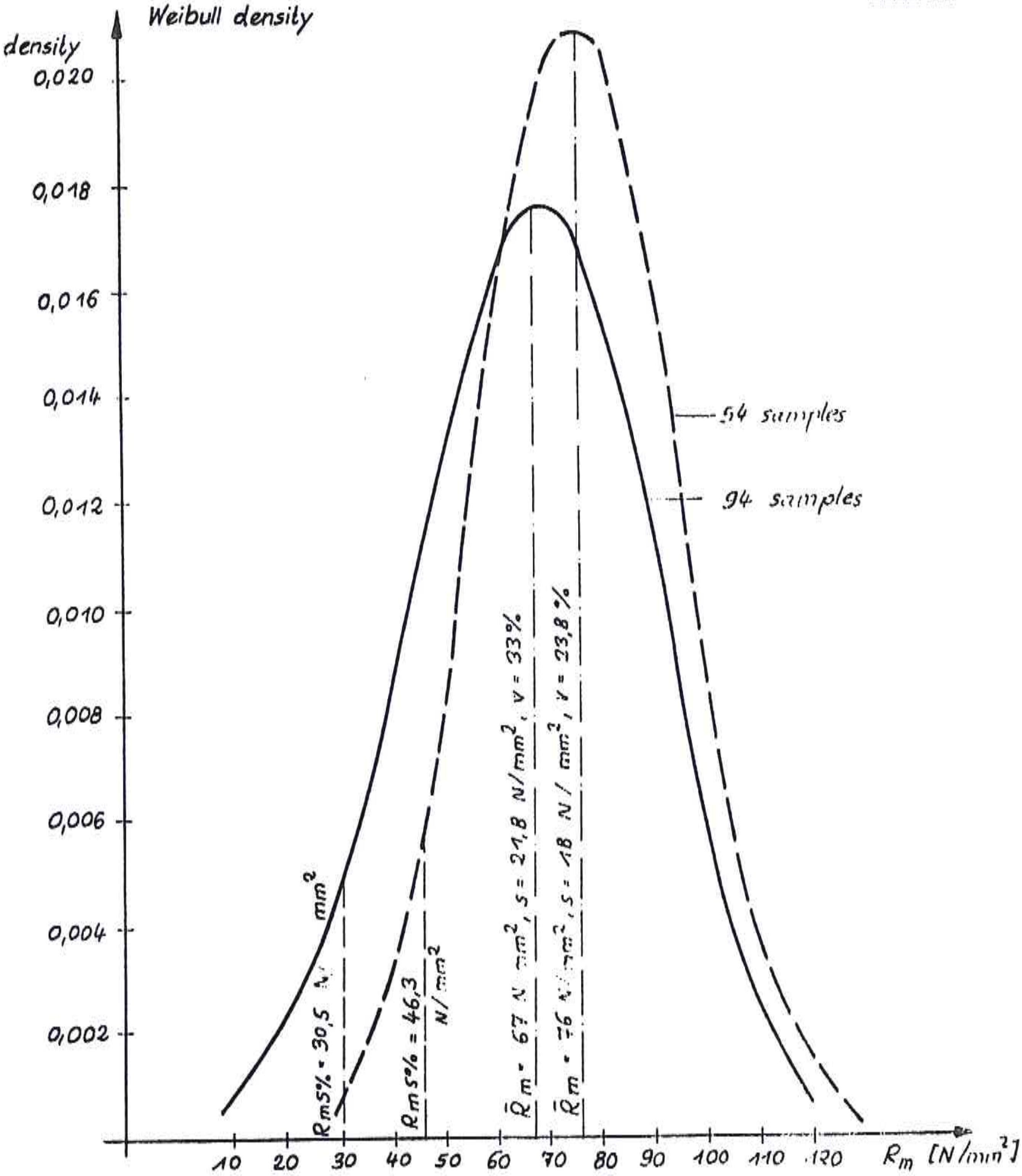
[ ] - strength class acc. to Eurocode 5, draft 1987, annex 2

Test arrangement:



Test conditions: temperature of 20 °C
moisture content 8 ... 13 %
test duration from 3 ... 5 minutes

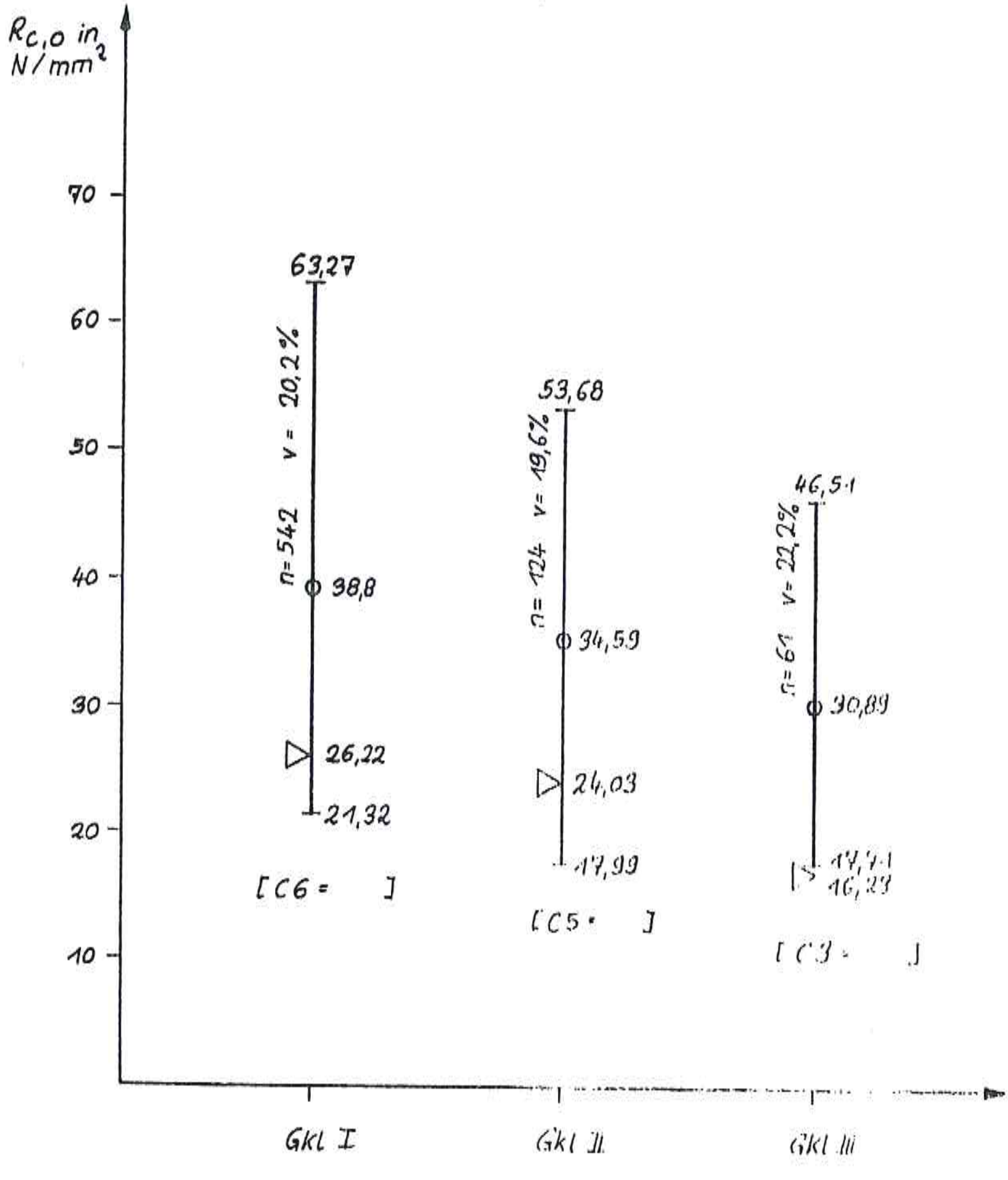
Figure 5: Bending strength of structural timber sorted acc. to various sorting procedures



- - - - strength class I (mechanically sorted solid timber)
——— quality class I (visually sorted solid timber)
— — — 5 %- quantile
—·—·— mean value

Figure 6: Comparison of mechanically and visually sorted structural timber of the strength class I and /or quality class I (bending failure strength)

Figure 7: Compression strength of sawn coniferous timber in parallel with the grain



□ mean value

▷ 5% - quantile of the 3 parametric Weibull distribution acc. to the GDR Code TGL 1/38791/03

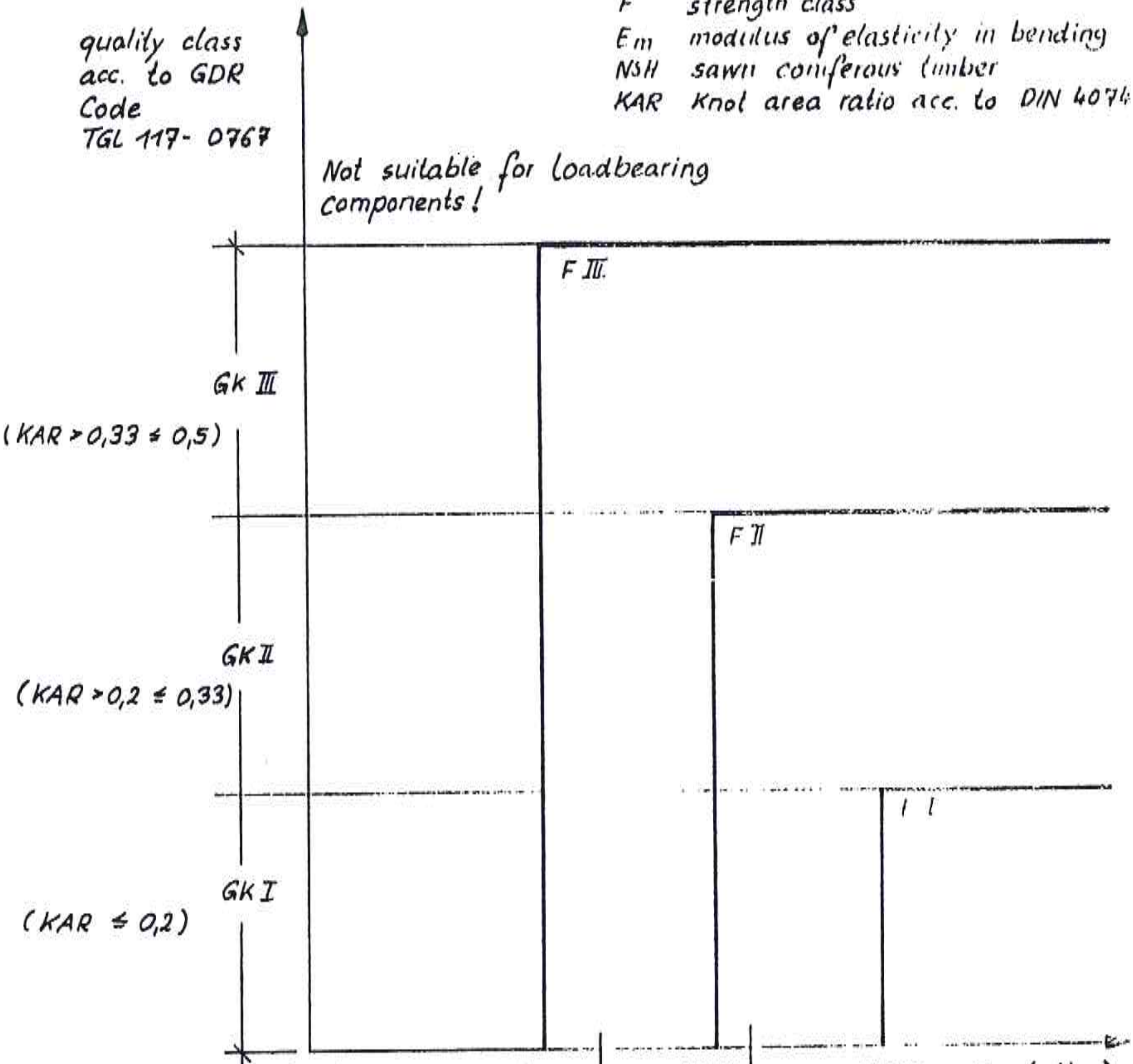
n number of specimens

v variation coefficient

[ ] strength class acc. to Eurocode 5; draft 1987, annex 2

Meanings:

GK quality class
F strength class
Em modulus of elasticity in bending
NSH sawn coniferous timber
KAR Knot area ratio acc. to DIN 4074



variant 0	a) old :	6000	9000	12000	Em $\left(\frac{N}{mm^2}\right)$
	b) new :	7000	9500	1200	
variant 1	a) min E	4000	5000	6500	
variant 2	b) Emean	10000	11000	12000	
variant 3	c) Emean	8000	10000	11000	

Figure 8: Strength classes of structural timber (sawn coniferous timber) or layers of glued laminated timber

Figure 8a: Bulk density of sawn coniferous timber (structural timber) sorted visually by quality classes (GK)
Specimens: Wismar, 1987

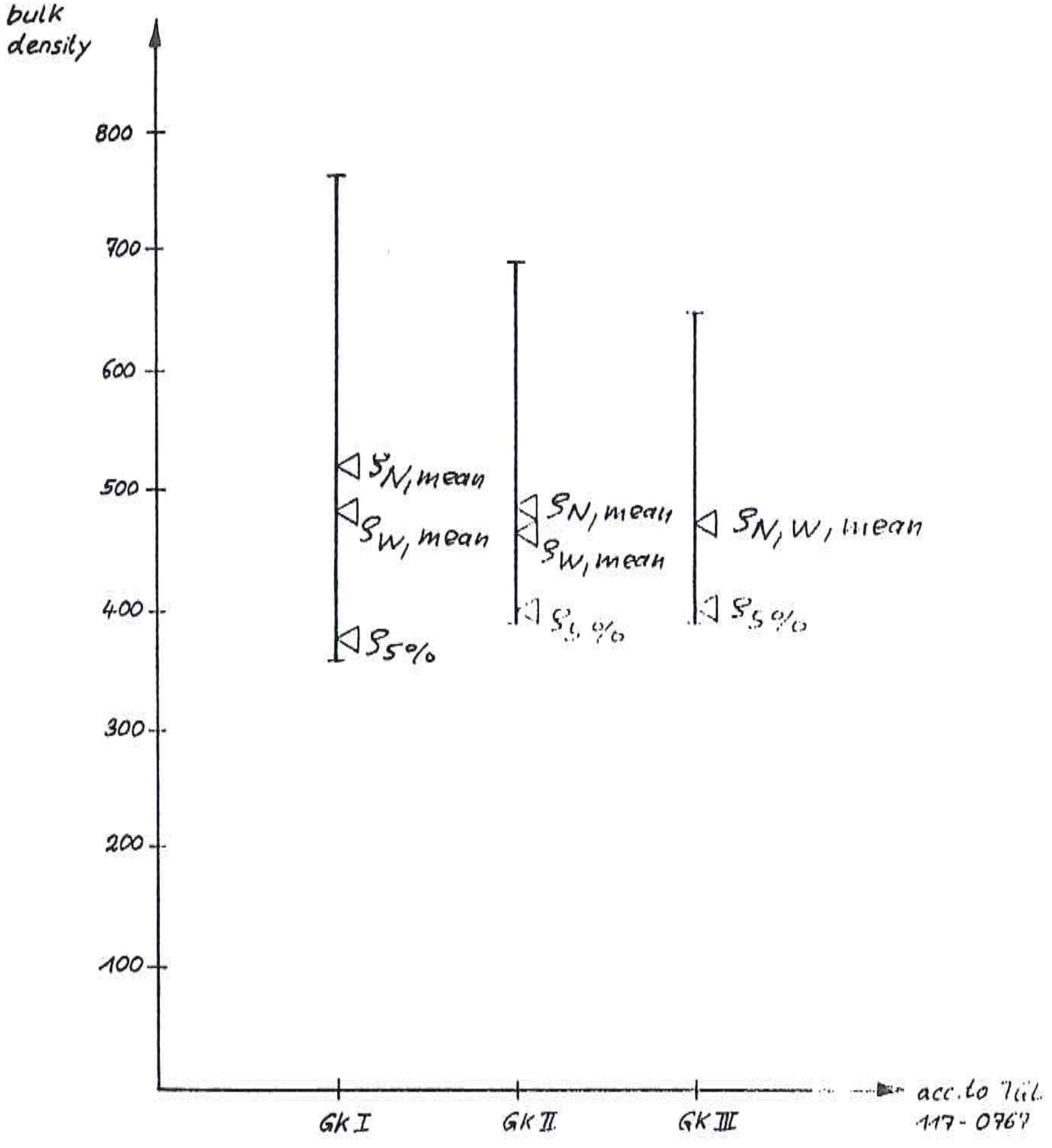
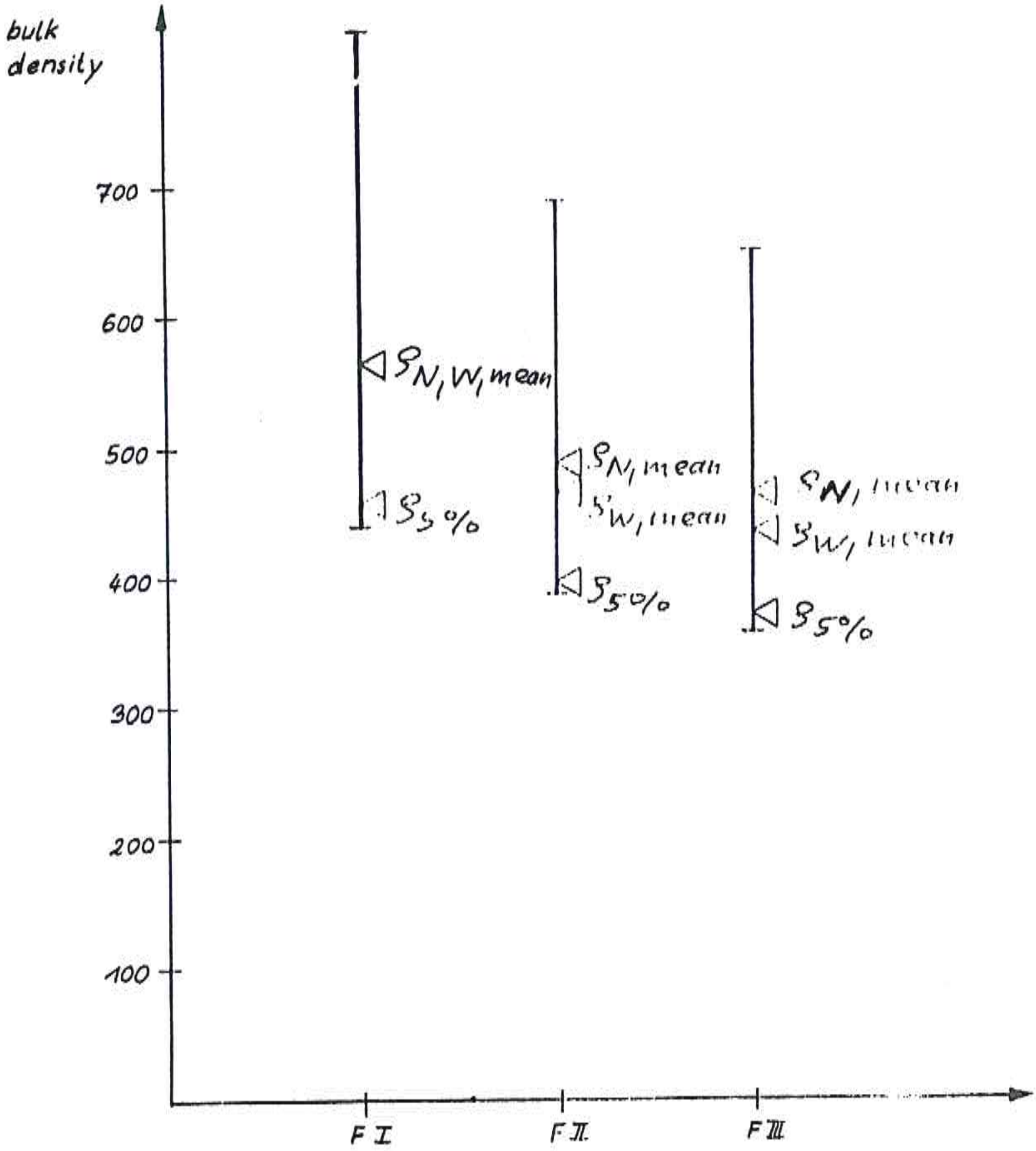
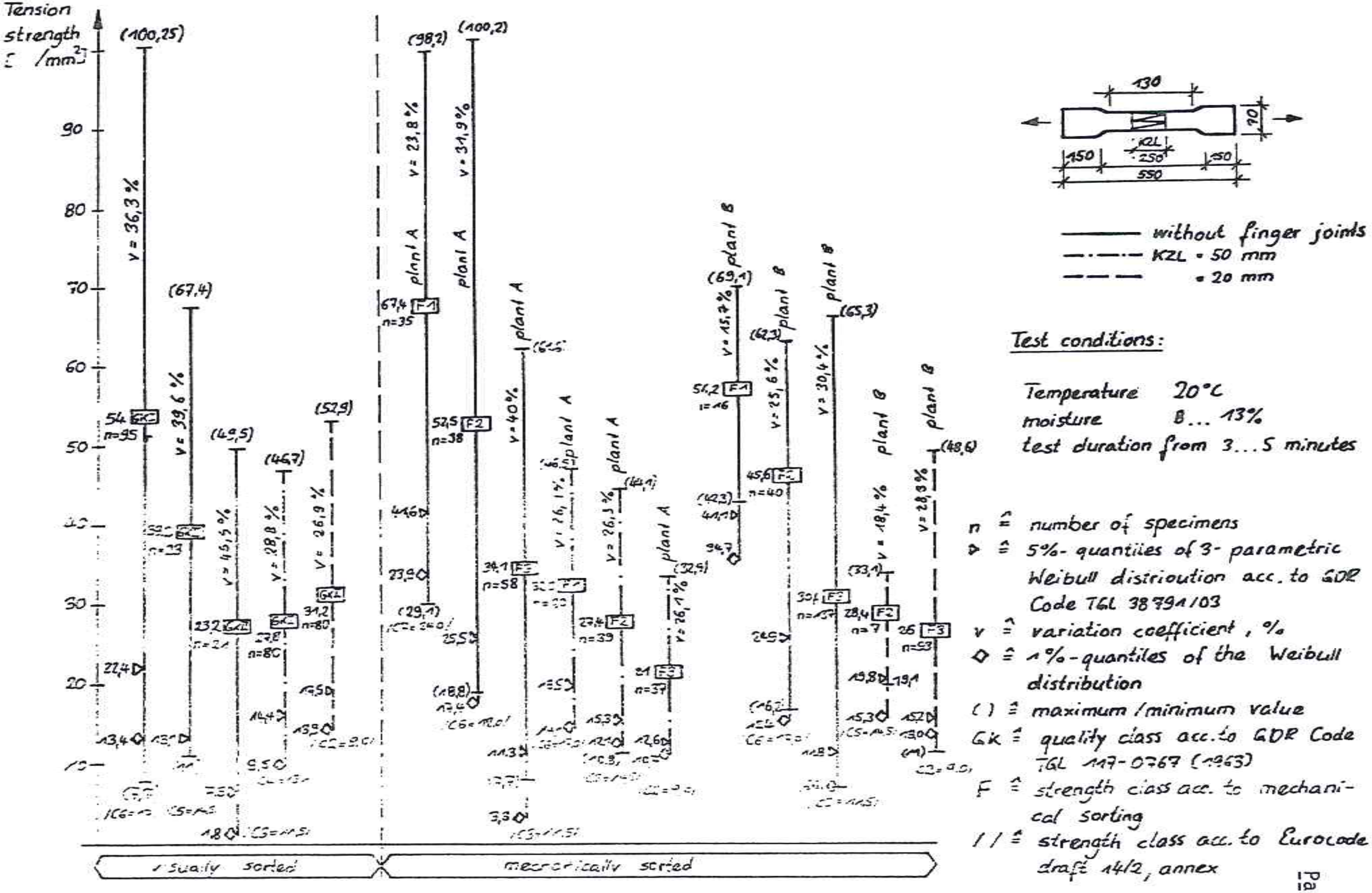


Figure 8 b: Bulk density of sawn coniferous timber (structural timber) sorted mechanically by strength classes (F)
Specimens : Wismar, 1987





Test conditions:

Temperature 20°C
moisture 8 ... 13%
test duration from 3 ... 5 minutes

n ≙ number of specimens
▷ ≙ 5%- quantiles of 3- parametric Weibull distribution acc. to GDR Code TGL 38791/03
v ≙ variation coefficient , %
◇ ≙ 1%-quantiles of the Weibull distribution
( ) ≙ maximum / minimum value
GK ≙ quality class acc. to GDR Code TGL 117-0767 (1963)
F ≙ strength class acc. to mechanical sorting
/ / ≙ strength class acc. to Eurocode 5 draft 14/2, annex

Figure 9: Tension strength of boards for glued laminated timber

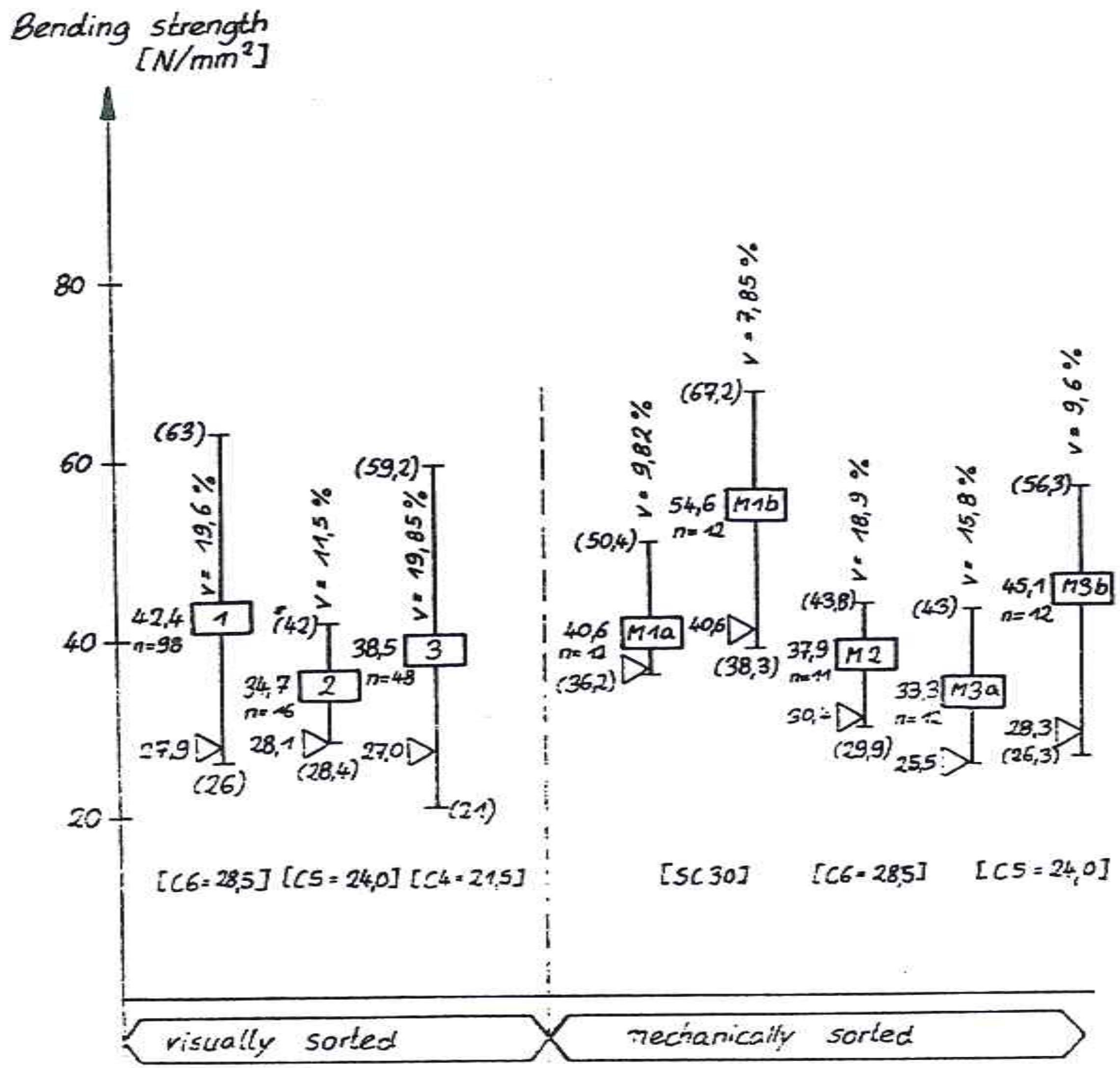


Figure 10: Bending strength of glued laminated timber; layers sorted acc. to various sorting procedures

1 Sort 1, production 85/86 h = 288 mm
2 Sort 2, production 84 h = 288 mm
3 Sort 3, production 85/86 h = 288 mm

M 1a Sort M 1 1.) h = 192 mm with key-dovetailing ("finger joints") in the outermost layer

M 1b Sort M 1 2.) h = 192 mm without key-dovetailing ("finger joints") in the outermost layer

M 2 1.)

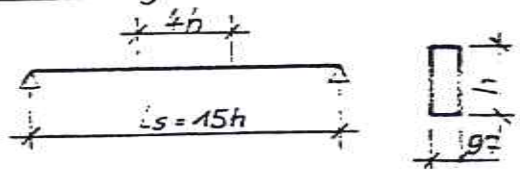
M 3a 1.)

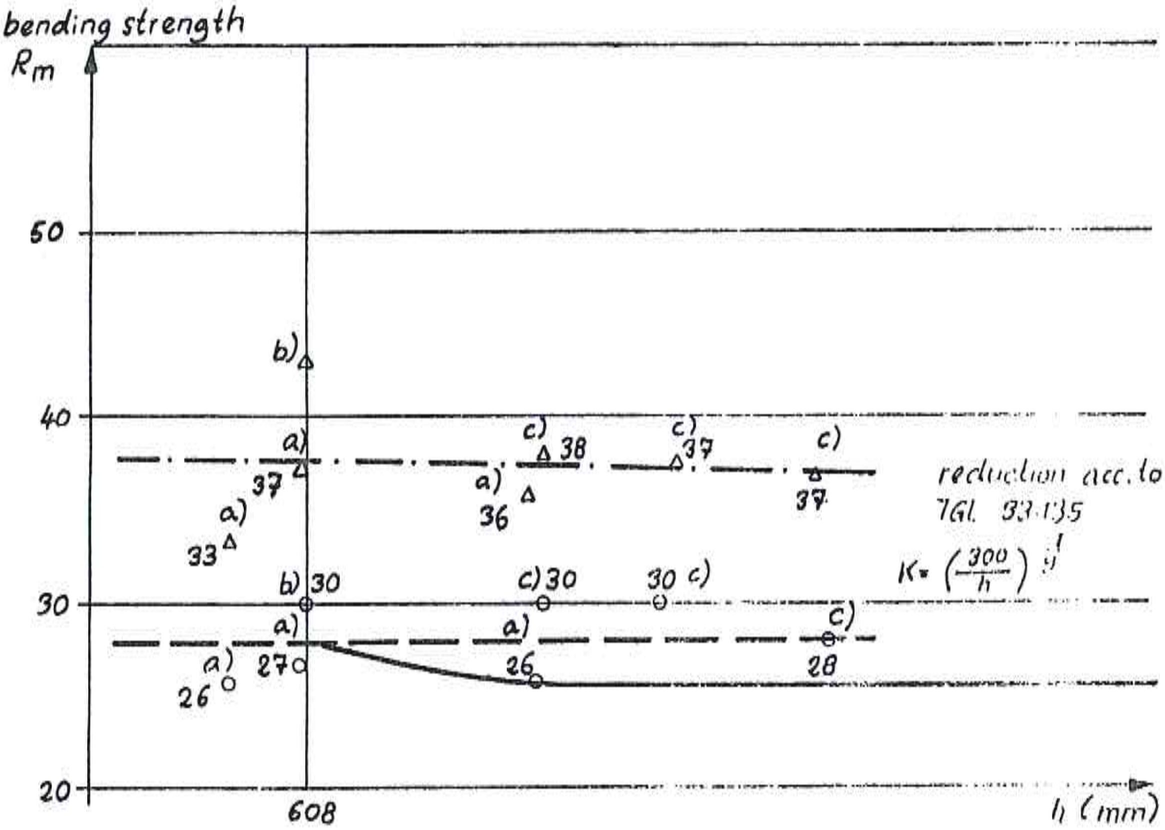
M 3b 2.)

Test conditions:
temperature of 20 ± 2°C
moisture content ≤ 10%
test duration from 3...5 minutes

n ≙ number of beams
▷ ≙ 5%-quantiles of 3-parameter Weibull distribution according to GDR-Code 33791/03
v ≙ variation coefficient, %
( ) maximum/minimum value
[ ] strength class for structural timber according to Eurocode 5; Annex 2

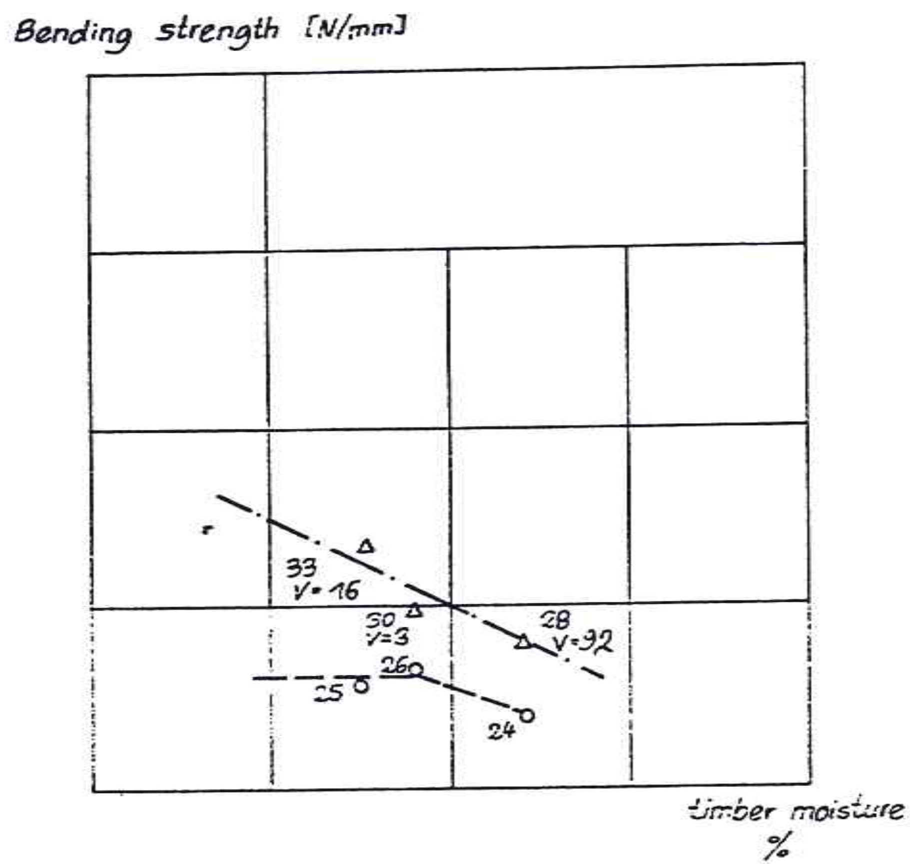
Test arrangement:





o 5% - quantile acc. to GDR Code TGL 33791/03
Δ mean values
a) test values of 1986/87, mechanical sorting (n = 12)
b) test values of 1985/86, visual sorting
c) test values (1974), visual sorting

Figure 11: Bending strength of glued laminated timber subject of the girder depth acc. to tests performed in the GDR



o 5% - quantile acc. to TGL 33751/02
Δ mean value (n = 12)
All beams with key-dovetail ("finger joints") staggering in the test zone

Figure 12: Bending strength of glued laminated timber subject to the timber moisture

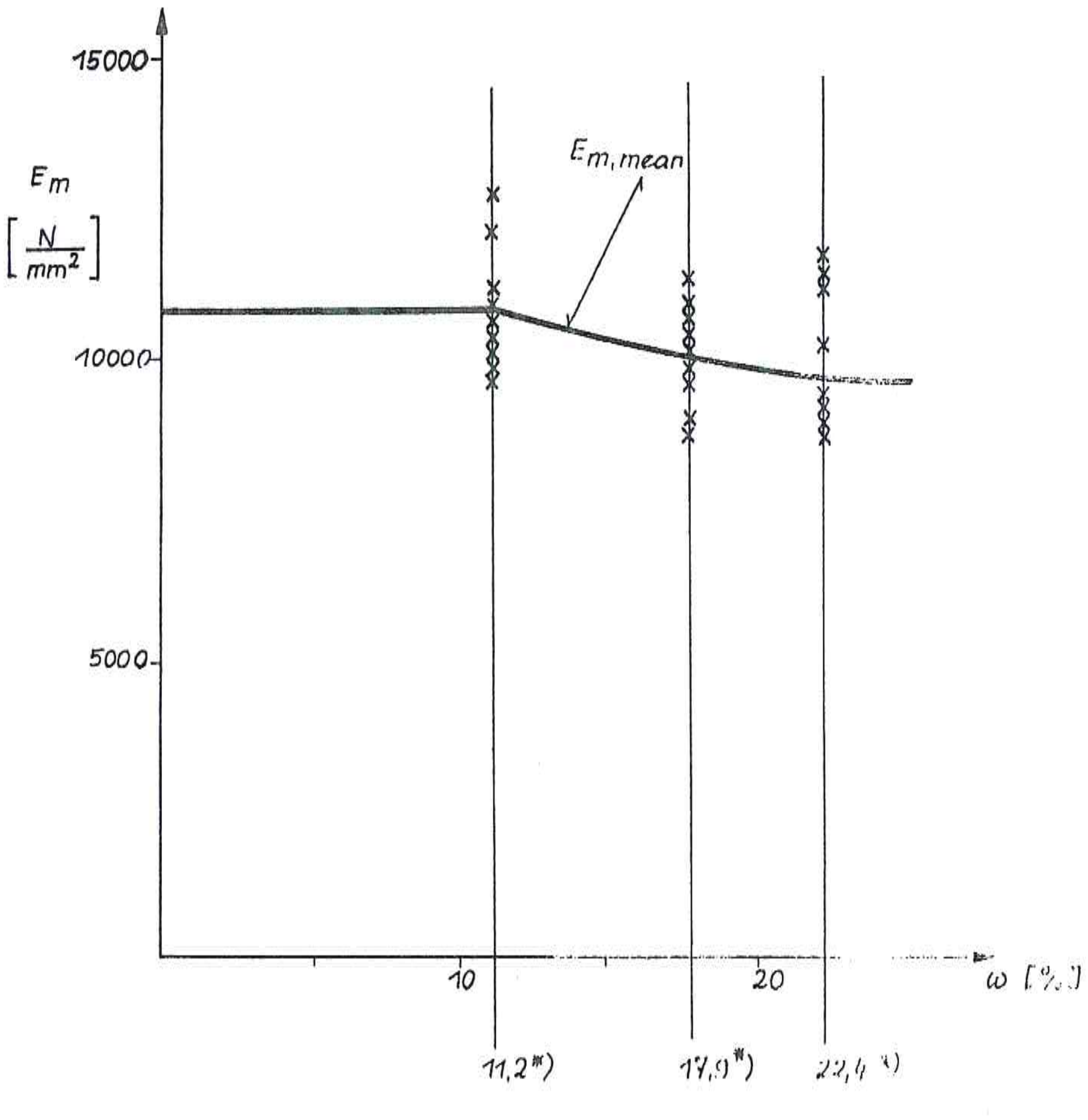
24,7	22,3	21,0	22,1	25,4	25,0
23,5	20,5	20,1	20,9	22,2	26,4
21,6	20,3	18,0	17,4	19,1	21,2
21,1	19,0	17,8	18,1	19,0	21,2
22,1	19,9	18,1	18,4	20,3	22,2
22,0	21,9	20,8	21,3	23,1	25,1

heart $\omega_{mean} \sim 18\%$

layer 1 (tension) $\omega_{mean} = 22,4\%$

97 × 192

Moisture distribution, ω (%), over the cross section of GLT after 146 days of storage with a climate of T = 20°C, φ = 95% (mean values from kiln - drying tests acc to / / of 12 girders)



*) in the tension boundary layer

Figure 13 : The modulus of elasticity in bending Em subject to the timber moisture ω with glued laminated timber (BSH M3) girders.

Tension in the direction of grain

$$\sigma_{t,o,d} \leq f_{t,o,d}$$

Meanings:

$\sigma_{t,o,d}$ design value of the stress

$f_{t,o,d}$ design value of the strength

$$f_{t,o,d} = \frac{f_{t,o,K} \cdot K_{mod,i}}{\gamma_M}, \quad i = 1 \text{ to } 4$$

where

$f_{t,o,K}$ characteristic value of the strength acc. to /5/, table A 2.1a

$K_{mod,i}$ modification factor acc. to /5/, table 3.1.3.

γ_M material factor acc. to /5/, table 2.3.3.2.

Tension perpendicular to the direction of grain

$$\sigma_{t,90,d} \leq K_{vol} \cdot K_{dis} \cdot f_{t,90,d}$$

Meanings:

K_{vol} factor taking into account the influence of the size of the stressed volume V on the strength, acc. to /5/, (5.1.3.b)

K_{dis} factor taking into account the influence of the stress distribution on the strength, acc. to /5/, (5.1.3.c)

Figure 14 : Calculation of individual components; tension

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