# Solid timber - Strength classes

STEP lecture A7
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## Objective

To describe the system of strength classes standardised in EN 338 which simplifies and improves both supply and use of structural timber.

## Prerequisite

A 6 Strength grading

## Summary

The lecture describes the advantages of a strength class system which aims at reducing the number of species/grade/source choices in order to simplify timber specification for the designer of timber structures and reduce restrictions on the supplier of structural timber, for example, reduce his need to stock a large range of species. It describes the strength classes established in EN 338 "Structural timber - Strength classes" and explains how grade/species combinations are assigned to these strength classes and how characteristic design values other than those included in EN 338 can be determined.

## Introduction

EC5 in common with the other Eurocodes provides no data on strength and stiffness properties for structural materials. It merely states the rules appropriate to the determination of these values to achieve compatibility with the safety format and the design rules of EC5.

The following requirements apply for structural timber:

- It shall be visually or machine strength graded.
- Visual grading shall be carried out according to standards which fulfil the minimum requirements of EN 518 "Structural timber - Grading - Requirements for visual strength grading standards".
- Machine strength grading must meet requirements given in EN 519 "Structural timber - Grading - Requirements for machine strength graded timber and grading machines" (see STEP lecture A6).
- Characteristic values for strength, stiffness and density shall be determined according to EN 384 "Structural timber - Determination of characteristic values of mechanical properties and density".

Any timber, regardless of origin can therefore be used for timber structures designed according to EC5 rules provided it has been strength graded according to the rules of EN 518 or EN 519, the characteristic values for strength, stiffness and density having been determined according to EN 384 and this has been certified in an "attestation of conformity". However, as yet, there are no directives as to the procedure.

In individual cases this procedure of assigning characteristic values to separate grades will always be possible. However, it may be impractical and confusing where many timbers of different qualities, different sources and graded to different rules, are available. This is usually the case with structural timber. In a typical timber importing country such as the UK over 100 different species/ source/grade combinations are offered (Fewell, 1991). There will be a growing tendency towards a more varied timber supply in all EU and EFTA countries due in particular to the fact that about half the sawn timber used in these countries is being imported. Furthermore it is to be expected that timber presently used in single grades only will be assigned to a larger number of grades due to growing market demands and the use of improved grading methods.

Greater competition in the supply of timber will reduce costs. However the increasing numbers of grades and characteristic values will cause confusion and limited specifications may lead to problems in supply.

To avoid these problems it was decided to introduce a strength class system as a result of the success of similar systems in the UK and Australia.

A strength class system comprises a limited number of classes each with its own set of strength properties, to which species/grade combinations of similar strength are allocated. This makes the entire process of timber specification much more simple.

In principle, a strength class system may create economic losses for grades which have just failed to meet the specifications of one class and have to be allocated to the next lower one. This problem, however, only occurs in visual grading, whereas in machine grading, timber can be directly graded to a strength class by appropriate machine setting. Economic losses for visual grades may be minimized by adjusting strength class boundaries to the characteristic values of the most economically important grades.

The introduction of strength classes is advantageous both to the timber user and the timber supplier. The designer does not need to acquaint himself with a multitude of different grades and related characteristic values, no matter in which European country his project will be built. Instead, he can simply choose the strength class suitable for his project from a concise table, similar to those used for other structural materials. The timber producer has the advantage that he can achieve higher prices for his timber since the better the grading process applied, the higher the strength classes to which his timber is allocated. Grading machines can be used to grade the timber directly into strength classes and also into classes which could not be achieved by visual grading. The timber supplier has the advantage that he can select the most economic source for a specific grade.

## The EN 338 strength class system

The strength class system established in EN 338 "Structural timber - Strength classes" is shown in Tables 1 and 2. It consists of 9 classes for coniferous species and poplar (Table 1) and 6 classes for deciduous species (Table 2). It ranges from the weakest grade of softwood, C14, to the highest grade of hardwood, D 70, currently used in Europe.

EN 338 gives characteristic strength and stiffness properties and density values for each strength class and provides rules for the allocation of timber, i.e. combinations of species/source/strength grade, to the classes.

| | C14 | C16 | C18 | C22 | C24 | C27 | C30 | C35 | C40 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | in $N/mm^2$ | | | | |
| $f_{m,k}$ | 14 | 16 | 18 | 22 | 24 | 27 | 30 | 35 | 40 |
| $f_{t,0,k}$ | 8 | 10 | 11 | 13 | 14 | 16 | 18 | 21 | 24 |
| $f_{t,90,k}$ | 0,3 | 0,3 | 0,3 | 0,3 | 0,4 | 0,4 | 0,4 | 0,4 | 0,4 |
| $f_{c,0,k}$ | 16 | 17 | 18 | 20 | 21 | 22 | 23 | 25 | 26 |
| $f_{c,90,k}$ | 4,3 | 4,6 | 4,8 | 5,1 | 5,3 | 5,6 | 5,7 | 6,0 | 6,3 |
| $f_{v,k}$ | 1,7 | 1,8 | 2,0 | 2,4 | 2,5 | 2,8 | 3,0 | 3,4 | 3,8 |
| | | | | | in $kN/mm^2$ | | | | |
| $E_{0,mean}$ | 7 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 |
| $E_{0,05}$ | 4,7 | 5,4 | 6,0 | 6,7 | 7,4 | 8,0 | 8,0 | 8,7 | 9,4 |
| $E_{90,mean}$ | 0,23 | 0,27 | 0,30 | 0,33 | 0,37 | 0,40 | 0,40 | 0,43 | 0,47 |
| $G_{mean}$ | 0,44 | 0,50 | 0,56 | 0,63 | 0,69 | 0,75 | 0,75 | 0,81 | 0,88 |
| | | | | | in $kg/m^3$ | | | | |
| $\rho_k$ | 290 | 310 | 320 | 340 | 350 | 370 | 380 | 400 | 420 |

*Table 1* *Strength classes and characteristic values according to EN 338. Coniferous species and Poplar.*

| | D30 | D35 | D40 | D50 | D60 | D70 |
|---|---|---|---|---|---|---|
| | | | in $N/mm^2$ | | | |
| $f_{m,k}$ | 30 | 35 | 40 | 50 | 60 | 70 |
| $f_{t,0,k}$ | 18 | 21 | 24 | 30 | 36 | 42 |
| $f_{t,90,k}$ | 0,6 | 0,6 | 0,6 | 0,6 | 0,7 | 0,9 |
| $f_{c,0,k}$ | 23 | 25 | 26 | 29 | 32 | 34 |
| $f_{c,90,k}$ | 8,0 | 8,4 | 8,8 | 9,7 | 10,5 | 13,5 |
| $f_{v,k}$ | 3,0 | 3,4 | 3,8 | 4,6 | 5,3 | 6,0 |
| | | | in $kN/mm^2$ | | | |
| $E_{0,mean}$ | 10 | 10 | 11 | 14 | 17 | 20 |
| $E_{0,05}$ | 8,0 | 8,7 | 9,4 | 11,8 | 14,3 | 16,8 |
| $E_{90,mean}$ | 0,64 | 0,69 | 0,75 | 0,93 | 1,13 | 1,33 |
| $G_{mean}$ | 0,60 | 0,65 | 0,70 | 0,88 | 1,06 | 1,25 |
| | | | in $kg/m^3$ | | | |
| $\rho_k$ | 530 | 560 | 590 | 650 | 700 | 900 |

*Table 2* *Strength classes and characteristic values according to EN 338. Deciduous species.*

The establishment of strength classes and related strength and stiffness profiles is possible because, independently, nearly all softwoods and hardwoods commercially available exhibit a similar relationship between strength and stiffness properties.

Experimental data shows that all important characteristic strength and stiffness properties can be calculated from either bending strength, modulus of elasticity (E) or density (see Figures 1 to 3). However, further research is required to establish the effect of timber quality on these relationships and to decide whether accuracy could be improved by modifying these relationships for different strength classes.

Deciduous species have a different anatomical structure from coniferous species. They generally have higher densities but not correspondingly higher strength and stiffness properties. This is why EN 338 provides separate strength classes for coniferous and deciduous species. Poplar, increasingly used for structural purposes, shows a density/strength relationship closer to that of coniferous species and was therefore assigned to coniferous strength classes.

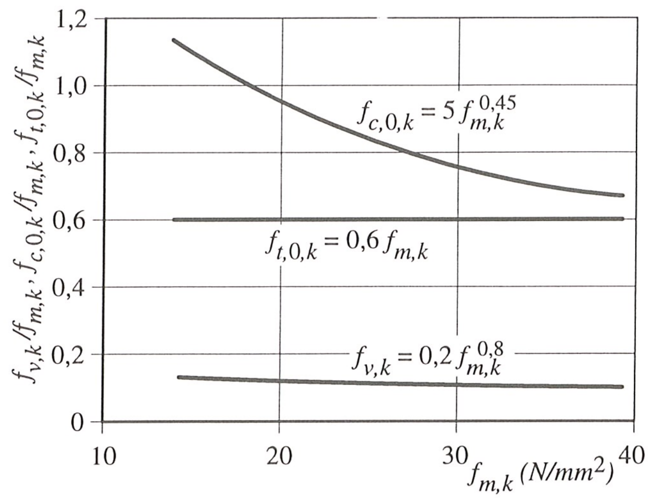


*Figure 1* *Relationship between tension, compression and shear strength and bending strength.*

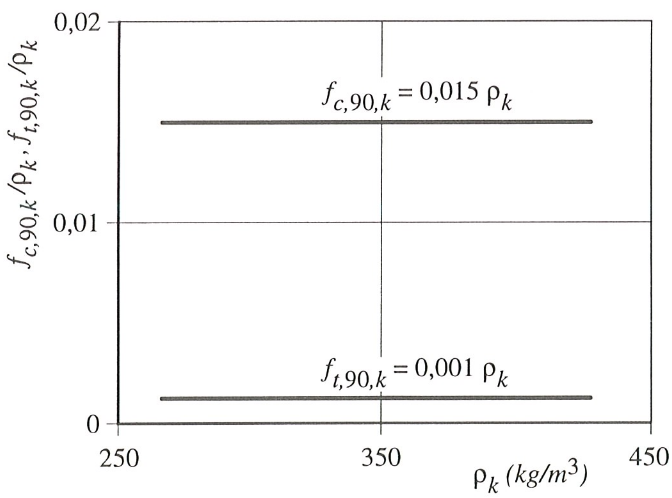


*Figure 2* *Relationship between compression perpendicular and tension perpendicular strength and density.*

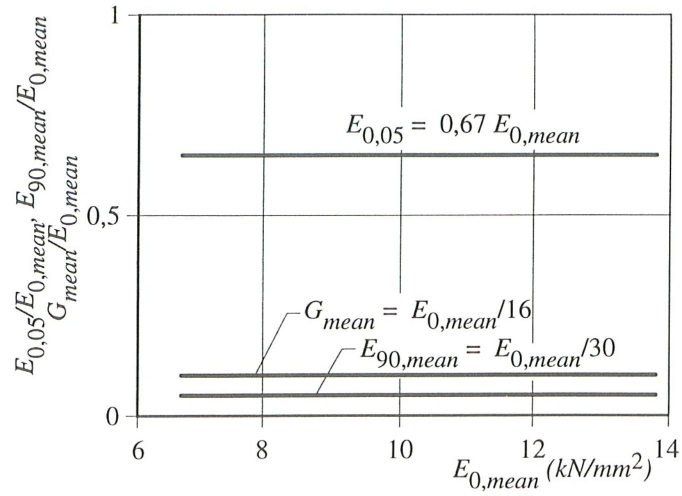


*Figure 3* *Relationship between lower 5-percentile modulus of elasticity parallel, modulus of elasticity perpendicular and shear modulus and modulus of elasticity parallel.*

Due to the relationships between strength, stiffness and density shown in Figures 1 to 3 a species/source/grade combination can be assigned to a specific strength class based on the characteristic values of bending strength, modulus of elasticity and density.

According to EN 338 a timber population can thus be assigned to a strength class provided

- the timber has been visually or machine strength graded according to the specifications of EN 518 or EN 519.
- the characteristic strength, stiffness and density values have been determined according to EN 384 "Determination of characteristic values of mechanical properties and density".
- the characteristic values of bending strength, modulus of elasticity and density of the population are equal to or greater than the corresponding values of the related strength class.

The European Standard CEN/TC 124.215 "Structural timber - Strength classes - Assignment of visual grades and species" lists visual strength grades and species of timber, and specifies the strength classes from EN 338 to which they are assigned.

The grades and species included are those which have been used for a long time and/or for which satisfactory test data exist (see Table 3).

Timber graded by machine to EN 519 may be graded directly into the strength classes and marked accordingly and is therefore not referenced in this Standard.

| Strength Class | Grading rule publishing country (Grading standard) | Grade | Species<br>Commercial name | Source |
|---|---|---|---|---|
| C24 | Austria (ÖNORM B 4100-2) | G.BH | Spruce, Pine, Fir, Larch | CNE Europe |
| | France (NFB 52001-4) | CF22 | Whitewood, Douglas fir | France |
| | Germany (DIN 4074-1) | S10 | Spruce, Pine, Fir, Larch | CNE Europe |
| | Nordic Countries (INSTA 142) | T2 | Redwood, Whitewood | NNE Europe |
| | The Netherlands (NEN 5466) | B | Spruce + fir | NC Europe |
| | UK (BS 4978) | SS | Redwood, Whitewood | CNE Europe |
| | | SS | Douglas fir, Larch, Hem-fir, S-P-F | USA + Canada |
| | | SS | Southern pine | USA |
| | | SS | Parana pine | Brazil |
| | | SS | Pitch pine | Caribbean |
| | USA + Canada (NGRDL+ NLGA) | J + P Sel | Douglas fir, Larch, Hem-fir, S-P-F | USA + Canada |

*Table 3* *Strength class C 24, assignment of visual grades and species according to CEN/TC 124.215.*
*CNE Europe: Central, North & Eastern Europe*
*NNE Europe: Northern & North eastern Europe*
*NC Europe: Northern and Central Europe.*

For combinations of species and visual grades which meet the requirements of EN 518 but are not listed in this standard, the assignment to strength classes can be made according to EN 338 using characteristic values determined in accordance with EN 384.

## Determination of characteristic values

A characteristic strength value is defined in EC5 as a population lower 5-percentile value which must be evaluated experimentally. The results depend, inter alia, on the following (see also Figure 4):

- The definition of the population including the difficulty encountered when linking one sub-population (the sample) to other sub-populations (the timber likely to be obtained from one source and used in one structure),
- the sampling plan. Due to its limited size no sample represents its population exactly, and the smaller the sample, the less accurate the model,
- the testing methods including systematic differences between different test standards,
- the data analysis including the statistical models used,
- the adjustment to standard reference conditions, such as moisture content, member size, test configuration.

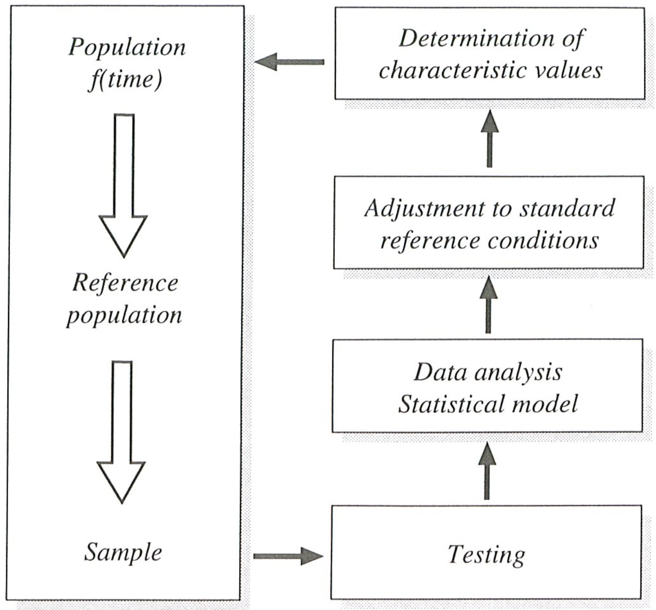


*Figure 4 Determination of characteristic strength values. Potential influencing factors.*

EN 384 specifies the methods that must be used when determining characteristic values in order to ensure comparability when assigning different combinations of grades and species to strength classes. Important points are:

- The population shall be defined in terms of species, source and manufacturing process. The population definition shall also include the stress grade, except where the information on the total range of strength is required to determine relations between the mechanical properties used in deriving settings for grading machines.

- Samples shall be selected from the population. Any known or suspected differences in the mechanical properties of the population distribution due to growth regions, sawmills, tree size, method of conversion etc. must be represented within the number of samples selected, by a similar proportion to their frequency in the reference population. This requirement shall be the major influence in determining the number and size of samples.

- Testing shall be carried out in accordance with EN 408 "Timber structures - Structural timber and glued laminated timber - Determination of some physical and mechanical properties".

- Sample lower 5-percentiles are determined for strength properties by ranking, and for density from a normal distribution.

- Characteristic values are determined as the weighted means of the sample lower 5-percentiles for strength properties and density, and as the weighted mean of the sample means for modulus of elasticity.

- The characteristic strength values are adjusted for small and/or few samples and for extreme between-sample variability. Few samples and a small sample size are taken into account by a reduction factor $k_s$ (see Figure 5). To cover between-sample variability the characteristic value must not be greater than 1,2 times the lower 5-percentile value of the lowest sample ($f_{05} \leq 1{,}2 \min f_{05}$).

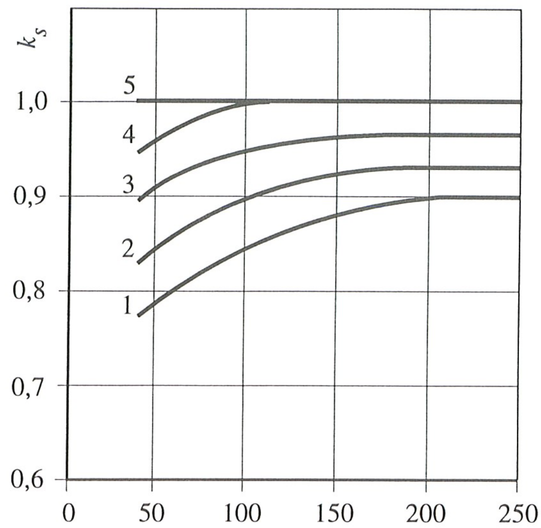


*Figure 5* *The effects of the number of samples (1...5) and the number of pieces in smallest sample (40...250) on the factor $k_s$.*

- The reference conditions are as set out in EC5, for example 20C/65% r.h. for all properties, and 150 *mm* depth/width for bending/tension properties respectively.

## Concluding summary

- The European Common Market will lead to a more varied timber supply in most EU and EFTA countries, with a correspondingly larger number of grades and characteristic values. To keep the specification process of timber simple and to avoid confusion, a strength class system is being introduced, to which species/ grade combinations of similar strength and stiffness may be allocated.

- A strength class system has been established in EN 338. It consists of 9 classes for coniferous species and poplar and 6 classes for deciduous species. It provides characteristic strength and stiffness properties and density values for each strength class and gives rules for the allocation of timber to these classes.

- Characteristic values of individual species/grade combinations shall be determined according to specific rules, defined in EN 384.

## References

Fewell, A.R., Glos, P. (1988). The determination of characteristic strength values for stress grades of structural timber. Part 1. In: Proc. of the CIB W18 Meeting, Parksville, Canada, Paper 21-6-2.

Fewell, A.R. (1991). CEN Standard for strength classes and the determination of characteristic values. In: Proc. of the 1991 Int. Timber Eng. Conf., London, UK, 1.122-1.128.