BS EN 14081-2:2018



BSI Standards Publication

Timber structures – Strength graded structural timber with rectangular cross section

Part 2: Machine grading; additional requirements for type testing

bsi.

National foreword

This British Standard is the UK implementation of EN 14081-2:2018. It supersedes BS EN 14081-2:2010+A1:2012, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/518, Structural timber.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2018
Published by BSI Standards Limited 2018

ISBN 978 0 580 93551 0

ICS 79.040

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2018.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14081-2

October 2018

ICS 79.040

Supersedes EN 14081-2:2010+A1:2012

English Version

Timber structures - Strength graded structural timber with rectangular cross section - Part 2: Machine grading; additional requirements for type testing

Structures en bois - Bois de structure à section rectangulaire classé pour sa résistance - Partie 2 : Classement mécanique par machine; exigences supplémentaires concernant les essais de type

Holzbauwerke - Nach Festigkeit sortiertes Bauholz für tragende Zwecke mit rechteckigem Querschnitt - Teil 2: Maschinelle Sortierung; zusätzliche Anforderungen an die Erstprüfung

This European Standard was approved by CEN on 13 August 2018.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

© 2018 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No. EN 14081-2:2018 E

Contents

Page

European foreword ... **4**

Introduction ... **5**

1 Scope ... **6**

2 Normative references ... **6**

3 Terms and definitions ... **6**

4 Symbols and abbreviations ... **8**

5 Requirements for strength grading machines ... **9**

6 Derivation of settings for machine control systems ... **10**
6.1 Requirements on sampling ... **10**
6.2 Requirements for grading process, destructive testing and calculation of grade determining properties ... **11**
6.2.1 Grading process ... **11**
6.2.2 Destructive testing ... **11**
6.2.3 Calculations of grade determining properties ... **11**
6.3 Requirements for a setting area ... **12**
6.3.1 General ... **12**
6.3.2 Standardized areas ... **12**
6.4 Requirements for the derivation and verification of machine settings ... **12**
6.4.1 Derivation of machine settings ... **12**
6.4.2 Verification of machine settings ... **13**
6.5 Fixed settings ... **15**
6.6 Reporting ... **15**

7 Additional verification requirements for a new grading machine or a change in scope of existing grading machines for machine control systems ... **17**
7.1 Repeatability ... **17**
7.2 Machine installation check ... **17**

8 Derivation of settings for output control systems ... **18**
8.1 General ... **18**
8.2 Initial machine settings ... **18**
8.3 Verification of machine settings ... **18**
8.3.1 Sampling ... **18**
8.3.2 Destructive testing and calculation of characteristic values ... **18**
8.3.3 Requirements for verification of machine settings ... **18**
8.4 Report ... **18**

9 Requirements for adaptive settings ... **19**
9.1 Method ... **19**
9.2 Conditions ... **20**

Annex A (informative) **Guidelines for sampling a growth area for deriving machine settings** ... **21**

Annex B (informative) **Prediction limit method** ... **23**

B.1 General ... **23**

B.2 Model determination ... **23**

B.3 Settings calculation **24**
Annex C (normative) **Determination of the global cost matrix** **25**
C.1 Introduction **25**
C.2 Optimum grading **25**
C.3 IP grading **25**
C.4 Calculation of size matrix **26**
C.5 Calculation of elementary cost matrix **26**
C.5.1 Introduction **26**
C.5.2 Factors for wrongly upgraded pieces **26**
C.5.3 Factors for wrongly downgraded pieces **27**
C.5.4 Examples of elementary cost matrices for C, T and D classes **27**
C.6 Calculation of a global cost matrix **30**
Annex D (informative) **Settings for C and T-classes** **31**
Bibliography **38**

European foreword

This document (EN 14081-2:2018) has been prepared by Technical Committee CEN/TC 124 "Timber structures", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2019, and conflicting national standards shall be withdrawn at the latest by April 2019.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document will supersede EN 14081-2:2010+A1:2012.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

Compared to EN 14081-2:2010+A1:2012, the following main modifications have been made:

— new definitions added in Clause 3;

— new requirements for sampling, settings areas and minimum cross-section area;

— introduction of standardized areas;

— method for deriving settings is no longer normative, since several methods may be used; an example of a method is given in Annex B;

— new method for verification of settings;

— cost matrix requirements are changed, to better allow settings that aim for reduced reject rather than yield in the highest grade;

— new method for output control systems;

— introduction of adaptive settings;

— introduction of fixed settings.

This standard is part of a series of standards on *Timber structures — Strength graded structural timber with rectangular cross section* ("EN 14081") that includes:

— *Part 1: General requirements;*

— *Part 2: Machine grading; additional requirements for type testing;*

— *Part 3: Machine grading; additional requirements for factory production control.*

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Machine grading is in common use in a number of countries. There are two basic systems, referred to as "output control" and "machine control". Both systems require a visual override inspection to cater for performance reducing characteristics that are not automatically sensed by the machine.

The output control system is suitable for use where the grading machines are situated in sawmills grading limited sizes, species and grades in repeated production runs of around one working shift or more. This enables the system to be controlled by testing timber specimens from the daily output. These tests together with statistical procedures are used to monitor and adjust the machine settings to maintain the required strength properties for each strength class. With this system it is permissible for machine approval requirements to be less demanding and for machines of the same type to have non-identical performance.

The machine control system was developed in Europe. Because of the large number of sizes, species and grades used it was not possible to carry out quality-control tests on timber specimens drawn from production. The system relies therefore on the machines being strictly assessed and controlled, and on considerable research effort to derive the machines settings, which, under basic machine control operation, remain constant for all machines of the same type.

Additional factory production control requirements are given in EN 14081-3.

This standard provides a new approach, applicable to both machine control and output control systems, which permits fine adjustment of settings on a grading machine based on continuous monitoring of Indicating Property (IP) data during grading. This approach is called "adaptive settings".

The acceptability of grading machines and the derivation of settings rely on statistical procedures and the results will therefore depend on the method used. For this reason this document gives appropriate statistical procedures.

Grading assignments to strength classes are based on grading reports. When these grading reports are evaluated and approved by CEN/TC 124 /WG 2 /TG 1, they become Approved Grading Reports (AGR).

The requirements in this European Standard are based on machines in current use and on future types of machines as far as these can be foreseen. It is recognized that additional clauses or standards may be required if unforeseen developments take place.

Since the previous version of this European Standard (EN 14081-2:2010+A1:2012), grading settings work, and research data, have provided more information about the variation in wood properties. Several new rules were created by CEN/TC 124 /WG 2 to update the procedures and ensure safety of grading – particularly of settings covering many countries, and are referenced in the guidance paper (see Annex A). This new version of the standard updates the procedures according to the guidance paper.

1 Scope

This document specifies requirements, additional to those of EN 14081-1, for type testing of machine graded structural timber with rectangular cross-sections shaped by sawing, planning or other methods, and having deviations from the target sizes corresponding to EN 336. This includes requirements for strength grading machines.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 384, *Structural timber — Determination of characteristic values of mechanical properties and density*

EN 408, *Timber structures — Structural timber and glued laminated timber — Determination of some physical and mechanical properties*

EN 14358, *Timber structures — Calculation and verification of characteristic values*

EN 13556, *Round and sawn timber — Nomenclature of timbers used in Europe*

EN ISO 3166-1, *Codes for the representation of names of countries and their subdivisions — Part 1: Country codes*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
assigned grade
grade to which a piece of timber is assigned when using the appropriate setting for that specific grade

3.2
characteristic value
representative value of a material property used for design, which is based either on 5-percentile values (e.g. strength properties and density) or on a mean value (e.g. modulus of elasticity)

3.3
critical feed speed
speed, within the intended usable range, at which the grading machine is least accurate in measuring its indicating property

3.4
depth
in the case of bending, the cross sectional dimension parallel to the direction of loading, and in the case of tension, the width

3.5
grade combination
set of one or more grades plus reject graded together

3.6
grade determining property (GDP)
mechanical or physical property, for which a particular value of that property is required for the material to be assigned to that grade

Note 1 to entry: E.g. bending strength, mean MOE and density for the C and D strength classes of EN 338.

3.7
growth area
source from which timber is intended to be strength graded

3.8
indicating property (IP)
measurement or combination of measurements made by the grading machine, used in estimating one or more of the grade determining properties, and upon which the settings are based

3.9
optimum grade
grade to which a piece of timber is assigned, such that the highest possible yield is obtained in the highest grade when using the GDPs as the indicating properties

3.10
p-percentile
value for which the probability of getting lower values is p %

3.11
sample
number of ungraded specimens of one timber species or species combination, one timber source, with sizes and quality representative of the timber population (of the species/species combination from the timber source)

3.12
setting (S)
value of the parameters used to set the machine to grade timber, which are mathematically related to the indicating property

3.13
setting area
combination of countries and / or standardized areas for which the same settings are valid

Note 1 to entry: a setting area is usually part of a test area.

3.14
standardized area
countries that can be combined to one setting area without further justification

3.15
test area
combination of countries and / or standardized areas from which timber is to be tested to obtain a setting area

Note 1 to entry: test area is part of a growth area.

3.16
thickness
lesser dimension perpendicular to the longitudinal axis of a piece of timber

3.17
timber source
identifiable geographical origin of a species or species combination from which timber is, or is intended to be, strength graded

3.18
width
larger dimension perpendicular to the longitudinal axis of a piece of timber

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

a_{DENS}	slope in the DENS formula
a_{MOE}	slope in the MOE formula
a_{MOR}	slope in the MOR formula
b	thickness for edgewise bending and width for flatwise bending
b_{DENS}	intercept in the DENS formula
b_{MOE}	intercept in the MOE formula
b_{MOR}	intercept in the MOR formula
c	load configuration constant
$DENS$	density
$DENS_{req}$	required density
E	modulus of elasticity parallel to grain
$E_{optimum}$	optimum modulus of elasticity
$E_{assigned}$	assigned modulus of elasticity
f_0	measured first-mode longitudinal resonant frequency
f	strength
$f_{k,assigned}$	assigned characteristic strength
$f_{assigned}$	assigned strength
$f_{k,optimum}$	optimum characteristic strength
$f_{optimum}$	optimum strength
F	force
h	depth

IP	indicating property
$IP_{mean,ref,grade}$	mean value of IP of the reference sample
$IP_{mean,prod,grade}$	running value of IP
l	span
MOE	modulus of elasticity parallel to the grain
MOE_{req}	required MOE
MOR	bending strength
MOR_{req}	required MOR
r	correlation coefficient between *IP* and grade determining property in the whole ungraded data set which is used for determination of initial settings
S_{adapt}	adaptive setting
$s_{\delta,DENS}$	standard error of density estimates
S_{DENS}	setting for DENS
S_{ini}	initial setting
S_{MOE}	setting for MOE
$s_{\delta,MOR}$	standard error of MOR estimates
s_{δ}	standard error of the estimate
S_{MOR}	setting for MOR
t	a factor from Student's t-distribution
u	timber moisture content
β_{ach}	achieved safety index
β_{tar}	target safety index
δ	generic deformation
μ	mean value
ρ	timber density

5 Requirements for strength grading machines

The machine shall be of a type that meets the requirements given in Clauses 6 and 7 if it is part of a machine control system, or Clause 8 if it is a part of an output control system. It shall be installed and set up according to the manufacturer's specification and to any additional requirements resulting from the tests given here. The following information shall be provided in the manufacturer's specification for the machine:

a) specification and description of the mechanical and electrical operation of the machine, and the software used by the machine to grade timber (this includes information on data processing such as smoothing of the output signals);

b) range of environmental conditions under which the machine will operate;

c) installation, maintenance and operating instructions;

d) method, extent and frequency of calibration procedures, including the use of control planks if applicable;

e) species populations, sizes and tolerances, surface finish, moisture content, grades, environmental operating temperature range, throughput speed, and limits of warp of the timber to be graded;

f) checking and adjustment procedures for all components that may affect the machine's grading accuracy.

Operational accuracy of transducers shall ensure that production machines meet the requirements of this European Standard, and are compatible with grade settings derived for the machine type.

The grading machine shall not damage the timber during the grading operation to an extent that it affects the intended use of the timber. For example, in bending type machines, damage should not be caused by large compression perpendicular to grain stresses and/or large bending stresses.

NOTE When approving a new machine, consideration of already approved machines having the same technology can contribute to the approval procedure, including settings derivation.

Grading machines whose indicating property does not take account of the material properties along the whole length of each piece of timber, but whose indicating property measurements are influenced by strength reducing characteristics away from the measuring position (as in bending type machines), shall measure the indicating property to within 800 mm of each end of the piece of timber. Where the indicating property is influenced only by strength reducing characteristics at the measuring position (as in radiation type machines), the measurements shall be made to within 150 mm of each end.

When a new species is required to be graded by a machine that has already been shown to meet the requirements of this European Standard, those requirements given in this clause that are not likely to be affected by species differences may be disregarded for the new species.

Machine settings that were derived in accordance with previous versions of this standard remain valid unless there is evidence that the required grade determining properties are not met. In that case, new settings shall be derived according to this version of the standard.

6 Derivation of settings for machine control systems

6.1 Requirements on sampling

Sampling shall be representative of the timber to be graded. The timber shall represent the timber source, species, range of sizes and quality to be graded in production with the most demanding surface finish for the performance of the grading machine.

NOTE 1 Annex A gives guidance on sampling.

For each species or species combination, the minimum number of specimens required for deriving or expanding settings shall be taken from Table 1:

Table 1 — Minimum number of specimens required for deriving or expanding settings

	Specimens	Total number of samples	Specimens per sample
Total settings area (see 6.4.2.2)	≥ 450	≥ 4	≥ 100
Expansion check: for each additional country or standardized area (see 6.4.2.3)	≥ 150	≥ 1	≥ 100

NOTE 2 Usually it is necessary to increase the total number of specimens to take into account the variability of the timber source, the performance of the machine, and the range of sizes and grades to be produced.

The minimum size of a setting area defined in this standard is normally a country or standardized area. Parts of countries or standardized areas may also be considered if they are clearly geographically defined.

Sampling for a setting area that includes more than one country shall contain at least one sample from each country, unless information exists which verifies that timber from one country can be safely graded using settings from another country without being included in the sampling.

The range of permitted thickness and width for which settings shall be used in production shall not be extrapolated more than 10 % from the maximum and minimum thickness and widths tested. This requirement should be considered when carrying out the sampling.

The minimum cross section area for which settings shall be used in production shall not be extrapolated more than 10 % from the minimum cross section area tested. This requirement should be considered when carrying out the sampling.

A minimum of 40 pieces shall be included in the sampling on all ends of the cross section thickness and width. This means that at least 40 pieces shall be in the range of 10 % of the upper tested timber thickness and width and at least 40 pieces shall be in the range of 10 % of the lower tested timber thickness and width.

A minimum of 40 pieces shall be included in the sampling for the smallest cross section area.

6.2 Requirements for grading process, destructive testing and calculation of grade determining properties

6.2.1 Grading process

Each piece shall be graded by the machine at the critical feed speed while documenting the moisture content, all variables necessary for calculating the IP, and any other variables that may affect the IP.

6.2.2 Destructive testing

Each piece shall be tested to determine the grade determining properties in accordance with EN 384 and EN 408. The characteristic values shall be calculated based on EN 384 and rounded to three significant digits.

In the case of a portable machine, the k_V factor (given in EN 384) shall be taken as 1.

6.2.3 Calculations of grade determining properties

One or more models (e.g. mathematical, statistical) relating the machine's measured parameters to one or more indicating properties to the grade determining properties shall be developed. Models may include variables such as size and moisture content, or may be determined from the data after adjusting the properties for such variables.

Where the machine measures the moisture content of each piece, moisture content may be used to adjust the settings model.

The moisture range for which the grade determining properties apply shall be defined.

The effect of moisture content on the IP values when deriving settings shall be accounted for e.g. by correction of the IP values to u = 12 % according to EN 384.

6.3 Requirements for a setting area

6.3.1 General

A setting area shall be established as follows:

a) a test program shall be performed with samples from countries and/or standardized areas (see 6.3.2) which constitute the test area;

b) based on the data of this specific test area, settings shall be derived (see 6.4);

c) the setting area may be expanded to a country or standardized area when all pieces from that country or standardized area are graded with the derived settings and all characteristic values according to EN 384 of the GDP of the grades meet the requirements of the strength classes in the strength class combination. (see 6.4.2.3).

6.3.2 Standardized areas

The standardized areas given in Table 2 may be used for forming a test area and/or deriving settings. For a standardized area, a representative sample from one country can be considered representative for the other countries in the same standardized area.

These standardized areas are valid for machines and grading principles without further verifications for all species growing there.

NOTE These standardized areas can be used for the development of setting areas to limit the number of samples from a country or standardized area.

Table 2 — Standardized areas

Standardized area	Countries belonging to the standardized area
Alp area	Liechtenstein [a], Slovenia, Switzerland, Austria
Balkan area	Montenegro [a], Macedonia, Albania, Bosnia-Herzegovina, Croatia, Serbia, Kosovo
Baltic area	Estonia, Latvia, Lithuania
Benelux area	Luxembourg, Belgium, Netherlands
Black Sea area	Moldova, Romania
French area	Andorra [a], France
[a] These countries alone cannot be considered representative for the standardized area.	

6.4 Requirements for the derivation and verification of machine settings

6.4.1 Derivation of machine settings

Settings shall be derived, rounded to not more than four significant digits, using an appropriate method to grade one or more grades in one pass so that the grade determining properties for each grade within each grade combination are met. The characteristic values shall be calculated according to EN 384. The minimum number of pieces shall be 20 in each grade within each grade combination. Additionally, for

each grade combination, settings shall be derived such that a minimum of 5 pieces or 0,5 % of the total data set, whichever is the higher, are assigned as reject.

NOTE Annex B provides a simple method, although other methods can provide much better yields.

6.4.2 Verification of machine settings

6.4.2.1 Introduction

The purpose of verification is to validate the settings by checking that the required characteristic values of the grade determining properties are met. Verification is carried out on verification samples, depending on the situation:

For new settings, the verification is performed on the whole sample, and again on verification samples that are drawn from the whole sample.

For expansion of existing settings to a larger setting area (an expansion check), the verification sample is the sample or samples from the additional country or standardized area being checked. For this check, each additional country or standardized area is verified separately.

For verifying that existing settings are grading timber that meets the required characteristic values, the verification sample is a set of new specimens covering a particular area. This verification applies to the area sampled and not the whole settings area.

Characteristic values shall be derived according to EN 384 and EN 14358, using specific rules cited in Table 3, depending on the property and the number of specimens. The characteristic values shall be rounded to three significant digits.

Verification of the derived characteristic values against the strength class values, after any adjustment from EN 384, shall be done according to Table 3, depending of the sub-clause cited in this table.

Table 3 — Requirement for derivation and verification of characteristic values

	Calculation		**Requirements (derived characteristic value / strength class value)**			
	Number of specimens	**Number of specimens**	**6.4.2.2**		**6.4.2.3**	**6.4.2.4**
	≥ 40	**< 40**	**Step 1**	**Step 2**		
Strength	Non parametric; no confidence interval adjustment	Parametric; with confidence interval adjustment	≥ 100%	≥ 90%	≥ 100%	≥ 90%
MOE	Simple mean		≥ 100%	≥ 95%	≥ 100%	≥ 95%
Density	Non parametric; no confidence interval adjustment	Parametric; with confidence interval adjustment	≥ 100%	≥ 90%	≥ 100%	≥ 90%

6.4.2.2 Verification for new settings

When calculating new settings, the settings shall be verified for each grade within all desired grade combinations, on the whole setting area, by the following procedure.

Step 1: verification of the whole sample

To verify a particular grade in a particular grade combination, the rules cited in Table 3 shall apply.

There shall be at least 20 specimens for this calculation.

Step 2: verification for countries, standardized areas and parts of countries

The whole sample shall be divided into at least 4 verification samples. For each country or standardized area there shall be at least one verification sample made only with the specimens from that country or standardized area. Countries or standardized areas may be divided into more than one verification sample on the basis of sampling location, and this is most appropriate for large countries, and countries where there are large differences that may affect grading (e.g. growth conditions and forest practices). Where timber is sampled across a national border, the sample shall be apportioned to a country or standardized area with due consideration to geography and forest practice.

To verify a particular grade in a particular grade combination, the rules given in Table 3 shall apply.

This procedure may also be used for an additional verification of settings on non-geographical subsets of the whole sample, such as certain thickness and width range.

If any part of this verification fails (in steps 1 or 2), the settings are not verified. The verification may be performed again after adjusting the settings and/or grade combinations; or restricting settings to a smaller setting area or a smaller range of width and thickness; or after additional sampling.

Step 3: Global cost matrix

In order to assess the performance of the machine, a global cost matrix shall be calculated according to Annex C for each grade combination.

In order to approve a grade combination, none of the cell values of the global cost matrix indicating wrongly upgraded pieces shall be greater than 0,40.

If any cell value is higher than 0,40 for a grade combination, alternative solutions such as increasing the sample size or improving the IP prediction may be investigated. If no solution passes, the grade combination is not verified.

6.4.2.3 Verification of expansion of existing settings to a larger setting area (expansion check)

When expanding existing settings to new areas, the settings shall be verified for each grade within all grade combinations by the following procedure. This shall be done on the new parts of the setting area and each country or standardized area shall be verified separately.

The sampling for the country or standardized area shall comply with the requirements of 6.1. The range of thickness and width in this sampling shall comply with the requirements of 6.1 for meeting the permitted thickness and width range of the settings being checked.

To verify a particular grade in a particular grade combination, the rules given in Table 3 shall apply.

There shall be at least 20 specimens for this calculation.

For countries/standardized areas with large variation in timber quality, additional verification checks on samples smaller than the country/standardized area may be made according to 6.4.2.3.

If a country or standardized area passes this verification check, the grade combinations for which there is a pass may be expanded to this country or standardized area.

6.4.2.4 Checking that existing settings are grading correctly in a particular location

When checking that existing settings are grading timber that meets the required characteristic values, the settings shall be verified for grades within grade combinations that are desired to be checked, by the following procedure.

A number of specimens are graded under production conditions, and tested in accordance with 6.2.2.

To verify a particular grade in a particular grade combination, the rules given in Table 3 shall apply.

At least 40 specimens are required for this calculation.

This procedure verifies that existing settings are grading correctly for the location and cross-section sizes sampled. It does not verify the settings for the whole settings area. The settings for a whole settings area can be verified by the procedure in 6.4.2.2 using sampling that meets the requirements for new settings.

6.5 Fixed settings

Unless there is evidence of unsafe grading, settings given in Annex D can be used for Norway spruce (*Picea abies*) and Silver fir (*Abies alba*) grown in Europe without further justification. Settings are given for the grade combinations C24/C18 and T14/T11 as well as for the respective single grades. Settings are given for IPs which are calculated based on Formula (1):

$$IP = \frac{\left(2 f_0 l\right)^2 \rho}{1 - 0{,}01\left(u - 12\right)} 10^{-6} \qquad (1)$$

where

f_0 is measured frequency (first mode of longitudinal vibration), in Hz;

l is measured length of timber, in m;

u is timber moisture content, in %;

ρ is timber density, in kg/m^3.

When density is measured by the machine, settings given in column "IP based on frequency and density" shall be used.

When density is not measured, the value 450 kg/m^3 shall be used for density in Formula (1), and the settings in column "IP based on frequency" shall be used.

6.6 Reporting

The following is a list of information that shall be included in a report on the derivation of grading machine settings:

a) general:

1) details of the grading machine, the timber species and setting area and the grades to be graded;

2) a note of any strength reducing characteristics that are not detected by the grading machine nor by the visual override inspection;

3) details of the sampling method (see 6.1) and explanation of its representativeness with regard to the growth area;

4) details of the testing, which shall be carried out to EN 408 as required by EN 384, including any adjustment for test span. For MOE, the clause number in EN 408 shall be given in the report and details of conversion to shear free MOE should be given, including reference to any supporting documents;

5) range of timber sizes to be graded in production (see 6.1 above);

6) if the settings are for a machine that has not previously been approved for grading in Europe according to this standard:

i) information of this method of operation according to requirements of Clause 5;

ii) the description of how the IPs are calculated and how parameters of grading influence them;

iii) repeatability check according to 7.1 which shall include a graph of all indicating property values for each pass (see 7.1) of each piece plotted against the median value of indicating property for each piece;

7) the report should reference all previous reports that are still relevant (including repeatability);

8) table showing the different cross sections and lengths, number of specimens, countries and the moisture content for each sample;

9) table with means and coefficients of variation of the grade determining properties for all samples and the total data set;

10) the critical feed speed used during grading of the total sample (see 6.2.1);

11) the formula for the mathematical model involving the indicating property, grade determining properties and the settings;

12) a table giving the settings;

13) the following scatter plots for the total data set, with each sample in a clearly distinguishable manner, together with coefficients of determination for each sample referenced to the relevant IP model(s) to be used in production;

i) MOR versus IP;

ii) MOE versus IP;

iii) density versus IP;

14) details on moisture content both at time of testing and time of grading;

b) for each strength class or strength class combination each report shall include:

1) table giving the required characteristic values and the achieved values using the settings developed for the grades;

2) table giving all settings;

3) the characteristic values for the assigned grades;

4) for machine where the option of adaptive settings exist, the mean IP values;

c) a summary table for inclusion in the approved grading report (AGR) containing:

1) reference to the report containing the settings model;

2) country or countries comprising the settings area;

3) information required for identifying the country, or region of origin, at least the country code in accordance with EN ISO 3166-1;

4) species (including botanical name) in accordance with EN 13556;

5) permitted timber size (thickness, width and cross-section area);

6) settings for each grade or grade combination;

7) moisture content range (see part 6.2), timber temperature range;

8) comments and additional requirements (such as feed speed, timber surface, definition of user defined grades).

7 Additional verification requirements for a new grading machine or a change in scope of existing grading machines for machine control systems

7.1 Repeatability

Repeatability of the machine shall be checked for each indicating property used by the machine.

This procedure shall be followed for any new machine. For an existing machine, it shall be repeated if there are substantial changes in the measurement technology or in the IP models. At least 100 pieces of timber shall be randomly selected. These pieces shall be passed through the machine five times at its critical feed speed, to obtain a grade determining indicating property value for each pass. This range of indicating property values shall then be divided into a number of fictitious grades equal to the number of grades to be graded in one pass in production plus one (to allow for the rejects) such that there are approximately the same number of pieces in each grade. These grades are called the assigned grades. The most frequent grade assigned by the machine for each piece over the five passes shall be designated its optimum grade, to determine a size matrix (as in C.4). The values for the elementary cost matrix shall equal the number of grades the assigned grade differs from the optimum grade, e.g. 0 if the assigned grade equals the optimum, 1 if the assigned grade is one away from the optimum, etc. (see Table 3).

No cell value in the global cost matrix rounded to two significant digits shall exceed 0,10 when calculated as the elementary cost value times the number in the equivalent cell of the size matrix divided by the sum of the pieces in all cells for the assigned grade. Where varying numbers of grades are to be graded in production, the above procedure shall be repeated for all such numbers of grades.

Only if the repeatability check is successful for a number of grades shall the machine be allowed to grade this number of grades together.

7.2 Machine installation check

This clause applies only to machines installed on a production line and not to portable machines.

This check shall be carried out to verify that the machine has been correctly installed and that, for example, the conveyors and measuring devices are correctly aligned, in accordance with the manufacturers' instructions.

After the initial installation of a grading machine for the production of strength graded timber, at least 40 pieces of timber, for which the same settings apply shall be selected, without bias, from the highest grade to be produced, ignoring pieces graded by visual overrides. These specimens shall be tested for the grade determining properties according to EN 384 and EN 408 and shall meet the requirements in EN 14358 for verification of a lot.

The required values are calculated considering the k_v factor (given in EN 384) for strength and the 95 % factor for modulus of elasticity according to EN 384.

NOTE Number of pieces of timber may need to be increased according EN 14358.

If machine installation check fails, then any influencing parameters on the machine performance shall be verified and corrected if necessary and the machine installation check repeated.

The machine installation check shall be also performed if the highest grade to be produced is increased, or if there is a significant change in the machine setup.

8 Derivation of settings for output control systems

8.1 General

Machine settings can be derived to minimize rejects or maximize yield in a particular grade.

Since both options lead to very different settings the procedure described in 8.3 and 8.4 shall be followed.

8.2 Initial machine settings

Initial machine settings for each grade or grade combination, species or species combination, size and timber source shall be based on best available information.

8.3 Verification of machine settings

8.3.1 Sampling

Timber shall be graded by the machine using the settings to be verified, and therefore this procedure shall be repeated for each set of settings to be used. The moisture content at grading shall be measured.

At least 40 specimens shall be randomly sampled for each grade in a grade combination, for each species, size and timber source.

8.3.2 Destructive testing and calculation of characteristic values

Each specimen shall be tested in accordance with EN 384 and EN 408 to evaluate all grade determining properties.

The characteristic values of grade determining properties shall be calculated in accordance with EN 384 and EN 14358 using the frame of initial type testing.

8.3.3 Requirements for verification of machine settings

The settings are verified only if the characteristic values of bending or tension strength, mean modulus of elasticity in bending or tension and density are equal to or exceed the values for the strength class declared. The verification shall separately be carried out for each grade or grade combination, species or species combination, size and timber source.

If the verification fails the initial settings given in 8.2 shall be adjusted and the procedure described in 8.3 shall be repeated.

8.4 Report

For each grade or grade combination, species or species combination, size and timber source the following information shall be included in a dated and signed report on the verification of settings for output control systems:

a) name of person responsible for the output control system (machine grading, testing and analysis);

b) identification of the grading machine;

c) settings to be verified;

d) details of grading (date, machine operator, feed speed, moisture content, yield, etc.);

e) details of testing (date, person who carries out testing, method, remarks, etc.);

f) individual test results (strength, modulus of elasticity, density and moisture content);

g) mean and coefficient of variation for individual test results;

h) calculated characteristic values (strength, modulus of elasticity and density);

i) information on, when and why settings are adjusted.

9 Requirements for adaptive settings

9.1 Method

Adaptive settings may be used for grade combinations which are produced regularly or in large numbers while grades which are seldom produced or from various sources shall be graded by using constant settings.

When first implementing adaptive settings, the producer shall ensure that the settings are correct and verifiable.

Settings determined in Clauses 6 and 8 are called initial settings (S_{ini}).

The adaptive settings method is an option for machines capable of using the real time analysis of online IP information. The IP information captures the variability of the incoming material and the analysis reduces the variability of graded timber.

This method is only applicable when the IP is a linear positively proportional model of the grade determining property.

Adaptive settings (S_{adapt}) shall be determined according to the Formula (2):

$$S_{adapt} = S_{ini} + r^2 \cdot \left(IP_{mean,ref,grade} - IP_{mean,prod,grade} \right) \quad (2)$$

where

$IP_{mean,ref,grade}$ is mean value of *IP*, calculated separately for each grade and grade combination in a reference sample which is used for determination of initial settings;

$IP_{mean,prod,grade}$ is running mean value of *IP* during grading calculated separately for at least the 300 latest timber pieces of each grade and grade combination from a well-defined timber source;

r is correlation between *IP* and grade determining property in the whole ungraded data set which is used for determination of initial settings. When separate *IP*s are used for *MOR*, *MOE* and/or *DENS*, settings S_{MOR}, S_{MOE} and S_{DENS} are adjusted separately according to Formula (2). When same *IP* is used for more than one grade determining property, the smallest value of r^2 is used.

Settings shall be adjusted automatically for each timber piece based on at least the 300 previous timber pieces in each grade and at intervals of no more than 1 000 previous pieces. When grading begins, $IP_{mean,prod,grade} = IP_{mean,ref,grade}$ is used until at least 300 timber pieces in the grade are available. If the grading equipment is such that frequent adjustments are difficult to handle, adjustment of settings based on Formula 2 can also be made after longer intervals, however at intervals of no more than 1 000 timber pieces.

9.2 Conditions

Settings may be adapted according to Formula (2) when the following conditions are met:

a) grading machine (or connected computer) makes a continuing record of grading data including IP-values of individual timbers;

b) $IP_{mean,ref,grade}$ values are available for the sample used for determination of the initial settings. Use of adaptive settings is limited to the same region (country, standardized area) where the initial settings may be used without adaptation;

c) if the producer decides to use adaptive settings for a production run, it shall use the settings irrespective of whether they are lower or higher than initial settings;

d) for a producer that uses adaptive settings, the use or non-use of adaptive settings shall be recorded in the factory production control as well as individual IPs, settings and grades.

Annex A
(informative)

Guidelines for sampling a growth area for deriving machine settings

These guidelines are written because rules that cover every eventuality in sampling cannot be given in the standard. Although sampling is partly subjective it has a major influence on the safety of settings and consequently the safety of timber structures. Those people doing settings are therefore required to use their knowledge and experience, and that of others, when designing the sampling strategy. It is important that whatever decisions are made are justified in the report:

1) the overall requirement is that the timber tested is representative of the timber to be graded in production with these machine settings. The aim is for the sample to resemble this timber population in terms of: the mean and variance of grade determining properties; and the variation in correlations between the grade determining properties and those characteristics assessed during grading (IP for machine grading). This means that the sampling strategy shall not be designed in order to maximize yield (beyond increasing the number of specimens to reduce statistical uncertainty);

2) the first thing to consider is the size of the growth area (source from which timber is intended to be strength graded) and the variation within it of factors that affect timber quality. If there is knowledge from previous research on the variability of the timber in the growth area this can be used to select the sources strategically;

3) the availability of knowledge about the variability within the growth area should influence the number of locations sampled. If weak areas are known, they should be taken into account accordingly. Where there is a lack of knowledge, more locations should be used and/or contain more specimens.
   The species combination should reflect industrial practice. If species are graded together without being differentiated, then the sampling should be based on that species combination. This should be described in the report. For the sampling, it is not necessary to be able to identify the species of specific specimens – only to know that the species is within the species combination and that the ratio of species in the sampling is broadly similar to that in practice. However, for grading to work the species shall be sufficiently similar, and this shall be considered and justified in the report;

4) ideally, the timber to be tested should be specimens taken from normal sawmill production (sawn or planed) provided the source is known well enough to meet the sampling criteria;

5) pieces that have defects that would be rejected by visual override inspection should not be included, since these would not be included in the graded timber;

6) sampling based on selecting logs is acceptable provided normal sawing patterns are used (non-standard sawing patterns may make the sample unrepresentative), and a sufficient number and diversity of logs are selected such that the sampling is not made to be unrepresentative;

7) it is important that the length of the specimens is sufficient to enable a choice to be made for the critical section. However, care should be taken to avoid biasing the sample through selection of unusually long lengths compared to industrial practice;

8) the range of cross-section dimension should be representative of the timber to be graded in production with these settings or assignments (unless justified otherwise). For machine grading, remember that the range of sizes (thickness and width) permitted to be graded is ± 10 % of the tested sizes.

Annex B
(informative)

Prediction limit method

B.1 General

The prediction limit method is based on linear regression. It is used to predict a single value from the regression model by taking into account the errors between the model and observations.

The following steps provide an initial guess for the settings. The settings shall satisfy the requirements in the body of the standard.

B.2 Model determination

Three models should be determined according to the Formulae (B.1), (B.2) and (B.3):

$$MOR = a_{MOR} \cdot IP + b_{MOR} - t \cdot s_{\delta,MOR,} \tag{B.1}$$

$$MOE = a_{MOE} \cdot IP + b_{MOE} \tag{B.2}$$

$$DENS = a_{DENS} \cdot IP + b_{DENS} - t \cdot s_{\delta,DENS} \tag{B.3}$$

where

IP		is the machine output, it can be same or different for MOR, MOE and DENS;
a_{XXX}	and	are coefficients of regression line between GDP and IP;
b_{XXX}		
s_δ		is standard error of the estimate;
t		is a factor from the Student's t-distribution.

The value of t is dependent on the probability level and the number of observations. With the sample sizes used in the determination of settings an infinite number of observations can be assumed. The probability level used is a choice made by the user. However, the 5 % probability level for MOR and DENS, and the regression line for MOE is usually fulfilling the required GDP if an interval of the required strength of at least 5 MPa between bending-grades and 3 MPa between tension-grades in grade combinations is used. In that case, the t-factor shall be taken as t = 1,645. Table B.1 gives the applicable t-factor for some common prediction levels.

Table B.1 — t-factor for some common prediction levels

Prediction level	t-factor
15 %	1,036
10 %	1,282
5 %	1,645

B.3 Settings calculation

Settings should be calculated for each grade according to the Formulae (B.4), (B.5) and (B.6):

$$S_{MOR} = \frac{MOR_{req} - b_{MOR} + t \cdot s_{\delta,MOR}}{a_{MOR}} \quad \text{(B.4)}$$

$$S_{MOE} = \frac{MOE_{req} - b_{MOE}}{a_{MOE}} \quad \text{(B.5)}$$

$$S_{DENS} = \frac{DENS_{req} - b_{DENS} + t \cdot s_{\delta,DENS}}{a_{DENS}} \quad \text{(B.6)}$$

where

MOR_{req}, $DENS_{req}$ and MOE_{req} are the requirements for GDP according to their definition (e.g. EN 338) and EN 384.

If the same IP was used for modelling all three GDPs then use the most conservative of the three calculated settings. If different IPs were used for modelling GDPs then use all settings parallel in grading.

Annex C
(normative)

Determination of the global cost matrix

C.1 Introduction

The calculation consists of the following steps:

1) optimum grading;

2) IP grading;

3) calculation of size matrix;

4) calculation of elementary cost matrix;

5) calculation of global cost matrix.

C.2 Optimum grading

The pieces of the total sample shall be sorted, on the basis of the grade determining properties, in such a way that the yields are maximized for the highest grades, and that the required values for each grade are met. The grade so determined for each piece is its optimum grade.

The procedure with the following steps has been shown to be efficient when determining the optimum grade:

1) rank the data set for a grade determining property, then determine and identify the maximum number of pieces that meet the required value for that property for the highest grade;

2) repeat step 1) for all other grade determining properties;

3) label the grade determining properties named as e.g. (a), (b) and (c) with (a) having the largest number of pieces identified in step 1) and step 2) above, and (c) the least;

4) using only the pieces identified for property (a), rank them primarily for property (b) with secondary rankings for properties (c) and (a), and determine the maximum number of pieces that meet the required value for property (b). Using only these pieces rank them primarily for property (c) with secondary rankings for properties (b) and (a). Determine and identify the maximum number of pieces that meet the required value for property (c). Check that these pieces meet the other required properties and if so identify them as that grade. Otherwise adjust as appropriate;

5) remove the pieces assigned to that grade and repeat 1) to 5) for all grades beginning with the next highest grade.

C.3 IP grading

The IP and the settings shall be used to grade each piece according to its IP value. These grades are known as assigned grades.

C.4 Calculation of size matrix

A size matrix giving the number of pieces in each of the optimum and assigned grades shall be determined for the total sample.

NOTE Table C.1 is an example of size matrix with 3 target grades, C35, C27 and C22.

Table C.1 — Example: Size matrix

Optimum grade	Assigned grade			
	C35	C27	C22	Reject
C35	207	32	16	2
C27	10	168	12	1
C22	4	13	84	2
Reject	0	2	2	24

C.5 Calculation of elementary cost matrix

C.5.1 Introduction

An elementary cost matrix shall be calculated from the formulae given in this clause. Elementary cost matrix values for reject shall be calculated from the formulae given in this clause using characteristic values that are 75 % of the required values for the lowest grade from which the pieces are rejected. Values in the matrix shall be rounded to two decimal places.

NOTE Elementary cost matrix for C, T and D strength classes of EN 338 are reported in Tables C.2 to C.4.

C.5.2 Factors for wrongly upgraded pieces

These factors represent an increased relative cost due to the increased probability of failure, and shall be calculated as the difference between the target safety index β_{tar} and the achieved safety index β_{ach}. Therefore:

$$COST = 10 \cdot \left(\beta_{tar} - \beta_{ach}\right) = \frac{10}{3} \cdot \left(\frac{f_{k,assigned}}{f_{k,optimum}} - 1\right) \quad \text{(C.1)}$$

where

$\beta_{tar} = 3,0$;

$$\beta_{ach} = \frac{\mu\left(f_{optimum}\right) - \mu\left(f_{assigned}\right) + 0,9\mu\left(f_{assigned}\right)}{0,3\mu\left(f_{optimum}\right)}$$

μ is the mean value of strength for the optimum or assigned grades;

$$\mu\left(f_{optimum}\right) = e^{\left[ln\left(f_{k,optimum}\right)+0,54\right]};$$

$$\mu\left(f_{assigned}\right) = e^{\left[ln\left(f_{k,assigned}\right)+0,54\right]};$$

$f_{k,optimum}$ is the required characteristic strength for the optimum grade (in N/mm^2);

$f_{k,assigned}$ is the characteristic strength for the assigned grade (in N/mm^2).

None of the strength values in this clause shall contain the k_v factor given in EN 384.

C.5.3 Factors for wrongly downgraded pieces

These factors represent an increased relative cost due to the increased amount of timber required for a structural member. For example, the size (depth) of bending members is governed by deformations through formulae of the form:

$$\delta = \frac{c \cdot F \cdot l^3}{E \cdot b \cdot h^3} \tag{C.2}$$

where

c is a constant, depending on the load configuration;

F is the force (in N);

l is the span (in mm);

b is the thickness for edgewise bending and the width for flatwise bending (in mm);

h is the depth (in mm);

and therefore

$$h = \left(\frac{c \cdot F \cdot l^3}{E \cdot b \cdot \delta^3} \right)^{\frac{1}{3}}$$

Similar expressions can be derived for tension members. Therefore, cost shall be calculated as:

$$COST = 10 \cdot \left[\left(\frac{E_{optimum}}{E_{assigned}} \right)^{\alpha} - 1 \right] \tag{C.3}$$

where

$E_{optimum}$ is the mean E of optimum grade (in N/mm^2);

$E_{assigned}$ is the mean E of assigned grade (in N/mm^2);

$$\alpha = \begin{Bmatrix} 1/3 \text{ for bending members} \\ 1 \text{ for tension and compression members} \end{Bmatrix}.$$

None of the E values in this clause shall contain the 95 % factor given in EN 384.

C.5.4 Examples of elementary cost matrices for C, T and D classes

The three Tables C.2, C.3 and C.4 are examples of elementary cost matrices for C, T and D classes.

Table C.2 — Elementary cost matrix for C classes

Optimum grade	Assigned grade											
	C50	**C45**	**C40**	**C35**	**C30**	**C27**	**C24**	**C22**	**C20**	**C18**	**C16**	**C14**
C50	0	0,22	0,46	0,72	1,01	1,16	1,33	1,70	1,90	2,11	2,60	3,17
C45	0,37	0	0,23	0,49	0,77	0,93	1,09	1,45	1,64	1,86	2,33	2,89
C40	0,83	0,42	0	0,25	0,53	0,68	0,84	1,19	1,38	1,59	2,05	2,60
C35	1,43	0,95	0,48	0	0,27	0,42	0,57	0,91	1,10	1,30	1,76	2,29
C30	2,22	1,67	1,11	0,56	0	0,14	0,29	0,63	0,81	1,01	1,45	1,97
C27	2,84	2,22	1,60	0,99	0,37	0	0,15	0,48	0,66	0,85	1,29	1,80
C24	3,61	2,92	2,22	1,53	0,83	0,42	0	0,32	0,50	0,69	1,12	1,63
C22	4,24	3,48	2,73	1,97	1,21	0,76	0,30	0	0,17	0,36	0,77	1,26
C20	5,00	4,17	3,33	2,50	1,67	1,17	0,67	0,33	0	0,18	0,59	1,07
C18	5,93	5,00	4,07	3,15	2,22	1,67	1,11	0,74	0,37	0	0,40	0,87
C16	7,08	6,04	5,00	3,96	2,92	2,29	1,67	1,25	0,83	0,42	0	0,46
C14	8,57	7,38	6,19	5,00	3,81	3,10	2,38	1,90	1,43	0,95	0,48	0

Table C.3 — Elementary cost matrix for T classes

Optimum Grade	Assigned grade																	
	T30	**T28**	**T27**	**T26**	**T24**	**T22**	**T21**	**T18**	**T16**	**T15**	**T14,5**	**T14**	**T13**	**T12**	**T11**	**T10**	**T9**	**T8**
T30	0	0,33	0,33	1,07	1,48	1,92	1,92	2,92	3,48	3,48	4,09	4,09	5,50	6,32	7,22	9,38	10,67	12,14
T28	0,24	0	0,00	0,71	1,11	1,54	1,54	2,50	3,04	3,04	3,64	3,64	5,00	5,79	6,67	8,75	10,00	11,43
T27	0,37	0,12	0	0,71	1,11	1,54	1,54	2,50	3,04	3,04	3,64	3,64	5,00	5,79	6,67	8,75	10,00	11,43
T26	0,51	0,26	0,13	0	0,37	0,77	0,77	1,67	2,17	2,17	2,73	2,73	4,00	4,74	5,56	7,50	8,67	10,00
T24	0,83	0,56	0,42	0,28	0	0,38	0,38	1,25	1,74	1,74	2,27	2,27	3,50	4,21	5,00	6,88	8,00	9,29
T22	1,21	0,91	0,76	0,61	0,30	0	0,00	0,83	1,30	1,30	1,82	1,82	3,00	3,68	4,44	6,25	7,33	8,57
T21	1,43	1,11	0,95	0,79	0,48	0,16	0	0,83	1,30	1,30	1,82	1,82	3,00	3,68	4,44	6,25	7,33	8,57
T18	2,22	1,85	1,67	1,48	1,11	0,74	0,56	0	0,43	0,43	0,91	0,91	2,00	2,63	3,33	5,00	6,00	7,14
T16	2,92	2,50	2,29	2,08	1,67	1,25	1,04	0,42	0	0,00	0,45	0,45	1,50	2,11	2,78	4,38	5,33	6,43
T15	3,33	2,89	2,67	2,44	2,00	1,56	1,33	0,67	0,22	0	0,45	0,45	1,50	2,11	2,78	4,38	5,33	6,43
T14,5	3,56	3,10	2,87	2,64	2,18	1,72	1,49	0,80	0,34	0,11	0	0,00	1,00	1,58	2,22	3,75	4,67	5,71
T14	3,81	3,33	3,10	2,86	2,38	1,90	1,67	0,95	0,48	0,24	0,12	0	1,00	1,58	2,22	3,75	4,67	5,71
T13	4,36	3,85	3,59	3,33	2,82	2,31	2,05	1,28	0,77	0,51	0,38	0,26	0	0,53	1,11	2,50	3,33	4,29
T12	5,00	4,44	4,17	3,89	3,33	2,78	2,50	1,67	1,11	0,83	0,69	0,56	0,28	0	0,56	1,88	2,67	3,57
T11	5,76	5,15	4,85	4,55	3,94	3,33	3,03	2,12	1,52	1,21	1,06	0,91	0,61	0,30	0	1,25	2,00	2,86
T10	6,67	6,00	5,67	5,33	4,67	4,00	3,67	2,67	2,00	1,67	1,50	1,33	1,00	0,67	0,33	0	0,67	1,43
T9	7,78	7,04	6,67	6,30	5,56	4,81	4,44	3,33	2,59	2,22	2,04	1,85	1,48	1,11	0,74	0,37	0	0,71
T8	9,17	8,33	7,92	7,50	6,67	5,83	5,42	4,17	3,33	2,92	2,71	2,50	2,08	1,67	1,25	0,83	0,42	0

Table C.4 — Elementary cost matrix for D classes

Optimum grade	Assigned grade													
	D80	**D75**	**D70**	**D65**	**D60**	**D55**	**D50**	**D45**	**D40**	**D35**	**D30**	**D27**	**D24**	**D18**
D80	0,00	0,29	0,63	0,91	1,22	1,57	1,97	2,11	2,27	2,60	2,97	3,17	3,39	3,62
D75	0,22	0,00	0,32	0,59	0,90	1,24	1,63	1,77	1,92	2,24	2,60	2,80	3,01	3,23
D70	0,48	0,24	0,00	0,26	0,56	0,89	1,26	1,40	1,54	1,86	2,21	2,40	2,60	2,82
D65	0,77	0,51	0,26	0,00	0,29	0,61	0,97	1,11	1,25	1,55	1,89	2,08	2,28	2,49
D60	1,11	0,83	0,56	0,28	0,00	0,31	0,67	0,80	0,94	1,23	1,56	1,74	1,93	2,14
D55	1,52	1,21	0,91	0,61	0,30	0,00	0,35	0,47	0,60	0,89	1,21	1,39	1,57	1,77
D50	2,00	1,67	1,33	1,00	0,67	0,33	0,00	0,12	0,25	0,53	0,84	1,01	1,19	1,38
D45	2,59	2,22	1,85	1,48	1,11	0,74	0,37	0,00	0,13	0,40	0,71	0,87	1,05	1,24
D40	3,33	2,92	2,50	2,08	1,67	1,25	0,83	0,42	0,00	0,27	0,57	0,74	0,91	1,10
D35	4,29	3,81	3,33	2,86	2,38	1,90	1,43	0,95	0,48	0,00	0,29	0,46	0,63	0,81
D30	5,56	5,00	4,44	3,89	3,33	2,78	2,22	1,67	1,11	0,56	0,00	0,16	0,32	0,50
D27	6,54	5,93	5,31	4,69	4,07	3,46	2,84	2,22	1,60	0,99	0,37	0,00	0,16	0,34
D24	7,78	7,08	6,39	5,69	5,00	4,31	3,61	2,92	2,22	1,53	0,83	0,42	0,00	0,17
D18	11,48	10,56	9,63	8,70	7,78	6,85	5,93	5,00	4,07	3,15	2,22	1,67	1,11	0,00

C.6 Calculation of a global cost matrix

A global cost matrix shall be determined with the value in each cell equal to the number of pieces in each cell in the size matrix multiplied by the value in the equivalent cell elementary cost matrix divided by the total number of pieces in the assigned grade. Values in the matrix shall be rounded to two decimal places.

NOTE As an example, the global cost matrix for the example size matrix is shown in Table C.5.

Table C.5 — Example: Global cost matrix

Optimum grade	Assigned grade			
	C35	**C27**	**C22**	**Reject**
C35	0,00	0,06	0,13	0,14
C27	0,04	0,00	0,05	0,05
C22	0,04	0,05	0,00	0,07
Reject	0,00	0,02	0,02	0,00

Annex D
(informative)

Settings for C and T-classes

Table D.1 — Settings for C-classes based on frequency and density

Source mark [a]	Species	Permitted timber size [b] (mm)	Grade or grade combination	Model value IP	Comments and additional requiremer
AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, FI, FO, FR, GB, GI, GR, HR, HU, IE, IM, IS, IT, LI, LT, LU, LV, MC, MD, ME, MK, MT, NL, NO, PL, PT, RO, RS, RU [c], SE, SI, SK, SM, TR [c], UA, VA	Norway spruce *Picea abies* Silver fir *Abies alba*	$32 \leq t_n \leq 55$ $85 \leq b_n \leq 240$ Minimum cross-section area of 3 600 mm²	C24	10 300	Requirements for grading: Timber temperature: > −10 °C. Moisture content: Where the machine measures the moi settings model to determine the grade. Moisture content of each piece shall be b Where the machine doesn't measure th batch is fed in by the machine operato accordingly to determine the grade. Mean moisture content of a batch shall b batch shall not deviate by more than fou Where there is no moisture measuremer Moisture content of each piece shall be b Or Mean moisture content of a batch shall be shall not deviate by more than four perc Maximum feed speed: According to the machine specifications Timber surface planed or sawn.
			C18	9 660	
			C24	11 600	
			C18	9 660	

Source mark [a]	Species	Permitted timber size [b] (mm)	Grade or grade combination	Model value IP	Comments and additional requireme
					$IP = \frac{\left(2 f_0 l\right)^2 \rho}{1 - 0{,}01\left(u - 12\right)} 10^{-6}$ *Picea abies* and *Abies alba* are proc combination is referred to as WPCA acc

a Code identifying the country or region of origin in accordance with EN ISO 3166-1.

b Timber size shall be to EN 336.

c European part.

Table D.2 — Settings for C-classes based on frequency

Source mark [a]	Species	Permitted timber size [b] (mm)	Grade or grade combination	Model value IP	Comments and additional requiremen
AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, FI, FO, FR, GB, GI, GR, HR, HU, IE, IM, IS, IT, LI, LT, LU, LV, MC, MD, ME, MK, MT, NL, NO, PL, PT, RO, RS, RU [c], SE, SI, SK, SM, TR [c], UA, VA	Norway spruce *Picea abies* Silver fir *Abies alba*	$32 \le t_n \le 55$ $85 \le b_n \le 240$ Minimum cross-section area of 3 600 mm^2	C24	13 100	Requirements for grading: Timber temperature: > −10 °C. Moisture content: Where the machine measures the mois settings model to determine the grade. Moisture content of each piece shall be be Where the machine doesn't measure the batch is fed in by the machine operator a accordingly to determine the grade. Mean moisture content of a batch shall be batch shall not deviate by more than four Where there is no moisture measuremen Moisture content of each piece shall be be Or Mean moisture content of a batch shall be batch shall not deviate by more than four Maximum feed speed: According to the machine specifications Timber surface planed or sawn. $IP = \frac{\left(2 f_0 l\right)^2 \rho}{1 - 0{,}01\left(u - 12\right)} 10^{-6}$ A value of 450 kg/m^3 for density shall be *Picea abies* and *Abies alba* are processed t combination is referred to as WPCA accor
			C18	9 550	
			C24	13 100	
			C18	9 550	

Source mark [a]	Species	Permitted timber size [b] (mm)	Grade or grade combination	Model value	Comments and additional requiremen
				IP	

a Code identifying the country or region of origin in accordance with EN ISO 3166-1.

b Timber size shall be to EN 336.

c European part.

Table D.3 — Settings for T-classes based on frequency and density

Source mark [a]	Species	Permitted timber size [b] (mm)	Grade or grade combination	Model value IP	Comments and additional requiremen
AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, FI, FO, FR, GB, GI, GR, HR, HU, IE, IM, IS, IT, LI, LT, LU, LV, MC, MD, ME, MK, MT, NL, NO, PL, PT, RO, RS, RU [c], SE, SI, SK, SM, TR [c], UA, VA	Norway spruce *Picea abies* Silver fir *Abies alba*	$32 \le t_n \le 55$ $80 \le b_n \le 250$ Minimum cross-section area of 3 500 mm^2	T14	10 600	Requirements for grading: Timber temperature: > −10 °C. Moisture content: Where the machine measures the moistu model to determine the grade. Moisture content of each piece shall be b Where the machine doesn't measure the is fed in by the machine operator and the to determine the grade. Mean moisture content of a batch shall batch shall not deviate by more than four Where there is no moisture measuremen Moisture content of each piece shall be b Or Mean moisture content of a batch shall b shall not deviate by more than four perce Maximum feed speed: According to the machine specifications Timber surface planed or sawn. $IP = \frac{\left(2 f_0 l\right)^2 \rho}{1 - 0{,}01\left(u - 12\right)} 10^{-6}$ *Picea abies* and *Abies alba* are processed t is referred to as WPCA according to EN 1
			T11	8 400	
			T14	11 600	
			T11	8 930	

a Code identifying the country or region of origin in accordance with EN ISO 3166-1.

Source mark [a]	Species	Permitted timber size [b] (mm)	Grade or grade combination	Model value IP	Comments and additional requiremen
[b] Timber size shall be to EN 336.					
[c] European part.					

Table D.4 — Settings for T-classes based on frequency

Source mark [a]	Species	Permitted timber size [b] (mm)	Grade or grade combination	Model value IP	Comments and additional requiremen
AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, FI, FO, FR, GB, GI, GR, HR, HU, IE, IM, IS, IT, LI, LT, LU, LV, MC, MD, ME, MK, MT, NL, NO, PL, PT, RO, RS, RU [c], SE, SI, SK, SM, TR [c], UA, VA	Norway spruce *Picea abies* Silver fir *Abies alba*	$32 \le t_n \le 55$ $80 \le b_n \le 250$ Minimum cross-section area of 3 500 mm²	T14	13 100	Requirements for grading: Timber temperature: > −10 °C. Moisture content: Where the machine measures the moistu model to determine the grade. Moisture content of each piece shall be be Where the machine doesn't measure the is fed in by the machine operator and the to determine the grade. Mean moisture content of a batch shall b batch shall not deviate by more than four Where there is no moisture measuremen Moisture content of each piece shall be be Or Mean moisture content of a batch shall be shall not deviate by more than four perce Maximum feed speed: According to the machine specifications Timber surface planed or sawn. $IP = \frac{\left(2 f_0 l\right)^2 \rho}{1 - 0{,}01\left(u - 12\right)} 10^{-6}$
			T11	8 500	
			T14	13 100	
			T11	9 350	

Source mark [a]	Species	Permitted timber size [b] (mm)	Grade or grade combination	Model value	Comments and additional requiremen
				IP	
					A value of 450 kg/m^3 for density shall be *Picea abies* and *Abies alba* are processed t is referred to as WPCA according to EN 1

a Code identifying the country or region of origin in accordance with EN ISO 3166-1.

b Timber size shall be to EN 336.

c European part.

Bibliography

[1] EN 336, *Structural timber — Sizes, permitted deviations*

[2] EN 338, *Structural timber — Strength classes*

[3] EN 14081-1, *Timber structures — Strength graded structural timber with rectangular cross section — Part 1: General requirements*

[4] EN 14081-3, *Timber structures — Strength graded structural timber with rectangular cross section — Part 3: Machine grading; additional requirements for factory production control*

This page deliberately left blank

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Copyright in BSI publications

All the content in BSI publications, including British Standards, is the property of and copyrighted by BSI or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use.

Save for the provisions below, you may not transfer, share or disseminate any portion of the standard to any other person. You may not adapt, distribute, commercially exploit, or publicly display the standard or any portion thereof in any manner whatsoever without BSI's prior written consent.

Storing and using standards

Standards purchased in soft copy format:

- A British Standard purchased in soft copy format is licensed to a sole named user for personal or internal company use only.
- The standard may be stored on more than 1 device provided that it is accessible by the sole named user only and that only 1 copy is accessed at any one time.
- A single paper copy may be printed for personal or internal company use only.
- Standards purchased in hard copy format:
- A British Standard purchased in hard copy format is for personal or internal company use only.
- It may not be further reproduced – in any format – to create an additional copy. This includes scanning of the document.

If you need more than 1 copy of the document, or if you wish to share the document on an internal network, you can save money by choosing a subscription product (see 'Subscriptions').

Reproducing extracts

For permission to reproduce content from BSI publications contact the BSI Copyright & Licensing team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email subscriptions@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Useful Contacts

Customer Services
Tel: +44 345 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 345 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.