BRITISH STANDARD

BS EN 384:2004

Structural timber — Determination of characteristic values of mechanical properties and density

The European Standard EN 384:2004 has the status of a British Standard

ICS 79.040

British Standards

National foreword

This British Standard is the official English language version of EN 384:2004. It supersedes BS EN 384:1995 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/518, Structural timber, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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Structural timber - Determination of characteristic values of mechanical properties and density

Bois de structure - Détermination des valeurs caractéristiques des propriétés mécaniques et de la masse volumique

Bauholz für tragende Zwecke - Bestimmung charakteristischer Werte für mechanische Eigenschaften und Rohdichte

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Foreword

This document (EN 384:2004) has been prepared by Technical Committee CEN/TC 124 “Timber structures”, the secretariat of which is held by DS.

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of an identical text or by endorsement, at the latest by July 2004, and conflicting national standards shall be withdrawn at the latest by July 2004.

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Introduction

In this revised edition the method for determining characteristic values from tests on small clear specimens is now only permitted for hardwoods. Changes to factor k_v and other minor changes have also been made.

Structural codes can only function effectively if standard methods of determining the mechanical and physical properties exist.

Whilst total accuracy of characteristic values for any defined population is an aim, it is recognized that this is not achievable. A major aim of the procedures given in this standard is to produce characteristic values that are comparable in terms of the populations they represent. It is also important that the standard permits the use of as much existing test data as possible from various sampling and testing techniques.

Where methods are given to permit characteristic values to be determined from a less than ideal amount of structural size test data or from small, clear, defect-free specimen test data, reduction factors to reflect a lower degree of confidence are employed.

This standard covers the stages of population definition, sampling, testing and analysis of data in the determination of characteristic values.

1 Scope

This standard gives a method for determining characteristic values of mechanical properties and density, for defined populations of timber of visual and/or mechanical strength grades.

A method is also given for checking the strength of a timber sample against its designated value.

The values determined in accordance with this standard for mechanical properties and density are suitable for assigning grades and species to the strength classes of EN 338.

NOTE For assigning grades and species to the strength classes in EN 338 only three characteristic values, i.e. bending strength, mean modulus of elasticity parallel to grain and density need to be determined, other properties may be taken from the table in EN 338.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 408:2003, *Timber structures - Structural timber and glued laminated timber - Determination of some physical and mechanical properties*

prEN 14081-1, *Timber structures – Strength graded structural timber with rectangular cross section – Part 1: General requirements*

ISO 3131:1975, *Wood - Determination of density for physical and mechanical tests.*

3 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply:

3.1
characteristic value
generally a value that corresponds to a fractile of the statistical distribution of a timber property. For strength properties, modulus of elasticity and density the fractile is the 5-percentile. For modulus of elasticity, the mean value is also a characteristic value.

3.2
p-percentile
value for which the probability of getting lower values is p%.

3.3
population
material for which the characteristic values are relevant.

NOTE The population is defined by parameters such as species or species grouping, source and strength grade.

3.4
sample
a number of specimens of one cross section size and from one population.

3.5
small clear test
test to determine mechanical properties of small defect-free specimens.

3.6
specimen
piece of timber for testing.

3.7
thickness
lesser dimension perpendicular to the longitudinal axis of a piece of timber.

3.8
width
greater dimension perpendicular to the longitudinal axis of a piece of timber.

3.9
depth
dimension perpendicular to the longitudinal axis of a timber beam, in the plane of the bending forces.

4 Symbols and abbreviations

a_f	distance between the inner load points of the bending test (in mm)
$\overline{E}$	mean modulus of elasticity for one sample (in N/mm^2)
$E_{0,mean}$	mean characteristic value of modulus of elasticity parallel to grain (in N/mm^2)
$E_{0,05}$	5-percentile characteristic value of modulus of elasticity parallel to grain (in N/mm^2)
$E_{90,mean}$	mean characteristic value of modulus of elasticity perpendicular to grain (in N/mm^2)
f	strength property
$f_{c,0,k}$	characteristic value of compression strength parallel to grain (in N/mm^2)
$f_{c,90,k}$	characteristic value of compression strength perpendicular to grain (in N/mm^2)
f_k	characteristic value of strength (in N/mm^2)
$f_{m,k}$	characteristic value of bending strength (in N/mm^2)
f_{mean}	sample mean value of strength (in N/mm^2)
f_r	5-percentile ranked test value (in N/mm^2)
$f_{t,0,k}$	characteristic value of tensile strength parallel to grain (in N/mm^2)
$f_{t,90,k}$	characteristic value of tensile strength perpendicular to grain (in N/mm^2)
f_{05}	5-percentile value for each sample (in N/mm^2)
$\overline{f}_{05}$	the mean value of f_{05} for several samples (in N/mm^2)
$f_{v,k}$	characteristic value of shear strength (in N/mm^2)
G_{mean}	mean characteristic value of shear modulus (in N/mm^2)
h	depth of a bending specimen or width of a tension specimen (in mm)
k_g	factor used for determining characteristic values of tension and compression parallel to grain and shear
k_h	factor for adjusting f_k when h is different from 150 mm
k_l	factor for adjusting length;

k_n factor for obtaining characteristic value from mean value;

k_q factor for use when checking the quality of a graded sample

k_s factor for adjusting number and size of samples

k_v factor for adjusting machine grading

ℓ span (in mm)

ℓ_{es} effective length for the standard test procedure (in mm)

ℓ_{et} effective length for the test (in mm)

n number of specimens in a sample

s standard deviation

$\bar{\rho}$ sample mean value of density (in N/mm^2)

ρ density (in kg/m^3)

ρ_k characteristic density (5-percentile) (in kg/m^3)

ρ_{05} 5-percentile density for a sample (in kg/m^3)

5 Mechanical properties determined from full-size specimens

5.1 Sampling

Samples shall be selected from the population of timber graded visually or by machine to the requirements given in prEN 14081-1. The population shall be capable of being identified at all stages of production and supply, including the construction site.

The test material shall be representative of the population. The timber shall represent the timber source, sizes, and quality that will be graded in production. Each sample shall be from one source.

NOTE 1 Any known or suspected difference in the mechanical properties of the population distribution due to growth regions, sawmills, tree size or method of conversion should be represented within the number of samples selected, by a similar proportion to their frequency in the population. This should be the major influence in determining the number and size of samples.

The number of specimens in each sample shall be not less than 40.

NOTE 2 Where samples are small and/or few in number the characteristic values will be penalized, see **5.4**.

The cross section size of specimens shall be the same within a sample, but different for other samples, reflecting the range of sizes to which the grading rules are applicable. However, if the size effect for the grading rule has been established for a similar species, then fewer sizes may be tested.

Test specimens for shear, tension perpendicular to grain and compression perpendicular to grain strengths are comparatively small and therefore shall be free of strength reducing characteristics, but must represent the full range of growth areas, density and rates of growth.

5.2 Testing

Testing shall be carried out in accordance with EN 408:2003. Except for the strength properties of shear, tension perpendicular to grain and compression perpendicular to grain, a critical section shall be selected in each piece of timber. This section is the position at which failure is expected to occur, based on a visual examination and any other information such as measurements from a strength grading machine. The critical section shall be in a position

that can be tested, e.g. not outside the inner load points in a bending test or in close proximity to the jaws in a tension test. For tests to determine modulus of elasticity, the procedure shall be as given in clause 10 in EN 408:2003 and the critical section shall be positioned between the loading heads. The grade of the piece of timber shall be deemed to be the grade of the critical section.

NOTE 1 Because the method used for determining the 5-percentile values of the strength properties is non-parametric (see **5.3.1**), not all specimens in the test samples need to be tested to failure.

For a bending test for strength or modulus of elasticity, the tension edge shall be selected at random.

For a tension test for strength or modulus of elasticity, the timber test length clear of the machine grips shall be nine times the width of the piece.

NOTE 2 Existing data from different test methods or moisture conditions are acceptable provided sufficient information exists to adjust the results to the reference conditions given in **5.3.3**. These differences might be in moisture content, test spans or orientation of test specimens. If these data are not available, recommendations for some of these adjustments are given in **5.3.4**.

5.3 Analysis of data

5.3.1 Determination of sample 5-percentile

For each sample, a 5-percentile value f_{05} shall be determined from the equation: $f_{05}=f_r$
f_r is obtained by ranking all the test values for a sample in ascending order. The 5-percentile value is the test value for which 5% of the values are lower or equal. If this is not an actual test value (i.e. the number of test values is not divisible by 20) then interpolation between the two adjacent values is required.

5.3.2 Determination of the sample mean of modulus of elasticity

The sample mean value of modulus of elasticity $\overline{E}$ shall be calculated from the following equation, which includes an adjustment to a pure bending modulus of elasticity:

$$\overline{E} = [\sum E_i/n]\ 1{,}3 - 2690$$

where

E_i is the i'th value of modulus of elasticity (see **5.2**) in the range 1 to n expressed in Newtons per square millimetre (in N/mm^2).

5.3.3 Reference conditions

5.3.3.1 Moisture content

The reference moisture content shall be consistent with 20^{0}C and 65% relative humidity.

NOTE For most softwoods this corresponds to a moisture content of about 12%.

5.3.3.2 Bending strength

The reference condition corresponds to a depth of 150 mm and to the standard test set-up proportions of third point loading with an overall span of 18 times the specimen depth.

5.3.3.3 Tension strength

The reference condition corresponds to a width of 150 mm. All other requirements are implicit in **5.2**.

5.3.4 Adjustment factors

5.3.4.1 General

Each sample 5-percentile or mean value shall be adjusted to the standard reference conditions.

5.3.4.2 Moisture content of the samples

For samples not tested at the reference conditions but having a mean moisture content in the range 10% to 18%, adjustment of the lower 5-percentile or mean to 12% moisture content (or a value shown by test to be more appropriate to the reference conditions for that species), shall be as follows. If other more relevant factors are available from test data, then they shall be used instead.

a) For bending and tension strength: no adjustment.

b) For compression parallel to grain strength: 3% change for every percentage point difference in moisture content.

c) For modulus of elasticity: 2% change for every percentage point difference in moisture content.

d) For compression parallel to grain strength and modulus of elasticity: the adjustments are carried out so that the properties increase if the data are adjusted from a higher moisture content, and vice versa.

5.3.4.3 Timber size and test length

5-percentiles of bending and tensile strength shall be adjusted to 150mm depth or width by dividing

by

$$k_h = \left(\frac{150}{h}\right)^{0,2}$$

Where the bending test arrangement is not as in EN 408:2003 (i.e. span, ℓ =18h and distance between inner load points, a_f = 6h) then the 5-percentile bending strength shall be adjusted by dividing by

$$k_l = \left(\frac{\ell_{es}}{\ell_{et}}\right)^{0,2}$$

where

ℓ_{es} and ℓ_{et} are calculated as follows:

ℓ_{es} or $\ell_{et} = \ell + 5a_f$

where a_f and ℓ have the respective values for the standard test procedure and for the test.

5.3.4.4 Other adjustments

If the test methods and/or conditions differ from the reference conditions in any way other than described in **5.3.4.2** and **5.3.4.3**, then adjustment factors shall be derived from similar methods and/or conditions and used to adjust the 5-percentile or mean value to the reference conditions.

5.4 Strength properties

The characteristic value of strength f_k shall be calculated from the equation:

$$f_k = \overline{f}_{05}\, k_s\, k_v$$

where

$\overline{f}_{05}$ is the mean (in N/mm2) of the adjusted 5-percentile values (f_{05}) for each sample, weighted according to the number of pieces in each sample. If $\overline{f}_{05}$ is greater than the lowest adjusted sample value of f_{05} times 1,2

then either the reference population shall be redefined to eliminate the lowest value, or $\overline{f}_{05}$ shall be given the value of 1,2 times the extreme low value of f_{05};

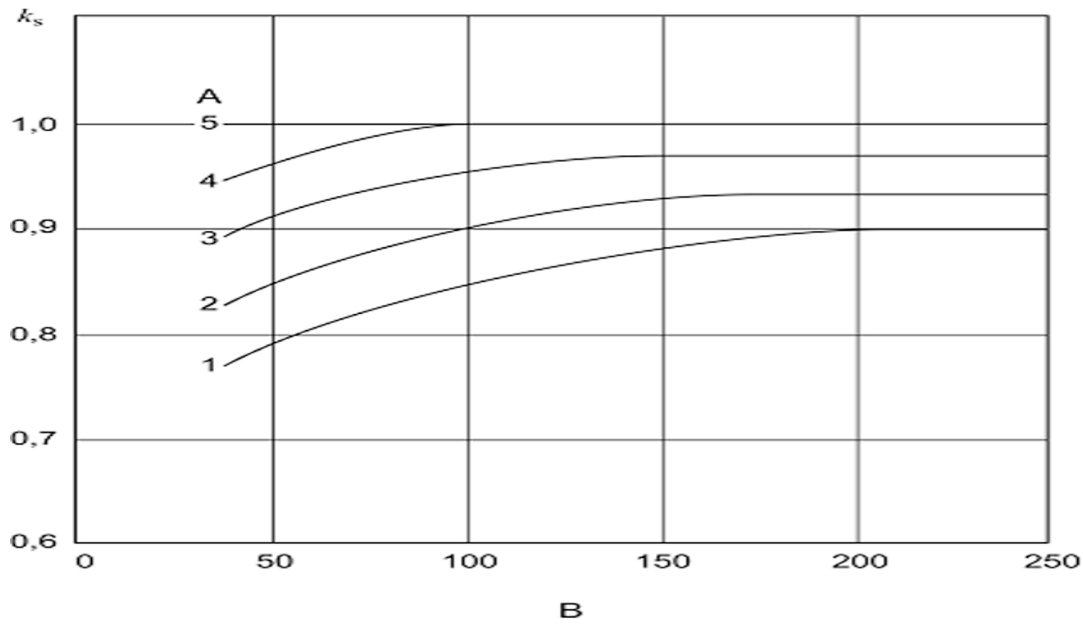
k_s is a factor to adjust for the number of samples and their size and shall be obtained from Figure1.

k_v is a factor to allow for the lower variability of f_{05} values between samples for machine grades in comparison with visual grades;

for machine grades with f_{mk} greater than 30 N/mm^2, and all visual grades, k_v =1,0

for machine grades with f_{mk} equal to or less than 30 N/mm^2, k_v =1,12.

Factors k_s and k_v shall not be used to calculate characteristic values of shear, tension perpendicular to grain and compression perpendicular to grain strengths.



A Number of samples

B Number pieces in the smallest samples

Figure 1 The effects of the number of samples and their size on the factor k_s

5.5 Modulus of elasticity

After adjusting the value of $\overline{E}$ for each sample (see **5.3.2**) to the reference conditions (see **5.3.4**) the characteristic value $E_{0,mean}$ shall be calculated from the equation:

$$E_{0,\text{mean}} = \frac{\sum \overline{E}_j n_j}{\sum n_j}$$

where

n_j is the number of specimens in sample j;

$\overline{E}_j$ is the mean value of modulus of elasticity for sample j expressed in Newtons per square millimetre (in N/mm^2).

6 Density

The characteristic density shall be calculated from density measurements of samples selected according to **5.1**.

The measurements shall be carried out in accordance with **6.1** of ISO 3131:1975. Where the moisture content is higher than 12%, the density shall be decreased by 0,5% for every percentage point difference in moisture content and, where the moisture content is lower than 12%, the density shall be increased by 0,5% for every percentage point difference in moisture content. This assumes that both the mass and volume are measured at the test moisture content. The sample 5-percentile density ρ_{05} shall be calculated from the equation:

$$\rho_{05} = \left(\bar{\rho} - 1{,}65s\right) \text{ kg/m}^3$$

where

$\bar{\rho}$ and s are the mean and standard deviations respectively of the densities of all specimens in the sample (in kg/m^3).

Where not all the specimens are tested to failure, the density of each specimen is permitted to be determined from the mass and volume of the whole specimen and adjusted to the density of the small defect-free prisms given in ISO 3131:1975, by dividing by 1,05. This does not include any adjustment for moisture content, which may also be necessary.

The characteristic density ρ_k shall be calculated from the equation:

$$\rho_k = \frac{\sum \rho_{05,j} n_j}{\sum n_j}$$

where

n_j is the number of specimens in sample j;

$\rho_{05,j}$ is the 5-percentile value of density for sample j.

7 Alternative methods of determining mechanical properties

7.1 Bending strength and modulus of elasticity determined from small, clear specimens

This procedure is only permitted for hardwood species.

Factors to determine characteristic values of bending strength and modulus of elasticity may be derived where both small clear and structural size data are available for at least three other species. (It is essential that these species are similar). These factors shall then be derived from ratios of the characteristic values from the structural size data to the mean values of the small clear data. These factors are then permitted to be applied to species where only small, clear data exist.

For the small clear data, the number of specimens in a sample shall be at least 40 taken from at least five trees, and the test method shall be the same in all cases.

Characteristic values determined in this way shall be reduced by multiplying by 0,9.

7.2 Other mechanical properties

7.2.1 General

If no structural size test data are available for the relevant properties, then the characteristic values shall be determined in accordance with **7.2.2** to **7.2.7** from the characteristic values for bending strength, mean modulus of elasticity and density, provided that those values have been determined in accordance with clauses **5, 6, 7** and **8**.

7.2.2 Tension and compression parallel to grain strength and shear strength

The characteristic values of tensile strength parallel to grain, $f_{t,0,k}$, compressive strength parallel to grain, $f_{c,0,k}$, and shear strength, $f_{v,k}$, for softwood species, shall be calculated from the following equations:

$$f_{t,0,k} = 0{,}6 f_{m,k}$$

$$f_{c,0,k} = 5(f_{m,k})^{0,45}$$

$$f_{v,k} = \min.\begin{cases} 3{,}8 \\ 0{,}2\left(f_{m,k}\right)^{0,8} \end{cases}$$

7.2.3 Tension perpendicular to grain strength

The characteristic value of tensile strength perpendicular to grain, $f_{t,90,k}$, shall be calculated from the equation:

$$f_{t,90,k} = \min.\begin{cases} 0{,}6 \\ 0{,}0015\rho_k \end{cases}$$

7.2.4 Compression perpendicular to grain strength

The characteristic value of compressive strength perpendicular to grain, $f_{c,90,k}$, shall be calculated from the equation:

$f_{c,90,k} = 0{,}007\rho_k$ for softwoods

$f_{c,90,k} = 0{,}015\rho_k$ for hardwoods

7.2.5 Characteristic fifth percentile modulus of elasticity parallel to grain

The characteristic modulus of elasticity parallel to grain $E_{0,05}$ shall be calculated

for softwood species: $E_{0,05} = 0{,}67 E_{0,mean}$

for hardwood species: $E_{0,05} = 0{,}84 E_{0,mean}$

7.2.6 Mean modulus of elasticity perpendicular to grain

The mean modulus of elasticity perpendicular to grain E_{90}, mean shall be calculated from the equation

for softwood species: $E_{90,mean} = E_{0,mean}/30$

for hardwood species: $E_{90,mean} = E_{0,mean}/15$

7.2.7 Shear modulus

The mean shear modulus G_{mean} shall be calculated from the equation: $G_{mean} = E_{0,mean}/16$

8 Mechanical properties for other grades

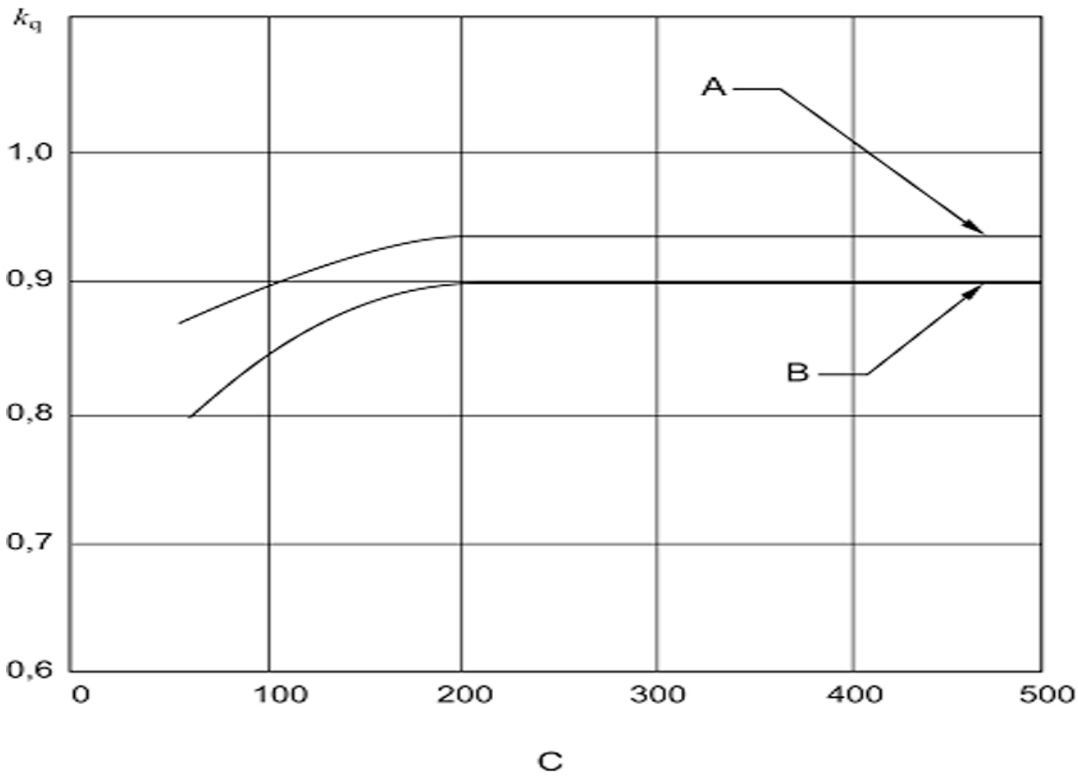
Where data to determine characteristic values of bending strength, modulus of elasticity and density, in accordance with clauses **5** and **6**, are available for only one grade of a species or species group, then characteristic values for other grades of the same species may be determined by applying grade relativity factors. These factors shall be derived from the ratios of characteristic values, determined in accordance with clauses **5** and **6**, from at least three other similar species of species groups for which data exist for all the grades required.

9 Verification

To check a stated characteristic value for a given population, a sample of that population conforming to the requirements of **5.1** shall be tested in accordance with **5.2**.

For strength properties, the 5-percentile value calculated and adjusted in accordance with **5.3.1** and **5.3.4** shall not be less than the characteristic value multiplied by k_q, given in figure 2, and divided by k_v, given in **5.4**.

For modulus of elasticity, the mean value calculated and adjusted in accordance with **5.3.2** and **5.3.4** shall be not less than the characteristic value multiplied by k_q given in figure 2.



A Bending strength machine graded timber

B All other grades and properties

C Sample size

Figure 1 - Values of factor k_q

10 Report

A written report giving details of the population, sampling, testing, analytical procedure and calculations shall be prepared.

Note Where a grade and species is to be considered for listing in EN1912 as meeting the requirements of a strength class, the sample distributions of knot size (at the critical section), rate of growth and density will be required. A sample form to be filled in giving details of the characteristic values is shown in annex A.

Annex A
(informative)

Bibliography

EN 1912, *Structural timber – Strength classes – Assignment of visual grades and species.*

EN 338, *Structural timber - Strength classes*

prEN 14081-2, *Timber structures – Strength graded structural timber with rectangular cross section - Part 2: Machine Grading - Additional requirements for initial type testing*

prEN 14081-3, *Timber structures - Strength graded structural timber with rectangular cross section - Part 3: Machine Grading - Additional requirements for factory production control*

Annex B(informative)

Sample form containing characteristic values

Required when applying for grades and species to be assigned to strength classes in EN 1912 (see **10**)

Species	Source	Grade	Thickness	width	No of pieces	Moisture content	MOR mean	MOR Std Dev	MOR 5% rank	Adjustment Factor	Reason	Adjusted MOR	Char.MOR	MOE Mean	Adjustment factor	Reason	Adjusted MOE	Char. MOE	Density 5%	Adjustment factor	Reason	Adjusted density	Char. density

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