

Prefabricated reinforced components of lightweight aggregate concrete with open structure

The European Standard EN 1520:2002 has the status of a
British Standard

ICS 91.100.30

National foreword

This British Standard is the official English language version of EN 1520:2002, including Corrigendum May 2003.

EN 1520 is a candidate “harmonized” European Standard and fully takes into account the requirements of the European Commission mandate M100 Precast concrete products, given under the EU Construction Products Directive (89/106/EEC), and intended to lead to CE marking. The date of applicability of EN 1520 as a “harmonized” European Standard, i.e. the date after which this standard may be used for CE marking purposes, is subject to an announcement in the *Official Journal of the European Communities*.

The Commission in consultation with Member States have agreed a transition period for the co-existence of “harmonized” European Standards and their corresponding national standard(s). It is intended that this period will comprise a period, usually nine months after the date of availability of the European Standard, during which any required changes to national regulations are to be made, followed by a further period, usually of 12 months, for the implementation of CE marking. At the end of this co-existence period, the national standard(s) will be withdrawn.

EN 1520 is the subject of transitional arrangements agreed under the Commission mandate. In the UK, there is no corresponding national standard.

The UK participation in its preparation was entrusted to Technical Committee B/523, Prefabricated reinforced components of autoclaved aerated concrete and lightweight aggregate concrete with open structure, 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.

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

Cross-references

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English version

Prefabricated reinforced components of lightweight aggregate concrete with open structure

Produits préfabriqués armés en béton de granulats légers à
structure ouverte

Vorgefertigte bewehrte Bauteile aus haufwerksporigem
Leichtbeton

This European Standard was approved by CEN on 16 October 2002.

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 Management Centre or to any CEN member.

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Foreword

This document EN 1520:2002 has been prepared by Technical Committee CEN /TC 177, "Prefabricated reinforced components of autoclaved aerated concrete or lightweight aggregate concrete with open structure", the secretariat of which is held by DIN.

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 May 2003, and conflicting national standards shall be withdrawn at the latest by August 2004.

This European Standard has been prepared under mandate M100 given to CEN by the European Commission and the European Free Trade Association and supports essential requirements of Directives 89/106/EEC.

For relationship with EU Directives, see informative annex ZA, which is an integral part of this standard.

Regulatory classes are only given for "Reaction to fire" and "Resistance to fire". All other classes used in this European Standard, i. e. density classes and strength classes, are technical classes.

Annexes A and B are normative.

Annex C is informative.

This document includes a Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard : Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard is for prefabricated reinforced components of lightweight aggregate concrete with open structure intended to be used in building constructions

a) for structural elements:

- loadbearing wall components (solid, hollow core or multilayer);
- retaining wall components (solid) with or without surcharge loading;
- roof components (solid, hollow core or multilayer);
- floor components (solid, hollow core or multilayer);
- linear components (beams or piers).

b) for non-structural elements:

- non-loadbearing wall components (e.g. for partition walls);
- cladding components (without fixtures) intended to be used for external facades of buildings;
- small box culverts used to form channels for the enclosure of services;
- components for noise barriers.

Depending on the type and intended use of elements for which the components are utilised, the components can be applied - in addition to their loadbearing and encasing function - for purposes of fire resistance, sound insulation and thermal insulation in the relevant clauses of this European Standard.

Components covered by this standard are only intended to be subjected to predominantly non-dynamic actions, unless special measures are introduced in the relevant clauses of this European standard.

The term "reinforced" relates to reinforcement used for both structural and non-structural purposes.

This European Standard does not cover:

- rules for the application of these components in structures;
- joints (except their strength);
- fixtures;
- finishes for external components, such as tiling.

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 206-1:2000, *Concrete – Part 1: Specification, performance, production and conformity*.

EN 990, *Test methods for verification of corrosion protection of reinforcement in autoclaved aerated concrete and lightweight aggregate concrete with open structure*.

EN 991, *Determination of the dimension of prefabricated reinforced components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.*

EN 992, *Determination of the dry density of lightweight aggregate concrete with open structure.*

EN 1352, *Determination of static modulus of elasticity under compression of autoclaved aerated concrete or lightweight aggregate concrete with open structure.*

EN 1354, *Determination of compressive strength of lightweight aggregate concrete with open structure.*

EN 1355:1996, *Determination of creep strains under compression of autoclaved aerated concrete or lightweight aggregate concrete with open structure.*

EN 1356, *Performance test for prefabricated reinforced components of autoclaved aerated concrete or lightweight aggregate concrete with open structure under transverse load.*

EN 1364-1, *Fire resistance tests for non-loadbearing elements – Part 1: Walls.*

EN 1365-1, *Fire resistance tests for loadbearing elements – Part 1: Walls.*

EN 1365-2, *Fire resistance tests for loadbearing elements – Part 2: Floors and roofs.*

EN 1365-3, *Fire resistance tests for loadbearing elements – Part 3: Beams.*

EN 1365-4, *Fire resistance tests for loadbearing elements – Part 4: Columns.*

EN 1521, *Determination of flexural strength of lightweight aggregate concrete with open structure.*

EN 1739, *Determination of shear strength for in-plane forces of joints between prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.*

EN 1740, *Performance test for prefabricated reinforced components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure under predominantly longitudinal load (vertical components).*

EN 1741, *Determination of shear strength for out-of-plane forces of joints between prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.*

EN 1745, *Masonry and masonry products – Methods for determining design thermal values.*

EN 1793-1, *Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 1: Intrinsic Characteristics of sound absorption.*

EN 1793-2, *Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 2: Intrinsic characteristics of airborne sound insulation.*

EN 10002-1, *Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature.*

EN 10025, *Hot rolled products of non-alloy structural steels – Technical delivery conditions.*

prEN 10080-1, *Steel for the reinforcement of concrete – Weldable reinforcing steel – Part 1: General requirements.*

EN 12354-1, *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 1: Airborne sound insulation between rooms.*

EN 12354-2, *Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 2: Impact sound insulation between rooms.*

EN 12524, *Building materials and products - Hygrothermal properties - Tabulated design values.*

EN 12664, *Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meter methods – Dry and moist products of medium and low thermal resistance.*

EN 12667 *Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Products of high and medium thermal resistance.*

EN 12939, *Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meter methods – Thick products of high and medium thermal resistance.*

EN 13055-1, *Lightweight aggregates – Part 1: Lightweight aggregates for concrete, mortar and grout.*

EN 13501-1, *Fire classification of construction products and building elements – Part 1: Classification using test data from reaction to fire tests.*

prEN 13501-2, *Fire classification of construction products and building elements – Part 2: Classification using data from fire resistance tests (excluding products for use in ventilation systems).*

EN 20354, *Acoustics – Measurement of sound absorption in a reverberation room (ISO 354:1985).*

EN ISO 140-3, *Acoustics - Measurement of sound insulation in buildings and of building elements - Part 3: Laboratory measurements of airborne sound insulation of building elements (ISO 140-3:1995).*

EN ISO 140-6, *Acoustics – Measurement of sound insulation in buildings and of building elements – Part 6: Laboratory measurements of impact sound insulation of floors (ISO 140-6:1998).*

EN ISO 717-1, *Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation (ISO 717-1:1996).*

EN ISO 717-2, *Acoustics – Rating of sound insulation in buildings and of building elements – Part 2: Impact sound insulation (ISO 717-2:1996).*

EN ISO 6946, *Building components and building elements – Thermal resistance and thermal transmittance – Calculation method (ISO 6946:1996).*

EN ISO 10456, *Building materials and products - Procedures for determining declared and design thermal values (ISO 10456:1999).*

EN ISO 12572, *Hygrothermal performance of building materials and products – Determination of water vapour transmission properties (ISO 12572:2001).*

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO 1000 AMD 1, *SI units and recommendations for the use of their multiples and of certain other units - Part Amendment 1.*

3 Definitions, symbols and abbreviations

3.1 Terms and definitions

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

3.1.1

lightweight aggregate (LWA)

aggregate consisting of grains with a porous structure and with a particle density of not more than 2 000 kg/m³ or a loose bulk density of not more than 1 200 kg/m³

3.1.2**lightweight aggregate concrete (LAC)**

concrete with an open structure having an oven-dry density of not more than 2 000 kg/m³ and made with aggregates consisting entirely or mainly of lightweight aggregates (LWA)

3.1.3**open structure**

internal structure of a concrete composed in such a manner that a part of its volume (typically more than 3 %) consists of voids between the aggregate grains (These voids are due to a reduced content of aggregate fines and/or cementitious material.)

3.1.4**loadbearing component**

component, which is essential to the overall stability of the structure

3.1.5**non loadbearing component**

component, which is not essential to the overall stability of the structure. The component carries its own dead weight. Components exposed to wind loads are considered to be loadbearing

3.2 Symbols**3.2.1 General symbols**

A area;

b width of component;

d effective depth or thickness of component;

e eccentricity;

E modulus of elasticity;

f strength;

h depth or thickness of component;

i radius of inertia;

I moment of inertia;

k coefficient, factor;

l length, height of wall component, span length of a roof or floor component;

M bending moment;

N axial compression force;

t time;

V shear force;

γ partial safety factor, confidence level;

ε strain;

σ normal stress;

τ shear stress.

3.2.2 Subscripts

a	anchorage;
c	concrete parameter, compression;
comp	component;
cr	critical;
d	design value;
dry	dry state;
eff	effective value;
fl	flexural;
g	declared value;
h	horizontal;
hum	in the moist state;
k	characteristic value;
M	material;
m	mean, mandrel;
pl	plastic;
R	resistance;
s	steel parameter, shear; drying shrinkage;
t	tension;
u	ultimate (in the ultimate limit state ULS);
w	welded, web (shear reinforcement), weak axis;
y	yield value (for steel);
0	effective value.

3.2.3 Symbols used in this European Standard

a	dimension of a support perpendicular to the plane of the wall, width of a cavity in hollow core components;
A_c	area of the lightweight aggregate concrete section; compression zone of the cross-section;
A_{s1}	area of tension reinforcement;
A_{sw}	area of shear reinforcement;
b	width of component;
b_0	minimum residual cross-sectional width of a slab;

b_w	minimum width of the section over the effective depth, minimum width of the section in the compression zone;
d	design thickness of a pier or wall (for a solid wall $d = h$), effective thickness of a cross-section;
E_{cm}	mean modulus of elasticity of concrete;
E_s	modulus of elasticity of steel;
e_a	additional eccentricity of the longitudinal action due to geometrical imperfections;
e_{cr}	eccentricity e_0 of the vertical action including the geometrical imperfections, for the calculation of N_{cr} it shall be assumed greater than or equal to 1/500 of the wall height;
e_g	declared eccentricity at the top of a vertical component, i.e. the eccentricity used in the operational testing;
e_N	eccentricity of the longitudinal action in the plane of the component;
e_0	first order eccentricity of the longitudinal action determined on the basis of both the vertical and the horizontal actions;
e_t	resulting first order eccentricity perpendicular to the plane of the component, taken as the sum of e_0 and e_a ;
f_{cd}	design value of the compressive strength of LAC;
f_{ck}	characteristic value of the compressive strength of LAC;
$f_{ck,g}$	declared characteristic compressive strength;
$f_{c,n}$	required minimum compressive strength of a test set with $n \geq 6$ test specimens;
$f_{c,3}$	required minimum compressive strength of each test set of three consecutive test specimens;
f_k	characteristic value of strength parameters;
f_{min}	required minimum strength;
$f_{m,n}$	mean value of n strength results;
$f_{t,flk}$	characteristic flexural strength of LAC;
f_u	moisture conversion coefficient;
f_{yd}	design value of the yield strength of the steel;
f_{yk}	characteristic value of the yield strength of the steel;
f_{ywd}	design value of the yield strength of the shear reinforcement;
f_{ywk}	characteristic value of the yield strength of the shear reinforcement;
h	thickness of roof or floor component or beam;
h_1	thickness of the top layer of a hollow core or multilayer slab;
h_2	thickness of the bottom layer of a hollow core or multilayer slab;
h_i	overall depth of the cross-section;
h_w	overall thickness of a component in the direction of the weak axis;

i_c	radius of inertia of the compressive zone of the cross-section;
i_w	radius of inertia in the direction of the weak axis;
I_c	moment of inertia of the compressive zone;
k	factor for the shear strength;
K_n	statistical coefficient for determination of characteristic strength; (λ is used in EN 206-1);
k_s	column factor;
k_{sg}	column factor for operational testing;
k_1	factor for the support strength;
l	span length or height;
l_a	anchorage length;
l_h	horizontal length of a wall;
$l_{h,eff}$	effective horizontal length of a wall;
$l_{h,g}$	declared horizontal length of the component, i.e. the horizontal length of the component used in operational testing;
l_s	shear span (distance of a point load or line load from the axis of the support reaction);
l_0	effective height with respect to buckling;
l_{0g}	declared wall or pier height, i.e. the height used in operational testing;
M_{Rd}	design bending capacity of component;
M_h	bending moment resulting from horizontal actions;
M_{Rk}	characteristic bending capacity of component;
N	axial compression force in the section under consideration;
n	number of test specimens in a sample, number of test results;
N_{cr}	critical axial design compression force determined for the eccentricity e_{cr} ;
N_d	design axial compression force;
N_{Rd}	resisting design axial compression force;
N_{Rg}	declared resisting axial compression force;
N_{Rk}	characteristic resisting axial compression force;
N_{Sd}	design value of axial compression force in the section;
S	slenderness ratio;
S_n	statistical coefficient;
s	spacing of the shear reinforcement bars;
s_n	standard deviation of n test results;

t_0	age at loading;
u	perimeter of a component exposed to surrounding atmosphere (in the case of hollow core slabs without the perimeter of the hollow cores);
V_d	design loadbearing capacity in out-of-plane shear for a joint;
V_r	characteristic loadbearing capacity in out-of-plane shear for a joint;
V_{Rd}	contribution of the LAC to design shear resistance of a wall or pier component;
V_{Rd1}	design shear resistance of a component without shear reinforcement;
V_{Rd2}	design shear crushing resistance (maximum shear force that can be carried without crushing of the notional concrete compressive struts);
V_{Rd3}	design shear resistance of a component with shear reinforcement;
V_{Rk}	characteristic value of shear resistance;
V_{Sd}	design shear force in the section;
V_{wd}	contribution to the design shear resistance from any vertical shear reinforcement;
x	neutral axis depth;
z	height of the shear zone, lever arm of internal forces;
α	reduction factor for long term effects on the compressive strength of LAC;
β	coefficient for the situation of C in the strain diagram according to Figure A.3;
γ_B	partial safety factor for transversely loaded components for brittle failure;
γ_C	partial safety factor for concrete (also for LAC);
γ_{comp}	partial safety factor for component (general);
γ_D	partial safety factor for transversely loaded components for ductile failure;
γ_M	partial safety factor for material (general);
γ_S	partial safety factor for reinforcing steel;
γ_W	partial safety factor for longitudinally loaded components for brittle failure;
ϵ_{cu}	ultimate compressive strain of LAC;
ϵ_s	steel strain;
ϵ_{s0}	basic shrinkage of normal weight concrete according to Table 8;
ϵ_{s1}	strain of tensile reinforcement;
ϵ_{s2}	strain of compression reinforcement;
ϵ_{suk}	characteristic value of ultimate steel strain;
$\epsilon_{s\infty}$	final shrinkage of LAC according to equation (5);
η_1	coefficient according to equation (2);

η_2	coefficient according to equation (4);
η_3	coefficient according to Table 9;
η_4	coefficient according to Table 11;
λ	thermal conductivity;
λ_{dry}	thermal conductivity in the dry state;
$\lambda_{10\text{dry}}$	thermal conductivity in the dry state, determined at a mean test temperature of 10 °C;
λ_{d}	design thermal conductivity in the moist state, at a moisture content μ_{m} ;
μ_{m}	moisture content, related to mass;
ν	efficiency factor (see equation (A.11));
ρ	dry density of LAC;
ρ_1	reinforcement ratio;
ρ_3, ρ_4	reduction factors for design shear capacity in the case of short anchorage length;
σ_{cd}	design value of concrete compressive stress;
σ_{cpl}	concrete compressive stress for plastic distribution;
σ_{d}	design stress;
σ_{td}	design value of tensile stress;
τ_{Rd}	basic shear strength;
τ_{Rk}	characteristic shear strength;
$\varphi(\infty, t_0)$	design value of creep coefficient of LAC according to equation (6);
$\varphi_0(\infty, t_0)$	creep coefficient (of normal weight concrete) according to Table 10;
ϕ	diameter;
ϕ_{m}	diameter of mandrel (see Figure 3);
ϕ_{s}	diameter of reinforcing bar.

3.3 Abbreviations

LC	lightweight concrete;
LWA	lightweight aggregate;
LAC	lightweight aggregate concrete with open structure;
RH	relative humidity;
SLS	serviceability limit state;
ULS	ultimate limit state.

3.4 Units

Units shall be used in accordance with ISO 1000 and ISO 1000 AMD1.

For calculations, the following units are recommended:

- forces and loads: kN, kN/m, kPa (= kN/m^2);
- density: kg/m^3 ;
- unit weight: kN/m^3 ;
- stresses and strengths, modulus of elasticity: MPa (= N/mm^2 or MN/m^2);
- moments (bending...): kNm.

4 Properties and requirements of materials

4.1 Constituents

4.1.1 General

The LWA shall comply with EN 13055-1.

The constituent materials of LAC shall comply with EN 206-1:2000, 5.1.

4.1.2 Release of dangerous substances

The LAC shall not release critical levels of any dangerous substance in its intended use.

The manufacturer shall ensure from suppliers product safety data sheets that the emission of dangerous substances from constituent materials is not higher than defined in Community law and in national provisions applicable in the place of use.

4.2 Reinforcing steel

4.2.1 General

In general the reinforcement in LAC components consists of reinforcing steel (i.e. bars, coiled rods, and welded fabrics).

Reinforcing steel shall comply with prEN 10080-1 (for ribbed bars) or with the relevant clauses of EN 10025 (for plain smooth bars).

4.2.2 Ultimate tensile strength and tensile yield strength

The ultimate tensile strength and the yield strength of the steel shall be declared by the manufacturer of the LAC-component using the results of tests in accordance with EN 10002-1.

A manufacturer purchasing steel with a CE mark or other certificate approved at the place of use of the LAC-component may make his declaration on the basis of the data supplied by the steel producer, provided that the properties of the steel are not changed significantly in the course of the manufacturing process of the LAC-components.

NOTE The properties of the steel can be changed, e. g., by the straightening process when using steel from a coil.

4.3 Lightweight aggregate concrete parameters

4.3.1 Dry density

4.3.1.1 General

The dry density, determined in accordance with EN 992, shall be indicated by the manufacturer, either as a declared mean value or as a declared density class.

4.3.1.2 Declared mean density

The manufacturer may declare the density as a mean value. The tolerances on the declared mean value are specified in Table 1. The declared mean value of dry density of LAC shall be at least 400 kg/m³ and not higher than 2 000 kg/m³.

Table 1 — Tolerances on declared mean value of dry density of LAC

Dry density in kilograms per cubic metre

Declared mean value of dry density	$\leq 1\,000$	$> 1\,000$
Maximum deviation between actual mean value in sample and declared mean value	50	100
Maximum deviation between individual values in sample and declared mean value	100	150

4.3.1.3 Declared density class

The manufacturer may declare the dry density in accordance with the density classes in Table 2. The mean value shall be within the indicated limits, but individual values may be up to 50 kg/m^3 beyond the indicated limits.

Table 2 — Density classes of LAC

Dry density in kilograms per cubic metre

Density class	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4	1,6	1,8	2,0
Mean dry density kg/m^3	≥ 400 ≤ 500	> 500 ≤ 600	> 600 ≤ 700	> 700 ≤ 800	> 800 ≤ 900	> 900 $\leq 1\,000$	$> 1\,000$ $\leq 1\,200$	$> 1\,200$ $\leq 1\,400$	$> 1\,400$ $\leq 1\,600$	$> 1\,600$ $\leq 1\,800$	$> 1\,800$ $\leq 2\,000$

4.3.2 Characteristic strength values

The characteristic value f_k of strength parameters of LAC or LAC components, as compressive strength or flexural strength of the material or the strength from functional testing of components according to annex B, shall be determined from the mean value $f_{m,n}$ and the standard deviation s_n of n test results according to the second line of Table 3. The K_n -values, depending on the number n of test results, shall be taken from Table 4.

Table 3 — Determination of the characteristic strength f_k and required minimum strength $f_{\min}$

Number of results n	$n < 6$	$6 \leq n \leq 9$	$n \geq 10$
f_k	$0,8 f_{m,n}$	$f_{m,n} - K_n \times s_n$	
$f_{\min}$	$\geq 0,90 f_k$	$\geq 0,75 f_k$	$\geq 0,67 f_k$

4.3.3 Compressive strength**4.3.3.1 General**

The compressive strength of LAC shall be indicated by the manufacturer either as declared characteristic compressive strength according to 4.3.3.3 or as a declared strength class according to 4.3.3.4.

4.3.3.2 Characteristic compressive strength

The characteristic compressive strength is derived from the strength of cores with an equal length and diameter or of cubes, both with a minimum dimension of 100 mm, which are taken from prefabricated components and tested according to EN 1354. These are the reference test specimens.

If test specimens with other dimensions extracted from prefabricated components are used for the verification of the compressive strength, the results shall be converted by multiplication by the reduction factors specified in Table 5, unless other factors derived from tests are available.

If moulded test specimens are used, the strength results of these test specimens, converted to the strength of cores with a diameter of 100 mm and equal length (or of 100 mm cubes, giving the same value) shall be at least 1/0,85 times higher than that required from test specimens with the above dimensions extracted from prefabricated components.

For the purpose of conversion, the strength of moulded test specimens shall be multiplied by the conversion factors in Table 6, unless other factors derived from tests are available.

4.3.3.3 Declared characteristic compressive strength

If the manufacturer declares the characteristic compressive strength $f_{ck,g}$, the actual characteristic compressive strength f_{ck} , determined from test results, shall be equal to or greater than the declared value, and the minimum individual value f_{min} shall fulfil the requirements of Table 3. The declared characteristic compressive strength of LAC shall be at least 2 MPa and not higher than 25 MPa.

4.3.3.4 Declared strength class

If the manufacturer declares the compressive strength in terms of a declared strength class, the actual compressive strength determined in accordance with EN 1354 (if appropriate converted to the strength of the reference test specimens, see 4.3.3.2) shall fulfil the requirements of Table 7.

Table 4 — Statistical coefficient K_n for determination of characteristic strength

Number of test results n	K_n
6	1,87
7	1,77
8	1,72
9	1,67
10	1,62
11	1,58
12	1,55
13	1,52
14	1,50
≥ 15	1,48

Table 5 — Reduction factors for compressive strength of cores with equal length and diameter or of cubes with different sizes

Diameter or length mm	Reduction factor
> 100	1,00
90	0,98
80	0,96
70	0,94
60	0,92
50	0,90
40	0,88

Table 6 — Conversion factors for conversion of test results of moulded test specimens to the strength of reference test specimens (drilled cores with 100 mm diameter and equal length or 100 mm cubes)

Shape and size of moulded test specimen	Conversion factor
Cubes - 150 mm	1,00
Cubes - 200 mm	1,05
Cylinders 150 mm/300 mm, depending on strength MPa	
2	1,05
4	1,05
6	1,06
8	1,07
10	1,08
12	1,10
15	1,12
20	1,15
25	1,18

Table 7 — Strength classes and strength requirements for LAC

Compressive strengths in megapascals

Strength class	LAC 2	LAC 4	LAC 6	LAC 8	LAC 10	LAC 12	LAC 15	LAC 20	LAC 25
f_{ck}	2	4	6	8	10	12	15	20	25
$f_{c,3}^a$	≥ 4	≥ 7	≥ 9	≥ 11	≥ 13	≥ 15	≥ 18	≥ 24	≥ 29
$f_{c,n}^b$	$\geq f_{ck} + K_n \times s_n^d$								
f_{cmin}^c for $n < 6$	$\geq 1,5$	$\geq 3,5$	$\geq 5,5$	$\geq 7,0$	$\geq 9,0$	≥ 11	≥ 14	≥ 19	≥ 24
f_{cmin}^c for $6 \leq n \leq 9$	$\geq 1,5$	$\geq 3,0$	$\geq 4,5$	$\geq 6,0$	$\geq 7,5$	$\geq 9,0$	≥ 12	≥ 17	≥ 22
f_{cmin}^c for $n \geq 10$	$\geq 1,5$	$\geq 3,0$	$\geq 4,0$	$\geq 5,5$	$\geq 7,0$	$\geq 8,0$	≥ 11	≥ 16	≥ 21
^a Required mean compressive strength of each test set of three consecutive test specimens. ^b Required mean compressive strength of a test series with $n \geq 6$ test specimens. The K_n-values, depending on the number n of test specimens, shall be taken from Table 4. ^c Minimum individual value of compressive strength of a test series of n test specimens. ^d s_n is the standard deviation of compressive strength of a test series with n test results.									

4.3.4 Flexural strength

The flexural strength may be estimated as follows:

$$f_{t,flk} = 0,42 f_{ck}^{2/3} \times \eta_1 \quad (1)$$

$$\eta_1 = 0,4 + 0,6 (\rho / 2\,200) \text{ for } \rho > 1\,400 \text{ kg/m}^3 \quad (2a)$$

$$\eta_1 = 0,78 \text{ for } \rho \leq 1\,400 \text{ kg/m}^3 \quad (2b)$$

where

$f_{t,flk}$ is the characteristic flexural strength of LAC, in megapascals;

ρ is the mean value of the dry density of LAC, in kilograms per cubic metre;

f_{ck} is the characteristic compressive strength of LAC according to 4.3.3, in megapascals.

The flexural strength may also be obtained by tests according to EN 1521, the characteristic value determined according to 4.3.2.

4.3.5 Stress-strain diagram

The idealised stress-strain diagram for LAC consists of a linear relationship between stress and strain up to a compressive strain of 0,002 at design strength level, continuing at a constant stress level up to the ultimate limit state for the strain, the ultimate strain value depending on the dry density of the LAC (see A.3.2 and Figure A.1).

4.3.6 Modulus of elasticity

The modulus of elasticity may be estimated as follows:

$$E_{cm} = 10\,000 f_{ck}^{1/3} \times \eta_2 \quad (3)$$

where

E_{cm} is the mean value of the modulus of elasticity, in megapascals;

f_{ck} is the characteristic compressive strength according to 4.3.3, in megapascals;

η_2 is a coefficient according to equation (4a) or (4b);

$$\eta_2 = (\rho / 2\,200)^2 \quad \text{for } \rho > 1\,400 \text{ kg/m}^3 \quad (4a)$$

$$\eta_2 = 0,64 (\rho / 2\,200) \quad \text{for } \rho \leq 1\,400 \text{ kg/m}^3 \quad (4b)$$

ρ is the mean value of the dry density, in kilograms per cubic metre.

The modulus of elasticity may also be obtained by testing according to EN 1352.

4.3.7 Poisson's ratio

For design purposes, Poisson's ratio for elastic strains may be taken as 0,2. If cracking is permitted in concrete in tension, Poisson's ratio may be taken as 0,0.

4.3.8 Coefficient of thermal expansion

For design purposes, the coefficient of thermal expansion may be taken as $8 \times 10^{-6} \text{ K}^{-1}$.

4.3.9 Drying shrinkage

The design value of the final drying shrinkage $\varepsilon_{s\infty}$ may be taken as:

$$\varepsilon_{s\infty} = \varepsilon_{s0} \times \eta_3 \quad (5)$$

where

ε_{s0} is the final drying shrinkage of LAC, in millimetres per metre;

ε_{s0} is the basic drying shrinkage of normal weight concrete according to Table 8, in millimetres per metre;

η_3 is a coefficient according to Table 9.

Table 8 — Basic drying shrinkage ε_{s0} of normal weight concrete

Drying shrinkage in millimetre per metre (or per mille)

Location of the component	Relative humidity %	Notional size $2A_c/u$ mm	
		≤ 150	600
Inside	50	0,60	0,50
Outside	80	0,33	0,28

A_c is the net cross-sectional area of concrete (in the case of hollow core slabs excluding the area of the hollow cores), in square millimetres;
 u is the perimeter of the component exposed to surrounding atmosphere (in the case of hollow core slabs excluding the perimeter of the hollow cores), in millimetres.

Table 9 — Coefficient η_3 for evaluation of final drying shrinkage of LAC

Strength class	LAC 2	LAC 4	LAC 6	LAC 8	LAC 10	LAC 12	LAC 15	LAC 20	LAC 25
η_3	2,0	2,0	2,0	1,8	1,8	1,5	1,5	1,2	1,2

In Tables 8 and 9 linear interpolation between the values is permitted. More accurate values may be determined by tests. The shrinkage values obtained on comparison test specimens according to EN 1355:1996, 6.1 and clause 7, may be applied for this purpose.

4.3.10 Creep

The design value of the final creep coefficient $\varphi(\infty, t_0)$ can be calculated as the product of $\varphi_0(\infty, t_0)$ and the coefficients η_2 and η_4 as:

$$\varphi(\infty, t_0) = \varphi_0(\infty, t_0) \eta_2 \eta_4 \quad (6)$$

Where $\varphi_0(\infty, t_0)$ is taken from Table 10, η_2 is calculated from equation (4) and η_4 is taken from Table 11.

Table 10 — Final creep coefficient $\phi_0(\infty, t_0)$ of normal weight concrete

Age at loading t_0	Notional size $2A_c/u$ mm					
	50	150	600	50	150	600
	Dry atmospheric conditions (inside) (RH = 50 %)			Humid atmospheric conditions (outside) (RH = 80 %)		
1	5,5	4,6	3,7	3,6	3,2	2,9
7	3,9	3,1	2,6	2,6	2,3	2,0
28	3,0	2,5	2,0	1,9	1,7	1,5
90	2,4	2,0	1,6	1,5	1,4	1,2
365	1,8	1,5	1,2	1,1	1,0	1,0
A_c is the net cross-sectional area of concrete (in the case of hollow core slabs excluding the area of the hollow cores), in square millimetres; u is the perimeter of the component exposed to surrounding atmosphere (in the case of hollow core slabs excluding the perimeter of the hollow cores), in millimetres.						

Table 11 — Coefficient η_4 for evaluation of the final creep coefficient of LAC

Strength class	LAC 2	LAC 4	LAC 6	LAC 8	LAC 10	LAC 12	LAC 15	LAC 20	LAC 25
η_4	1,8	1,8	1,8	1,5	1,5	1,3	1,3	1,0	1,0

In Tables 10 and 11 linear interpolation between the values is permitted. More accurate values may be obtained by tests according to EN 1355 and may be declared as mean values.

4.3.11 Thermal conductivity

4.3.11.1 General

The thermal conductivity of LAC shall be stated along with the dry density. In the case of multilayer components consisting of different materials the design thermal conductivity and the dry density of each material shall be stated. Design thermal conductivity values may be either calculated from measurements carried out on test specimens or taken from tables and corrected for moisture in accordance with 4.3.11.8.

4.3.11.2 Procedure for determination of dry thermal conductivity by testing

Where tests are carried out, the procedure according to 4.3.11.3 to 4.3.11.6 shall be followed.

4.3.11.3 Test method

The reference test methods are specified in EN 12664, EN 12667 or EN 12939 as relevant. For LAC the mean test temperature shall be 10 °C. Alternative test methods which can require specimens of different size and different conditioning may be used if the correlation between the reference test method and the alternative test method can be given.

4.3.11.4 Test specimens

The test specimens shall be homogeneous. Specimen sizes and requirements as to planeness will depend upon the size of apparatus used and on the thermal conductivity of the material. Test specimens shall contain no reinforcement.

4.3.11.5 Conditioning of test specimens

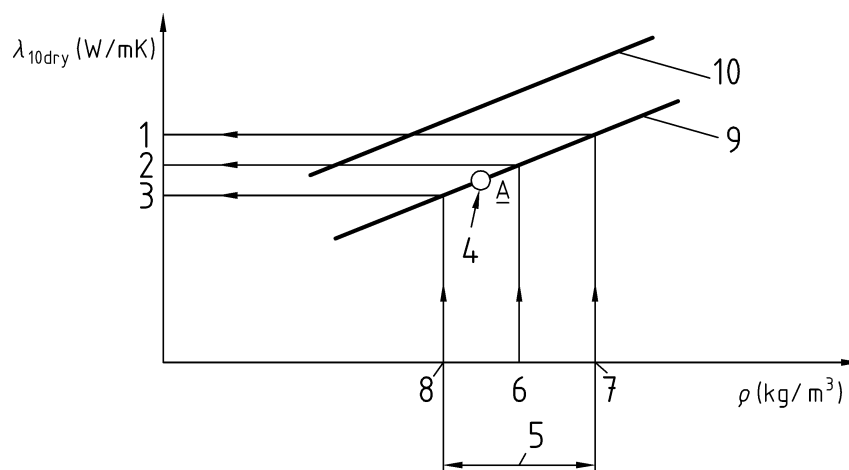
The test specimens shall be conditioned to constant mass at $(23 \pm 2) ^\circ\text{C}$ and $(50 \pm 5) \% \text{RH}$. Constant mass is considered to be obtained when the difference between two consecutive weighings, 24 h apart, does not exceed 0,2 %.

Other test conditions (e.g. oven-dry state) may be used if the correlation between the reference test conditions and the alternative test conditions can be given.

4.3.11.6 Determination of dry mean value and limit values

In order to ensure that the results are representative of current material produced, tests shall be carried out on test specimens selected from three different production batches within the stated density range of the product under consideration. The mean value of the three test results of thermal conductivity shall be calculated and corrected to zero moisture content as indicated in 4.3.11.8. The dry density of each of the three specimens shall be determined in accordance with EN 992, and the mean value of the three results shall be calculated.

A graph of thermal conductivity $\lambda_{10\text{dry}}$ (W/mK) and dry density ρ (kg/m^3) is plotted using the tabulated values given in 4.3.11.7. The mean measured $\lambda_{10\text{dry}}$ value is plotted against the corresponding measured mean dry density (see point A in Figure 1). A curve parallel to the line representing the tabulated values is drawn through this point. From this curve the mean and the limit values of the thermal conductivity can be determined as a function of the mean dry density of the product and the 10 % and 90 % fractile of the manufactured dry product density with a confidence level of $\alpha = 90 \%$ according to EN ISO 10456.



Key

- 1 Upper limit
- 2 Mean value
- 3 Lower limit
- 4 Point A: average of test results
- 5 Manufactured dry density range
- 6 Mean manufactured dry density
- 7 90 % of production
- 8 10 % of production
- 9 Parallel curve through point (A)
- 10 Curve representing tabulated values

Figure 1 — Determination of dry thermal conductivity