BS EN 15191:2009

BSI Standards Publication

Precast concrete products — Classification of glassfibre reinforced concrete performance

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 15191:2009.

The UK participation in its preparation was entrusted to Technical Committee B/524, Precast concrete products.

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.

ISBN 978 0 580 67153 1

ICS 91.100.30

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 August 2010.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 15191

December 2009

ICS 91.100.30

English Version

Precast concrete products - Classification of glassfibre reinforced concrete performance

Produits préfabriqués en béton - Classification des performances des composites ciment-verre

Betonfertigteile - Klassifizierung der Leistungseigenschaften von Glasfaserbeton

This European Standard was approved by CEN on 1 November 2009.

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 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 Management Centre has the same status as the official versions.

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

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

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 15191:2009: E

Contents

Page

Foreword

This document (EN 15191:2009) has been prepared by Technical Committee CEN/TC 229 “Precast concrete products”, 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 June 2010, and conflicting national standards shall be withdrawn at the latest by June 2010.

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

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

Introduction

The classification covers all GRC formulation and production processes.

The properties of GRC depend on:

a) the constituent materials used;

b) the composition of glassfibre reinforced concrete;

c) the production processes.

The classification of GRC is based on the material properties that can be achieved.

1 Scope

This European Standard deals with the classification of glassfibre reinforced concrete. This classification conforms to the needs of the design process of glassfibre reinforced concrete components. This European Standard applies only if EN 1169 is followed.

This standard does not deal with design methods.

2 Normative references

The following referenced documents are indispensable for the application 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 196-1, *Methods of testing cement — Part 1: Determination of strength*

EN 196-2, *Methods of testing cement — Part 2: Chemical analysis of cement*

EN 1170-4, *Precast concrete products — Test method for glass-fibre reinforced cement — Part 4: Measuring bending strength, "Simplified bending test" method*

EN 1170-5, *Precast concrete products — Test method for glass-fibre reinforced cement — Part 5: Measuring bending strength, “Complete bending test” method*

EN 1170-6, *Precast concrete products — Test method for glass-fibre reinforced cement — Part 6: Determination of the absorption of water by immersion and determination of the dry density*

EN 1170-7, *Precast concrete products — Test method for glass-fibre reinforced cement — Part 7: Measurement of extremes dimensional variations due to moisture content*

EN 1170-8, *Test method for glass-fibre reinforced cement — Part 8: Cyclic weathering type test*

EN 1339, *Concrete paving flags — Requirements and test methods*

EN 13198, *Precast concrete products — Street furniture and garden products*

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

EN 14649, *Precast concrete products — Test method for strength retention of glass fibres in cement and concrete (SIC TEST)*

EN 15422, *Precast concrete products — Specification of glassfibres for reinforcement of mortars and concretes*

EN ISO 6946, *Building components and building elements — Thermal resistance and thermal transmittance — Calculation method (ISO 6946:2007)*

ISO 12491:1997, *Statistical methods for quality control of building materials and components*

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

3 Definitions and abbreviations

3.1 Terms and definitions

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

3.1.1
addition
product that may be added by weight or volume/weight to the matrix composition to improve some properties

NOTE 1 An addition can be reactive or inert, mineral or organic.

NOTE 2 Silica fumes are reactive and polymer dispersions are organic.

3.1.2
admixture
product added in quantity less than 5 % by weight), before or during mixing and giving expected modifications to the initial and final properties

NOTE The quantity of admixture is related to the mass of cement. The properties are for example: workability, air content.

3.1.3
AR glassfibre
glassfibre product with a proven resistance to the alkaline environment of matrices made from hydraulic cement

3.1.4
basic strand
glassfibre obtained by stranding a number of filaments having a defined individual diameter

NOTE Number of filaments: typically 100 to 200; individual diameter: typically 10 µm to 30 µm.

3.1.5
roving
number of parallel strands wound together on a mandrel to form uniform cylindrical package size

3.1.6
glassfibre reinforced concrete
GRC
composite material consisting of a matrix reinforced with glassfibres, these materials being compatible

3.1.7
matrix
part of GRC which is not fibres, normally composed of sand, cement, water and any additions and admixtures

3.1.8
spray process
process whereby continuous glassfibres are cut into set lengths and sprayed together with the matrix

NOTE The processes are designed to give a glassfibre reinforced concrete in which the fibres are oriented parallel to the mould surface.

3.1.9
premix process
process whereby chopped strands of glassfibres are blended with the matrix to make a glassfibre reinforced concrete ready for processing

NOTE The processes can be “casting and vibration”, wet spraying, injection, extrusion, etc.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

3.1.10
process with oriented fibres
process whereby chopped strands or roving of glassfibre are placed in the matrix in a defined direction

3.1.11
facing coat
outer surface layer of fine-grained concrete which is often pigmented

3.1.12
SIC test
test method for strength retention of glass fibres in cement and concrete

3.1.13
fibre content
fibre content of glassfibre reinforced concrete is given in percentage by weight and it is related to the total weight of the GRC

3.1.14
limit of proportionality
LOP
bending stress at which the linear-elastic material behaviour becomes plastic in the stress-strain diagram

3.1.15
modulus of rupture
MOR
ultimate bending stress as determined in accordance with EN 1170-4 or EN 1170-5

3.1.16
characteristic property
value of a property above which 95 % of the population of all possible measurements of that property of the specified GRC are expected to lie

3.1.17
acceptance test
test carried out on a predetermined regular basis to confirm that batches of product conform to specification

3.1.18
initial type testing
complete set of tests or other procedures described in the technical specification, to determine the performance of samples of products representative of the product type for the characteristics

3.1.19
cement
hydraulic binder
finely ground inorganic material which, when mixed with water, forms a paste that sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water

NOTE The cement should conform to EN 197-1.

3.1.20
sand
granular mineral material suitable for use in cement or concrete

NOTE Sands may be natural or artificial. The sand should conform to EN 12620.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

3.2 Symbols and abbreviated terms

AR alkali resistant

GRC glassfibre reinforced concrete

LOP limit of proportionality

MOR modulus of rupture

SIC strand in cement

4 Properties of glassfibre reinforced concrete

4.1 Characteristics of composite material

Glassfibre reinforced concrete is a composite material for which the glassfibre has the function of a reinforcement for the cementitious matrix.

The properties of the composite material as manufactured depend on:

a) the properties of the matrix as base;

b) the properties, geometry, quantity and orientation of the glassfibre as reinforcement;

c) the bond between matrix and glassfibre;

d) the manufacturing processes;

e) the conditions and the treatments during production (curing).

4.2 Composition of GRC

The mechanical properties of GRC depend on the mix design and shall be consistent with the product requirements. The mix designs in Table 1 are intended as a guide; mix designs falling outside these values may be acceptable if practical experience is available and the performance has been verified before use.

Table 1 — Basic formulations of GRC

Manufacturing technique		Spray processes	Premix processes
fibre content in weight	%	3,0 to 5,5	1,5 to 3,5
length of AR fibres [a]	mm	≥ 25	≤ 25
water/cement ratio [b]		0,35 ± 0,05	0,37 ± 0,05
sand/cement ratio [c]		0,67 to 2	0,67 to 2
polymer in volume [d]	%	0 το 7	0 to 7

[a] In case of oriented fibres the fibre length depends on the product.

[b] Water/cement ratio: the ratio of the mass of total water to the mass of dry cement in the GRC in the uncured state. When pozzolanic fillers are used they may be considered as cementitious and the water/cement ratio may be expressed as a water/total binder ratio (for examples: such pozzolanic fillers are pulverised fuel ash, micro-silica) and metakaolin. Metakaolin: the rules valid at the place of use therefore apply.

[c] Sand/cement ratio: the ratio of the mass of total dry aggregate to the mass of cement in the GRC.

[d] The values of polymer refer to the dispersion with solid content of 50 %.

4.3 Performance

4.3.1 GRC using spray or premixing processes

The following values are average values.

Table 2 — Performance of GRC using spray processes and premix processes

Manufacturing technique		Spray processes	Premix processes	Test method
Dry density	kg/m^3	1900^{+300}_{-200}	1900^{+300}_{-200}	EN 1170-6
28 day bending strength				EN 1170-5
LOP	MPa	8 ± 2	7 ± 2	
MOR	MPa	20 ± 5	9 ± 3	
Ultimate strain (ε) at MOR	%	0,8 ± 0,2	≥ 0,1	
strength after ageing (50 immersion/drying cycles):				
MOR	MPa	16 ± 4	8 ± 2	EN 1170-8
Ultimate strain (ε) at MOR	%	≥ 0,1	≥ 0,05	EN 1170-5
water absorption at 24 h	%	11 ± 3	11 ± 3	EN 1170-6
shrinkage/swelling	mm/m	1,2 ± 0,3	1,2 ± 0,3	EN 1170-7
modulus of elasticity	MPa			
at 28 days		10 000 to 20 000		
in the long term		15 000 to 25 000		
NOTE Tensile strength is typically 50 % of LOP. This value can be used in absence of any information.				

Table 3 — Additional characteristics

		Performance	Test method
impact resistance	J		
dead impact		> 1 000	
sharp impact		> 10	
fatigue strength		Similar to concrete	
abrasion resistance		Similar to concrete	EN 1339
compressive strength	MPa	40 to 70	EN 196-1
thermal expansion for dry GRC	µm/mK	10 up to 20 in humid condition	
thermal conductivity	W/mK	0,8 to 1	EN ISO 6946
permeability to air and water		Equal or less than concrete	
freeze-thaw resistance		Equal or greater than that of concrete	EN 13198
chemical resistance		Similar to concrete	EN 196-2
reaction to fire		Euroclass A1 or A2	EN 13501-1
sound attenuation for an 8 mm thick sheet	dbA	30	

4.3.2 GRC with oriented fibres

Processes using oriented fibres may result in mechanical properties that differ from the above. The achievable properties depend on the following factors:

a) geometry of the product;

b) direction of the oriented fibres;

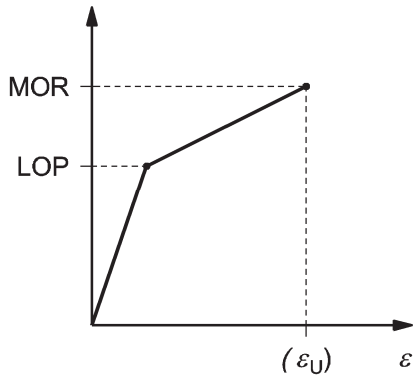
c) position and cross section of the oriented fibres in the product.

In case of oriented fibres, the position of the test pieces in the test according to EN 1170-5 is defined by the orientation of the fibres. In this case the classification of GRC is related to the direction of the fibre in the test.

5 Classification of GRC

5.1 Classification according to mechanical properties

Glassfibre reinforced concrete is classified in accordance with this standard on the basis of the LOP and MOR-values as its material specific properties as determined in accordance with EN 1170-5.



Key
ε Strain
ε_U Ultimate strain

Figure 1 — Stress – strain diagram

5.2 Application-specific values

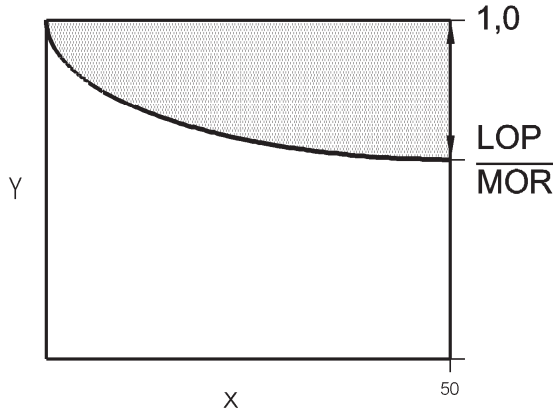
Depending on the application, the MOR-value of GRC exposed to natural weathering can change in long term. This fact is taken into account by the application factor k_2.

For each formula in use, the corresponding k_2 factor is determined by type-test in accordance with EN 1170-8.

For GRC products exposed to natural weathering during their service life, the application factor k_2 can be determined by Equation (1):

$$k_2 = \frac{\mathrm{MOR}_{\text{long term value}}}{\mathrm{MOR}_{28\,\text{days}}} \text{ with } 1{,}0 \geq k_2 \geq \frac{\mathrm{LOP}}{\mathrm{MOR}} \quad (1)$$

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013



Key
X Cycles
Y LOP/MOR

Figure 2 — Value range of k_2 (time related change of MOR due to conditions of use) for different GRC compositions

For GRC products not exposed to natural weathering or any other degrading process and stored in a dry environment, there is no time related change of MOR to be expected.

For this application $k_2 = 1{,}0$.

5.3 Material classes

5.3.1 Classification parameters

The material class of GRC is defined on the basis of the following characteristic values:

a) limit of proportionality (LOP);

b) modulus of rupture (MOR).

The general ranges of these characteristic values are given in Table 4:

Table 4 — Range of characteristic values for the classification of GRC

LOP (MPa)	**MOR** (MPa)							
5	5	8	10					
6		8	10	12	14	16		
7			10	12	14	16	18	20
8				12	14	16	18	20

5.3.2 Specification of the parameters

The characteristic values correspond to the 5 % fractile values with a probability of 95 %. The values are related to test performed on specimens at the age of 28 days.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

The characteristic values (*fc*) defined by the producer refer to his factory production control. The values are obtained by statistical analysis of the test results in accordance with the equation *fc* = *f* – *ks* (see Equations (2) and (3)).

with

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$, standard deviation; (2)

$$f = \frac{1}{n}\sum_{i=1}^{n} x_i$$, arithmetic mean value. (3)

Table 5 — Coefficients k for estimation of the fractile when the population standard deviation (s) is known (see Table 5 of ISO 12491:1997 with γ = 0,75 and p = 0,95); *n* represents the size of the samples

n	3	4	5	6	10	30	50	100
k	2,03	1,99	1,95	1,92	1,86	1,77	1,74	1,71

Examples of GRC denomination:

— GRC 8/18 corresponding to LOP = 8 MPa and MOR = 18 MPa;

— GRC 7/10 corresponding to LOP = 7 MPa and MOR = 10 MPa.

5.4 Application specific parameter

With the application specific parameter k_2 the conditions to which the GRC components will be exposed to at the place of use are considered.

6 Special properties

When further requirements in addition to the materials and application specific requirements of this standard, are made on GRC or a component made thereof, e.g.:

a) resistance to fire;

b) resistance to frost;

c) impermeability to water;

an appropriate proof shall be made as well as in case of other special requirements.

7 Test methods

7.1 Application class

The application specific coefficient k_2 shall be performed in accordance with EN 1170-8, *Test method for glass-fibre reinforced cement — Part 8: Cyclic weathering type test*.

Licensed copy: Lee Shau Kee Library, HKUST, Version correct as of 03/01/2015, (c) The British Standards Institution 2013

7.2 Requirements of glassfibre

The glassfibre shall be performed in accordance with EN 15422, *Precast concrete products — Specification of glassfibres for reinforcement of mortars and concretes* and the test method for strength retention of glassfibre in cement and concrete (SIC TEST) is defined in EN 14649.

NOTE Category A: strength retention by strand (SIC) test ≥ 250 MPa; Category B: strength retention by strand (SIC) test ≥ 350 MPa.

Bibliography

[1] EN 197-1, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*

[2] EN 1169, *Precast concrete products — General rules for factory production control of glass-fibre reinforced cement*

[3] EN 1170-1, *Precast concrete products — Test method for glass-fibre reinforced cement — Part 1: Measuring the consistency of the matrix, "Slump test" method*

[4] EN 1170-2, *Precast concrete products — Test method for glass-fibre reinforced cement — Part 2: Measuring the fibre content in fresh GRC, "Wash out test"*

[5] EN 1170-3, *Precast concrete products — Test method for glass-fibre reinforced cement — Part 3: Measuring the fibre content of sprayed GRC*

[6] EN 1170-4, *Precast concrete products — Test method for glass-fibre reinforced cement — Part 4: Measuring bending strength, "Simplified bending test" method*

[7] EN 12620, *Aggregates for concrete*

This page deliberately left blank

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.

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 bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

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.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 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.

...making excellence a habit.™