BS EN 14227-2:2013

BSI Standards Publication

Hydraulically bound mixtures — Specifications

Part 2: Slag bound granular mixtures

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National foreword

This British Standard is the UK implementation of EN 14227-2:2013. It supersedes BS EN 14227-2:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/510/4, Cementitious bound materials, unbound granular materials, waste materials and marginal materials.

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.

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Foreword

This document (EN 14227-2:2013) has been prepared by Technical Committee CEN/TC 227 “Road materials”, 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of an identical text or by endorsement, at the latest by November 2013, and conflicting national standards shall be withdrawn at the latest by November 2013.

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.

This document supersedes EN 14227-2:2004.

Compared with EN 14227-2:2004, the following changes have been made:

— Changing of the title;

— Revision of Clause 3 "Terms and definitions";

— Revision of Clause 4 "Symbols and abbreviated terms";

— Revision of Clause 5 "Constituents".

This standard is one of a series of parts for EN 14227, *Hydraulically bound mixtures — Specifications:*

— *Part 1: Cement bound granular mixtures*

— *Part 2: Slag bound granular mixtures*

— *Part 3: Fly ash bound granular mixtures*

— *Part 4: Fly ash for hydraulically bound mixtures*

— *Part 5: Hydraulic road binder bound granular mixtures*

— *Part 10: Soil treated by cement*

— *Part 11: Soil treated by lime*

— *Part 12: Soil treated by slag*

— *Part 13: Soil treated by hydraulic road binder*

— *Part 14: Soil treated by fly ash*

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1 Scope

This European Standard specifies slag bound granular mixtures for, roads, airfields, and other trafficked areas, and specifies the requirements for their constituents, composition and laboratory performance classification. In this European Standard slag refers to slag from the iron and steel industry.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 459-1, *Building lime — Part 1: Definitions, specifications and conformity criteria*

EN 933-1, *Tests for geometrical properties of aggregates — Part 1: Determination of particle size distribution — Sieving method*

EN 1097-6:2000, *Tests for mechanical and physical properties of aggregates — Part 6: Determination of particle density and water absorption*

EN 1097-7, *Tests for mechanical and physical properties of aggregates — Part 7: Determination of the particle density of filler — Pyknometer method*

EN 13242, *Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction*

EN 13286-1, *Unbound and hydraulically bound mixtures — Part 1: Test methods for laboratory reference density and water content — Introduction, general requirements and sampling*

EN 13286-2, *Unbound and hydraulically bound mixtures — Part 2: Test methods for laboratory reference density and water content — Proctor compaction*

EN 13286-3, *Unbound and hydraulically bound mixtures — Part 3: Test methods for laboratory reference density and water content — Vibrocompression with controlled parameters*

EN 13286-4, *Unbound and hydraulically bound mixtures — Part 4: Test methods for laboratory reference density and water content — Vibrating hammer*

EN 13286-5, *Unbound and hydraulically bound mixtures — Part 5: Test methods for laboratory reference density and water content — Vibrating table*

EN 13286-40, *Unbound and hydraulically bound mixtures — Part 40: Test method for the determination of the direct tensile strength of hydraulically bound mixtures*

EN 13286-41, *Unbound and hydraulically bound mixtures — Part 41: Test method for the determination of the compressive strength of hydraulically bound mixtures*

EN 13286-42, *Unbound and hydraulically bound mixtures — Part 42: Test method for the determination of the indirect tensile strength of hydraulically bound mixtures*

EN 13286-43, *Unbound and hydraulically bound mixtures — Part 43: Test method for the determination of the modulus of elasticity of hydraulically bound mixtures*

EN 13286-44, *Unbound and hydraulically bound mixtures — Part 44: Test method for the determination of the alpha coefficient of vitrified blast furnace slag*

EN 13286-45, *Unbound and hydraulically bound mixtures — Part 45: Test method for the determination of the workability period of hydraulically bound mixtures*

EN 13286-47, *Unbound and hydraulically bound mixtures — Part 47: Test method for the determination of California bearing ratio, immediate bearing index and linear swelling*

EN 13286-50, *Unbound and hydraulically bound mixtures — Part 50: Method for the manufacture of test specimens of hydraulically bound mixtures using Proctor equipment or vibrating table compaction*

EN 13286-51, *Unbound and hydraulically bound mixtures — Part 51: Method for the manufacture of test specimens of hydraulically bound mixtures using vibrating hammer compaction*

EN 13286-52, *Unbound and hydraulically bound mixtures — Part 52: Method for the manufacture of test specimens of hydraulically bound mixtures using vibrocompression*

EN 13286-53, *Unbound and hydraulically bound mixtures — Part 53: Methods for the manufacture of test specimens of hydraulically bound mixtures using axial compression*

EN 15167-1, *Ground granulated blast furnace slag for use in concrete, mortar and grout — Part 1: Definitions, specifications and conformity criteria*

3 Terms and definitions

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

3.1
hydraulically bound mixture
mixture which sets and hardens by hydraulic reaction

3.2
slag bound granular mixture
hydraulically bound granular mixture whose performance relies on blast-furnace and or steel slag

Note 1 to entry: The mixture may include an activator.

3.3
air-cooled blast furnace slag
aggregate made mainly of crystalline silicates and aluminosilicates of calcium and magnesium, obtained by slow air cooling of molten blast furnace slag

Note 1 to entry: The cooling process may be assisted by the controlled application of water. Air-cooled blast furnace slag hardens by hydraulic reaction and carbonation.

3.4
air-cooled steel slag
aggregate made mainly of crystalline calcium silicates and calcium ferrites comprising CaO, SiO_2, MgO and iron oxides, obtained by slow air cooling of molten steel slag

Note 1 to entry: The cooling process may be assisted by the controlled application of water. Air-cooled steel slag hardens mainly by carbonatic reactions.

3.5
granulated blast furnace slag
vitrified sandy material made up mainly of CaO, SiO_2, Al_2O_3 and MgO, produced generally by rapid water quenching of molten blast furnace slag

Note 1 to entry: Granulated blast furnace slag hardens by hydraulic reaction.

Note 2 to entry: Pelletised and dry granulated blast-furnace slag may have similar hydraulic properties.

3.6
partially ground granulated blast furnace slag
granulated blast furnace slag partially ground in order to increase the proportion of material finer than 0,063 mm

3.7
ground granulated blast furnace slag
granulated blast furnace slag more fully ground in order to further increase the proportion of material finer than 0,063 mm

3.8
slenderness ratio
height to diameter ratio of the specimen

3.9
compacity
ratio of the absolute volume of the solid to the apparent volume of the mixture (see Annex C)

3.10
alpha (α) coefficient
product of the specific surface of the natural elements of the slag smaller than 0,080 mm and the friability where the friability is the percentage of elements smaller than 0,080 mm obtained after grinding according to this European Standard

Note 1 to entry: The α coefficient characterises the reactivity of a fresh vitrified blast furnace slag used for road construction (see EN 13286-44).

4 Symbols and abbreviated terms

For the purpose of this document, the following symbols and abbreviated terms apply.

CBR is the California bearing ratio, expressed in percent (%)

R_c is the compressive strength, expressed in megapascals (MPa)

R_i is the compressive strength after immersion, expressed in megapascals (MPa)

R_t is the direct tensile strength, expressed in megapascals (MPa)

R_{it} is the indirect tensile strength, expressed in megapascals (MPa)

E is the modulus of elasticity, expressed in megapascals (MPa)

E_C is the E determined by compressive strength, expressed in megapascals (MPa)

E_t is the E determined in direct tension, expressed in megapascals (MPa)

E_{it} is the E determined in indirect tension, expressed in megapascals (MPa)

5 Constituents

5.1 Aggregates

Aggregates shall comply with EN 13242.

The properties and the appropriate categories of the aggregates shall be specified in accordance with regulations in the place of use.

Aggregates shall be volumetrically stable. When this is not the case, the use of the mixture shall be permitted provided there is a satisfactory performance record or a thorough laboratory evaluation of the mixture has been carried out in accordance with provisions valid in the place of use.

5.2 Granulated blast furnace slag

When required, the content of SiO_2, Al_2O_3, CaO, MgO and the C.A category in accordance with Annex A (normative) shall be declared.

When required, the alpha coefficient category shall be declared in accordance with Annex A.

5.3 Partially ground granulated blast furnace slag

When required, the content of SiO_2, Al_2O_3, CaO, MgO and the C.A category in accordance with Annex A shall be declared.

When required, the fines content category shall be declared in accordance with Annex A.

When required, the alpha coefficient category (measured before grinding) shall be declared in accordance with Annex A.

5.4 Ground granulated blast furnace slag

Ground granulated blast furnace slag shall conform to EN 15167-1.

5.5 Water

Water shall not contain components that adversely affect the hardening and performance of the slag bound mixture.

5.6 Activators

Activators include quick lime, hydrated lime, gypsum, air-cooled steel slag or other similar products containing lime and/or sulfate.

Quick lime (CaO) or hydrated lime [$Ca(OH)_2$] shall be type CL90 or CL80 in conformity with EN 459-1.

Quick lime shall comply with reactivity R4 or R5 and particle size distribution P1, P2, P3 or P4.

6 Slag bound granular mixtures

6.1 Types

Using the constituents specified in Clause 5, slag bound granular mixture shall be selected from the types and sub-types described in 6.2 to 6.7 and shall conform to the specified requirements for the selected mixture.

6.2 Slag bound granular mixture 1

Granular mixture that contains granulated (or ground or partially ground granulated) blast furnace slag.

The grading of the mixture, determined in accordance with EN 933-1, shall comply with Table 1.

Table 1 — Grading of slag bound granular mixture 1

Column	1	3
Line	**Slag bound granular mixture**	**Grading envelopes**
1	1 – 0/31,5 G1 or G2	Figure 1
2	1 – 0/16	Figure 2
3	1 – 0/8	Figure 3

6.3 Slag bound granular mixture 2

Granular mixture with compacity requirement that contains granulated (or ground or partially ground granulated) blast furnace slag.

The grading of the selected sub-type, determined in accordance with EN 933-1, shall comply with Table 2.

Either category G1 or category G2 of the grading envelopes in Figures 4 to 6 shall be specified.

Compacity shall comply with 6.10.1.

Mixture 2 - 0/10 shall satisfy the immediate bearing index requirement stated in 6.10.2.

Table 2 — Grading of slag bound granular mixture 2

Column	1	2	3
Line	**Slag bound granular mixture**	**Grading category**	**Grading envelopes**
1	2 – 0/20	G1 or G2	Figure 4
2	2 – 0/14	G1 or G2	Figure 5
3	2 – 0/10	G1 or G2	Figure 6

6.4 Slag bound granular mixture 3

Granular mixture that contains granulated (or ground or partially ground granulated) blast furnace slag with a maximum nominal size of D equal or less than 6,3 mm and with an immediate bearing index requirement.

Slag bound granular mixture 3 shall be a mixture with a maximum nominal size of D equal or less than 6,3 mm with an immediate bearing index requirement.

The grading of the mixture, determined in accordance with EN 933-1, shall comply with Table 3.

The immediate bearing index category shall be selected from 6.10.2.

Table 3 — Grading of slag bound granular mixture 3

Column	1	2	3	4
Line	**Sieve** mm	$2D$	D	0,063
1	Percentage of mixture passing by mass	100	≥85	≤35

6.5 Slag bound granular mixture 4

Granular mixture with manufacturer declared value for the grading including declared upper and lower limits and, when required, an immediate bearing index category selected from Table 5.

The grading of the mixture shall be determined in accordance with EN 933-1.

6.6 Slag bound granular mixture 5

Granular mixture that contains granulated (or ground or partially ground granulated) blast furnace slag.

The grading of the mixture when tested in accordance with EN 933-1 shall comply with Table 4.

When required, the immediate bearing index category shall be selected from Table 5.

Table 4 — Grading of slag bound granular mixture 5

Sieve mm	**Percentage of mixture passing by mass**	
	Minimum	**Maximum**
45	100	100
31,5	75	100
16	50	100
8	35	100
4	25	100
2	15	100
0,5	5	75
0,25	3	60
0,063	0	25

6.7 Examples of slag bound granular mixture

Examples of slag bound granular mixtures are given in Annex B.

NOTE The examples are not exhaustive, nor the proportions intended to be restrictive, but they illustrate the current use in Europe.

6.8 Water content of mixtures

The water content shall be selected to permit compaction on site by rolling and to optimise the mechanical performance of the mixture. The water content shall be determined by the Proctor test or other method in accordance with EN 13286-1, EN 13286-2, EN 13286-3, EN 13286-4 and EN 13286-5 ,and limits set to give a workable range of water content on site compatible with the compaction and the desired mechanical performance of the mixture.

6.9 Proportioning of the constituents, grading and dry density for mixtures

The proportioning of the constituents, expressed as a percentage by dry mass of the total dry mass of the mixture, the target grading, including lower and upper limits, if required, and the dry density of the mixture, shall be declared. The declared proportions shall be based on the laboratory mixture design and/or practical experiences with mixtures produced with the same constituents and under the same conditions in a way that the mixture complies with the requirements of this European Standard.

Irrespective of the binder content necessary to fulfil the strength requirements of this European Standard, the binder content should normally not be less than a minimum value fixed by provisions valid at the place of use to ensure adequate distribution of the binder throughout the mixture.

6.10 Other requirements for fresh mixtures

6.10.1 Compacity

In the case of slag bound granular mixture 2, the minimum compacity of the mixture at the maximum modified Proctor dry density shall be 0,80 in accordance with Annex C (normative).

6.10.2 Immediate bearing index

Mixture 2-0/10 shall comply with immediate bearing index category IPI_{50} from Table 5.

For mixture 3, and when required for mixtures 4 and 5, the appropriate IPI category shall be selected from Table 5.

The immediate bearing index of the mixture shall be determined in accordance with EN 13286-47 using modified Proctor compaction.

Table 5 — Immediate bearing index categories

Column	1	2
Line	**Immediate bearing index requirement**	**Immediate bearing index category**
1	Declared value	IPI_{DV}
2	≥ 50	IPI_{50}
3	≥ 40	IPI_{40}
4	≥ 25	IPI_{25}
5	No requirement	IPI_{NR}

Mixtures with an immediate bearing index less than 40 may not support immediate trafficking and should be used with care. The addition of another aggregate can be necessary to achieve the immediate bearing index required for immediate use.

6.10.3 Workability period

When required, the workability period, determined in accordance with EN 13286-45, shall be declared.

7 Laboratory mechanical performance classification

7.1 General

The laboratory mechanical performance shall be characterised and classified by one of the following three methods:

— by California bearing ratio test;

— by compressive strength R_c;

— by the combination R_t, E of tensile strength R_t and modulus of elasticity E.

NOTE No correlation is intended nor should be assumed between the three methods.

7.2 Classification by California bearing ratio

Slag bound mixtures shall be classified by both:

— immediate California bearing ratio (CBR_0);

— ΔCBR after 28 days (or 91 days, see last paragraph of this clause), calculated in accordance with the following formula:

$$\Delta CBR_{28} = ((CBR_{28} - CBR_0)/CBR_0) \times 100\ \% \quad (1)$$

where

ΔCBR_{28} is the percentage change in California bearing ratio after 28 days, in percent (%);

CBR_{28} is the California bearing ratio value after 28 days;

CBR_0 is the immediate California bearing ratio value.

The determination of California bearing ratio value shall be carried out in accordance with Annex D (normative).

The California bearing ratio class shall be selected from Table 6.

Table 6 — California bearing ratio classification

Column	1	2	3
Line	**CBR_0 %**	**ΔCBR_{28} %**	**Class**
1	≥ 50	≥ 25	$CBR_{50/25}$
2	≥ 30	≥ 25	$CBR_{30/25}$
3	≥ 50	≥ 35	$CBR_{50/35}$
4	≥ 30	≥ 35	$CBR_{30/35}$
5	≥ 50	≥ 50	$CBR_{50/50}$
6	≥ 30	≥ 50	$CBR_{30/50}$

In the case that ΔCBR after 28 days does not fulfil the requirements of the chosen California bearing ratio test class, ΔCBR after 91 days or earlier shall be determined. After this time, ΔCBR shall fulfil the ΔCBR_{28} requirement.

7.3 Classification by compressive strength

Mixtures shall be classified by compressive strength determined in accordance with EN 13286-41 carried out on specimens manufactured in accordance with EN 13286-50, EN 13286-51, EN 13286-52 and EN 13286-53.

The class of compressive strength shall be selected from Table 7 in combination with the selected method of specimen manufacture.

NOTE The permitted methods of specimen manufacture realise different specimen shapes and density, and thus for the same mixture, different strengths. Hence, it is important, on the basis of experience and utilisation, not to separate strength from the method of specimen manufacture.

The age of classification and curing conditions shall be specified in accordance with practice at the place of use.

For characterisation or mixture design testing in the laboratory, compressive strength shall be the average result from at least three specimens. If one value varies by more than 20 % of the average, it shall be discarded and R_c taken as the average of the other values.

Table 7 — Compressive strength classification

Column	1	2	3
Line	**Minimum R_c for cylinders of slenderness ratio 2**[a] MPa	**Minimum R_c for cylinders of slenderness ratio 1**[a] **and cubes** MPa	**R_c Class**
1	0,4	0,5	$C_{0,4/0,5}$
2	0,8	1	$C_{0,8/1}$
3	1,5	2	$C_{1,5/2}$
4	2,3	3	$C_{2,3/3}$
5	3	4	$C_{3/4}$
6	4	5	$C_{4/5}$
7	5	6	$C_{5/6}$
8	6	8	$C_{6/8}$
9	8	10	$C_{8/10}$
10	9	12	$C_{9/12}$
11	12	16	$C_{12/16}$
12	15	20	$C_{15/20}$
13	18	24	$C_{18/24}$
14	21	28	$C_{21/28}$
15	24	32	$C_{24/32}$
16	27	36	$C_{27/36}$
17	30	40	$C_{30/40}$
18	33	44	$C_{33/44}$
19	36	48	$C_{36/48}$
20	Declared value	Declared value	C_{DV}

[a] If cylinders with slenderness ratios other than 1 or 2 are used, then the correlation with cylinders of either slenderness ratio 1 or 2 shall be established before use.

7.4 Classification by R_t, E

7.4.1 General

Mixtures shall be classified by the combination of tensile strength R_t and modulus of elasticity E, designated R_t, E.

The class of R_t, E shall be selected from Figure 7.

The age of classification and curing conditions shall be specified in accordance with practice at the place of use.

For characterisation or mixture design testing in the laboratory, R_t and E shall be the average result from at least three specimens. If one value varies by more than 20 % of the average, it shall be discarded and R_t and E taken as the average of the other values.

R_t and E shall be established using one of the equivalent methods outlined in 7.4.2 to 7.4.4.

7.4.2 Method by direct tensile testing

R_t shall be determined in accordance with EN 13286-40.

E shall be determined in direct tension E_t in accordance with EN 13286-43.

For both, specimens shall be manufactured using vibrocompression in accordance with EN 13286-52.

7.4.3 Method by indirect tensile testing

R_t shall be derived from R_{it} determined in accordance with EN 13286-42 using the relationship $R_t = 0{,}8\ R_{it}$.

E shall be derived from E_{it} (E measured in indirect tension) determined in accordance with EN 13286-43 using the relationship $E = E_{it}$.

Specimens shall be manufactured using:

— either Proctor compaction for both in accordance with EN 13286-50;

— or vibrating hammer for both in accordance with EN 13286-51;

— or vibrocompression for both in accordance with EN 13286-52;

— or axial compression for both in accordance with EN 13286-53.

NOTE The permitted methods of specimen manufacture realise different specimen shapes and density, and thus for the same mixture, different strengths. Hence, it is important, on the basis of experience and utilisation, not to separate strength from the method of specimen manufacture.

7.4.4 Method by indirect tensile and compression testing

R_t shall be derived from R_{it} determined in accordance with EN 13286-42 using the relationship $R_t = 0{,}8\ R_{it.}$

E shall be derived from E_c (E measured in compression) determined in accordance with EN 13286-43 using the relationship $E = E_c$.

Specimens shall be manufactured using:

— either Proctor compaction for both in accordance with EN 13286-50;

— or vibrating hammer for both in accordance with EN 13286-51;

— or vibrocompression for both in accordance with EN 13286-52;

— or axial compression for both in accordance with EN 13286-53.

NOTE The permitted methods of specimen manufacture realise different specimen shapes and density, and thus for the same mixture, different strengths. Hence, it is important, on the basis of experience and utilisation, not to separate strength from the method of specimen manufacture.

8 Other requirements for the mixture

8.1 Strength after immersion in water

When required, the mixture shall satisfy the selected category for strength after immersion from Table 8.

In Table 8, R_i shall mean the average strength of not less than 3 specimens after Z days sealed curing followed by W days full immersion curing in aerated water, and R shall mean the average strength of not less than 3 specimens after (Z + W) days sealed curing. All the specimens shall be manufactured from the same batch of mixture, using the same method of manufacture, and shall be cured at the same temperature. Z and W shall be specified in accordance with the practice and requirements at the place of use.

Table 8 — Strength after immersion categories for the mixture

R_i/R **ratio**	**Category**
No requirement	I_{NR}
$>$ 0,6	$I_{0,6}$
$\geq$ 0,7	$I_{0,7}$
$>$ 0,8	$I_{0,8}$
Declared value	I_{DV}

8.2 Other characteristics

Where appropriate, other characteristics, such as frost resistance, shall be examined in accordance with the provisions valid in the place of use.

9 Production control

See informative Annex E.

10 Designation and description

10.1 Designation

The product shall be designated by:

a) manufacturer code of the mixture formulation;

b) reference to this European Standard;

c) manufacturer and place of production;

d) type and characterisation of the slag bound granular mixture (e.g. slag bound granular mixture 2 – 0/20 – G2 – T3).

10.2 Description

The product shall be described by:

a) description of the constituents;

b) mixture proportions (in % by mass);

c) method of manufacture, curing mode and period, and testing of specimens;

d) dry density of the specimens;

e) laboratory mechanical performance values;

f) other declared characteristics.

11 Marking and labelling

The delivery ticket shall contain at least the following:

a) name of manufacturer or supplier;

b) reference to this standard;

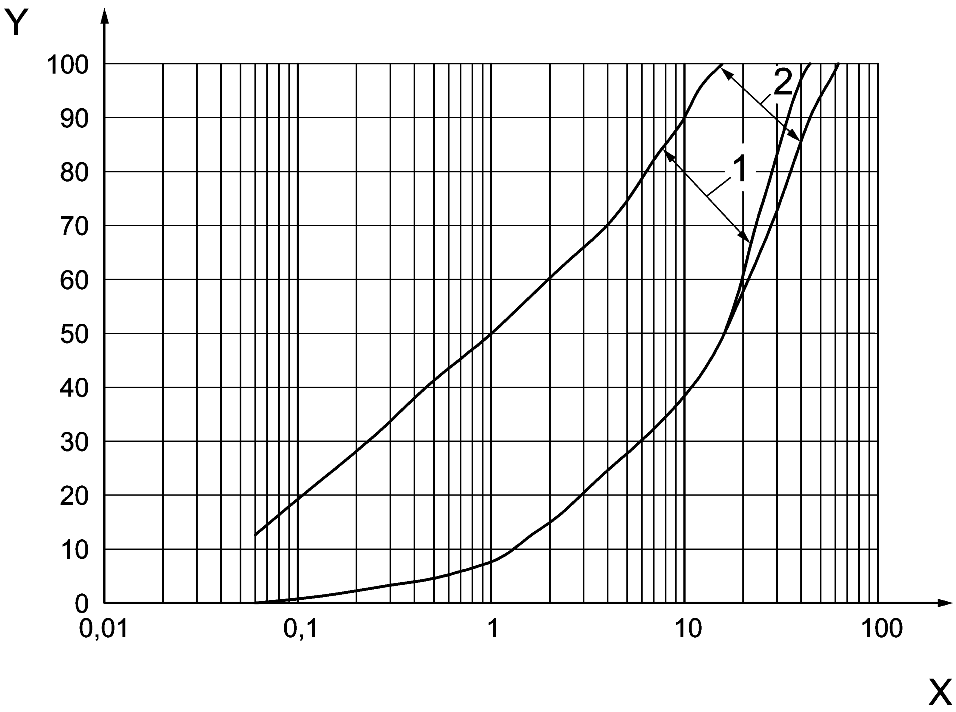
c) designation;

d) date of dispatch;

e) quantity;

f) serial number of the ticket.

12 Figures



Key

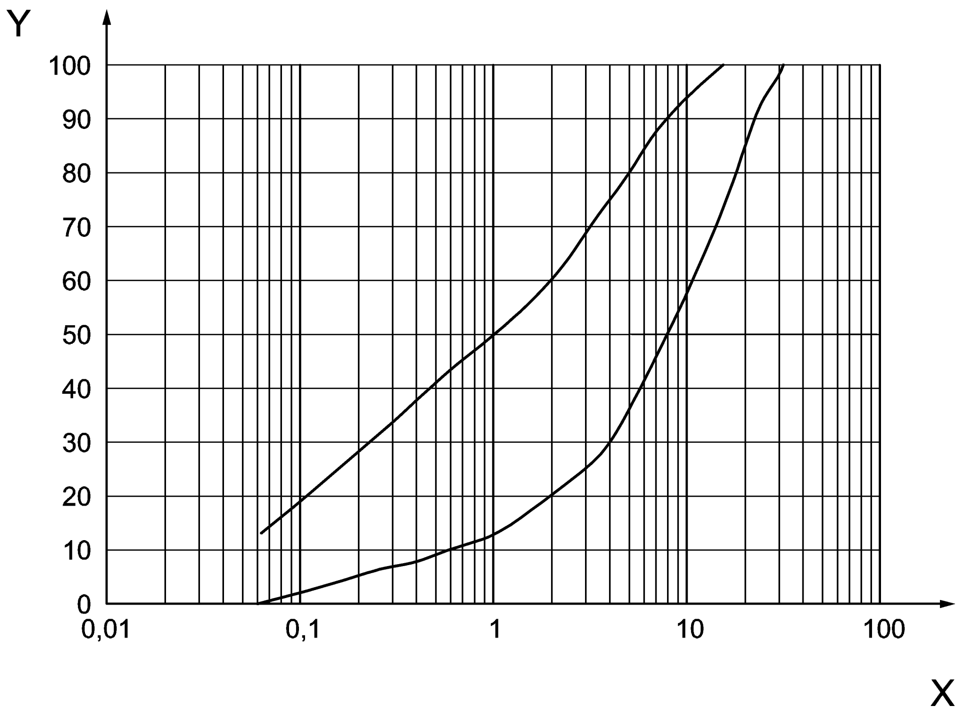
X sieve size, in mm
Y percentage of the mixture passing by mass
1 category G1
2 category G2

See Table 9.

Figure 1 — Grading requirements for slag bound granular mixture 1-0/31,5

Table 9

Sieve mm	**Percentage of the mixture passing by mass**		
	Minimum Category G1	**Minimum Category G2**	**Maximum**
63	100	100	100
45	100	90	100
31,5	85	75	100
16	50	50	100
8	35	35	85
4	25	25	70
2	15	15	60
1	8	8	50
0,5	5	5	41
0,25	3	3	31
0,063	0	0	13



Key

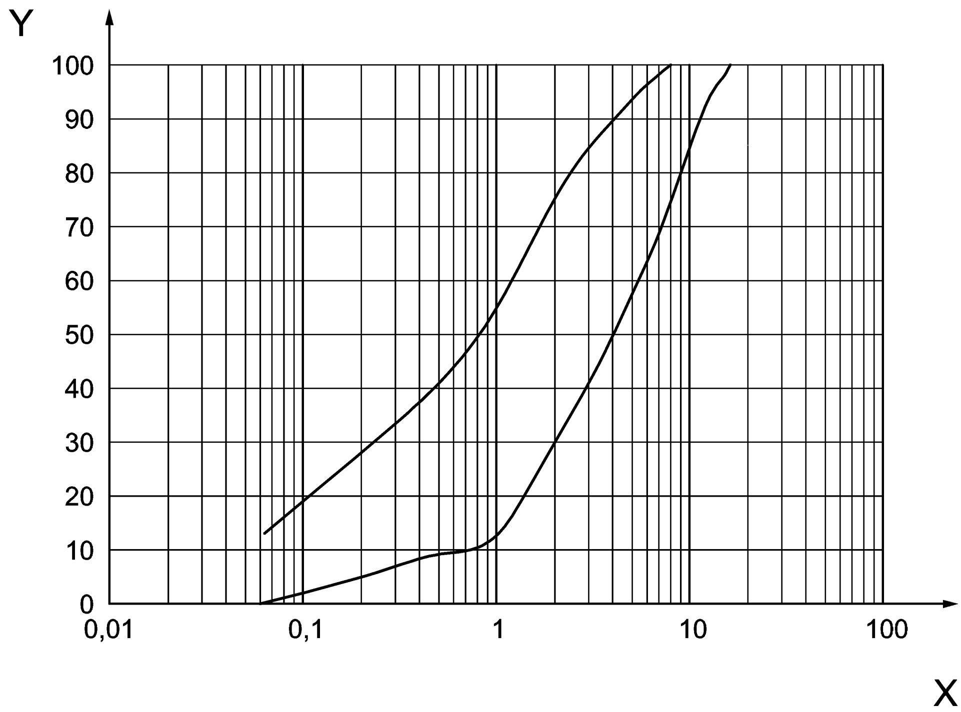
X sieve size, in mm
Y percentage of the mixture passing by mass

See Table 10.

Figure 2 — Grading requirements for slag bound granular mixture 1-0/16

Table 10

Sieve mm	**Percentage of the mixture passing by mass**	
	Minimum	**Maximum**
31,5	100	–
22,4	90	100
16	75	100
8	50	90
4	30	75
2	20	60
1	13	50
0,500	9	41
0,250	6	31
0,063	0	13



Key

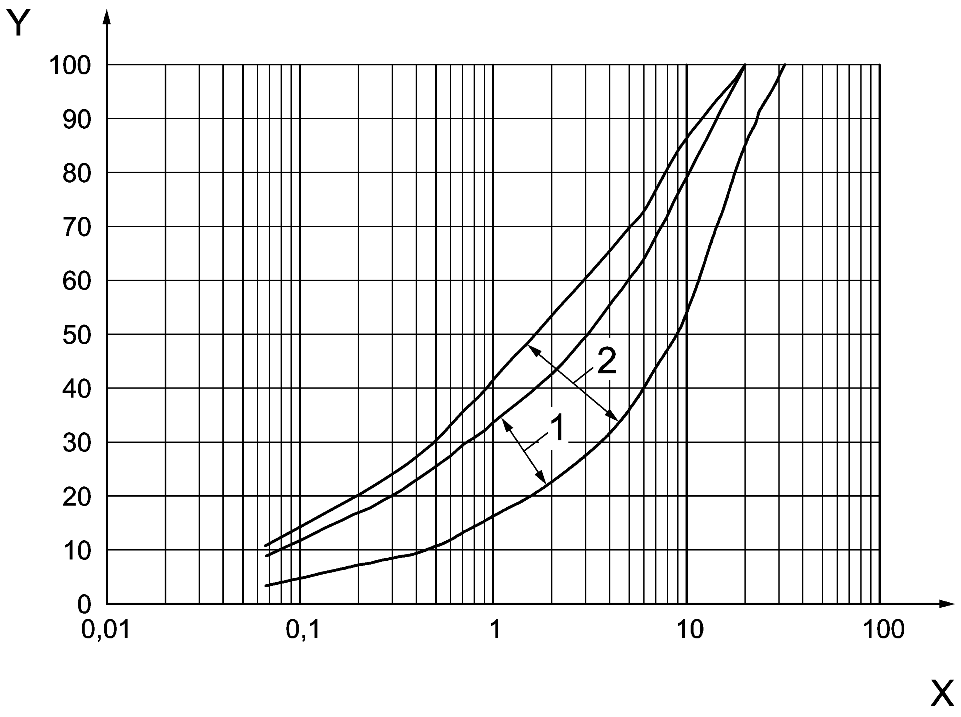
X sieve size, in mm
Y percentage of the mixture passing by mass

See Table 11.

Figure 3 — Grading requirements for slag bound granular mixture 1-0/8

Table 11

Sieve mm	**Percentage of the mixture passing by mass**	
	Minimum	**Maximum**
16	100	—
11,2	90	100
8	75	100
4	50	90
2	30	75
1	13	55
0,500	9	41
0,250	6	31
0,063	0	13



Key

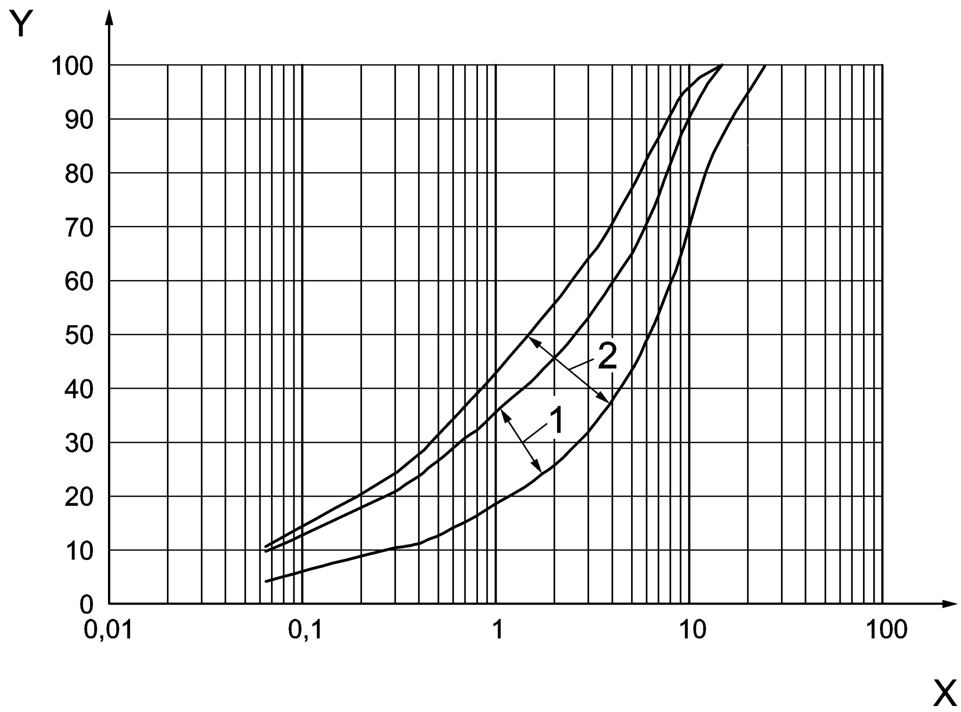
X sieve size, in mm
Y percentage of the mixture passing by mass
1 category G1
2 category G2

See Table 12.

Figure 4 — Grading requirements for slag bound granular mixture 2 – 0/20

Table 12

Sieve mm	**Percentage of the mixture passing by mass**		
	Minimum	**Maximum Category G1**	**Maximum Category G2**
31,5	100		
20	85	100	100
10	55	80	87
6,3	42	66	75
4	32	56	66
2	23	43	54
0,5	11	26	31
0,25	8	19	23
0,063	3,5	9	11



Key

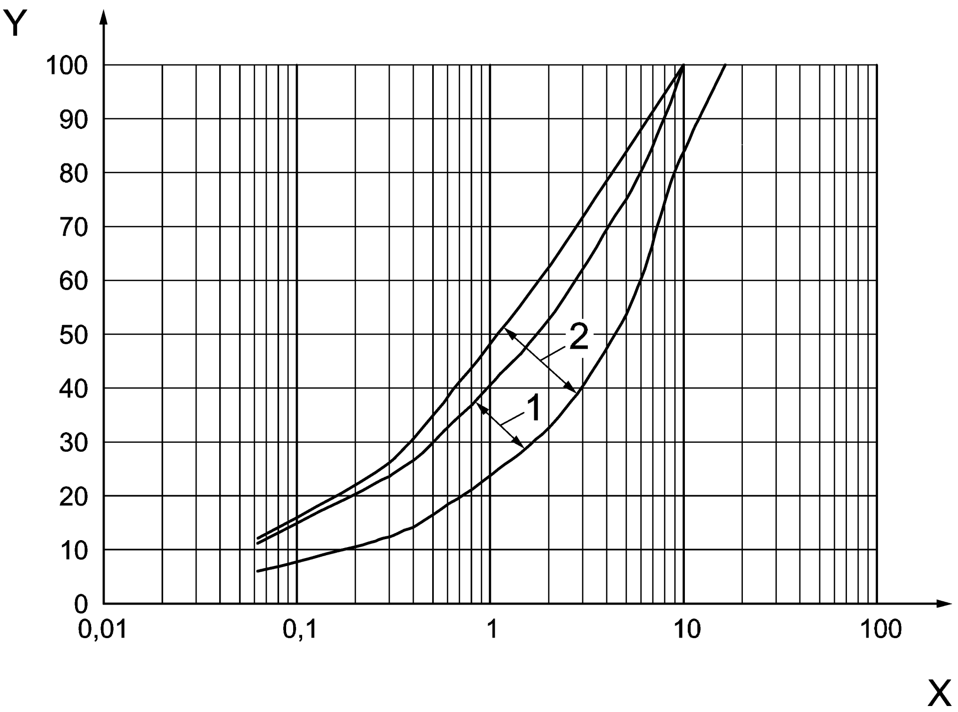
X sieve size, in mm
Y percentage of the mixture passing by mass
1 category G1
2 category G2

See Table 13.

Figure 5 — Grading requirements for slag bound granular mixture 2 – 0/14

Table 13

Sieve mm	**Percentage of the mixture passing by mass**		
	Minimum	**Maximum Category G1**	**Maximum Category G2**
25	100		
14	85	100	100
10	68	90	97
6,3	50	72	84
4	38	60	71
2	26	46	56
0,5	13	27	32
0,25	10	20	23
0,063	4,5	10	11



Key

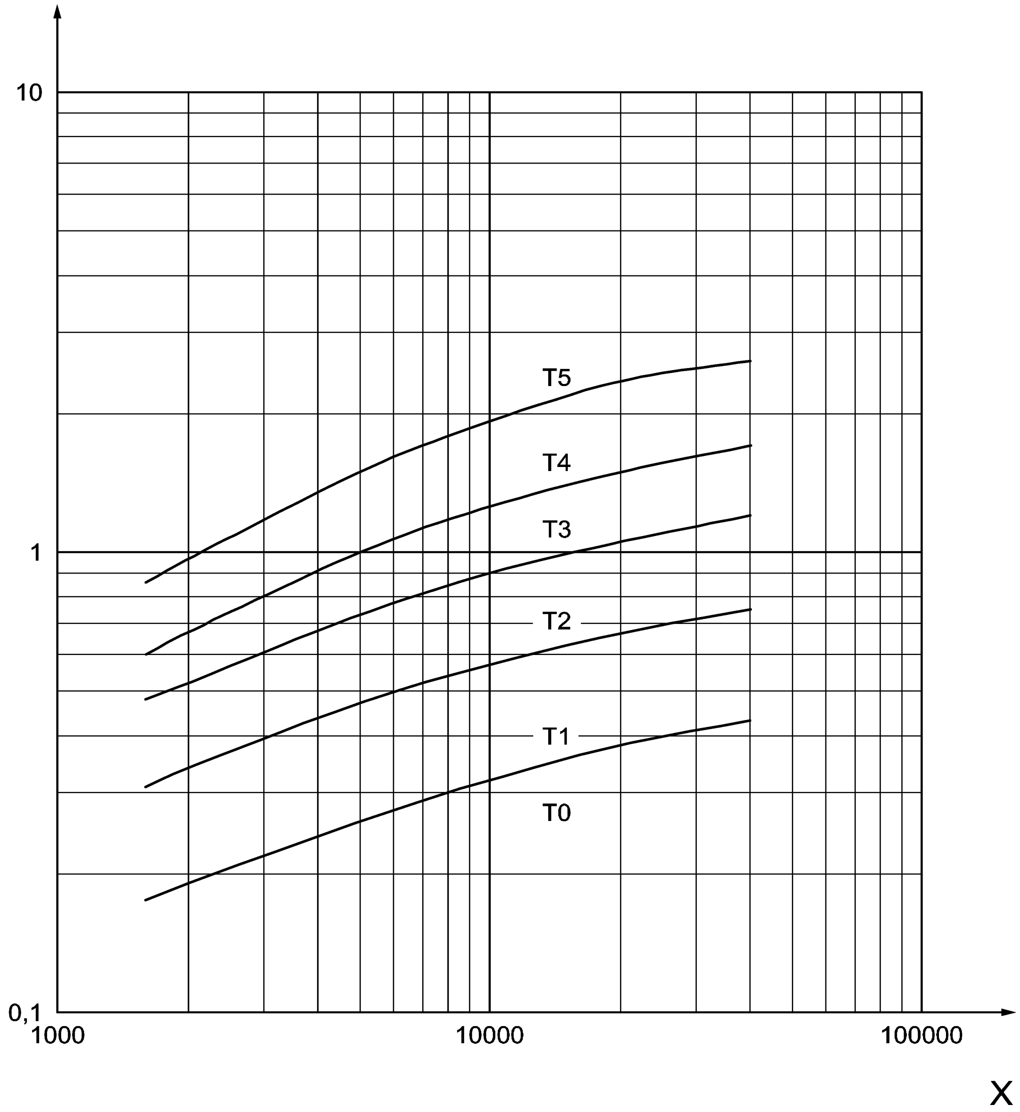
X sieve size, in mm
Y percentage of the mixture passing by mass
1 category G1
2 category G2

See Table 14.

Figure 6 — Grading requirements for slag bound granular mixture 2 – 0/10

Table 14

Sieve mm	**Percentage of the mixture passing by mass**		
	Minimum	**Maximum Category G1**	**Maximum Category G2**
16	100		
10	85	100	100
6,3	62	83	91
4	48	71	81
2	33	54	64
0,5	17	31	36
0,25	12	23	25
0,063	6,5	12	13



Key

Y direct tensile strength R_t, in MPa
X elastic modulus E, in MPa

See Table 15.

Figure 7 — Classification by R_t, E

Table 15

E MPa	**2 000**	**5 000**	**10 000**	**20 000**	**40 000**
Low limit of category	R_t MPa				
T5	0,97	1,50	1,93	2,35	2,60
T4	0,67	1,00	1,26	1,49	1,70
T3	0,52	0,73	0,90	1,05	1,20
T2	0,34	0,47	0,57	0,67	0,75
T1	0,19	0,26	0,32	0,38	0,43
NOTE The Table gives the values of R_t and E used to draw the curves limiting the categories T5, T4, T3, T2 and T1.					

Annex A
(normative)

Hydraulic activity of granulated and partially ground granulated blast furnace slag

A.1 Hydraulic activity

The hydraulic activity of granulated blast furnace slag is a function of chemical composition, activators and fines contents. An increase in fines content can increase the reactivity of slag considered relatively un-reactive because of chemical composition.

A.2 C.A product

In terms of chemical composition, the important factor is the C.A product, where C is the CaO content and A the Al_2O_3 content. The higher the C.A product the more reactive the slag. Typically there are three categories based on C.A product:

Table A.1 — Categories of C.A products

Column	1	2
Line	**C.A product**	**Category**
1	> 550	CA 1
2	425 to 550	CA 2
3	< 425	CA 3

A.3 Alpha coefficient of granulated blast furnace slag

The proportion of fines in a compacted slag bound granular mixture using granulated blast furnace slag is a function of the friability of the granulated blast furnace slag. The softer the slag, the more the production of fines under the roller, and the more reactive the slag. The friability of granulated blast furnace slag is assessed by determination of its alpha coefficient in accordance with EN 13286-44. The lower the alpha coefficient the less friable the granulated blast furnace slag. The classification is as follows:

Table A.2 — Categories of alpha coefficient

Column	1	2
Line	**Alpha coefficient**	**Category**
1	< 20	α 1
2	20 to 40	α 2
3	40 to 60	α 3
4	> 60	α 4

A.4 Fines content of partially ground granulated blast furnace slag

Fines can also be produced by partial grinding of granulated blast furnace slag. There are four categories based on the “finer” than 0,063 mm content (called “fines”) determined in accordance with EN 933-1.

Table A.3 — Categories of fines content

Column	1	2
Line	**Fines** %	**Category**
1	1 to < 5	PG 1
2	≥ 5 to < 8	PG 2
3	≥ 8 to < 14	PG 3
4	≥ 14	PG 4

Annex B
(informative)

Examples of slag bound granular mixtures

Table B.1 — Examples of slag bound granular mixtures

Slag bound granular mixture type	Constituents (illustrative proportions as a percentage by dry mass of the mixture)			
	Air-cooled blast furnace slag	**Air-cooled steel slag**	**Granulated blast furnace slag**	**Other constituent**
SBGM 1, 4 & 5	—	—	5 % to 12 % includes activator[a]	88 % to 95 % aggregate
SBGM 1: 0/16, 0/31,5	—	2 % to 25 %	2 % to 20 %	70 % to 90 % aggregate
SBGM 1: 0/16, 0/31,5	40 %	40 %	20 %	—
SBGM 1: 0/8, 0/16	15 %	15 %	70 %	—
SBGM 1: 0/16	—	50 %	50 %	—
SBGM 2	—	—	10 % to 25 % includes activator[b]	75 % to 90 % aggregate
SBGM 2 & 3	—	—	10 % to 15 % includes activator[c]	85 % to 90 % aggregate
SBGM 55: 0/31,5	100 %	—	—	—
SBGM 55: 0/16, 0/31,5	—	100 %	—	—
SBGM 55: 0/31,5	75 %	25 %	—	—
SBGM 55: 0/16	50 %	—	50 %	—
SBGM 55: 0/16	—	—	50 %	50 % aggregate
SBGM 55: 0/8, 0/31,5	—	80 % to 85 %	10 % to 15 %	—
SBGM 55: 0/31,5	80 % – 90 %	0 to 20 %	0 to 20 %	—

NOTE The examples are not exhaustive, nor the proportions intended to be restrictive, but they illustrate the current use in Europe.

a 3,5 % to 10,5 % ground granulated blast-furnace slag with, typically, 1,5 % to 2,5 % lime.

b 9 % to 24 % granulated blast furnace slag with, typically, 1 % lime or 1 % sulfate-lime.

c 9 % to 14 % partially ground granulated blast furnace slag with, typically, 1 % sulfate-lime.

Annex C
(normative)

Compacity of a slag bound granular mixture 2

The compacity before setting of a slag bound granular mixture 2 shall be defined as the value of the ratio:

— absolute volume of solid/apparent volume of the mixture.

This shall be calculated by the following formula:

$$C = (\gamma m/100) \times (a/\gamma A + b/\gamma B + c/\gamma C \ldots) \qquad \text{(C.1)}$$

where

C is the compacity;

γm is the maximum dry density of the mixture, in megagrams per cubic metre (Mg/m^3);

γA is the particle density of the constituent A, in megagrams per cubic metre (Mg/m^3);

γB is the particle density of the constituent B, in megagrams per cubic metre (Mg/m^3);

γC is the particle density of the constituent C, in megagrams per cubic metre (Mg/m^3);

a is the constituent A content in mass related to the mixture, in percent (%);

b is the constituent B content in mass related to the mixture, in percent (%);

c is the constituent C content in mass related to the mixture, in percent (%).

The particle density of the constituents (γA, γB, γC, ...) shall be determined according to EN 1097-6:2000, Annex A, (pre-dried particle density) or EN 1097-7, depending upon their particle size.

For example, the compacity at the maximum modified Proctor dry density of the mixture described below shall be calculated as follows:

Table C.1

Column	1	2	3	4
Line	**Constituent**	%	**Particle density** Mg/m³	
1	Coarse aggregate 6,3/20	49	γA	2,69
2	Fine aggregate 0/6,3	38	γB	2,65
3	Partially ground granulated blast furnace slag	12	γC	2,78
4	Activator	1	γD	2,61
5	Maximum modified Proctor dry density of the mixture, Mg/m^3		γm	2,19
$C = (2{,}19/100) \times (49/2{,}69 + 38/2{,}65 + 12/2{,}78 + 1/2{,}61) = 0{,}82$				

Annex D
(normative)

CBR value of slag bound granular mixtures

D.1 Sampling and preparation of the test samples

The sample, sufficient to manufacture 15 specimens after sieving on a 22,4 mm sieve, shall be dried in an oven at a temperature of (60 ± 5) °C, or other appropriate temperature depending on the composition of the mixture, or air dried at room temperature. It shall be sieved on the 22,4 mm sieve. The material passing this sieve shall be mixed to obtain a homogeneous mixture. This material shall be divided into 10, or if necessary, 15 representative samples, each with enough mass for one CBR test.

D.2 Specimen manufacture and curing

A sample shall be placed in the mixing bowl. Water shall be added to attain the estimated optimum moisture content as described for the one point Proctor compaction in EN 13286-2. Mix the material and water thoroughly using the scoop until a homogeneous mixture is obtained.

Using the procedure in EN 13286-47, the mixed material shall be compacted in a Proctor mould B using rammer A as defined in EN 13286-2 in three equal layers. The surface of each layer shall be given 56 blows with the rammer falling freely from a height of (305 ± 5) mm.

With each sample, a test specimen shall be prepared in the same way as described above.

Using 5 specimens and surcharge of (5,8 ± 0,2) kg, the immediate CBR value, CBR_O, (see 7.2) shall be determined as described in EN 13286-47 immediately after preparation of the specimen and reported to the nearest 1 %.

The remaining 10 specimens shall be cured at (20 ± 2) °C using method a) in EN 13286-47.

After 28 days and or 91 days and using 5 specimens for testing at each age, the CBR value shall be determined as described above.

D.3 Calculation and expression of results

Calculate the CBR values after 0 days, 28 days and/or 91 days as the mean value of the five specimen results to the nearest 1 %. Calculate the increase of the CBR value after 28 days and/or 91 days or earlier as described in 7.2 to the nearest 1 %.

Annex E
(informative)

Production control for slag bound granular mixtures

E.1 General

This annex describes the recommendations for a production control system for manufacturers of hydraulically treated mixtures (e.g. aggregates and soils treated by lime, hydraulic binders or hydraulic combinations).

The objective of production control is to give assurance that the mixture conforms to the specification.

E.2 Quality manual

The manufacturer should establish and maintain his policy and procedures for production control in a quality manual that should include:

- the manufacturer's organisational structure relating to quality;
- control of constituents and mixtures;
- process control, calibration and maintenance;
- requirements for the handling and storage of the mixture when appropriate;
- inspection, calibration and control of the measuring equipment in the process, and laboratory testing equipment for the mixture;
- procedures for handling non-conforming mixture.

E.3 Organisation

E.3.1 Responsibility and authority

The responsibility, authority and inter-relation of all personnel who manage, perform and verify work affecting quality should be defined in the quality manual, particularly personnel who have authority to identify, record and rectify any mixture quality problems.

E.3.2 Management representative

The manufacturer should appoint a person with appropriate authority, knowledge and experience of production control to ensure that the requirements of the quality manual are implemented and maintained.

E.3.3 Internal audits

The manufacturer should carry out internal quality audits to verify compliance with the planned arrangements and the effectiveness of the quality system. Audits should be scheduled on the basis of the status and importance of the activity. The audits and follow up action should be carried out in accordance with documented procedures. The results of the audits should be documented and brought to the attention of the personnel having responsibility in the area audited. The management personnel responsible for the area should take timely corrective action on the deficiencies found by the audit and should keep a record of the action taken.

E.3.4 Management review

The production control system should be reviewed at appropriate intervals by management to ensure its continuing suitability and effectiveness. Records of such reviews should be maintained.

E.3.5 Sub-contract services

Where any services are supplied from outside the manufacturer's resources, means of control should be established.

E.3.6 Records

The production control system should contain adequately documented procedures and instructions.

The intended frequencies of tests and inspections by the manufacturer should be documented and the results of tests and inspections recorded.

Sampling location, date and time, as well as details of the mixture or constituents tested, should be recorded together with any other relevant information.

Where the constituent or mixture examined does not satisfy the requirements of the appropriate specification and this standard, records should be kept of corrective actions taken to ensure the quality of the mixture is maintained.

Records should be kept in such a way that they are retrievable and be retained for the period stated in the quality manual, usually a minimum of 3 years or longer if legally required.

E.3.7 Training

The manufacturer should establish and maintain procedures for the training of all personnel involved in activities affecting quality. Personnel performing specific assigned tasks should be suitably qualified on the basis of appropriate education, training or experience, as required. Training records should be kept.

E.4 Control procedures

E.4.1 Production management

The production control system should contain the following:

a) the composition of the mixture to be produced;

b) procedures to adjust mixture composition;

c) procedures to ensure that constituents comply with requirements;

d) procedures to ensure that production equipment, including mixture storage facilities, maintain the composition, homogeneity, and consistency of the mixture;

e) procedures for:

   1) calibrating, maintaining and adjusting the process and testing equipment;

   2) sampling the constituents and mixture;

   3) data recording during processing;

   4) adjusting the process according to weather conditions;

f) instructions so that the mixture is identifiable up to the point of delivery as regards source and type.

E.4.2 Composition of the mixture

The composition of the mixtures should be established from a laboratory mixture design procedure intended to ensure the mixture will have properties conforming to the relevant standard.

Where applicable, the composition of regularly produced mixtures should be included in a catalogue of mixtures compositions and considered as the mixture baseline or target composition.

The compositions should be re-established in case of significant change in constituents and should be reviewed periodically to ensure the mixture conforms to requirements taking account any change in properties of constituents.

E.4.3 Constituents

Documentation should detail the source and type of each constituent of the mixture for use at the production location.

Adequate supplies of constituent should be available to ensure that the planned rates of production and delivery can be maintained.

The specifications for incoming constituents should be established and communicated to suppliers by means of written orders.

The control procedures should check that constituents are capable of providing the required quality.

Constituents should be transported and stored in such a manner as to avoid intermingling, contamination or deterioration that may affect the quality of the product.

E.4.4 Process control

The quality manual should include:

— a description of equipment and installation;

— a description of the flow of constituents and the processes carried out on them. If appropriate this should incorporate a flow diagram;

— a schedule for monitoring the performance of the process (manual or automatic systems), including a record of equipment performance against the stated tolerances.

E.4.5 Inspection, calibration and control of process equipment

The quality manual should identify items of measuring devices that require calibration and the frequency of such calibration.

Calibration procedures should be provided, including the permitted tolerances for the devices to remain in service. The quality manual should state the required accuracy of all calibrations.

The equipment should be adequately maintained to ensure that it continues to be capable of producing a mixture to the required specifications and tolerances.

E.4.6 Handling and delivery

The quality manual should contain procedures to ensure that the mixture is handled and (where appropriate) delivered with the minimum of segregation or degradation and within the permitted water content range and time limit.

At the point of delivery, the mixture should be identifiable and traceable with regard to its production data. The manufacturer should maintain records of relevant data of production, which can be referenced from information when appropriate on the delivery ticket.

If appropriate, the manufacturer's quality manual should describe the characteristics of any mixture storage system and define its mode of operation. The manufacturer should ensure through checks, inspections and records that such systems are used correctly and that mixtures maintain their suitability for use.

E.5 Inspection and testing of constituents and mixtures during production

E.5.1 General

At the start of the production process, the homogeneity of the mixture should be considered with regard to the specification, the type and quality of the production plant and the quality and homogeneity of the constituents. This can be appreciated either from past production experience or by undertaking specific tests.

The quality manual should specify the frequency and nature of regular tests/checks/inspections that should be carried out during production. The manufacturer should prepare a schedule of frequencies considering:

- test frequencies in relation to periods of actual production of each mixture;
- test frequency where automated surveillance and monitoring of the production process exists;
- statistical approach for testing.

Reasons for changing the test frequencies and analysis should be stated in the quality manual.

NOTE If appropriate, long-term experience of the consistency of a particular property as well as mixtures with an established record for conformity can be taken into account.

E.5.2 Characteristics that require control during production

These may include:

- properties of the constituents including water content (before production);
- proportioning of the constituents including added water;
- grading of the fresh mixture;
- water content of the fresh mixture.

The above characteristics should comply with the requirements of the target composition of the mixture (see E.4.2).

E.5.3 Frequency of sampling the mixture

During the regular production of the mixture, the sample frequency may be as follows:

— In the case of a mixing plant with a validated and accepted automated surveillance and data collection system, a minimum of one sample should be taken every 2 000 t or 1 000 m^3 or one per day for lesser quantities.

— In the case of other types of plants or production, one sample should be taken every 300 t or 150 m^3, with a minimum of 1 sample per day.

— Alternatively and independent of the type of mixing plant, the frequency of sampling can be on a time related, rather than a quantity related basis, such as a minimum of 1 sample per week or 1 sample per day depending on the characteristic being measured.

In the case of occasional production of a standard mixture, the production should be assessed cumulatively with previous production with the same or similar criteria. The frequency of sampling can be adjusted on a contract-by-contract basis according to the overall quantity of production required.

E.6 Inspection and testing equipment

E.6.1 General

All necessary facilities, equipment and personnel should be available to carry out the required inspections and tests.

Normally the testing should be performed according to the specified test methods given in the relevant standard.

Other test methods may be used, if correlations or safe relationships between the results of these test methods and the reference methods have been established.

E.6.2 Measuring and testing equipment

The manufacturer should be responsible for the control, calibration and maintenance of his inspection, measuring and testing equipment.

E.6.3 Measuring and testing equipment in the process

The points in the process where measuring equipment needs to be deployed should be stated in the quality manual.

The quality manual should indicate when control is carried out automatically or manually. There should be a description of how equipment is maintained and calibrated.

E.6.4 Measuring and testing equipment in laboratory

The testing equipment should be in a known state of calibration and accuracy, consistent with the required measurement capability.

The following points should be addressed:

— accuracy and frequency of calibration, which should be in accordance with the relevant test standards;

— equipment to be used in accordance with documented procedures;

— equipment to be uniquely identified and calibration records should be retained.

E.7 Non-conformity

E.7.1 General

Non-conformity can arise at the following stages:

- constituent delivery;
- constituent in storage;
- mixture production;
- handling, storage and delivery of the mixture if appropriate.

In the event that a non-conforming constituent, process or mixture is identified, investigations should be initiated to determine the reasons for non-conformity and effective corrective action should be implemented to prevent recurrence in accordance with procedures documented in the quality manual.

E.7.2 Non-conformity of constituents

In the case of non-conforming constituents, corrective action may involve:

- reclassifying the constituent;
- reprocessing;
- adjusting process control to allow for constituent non-conformity;
- rejection and disposal of the non-conforming constituent.

E.7.3 Non-conformity of the mixture

Non-conforming mixture should be evaluated and procedures for taking action should be followed.

The quality manual should identify the action to be taken when a non-conforming product is identified and should state the circumstances under which the customer will be notified of non-conforming results.

Such action may involve:

- corrective action (for example modification of the mixture and or adjustment of equipment);
- acceptance of the mixture following the agreement of the customer to accept a non-conforming mixture;
- if the mixture produced is incorrect it can be redirect to an alternative customer if appropriate;
- rejection of the mixture.

Bibliography

[1] EN 13285, *Unbound mixtures — Specifications*

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