Eumeps Construction
European Manufacturers of EPS

EPS White Book

EUMEPS Background Information on standardisation of EPS

Issued by EUMEPS in 2011

Version 31/03/11

Content

1 General

1.1 Purpose and scope of this document

As a result of a decision of the European Commission (EC) barriers to trade had to be eliminated. This meant that thermal insulation products, which were chosen as the very first group of construction products, had to be standardised.

The Technical Committee 88 (TC88) of CEN has been dealing with thermal insulating products for EPS, working in Working Group 4 (WG4), many data have been collected from various countries and new data have been produced to describe the performance of EPS. The large variety of applications all over Europe has been studied and the experiences have been exchanged and recorded. The work in CEN/TC88/WG4 has lead to a huge collection of European data, experience and knowledge of EPS. To make all this information available to producers, designers and users of EPS is the goal of this White Book.

This White Book will also explain the background of the standardisation work, which has lead to a specific structure and content of the standards, which follow a common format agreed by CEN TC88.

For EPS several standards have been published and developments still continue. For instance, the subject of ecological assessment and the release of dangerous substances are still under discussion. The standardisation is an ongoing process. Data from research and developments in connection with these projects will be incorporated later. That is why this White Book is a living paper and will be revised from time to time.

1.2 Background

In 1985 the European Council published a white paper on completing the internal market for the European Community. The purpose of creating an internal market is to eliminate barriers to trade for products (and services) thus allowing them to be marketed freely through the EU and thereby promote competition. The construction industry, as an important part of commercial activity in the EU, was therefore to become subject to a directive covering construction products - the Construction Products Directive (CPD) - Council Directive 89/106/EEC [5].

This Directive is the practical manifestation of freeing the market in the construction sector by making transparent the technical specification of construction products, which are a major part of trade in the construction sector. The CPD only contains ways to declare properties, leaving the required level of a property in end-use condition to the Member States. These levels are generally laid down in National Building Regulations

The CPD introduces the concept of harmonised standards which manufacturers must comply with when placing products on the market. These requirements are detailed in the standards and address the six *Essential Requirements* which Building Works must comply with. When products comply with the requirements of the Essential Requirements on the level that is laid down in the National Building Regulations, the construction works are deemed to satisfy the regulations.

The six Essential Requirements are :

1) Mechanical resistance and stability
2) Safety in case of fire
3) Hygiene, health and the environment
4) Safety in use
5) Protection against noise
6) Energy economy and heat retention

Standardisation
To obtain common technical specifications all over Europe, European product standards (or technical approvals) have to be created. In order to ensure that this work is properly directed to fulfil the Commissions objective with the CPD a Standing Committee for Construction (SCC) had been established (CPD Article 19). Representing Regulators responsible for laws governing construction in the Member States, the SCC determines the properties to be included in the harmonised standards, testing of the products, levels of attestation of conformity to be applied and rules governing labelling and marking.

To support all this activity a range of Interpretative Documents and a series of Guidance Papers have been published to ensure uniformity of interpretation of the CPD.

This standardisation is 'mandated' by the Commission, as advised by the SCC, in support of the CPD. The output must therefore be accepted by the Member States, which are represented in the SCC. The work for the standardisation is through the mandates given to CEN (Comité Européen de Normalisation) or EOTA (European Organisation for Technical Approvals).

- CEN, develops mandatory standards (hEN's – harmonised European Standards) for well known products and/or applications.

- EOTA develops produces voluntary guidelines (ETAG's – European Technical Approval Guidelines) for special and/or innovative applications.

For insulation products, the work within CEN is mainly covered by *CEN TC 88 "Thermal insulating materials and products",* following the mandates M/103, M/126, M/130 and M/138 given under the CPD.

For concrete floor EPS products, the work within CEN is covered by *CEN TC 229 "Precast concrete products",* following the mandate M/100 given under the CPD.

The European product standards were all created to obtain a common European market. The product standards were developed in the various Working Groups (WG's) within TC 88, WG4 developed the standard for EPS for building applications, WG10 for building equipment and industrial installations, WG15 for in situ products and WG18 for External Thermal Insulation Composite Systems (ETICS). The product standards for precast concrete products are being developed in the various WG's in TC 229; WG 1 TG 5 is developing the standard for EPS blocks for beam-and-block floor systems

To achieve a common assessment of product performance harmonised European test methods are necessary. All test methods for mechanical and/or physical properties were developed by CEN/TC88/WG1. Other test methods were developed by other TC's (see below at horizontal TC's). Where international standards (ISO) are available, these standards are taken into account according to the Vienna agreement (50).

If a product conforms to a harmonised standard, it is allowed to bear CE marking and then has a "passport" to travel inside the EC.

The values of the properties measured according to the harmonised test methods may be subject to calculation rules and/or correction factors related to its application.

In all European countries where application rules for thermal insulation products were established, these rules had to be revised because they have to refer to the European product standards and to the levels and classes provided there. Figure 1 shows the area of European standardisation and the limit to the remaining field of national standardisation/regulations.

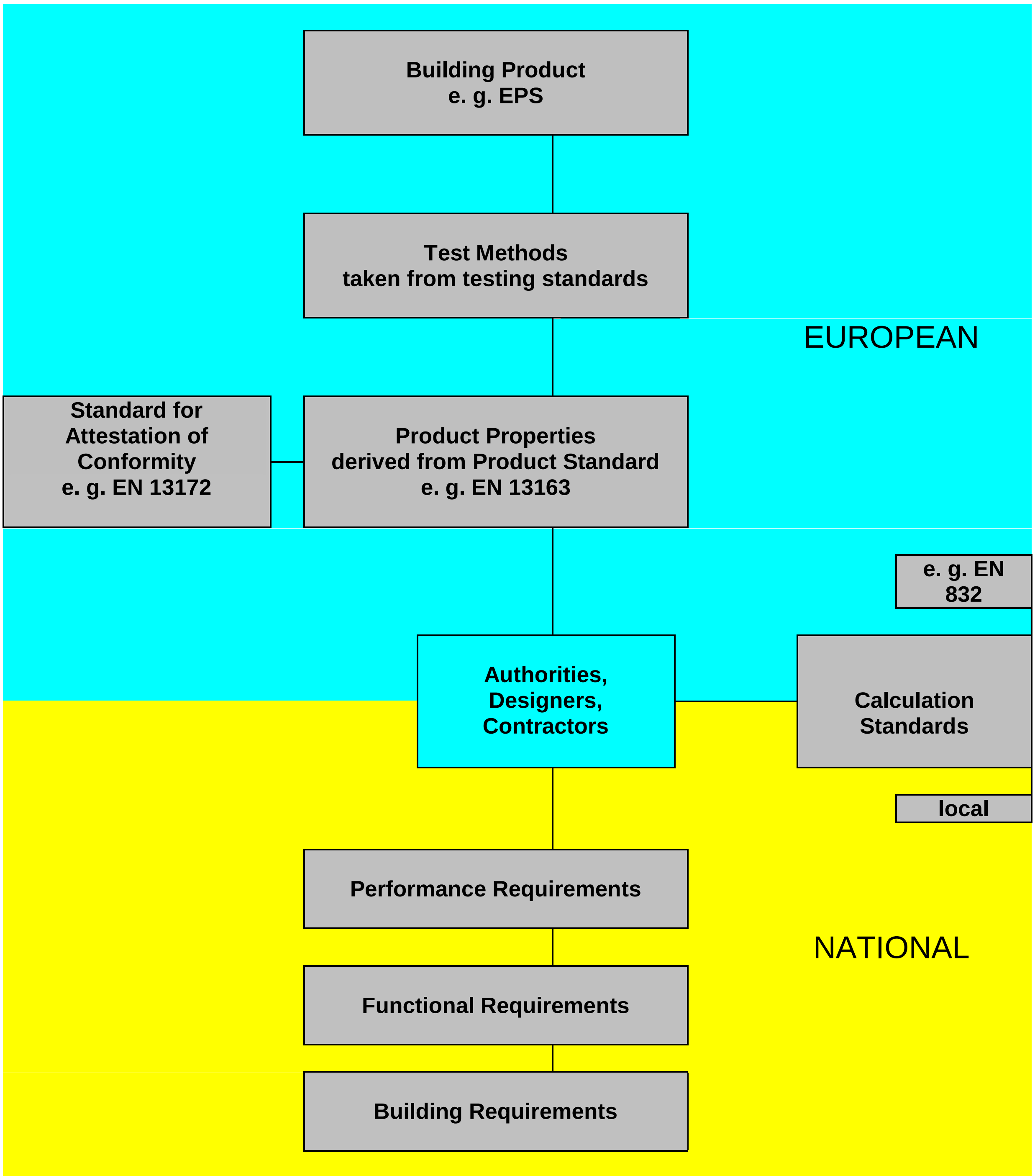


Figure 1: Limitation between European and national standardisation issues.

This Figure 1 can be created for every standardised building product.

Beside the product oriented TC's several TC's develop rules to cover aspects for all building products in a "horizontal" way. Those horizontal TC's are:

- TC 89 "Thermal performance of buildings and building components" for calculation methods of the energy performance of products and buildings;
- TC 126 "Acoustic properties of building products and of buildings" for calculation methods of the acoustical properties of products and buildings;
- TC 127 "Fire safety in buildings" for test methods and classification rules for the reaction to fire and fire resistance of products and building constructions;
- TC 350 "Sustainability of construction works" describing methods to determine the sustainability of products and works;
- TC 351 "Construction Products - Assessment of release of dangerous substances".

For EPS the following standards exist:

- EN 13163:2008, Thermal insulation products Factory made products of expanded polystyrene (EPS) – *Specification:* A package of ten standards for factory made product standards for buildings was developed at the same time and all standards of this package were launched as EN's in 2001 and revised in 2008.
- EN 13499: 2003, Thermal insulation products for buildings - External thermal insulation composite systems (ETICS) based on expanded polystyrene – *Specification:* For ETICS two standards were developed and launched as EN's in 2003 as non-harmonised standards, since no mandate was given at that time. A mandate has been given end 2010 and the revision to a harmonised standards has started.
- EN 14309:2009, Thermal insulation products for building equipment and industrial installations - Factory made products of expanded polystyrene (EPS) – *Specification*: A package of nine standards for building equipment and industrial installations were developed at the same time and as a package launched as EN's in 2009
- EN 14933:2007 Thermal insulation and light weight fill products for civil engineering applications - Factory made products of expanded polystyrene (EPS) – *Specification*: For CEA two standards (for EPS and XPS) were developed and launched as EN's in 2007.

Under development are:

- prEN 16025-1 Thermal and/or sound insulating products in building construction - Bound EPS ballasting - Part 1: Requirements for factory premixed EPS dry plaster,
- prEN 16025-2 Thermal and/or sound insulating products in building construction - Bound EPS ballasting - Part 2: Processing of the factory premixed EPS dry plaster,
- prEN 15037-4, Precast concrete products - Beam-and-block floor systems - Part 4: Expanded polystyrene blocks.

For in situ EPS new work items have been agreed and two standards will be developed for bonded beads primarily for use in masonry cavity walls.

Every product standard defines specifications for the product. This includes all relevant properties, how to test and declare these properties, marking and labelling, and the required level of attestation of conformity. This leaves the required level of a property in end-use condition to the Member States. These levels are generally laid down in National Building Regulations.

The harmonised European product standards contain mandatory parts and may contain voluntary parts. The requirements as mentioned in the relevant mandates are listed in Annex ZA in all harmonised product standards. All standards listed above, except EN 13499 are harmonised. The practical translation of Annex ZA is given in paragraph 2.5.2 For all applications (4.2). In the next paragraphs the listed published standards will be explained.

The standards EN 13163, EN 13499, EN 14309 and EN 14933 are developed in TC88 and have a similar structure. In Chapter 2: "Explanation of the EPS Standard for buildings EN 13163", EN 13163 will be explained in detail, having a structure that mirrors EN 13163. For the other three standards only the differences will be given in the Chapters 3, 4 and 5.

2 Explanation of the EPS Standard for buildings EN 13163

2.1 Foreword

The foreword gives general information about the creation of the standard.

2.2 Scope

(EN 13163: Clause 1). The scope covers all EPS products used as thermal insulation for buildings including shaped products, where the term preformed ware is used. Also all kinds of coatings and facings are included except those, which are covered by another product standard. e. g. EN 13168 [8] which covers wood wool products and composite wood wool slabs. These wood wool slabs are composite insulation products in which wood wool is bonded on one or both face(s) to an EPS core.

Composite panels made from EPS and gypsum boards are specified in EN 13950 [25]. Self supporting metal composite panels with an EPS core are covered by EN 14509 [26].

The minimum thermal resistance is given as 0,25 $m^2 \cdot K/W$ and the maximum thermal conductivity as 0,060 W/m·K to ensure a minimum thermal resistance. Products having a thermal conductivity of 0,040 W/m·K must be at least 10 mm thick.
Normal EPS products have a thermal conductivity much lower than 0,060 W/m·K, typically in the range 0,030 to 0,045 W/m·K.

2.3 Normative references

(EN 13163: Clause 2). This clause lists in a numerical order all standards which are referred to in the normative part of EN 13163.

Normally standards are referred to as undated references to avoid revisions of EN 13163 each time a new version of the reference standards is published. Only draft standards (prEN) and EN 13172 are dated.

2.4 Terms, definitions, symbols, units and abbreviated terms

(EN 16163: Clause 3).

2.4.1 Terms and definitions

In this clause all EPS specific expressions are listed and defined. For specific terms of reaction to fire see 2.5.2.5.

EN 13163 contains definitions, which are used in this standard and which are not to be found in EN ISO 9229 [9]. For other fields of building products there are other definition standards in preparation:

prEN 27345 Thermal insulation – Physical quantities and definitions [30]
prEN 45020 Standardization and related activities - General vocabulary [10]
prEN ISO 13943 Fire safety – Vocabulary [11]

2.4.2 Symbols

Symbols in addition to those which are defined in EN 13163, EN 13499, EN 14309 and EN 14933 and are used in this White Book are listed in Annex A.1 – Tables.

Abbreviated Terms
Abbreviated terms in addition to those given in EN 13163, EN 13499, EN 14309 and EN 14933 and used in this White Book are listed in Annex A2 – Tables.

2.5 Requirements

(EN 13163: Clause 4). To be recognised as a thermal insulation product, various properties must be determined. Those properties are material related or relevant for all applications. Those properties are mentioned in clause 4.2. in EN 13163. Consequently, before EPS products are placed on the market with the CE mark every property given in clause 4.2 must be declared. In addition to these properties the manufacturer may choose and declare levels / classes of properties given in clause 4.3, depending on the application of the product.

2.5.1 General

(4.1). A product property is assessed by testing according to a test method. In that test method the minimum number of tests to be performed is given. The product property is the average of the results of those tests. This rule is valid for all requirements where limit values are requested. In cases where statistical evaluation is required, calculation rules as given in Annex A and B of EN 13163 have to be followed.

For mechanical and a few other properties it is not allowed to have single measured values more than 10 % lower than the declared value. This has to be taken into account when testing dimensional stability, compressive stress at 10 % deformation, bending strength, tensile strength perpendicular to faces, deformation under specified load and temperature conditions, compressive creep, water vapour transmission, dynamic stiffness and compressibility.

2.5.2 For all applications (4.2)

2.5.2.1 Thermal resistance and thermal conductivity

(4.2.1). The thermal properties of a sample of insulation board are measured according to EN 12667 or EN 12939 (for boards between 100 and 150 mm thickness), taking into account the thickness (measured according to EN 823). The result of the test is the thermal resistance of that specific sample. When the sample is sourced from a product type with no thickness effect and/or is not a multi-layered sample, the thermal conductivity can be calculated using the equation

$$\lambda_{meas} = \frac{d_{meas}}{R_{meas}} \quad \text{in W/m·K}$$

In accordance with EN 13163 - B.2.4 boards of a thickness of 50 mm and a thermal conductivity equal to or less than 0,038 W/m·K the thickness effect is negligible. For more information on thickness effect; see 2.12.2.2. A tapered board must be made flat (uniform thickness) before measuring.

Statistical treatment is then necessary to obtain the declared value which must represent 90 % of the production determined with a confidence level of 90 % (90/90). At least 10 measurements must be performed before the statistical treatment can start. Statistical treatment gives an $R_{90/90}$ and/or $\lambda_{90/90}$. When rounded downwards to the nearest 0,05 m²·K/W for the R value and upwards to the nearest 0,001 W/(m·K) for the λ value) the R_D and/or λ_D are determined The thermal resistance R_D shall always be declared for flat products and if possible the thermal conductivity λ_D as well. In most cases the EPS producer will choose to apply the statistics to the thermal conductivity values in one defined product group. He will then state in his official documents the declared thermal resistance R_D at that thickness and the declared thermal conductivity λ_D.

<u>Effect of temperature on thermal conductivity</u>
The thermal conductivity for building products is declared at a mean temperature of 10° C. For normal building applications this is sufficient. In chapter 4 “”Explanation of EN 14309 – Thermal insulation products for building equipment and industrial installations - Factory made products of expanded polystyrene (EPS)“ additional information is given on data at other temperatures.

<u>Mechanism of heat transfer</u>
The mechanism of heat transfer in a thermal insulation layer like EPS can be divided in three components:

- Conductivity;
- Radiation;
- Mass transfer.

More details are to be found in ISO 9251 [35]. For radiation see [36] and for mass transfer see [37].

For non infra red absorbing EPS (mostly coloured white) there is a distinct relation between thermal conductivity and density, which can be calculated as follows:

Regression for 8 kg/m³ ≤ ρ_a ≤ 55 kg/m³;

λ_{mean} = 0,025314 W/(m·K) + 5,1743 x 10^{-5} W·m²/(kg·K) x ρ_a + 0,173606 W·/(m^4·K)/ρ_a[W/(m·K)]

λ_{pred} = 0,027174 W/(m·K) + 5,1743 x 10^{-5} W·m²/(kg·K) x ρ_a + 0,173606 W·/(m^4·K)/ρ_a[W/(m·K)]

For all types of EPS, non infra red absorbing -"white"- as well as infra red absorbing –"grey"-, there is a distinct relation between thermal conductivity and density as well as thickness effect which can be calculated as follows:

For the regression: $\lambda_{mean} = b_0 + b_1\rho_a + \dfrac{b_2}{b_3/d + b_4\rho + b_5}$

For the upper prediction curve: $\lambda_{90/90} = \lambda_{pred} = \lambda_{mean} + t_{n-5,95\%} s_\lambda \sqrt{1 + \vec{\rho}^T \cdot C \cdot \vec{\rho}}$

For use in practice design values must be derived from the declared values, λ_D, taking into account the effects on thermal conductivity according to EN-ISO 10456.

$\lambda_u = \lambda_D \times F_T \times F_a \times F_m$ [W/(m·K)]

Where
F_T is the factor for the thickness effect
For EPS this effect is negligible for types having a thermal conductivity better or equal to 0,038 W/(m·K). Specific rules are given in Annex B of the standard (see also 2.12.3), the factor normally being 1.

F_m is the factor for the moisture effect
For EPS this effect is negligible for normal applications in building construction, the factor being 1. Specific application, e.g. inverted roofs will have an effect. More information is to be found in 2.4.3.9

F_a is the factor for the ageing affect
For EPS this effect does not occur, the factor being 1

2.5.2.2 Length and Width, Thickness, Squareness and Flatness

(4.2.2, 4.2.3, 4.2.4 and 4.2.5). The classes of tolerances for length and width, thickness, squareness and flatness are given in Table 1 of EN 13163.The table gives commonly used tolerances and one or more tighter tolerances which are only needed for specific applications.

2.5.2.3 Dimensional stability

(4.2.6). The classes of dimensional stability are given in Table 2 of EN 13163. The Table gives a class that is commonly used and a class for specific applications.
The dimensional stability is also used to prove the durability of thermal resistance against ageing and degradation, see table ZA.1 of EN 13163.

2.5.2.4 Bending strength

(4.2.7). Bending strength in this clause of the standard is only used to ensure handling properties for EPS. In the mandate for the thermal insulation products tensile strength is foreseen for this requirement. The standardiser is free to replace e. g. the tensile strength by another property which is the case for EPS. In table ZA.1 of EN 13163 tensile strength or flexural strength is required to ensure handling and this was combined with bending strength.

For applications where higher levels of bending strength are required see clause 4.3.2 of EN 13163. In clause 4.2.7 a threshold value of only 50 kPa is required, which will be easily achieved by every well fused EPS product. In the case that a higher value than 50 kPa is declared, it is obviously not necessary to test the bending strength of 50 kPa as well, only to prove the handling ability.

2.5.2.5 Reaction to fire

(4.2.8). Although the CPD refers in the essential requirements to building constructions (products in their end-use condition), the product standards refer in this clause only to the determination of reaction to fire of the products as placed on the market.

The European fire test to determine the reaction to fire package includes:

- EN ISO 1182	Non-combustibility test [32]
- EN ISO 1716	Determination of calorific value [33]
- EN ISO 11925-2	Ignitability test
- EN 13823	Single Burning item (SBI) Test

Results of these tests are used for reaction to fire classification (Euro classes A1 to F, see *Table 1*) according to the classification standard (EN 13501-1)

Table 1: Classes of reaction to fire performance for construction products except floorings and linear products

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 (1); and	$\Delta T \leq$ 30°C; and $\Delta m \leq$ 50%; and t_f = 0 (i.e. no sustained flaming)	
	EN ISO 1716	$PCS \leq$ 2,0 MJ $\cdot kg^{-1}$ (1); and $PCS \leq$ 2,0 $MJ \cdot kg^{-1}$ (2) (2a); and $PCS \leq$ 1,4 $MJ \cdot m^{-2}$ (3); and $PCS \leq$ 2,0 $MJ \cdot kg^{-1}$ (4)	
A2	EN ISO 1182 (1); or	$\Delta T \leq$ 50°C; and $\Delta m \leq$ 50%; and $t_f \leq$ 20s	
	EN ISO 1716; and	$PCS \leq$ 3,0 $MJ \cdot kg^{-1}$ (1); and $PCS \leq$ 4,0 $MJ \cdot m^{-2}$ (2); and $PCS \leq$ 4,0 $MJ \cdot m^{-2}$ (3); and $PCS \leq$ 3,0 $MJ \cdot kg^{-1}$ (4)	
	EN 13823 (SBI)	*FIGR*A $\leq$ 120 $W \cdot s^{-1}$; and *LFS* < edge of specimen; and $THR_{600s} \leq$ 7,5 MJ	Smoke production(5); and Flaming droplets/ particles (6)
B	EN 13823 (SBI); and	*FIGRA* $\leq$ 120 $W \cdot s^{-1}$; and *LFS* < edge of specimen; and $THR_{600s} \leq$ 7,5 MJ	Smoke production(5); and Flaming droplets/ particles (6)
	EN ISO 11925-2(8): Exposure = 30s	*Fs* $\leq$ 150 mm within 60 s	
C	EN 13823 (SBI); and	*FIGRA* $\leq$ 250 $W \cdot s^{-1}$; and *LFS* < edge of specimen; and $THR_{600s} \leq$ 15 MJ	Smoke production(5); and Flaming droplets/ particles (6)
	EN ISO 11925-2(8): Exposure = 30s	*Fs* $\leq$ 150mm within 60s	
D	EN 13823 (SBI); and	*FIGRA* $\leq$ 750 $W \cdot s^{-1}$	Smoke production(5); and Flaming droplets/ particles (6)
	EN ISO 11925-2(8): Exposure = 30s	*Fs* $\leq$ 150mm within 60s	
E	EN ISO 11925-2(8): Exposure = 15s	*Fs* $\leq$ 150mm within 20s	Flaming droplets/ particles (7)
F	No performance determined or failure to Euro class E		

(1) For homogeneous products and substantial components of non-homogeneous products.
(2) For any external non-substantial component of non-homogeneous products.
(2a) Alternatively, any external non-substantial component having a $PCS \leq 2{,}0\ MJ \cdot m^{-2}$, provided that the product satisfies the following criteria of EN 13823(SBI) : $FIGRA \leq 20\ W \cdot s^{-1}$; and LFS < edge of specimen; and $THR_{600s} \leq 4{,}0$ MJ; and *s*1; and *d*0.
(3) For any internal non-substantial component of non-homogeneous products.
(4) For the product as a whole.
(5) *s*1 = $SMOGRA \leq 30 m^2 \cdot s^{-2}$ and $TSP_{600s} \leq 50 m^2$; *s*2 = $SMOGRA \leq 180 m^2 \cdot s^{-2}$ and $TSP_{600s} \leq 200 m^2$; *s*3 = not *s*1 or *s*2.
(6) *d*0 = No flaming droplets/ particles in EN 13823(SBI) within 600 s; *d*1 = No flaming droplets / particles persisting longer than 10 s in EN 13823(SBI) within 600 s; *d*2 = not *d*0 or *d*1; Ignition of the paper in EN ISO 11925-2 results in a *d*2 classification.
(7) Pass = no ignition of the paper (no classification); Fail = ignition of the paper (*d*2 classification).
(8) Under conditions of surface flame attack and, if appropriate to the end–use application of the product, edge flame attack.

The SBI criteria are:

- FIGRA = Fire Growth Rate Index
- LFS = Lateral Flame Spread
- THR_{600} = Total Heat Release during the first 600 seconds

Smoke production (s_1 to s_3) and the occurrence of burning droplets (d_0 to d_2) are additional classifications.

These are based on:

- SMOGRA = Index for rate of Smoke Development (for s-ranking)
- Burning droplets = Occurrence and burning duration of burning droplets (for d-ranking)

In most EU Member States there are no requirements for smoke and flaming droplets/particles.

EPS-SE passes the small burner test (EN ISO 11925-2) at all thicknesses and densities and therefore meets the requirements of Euroclass E. EPS without flame retardant additives (Standard EPS or N-grade) is classified as Euroclass F (without testing). Higher classes, determined in the SBI test (EN 13823), depend on the thickness, density and mounting & fixing, representing the end-use condition, of the samples. EPS is used in many different applications. Depending on that application Euroclass E, D, C or B can be obtained. E.g. EPS in its application behind plasterboard, cavity wall or steel sandwich panel can obtain Euroclass B.

The durability of reaction to fire behaviour is covered in 2.5.2.6. For definitions in the field of fire safety, see EN ISO 13943 [11].

A product's performance in reaction to fire is related to its fundamental material properties as well as to its end-use conditions. Product performance should therefore also be tested reflecting its end use. A product can therefore have different performances and hence classifications depending upon its application.

In order to make clear how products react to fire in a building construction, a separate standard, valid for all insulation materials is developed (EN 15715 - Instructions for mounting and fixing for reaction to fire testing) where a number of standardised assemblies is given to test the product in its application.

The level of (fire) safety in the individual Member States is laid down in National regulations, according to the European classification. The safety levels in the Member states, representative of a country's building practice and experience in construction and fire, remain their prerogative and are not harmonised.

A manufacturer or association can have a classification report made for a product in a certain application, in order to save customers time and money to prove that the construction fulfils the requirements of the national building regulations.

On constant exposure to temperatures from 80 °C onwards, EPS softens and shrinks and finally melts. On further exposure to heat, gaseous combustible products are formed by decomposition of the melt. Whether or not these can be ignited by a flame or spark depends largely on the temperature, duration of exposure to heat and the air flow around the material (oxygen availability).

Molten EPS will normally not be ignited by welding sparks or glowing cigarettes; however, small flames will ignite a standard grade EPS readily unless it contains flame retardant additives. These flame retarded (FR) grades of EPS, also referred to as EPS-SE quality, contain a small quantity of a cycloaliphatic organobromine compound. When exposed to a fire source the decomposition products of the additive cause flame quenching so that when the ignition source is removed EPS-SE will not continue to burn.

When tested to ASTM D 1929 [48], the flash ignition temperature in the presence of a pilot flame of standard grade EPS is 360 °C and that of EPS-SE is 370 °C. These values indicate that, when molten EPS decomposes, ignitable gases are only formed at or above 350 °C. In the absence of a pilot flame, the self-ignition temperature of molten EPS is 450 °C.

In the presence of large ignition sources or significant heat fluxes, e.g. greater then 50 kW/m^2 from fires involving other material, EPS-SE will eventually burn, reflecting the organic nature of polystyrene. Burning EPS has a heat release of 40 MJ/kg (by mass) or 400-2.000 MJ/m^3 (by volume) [17]. Although the caloric value of EPS is relatively high, the contribution to the fire load is normally limited due to the low density of EPS.

2.5.2.6 Durability of reaction to fire against heat, weathering, ageing/degradation

(4.2.9.2). The long term behaviour of expanded polystyrene classified as ‘B1’ (hardly flammable) including ‘B2’ (normally flammable) products according DIN 4102 [1] was evaluated [2]. Polystyrene foam boards, containing flame retardants have been used in Europe for construction applications since the 1960’s. Since the late seventies, materials classified as ‘B1’ including ‘B2’ have been required for these applications in Germany. It was investigated as whether polystyrene foam boards containing flame retardants maintain their ‘B1’ respectively ‘B2’ product characteristic in the long term, or whether ageing occurs, which could result in a change of the classification.

In order to answer this question, the radical burning mechanism of polystyrene and the action of the flame retardants are being summarised. Further, the calculated results of the temperature and time dependent behaviour of the flame retardants that the polystyrene foam contain are given. Additionally the leaching/migration behaviour of the flame retardants in the polystyrene has been experimentally determined. Various West-European EPS raw material producers have gathered laboratory data and results from practice related to the burning behaviour of polystyrene foam boards over a long term. These are also included in the report.

It is concluded that under the conditions tested no ageing of the flame retardants system used in EPS boards occurs far beyond the normal life span of a building of at least 100 years. So an ageing related change of the ‘B1’ respectively ‘B2’ classification does not occur and hence it can be assumed that the relevant Euroclasses established for EPS products are also stable.

2.5.2.7 Durability of thermal resistance against heat, weathering, ageing/degradation

(4.2.9.3) EPS does not contain blowing agents that influence the thermal conductivity, only air. Research in Germany and Switzerland show that over a longer period (25 years) the thermal conductivity does not increase [53] [54].

2.5.2.8 Durability of compressive strength against ageing and degradation

(4.2.9.4) The durability of compressive strength against ageing is assessed by compressive creep and long term thickness reduction for products used in floating floors. The evidence of the long term compressive behaviour is detailed in 2.5.3.8.

2.5.3 For specific applications (4.3)

2.5.3.1 General

(4.3.1). Every insulation product according EN 13162 through EN 13171 has to cover the requirements described in clause 4.2 of the EN's whereas the requirements given in clause 4.3 are optional. These additional requirements will be declared by the manufacturer only if they are needed for the intended use. The application related requirements come from national regulations such as application standards, approvals or others. See also 7.3.

2.5.3.2 Dimensional stability under specified temperature and humidity conditions

(4.3.2). There is no application rule known in Europe where dimensional stability under specified temperature and humidity is required for EPS. For harmonisation reasons (between the different thermal insulation product standards) this property was adopted in EN 13163.
Humidity conditions do not affect the dimensions of EPS.

2.5.3.3 Deformation under specific compressive load and temperature conditions

(4.3.3). The deformation under specific compressive load and temperature is needed in some countries for applications where pressure and temperature prevail for example on flat roofs.
The measurements from Zehendner [19] show that the pressure-deformation behaviour depends on the environmental temperature.

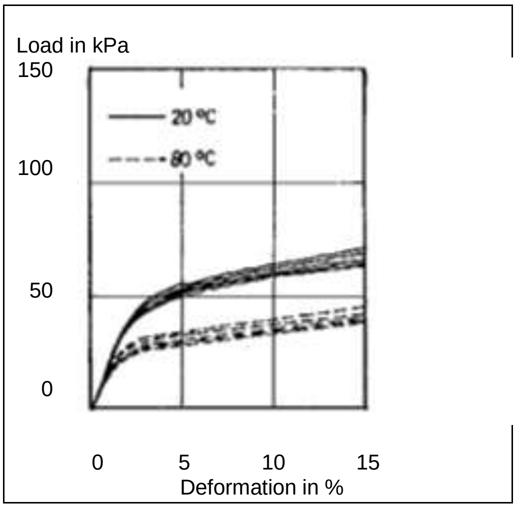


Figure 2:
Compressive load and deformation of non flame retarded EPS, density 14 kg/m³ [19].

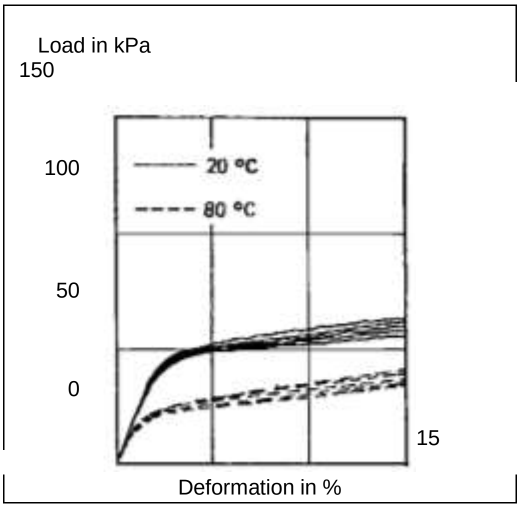


Figure 4:
Compressive load and deformation of flame retarded EPS, density 14 kg/m³ [19].

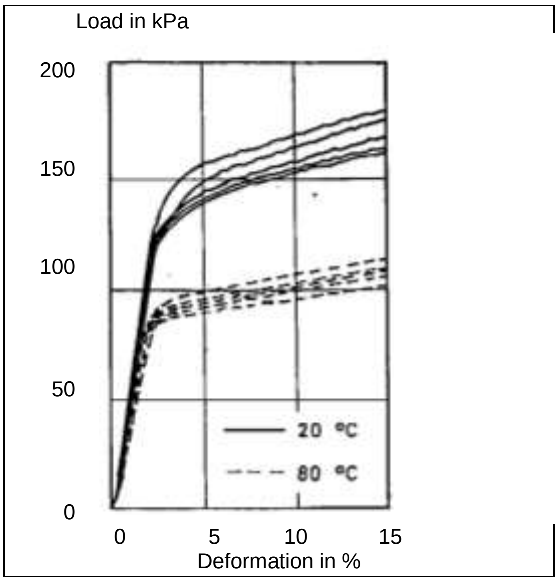


Figure 3:
Compressive load and deformation of non flame retarded EPS, density 24 kg/m³ [19].

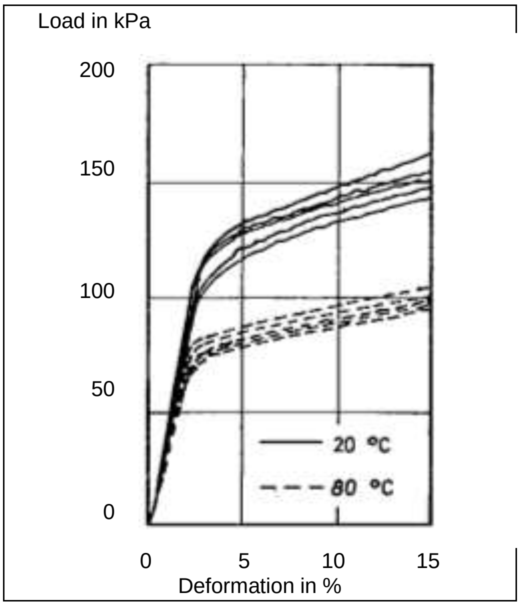


Figure 5:
Compressive load and deformation of flame retarded EPS, density 24 kg/m³ [19]

2.5.3.4 Compressive stress at 10% deformation

(4.3.4). The compressive stress at 10 % deformation (σ_{10}) is only used to classify EPS products and to obtain reproducible and repeatable test results for factory production control purposes. Compressive strength is normally needed for applications where a load prevails on the EPS e.g. under a floor, on a flat roof, perimeter insulation and so on. The long term deformation (over 50 years) of EPS (compressive creep, see also 2.5.3.8) caused by continuous permanent compressive stress should not be above 2%. The maximum allowed load can be found by multiplying the σ_{10} by 0,3, regardless of the material factor γ_m. (see5.4.2.3).

The compressive strength of EPS is one of the most important properties and therefore it is used to classify EPS products. Classification and relationship with bending strength is described in Annex C of EN 13163. The compressive strength depends directly on the density as shown in Annex B, clause B.2.2 of EN 13163. The relationship between compressive strength and the water vapour diffusion resistance factor / water vapour permeability is given in Annex D, clause D.4 of EN 13163.

Compressive strength depends on the temperature of test which is also described in 2.5.3.3. The compressive behaviour at 20 °C is shown in Figure 6.

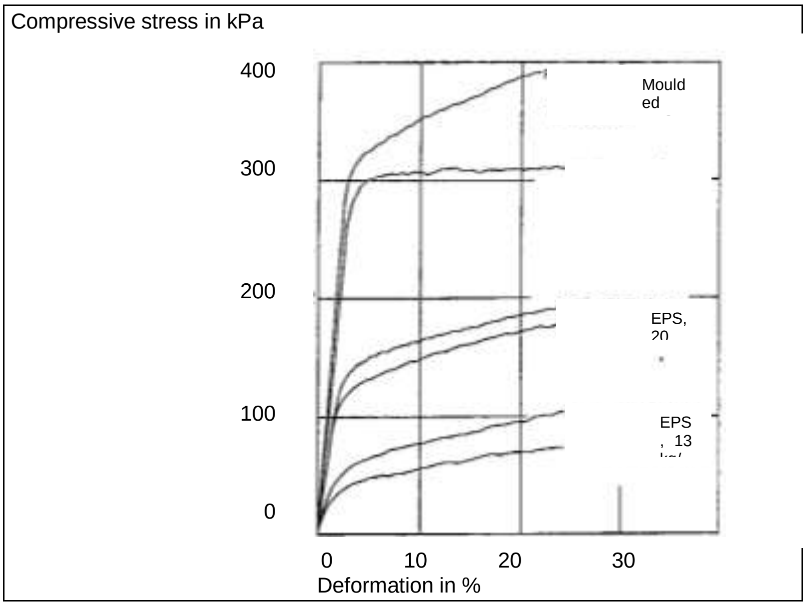


Figure 6:
Compressive strength at 20 °C of different densities of EPS [21].

Different values of compressive stress at 10 % deformation at different temperatures were measured by Zehendner [21] and given in Table 2.

Table 2: Compressive strength at 10 % deformation at different reference temperatures.

Material	Density	Compressive strength at different temperatures in kPa				
		-170 °C	-60 °C	-30 °C	20 °C	70 °C
EPS block moulded, non flame retarded	14	42	46	58	56	42
	22	210	150	160	160	120
EPS block moulded, flame retarded	14	62	75	77	83	62
	22	190	170	170	160	120
EPS, moulded board	42	510	450	420	360	240

2.5.3.5 *Tensile strength perpendicular to faces*

(4.3.5). When EPS is subjected to bond stress (caused by the intrinsic weight or wind suction) the tensile strength becomes relevant. For well fused EPS products a relationship between tensile strength and density can be shown [46].

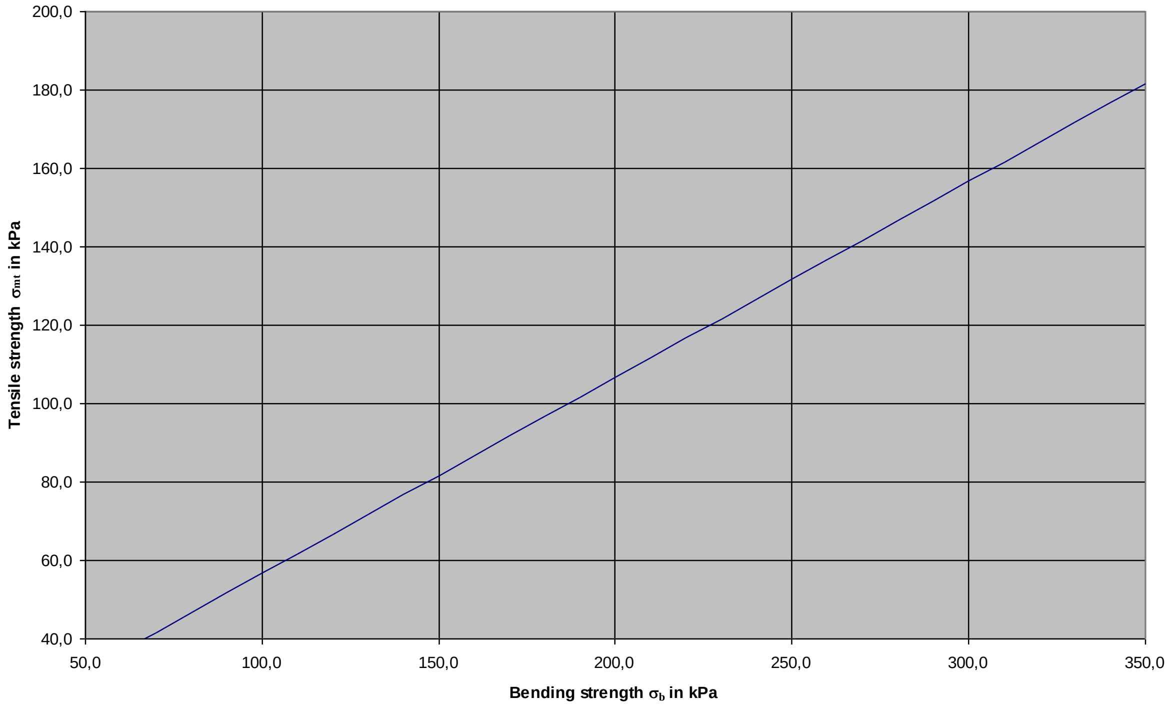


Figure 7:
Relationship between tensile strength perpendicular to faces and density for well fused products.

σ_{mt}= 14,00·ρ - 72,5 kPa

Different values of tensile strength at different temperatures were measured by Zehendner [21] and given in Table 3.

Table 3: Tensile strength at different reference temperatures.

Material	Density	Tensile strength at different temperatures in kPa			
		-170 °C	-60 °C	20 °C	70 °C
EPS block moulded, non flame retarded	14	190	120	120	80
	24	330	400	370	250
EPS block moulded, flame retarded	14	190	190	190	130
	23	320	320	300	210
EPS, moulded board	40	720	790	550	270

2.5.3.6 Bending strength

(4.3.6). Since bending strength is much easier to determine than tensile or flexural strength it is used for quality control concerning the fusion of the EPS material. For a well fused product bending strength depends on the density as shown in Figure 8.

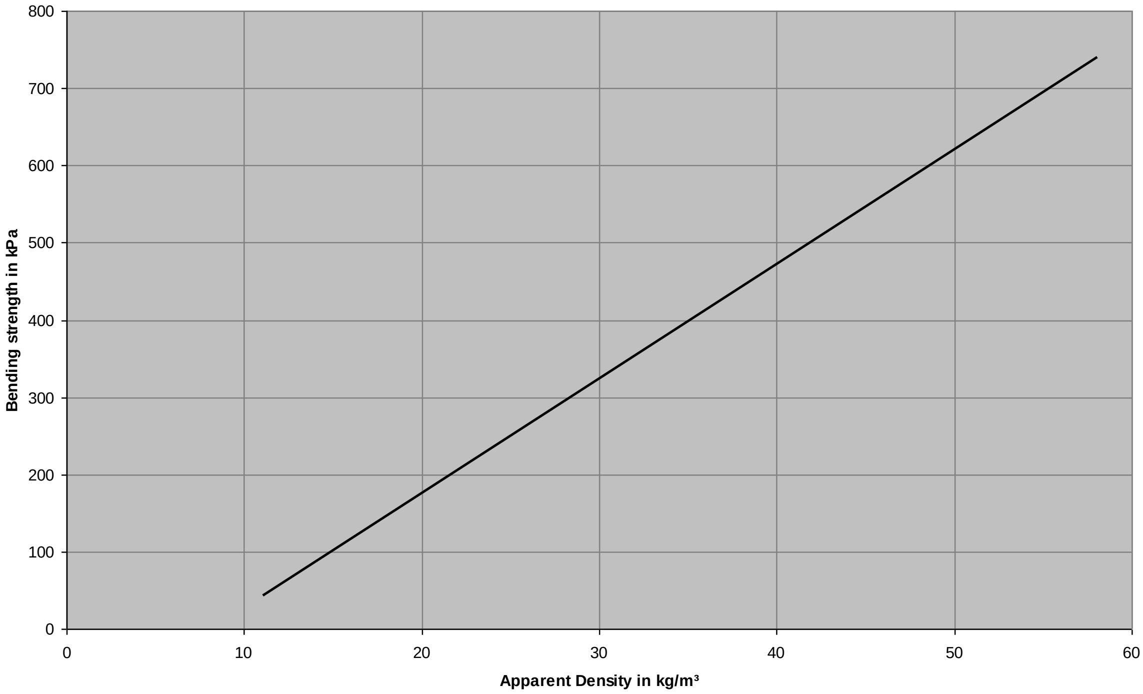


Figure 8: Correlation between bending strength and density.

To calculate the bending strength from density use the equation below.

$$\sigma_b = 14{,}84\rho_a - 122{,}6kPa$$

In Annex C of EN 13163 a link between compressive stress and bending strength is given for classification purpose. The figures in Table C.1 do not reflect the real correlation between these properties. The bending strength values in that table represent the minimum requirement for a well fused product. The average bending strength corresponding to compressive stress at 10 % deformation is significant higher than those values given in Annex C, table C.1 of EN 13163.

Different values of bending strength at different temperatures were measured by Zehendner [21] and given in *Table 4*.

Table 4: Bending strength at different temperatures.

Material	Density	Bending strength at different temperatures in kPa			
		-170 °C	-60 °C	20 °C	70 °C
EPS block moulded, non flame retarded	14	160	220	150	130
	23	290	300	330	290
EPS block moulded, flame retarded	14	200	200	170	130
	22	370	330	280	230
EPS, moulded board	40	690	670	510	300

Relationship to shear see 0.

2.5.3.7 Point load

(4.3.7). The point load test method was developed specially for products that behave in a particular way on flat roofs during installation (e.g. mineral wool can be very flexible and cellular glass can be very brittle). EPS behaves in a different way, the loads during construction are rather low compared to the possible loads determined from compressive strength and they will certainly not affect EPS. Therefore the point load test method is not mentioned in clause 4.3.7 of EN 13163, stating that determination of compressive stress at 10% deformation is sufficient for flat roof applications.

2.5.3.8 Compressive creep

(4.3.8). The long term behaviour under load is determined by compressive creep. Compressive creep is the deformation under a specified load, σ_c, in relationship to the time.
Just after the beginning of the load there is an initial deformation X_0. The total deformation, X_t, under load can be calculated as follows:

$$X_t = X_0 + 10^a * t^b$$

In this formula t is used for the time in hours and a and b are coefficients which have to be calculated according EN 1606.

Compressive creep will normally be needed for applications where continuous high loads are imposed on a structure supported by EPS, e. g. such as building foundations or cold store floors.

The SP Swedish National Testing and Research Institute in Gothenburg has published results of creep data of EPS in 2001 [28]. SP has measured samples of block moulded EPS of a mean densities of 18,9 kg/m³ and 30,0 kg/m³ over a period of 15.869 h (corresponding to 662 days, see also note 1 of clause 4.3.8 in EN 13163). The tested compressive stress, σ_c, was taken as a ratio from the compressive stress at 10 % deformation, σ_{10}. The following three different ratios have been tested:

$$q_1 = \sigma_{c1}/\sigma_{10} = 0{,}25$$

$$q_2 = \sigma_{c2}/\sigma_{10} = 0{,}35$$

$$q_3 = \sigma_{c3}/\sigma_{10} = 0{,}45$$

Figure 9 and Figure 10 show the long term creep behaviour evaluated according EN 1606.

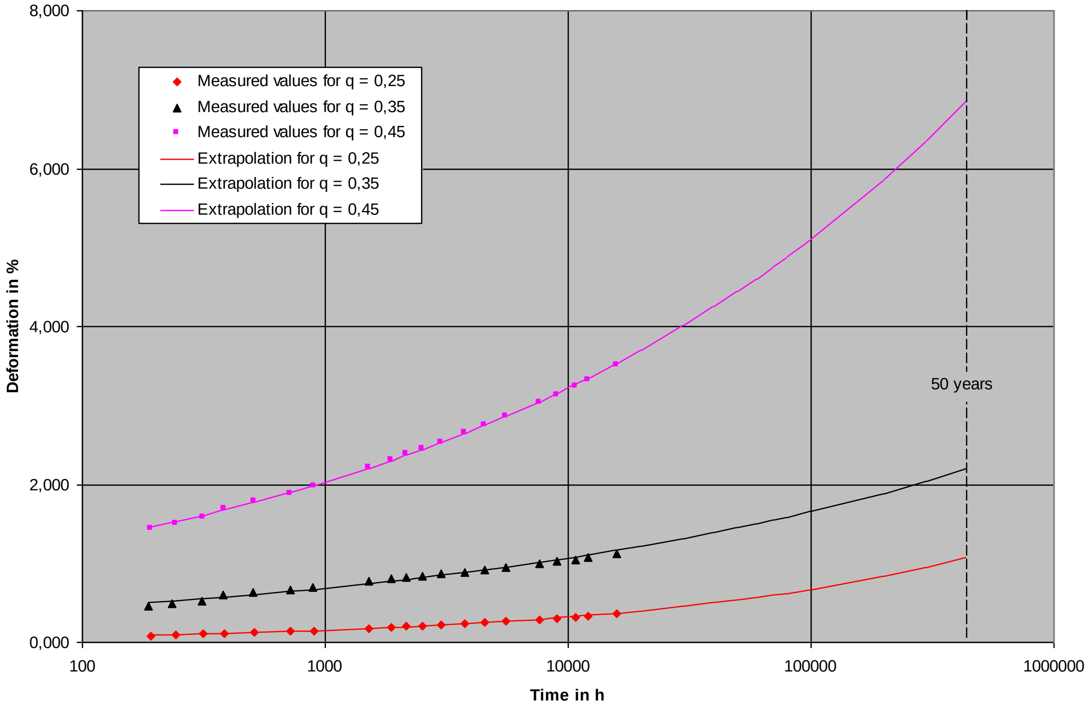


Figure 9:
Measured total deformation of EPS 100, ε_t, and extrapolation to 50 years.

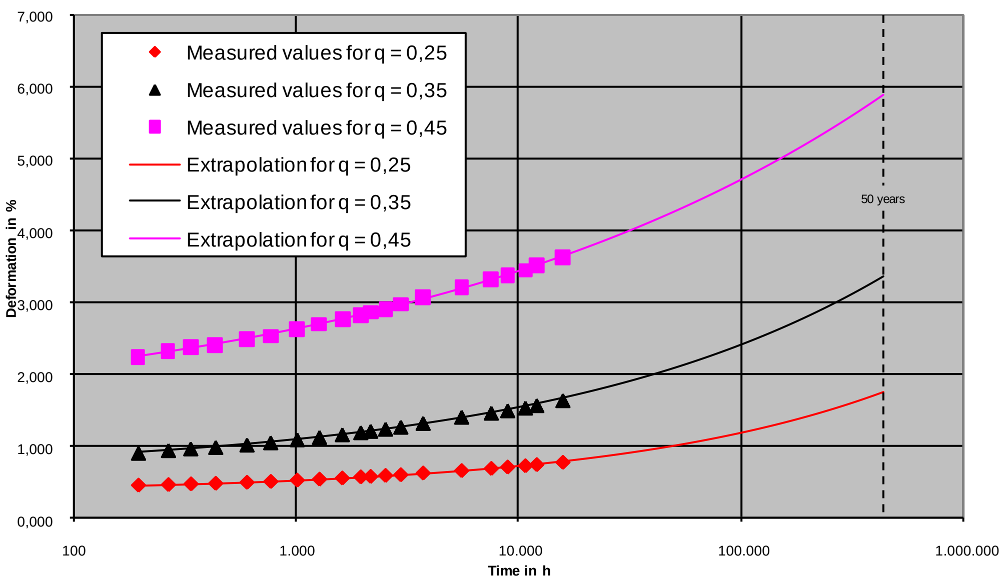


Figure 10:
Measured total deformation of EPS 200, ε_t, and extrapolation to 50 years.

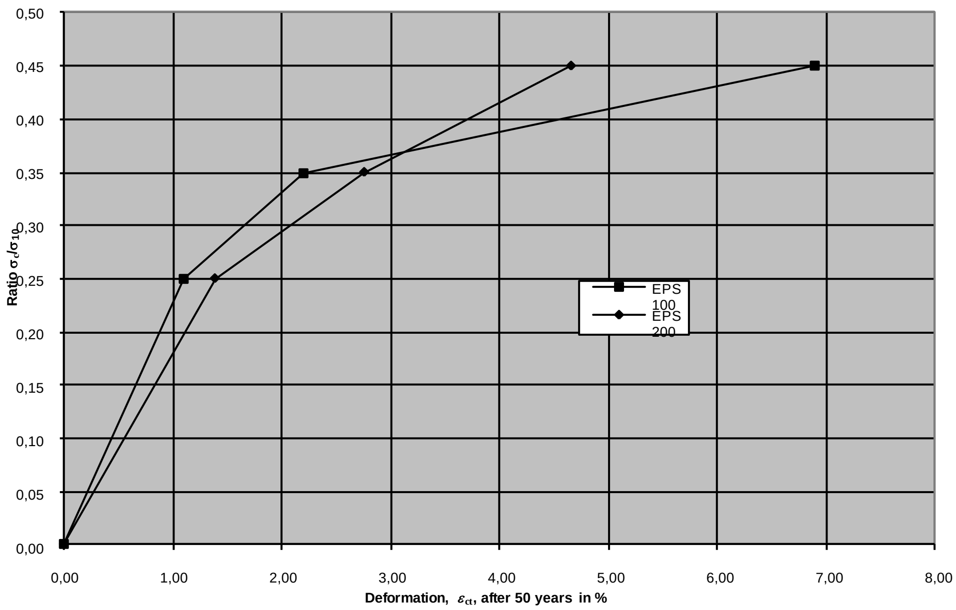


Figure 11:
Creep compression, ε_{ct}, of EPS 100 and EPS 200 after 50 years in relationship to the ratio q.

To avoid a huge number of measurements for all possible products and practical conditions the ratio q may be used to declare the correct compressive stress, σ_c, which leads to a deformation of 2 % after 50 years. According to Figure 11 this ratio is about 0,30 which proves that the factor of 0,30 given in D.2 of EN 13163 is correct.

The initial deformation derived from the measurements from SP are for a ratio of 0,30 as follows:

EPS 100 0,54 %
EPS 200 0,48 %

Example

An EPS insulation shall be designed for the use under a foundation which will impose a compressive stress of 75 kPa. The deformation of 2 % shall not be exceeded. Which material has to be chosen?

σ_c = 75 kPa

$\sigma_{10} = \sigma_c / q$ = 75 kPa / 0,30 = 250 kPa

That means an EPS material of σ_{10} = 250 kPa has to be chosen for this application. To decide on the apparent density, ρ_a, which has to be selected the equation B.2 of EN 13163 (Annex B) may apply:

$\sigma_{10,\ pred} \approx 10{,}0\ \text{kPa}\cdot\text{m}^3/\text{kg} \times \rho_a - 109{,}1\ \text{kPa}$

$\rho_a = (\sigma_{10,\ pred} + 109{,}1\ \text{kPa}) / 10{,}0\ \text{kPa}\cdot\text{m}^3/\text{kg}$

$\rho_a = (250\ \text{kPa} + 109{,}1\ \text{kPa}) / 10{,}0\ \text{kPa}\cdot\text{m}^3/\text{kg}$

$\rho_a = \underline{35{,}9\ \text{kg/m}^3}$

The compressive creep of a product designed in such a way would have a declared value of CC(2%/1,5%,50)75.

If the producer uses a specific proven correlation of compressive stress and density this may be applied which may lead to other results.

2.5.3.9 Water absorption

(4.3.9). For normal building applications the water uptake of EPS is negligible, The different test methods for water absorption are accelerated tests to describe the material but the results may not directly be relevant for design purposes. For common applications the design thermal conductivity, λ_U, is the same as the declared thermal conductivity, λ_D (2.5.2.1). In applications where the EPS product is in permanent contact with water, the moisture conversion factor of the thermal conductivity should be estimated according to EN ISO 10456.
Water absorption can be measured short term or long term, by partial or total immersion or by diffusion.

The change of thermal conductivity with moisture content from thermal insulation and other construction materials was determined by a German research [49]. This literature shows that EPS has a much more favourable behaviour concerning the increase of thermal conductivity than other insulation materials having no closed cell structure. To calculate the relationship between moisture content and thermal conductivity for different densities the factor F_Ψ was introduced by the authors of this research. The equations below present this relationship more precisely than the values given in *Table 5* and *Table 6*.

NOTE: The factor F_Ψ is referred to as F_m in EN-ISO 10456.

$F_\Psi = \lambda_u / \lambda_{u=0}$
Where u is the variable water content in vol-% and $\lambda_{u=0}$ is the thermal conductivity of a dry material.

$F_\Psi = 1{,}0 + 0{,}032078 \cdot u + 0{,}0010031 \cdot u^2$

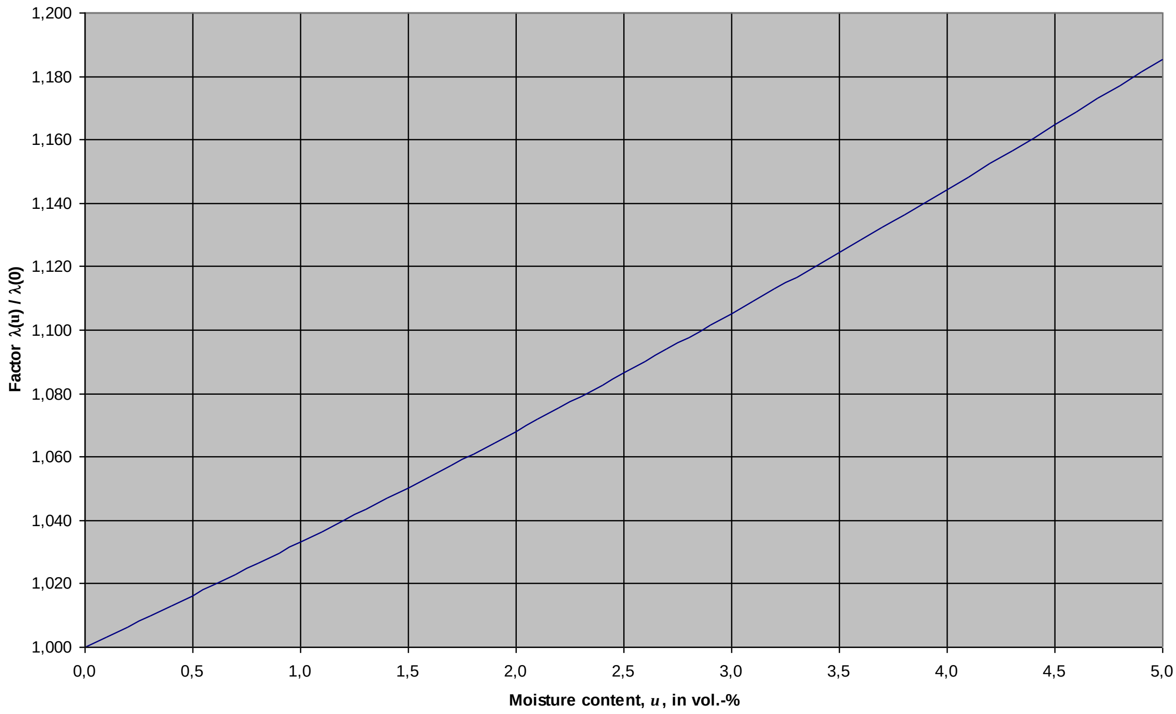


Figure 12: Change of thermal conductivity with moisture ref. [49].

Table 5: Thermal conductivity in relationship to moisture content according ISO 10456.

Moisture content %	**Design thermal conductivity (λ_u)**	
	λ_D = 0,033 W/mK	λ_D = 0,036 W/mK
1,0	0,034	0,037
2,0	0,036	0,039
3,0	0,037	0,041
5,0	0,040	0,044
10,0	0,049	0,054
15,0	0,060	0,066

<u>Example</u>

In drained building foundations where the EPS product is against or within the ground, the practical long term water content, W_p, is approximately

$$W_p \approx W_{lt} / 2$$

and in non drained foundations

$$W_p \approx W_{lt}$$

According to the levels given in EN 13163 (table 8) the design thermal conductivity may be calculated as follows:

$$\lambda_U = \lambda_D \cdot F_\Psi$$

The values for F_ψ are given in Table 6.

Table 6: Moisture conversion factor F_ψ derived from [4].

Level according to EN 13163	Practical water content W_P vol-%		Moisture conversion factor F_ψ 1	
	Drained	Not drained	Drained	Not drained
WL(T)5	≤ 2,5	≤ 5,0	1,11	1,22
WL(T)3	≤ 1,5	≤ 3,0	1,06	1,13
WL(T)2	≤ 1,0	≤ 2,0	1,04	1,08
WL(T)1	≤ 0,5	≤ 1,0	1,02	1,04

For the behaviour under water exposure in practical conditions see also 2.5.3.10.

2.5.3.10 Freeze thaw resistance

(4.3.10). The determination of the freeze-thaw resistance is only needed for applications where EPS is permanently exposed directly to water and a temperature range from below zero up to higher than zero degrees Celsius. These conditions can occur in non-protected frost insulation systems (no gravel layers or insulation under groundwater etc.) or in inverted roofs.

The freeze-thaw resistance is tested according to EN 12091 in which the changes of compression strength and moisture content will be determined. The test has 300 cycles from dry conditions at the temperature of – 20 ºC to the wet conditions at the temperature of + 20 º C. A large amount of measurements of the freeze-thaw resistance shows that EPS products having a density higher than 20 kg/m³ and a bending strength of at least 150 kPa are not degraded by freeze-thaw cycles. Also the thermal conductivity of EPS frost insulation boards is not affected by freeze-thaw cycles.

The Canadian Institute for Research in Construction has tested moulded EPS boards in a perimeter application over a long term period of two years [38]. The thickness of boards was 76 mm and the density varied approximately from 12 to 18 kg/m³. After a two year monitoring period the measurements indicated stable thermal performance of EPS frost insulation. The thermal performance of the specimen was not significantly affected by water movement. It also appears that the EPS insulation protected the concrete during these events. Thermal conductivity showed no significant difference from that measured on the initial EPS product. Also the compressive strength of the EPS samples were the same as those of samples tested at the beginning of the test. The in situ performance of EPS frost insulation indicated a high stability of EPS.

For horizontal frost insulation materials, the determination of the freeze-thaw resistance is not necessary when the insulation is used in normal drained conditions (insulation above the ground water level). The ground slab should be surrounded from both sides by layers of gravel and sand that have low capillarity. These layers form a part of drainage system that keeps the free water level mainly below the insulation layer. EPS frost insulation should have only occasional contact with free water. At least a 200 mm layer of gravel and sand is recommended to be used between the free water level and frost insulation. The EPS frost insulation should also be protected against high moisture loads from above. Both the ground surface and the frost insulation layers should be inclined (at least 2 %) away from the building so that the possible free water from above will be lead away from the foundation. In the above mentioned conditions the long term moisture content of EPS frost insulation with properly arranged drainage of free water will typically be in the range of 0,5 to 2,5 % Vol. [47].

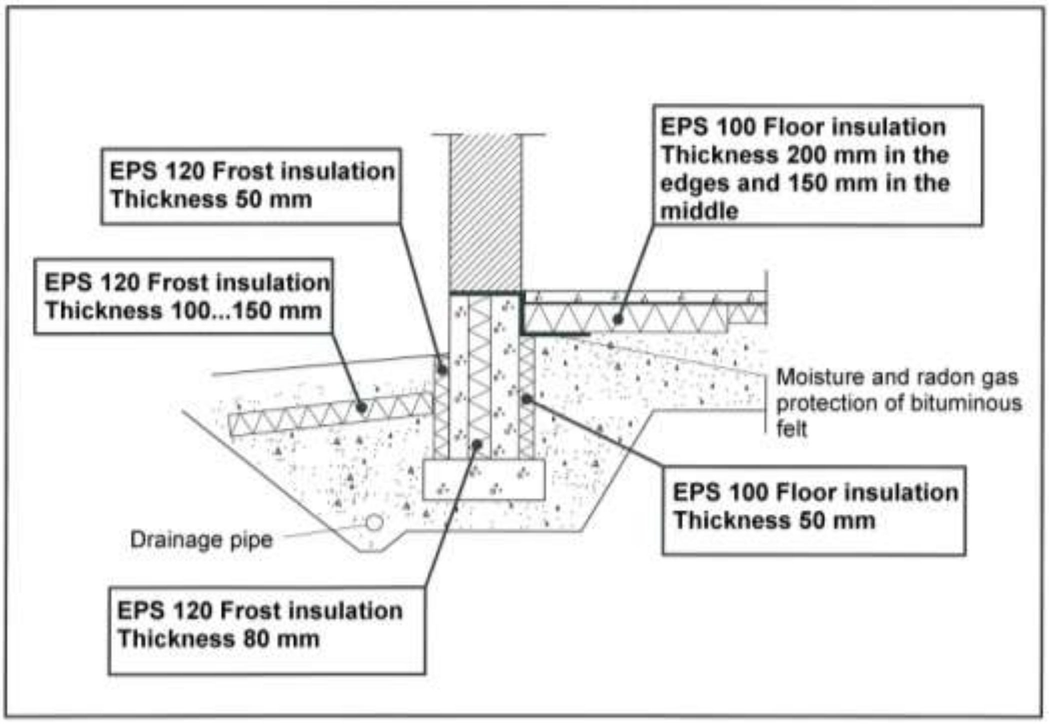


Figure 13:
Example of how to use EPS frost and floor insulation materials in ground slab structures.

<u>Conclusion:</u>

- EPS frost insulation materials with a density of 22 kg/m³ or above have good results in freeze-thaw tests, if the boards are well fused.
- The classification of Finnish EPS Division's EPS frost products is (based on test method EN 12087, method 2A):
  - EPS 120 Frost: short-term compressive strength at 10 % deformation 120 kPa, and the moisture content below 2 Vol %
  - EPS 200 Frost: short-term compressive strength at 10 % deformation 200 kPa and the moisture content below 1 Vol %
  - EPS 300 Frost: short-term compressive strength at 10 % deformation 300 kPa and the moisture content below 1 Vol %
  - EPS 400 Frost: short-term compressive strength at 10 % deformation 400 kPa and the moisture content below 1 Vol %

2.5.3.11 Water vapour transmission

(4.3.11). The water vapour transmission through the thermal insulation product is needed for constructions where the water vapour condensation has to be calculated. A calculation method for this purpose is given in EN 13788 [23], which defines water vapour diffusion resistance factors. These factors are given in Annex D, table D.2 of EN 13163. Since there is always a range given in table D.2 some national application rules require the use of the unfavourable value and therefore it has to be decided whether the upper or the lower value should be used. In cases where the condensation point is located inside the insulation layer the higher value should be used. In cases where the condensation point is located outside the insulation the lower value should be used. If the condensation is located inside the EPS layer it makes no difference which value has been chosen.

In addition to EN 12086, EN ISO 12572 is another test standard for this property._For other building materials EN 12524 [16] containing tabulated values may be used.

2.5.3.12 Dynamic stiffness

(4.3.12). The dynamic stiffness is needed for applications where acoustical performances have to be assessed. The type of EPS for this application is EPS T. The dynamic stiffness describes the transmission of vibrations through EPS between two layers. Low values of dynamic stiffness lead to a high sound reduction index. For indirect testing of dynamic stiffness see Annex B, clause B.2.5 of EN 13163.
Normally the dynamic stiffness is needed to calculate the weighted impact sound reduction index of intermediate floors with a floating floor finish.

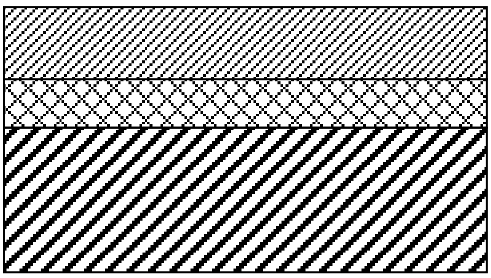


Figure 14: Example of a ceiling construction with a floating floor.

For detailed information how to calculate the impact sound reduction see the following example and EN 12354-2 [24].

Example

Two floors of a building are separated by an in-situ concrete solid floor, thickness 200 mm. To achieve a certain acoustic performance a floating floor, thickness 60 mm, made of concrete shall be fabricated on a layer of EPS T. The properties of the EPS T are:

thickness	40 mm
compressibility	3 mm
dynamic stiffness	10 MN/m³

If the density of the concrete floor is 2.300 kg/m³ and the density of the slab is 2.000 kg/m³ the mass per unit area is

for the floor	460 kg/m²
for the screed	120 kg/m²

According to Annex B of EN 13254-2, equation B.5 the equivalent weighted normalised sound pressure level $L_{n,w,eq}$ of homogeneous floor constructions is

$$L_{n,w,eq} = 164 - 35 \lg \frac{m'}{m'_0} \text{ in dB}$$

where

m' is the mass per unit area of the floor and
m'_0 is 1 kg/m².

$$L_{n,w,eq} = 164 - 35 \lg \frac{460 kg/m^2}{1 kg/m^2} 164 - 35 \lg 460 = 164 - 35 \cdot 2{,}663 = 70{,}8 dB$$

The weighted reduction of impact sound pressure level, ΔL_w, for floating floor screeds may be taken from figure C.1 of EN 12354-2. For a mass per unit area of the screed of 120 kg/m² and a dynamic stiffness of 10 MN/m³ of the impact sound insulation layer ΔL_w is 33 dB.

The correction K for flanking transmission has to be taken from Table C.1 of EN 12354-2. Assuming the mean mass per unit area of the homogeneous flanking elements is 200 kg/m² the correction K will be 2 dB.

Now the weighted normalized impact sound pressure level, $L'_{n,w}$, between two rooms can be calculated:

$L'_{n,w} = L_{n,w,eq} - \Delta L_w + K$ = 71 dB – 33 dB + 2 dB = <u>40 dB</u>

Normally this is the required value in national application rules. If the weighted standardized impact sound pressure level is required the volume, V, of the receiving room has to be taken into account. Assuming a volume of 50 m³

$L'_{nT,w} = L'_{n,w} - 10\lg(V/30)$ = 40 dB – 2,2 dB = <u>38 dB.</u>

Furthermore products having a low value of dynamic stiffness improve the performance concerning air born sound in some constructions like gypsum board faced walls or ETICS. For this application a method is being developed to measure the air born soud insulation. A draft is bein set up in TC 88 WG 18.

The following equation can be used:

$R'_{w,R} = R'_{w,R,O} + \Delta R'_{w,R}$ [dB]
where
$R'_{w,R}$ = Air born sound insulation of an ETICS wall
$R'_{w,R,O}$ = Air born sound insulation of the carrier wall
$\Delta R'_{w,R}$ = Correction value, using the following equation:

$\Delta R'_{w,R} = \Delta R'_{w} - K_K - K_T$ [dB]
where
$\Delta R'_{w}$ = Correction value depending on the resonance frequency (see *Table 7*)
K_K = Correction for the percentage adhesive surface (see *Table 8*)
K_T = Correction for the evaluated sound insulation level of the carrier wall (see *Table 9*)

Table 7: Correction value depending on the resonance frequency

Resonance frequency f_R [Hz]	Correction value ΔR_W [dB]	
	Without dowels	With dowels
$f_R \leq 60$	13	7
$60 < f_R \leq 70$	12	6
$70 < f_R \leq 80$	10	5
$80 < f_R \leq 90$	8	4
$90 < f_R \leq 100$	6	2
$100 < f_R \leq 120$	4	1
$120 < f_R \leq 140$	2	-1
$140 < f_R \leq 160$	0	-2
$160 < f_R \leq 180$	-1	-3
$180 < f_R \leq 200$	-3	-4
$200 < f_R \leq 220$	-4	-4
$220 < f_R \leq 240$	-5	-5
$240 < f_R$	-6	-6

The resonance frequency, f_R, is to be calculated from the level of the declared dynamic stiffness in accordance with clause 4.3.12 of EN 13163:

$$f_R = 160\sqrt{s'/m'_p}$$

where
f_R = resonance frequency [Hz]
s' = the dynamic stiffness of the EPS board [MN/m³]
m'_p = area mass of the plaster layer [kg/m²]

Table 8: Correction for the percentage adhesive surface

Percentage adhesive surface (%)	K_K [dB]
20	-1
40	0
60	1
80	2
100	3

Table 9: Correction for the evaluated sound insulation level of the carrier wall

Resonance frequency f_R [Hz]	K_T [dB] depending on the evaluated sound insulation level of the carrier wall R_W [dB]					
	43-45	46-48	49-51	52-54	55-57	58-60
$f_R \leq 60$	-10	-7	-3	0	3	7
$60 < f_R \leq 80$	-9	-6	-3	0	3	6
$80 < f_R \leq 100$	-8	-5	-3	0	3	5
$100 < f_R \leq 140$	-6	-4	-2	0	2	4
$140 < f_R \leq 200$	-4	-3	-1	0	1	3
$200 < f_R \leq 300$	-2	-1	-1	0	1	1
$300 < f_R \leq 400$	0	0	0	0	0	0
$400 < f_R \leq 500$	1	1	0	0	0	-1
$500 < f_R$	2	1	1	0	-1	-1

Calculation of the sound insulation level, R_W, of the carrier wall shall be calculated as:

$R_W = [27,1 + 0,1243(m'_W – m'_0) – 0,000113(m'_W – m'_0)^2]$ [dB]
where
R_W = sound insulation level [dB]
m'_W = area-based mass of the carrier wall [kg/m²]
m'_0 = normative mass [kg/m²]

2.5.3.13 Compressibility

(4.3.13). The compressibility is used for EPS T products applied in load bearing constructions like floating floors. Since there are different levels of imposed load on the screed the compressibility levels are given in correlation to those load levels. To determine the compressibility, c, the thickness d_L and the thickness d_B have to measured first.

$c = d_L - d_B$

For constructions with a level of imposed load up to 5 kPa there is a great deal of experience of the long term behaviour. In these cases the long term thickness reduction is lower than or equal to c if the requirements of table 12 of EN 13163 are met. For higher levels of imposed load the long term thickness reduction, X_t must be determined in accordance with EN 1606.

2.5.3.14 Apparent density

(4.3.14). The apparent density is not a product performance but a very important parameter for quality assessment and for indirect testing. Many of the properties of an EPS product relate to density such as thermal conductivity, bending strength, deformation under load, compressive stress, tensile strength, compressive creep, water absorption, freeze thaw resistance, water vapour transmission, dynamic stiffness, compressibility, shear strength, dynamic load resistance. The properties bending strength, tensile strength, water absorption, freeze thaw resistance, water vapour transmission and shear strength depend very much on the fusion of the material. Guidance on how to use the density for indirect testing is given in the Annex B, clause B.2 of EN 13163.

2.5.3.15 Release of dangerous substances

(4.3.15)

2.5.3.15.1 General

The European Community has decided already in the CPD in 1990 that construction products should not emit or leach "dangerous" substances to the environment or should not contain "substances of very high concern". Guidance Paper H [29] is considered as the basic reference document with regard to the definition (and consequently the scope) and the approach ‘dangerous substances’ within the framework of the CPD.

The definition of ‘dangerous substances’ derived from the Guidance Paper and the CPD is:

- based on the release (emission to Indoor Air or leaching to Soil, Ground and Water) approach,
- focussed on the intended application of construction products,
- restricted to the normal use of construction products.

CEN has been requested to develop such procedures for the relevant release scenarios (evaporation, radiation, leaching etc.), the EC has granted a Mandate to CEN and CEN TC 351 was established in 2007.

A list of relevant dangerous substances released from construction products to the different types of environment to be protected when applied in the works was needed and taken from the existing DG Enterprise G5 database [30].

CEN TC 351 has - fall 2010 - drafted two sets of procedures to determine the release of these "Regulated Dangerous Substances (RDS)" and the EC funded TC 351 with budget for ruggedness testing of these procedures. Until verification of the procedures, the draft testing methods will not be available for use by involved parties (e.g. authorities, experts, institutes, contractors, producers).

2.5.3.15.2 Specific to EPS

EPS does not release any of the dangerous substances listed in reference [30] in such a way that it does not fulfil the local European environmental laws and guidelines. The released concentrations are of a lower order than the values set out in these legislations, see also *Table 7*

Table 10: Essential environmental properties.

Environmental effect / aspect	Abbreviation	Characterisation scores	Unit	Normalisation scores	Unit [b]
Environmental impact					
Abiotic depletion	ADP	0,83	1	1,04E-11	a
Global warming	GWP	5,98	kg	1,42E-12	a
Ozone depletion	ODP	2,11E-06	kg	3,75E-14	a
Human toxicity	HCT	0,0357	kg	9,06E-13	a
Aquatic ecotoxicity	ECA	101	m³	2,29E-13	a
Smog	POCP	0,0207	kg	3,28E-12	a
Acidification	AP	0,0278	kg	8,19E-13	a
Nutrification	NP	0,00241	kg	2,81E-13	a
Land use	LU*t	0,00274	m²		a
Environmental indicator					
Cumulative energy demand (excluding feedstock energy)	CED	48,9	MJ (lhv) [a]	8,45E-13	a
Cumulative energy demand (including feedstock energy)	CED+	93,1	MJ (lhv) [a]	1,61E-12	a
Not toxic final waste	W-NT	0,0453	kg	8,43E-14	a
Toxic final waste	W-T	0,0124	kg	3,09E-13	a

[a] lhv = lower heating value.
[b] a = year

2.6 Test methods

(EN 16163: Clause 5). To declare the properties of a product the products must be tested. Harmonised test methods are developed and referred to in clause 4. Those test methods are to be used; for Factory Production Control purposes alternative test methods can be used. If a dispute with a customer arises, the EN test methods are to be used. Additional properties described in Annex D of EN 13163 should also use the referenced test standards.

2.6.1 Sampling

(5.1). General sampling rules are given in the appropriate test method and specific sampling advice may be found in EN 13163.

2.6.2 Conditioning

(5.2). General conditioning rules are given in EN 13163 and specific conditioning advice may be found in the appropriate testing standard.

2.6.3 Testing

(5.3). The important information about testing is to be found in Table 13 of EN 13163.
Measured values which will be used for statistical evaluations shall be single values. It is not allowed to use mean values or use multiple values.

To measure thermal resistance and calculate thermal conductivity there are test methods given as described in *Table 11*

Table 11: Applicable test methods for thermal conductivity.

Test method	Title	Guidance, when to be used
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	For all samples with a thermal resistance R: 0,02 m²K/W $\leq R <$ 0,5 m²K/W
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	For all samples with a thermal resistance R: $R \geq$ 0,5 m²K/W
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	For all thick insulation products (100 mm – 150 mm), depending on the apparatus used, if the total thickness of the test specimen cannot be measured.

2.7 Designation code

(EN 13163: Clause 6). All products must be accompanied by a designation code. The designation must contain: the abbreviation code (EPS), the reference to the relevant standard (EN 13163), classes or levels of tolerance for all dimensions, dimensional stability, reaction to fire class and all levels or classes of the properties mentioned in clause 4.3 which are declared.

Properties in clause 4.2 for which only a limit value is required (e.g. bending strength) do not appear in the designation code. The producer may specify those properties on the product label or in his literature.

Examples of designation codes are given on the labels to be found in 2.9.

2.8 Evaluation of conformity

(EN 13163: Clause 7). The goal of the harmonised product standards is that all insulation products are produced according to their respective product standard, following the prescribed system of attestation of conformity. When a product conforms to the standard, it is allowed to bear the CE marking which enables free trade within the Member states.
EPS products labelled with the CE mark have to conform to EN 13163. It is the producer’s task to follow the requirements listed in clause 7 of EN 13163. This clause refers to EN 13172 for the details of the evaluation of conformity systems.

2.8.1 Attestation of conformity systems

The CPD gives four levels of attestation of conformity, from a manufacturer’s declaration up to systems where a third party is involved in the control schemes. In all cases the manufacturer must perform Initial Type Tests (ITT) and a continuous Factory Production Control (FPC).

2.8.2 Required level of attestation of conformity

The reaction to fire classification of the product determines the required level of attestation of conformity. Annex ZA, Table ZA.2 explains the required system of attestation of conformity related to the reaction to fire classification of the product. *Table 9* gives the possible systems of the attestation of conformity and the respective tasks for the manufacturer and the notified body.

System 1 is applicable for products in Euro class A1 up to C inclusive for which a clearly identifiable stage in the production process results in an improvement of the reaction to fire

classification (e.g. an addition to fire retardants). This is normally not applicable for EPS, since almost all converters do not add fire retardants during production process (it is already contained in the raw material).
System 3 is generally applicable for all other products, including EPS.

Assignment of the tasks for the manufacturer and/or the certification body is given in Annex ZA Table ZA.3 for system 1 and Table ZA.4 for systems 3 and 4.

Table 12: Tasks of the involved parties for different AoC Levels

Tasks	**Steps**	**Responsible**			
		AoC 1^+	**AoC 1**	**AoC 2^+**	**AoC 3**
Initial tests and inspection	Sampling for ITT	NB (M)	NB (M)	M	M
	Perform ITTs according to Table ZA.4	NB	NB	NB	NB
	Perform further ITTs	NB	NB	M	M
	Initial inspection of FPC	NB	NB	NB	M
Current surveillance	Current inspections of FPC	NB	NB	NB	M
	Collecting samples for product testing	NB	M	M	M
	Tests of properties according to Table ZA.4	NB	M	M	M
	Test of further properties	M	M	M	M
Declaration	Issue of a Certificate of Conformity of products	NB	NB	-	-
	Issue of a Certificate of FPC	-	-	NB	-
	Issue of a manufacturer declaration for products	-	M	M	M
Applications	EN 13163 EN 13499 EN 14933				X
	ETAG 004 EN 15037-4 (Block and Beams)			X	
	Future ETICS Standard		X		
	Voluntary Quality System	X			

Abbreviations:

AoC Attestation of Conformity
FPC Factory Production Control
ITT Initial Type Test
M Manufacturer
NB Notified Body

Since the EN standards are written to obtain a CE mark and thus be subject to free trade, one could expect that following the rules a CE mark with an attestation of conformity system 3 would be sufficient. The CE marking can be seen as a passport to cross borders between Member

States. The reality of today shows that a voluntary quality system (VQS), including third party control (system 1) is almost inevitable, sometimes even per Member State for the product to be practically accepted.

2.8.3 Third parties

Member States have appointed notifying authorities with the power to notify bodies for certification, testing and inspection of construction products, to the commission. The same is valid for countries, with which the European Union has concluded agreements (e. g. EEA, MRA, PECA) including such a notification procedure. States concerned may only notify bodies within their territories. The minimum requirements for the bodies to be notified are laid down in Annex IV of the CPD. Member States may add requirements for the bodies they notify. Additional requirements can be accreditation etc.

2.8.4 Manufacturer’s declaration of conformity

Once a manufacturer has had all the appropriate attestation tasks carried out for his product he is required to complete an ‘EC Declaration of conformity’ which is kept with his technical file concerning the product. This may be supported by a certificate of product conformity, FPC certificate, test laboratory reports or certificates, and / or own test results, depending on the attestation system required.

An outline of the manufacturer’s declaration of conformity and for the certificate of product conformity (if relevant), is given in Annex ZA.2.2.

2.9 Marking and Labelling

(EN 13163: Clause 8). Products must be marked, either on the product, or on the label or on the packaging. The marking must contain the product name or some other identifying characteristic, data from producer or his agent, traceability code, reaction to fire class, declared thermal resistance and/or declared thermal conductivity (where appropriate), nominal dimensions, the designation code (see 2.2) and the number of pieces and area in the package as appropriate. The CE marking and labelling are given in Annex ZA.

2.10 Annexes

All product standards contain normative as well as informative annexes. The normative annexes are an integral part of the standard. There are two kinds of informative annexes: those containing information which can be used by a manufacturer to declare additional properties and Annex ZA. When an additional property is declared by a manufacturer, the informative annex becomes mandatory. Annex ZA is included in all TC 88 product standards as an informative annex, but it is also mandatory. It contains the translation of the rules given by the EC into product requirements.

2.11 Determination of the declared values of thermal resistance and thermal conductivity

(EN 13163: Annex A – normative)

2.11.1 General

(A.1). All standards for insulation materials for building have an Annex A to determine the thermal conductivity with a fractile of 90 % of the production and a confidence level of 90 %. Further detailed information about the statistical background is given in [34].The manufacturer is and remains responsible for the declared values, which are to be expected during an economically reasonable working life under normal conditions (at least 25 years).

2.11.2 Input data

(A.2). Before a statistical evaluation can be started, at least 10 measurements must be available.

2.11.3 Declared values

(A.3). The declared thermal conductivity is calculated using the equation

$\lambda_{90/90} = \lambda_{mean} + k \times s_{\lambda}$
where
$\lambda_{90/90}$ = the 90% fractile with a confidence level of 90% for the thermal conductivity
λ_{mean} = the mean value of the measured thermal conductivity
k = number of measurements
s_{λ} = standard deviation

The declared thermal resistance is calculated using the equation

$R_{90/90} = R_{mean} - k \times s_R$

2.12 Factory Production Control

(EN 13163: Annex B – normative)

2.12.1 Testing frequencies

(B.1). The testing frequencies for all properties described in the normative part of the standard are given in table B.1 and for reaction to fire in table B.2.

Some properties must be verified at a short interval, some at a larger interval and some properties only have to be measured once (ITT). Products with the same property may be grouped; thus saving costs of testing. Rules for grouping are given in EN 13172.

Table B.1 contains footnotes, some of them need clarification:

a. The definition of an EPS production unit and an EPS production line is given in EN 13172. Production line: assemblage of equipment that produces products using a continuous process. Production unit: assemblage of equipment that produces products using a discontinuous process.
b. In cases where the measurements will be statistically evaluated one measurement shall always be one test result. See also 2.6.3.
c. Initial type testing (ITT) means once in a lifetime providing that the relevant production parameters remain unchanged.
d. As soon as test methods for dangerous substances are available the standards will be revised.

Table B.2 gives minimum product testing frequencies for the reaction to fire characteristics. For EPS boards the ignitability test (EN ISO 11925-2) is the most relevant test. According to footnote h in table B.2, this test may be performed once per week, when products are made from certified raw material according to CEN TR 15985 [52]. When products are made with non-certified raw material, the test must be performed once a day.

2.12.2 Indirect testing

2.12.2.1 Indirect testing

(B.2.1). Properties for which the relationship to another property, e. g. density, is well known, may be tested indirectly via that property. This option will be used if the indirect test is quicker or cheaper. In EN 13163 figures are given for the relationship compressive stress at 10% deformation versus Density, and Thermal conductivity versus Density.

2.12.2.2 Thickness effect

(B.2.2). Normally for EPS products, having a thickness of at least 50 mm and a $\lambda_D \leq 0{,}038$ W/(m·K), the thickness effect is negligible. For other products, the thickness effect is given in Table B.3

2.12.2.3 Dynamic stiffness

(B.2.3). When dynamic stiffness is required, this must be measured. The dynamic stiffness depends on the thickness of a product. To prevent too much and unnecessary testing, the relation between dynamic stiffness and dynamic elasticity modulus becomes relevant. For a range of thicknesses only the combination of the lowest dynamic elasticity modulus and the dynamic stiffness at the corresponding thickness have to be tested.

Example for testing (when grouping):

Thickness (mm)	Class	Test
40	SD10 - CP3	SD10
50	SD10 - CP3	
60	SD10 - CP3	CP3

2.13 Product classification

(EN 13163 : Annex C – normative). The normative Annex C contains definitions of EPS product types. Three types are given:

- EPS S, for non load bearing applications
- EPS 30 – EPS 500 for products with load bearing capability, where the figure stands for the level of compressive stress at 10% deformation
- EPS T for products with load bearing capability combined with acoustical properties.

To ensure a certain level of quality of the EPS product table C.1 combines two properties: compressive stress and bending strength. Compressive stress depends on density as shown in Annex B. Bending strength depends on the fusion of the EPS product. This combination of compressive stress and fusion quality ensures a good correlation with other properties.

For non load bearing applications there is no compressive stress required and in these cases EPS S may be used (e.g. in cavity walls and ETICS).

Although EPS T is used for load bearing applications there is no compressive stress required measured according to EN 826. The measurement of a certain level of compressibility according to EN 12431 ensures the load bearing capacity of the product for long time behaviour. The value of the compressibility is approximately the same as the long term compressive behaviour under a floating floor under practical conditions.

2.14 Additional properties

(Annex D - informative)

2.14.1 General

(D.1). Annex D has been designed to provide more information to the user of EPS than is given in the normative part of the EPS standard. Since the content of the normative part is restricted by the mandate M103 as given by the EC to CEN, there was a need to adopt further properties.

2.14.2 Long-term compressive behaviour

(D.2). The long term compressive behaviour, when determined according to EN 1606 is described in 2.5.3.8. Annex D.2 describes a simple calculation procedure to determine the loads which may be applied on EPS products to ensure predicted 50 year creep values of a maximum of 2 %. The calculation is established over a long period and based on [50].

Shear behaviour.
(D.3). The shear behaviour may be useful in cases where EPS is laminated and where EPS contributes to the mechanical performance of the element. The shear strength of EPS depends on the quality of fusion and on the density. For well fused products the correlation between shear strength and density is given in Figure 15.

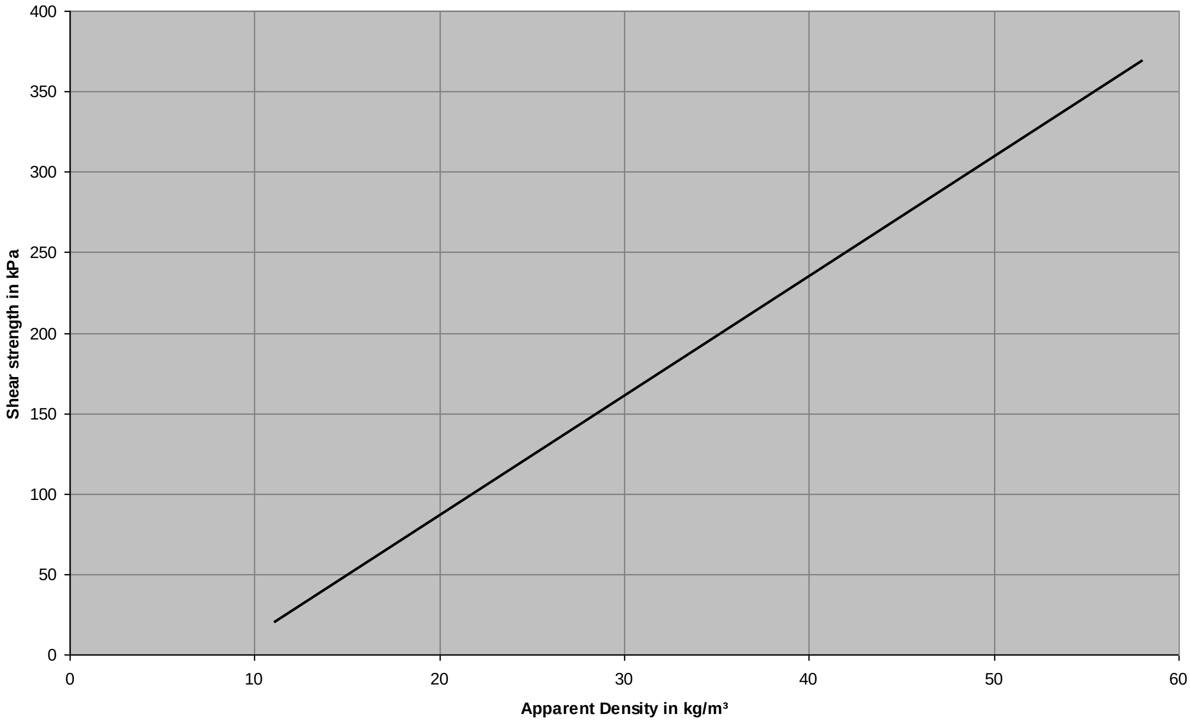


Figure 15: Correlation between shear strength and density.

$\tau = 7{,}43\rho_a - 62{,}8$ in kPa

Different values of shear strength at different temperatures were measured by Zehendner [21] and given in *Table 13*.

Table 13: Shear strength at different temperatures.

Material	Density	Shear strength at different temperatures in kPa	
		20 °C	70 °C
EPS block moulded, non flame retarded	14	550 – 1.000	280 – 410
	23	770 – 1.100	560 – 850
EPS block moulded, flame retarded	14	820 – 1.300	350 – 380
	22	670 – 1.300	530 – 750
EPS, moulded board	40	1.300 – 1.500	1.000 –1.100

More data are to be found in [46]. In literature [46] a relationship between shear strength and bending strength is shown, see Figure 16.

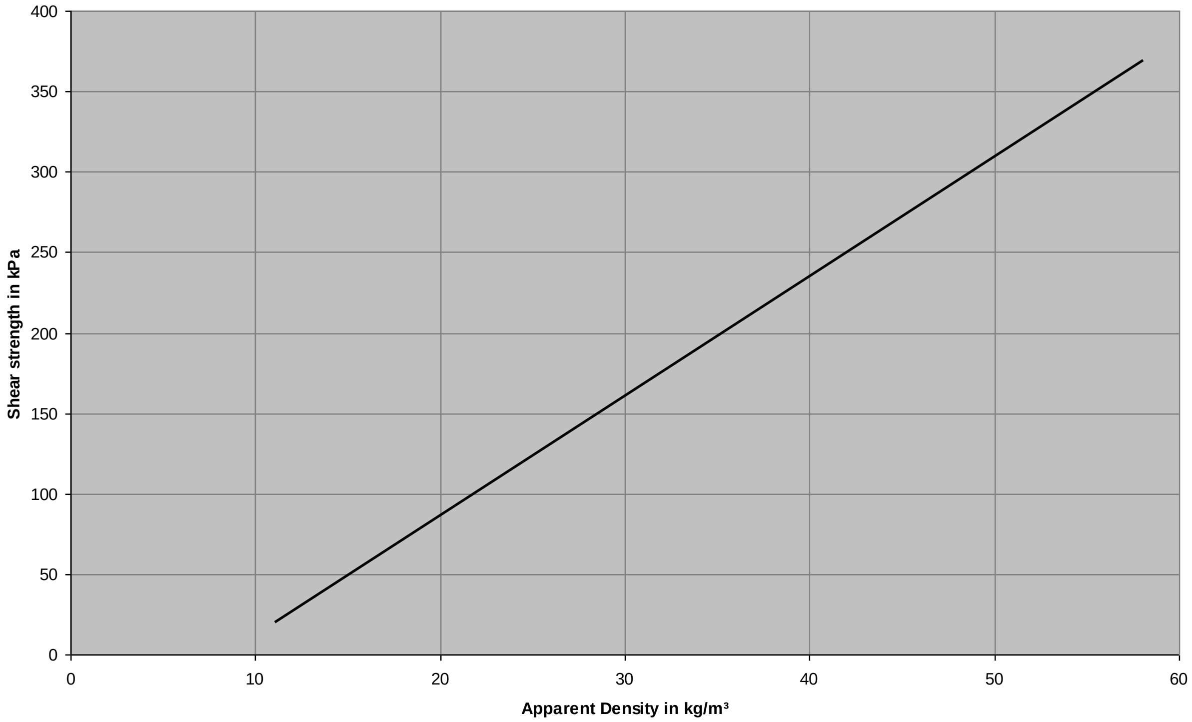


Figure 16: Relationship between shear strength and bending strength.

$\tau = 6{,}7\ \text{kPa} + 0{,}5 \cdot \sigma_b$

2.14.3 Water vapour diffusion resistance factor

(D.4). The water vapour diffusion resistance factor is used to calculate water vapour condensation inside a construction. For more details see 2.5.3.11.

In EN 12086 the following definitions are to be found:

Water vapour permeability, δ:
The product of the permeance and the thickness of the test specimen. The water vapour permeability of a homogeneous product is a property of the material. It is the quantity of water transmitted per unit of time through a unit of area of the product per unit of vapour pressure difference between its faces for a unit thickness.

Water vapour diffusion resistance factor, μ:
The quotient of the water vapour permeability of air and the water vapour permeability of the material or the homogeneous product concerned. It indicates the relative magnitude of the water vapour resistance of the product and that of an equally thick layer of stationary air at the same temperature.

The water vapour diffusion resistance factor µ is normally given at a temperature of 20 °C and a barometric pressure of 1.011 hPa. The water vapour permeability, δ_{air}, of air at that condition is:

$$\delta_{air} = \frac{D}{R_D \cdot T}\left(\frac{T}{273K}\right)^{1,81}$$

where
D = 0,083 m²/h
R_D = 462·10^{-6} Nm/(mgK)

$$\delta_{air} = \frac{0,083 m^2/h}{462 \cdot 10^{-6}\, Nm/(mgK) \cdot 283K}\left(\frac{283K}{273K}\right)^{1,81} = 0,635 mg/(Pa \cdot h \cdot m) \cdot 0,965^{1,81} = 0,6 mg/(Pa \cdot h \cdot m)$$

$$\delta = \frac{\delta_{air}}{\mu} = \frac{0,6}{\mu}$$

Due to this calculation table D.2 in EN 13163 has to be slightly revised as given in Table 14.

Table 14: Tabulated values of water vapour diffusion resistance factors and water vapour permeability.

Type	Water vapour diffusion resistance factor µ 1	Water vapour permeability δ mg/(Pa·h·m)
EPS 30	20 to 40	0,015 to 0,030
EPS 50	20 to 40	0,015 to 0,030
EPS 60	20 to 40	0,015 to 0,030
EPS 70	20 to 40	0,015 to 0,030
EPS 80	20 to 40	0,015 to 0,030
EPS 90	30 to 70	0,009 to 0,020
EPS 100	30 to 70	0,009 to 0,020
EPS 120	30 to 70	0,009 to 0,020
EPS 150	30 to 70	0,009 to 0,020
EPS 200	40 to 100	0,006 to 0,015
EPS 250	40 to 100	0,006 to 0,015
EPS 300	40 to 100	0,006 to 0,015
EPS 350	40 to 100	0,006 to 0,015
EPS 400	40 to 100	0,006 to 0,015
EPS 500	40 to 100	0,006 to 0,015
EPS T	20 to 40	0,015 to 0,030

The values given in Table 14 are the correct (tabulated) values and differ slightly from the values given in EN 13163.

2.14.4 Behaviour under cyclic loading

(D.5). When subjected to a cyclic loading EPS can be tested according to EN 13793. The deformation (in %), the number of load cycles and the stress (in kPa) is then to be declared. Cyclic loading is relevant in flat roof (walkability) and civil engineering applications.

2.14.5 Test methods

(D.6). Test methods referred to in an informative Annex do not appear in clause 2 Normative references. That is why they are listed in the table D.3 of this Annex.

2.14.6 Additional information

(D.7). The additional information contains advice for installation and chemical behaviour. For chemical resistance of EPS see 6.6.

2.15 Clauses of this European standard addressing the provisions of the EU Construction Products Directive

(EN 13163: Annex ZA informative).

2.15.1 Purpose

Annex ZA, in the context of the Construction Product Directive (CPD), is an informative yet compulsory annex which makes the standard harmonised. It shows which elements of this standard are the basis for the CE marking of an EPS product. Annex ZA is an integral part of the standard.

CE marking in conformity with Annex ZA means that products may be freely placed on the EEA market. Although a product may need to have certain levels of performance to be able to be used in certain end use conditions, a CE marked product cannot be refused access to any EEA market. CE marking will prevent the manufacturer from having to produce different products for different markets and the need for the product to be tested and/or certified again in the country of destination.

Annex ZA establishes the conditions for CE marking of the products covered by EN 13163 by identifying those clauses of the standard needed to meet the CPD (in sub-clause ZA.1) describing the systems of attestation of conformity in ZA.2, and giving the information that has to accompany the CE mark in Z.3.

Annex ZA identifies what properties all manufacturers have to declare when placing their products on the European market, both in their own country and in another EC country. There may be some flexibility in which characteristics need to be evaluated depending on the country and the intended use of the product. The requirement on a certain characteristic is not applicable in those Member States (MSs) where there are no regulatory requirements on that characteristic for the intended use of the product. In this case, manufacturers placing their products on the market of these MSs are not obliged to determine nor declare the performance of their products with regard to this characteristic and the option “No performance determined” (NPD) in the information accompanying the CE marking (see ZA.3) may be used. The NPD option may not be used however, where the characteristic is subject to a threshold level (thermal resistance (thermal conductivity and thickness).
Furthermore EPS products having a thermal conductivity greater than 0,060 W/mK (see Scope of EN 13163) are not covered, which can be seen as a threshold level as well.

2.15.2 Relevant Clauses

(ZA.1). The EC has given mandates to CEN to develop harmonised product standards such as those for thermal insulation products. The mandate M/103 contains for the EPS standard all characteristics listed in the first column of table ZA.1 in EN 13163. These mandated characteristics are covered by standardised requirements as in clause 4 of the EPS product standard, listed in second column of table ZA.1. In some cases there is more than one requirement to cover one mandated characteristic. E.g. the mandated characteristic Thermal resistance is to be fulfilled by the combined requirements on thermal conductivity and thickness.

2.15.3 Procedures for attestation of conformity of factory made expanded polystyrene products

2.15.4 (ZA.2).

2.15.4.1 Systems of attestation of conformity

(A.2.1). Annex ZA.2.1 describes the systems of Attestation of conformity as decided by the commission, depending on the reaction to fire classification.

2.15.4.2 EC certificate and declaration of conformity

(ZA.2.2). Annex ZA.2.2 describes the rules for the EC certificate and declaration of conformity, depending on the attestation of conformity level. For EPS products, normally attestation of conformity level 3 applies, therefore only a declaration of conformity is needed.

2.15.5 CE Marking and labelling

(ZA.3). The products have to be labelled at least as indicated in Annex ZA , clause ZA.3.

CE	*CE conformity marking, consisting of the "CE"-symbol given in Directive 93/68/EEC.*
01234	*Identification number of the certification body (for products under system 1)*
Any Co Ltd, PO Box 21, B-1050	*Name or identifying mark and registered address of the producer*
08	*Last two digits of the year in which the marking was affixed (ITT)*
01234-CPD-00234	*Certificate number (for products under system 1)*
EN 13163:2008	*No. of dated version of European Standard*
EPS board	*Description of product*
	Information on regulated characteristics
Reaction to fire – Class C	Reaction to fire – Euroclass
Thermal resistance 2,6 m²·K/W	Declared thermal resistance
Declared thermal conductivity 0,034 W/m·K	Declared thermal conductivity
Thickness 90 mm	Nominal thickness
EPS - EN 13163 – T1 – S1-P3 - DS(70;90)3 - CS(10)250 - BS350	Designation code (in accordance with clause 6 of this standard for the relevant characteristics according to Table ZA.1)

Figure 17 Example CE marking information

The example of the CE marking as given in Figure 17 is only a part of the labelling a manufacturer must put on his product, label or packaging. The full amount of required data is given in Clause 8. Additional voluntary indications may be needed e.g. reference to national application rules. These voluntary indications shall be clearly separated from those belonging to CE marking.

3 Explanation of EN 13499 - Thermal insulation products for buildings - External thermal insulation composite systems (ETICS) based on expanded polystyrene – Specification

3.1 General

EN 13499 deals with external thermal insulation composite systems (ETICS) based on expanded polystyrene. This standard is a product standard specifying a kit of components and it is not an application standard. However, since the components are only meant for one application, there is no division of Clause 4 into two parts (“For all applications” and “For specific applications”).
Since no mandate was given to CEN for standards for ETICS, this standard is not a harmonised standard. Therefore there is no Annex ZA and hence it is not possible to affix CE marking according to EN 13499. In autumn 2010 a draft mandate was given and the development of a new standard for ETICS was started. The ongoing work in TC 88 WG 18 will be continued in the development of this new standard.

3.2 Properties omitted from EN 13163

3.2.1 General

Since EN 13499 is a standard specifying test methods for ETICS kits, a reference is made to EN 13163 for test methods related to the properties needed for ETICS. This means that the test methods for EPS referred to in EN 13163 are not repeated in this standard. This includes the Annexes A (Determination of the declared values of thermal resistance and thermal conductivity), C (Product classification), D (Additional properties) and ZA (Clauses of this European standard addressing the provisions of the EU Construction Products Directive).

3.3 Properties which differ from EN 13163

3.3.1 Foreword

This standard is not harmonised and although not an application standard, it is application related and the Foreword only contains text relevant for ETICS.

3.3.2 Scope

(1) The scope refers to EPS products and kits for ETICS. No system shall have a thermal resistance lower than 1,0 m²K/W.

3.3.3 Terms, definitions and abbreviations

(3) This clause contains all relevant items related to ETICS.

3.3.4 Thermal resistance

(4.2) The thermal resistance of the system according EN-ISO 10456 and EN-ISO 6946 is taken into account. The determination of the thermal conductivity, needed for the thermal resistance of the system, must be performed according to EN 13163.

3.3.5 Designation code

(6) This clause mainly contains information on the system.

3.3.6 Marking an labelling

(8) This standard needs in addition to EN 13163 a lot of information on the system as well as the various components.

3.4 Properties in addition to EN 13163

3.4.1 Mechanical resistance and stability of the system

(4.3) Various aspects of the mechanical properties of the system must be declared, depending on fixing by adhesive or mechanical fixing.
For fixing by adhesive: The bond strength of the base coat to the EPS board as well as the bond strength of the adhesive must be at least 80 kPa, according to EN 13494.
For mechanical fixing: the pull-off resistance of the ETICS must be determined according to EN 13495. The test result, combined with the applied forces (wind load) on the system, determines the amount of needed anchors.

3.4.2 EPS boards

(4.4) with reference to EN 13163 for methods of determination the properties, this clause gives the requirements for the EPS boards used in an ETIC.

3.4.3 Tensile strength of the reinforcement

(4.6) The tensile strength of the glass fibre meshes shall be determined in accordance with EN 13496. The following requirements shall be satisfied:

- the mean value of the tensile strength shall be greater than 40 N/mm and no individual value shall be less than 36 N/mm at the initial state;
- the relation of the tensile strength to the elongation at failure, stored under normal conditions and in aggressive medium, shall be not less than 1 kN/mm;
- the tensile strength after storage in aggressive medium, in accordance with EN 13496, shall be greater than 50 % of the initial tensile strength.

3.4.4 Liquid water permeability of the system surface

(4.7) Liquid water permeability shall be determined in accordance with EN 1062-3. No test result shall be greater than 0,5 $kg/(m^2.h^{0,5})$. If the base coat complies with this requirement the finishing material need not be tested.

3.4.5 Resistance to impact

(4.8) The system must be tested according to EN 13497. Two levels can be declared:
Level I 2 (no damages at 2 J) and I 10 (no damages at 10 J).

3.4.6 Resistance to penetration

(4.9) The system must be tested according to EN 13498. Two levels can be declared:
Level PE 200 (> 200 N) and PE 500 (> 500 N).

3.4.7 Durability and adhesion of the finishing material on the base coat

(4.11) After conditioning according to EN 1062-11, samples of the system must be tested according EN 4628-2, EN 4628-4 and EN 4628-5. The way the results are interpreted is given in clause 4.11 of EN 13499.

3.4.8 Conditioning of the test specimen in accordance with EN 1062-11

For the determination of the tensile bond strength of the base coat to the thermal insulation material, liquid water permeability of the system surface, resistance to impact, resistance to penetration, water vapour permeability, durability and adhesion of the finishing material on the base coat. This clauses explain the conditioning according EN 1062-11, which is needed for the determination of the durability and adhesion of the finishing material.

4 Explanation of EN 14309 – Thermal insulation products for building equipment and industrial installations - Factory made products of expanded polystyrene (EPS) - Specification

4.1 General

The EPS standard for building equipment and industrial applications is written for that specific application. The manufacturing of EPS for that application does not differ from manufacturing EPS for other applications, but depending on the field of application some other properties can be relevant.

The EPS standard for building equipment and industrial applications has a similar structure as EN 13163. The properties which are described in both standards are to be found in clause 2 of the White Book. The deviations from EN 13163 are explained in the following clauses.

4.2 Properties omitted from EN 13163

4.2.1 Bending strength

(4.2.7 in EN 13163). Determination of bending strength is no longer a mandatory part of clause 4.2 and therefore moved to clause 4.3 in this standard.

4.2.2 Point load

(4.3.7 in EN 13163). This property is not applicable, therefore the clause is deleted.

4.3 Properties which differ from EN 13163

4.3.1 Foreword

In the Foreword an extra sub-paragraph is included, offering contracting parties which refer to EN 14309 the possibility to demand properties that are not a part of the standard.

4.3.2 Scope

(EN 14309, clause 1). The field of application covers a temperature range that is applicable for EPS: from – 180 °C up to + 80°C.

4.3.3 Thermal conductivity

(4.2.1). The thermal properties will be declared as thermal conductivity only. For building equipment and industrial installations it must be measured at various temperatures (at least three) to establish a curve of thermal conductivity for the declared temperature range. The curve must be verified according to EN ISO 13787. For EPS products only three measurements are needed to determine the curve, since the temperature dependency of the thermal conductivity is linear.
For cylindrical products a special test method (EN ISO 8497) has been developed.
It is clear that at different temperatures the thermal conductivity varies. The lower the temperature, the lower the thermal conductivity.

For products used in building equipment or industrial installations other mean temperatures may be of interest. The thermal conductivity versus temperature is described in reference [20] and shown in Figure 18.

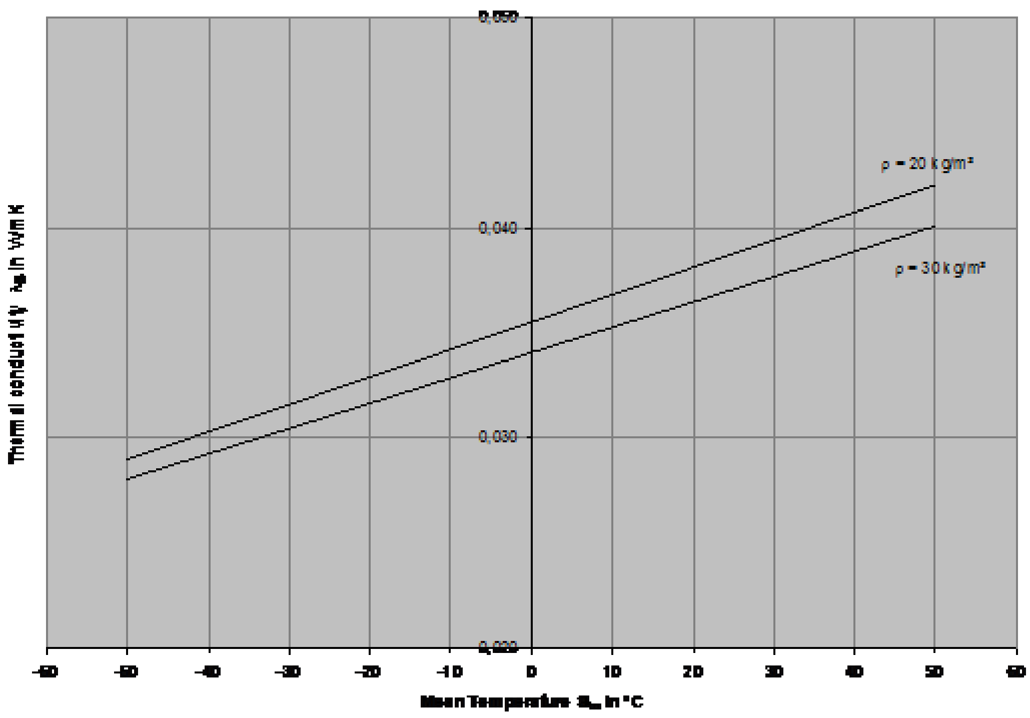


Figure 18: Thermal conductivity of EPS versus mean temperature derived from reference [20].

4.4 Properties in addition to EN 13163

4.4.1 Pipe section linearity

(4.2.2.4). The pipe section linearity is applicable for cylindrical products and comparable with the requirement on flatness for flat products.

4.4.2 Maximum service temperature

(4.3.2). The maximum service temperature must be determined when a product is applied at high temperatures. For EPS the commonly used maximum service temperature is 80° C (over 80 °C EPS will start to shrink). Measuring the maximum service temperature is therefore not necessary, only when EPS specialities (co-polymers of EPS) are used.

4.4.3 Minimum service temperature

(4.3.3). The minimum service temperature must be determined when a product is applied at low temperatures.
No EN test method is developed, because apparently different insulation materials react different on low temperatures. To determine the minimum service temperature a test method that is applicable for plastic insulation materials is put in the standards for plastic insulation materials in an Annex.

4.4.4 Trace quantities of water soluble ions and pH

(4.3.14). In certain applications a limit can be put to trace quantities of water soluble chloride, fluoride, silicate and sodium ions. A test method to determine those quantities and measuring the pH is developed (EN 13468).

4.4.5 Continuous glowing combustion

(4.3.16). For the time being this clause is placed in the standard as a placeholder. An EN test method is currently under development.

4.4.6 Annex C - Determination of minimum service temperature

This Annex, written as an EN test method within a standard explains the way to test the thermal conductivity and dimensions before and after the test.

5 Explanation of EN 14933 – Thermal insulation and light weight fill products for civil engineering applications - Factory made products of expanded polystyrene

5.1 General

This EPS standard is written for civil engineering applications (CEA). In general in this standard the load bearing properties are more important because of the functioning as light weight fill than the thermal properties in the case of frost insulation. It has in principle a similar structure as EN 13163. The deviations from EN 13163 are explained in the following clauses.

5.2 Properties that are omitted from EN 13163

5.2.1 Omitted properties

The following properties are not needed for civil engineering and have been omitted:

- Tensile strength,
- Dynamic stiffness,
- Compressibility.

5.2.2 Not defined EPS types

The EPS types EPS T, EPS S and EPS 30 are not suitable for civil engineering application and are therefore not defined.

5.2.3 Durability characteristics

(4.2).These clauses are introduced after publication of this standard. In the next revision they will be included.

5.3 Properties which differ from EN 13163

5.3.1 Dimensions

(4.2.1 to 4.2.4).Tolerances for dimensions are not always needed in civil engineering applications. Therefore zero classes have been introduced in Table 1; although for a thorough packaging of the EPS body a certain tolerance should be needed. Anyhow rough blocks without cutting the sides properly should be avoided.

5.3.2 Thermal conductivity

The determination of the thermal properties is taken from clause 4.2 (¨For all applications¨) and put in clause 4.3 (¨For specific applications¨).

5.3.3 Compressive stress at 10% deformation

(4.2.6). Compressive stress at 10 % deformation must always be declared. Additional deformations (2 % and 5 %) have been included in clause 4.3 (see below).

5.3.4 Continuous glowing combustion

(4.2.8.2). In this standard this clause is put in clause 4.2 (¨For all applications¨) as a placeholder. An EN test method is currently under development.

5.3.5 Sampling

(5.1). The number of samples depends on the fill size: up to 500 m³ 3 blocks, over 500 m³ 5 blocks.

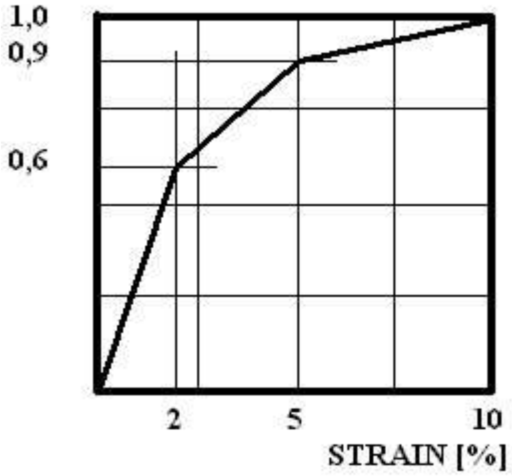
5.4 Properties which are in addition to EN 13163

5.4.1 Compressive stress at 2 % and/or 5 % deformation

(4.3.3). For specific applications determinations of 2 % and/or 5 % can be relevant. The calculation of the stress at those deformations must be done according to EN 826, although only the calculation at 10 % deformation is given in EN 826.

Note: on the basis of 10.000 test carried out by BASF an arbitrary relationship has been introduced in this standard between the strength at 2%, 5% and 10% deformation - the designation strength. This enables producers in the tender phase to quickly designate the requested compressive strength/ product type.

On the basis of the BASF-research the three tables in EN 14933 have been developed and incorporated. The relationship between stresses and strains are given in the next diagram.



This implies, that if a contractor/ consultant orders EPS with a compressive strength of 90 kPa at 2% deformation, in regular cases a EPS product- type of 90/0,6 = 150 kPa fulfills the requirements.

5.4.2 *Product properties of EPS and Eurocodes*

5.4.2.1 *Short-term compressive strength*

(4.3.3) As EPS product types are based on the declared value of the compressive strength at 10% deformation according to EN 13163/14933 and described as σ_{10} or CS(10) and tested according to EN 826[1] (e.g. EPS 100 has a short-term compressive strength σ_{10} of 100 kPa), this is the declared value following Eurocode 7. For the calculation of the design value of the short-term compressive strength $\sigma_{10;d}$ a material factor has to be taken into account (EN 1997 art 2.4.6.2); following EN 1990 and EN 14509 [2] this factor (γ_m) is 1,25 (e.g. for EPS 100: $\sigma_{10;d}$ =100/1,25 = 80 kPa).

Note: the material factor is based on equation EN 14509 - E.10. supposing a variance of 8% in production of EPS, using a substantial amount of secondary materials.

5.4.2.2 *Modulus of elasticity*

(4.3.3) Declared values can be derived using test results from EN 826 and are valid for the elastic part of the stress/strain curve. The same value can be used for the calculation of the dynamic behaviour due to cyclic loading. Values in Table 1 are based on the formula developed by Horvath[3]: E_t = (0,45 ρ -3) mPa (e.g. for EPS 100 (with a density ρ of 20 kg/m^3) this gives E_t = 0,45 * 20 -3 = 6 mPa = 6000 kPa). This is a “safe” approach. The relationship between density and compressive strength (“old” versus “new” product types) is defined in “EUMEPS Product Types” in 2003; see *Table 15: Design properties of EPS*

5.4.2.3 *Permanent compressive strength*

(4.3.3) EPS is expected to have a compressive creep deformation of 2% or less after 50 years when subjected to a permanent compressive stress of less than 0,30 * σ_{10}. Thus the declared

[1] No test result shall be lower than the values given for the declared level.
[2] EN 14509, the European harmonized sandwich product standard
[3] Horvath, J.S.: Geofoam Geosynthetic, Horvath Engineering, 1995 Scarsdale USA

value of the permanent compressive strength $\sigma_{10;perm}$ = 0,30 * σ_{10}. For the calculation of the design value $\sigma_{10;perm;d}$ the material factor (γ_m) has to be taken in to account (EN 1997 art 2.4.6.2); this factor (γ_m) is 1,25 (e.g. for EPS 100: $\sigma_{10;perm;d}$ = 0,3 * 100/1,25 = 24 kPa).

Note: this relationship is based on testing of materials over several decades; if a producer is able to prove (certified) better data for his specific products, this "better" result can be taken into account.

5.4.2.4 Compressive strength under cyclic load

(4.3.6) On the basis of extensive studies it has been concluded that, with a relative light permanent loading at the top (15 kN/m^2) and if the deformation under a cyclic load remains under 0,4% that deformation will be elastic and there will be no permanent deformation. Translated into stresses the maximum safe value due to cyclic loading is 0,35 * σ_{10}. This value has been recalculated from Duskov [4] thesis. Thus the declared compressive strength under cyclic load $\sigma_{10;cycl;d}$ = 0,35 * σ_{10} (e.g. for EPS 100: $\sigma_{10;cycl;d}$ =0,35 * 100 = 35 kPa). For the calculation of the design value $\sigma_{10;cycl;d}$ the material factor (γ_m) has to be taken in to account (according to EN 1997); this factor (γ_m) is 1,25 (e.g. for EPS 100: $\sigma_{10;cycl;d}$ = 35/ 1,25 = 28 kPa).
Apart from the test method EN 13793 which is the usual one for road building in case of any defined property for dynamic resistance and referred to in EN 13163, in the EPS standard for civil engineering applications another test method, SP 2687, a dynamic load test has been developed for railroad applications in the Nordic countries [27].

5.4.2.5 Tabulated properties

In *Table 15* tabulated values are given. These can be taken without any further testing.

Table 15: Design properties of EPS

Property			**EPS product type**				
Description	Symbol	Unit	EPS60	EPS100	EPS150	EPS200	EPS250
Declared value short-term compressive strength	σ_{10}	kPa	60	100	150	200	250
Design value short-term compressive strength	$\sigma_{10;d}$	kPa	48	80	120	160	200
Modulus of elasticity	E_t; E_{dyn}	kPa	4000	6000	8000	10000	12000
Declared value permanent compressive strength	$\sigma_{10;perm}$	kPa	18	30	45	60	75
Design value permanent compressive strength	$\sigma_{10;perm;d}$	kPa	14,4	24	36	48	60
Declared value compressive strength under cyclic load	$\sigma_{10;cycl}$	kPa	21	35	52,5	70	87,5
Design value compressive strength under cyclic load	$\sigma_{10;cycl;d}$	kPa	17	28	42	56	70

[4] Duškov, Milan: EPS as alight weight sub-base material; 1997 Delft NL

5.4.3 Eurocodes calculation rules for EPS

5.4.3.1 Introduction

In this clause the calculation rules of expanded polystyrene (EPS) are given for EPS in geotechnical/ civil engineering applications.

5.4.3.2 Design rules

A lot of nonofficial, voluntary design rules in the EU are used (e.g. BAST, CROW and NRRL guidelines). With Eurocodes into force designers and engineers are bound to fundamental approaches. This clause describes general rules as a help to design the required EPS properties.

5.4.3.3 Loadings

Loadings of own weight and imposed dead loads can be derived from Eurocodes; for EPS a design value of 100 kg/m^3 is mostly taken into account. Traffic (cyclic) loads idem.

5.4.3.4 Loading factors

For permanent loads a loading factor of $\gamma_{F;G}$ = 1,35 has to be applied; for traffic load a loading factor of $\gamma_{F;Q}$ = 1,50 has to be applied (see EN 1997 Annex A3 Table A3 Collection A1); in case of a possibility of floating other factors have to be used, see EN 1997 Annex A4 and table A15.

5.4.3.5 Design criteria

- *Ultimate Limit state (STR) short term*
  Loading combination: Multiply the dead and imposed load with their respective loading factors and combine both loads. Calculate the acting design compressive stress and compare it with the short term design compressive strength $\sigma_{10;d}$ (e.g. 80 kPa for EPS 100). The short term acting stress should be less than or equal to the short term strength.
- *Ultimate Limit state (STR) permanent*
  Loading combination: Multiply the dead load and the permanent part of the imposed load (mostly 0 in civil applications) with their respective loading factors and combine both loads. Calculate the acting design compressive stress and compare it with the permanent design strength $\sigma_{10;perm;d}$ (e.g. 24 kPa for EPS100). The permanent acting stress should be less than or equal to the permanent strength.
- *Ultimate Limit state (GEO) cyclic loads*
  Loading: Multiply the cyclic load with the factor γ_Q = 1,50. Calculate the acting design compressive stress and compare it with the design cyclic strength $\sigma_{10;cycl;d}$ (e.g. 24 kPa for EPS100).
- *Ultimate Limit state (UPL) floating*
  See Annex A4 of Eurocode 7; load factor $\gamma_{G;stb}$ = 0,9 in favourable situation and $\gamma_{G;dst}$ = 1,0 in unfavourable situation for permanent actions. Load factor $\gamma_{Q;dst}$ = 1,5 in unfavourable situation for variable actions.
- *Construction phase*
  The worst case scenario to be taken.

Example 1: Calculation typical Dutch polder road

As an example a typical road in the "Polders' in the western part of the Netherlands is herewith taken. The road is constructed by removing the peat soil to a depth of around 1,5 m; adding EPS 100 kPa blocks to a height of 2 m, putting a sand/gravel combination over it to distribute the point loads; it is finished with a double asphalt layer.

Cross section typical Polderroad NL

Loadings:
Permanent loads (γ=1,35)

0,15 m asphalt bitumen layers	0,15 * 2100 kg/m^3 = 3,1 kN/m^2
0,50 m gravel/sand	0,50 * 1800 kg/m^3 = 9,0 kN/m^2
2,0 m EPS 100	2,00 * 100 kg/m^3 = 2,0 kN/m^2
	TOTAL = 14,1 kN/m^2

Traffic load (γ =1,50)
Cyclic and uniformly distributed on EPS = 15,0 kN/m^2

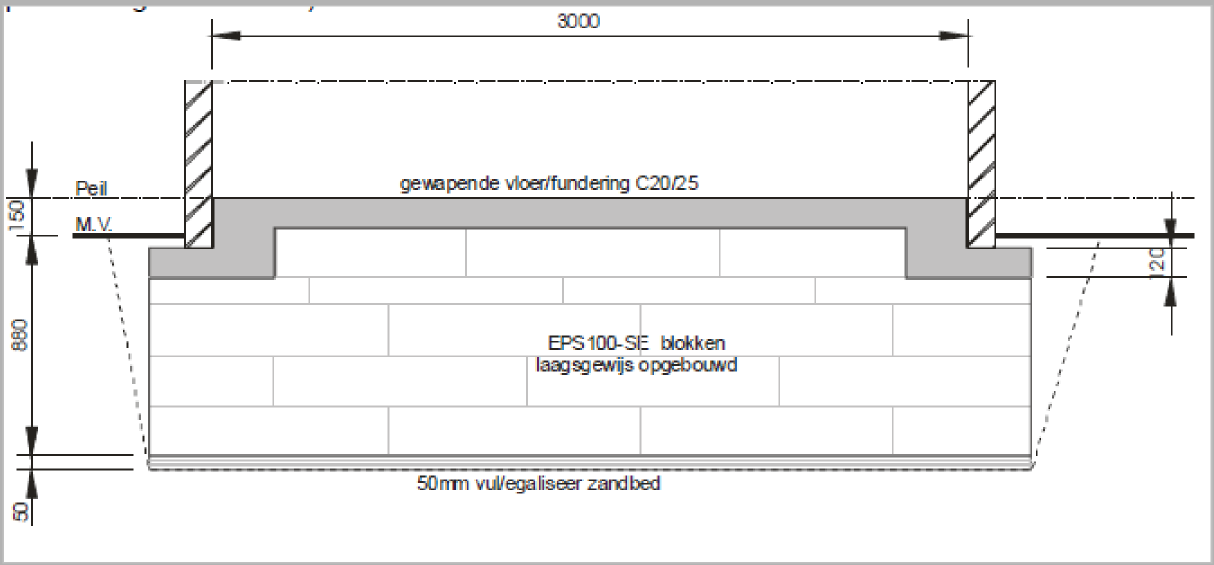
Loading combinations:
STR- short:
1,35 * 14,1 + 1,50 * 15 = 41,35 < 80 for EPS100 ? O.K.
STR-permanent
1,35 * 14,1 = 19,05 < 24 for EPS100? O.K.
GEO-Cyclic
1,50 * 15 = 22,50 < 28 for EPS100? O.K.

Conclusion: The product properties of EPS 100 fulfil the performance requirements

Example 2: Calculation cycle barn in dwelling area

Description

A cycle barn, dimensions 2,70 * 3,20 m; height 2,40m; single brick walls, timber roof structure, concrete floor 0,12 m thickness.



Loadings:

The total weight has been calculated at : $Q_{G;rep}$ = 108 kN
Imposed load (live load): $Q_{Q;rep}$ = 10 kN
permanent part of live load: 4 kN

Loading combinations:

STR- short:

1,35 * 108 + 1,50 * 10 = 160 kN.

STR-permanent

1,35 * 108 + 1,50* 4 = 151,8 kN.

Design values:

Applied is EPS100 with $\sigma_{10;d}$ = 80 kPa and $\sigma_{10;perm;d}$ = 24 kPa

Length of the foundation : 3,50 m; width: 3,0 m; surface: 10,50 m^2

STR-short gives: 160/ 10,50 = 15,3 kPa < 80? O.K.

STR- long gives: 151,8/ 10,50 = 14,5 kPa < 24 ? O.K.

Floating possible?

The max GWL is 0,15 m below upper side EPS; total floating force: 0,73 m * 10,50 m^2 * 10 kN is 76,65 kN; γ_{float} = 1.1 and $\gamma_{dead\ load}$ = 0,9 acc. to Eurocodes, so the safety factor is:
108 * 0,9/ 76,65 * 1,1 = 1,15 sufficient acc. to Dutch rules (1,1 in CROW 150 guideline)

6 Additional properties

6.1 Correlation between bending and tensile strength

The following correlation between bending strength and tensile strength was measured FIW. Properties described which are not mentioned in EN 13163, EN 13499, EN 14309 and EN 14933 are described here.

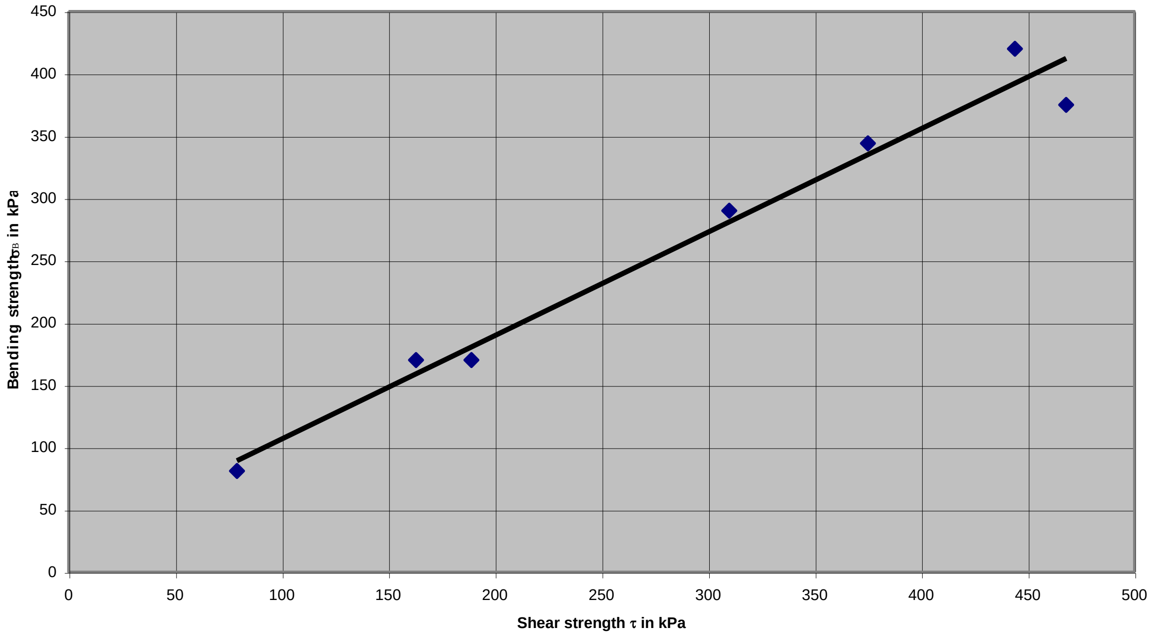


Figure 19: Correlation between bending and tensile strength.

The measured correlation is

$\sigma_b = 0{,}83\tau + 23{,}6$ kPa

6.2 Moisture content

The moisture content should be determined in accordance with EN 12570 [14]. In cases where EPS is installed between layers of other materials assessment according to EN ISO 12571 [15] may be useful.

6.3 Thermal expansion

The thermal expansion is used to calculate the reversible change of the dimensions versus the temperature.

$$x_{th} = x(1 + \alpha_{th} \cdot \Delta T)$$

Where α_{th} is the material specific coefficient of thermal expansion. The coefficient of thermal expansion was measured by Zehendner [21] and is indicated in *Table 16*.

Table 16: Coefficients of thermal expansion of EPS.

Material	Density [kg/m³]	Direction in respect on the board	Coefficient [K^{-1}]
EPS Block moulded Non flame retarded	14	parallel	$9,3 \cdot 10^{-5}$
		perpendicular	$8,0 \cdot 10^{-5}$
	23	parallel	$6,7 \cdot 10^{-5}$
		perpendicular	$6,7 \cdot 10^{-5}$
EPS Block moulded flame retarded	13	parallel	$9,5 \cdot 10^{-5}$
		perpendicular	$9,8 \cdot 10^{-5}$
	20	parallel	$7,2 \cdot 10^{-5}$
		perpendicular	$7,8 \cdot 10^{-5}$
EPS moulded board	42	parallel	$6,4 \cdot 10^{-5}$
		perpendicular	$6,7 \cdot 10^{-5}$

6.4 Hygric expansion coefficient

EPS products have no essential hygric expansion. In cases where this property (e. g. for coatings and facings) is needed it should be determined in accordance with EN 13009 [13].

6.5 Specific heat capacity

Tabulated values of the specific heat capacity of most building products are to be found in EN 12524 [16]. The specific heat capacity, c_p, of polystyrene is 1.300 J/(kg·K). The energy, Q, which is taken up or given up by polystyrene at a change of the temperature, ΔT, is calculated:

$Q = m \cdot \Delta T \cdot c_p$ [J]
where
m is the mass of polystyrene.

6.6 Chemical resistance

The resistance of EPS to chemicals depends partly on the way of manufacturing. The surface area of boards cut from a block gives a larger opportunity for chemical to penetrate than the surface area of moulded products. Also a lower density is damaged more rapidly than higher densities.

In practice (e. g. in the construction or packaging sectors) it is very important to know how EPS reacts to chemical substances in order to prevent faults in application.

The test for resistance is based on [40] "Testing of expanded foam materials; Determination of the reaction to liquids, vapours, gases and solid materials". In this DIN standard, 5 foam cubes without expansion skin and with sides measuring 5 cm are immersed in the test medium for a definite length of time and changes occurring in the samples, e.g. in mass and dimensions, are determined. The exposure time depends on the test medium: for liquids it is 72 hours; for gases 24 hours and for liquefied gases, at least three hours.

For liquefied gases the immersion temperature is at, or just under, the boiling point of the test medium in question; in other media, immersion takes place at room temperature.

For visual assessment of damage, DIN 53428 suggests a scale of criteria from 0 (no change) to 5 (severely damaged). To provide a simplified overview, *Table 17* contains the following assessment criteria:

+	= unchanged (≥ 0)	= resistant
+-	= slight change (≥ 2)	= limited resistance (small change in dimensions)
-	= severely damaged (≥ 5)	= not resistant

If EPS comes into contact with substances of unknown composition that could contain damaging solvents (e.g. paints or adhesives) it should be ensured in advance that the foam is not attacked by carrying out a trial under field conditions. The trial may be shortened considerably if it is carried out at temperatures above 20 °C (e.g. 50 °C). To obtain clearer evidence of the foam's resistance, the severity of the test conditions can be increased by testing foam with a density is much lower than that intended for the intended application.

Table 17 shows the resistance of expanded foam to the most important chemical substances.

Table 17: Chemical behaviour of EPS, derived from [3].

Water:		**Gases:**		**Alcohols:**	
Sea water	+	a) inorganic		Methanol	+-
Water	+	Ammonia	-	Ethanol	+-
		Bromine	-	Ethylene glycol	+
Alkalis:		Chlorine	-	Diethylene glycol	+
Ammonia water	+	Sulphur dioxide	-	Isopropanol	+
Bleaching solutions (hypochlorite, Hydrogen peroxide)	+			Butanol	+-
Potassium hydroxide solution	+	b) organic		Cyclohexanol	+
Lime water	+	Butadiene	-	Glycerine	+
Caustic soda solution	+	Butane	-	Coconut oil alcohol	+
Soap solutions	+	Butene	-		
		Natural gas	+	**Amines:**	
		Ethane	+	Aniline	-
Dilute acids:		Ethene (ethylene)	+	Diethylamine	-
Formic acid, 50%	+	Ethyne (acetylene)	+	Ethylamine	+
Acetic acid, 50%	+	Methane	+	Triethylamine	-
Hydrofluoric acid, 4%	+	Propane	+		
Hydrofluoric acid, 40 %	+	Propene (propylene)	+	**Miscellaneous organic substances:**	
Phosphoric acid, 7 %	+	Propene (propylen) oxide	-	Acetone	-
Phosphoric acid, 50%	+			Acetonitrile	-
Nitric acid, 13 %	+	**Liquefied gases:**		Acrylonitrile	-
Nitric acid, 50%	+	a) inorganic		Dimethylformamide	-
Hydrochloric acid, 7%	+	Ammonia	+	Esters	-
Hydrochloric acid, 18 %	+	Inert gases	+	Ethers	-
Sulphuric acid, 10%	+	Oxygen (risk of explosion)	+	Halogenated hydrocarbons	-
Sulphuric acid, 50%	+	Sulfur dioxide	-	Ketones	-
		Nitrogen	+	Paint thinners	-
		Hydrogen	+	Olive oil	+
Concentrated acids:				Tetrahydrofuran	-
Formic acid, 99 %	+	b) organic			
Acetic acid, 96 %	-	Methane	+	**Inorganic building materials:**	
Propane acid, 99%	-	Ethane	+	Anhydrite	+
Nitric acid, 65 %	+	Ethene	-	Gypsum	+
Hydrochloric acid, 36 %	+	Ethene oxide	-	Lime	+
Sulphuric acid, 98 %	+	Ethyne (acetylene)	-	Sand	+
		Propane	-	Cement	+
		Propene	-		
Fuming acids:		Propene oxide	-	**Organic building materials:**	
Nitric acid	-	Butane	-	Bitumen	+
Sulphuric acid	-	Butene	-	Water-based rapid-curing cutback and bítuminous knife fillers	+
		Butadiene	-	Solvent-based rapid-curing cutback and bituminous knife fillers (free from aromatics)	-
		Natural gas	+		
Anhydrides:				**Aromatics:**	
Acetic anhydride	-			Benzene	-
Carbon dioxide, solid	+	**Aliphatic hydrocarbons:**		Cumene	-
Sulphur trioxide	-	Cyclohexane	-	Ethylbenzene	-
		Díesel fuel, Heating oil	-	Phenol, 1 % aqu. soln.	+
		Heptane	-	Phenol, 33% aqu. soln.	-
Weak acids:		Hexane	-	Styrene	-
Humic acid	+	Paraffin oil	+-	Toluene	-
Carbonic acid	+	White spirit 55-95 °C	-	Xylene	-
Lactic acid	+	Whíte spirit 155-185 °C	-		
Tartaric acid	+	Vaseline	+	**Vapors of:**	
Citric acid	+	Gasoline (regular & super grades)	-	Camphor	-
				Naphthalene	-

Specific raw materials of polystyrene can be used to produce EPS that have increased resistance to aromatic free hydrocarbons by comparison with other EPS grades. The suitability of products for a particular application must be checked in each case.
The information submitted in this publication is based on current knowledge and experience. In view of the many factors that may affect processing and application, these data do not relieve processors of the responsibility of carrying out their own tests and experiments; neither do they imply any legally binding assurance of certain properties or of suitability for a specific purpose.

6.7 Air permeability

The air permeability of EPS in normal use is not needed. If in special cases this property is required it can be measured according EN 12114 [12].

6.8 Electrical properties

The electrical characteristics are similar to those of air. The dielectrical constant of EPS has a value of 1 in the frequency range from 100 Hz to 1 GHz at a temperature of 25 °C.
The surface resistance is 10^{11} to 10^{13} Ohm at a relative humidity of 50 %.

6.9 Sustainability, LCA data and EPD's

Based on growing concern for the environment, and in particular an increasing demand for sustainable building and development, the EC has commissioned CEN to develop horizontal standards for all building products to show the impact on the environment. CEN TC 350 was established. The most reliable way to present this information has proved to be the *Life Cycle Assessment (LCA)* approach. This approach investigates the process involved in the manufacture, use and disposal of a product or system – from cradle to grave.
EUMEPS already carried out in 1998 a study fulfilling the requirements of the international ISO 14040 standard [45], [46], [47]; reflecting the best available LCA data on EPS that could be made available. They can be found in the EUMEPS brochure on page 26. In between a set of procedures came available from this CEN TC 350 "Sustainability". It forces first to develop for a country or part of the world so called "Product Category Rules (PCR)" to set boundaries for a specific way of application and building and to develop more specific boundary conditions. This leads to uniformly, generally accepted "Environmental Product Declarations (EPD)". These dataset can be used to calculate the total environmental impact of works during building, use and end-of -life. The EPD for several EPS specifications will be ready beginning 2011 (see: www.eumeps.org).

Next to the development of data sets, CEN TC 350 was also charged to develop calculation methods for the total impact of buildings. Based on several existing voluntary calculation methods as "DuBoCalc" and "Greencalc" a general acceptable EU- method is drafted. This process is taking a long time as also socio/economic aspects have to be dealt with.

7 Application and calculation

7.1 International Application standards

EN 14114	Thermal insulation of building equipment and industrial installations – Calculation of water vapour diffusion – Cold pipe insulation systems
ISO/CD 12575-1	Building applications – Foundation insulating systems – Materials - Specification
ISO DTR 9774	Properties of thermal insulation products for buildings according to their application – Guideline for the harmonization of international standards or specifications
EN 13499	Thermal insulation products for buildings – External thermal insulation composite systems (ETICS) based on expanded polystyrene - Specification
UEATC Rules	

7.2 European Calculation standards

EN 832	Thermal performance of buildings – Calculation of energy use for heating – Residential building
EN 1190	Thermal performance of buildings – Heat exchange with the ground – Calculation methods
EN 1997	Eurocode 7, Geotechnical design
EN 13947	Thermal performance of curtain walling – Calculation of thermal transmittance – Simplified method
EN 27345	Thermal insulation – Physical quantities and definitions
EN 29251	Thermal insulation – Heat transfer conditions and properties of materials – Vocabulary
EN 29288	Thermal insulation – Heat transfer by radiation – Physical quantities and definitions
EN 29346	Thermal insulation – Mass transfer – Physical quantities and definitions
EN 30211	Building components and building elements – Thermal resistance and thermal transmittance – Calculation method
EN 32573	Thermal bridges in building construction – Heat flows and surface temperatures – General calculation methods
EN 33786	Thermal performance of building elements – Thermal inertia characteristics – Calculation methods
EN 33789	Thermal performance of buildings – Specific heat loss – Calculation method
EN ISO 10211-1	Thermal bridges in building constructions – Heat flows and surface temperatures – General calculation methods
EN ISO 10211-2	Thermal bridges in building construction – Calculation of heat flows and surface temperatures – Linear thermal bridges
EN ISO 13370	Thermal performance of buildings – heat transfer via the ground – Calculation methods
EN ISO 13786	Thermal performance of building components – Dynamic thermal characteristics – Calculation methods
EN ISO 13788	Hygrothermal performance of building components and building elements – Internal service temperature to avoid critical surface humidity and interstitial condensation - Calculation methods
EN ISO 13790	Thermal performance of buildings – Calculation of energy use for space heating
EN ISO 13791	Thermal performance of buildings – Internal temperatures in summer of a room without mechanical cooling – General criteria and calculation procedures
EN ISO 13792	Thermal performance of buildings – Internal temperatures in summer of a room without mechanical cooling – General criteria for simplified calculation methods
EN ISO 14683	Thermal bridges in building constructions – Linear thermal transmittance – Simplified method aund defaults values
EN ISO 15927-1	Hygrothermal performance of buildings – Calculation and presentation of climatic data – Data for accessing the annual energy demand for cooling and heating systems

EN ISO 15927-4	Hygrothermal performance of buildings – Calculation and presentation of climatic data – Data for accessing the annual energy demand for cooling and heating systems
EN ISO 15927-5	Hygrothermal performance of buildings – Calculation and presentation of climatic data – Winter external design air temperatures and related wind data
EN ISO 6946	Building components and building elements – Thermal resistance and thermal transmittance – Calculation method
EN ISO 8497	Thermal insulation – Determination of steady-state thermal transmission properties of thermal insulation for circular pipes
EN ISO 9251	Thermal insulation – Heat transfer conditions and properties of materials - Vocabulary
EN ISO 9288	Thermal insulation – Heat transfer by radiation – Physical quantities and definitions
EN ISO 9346	Thermal insulation – Mass transfer – Physical quantities and definitions
ISO 13789	Thermal performance of buildings – Transmission heat loss coefficient – Calculation method

7.3 National Application rules

Austria

ÖN B 3806 — Anforderungen an Baustoffe im Bauwesen in brandschutztechnischer Hinsicht

Germany

DIN V 4108-4 — Wärmeschutz und Energieeinsparung in Gebäuden – Wärme- und feuchteschutztechnische Kennwerte

DIN V 4108-10 — Wärmeschutz und Energieeinsparung in Gebäuden – Anwendungsbezogene Anforderungen an Wärmedämmstoffe – Werkmäßig hergestellte Wärmedämmstoffe

For CEA — Merkblatt für die Verwendung von EPS-Hartschaumstoffen beim Bau von Straßendämmen – Forschungsgesellschaft für Straßen- und Verkehrswesen

France

DTU 26.2/52.1 — Traveau de bâtiment – Mise en oevre des sous couche isolantes sous chape ou dalle flottantes et sous carrelage
(Building works – Placing of insulating underlayers underneath floating floor screeds or floors and underneath tile flowing

Finland — For floor and frost insulation products requirements for water absorption by immersion are given. For wall and roof applications water vapour transmission properties are required. Certificates are provided by VTT.

Netherlands — The Building Regulations (Bouwbesluit). Performance requirements are based on the function of the use of the relevant construction-part. Per aspect a “tabulated building rule” is given.

For buildings as a whole performance on energy is defined as the EPC-value (energy performance coefficient) with minimum requirements for the k-value of insulation in floors, walls and roofs.

The EPC-value is dependent on: the insulation, ventilation and installation, the situation of the components towards the sun etc.

Producers are bringing naked EPS as commodities on the market to be applied guarded by concrete / brickwork or as insulated panels for gables, pitched and flat roofs.

For applications materials and products are brought on the market with voluntary quality assurance, KOMO-certified and to be accepted by local authorities as if expected to fulfil the req.’s.

The requirements on reducing energy consumption are set in the “Building Regulations ”, in terms of an energy performance factor (E.P.C.) for the total building. Regardless of that threshold values are given for individual components, separating outdoor climate (k<0,4). Additional requirements are given for reducing air permeability of the building. Reaction to fire requirements are set in terms of performance requirements on the construction parts in end use applications. For the time being present NEN standards are considered on this.

Sweden

In Sweden there are:

BBR Building Rules, Byggregler 1999
and
Construction Rules BKR 1999

These rules are connected to guidelines or about 10 handbooks.
Energy saving and insulation requirements are given in 2 guidelines. They are connected to EN-ISO 6946, but will be revised and published in 2003.
The U-value has to be calculated of the whole building. The U-value shall not exceed the value:

$U_{m,\,krav} = 0{,}18 + 0{,}95 \cdot A_f / A_{om}$
where
A_f is the total area of windows, doors, gates
A_{om} is total perimetric area that has normal room temperature

$U_{m,\,krav}$ is the highest accepted average U value.

The average U_m value for the building is calculated as:

$U_m = (\Sigma\, (U_i \cdot A_i))/A_{om}$

For these U value calculations the computer program EPSU is used and developed by the Swedish Plastic Federation. The program is free for designers.

Spain

Spain has no additional rules in the application field of EPS. See also 8.2.17.

7.4 European EPS Types

7.4.1 EUMEPS EPS types

The thermal insulation product standards form a list of requirements of which the properties have to be declared by the manufacturer. These requirements are given in levels or classes to comfort all parties involved in comparing the specifications offered by the manufacturer on the one hand and the customer or legislator on the other hand. Two series of requirements exist: for general applications and for specific applications.
National or local Building Regulation requirements are set for products in end use-conditions and not to materials as such brought on the market.
The EPS product standard (EN 13163) is a so called “open standard”. It gives the producer the possibility to define his own product specifications and declare them to the market. This freedom enables him to offer products with an optional performance, a specified use of recycle material and specific production methods**.** There is no reference to density: density can, through a known relationship, be used for internal quality control, when for indirect testing a reference to a specific property is known.
An example: EPS that is used in sandwich panels is subject to shear forces but the market requires a minimal thickness e.g. lambda value. Other examples lay in the field of frost and perimeter insulation.

Producers of EPS offering/producing “downstream” products to the market will develop their own specific product types. Bringing EPS to the market for general or specific applications is also possible in a variety of specifications.
EUMEPS has agreed on a set of standard product types in order to give transparency to the customers and to enable “fair” competition between EPS producers.
This is hence for EPS brought on the market without intended specific application or for internal use in "down-stream" products (sandwich panels); these are often called "commodity EPS products".

Table 18: EUMEPS EPS types without intended specific application ("commodity").

EUMEPS-TYPE	**Compressive stress 10%**	**Bending strength**	**Thermal conductivity**	**Dimensional stability under normal laboratory conditions**	**Dimensional tolerances**
EPS 60	60	100	≤ 0,038	≤ 0.5	L1,W1,T1,S1,P2
EPS 100	100	150	≤ 0,036	≤ 0.5	L1,W1,T1,S1,P2
EPS 150	150	200	≤ 0,035	≤ 0.5	L1,W1,T1,S1,P2
EPS 200	200	250	≤ 0,034	≤ 0.5	L1,W1,T1,S1,P2
EPS 250	250	300	≤ 0,034	≤ 0.5	L1,W1,T1,S1,P2
	CS(10), [kPa]	BS, [kPa]	Lambda,[W/mK]	DS(N), %	Table 1, classes

All EPS types are available with or without of flame retardants. Products containing a flame retardant will achieve Euro class E (or better) and are identified with the addition of a red stripe. For historical reasons different member states the references in literature may differ and may continue to be used. For example reaction to fire class E may also be identified by the following equivalent definitions:

A or FRA United Kingdom
A1 Belgium
B1 Germany
F Sweden
M1 France, Spain
S Finland
SE Netherlands, Germany

For the EUMEPS types the following colour codes have been agreed for identification purposes:

Table 19: EUMEPS colour coding for EPS types.

EPS Eurotypes	Colour code for non flame retarded products			Colour code for flame retarded products			
	Description	Colour		Description	Colour		
EPS 30	Brown			Brown + red			
EPS 50	Blue			Blue + red			
EPS 60	Blue + blue			Blue + blue + red			
EPS 70	Brown + brown			Brown + brown + red			
EPS 80	Orange			Orange + red			
EPS 90	Orange + orange			Orange + orange +red			
EPS 100	black			Black + red			
EPS 120	Green + green			Green + green + red			
EPS 150	yellow			Yellow + red			
EPS 200	Black + black			Black + black + red			
EPS 250	Violet			Violet + red			
EPS 300	Violet + violet			Violet + violet + red			
EPS 350	Grey			Grey + red			
EPS 400	Grey + grey			Grey + grey + red			
EPS 500	Black + green			Black + green + red			
EPS T	Green			Green + red			

The colour code is applied on at least one edge of the boards.

7.4.2 Application

The European EPS product standards EN 13163, EN 13499, EN 14309 and EN 14933 are so called “open standards”. It gives a producer the possibility to define his own product specifications depending on the intended application and to declare the properties to the market. This freedom enables him to offer products with minimum raw material consumption, a specified use of recycle material and specific production methods**.** Producers of EPS offering/ producing “downstream” products to the market will develop their own specific product types for their intended use. In EUMEPS a set of standard product types have been developed in order to give transparency to the customers for “commodities”, here defined as products without any intended use. For specific, intended applications it was getting clear anyhow that there is a great comparability between product types and their applications throughout the EU/EUMEPS member companies.

In this document a overview of possible product/application combinations is given to make it easier making a choice for customers (authorities, contractors, suppliers, architects and owners).

The overview is given in a simple matrix, whereas the applications are taken from ISO TR 9774. This covers probably 95% of all the known building insulation EPS applications.
Bullet points give possible and most used applications/product types combinations; left from these the EPS properties are too low for a reliable application; right from the bullet points the quality may be too good in relation to the price.

Table 20: Overview of examples of applications and EPS product types

Application versus EPS type	**EPS S**	**EPS 60-100**	**EPS 100-150**	**EPS 150-200**	**EPS 200-250**	**EPS 250-300**	**EPS T**
CELLARS							
Internal insulation	●	●	–	–	–	–	–
External, protected	=	=	●	●	–	–	–
Perimeter insulation	=	=	●+)	●+)	●+)	–	–
GROUND FLOORS							
Slab- on- ground	=	●	●	●	●	–	–
Concrete floor element	=	●	●	–	–	–	–
On construction floor	=	●	●	–	–	–	●
Renovation el.	=	●1)	●	–	–	–	–
FLOORS							
Ceilings/ loft insulation	=	●	–	–	–	–	–
Floating floors	=	●	●	●	–	–	●
WALLS/GABLES							
Doublage	●	–	–	–	–	–	●
SIPS / others	=	●	●	–	–	–	–
Cavity wall insulation	●	●+)	●	–	–	–	–
Sandwich panels-steel	=	●	●	–	–	–	–
External insulation	●	●	–	–	–	–	●
ETICS	=	●+)	●	–	–	–	–
PITCHED ROOFS							
Internal-insulation (all)	=	●	–	–	–	–	–
Sandwich panels (all)	=	●	–	–	–	–	–
External insulation	=	●	●2)	●2)	–	–	–
FLAT ROOFS							
Warm roofs	=	● 1)	●	●	●	–	–
Cold roofs	=	●	●	–	–	–	–
Inverted roofs	=	=	=	●	–	–	–
CIVIL ENG APPL.							
All/ general	=	●	●	●	●	●	–

LEGEND:
● normally used in the EUMEPS member states.
= not possible from functional requirements.
– not necessary / applied normally unless properties are explicitly needed.
1) when load distribution boards are applied.
2) when load bearing.

Depending on the “local” building regulations the properties required may be more severe (indicated: +) than given in EN 13163.

8 Voluntary quality marks

8.1 European marks

KEYMARK

The European quality mark KEYMARK can be used for all products, for which European standards or approvals exist and a scheme has been approved. Complete rules for thermal insulation products – one of the first family of construction products to have a KEYMARK scheme – have been created successfully. In Europe, the KEYMARK offers for thermal insulation material a common system of inspection, surveillance and certification. The KEYMARK will only be used in connection with an existing national quality mark (e. g. RAL quality mark in Germany).

Only bodies, which are already accredited as a European certification body for insulation material standards, are admitted to grant the KEYMARK.

To obtain the KEYMARK the manufacturer needs a complete product certification. This means he has to operate a factory production control and as well as continuous product surveillance by a third party.

The rules of the KEYMARK for thermal insulation materials assure, that the manufacturers in Europe are all subjected to the same criteria and procedures. This prevents unfair competition by different expensive quality systems operating to different monitoring systems. The KEYMARK is likely to be attractive to companies operating internationally. The KEYMARK will only be awarded in conjunction with an existing national quality mark, which will increase its visibility and enhance its international reputation. In this way, the manufacturer has the opportunity to label products, which are distributed in different countries, in the same way.

The complete product certification will create a high confidence with the customer. The manufacturer can demonstrate that the products comply with European specifications. Regarding which the new warranty law which inverts the burden of evidence in the first six month this offers more security for the manufacturer because he can prove, that his products comply with his claims and have been controlled by an independent body.

Some European countries have given a benefit to those thermal insulation products subjected to third party control by imposing no addition to the design value of thermal conductivity or additional fees for product assurance. It is already known from France (18 %) and Germany (15 %) that these countries will implement an addition on thermal conductivity for non third party controlled products and it can be foreseen that other countries may follow this system.

In addition Germany will require a conformity mark (Ü mark) for the confirmation of the application related requirements (DIN 4108-10) by a certification body, which also includes a continuous surveillance by a third party. The combination of the national quality mark and the KEYMARK will cover in future all required assessments on a national and a European basis. All required performances will be tested by only one testing body leading to savings for international companies.

The national quality marks won’t be replaced by KEYMARK, but they must be based on European product standards in future. Therefore, the product needs to be tested only once to fulfil the requirements for both quality marks.

While the KEYMARK will assess the conformity of EPS with EN 13163, the national signs may focus in future on the conformity with the national application related requirements.

8.2 Voluntary national marks

8.2.1 Austria GPH

8.2.2 Belgium

8.2.3 Czech Republic

8.2.4 Denmark VIK

8.2.5 Finland VTT

8.2.6 France ACERMI

8.2.7 Germany GSH and IVH-BFA

Next to that, DIN V 4108-10 contains application related requirements for thermal insulation materials e. g. as for EPS in table 4.
DIN V 4108-4 contains regulations how to obtain the design value of the thermal conductivity to use for energy saving calculations such as EN 832. The design value, λ_U, will be calculated from the declared value of the thermal conductivity, λ_D, by the following equation:

$$\lambda_U = \gamma \cdot \lambda_D$$

The factor, γ, depends on the fact whether an optional approval from DIBt requiring a third party certification is involved or not. In cases where a notified body controls the FPC and the product properties the factor will be 1,05. In all other cases the factor is 1,2.

8.2.8 Greece

8.2.9 Iceland

8.2.10 Ireland

8.2.11 Italy

8.2.12 Luxemburg

8.2.13 Malta

8.2.14 Netherlands KOMO

The current situation in the Netherlands is one, totally on a voluntary basis, that exists already for two decades in its present format. This set-up was the result of negotiation between authorities (the Ministries of Housing, Economic Affairs and Internal Affairs), building industry (suppliers, contractors, subcontractors), consultants (engineers and architects) and the certification bodies.

Three types of markings exist:

a product certificate, for products of which a product standard exists;

a technical approval with certification, for products or construction parts with its intended use/performance requirements;

a process-certificate for the application of specific products or kits based either on product standards or/and on performance requirements and application requirements.

All the types are bearing the KOMO label, third party control is carried out by accredited certification bodies as KIWA, Intron, BKB and SKH.

In the building regulations ("Woningwet" and "Bouwbesluit") these labels are mentioned as labels for which is expected that the products/kits/processes fulfil at least the official requirements. They are all put on a list, which is yearly updated.

For the co-ordination of activities between certification bodies, authorities and the industry - including UEAtc and EOTA contacts - the "Stichting Bouwkwaliteit (SBK)" - foundation for building quality, was formed in 1990. This foundation issues the permission to use the KOMO-label for marking to certification bodies.

At this moment the expectation is, that next to this quality labels (KOMO) the CE label as conformity label will be introduced as an extra. The EC is focussing on this KOMO system at this moment supposing it being a not-acceptable system next to the CE-marking and labelling.

8.2.15 Norway

8.2.16 Portugal

8.2.17 Spain

Based on UNE-EN-13163 and UNE-EN-13172, on a voluntary base, it is just a product certification. In the Building Regulations the standards are mentioned as reference but not the certification. For EPS, the N mark means CE marking with AoC system 1 for all specifications.

8.2.18 Sweden

8.2.19 Switzerland

8.2.20 United Kingdom BBA

In the UK the BSI Kitemark has been used in the insulation sector but not specifically by the EPS industry. EPS manufacturers have relied on British Board of Agrement (BBA) or equivalent certification which covers not only the product quality but also the specific details of application. The more widely known applications for EPS are covered by this certification. In addition all producers of EPS have third party surveillance on their factory production control to BS EN ISO 9002.

9 References and bibliography

1. DIN 4102, Brandverhalten von Baustoffen.
2. Hamann, Klodt, Gellert, Pelzers. Long term behaviour of polystyrene foam classified as B1 respectively B2 material according to DIN 4102. Bauphysik 21 (1999), Journal 1. Ernst & Sohn Verlag, Berlin.
3. Gausepohl und R. Gellert. Kunststoff-Handbuch; 4. Hanser Verlag 1996.
4. Ojanen, T. & Kokko, E. Moisture Performance Analysis of EPS Frost Insulation. Insulation Materials: Testing and Applications: Third Volume, ASTM STP 1320, pp. 442-455, 1997.
5. Directive relating to Construction Products, Council Directive of 21 December 1988 (89/106/EEC)
6. EN 832: 1998 – Thermal performance of buildings – Calculation of energy use for heating – Residential buildings
7. EN 14309:2009, Thermal insulating products for building equipment and industrial installations – Factory made products of expanded polystyrene (EPS) – Specification
8. EN 13168: 2008, Thermal insulation for buildings – Factory made wood wool (WW) products – Specification
9. EN ISO 9229: Thermal insulation – Definition of terms
10. EN 45020, Standardization and related activities - General vocabulary
11. EN ISO 13943, Fire safety – Vocabulary
12. EN 12114: 2000, Thermal performance of buildings – Air permeability of building components and building elements
13. EN 13009: 2000, Hygrothermal performance of building materials and products – Determination of hygric expansion coefficient
14. EN 12570: 2000, Hygrothermal of building materials and products – Determination of moisture content by drying at elevated temperature
15. EN ISO 12571: 2000, Hygrothermal of building materials and products – Determination of hygroscopic sorption properties
16. EN 12524: 2000, Building materials and products – Hygrothermal properties- Tabulated design values
17. BS 6203: 1998, Guide to the fire characteristics and fire performance of expanded polystyrene materials (EPS and XPS) used in building applications
18. ISO DTR 9774, Properties of thermal insulation products for buildings according to their application – Guideline for the harmonization of international standards or specifications
19. Zehendner, Verhalten von Schaumkunststoffen unter Druckbeanspruchung bei 20 und 80°C
20. AGI-Arbeitsblatt Q 133 – Harte Schaumkunststoffe als Dämmstoffe für betriebstechnische Anlagen – Teil 1 Polystyrol(PS)-Partikelschaum
21. Zehendner, Untersuchungen der mechanischen Eigenschaften von Schaumkunststoffen im Bereich von –180 °C bis +70 °C
22. EN 12430: 1998, Thermal insulating products for building application – Determination of behaviour under point load
23. EN 13788, Hygrothermal performance of building components and building elements – Estimation of internal surface temperature to avoid critical surface humidity and calculation of interstitial condensation
24. EN 12354-2, Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 2: Impact sound insulation between rooms
25. EN 13950, Gypsum plasterboard thermal/acoustic insulation composite panels. Definitions, requirements and test methods
26. EN 14509 Self-supporting double skin metal faced insulating sandwich panels - Factory made products – Specification
27. SP 2687 Resistance to cyclic compressive loading with square-wave load
28. Lågtidsbelastning med extrapolering enligt EN 1606, EPS materail: Plastolit P-100. Swedish National Testing and Research Institute, Gothenburg, 2001
29. Guidance Paper H, A Harmonised approach Relating to Dangerous Substances Under the Construction Products Directive
30. DG Enterprise G5 [database of dangerous substances or components]. URL: http://europa.eu.int/comm/enterprise/construction/internal/dangsub/dangalf.htm
31. EN 27345, Thermal insulation – Physical quantities and definitions
32. EN ISO 1182, Reaction to fire tests for building products – Non-combustibility test

33. EN ISO 1716, Reaction to fire tests for building products – Determination of the heat of combustion
34. ISO 12491, Statistical methods for quality control of building materials and components
35. ISO 9251, Thermal insulation – Heat transfer conditions and properties of materials – Vocabulary
36. ISO 9288, Thermal insulation – Heat transfer by radiation – Physical quantities and definitions
37. ISO 9346, Thermal insulation – Mass transfer – Physical quantities and definitions
38. Swinton, Bomberg, Kumaran and Maref: In situ Performance of Expanded Molded Polystyrene in the Exterior Basement Insulation Systems (EIBS). Published in Journal of Thermal Env. & Bldg. SCI. Vol. 23-October 1999.
39. EN 13471 Thermal insulating products for building equipment and industrial installations – Determination of the coefficient of thermal expansion
40. DIN 53428, Prüfung von Schaumstoffen; Bestimmung des Verhaltens gegen Flüssigkeiten, Dämpfe, Gase und feste Stoffe, 1986-08
41. EN 13787, Thermal insulation products for building equipment and industrial installations – Determination of declared thermal conductivity
42. ISO/CD 12575 Building applications – Foundation insulating systems
43. European LCA-data for EPS building products, Seijdel R. R., PRC-Bouwcentrum report 886.001, August 1998
44. Critical review on LCA-data for EPS, Schuurmans A., Intron report M715490, 13 October 1998
45. ISO 14040 Environmental management - Life cycle assessment - Principles and framework
46. Erkennbare und verläßliche Qualität – europaweit, Güteschutzgemeinschaft Hartschaum e. V., Celle
47. VTT Building technology, Research Report No. RTE10018/96, Moisture-physical function of EPS frost-insulating materials in building foundations, Erkki Kokko, Tuomo Ojanen, Seppo Saarelainen, Harri Kivikoski, Espoo, Finland, 1996
48. ASTM D 1929 Standard Test Method for Determining Ignition Temperature of Plastics
49. Einfluß des Feuchtegehaltes auf die Wärmeleitfähigkeit von Bau- und Dämmstoffen, Bau- und Wohnforschung 1988
50. Struik, L.C.E., Physical aging in amorphous polymers and other materials, Elsevier Scientific Publishing Company, 1978
51. Agreement on technical cooperation between ISO and CEN (Vienna agreement)
52. CEN TR 15985 Voluntary certification of the raw material
53. FIW München: Achtziger, J.: Polystyrol- Hartschaum als Dämmstoff im Hochbau – 25 Jahre Forschung im Dienst der Qualitätssicherung, Veröffentlichung der Güteschutzgemeinschaft Hartschaum GSH (1987)
54. EPS- Verband Schweiz, Küssnacht: Langzeitverhalten von EPS- Dämmstoffen, aus: Alterungsbeständigkeit von EPS mit Langzeitnachweis, Carbotech AG, Basel, S-E-E.CH Tool (2004)

10 Authors

This document is revised by the experts of the EUMEPS TWG TG White Book

Dolf van Moorsel (Chairman)
Tapio Kilpeläinen
Edmar Meuwissen
Lutgarde Neirinckx
Hans Tepper
David Thompsett
Klaus Zipp

11 Alphabetic register

A

B

C

D

E

F

T

V

W

Annex A Tables

Annex A.1 List of symbols, explanations and units

Symbol	Explanation	Unit
$1 - \alpha$	confidence level	1
α_{th}	coefficient of thermal expansion	1/K
c_p	specific heat capacity	J(kg·K)
ϑ	temperature	°C
d_{meas}	measured thickness	m
D	water vapour diffusion coefficient	m²/h
δ	water vapour permeability	mg/(Pa·h·m)
δ_{air}	water vapour permeability of the air	mg/(Pa·h·m)
ϑ_{mean}	mean temperature	°C
$FIGRA$	Fire growth rate index	W/s
F_{ψ}	moisture conversion factor	1
Fs	Flame spread	mm
γ	factor to calculate λ_U (German regulations)	1
$k_{n,p,1-\alpha}$	k factor	1
λ_{ϑ}	thermal conductivity at a mean temperature ϑ	W/m·K
λ_{lim}	limit value of thermal conductivity	W/m·K
λ_D	declared thermal conductivity	W/m·K
λ_{meas}	measured thermal conductivity	W/m·K
λ_U	design thermal conductivity	W/m·K
λ_u	design thermal conductivity in relationship to the moisture content u	W/m·K
$L_{n, w, eq}$	equivalent weighted normalised sound pressure level	dB
$L'_{n, w}$	weighted normalised impact sound pressure level	dB
ΔL_w	weighted reduction of impact sound pressure level	dB
$L'_{nT, w}$	weighted standardized impact sound pressure level	dB
LFS	lateral flame spread	m
m	mass	kg
Δm	mass difference	kg
m'	mass per unit area	kg/m³
m'_0	mass per unit area	kg/m³
μ	water vapour diffusion resistance factor	1
n	number of measurements	1
p	fractile	1
PCS	gross calorific potential (pouvoir calorifique superieur)	MJ/kg
q	ratio	1
Q	energy	J
R_D	declared thermal resistance	m²K/W
R_{meas}	measured thermal resistance	m²K/W
σ_c	alternative stress (according EN 1606)	kPa
$s1$ - $s3$	Additional reaction to fire classes	non
$d0$ - $d2$	Additional reaction to fire classes	non
t_f	flaming time	s
ΔT	temperature difference	K
THR_{600}	Total Heat Release during the first 600 seconds	MJ
TSP_{600s}	Total smoke production	m²
u	Moisture content	vol-%
V	volume	m³
W_p	practical water content	vol-%
x_{th}	dimension depending on temperature	m
x	dimension	m
z	fractile of the standardised normal distribution	1

The term $1 - \alpha$ is described as prediction interval in EN 13163. In the context of its use in EN 13163 the correct term is confidence level.

Annex A2: Abbreviations

AoC	Attestation of conformity
ASTM	American Society for Testing and Materials (American standardisation body)
CEA	Civil Engineering Application
CEN	European Committee for Standardisation (Comité Européen de Normalisation)
CPD	Construction Products Directive
CUAP	Common Unique Acceptance Procedure
DIBt	Deutsches Institut für Bautechnik (German Regulator Body)
DOA	Date of Acceptance
DOW	Date of Withdrawal
EEA	European Economic Area
EC	European Commission
EN	European Norm (European Standard)
EOTA	European Organisation for Technical Approvals
EPS	Expanded Polystyrene
ETA	European Technical Approval
ETAG	European Technical Guideline
ETICS	External thermal insulation composite systems
EU	European Union
EUMEPS	European Manufacturers of EPS
FIGRA	Fire Growth Rate Index
FIW	Forschungsinstitut für Wärmeschutz e. V., München
FPC	Factory production control
FR	Flame retarded
ISO	International Standards Organization
LFS	Lateral Flame Spread
MRA	Mutual Recognition Agreements
PECA	Protocol to the European Agreement on Conformity Assessment
prEN	provisional European Norm (European standard)
SBI	Single Burning Item
SCC	Standing Committee of Construction
SIPS	Structurally Insulated Panel Systems
SMOGRA	Index for rate of Smoke Development
SP	Swedish National Testing and Research Institute, Gothenburg
TC	Technical Committee
UAP	Unique Acceptance Procedure
UEAtc	Union Européenne pour l'Agrément Technique dans la Construction (European Union of Agrément)
VTT	Finish Technical Research Center
WG	Working Group
WI	Work Item

Table A.3: CEN Members and affiliated CEN members

Abbreviation	Organisation	Country
AENOR	Asociación Española de Normalización y Certificación	Spain
AFNOR	Association Française de Normalisation	France
ASI	Austrian Standards Institute	Austria
ASRO	Romanian Standards Association	Romania
BDS	Bulgarian Institute for Standardisation	Bulgaria
BSI	British Standards Institution	United Kingdom
CYS	Cyprus Organisation for Standardisation	Cyprus
DIN	Deutsches Institut für Normung e.V.	Germany
DS	Danish Standards	Denmark
ELOT	Hellenic Organization for Standardization	Greece
EVS	Estonian Centre for Standardisation	Estonia
HZN	Croatian Standards Institute	Croatia
ILNAS	Institut Luxembourgeois de la normalisation, de l'accreditation, de la sécurité et qualité des produits et services	Luxemburg
IPQ	Instituto Português da Qualidade	Portugal
IST	Icelandic Standards	Iceland
LST	Lithuanian Standards Board	Lithuania
LVS	Latvian Standards Ltd	Latvia
MSA	Malta Standards Authority	Malta
MSZT	Hungarian Standards Institution	Hungary
NBN	Bureau de Normalisation/Bureau voor Normalisatie	Belgium
NEN	Nederlands Normalisatie-instituut	Netherlands
NSAI	National Standards Authority of Ireland	Ireland
PKN	Polish Committee for Standardization	Poland
SFS	Suomen Standardisoimisliitto r.y.	Finland
SIS	Swedish Standards Institute	Sweden
SIST	Slovenian Institute for Standardization	Slovaina
SN	Standards Norway	Norway
SNV	Schweizerische Normen-Vereinigung	Switzerland
SUTN	Slovak Standards Institute	Slovakia
UNI	Ente Nazionale Italiano di Unificazione	Italy
UNMZ	Czech Office for Standards, Metrology and Testing	Czech Republic

Affiliated CEN members are not obliged to follow the CEN rules and to implement all harmonised standards issued by CEN. They can be involved in the creation but not in the voting process of European standards.