EPS White Book

EUMEPS Background Information on standardisation of EPS

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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 European Council decided in 1985 that the internal market should be opened for products and services and that barriers to trade should be eliminated. Thus creating an open market would increase competition.
This led to the foundation/creation of Technical Committees (TC) within Comité Européenne de Normalisation (CEN), which was given the task to develop harmonised technical specifications through introduction of the Constructive Products Directive (CPD) in 1989. In understandable language: harmonised European standards. One of the pilot cases was insulation material.

The Technical Committee 88 (TC88) of CEN has been dealing with most standards for EPS thermal insulating products, 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 led to a huge collection of European data, experience and knowledge of EPS products. 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 led 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.

In this version of the Whitebook, the following changes are made:

- New information regarding the implementation of the Construction Products Regulations, especially on Delegated Acts and Annex ZA
- Changes in the field of voluntary quality marks
- Conditioning for thermal conductivity and reaction to fire

1.2 New approach of EPS in the market

~~Beginning of October 2014 the commercial name of EPS has been changed to airpop and is being implemented in most member states. If and when this will have implications on the technical approach of the material in standards and hence the Whitebook and other publications is not known at this moment. Therefore throughout the White book EPS will remain as the name for the material.~~

1.3 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].The implementation of the CPD was not implemented in all Member States.~~

The CPD (Council Directive 89/106/EEC [5] was put in force in 1989, the first harmonised standards (hENs) were published and cited in 2001.
After development of a standard, CEN publishes it as an EN standard, the European Commission (EUCOM) will cite the standard in the Official Journal of the European Union (OJEU) when the standard fulfils the requirements of the CPD. This citation converts the EN into a harmonised standard (hEN).The system worked, but was not perfect and since 2016 no building standards are cited any more.

Therefore and after evaluation the CPD the European Commission changed the CPD to the Construction Products Regulations (CPR) [55], published 9 March 2011 and in force since 1 July 2013. The CPR however is still a living Regulation ~~document~~ where changes may be necessary. These are given in the form of Delegated Acts. So far, delegated acts are published on the possibility to distribute a Declaration of Performance also electronically, the format of a DoP, the introduction of Assessment of the Verification of the Constancy of Performance systems for European Assessment documents and classification of the reaction to fire performance of construction products.

This Regulation (CPR) is the practical and legal manifestation of freeing the market in the construction sector by making transparent the technical specification and declaration of construction products, which are a major part of trade in the construction sector. The CPR only describes the ~~contains~~ ways to declare characteristics, leaving the required level of a characteristic in end-use condition to the Member States. These levels are generally laid down in National Building Regulations

The CPD introduced the concept of harmonised standards which manufacturers must comply with when placing products on the market. The CPR continues this, with changes compared to the CPD and as from 1 July 2013 with a legal status. In the CPR seven *Basic Work Requirements* which Building Works must comply with are addressed.

The seven Basic Work Requirements are :

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

~~For Construction Products harmonised technical specifications must be made. When a construction product conforms to the relevant technical specification, the construction works is deed to be satisfied.~~

The CPR was put in force in 2011, but in 2015 the implementation that should have been reflected in revised standards, was very low.
This was enough reason for EUCOM to stop citing draft hEN's in the OJEU.
In 2018 help was given by installing HAS consultants. Consultants appointed by EUCOM to check draft standards against the CPR. This led -so far- to no improvement.
In 2019 EUCOM introduced a new system to develop standards, the Standardisation Request (SReq). Only essential characteristics (and proxies or elements) linked to the BWRs can be accepted in the standards. In the process the member states shall be more involved. This process is running, but very slow.
And next to that EUCOM is discussing the revision of the CPR, with possibilities between no change at all to withdrawal of the CPR.

The result so far is that the standards which were cited up to 2015 remain in place until the whole process of renewal is finished.
End 2020 the expectation is that a revised CPR can be available at the earliest 2022.

Standardisation
To obtain harmonised technical specifications all over Europe, harmonised European product standards (or European Assessment document) had an sometimes still have to be created. In order to ensure that this work was 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 (now CPR). 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 voluntary guidelines (European Technical Assessment documents) 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.~~

As from 1 July 2013 the CPR (Construction Products Regulation) has replaced the CPD.
All standards developed under CPR must be approved by CEN and EUCOM. When EUCOM agrees to a proposed draft standard, it will be cited in the OJEU. This has not been actioned since 2016 for building standards.

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 standards for EPS for building applications and civil engineering 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 have been and are being developed in the various WG's in TC 229; WG 1 TG 5 has developed 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 (or European Assessment document), a declaration of performance (DoP) must be made and after that the product must bear CE marking. Having a CE mark gives the product its "passport" to travel freely 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.

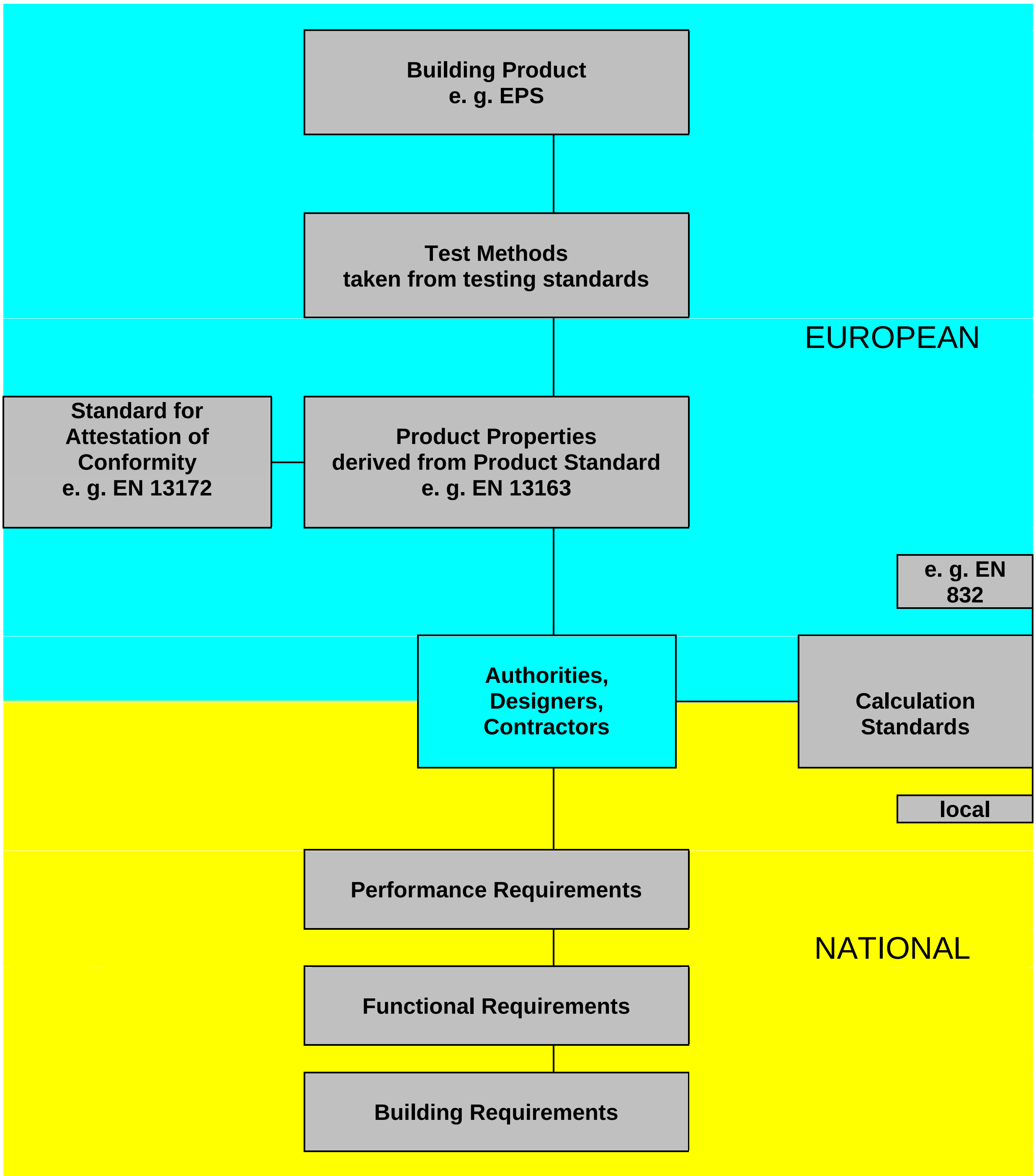


Figure 1: Limitation between European and national standardisation issues. This Figure 1 can be created for every standardised building product.

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 13163:2012, 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 and 2012. A first Amendment (A1) was published and cited in the OJEU in 2015. A second Amendment (A2) has been published by CEN, but not cited in the OJEU.
- 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 as voluntary non-harmonised standards, since no mandate was given at that time. In autumn 2010 a draft mandate was given and the development of a new standard for ETICS (including all possible materials that can be used in ETICS) started. Discussion is still going on about the elaboration of the content of the mandate.
- EN 13950: 2014, Gypsum board thermal/acoustic insulation panels – Definitions, requirements and test methods. This standard is developed by CEN TC 241.
- EN 14309:2009 + A1:2013, 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 launched as a package. Development of a ~~A~~ second amendment started at the end of ~~is under development end~~ 2016.
- EN 14933:2007, Thermal insulation and light weight fill products for civil engineering applications - Factory made products of expanded polystyrene (EPS) – Specification. For CEA three standards (for EPS, XPS and expanded clay) were developed and launched as EN's. Revision of this standard is foreseen in 2016-2017.
- EN 15037-4:2010 + A1:2013, Precast concrete products - Beam-and-block floor systems - Part 4: Expanded polystyrene blocks.
- EN 15037-5:2013, Precast concrete products – Beam-and-block floor systems – Part 5: Lightweight blocks for simple formwork.
- EN 16025-1: 2013, Thermal and/or sound insulating products in building construction - Bound EPS ballasting - Part 1: Requirements for factory premixed EPS dry plaster. This standard has ~~end 2016~~ not yet been cited in the OJEU and therefore remains voluntary.
- EN 16025-2: 2013, Thermal and/or sound insulating products in building construction - Bound EPS ballasting - Part 2: Processing of the factory premixed EPS dry plaster.
- ~~pr~~EN 16809-1: 2019, Thermal insulating products of buildings – In-situ formed products from loose-fill expanded polystyrene (EPS) beads and bonded expanded polystyrene beads – Part 1: Specification for the bonded and loose-fill products before installation. ~~This standard is in the stage of Formal Vote end 2016.~~ No citation took place, therefore this standard is voluntary.
- ~~pr~~EN 16809-2:2017, Thermal insulation products of buildings – In-situ formed products from loose-fill expanded polystyrene (EPS) beads and bonded expanded polystyrene beads – Part 2: Specification for the bonded and loose-fill products after installation.

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 Assessment and Verification of the Constancy of Performance (AVCP). 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, EN 16025-1, EN 16025-2, EN 16809-1 and EN 18608-2 are harmonised. The practical implementation of Annex ZA is mostly given in paragraph 4.2 For all applications in the standards. In the next paragraphs the listed published harmonised standards are explained.

2. Explanation of the structure of EPS Standards

2.1 Introduction

All EN standards contain ways of determination of properties of products, referring to harmonised EN test methods. The characteristics that must ~~have to~~ be declared are given in Annex ZA in the harmonised standards (Essential characteristics). In practice this is more or less translated to characteristics that must ~~have to~~ be declared in the clause "For all applications" in the various standards. Most EN standards are written in a similar way, containing the same clauses. These are explained in 2.2 to 2.12.

For in situ products, the design of the standards differs: there are two parts, one for the specification of the product and one for the installation. The second part of those standards is not harmonised, since CE marking (and DoP) of the products installed is not the responsibility of the manufacturer. The structure of the in situ standards is explained in 2.13.
EN 15037-4 differs completely. Its structure is explained in **¡Error! No se encuentra el origen de la referencia.**.

EN 13163 is the most used standard in the range of EPS standards and the most advanced standard according to the changing CEN rules. Therefore the explanation below is based on this standard and where other standards differ significantly, this will be noted.

The standards were ~~are~~ written during the period the CPD was in force and have not yet been adapted to the new terminology listed in the CPR. The CPR is in force since 1 July 2013 and declarations must fulfil the requirements given in the CPR. For readability the headings of the clauses in the explanation below are ~~is~~ as given in the standards (CPD terminology), but in the text appears the new (CPR) terminology. In Table 10 the old and new terminology is given.

Table10:Terminology

Equivalent terms	
CPD	CPR
Essential requirement (ER)	Basic Requirement (BR)
Attestation of conformity (AoC)	Assessment and Verification of Constancy of Performance (AVCP)
Evaluation of Conformity (EoC)	Verification of the Constancy of Performance (VCP)
Declaration of Conformity (DoC)	Declaration of Performance (DoP)
Initial Type testing (ITT)	Product Type determination (PTD)
Factory Production Control (FPC)	Factory Production Control (FPC)
Characteristics	Essential characteristics

2.2 Foreword

The foreword gives general information about the creation of the standard. In EN 14309 the Foreword is extended with an extra sub-paragraph, offering contracting parties the possibility to demand properties that are not a part of the standard.

2.3 1 Scope

The scope lists the products covered by the standard and excludes the products not covered by the standard

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].

When declared, the minimum thermal resistance is given as 0,25 [m²·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.
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].

EN 14933: For CEA products ~~not always~~ the thermal resistance/thermal conductivity do not need~~s~~ to be declared for most applications.

EN 14309: The field of application for building equipment and industrial installations covers a temperature range that is applicable for EPS: from – 180 [°C] up to + 80 [°C].

2.4 2 Normative references

This clause lists in a numerical order all standards which are referred to in the normative part of the standards.

Normally standards are referred to as undated references to avoid revisions of the standards each time a new version of the reference standards is published. The order is EN standards, EN-ISO standards and ISO standards. Dated references are given for prEN's an EN's when specific clauses of that standard are referred to.

2.5 3 Terms, definitions, symbols, units and abbreviated terms

Terms and definitions

In general EN ISO 9229 [9] contains all definitions. In some cases the standards have a different or additional definition. These are given in this clause.
EPS is divided into 4 types, depending on its application:

- EPS_i, for load bearing applications where i stands for the declared value (expressed in compressive stress at 10 % deformation).
- EPS S for non-loadbearing applications
- EPS SD for non-loadbearing applications with acoustic properties
- EPS T for floating floor applications
- These definitions only appear in EN 13163 for the time being and will be part of modification in other EPS standards where relevant

Other standards can be useful when discussion on specific items occurs (not referred to in EPS standards):
EN 45020:2007 Standardization and related activities - General vocabulary [10]
EN ISO 13943:2010 Fire safety – Vocabulary [11]

Symbols, units and abbreviated terms

Symbols and abbreviated terms used in the standards are listed in this clause. A complete list of symbols, explanations and units as well as abbreviations is given in Annex A - Tables.

2.6 4 Requirements

To be recognised as a thermal insulation product, various characteristics must be determined. EN 14933: Sometimes no thermal characteristics are declared for a product for CEA application. Characteristics can be material related or relevant for all applications. Those characteristics are listed in clause 4.2. Depending on a specific application other characteristics may be declared. These are listed in clause 4.3.

Every insulation product according EN 13162 through EN 13171 and EN 16069 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 0.

EN 13499: This standard 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. 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”).

A product characteristic 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 are given in Annexes.

2.7 5 Test methods

To declare the properties of a product the products must be tested. Harmonised test methods are developed and referred to in this clause. 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 must be used. Additional properties described in Annexes should also use the referenced test methods.

Sampling

General sampling rules are given in the appropriate test method and specific sampling advice may be found in the standards.

Conditioning

Generally no special conditioning is needed for EPS. For some tests and specific conditioning advice may be found in the appropriate testi~~ng standard~~ method. For determination of the thermal conductivity conditioning is needed, see 3.1., for determination reaction to fire, see 3.3.

Testing

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 1*: Applicable test methods for thermal conductivity.*

Table 1: 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.
EN ISO 8497	Thermal insulation- Determination of steady-state thermal transmission properties of thermal insulation for circular pipes (ISO 8497:1994)	For pipe sections

2.8 6 Designation code

All products must be accompanied by a designation code. The designation must contain: the abbreviation code (EPS), reference to the standard, classes or levels of the properties of the essential characteristics as given in Annex ZA, as well as the classes or levels of the properties declared according to Clause 4.3 - For specific applications of the standard.

Properties in Clause 4.2 for which only a limit value is require do not appear in the designation code. The producer may specify those properties on the product label or in his literature.

2.9 7 Assessment and Verification of the Constancy of Performance ~~(former: Evaluation of conformity)~~

In some standards, this clause is still given as Evaluation of conformity, but this will be changed into Assessment and Verification of the Constancy of Performance (AVCP) as soon as the standards are amended. The goal of the harmonised product standards is that all insulation products are produced according to their respective product standard, following the prescribed AVCP system. When a product conforms to the standard, a DoP must be made and CE marking must be given. The CE marking enables free trade within the Member states. The rules to declare according to a AVCP system are given in EN 13172.

2.10 8 Marking and labelling

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 2.8) and the number of pieces and area in the package as appropriate. Explanation on CE marking and Declaration of Performance are given in Annex ZA (see 0).

2.11 Annexes

Every standard contains a number of Annexes, some normative, some informative. The normative Annexes are an integral part of the standard, the informative are for information. However, if a manufacturer wants to declare a characteristic according to an informative Annex, it is mandatory to follow the rules given in that Annex.

Annex ZA is informative, however compulsory. It is the legal obligation giving the relation to the CPR (by means of a given Mandate that describes the essential characteristics that have to be declared for CE marking. Annex ZA appears only in harmonised EN's.

Some Annexes are in fact a test method, which is not commonly used and therefore put in an Annex in one or more standards. Those Annexes are explained in 3 Determination of characteristics

Annex: Determination of the declared values of thermal resistance and thermal conductivity

For most product standards this Annex is sufficient. EN 14309: Additional measurements must be performed to be able to declare a lambda curve.

General

All standards have an Annex 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 reference [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. ~~It is not clarified in the standards (because there is no general accepted method for assessment, but should be at least 25 years~~. This is not further classified in standards, but it can be assumed that EPS performance is stable for at least 50 years.

Annex: Product Type Determination (PTD), ~~former Initial Type Testing (ITT)~~ and Factory Production Control (FPC)

In some standards PTD is still referred to as ITT, but that will be changed when those standards are amended. Before a product is placed on the market, it's characteristics must be determined according to the standard, the Product Type Determination (PTD). After fulfilling the requirements, the product is allowed to be placed on the market. As long as that product is manufactured, a manufacturer must perform Factory Production Control (FPC) to ensure that the declared values do not change and the product shows continuous conformity with the standard.

Testing frequencies

The testing frequencies for all properties described in the normative part of the standard are given in two tables: one for Reaction to fire and one for the other characteristics.

When production of a product starts, the characteristics needed for that product must be determined: Product Type Determination (PTD). After fulfilling the requirements, a manufacturer must monitor the characteristics periodically: Factory Production Control (FPC). Products with the same property may be grouped; thus saving costs of testing. Rules for grouping are given in EN 13172. The grouping may be different in technical specifications for a specific application.

The Table with the number of tests needed for PTD and testing frequencies for FPC 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.
c. Product Type Determination (PTD) means that the product characteristics are declared. This must be repeated on a rather low frequency, since product characteristics tend to change in time due to developments in manufacturing.

d. As soon as test methods for dangerous substances are available the standards will be revised.

Indirect testing

Characteristics for which the relationship to another characteristic, e. g. density, is well known, may be tested indirectly via that characteristic. This option will be used if the indirect test is quicker or cheaper. Figures are given for the relationship Compressive stress at 10% deformation versus Density, and Thermal conductivity versus Density.

Dynamic stiffness

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

Annex: Product classification

The various types of EPS can be classified, depending on their intended application:
To ensure a certain level of quality of the EPS product Table C.1 in EN 13163, Annex C combines two properties: compressive stress and bending strength. Compressive stress relates to density as shown in Annex B, Figure B.1 of EN 13163. 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 term ~~time~~ behaviour. The value of the compressibility is approximately the same as the long term compressive behaviour under a floating floor under practical conditions.

Annex: Multi layered EPS products

Some products, as EPS, can be combined to two or more layers, developed for a specific application. All test methods as given in the standard apply, only the declaration of thermal resistance and thermal conductivity differ~~s a bit~~ slightly. For multi-layered products the R_D value is determined on one thickness, the related λ_D is only valid for the measured thickness

Annex: Verification of the reaction to fire classification of raw materials

This Annex describes the procedures for raw material suppliers to certify the performance their expandable beads ~~how to get a certificate~~, which can be used by manufacturers to decrease the frequency of reaction to fire test in Factory Production Control (FPC).

Annex: Additional properties (informative)

This annex is informative and provides additional information that is normally not suitable to put in the main body of the standard.

Annex ZA: Clauses of this European standard addressing the provisions of the EU Construction Products Directive

General

Annex ZA, in the context of the Construction Product Regulation (CPR), is an informative yet compulsory annex which makes the standard harmonised. 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 identifies which characteristics manufacturers need ~~have~~ to declare when placing their products on the European market, both in their own country and in another EC country. 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 may be used. The NPD option may not be used however, where the characteristic is subject to a threshold level (thermal resistance or thermal conductivity and thickness). Furthermore EPS products having a thermal conductivity greater than 0,060 W/m·K are not covered, which can be seen as a threshold level as well.

Annex ZA establishes the conditions for a Declaration of Performance (DoP) and CE marking of the products by identifying those clauses of the standard needed to meet the CPR (in sub-clause ZA.1) describing the possible systems of AVCP in ZA.2.

Systems of attestation of conformity

The CPR describes five levels of Assessment of the Verification of the Constancy of Performance (AVCP~~, former systems of attestation of conformity, AoC~~), depending on the reaction to fire classification and the way the product is manufactured. The systems vary from a manufacturer’s declaration up to systems where a third party is involved in the control schemes (see

Table 2). In all cases the manufacturer must perform Product Type Determination (PTD) and a continuous Factory Production Control (FPC).

Required level of AVCP

The reaction to fire classification of the product determines the required level of AVCP. Table 13 gives the possible systems of the AVCP and the respective tasks for the manufacturer and the notified body.

System 1 and 1^+ is applicable for products with reaction to fire Euroclass A1 up to C inclusive for which in 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. System 1 ~~2^+~~ is used for kits or very specific applications (e.g. ETICS, insulation of concrete floors). For ETICS this is according to Commission Decision 2011/14/EU as in the mandate for ETICS M489.

Table 2: Tasks of the involved parties for different AVCP levels

Tasks	Steps	Responsible				
		AVCP 1^{+}	AVCP 1	AVCP 2^{+}	AVCP 3	AVCP 4
Initial tests and inspection	Sampling for PTD	NB (M)	NB (M)	M	M	M
	Perform PTDs according to Table ZA.4	NB	NB	NB	NB	M
	Perform further PTDs	NB	NB	M	M	M
	Initial inspection of FPC	NB	NB	NB	M	M
Current surveillance	Current inspections of FPC	NB	NB	NB	M	M
	Collecting samples for product testing	NB	M	M	M	M
	Tests of properties according to Table ZA.4	NB	M	M	M	M
	Test of further properties	M	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	M
Applications	EN 13163 EN 14309 EN 14933 EN 16025-1 EN 16809-1				X	
	ETAG 004 EN 15037-4			X		
	Future ETICS Standard (prEN 17237)		X	~~X~~		
	Voluntary Quality System	X				

<u>Abbreviations:</u>

AVCP Assessment and Verification of Constancy of Performance
FPC Factory Production Control
PTD Product Type Determination

M Manufacturer
NB Notified Body (product certification body, production control certification body or testing laboratory)

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. Member states concerned may only notify bodies within their territories. The minimum requirements for the bodies (TAB's) to be notified are laid down in Annex IV of the CPR. Member States may add requirements for the bodies they notify. Additional requirements can be accreditation of the TAB.

Since the EN standards are written to make a DoP and obtain a CE mark and thus be subject to free trade, one could expect that following the rules a CE mark with an AVCP 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 Member States require system 1 for a product or at least one declared property to avoid penalties in the declaration. A VQS is not allowed to interfere with CE marking.

Declaration of Performance (DoP)

A manufacturer shall draw up a Declaration of Performance (DoP, former declaration of conformity). Examples are given in "EUMEPS guidance for EPS manufacturers on the Construction Products regulation". The DoP can group products. It must be given in the language of the country of destination and it may appear on a website. However, when a recipient requires a DoP in a paper form, the manufacturer must do so. The CPR has come into force on the 1 July 2013, therefore manufacturers must deliver a DoP for each product (or group), according to the CPR and Delegated Acts .

CE Marking and labelling

The products have to be labelled at least as indicated in Annex ZA, clause ZA.3. Examples are given in "EUMEPS guidance for EPS manufacturers on the Construction Products regulation".

CE marking 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 Marking and labelling. 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.

2.12 Bibliography

In the bibliography reference is made to documents that are not included in normative parts of the standard, but can be helpful.

2.13 In situ standards

EN 16025-1

Thermal and/or sound insulating products in building construction - Bound EPS ballasting - Part 1: Requirements for factory premixed EPS dry plaster

This standard describes the kind of EPS beads used (virgin or recycled), the bead size, amount of dust and mineral binder. Mortar is added to produce bound EPS beads. During production of beads and mortar coated beads all steps must be monitored.

Only finished products can be tested (thermal conductivity, reaction to fire, compression strength, compressibility, creep, water vapour diffusion resistance, water absorption, dynamic stiffness).

EN 16025-2

Thermal and/or sound insulating products in building construction - Bound EPS ballasting - Part 2: Processing of the factory premixed EPS dry plaster

This standard regulates the installation of the Bound EPS beads. This falls under the responsibility of the installer, not the EPS manufacturer.

EN 16809-1: 2019

Thermal insulation products of buildings – In-situ formed products from loose-fill expanded polystyrene (EPS) beads and bonded expanded polystyrene beads – Part 1: Specification for the bonded and loose-fill products before installation

This standard describes the kind of EPS beads used (virgin or recycled),the bead size and other characteristics.

Only finished products can be tested (thermal conductivity, reaction to fire, compression strength, compressibility, creep, water vapour diffusion resistance, water absorption, dynamic stiffness).

EN 16809-2: 2019

Thermal insulation products of buildings – In-situ formed products from loose-fill expanded polystyrene (EPS) beads and bonded expanded polystyrene beads – Part 2: Specification for the bonded and loose-fill products after installation

This standard regulates the installation of loose-fill or bonded EPS beads. This falls under the responsibility of the installer, not the EPS manufacturer.

3. Determination of characteristics

The characteristics as listed below do not necessarily appear in the same order in the various standards (mostly the order of EN 13163:2012 is followed), but give an overview of the way the characteristics are to be determined (where applicable).

3.1 Thermal resistance and thermal conductivity

Mechanism of heat transfer

The mechanism of heat transfer in a thermal insulation layer like EPS can be divided in three components:

- Conductivity
- Radiation
- Mass transfer

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

Measurement of thermal resistance and thermal conductivity

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

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

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. Four of these measures must be conducted by a certified test house, the remainder can be in-house tests. 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.

The declared thermal conductivity is calculated using the equation

$$\lambda_{90/90} = \lambda_{mean} + k \times S_{\lambda} \quad \text{[W/m·K]}$$

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

$$R_{90/90} = R_{mean} - k \times s_R \quad [m^2 \cdot K/W]$$

where

$R_{90/90}$ = the 90% fractile with a confidence level of 90% for the thermal resistance

R_{mean} = the mean value of the measured thermal resistance

k = number of measurements

s_R = standard deviation

Boards and blocks with different shapes than rectangular and planparallel must be made rectangular and flat (uniform thickness) before measuring.

EN 13499: For ETICS, the thermal resistance of the system according EN-ISO 10456 and EN-ISO 6946 is taken into account. The determination of the declared thermal resistance of the EPS product, needed for the thermal resistance of the system, must be performed according to EN 13163.

Conditioning

~~In EN 13163 rules are given for the conditioning for the determination of the thermal conductivity. This conditioning is needed to prevent an increase of the value of the thermal conductivity after the product has been placed on the market. This conditioning applies for both non-infrared as well as infrared absorbing EPS, but differ. The following procedure is to be used:~~
Conditioning is needed. When a new product will be placed on the market, PTD must be performed according to the following procedure:
Conditioning starts with a minimum of 6 h and a maximum of 3 days.
Determine the thermal conductivity according to EN 12667.
Store the product for 7 days at 60 °C and 50 °C for EPS T products.
Determine the thermal conductivity again.
If the results differ less or equal to 1%, the conditioning is deemed to be insignificant.
If not, another 7 days of storage at 60 °C (50 °C for EPS T products) and the thermal conductivity must be determined again.

After PTD the manufacturer must perform FPC. For FPC purposes an optimised PTD per product can be used.
~~Once a manufacturer has determined the conditioning time using a certain raw material, he should record this in his Factory Production Control and does need to repeat the conditioning procedure.~~
When a product is taken from the market to be checked (e.g. by a NB) it can be assumed that this product has already some lifetime. Therefore it is sufficient to keep the conditioning simple in Clause 5 of the standards: 4 weeks at normal laboratory conditions or 2 weeks at 50 °C for samples in the density range up to 25 kg/m³ mm at a thicknesses up to 200 mm.

Effect of temperature on thermal conductivity

The thermal conductivity for building products is declared at a mean temperature of 10 °C. For normal building applications this is sufficient. EN 14309: For products that are to be used in a wider temperature range 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 2: Thermal conductivity of EPS versus mean temperature derived from reference [20].

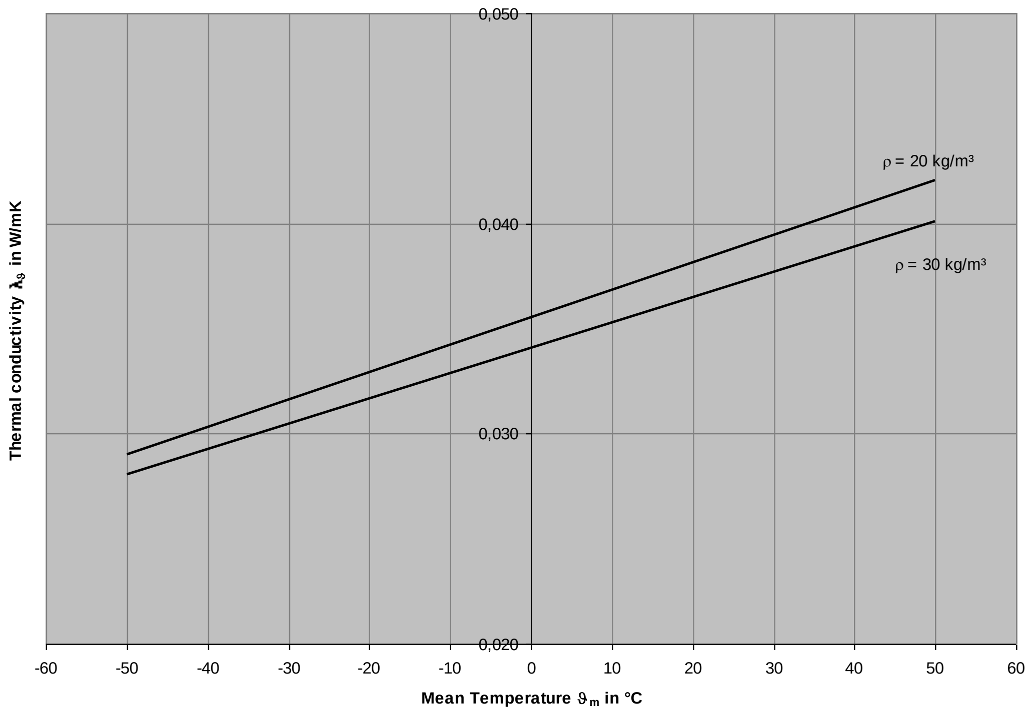


Figure 2: Thermal conductivity of EPS versus mean temperature derived from reference [20].

Relation thermal conductivity - density

For non-infrared 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·/(m⁴·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·/(m⁴·K)]/ρ_a [W/(m·K)]

For all types of EPS, non-infrared absorbing -"white"- as well as infrared 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: $\lambda_{mean} = b_0 + b_1\rho_a + \dfrac{b_2}{b_3/d + b_4\rho + b_5}$

where b_2 to b_5 are regression coefficients.

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

Design values

For use in practice design values, λ_u, 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

Normally for EPS products, having a thickness of at least 50 [mm] and a λ_D < 0,038 [W/(m•K)], the thickness effect is negligible, the factor being 1. Otherwise this formula must be used:

$$\lambda_{mean} = b_0 + b_1\rho_a + \frac{b_2}{b_3/d + b_4\rho + b_5}$$

where b_2 to b_5 are regression coefficients.

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 45.

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

For normal building applications the following formula is valid except for the applications given above):

$\lambda_u = \lambda_D$ [W/(m·K)]

3.2 Tolerances on Length and Width, Thickness, Squareness and Flatness

The classes of tolerances for length and width, thickness, squareness and flatness are given in Tables. EN 13163:2012 speaking classes are introduced, for most other EPS standards this is in development. This means that the index in the symbol corresponds with the actual tolerance. E.g. *L*1 has a tolerance on length of +/- 1 [mm].

- Permissible tolerances of EPS boards

Information about the permissible tolerances, taking into account dimensional tolerances and dimensional stability under normal laboratory conditions, should be given.

EN 14933: Tolerances for dimensions are not always needed in civil engineering applications. Therefore zero classes have been introduced: although for a complete build-up of EPS blocks a certain tolerance will be helpful. Uncut blocks should be avoided.

EN 14309: For building equipment and industrial installations, the pipe section linearity is applicable for cylindrical products and comparable with the requirement on flatness for flat products.

In specific applications and Technical Specifications stricter tolerances can be given. Also amended tolerances as squareness on the thickness as for ETICS.

3.3 Reaction to fire

Reaction to fire classification of EPS products according to the CPR and the harmonised European standards

The CPR refers to basic requirements for construction works. The basic requirements are "translated" by means of Mandates into essential requirements for the products. In the product standards the requirements and classification for reaction to fire are given for the products as placed on the market. Voluntarily producers can determine classification for a number of standardised assemblies representing the end use application.

The package to determine the European reaction to fire classification includes the following test methods:

- 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 (Euroclasses A1 to F, see *Table 3: Classes of reaction to fire performance for construction products except floorings and linear products*) according to the classification standard (EN 13501-1).

Table 3: Classes of reaction to fire performance for construction products except floorings and linear products

Class	Test method(s)	Classification criteria	Additional classification
A1 without testing	EN 13820		
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 ·kg^{-1}] (1); and $PCS \leq 2{,}0$ [MJ·kg^{-1}] (2) (2a); and $PCS \leq 1{,}4$ [MJ·m^{-2}](3); and $PCS \leq 2{,}0$ [MJ·kg^{-1}] (4)	
A2	EN ISO 1182 (1); or	$\Delta T \leq 50$ °C; and $\Delta m \leq 50$ %; and $t_f \leq 20$ [s]	
	EN ISO 1716; and	$PCS \leq 3{,}0$ [MJ·kg^{-1}] (1); and $PCS \leq 4{,}0$ [MJ·m^{-2}] (2); and $PCS \leq 4{,}0$ [MJ·m^{-2}] (3); and $PCS \leq 3{,}0$ [MJ·kg^{-1}] (4)	
	EN 13823 (SBI)	$FIGRA \leq 120$ [W·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·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* ≤ 150 [mm] within 60 [s]	
C	EN 13823 (SBI); and	*FIGRA* ≤ 250 [$W \cdot s^{-1}$]; and *LFS* < edge of specimen; and THR_{600s} ≤ 15 [MJ]	Smoke production(5); and Flaming droplets/ particles (6)
	EN ISO 11925-2(8): Exposure = 30s	*Fs* ≤ 150 [mm] within 60 [s]	
D	EN 13823 (SBI); and	*FIGRA* ≤ 750 [$W \cdot s^{-1}$]	Smoke production(5); and Flaming droplets/ particles (6)
	EN ISO 11925-2(8): Exposure = 30s	*Fs* ≤ 150 [mm] within 60 [s]	
E	EN ISO 11925-2(8): Exposure = 15s	*Fs* ≤ 150 [mm] within 20 [s]	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* ≤ 2,0 [$MJ \cdot m^{-2}$], provided that the product satisfies the following criteria of EN 13823(SBI) : *FIGRA* ≤ 20 [$W \cdot s^{-1}$]; and *LFS* < edge of specimen; and THR_{600s} ≤ 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* ≤ 30 [$m^2 \cdot s^{-2}$] and TSP_{600s} ≤ 50 [m^2]; *s*2 = *SMOGR*A ≤ 180 [$m^2 \cdot s^{-2}$] and TSP_{600s} ≤ 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 for products in Class E.

EPS without flame retardant additive (standard EPS FR-grade) is classified as Euroclass F (without testing). EPS for insulation purposes with flame retardant additive (FR-grade) passes the small burner test (EN ISO 11925-2) at all thicknesses and therefore meets the requirements of Euroclass E. Other classes can be reached for EPS in the SBI test (EN 13823), depending on the thickness, density and mounting & fixing of the samples. These results are only valid for the

tested thickness range and the tested mounting an fixing conditions (backing board, type of fixing).
EPS is used in many different applications. If tested as assembly simulating end-use conditions, classes up to B can be reached, depending on the application. For example, EPS in the application behind plasterboard, in a cavity wall or steel sandwich panel can obtain Euroclass B. In EN 15715 (Instructions for mounting and fixing for reaction to fire testing) standardised assemblies simulating end use applications are defined.

The Table for testing on reaction to fire (Annex B of EN 13163) 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. In EN 13163 (informative) Annex E verification of the reaction to fire classification of raw materials is included for that purpose. This Annex is based on CEN TR 15985 [52]. Annex E contains tasks for the raw material supplier to obtain a certificate on his raw material. It is written according to CEN rules, only explaining what has to be done and not by whom. When an EPS manufacturer uses a certified raw material, he must ensure that the certificate is valid. When products are made with non-certified raw material, the test must be performed once a day.

If a producer of EPS insulation boards declares class E for his product in the context of CE marking, he has to have regular factory control in place. This means that he has to do daily control of the reaction to fire performance of his products, using the small burner test according to EN ISO 11925-2. If the raw material producer has a certificate, confirming the verification of the reaction to fire, the frequency of testing can be reduced to one test per week or per batch.

The durability of reaction to fire behaviour is covered 3.4. For definitions in the field of fire safety, see EN ISO 13943 [11].

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. The level of (fire) safety in the individual Member States is laid down in National building regulations referring to European classification and test ethods.

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.

Conditioning

Conditioning is needed. When a new product will be placed on the market, PTD must be performed according to the following procedure:
Conditioning starts with a minimum of 6 h and a maximum of 3 days.
Determine the thermal conductivity according to EN 12667.
Store the product for 7 days at 60 °C and 50 °C for EPS T products.
Determine the thermal conductivity again.
If the results differ less or equal to 1%, the conditioning is deemed to be insignificant.
If not, another 7 days of storage at 60 °C (50 °C for EPS T products) and the thermal conductivity must be determined again.
After PTD the manufacturer must perform FPC. For FPC purposes an optimised PTD per product can be used. Once a manufacturer has determined the conditioning time using a certain raw material, he should record this in his Factory Production Control and does need to repeat the conditioning procedure.
When a product is taken from the market to be checked (e.g. by a NB) it can be assumed that this product has already some lifetime. Therefore it is sufficient to keep the conditioning simple in Clause 5 of the standards: 4 weeks at normal laboratory conditions or 2 weeks at 50 °C for samples in the density range up to 25 kg/m³ mmm at a thicknesses up to 200 mm.

Behaviour of EPS in the presence of heat and different ignition sources

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).

EPS with flame retardants will not be ignited by welding sparks or glowing cigarettes or by small flames. When exposed to a fire source the decomposition products of the flame retardant additive will 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 than 50 kW/m² from fires involving other material, EPS with flame retardant will eventually burn, reflecting the organic nature of polystyrene. Burning EPS has a heat release of 40 [MJ/kg (by mass)] [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.

3.4 Durability

Service life of EPS

EUMEPS EPDs state to the reference service life: If applied correctly the lifetime of EPS insulation is equal to the building life time, usually without requiring any maintenance. Durability studies on applied EPS show no loss of technical properties after 35 years. Additional tests with products under artificial aging show that “no deficiencies are to be expected from EPS fills placed in the ground over a normal life cycle of 100 years.” /Langzeitverhalten 2004/, /Long-term performance 2001.

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

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.

The report concludes 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.

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

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].

Durability of compressive strength against ageing and degradation

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 3.10.

3.5 Dimensional stability

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

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.

Mechanical characteristics are listed as a group in 3.6 to 3.12

In specific applications and Technical Specifications stricter tolerances can be given. Also amended tolerances as on dimensional stability for EPS in ETICS.

3.6 Compressive stress at 10% deformation

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 3.9) 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. (0).

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 Table 2. The compressive behaviour at 20 °C is shown in Figure 3:.

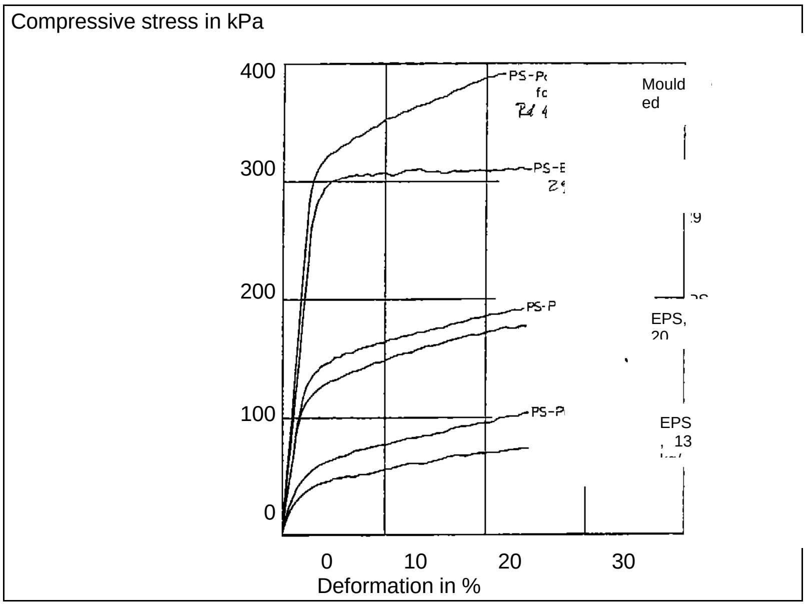


Figure 3:
Compressive strength at 20 °C of different densities of EPS [21].

Different values of compressive stress at 10 % deformation at different temperatures were measured by Zehendner [21] and given in *Table 4*.

Table 4: 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

3.7 Bending strength

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 4: Correlation between bending strength and density..

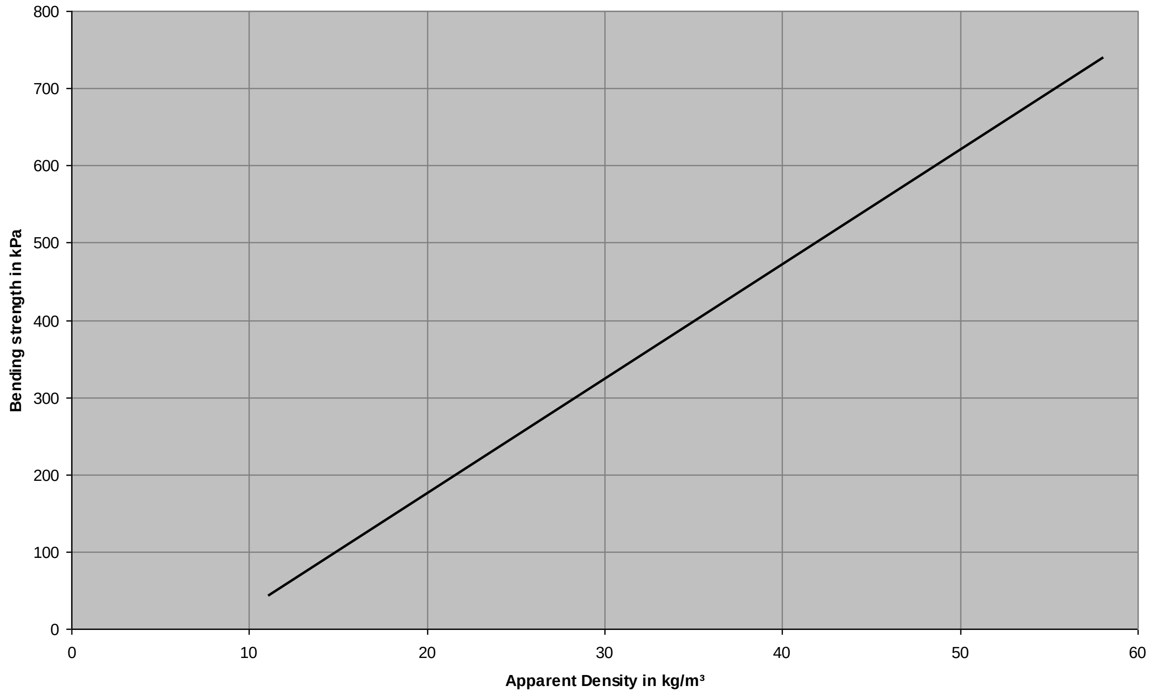


Figure 4: Correlation between bending strength and density.

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 5.

Table 5: 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 strength, see 36.

3.8 Tensile strength perpendicular to faces

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, see Figure 5: [46].

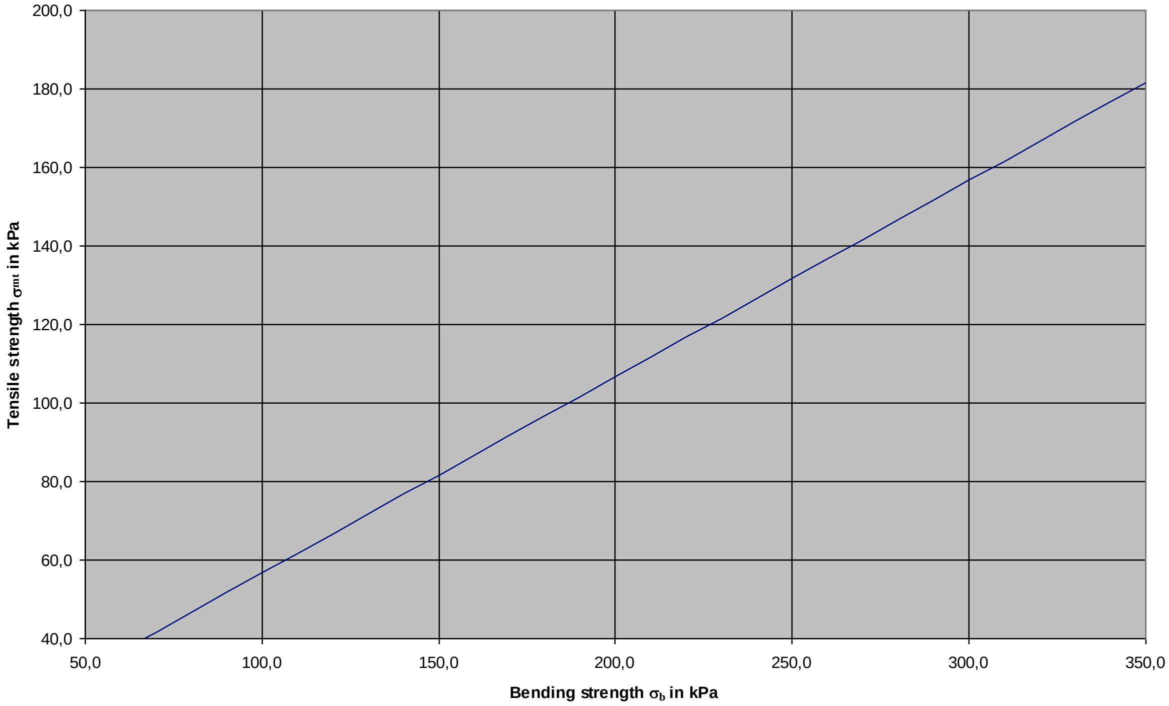


Figure 5:
Relationship between tensile strength perpendicular to faces and density for well fused products.

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 6.

Table 6: 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

3.9 Deformation under specific compressive load an temperature conditions

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.

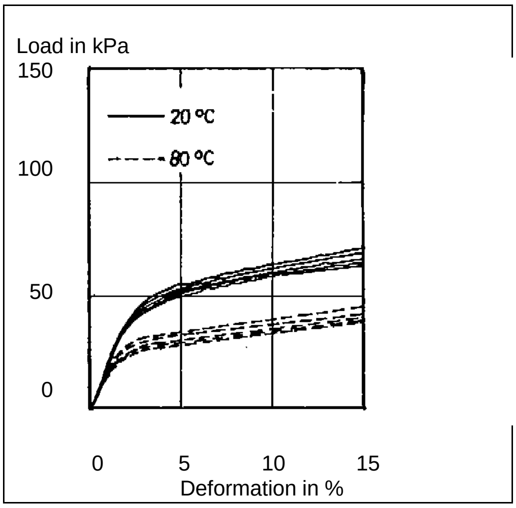


Figure 6:
Compressive load and deformation of non flame retarded EPS, density 14 [kg/m³] [19].

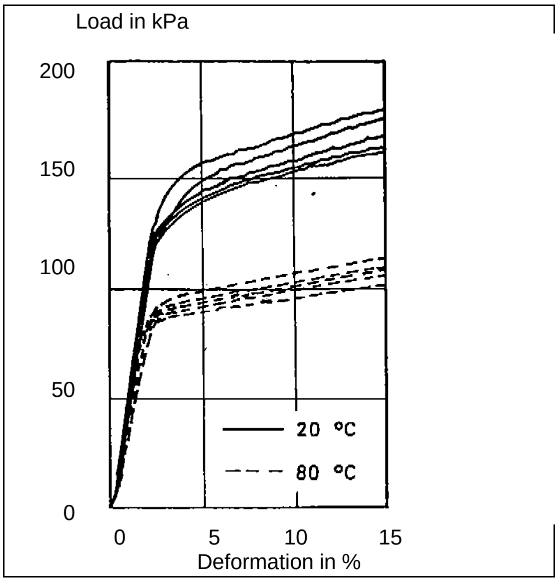


Figure 7:
Compressive load and deformation of non flame retarded EPS, density 24 [kg/m³] [19].

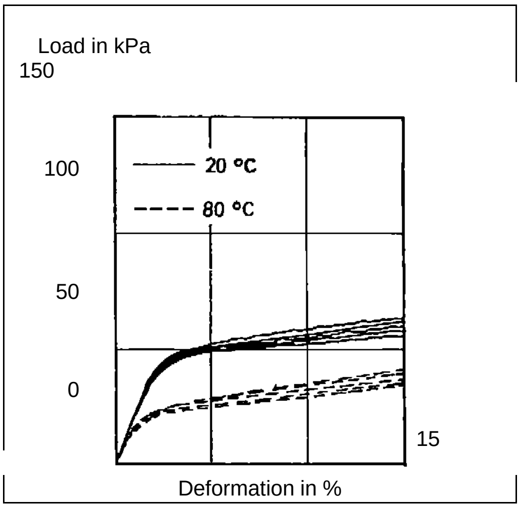


Figure 8:
Compressive load and deformation of flame retarded EPS, density 14 [kg/m³] [19].

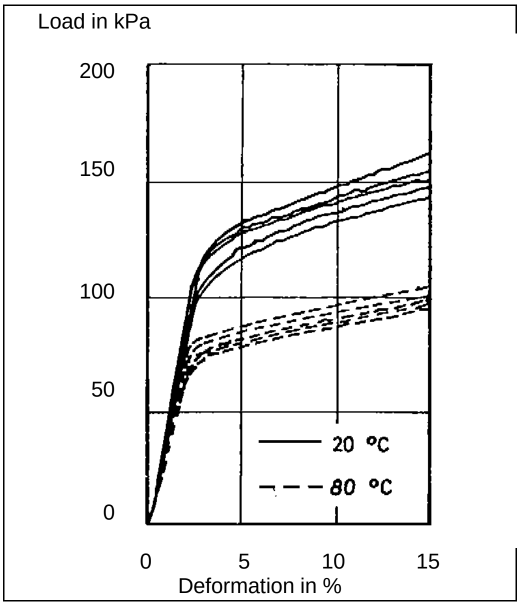


Figure 9:
Compressive load and deformation of flame retarded EPS, density 24 [kg/m³] [19]

3.10 Compressive creep

The long term behaviour under load is determined by compressive creep. Compressive creep, ε_{ct}, 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). 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 10 and Figure 11 show the long term creep behaviour evaluated according EN 1606.

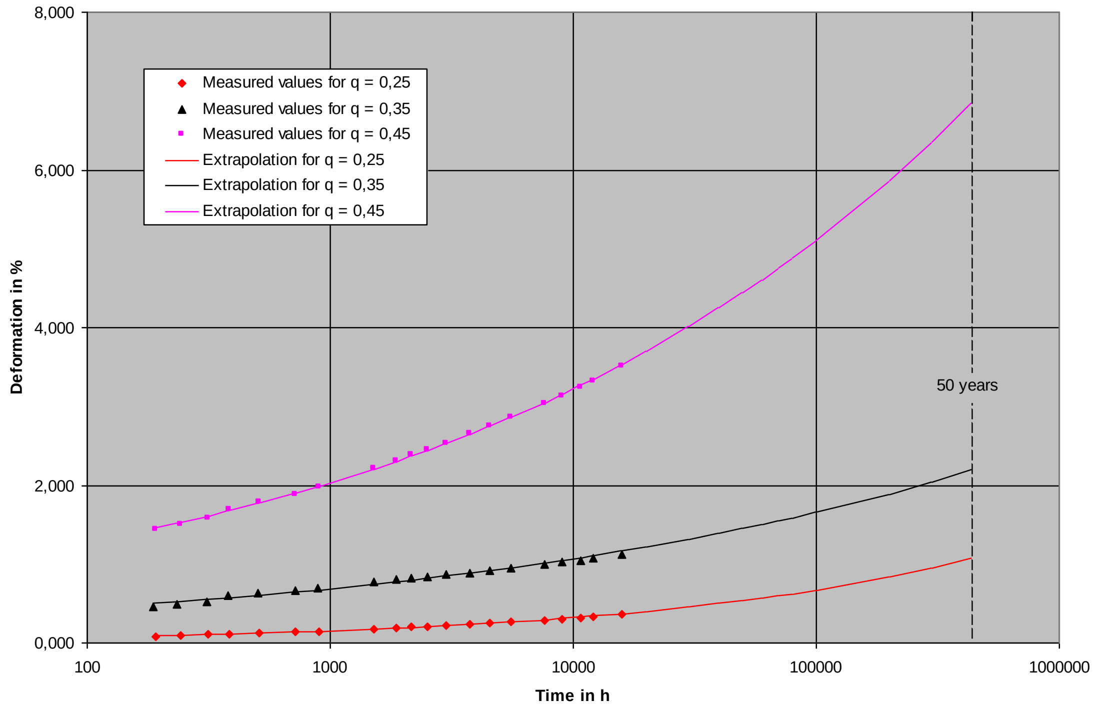


Figure 10:
Measured total deformation of EPS 100, ε_t, and extrapolation to 50 years.

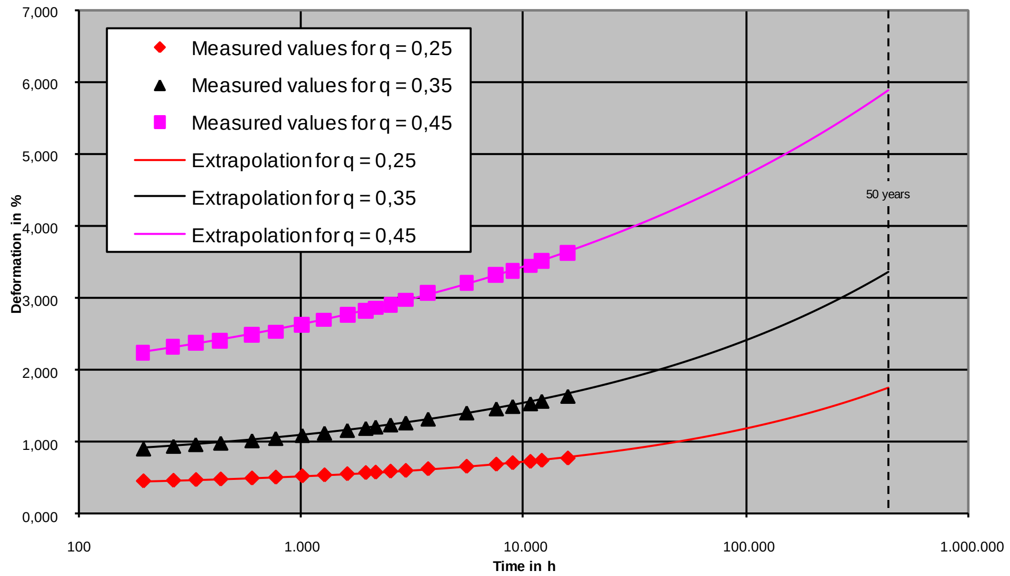


Figure 11:
Measured total deformation of EPS 200, ε_t, and extrapolation to 50 years.

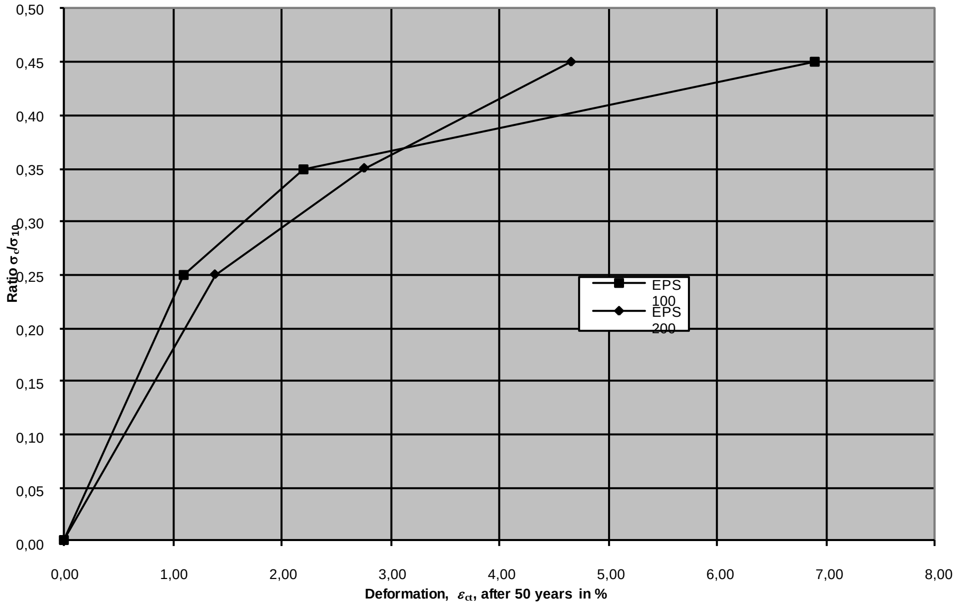


Figure 12:
Creep compression, ε_{ct}, of EPS 100 and EPS 200 after 50 years in relationship to the ratio q.

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 12 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 kPa·m³/kg × ρ_a - 109,1 [kPa]

$\rho_a = (\sigma_{10,\ pred}$ + 109,1 kPa) / 10,0 [kPa·m³/kg]

ρ_a = (250 kPa + 109,1 kPa) / 10,0 [kPa·m³/kg]

ρ_a = 35,9 [kg/m³]

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.

EN 1606 is the harmonised test method to determine compressive creep. For EPS mostly a simpler method is used, a tabulated value as given in [50]. EPS products ensure a maximum creep value of 2 % over a predicted 50 year period.

3.11 Shear behaviour.

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 Correlation between shear strength and density..

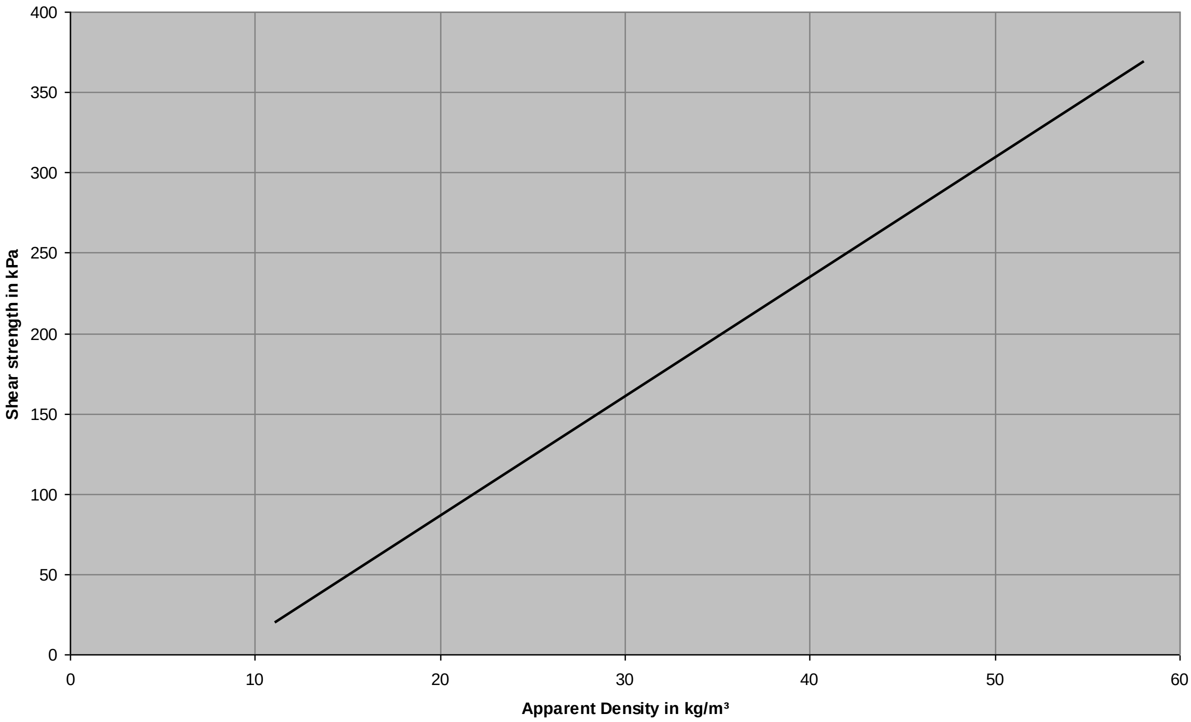


Figure 13: Correlation between shear strength and density.

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

Different values of shear strength at different temperatures were measured by Zehendner [21] and given in *Table 7*.

Table 7: 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 .

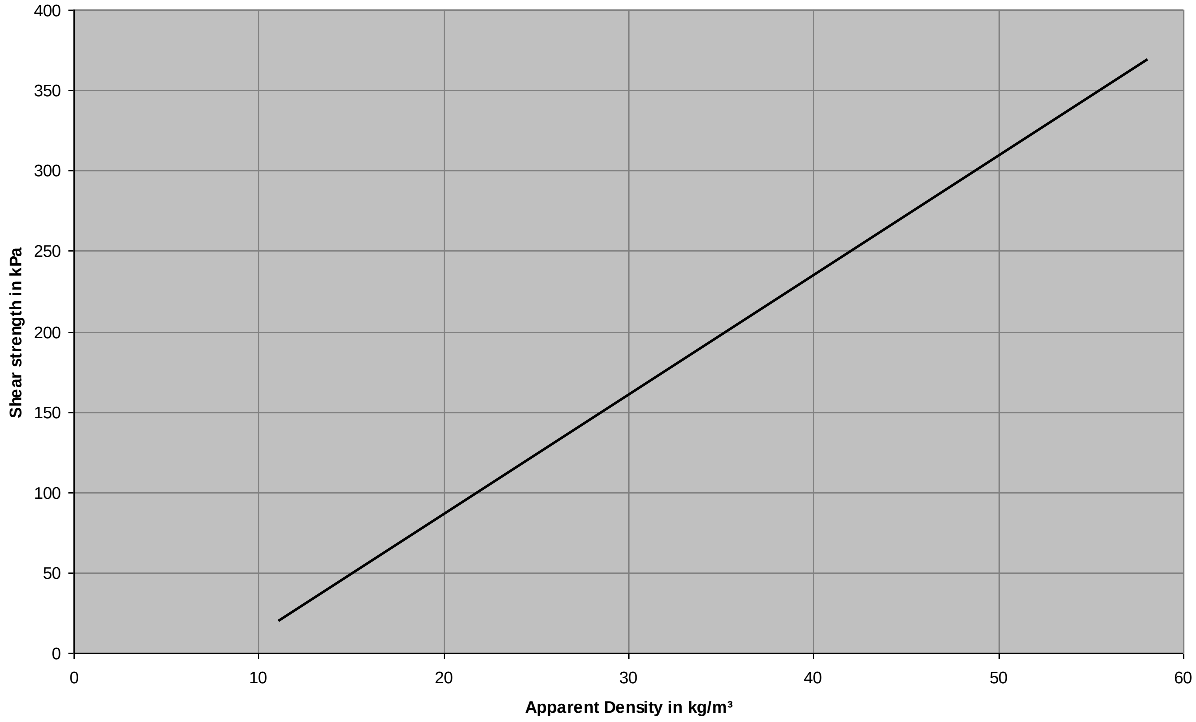


Figure 14: Relationship between shear strength and bending strength.

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

3.12 *Behaviour under cyclic loading*

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. For walkability a suitable test method is still under development.
For CEA applications the test method is already suitable. See also 3.14.5

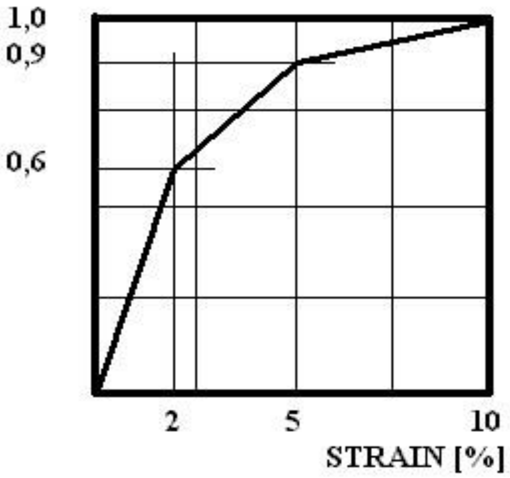
Special for CEA applications the compressive behaviour is listed in 3.13 and 3.14.

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

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] fulfils the requirements.

3.14 Product properties of EPS and Eurocodes

Short-term compressive strength

The stress/strain curve of EPS has a particular shape and resembles very much the stress/strain curve of wood products. Creep that appears at long term load at a certain stress level up to 9/16 of the short term compressive strength will ~~and~~ be reduced to zero in the end. When the stress level at the beginning is too high, progressive collapse will show rather quickly. The relation is given in Figure 17.

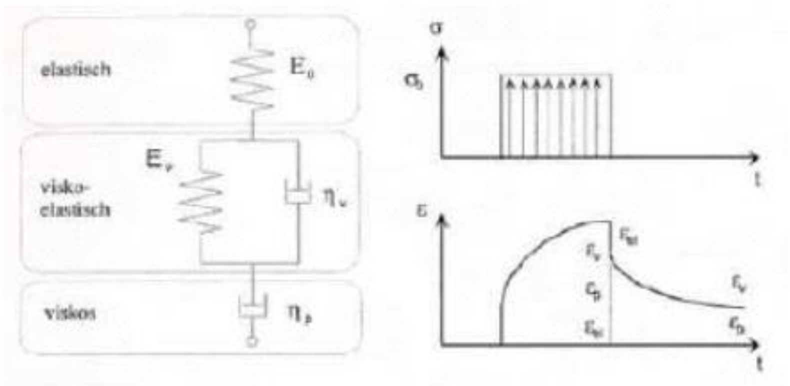
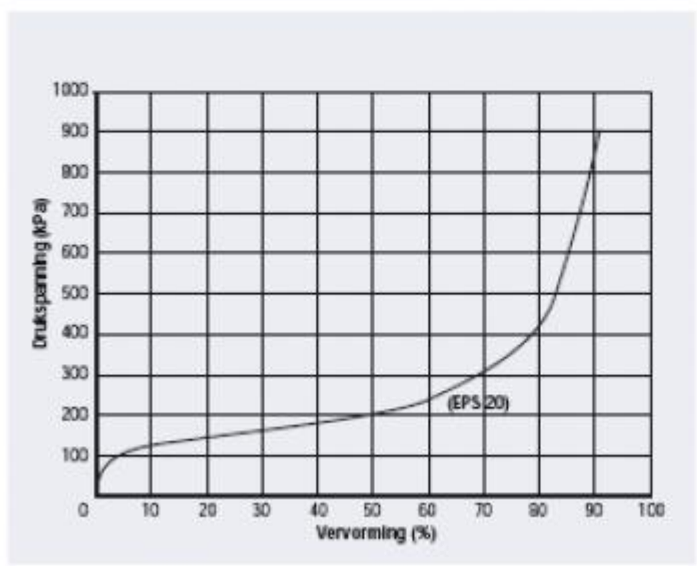


Figure 17 Stress/strain curve of EPS 100

When in accordance with EN 826 the compression strength is determined, the linear – elasticity limit (or proportionality limit) will be reached at 1 – 1,5 % deformation. For compression strength, as defined in EN 826, a value at 10% deformation is commonly used. This σ_{10} characteristics is used as product classification. When tested according to EN 826, the speed of compression is approximately 10 % of the thickness of the sample per minute. This initially linear-elastic deformation is used to determine the tangent modulus E_t [kPa].
Figure 20 shows the stress/strain relation for the rest of the section of the test.



Figuur 1: Last-vervormingsdiagram.

Figure 20 Stress/deformation curve of EPS (initial)

In this second part one can already see the non-linear elastic stress/strain development.
In Figure 21 is shown how the first part of the section develops and how the " yield" is defined.
This yield is approximately 75 % of the compressive stress, at all types of EPSi.
The requirement on short term compressive strength, determined at 10 % deformation, is declared in the CE mark.

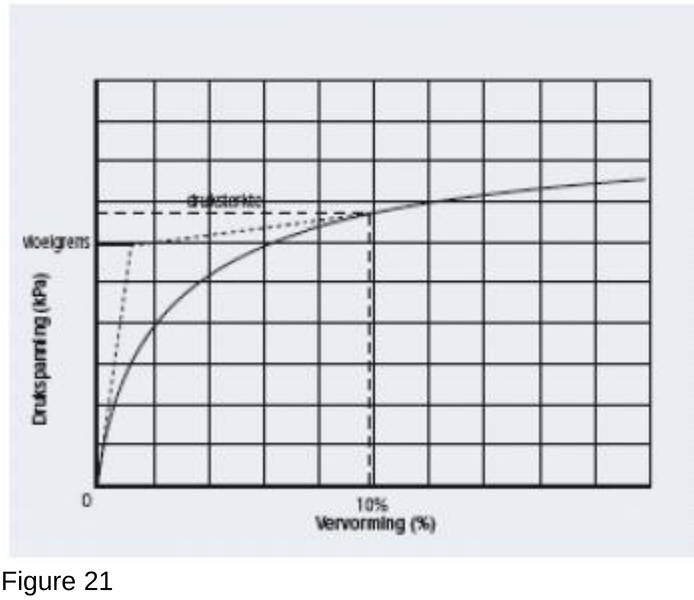


Figure 21

The third section is created by reinforcing behaviour as a result of the compression of the structure of the beads, up to ca. 25 % at EPS 60 to 50 % at EPS 300. When a product has a deformation of ca 70 %, a one sided fracture occurs and EPS becomes hard polystyrene. According to Eurocode 7 (EN 1997-1) a material factor (γ_m) = 1,1 must be introduced to determine the design value of the short term compressive strength σ_{10}. Example for EPS 100: $\sigma_{10,d}$ = 100/1,1 = 90 [kPa]. This value is given in CROW Richtlijn "Lichte ophoogmaterialen" chapter 5.4.2, edition 2013 [56].

Creep and relaxation

Creep is the phenomenon where the deformation increases with time as a result of a certain load. For EPS there are five independent variables: density, stress, deformation, time and temperature. The same goes for relaxation, the phenomenon where at a given deformation the (internal) stress decreases with time. An example is given in Figure 22: the time/deformation curve of EPS 150 (ρ= 23,5 [kg/m^3]) at three stress levels (30, 50 and 70 [kPa]), at a (laboratory)temperature of 23 °C over a period of 500 days.
This curve can also be given as the stress/deformation diagram at various times (Figure 23).

Conclusion: the deformation at long term stress at approximately 25 % of the short term stress, is maximum 1 % and creep is negligible.

In calculations the EN standards are applied: at a stress level of ca.0,3* σ_{10}, the total deformation will be 2 % after 50 years.Research has shown that the expected creep of EPS 60 and EPS 100 at a stress of approximately 25 % of the short term compression strength after one year is less than 0,2 %. Half of the creep behaviour occurs after one day. The creep behaviour on a logarithmic scale is linear. The initial deformation is ca. 0,5 %. Over a period of 50 years this comes down to a total of 2,5 %.

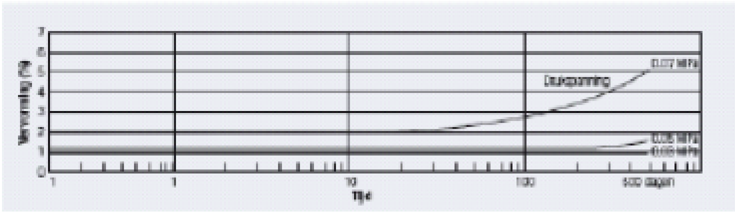


Figure 22 Time/deformation curve of EPS 150

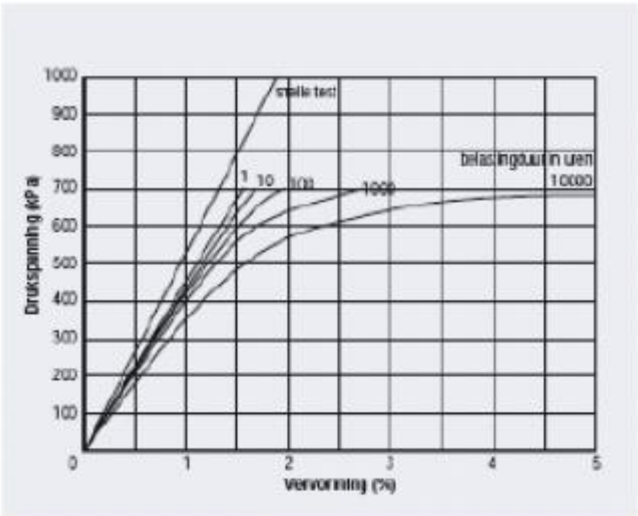


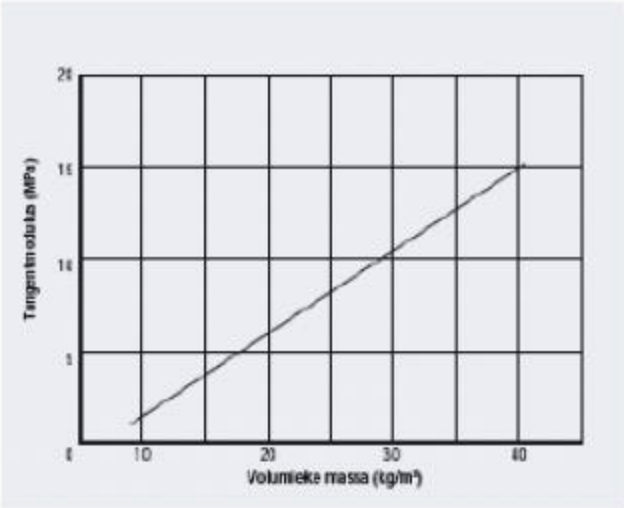
Figure 23

Long term compressive strength

The long-term compressive strength is the continuous permanent admissible stress level over a period of 50 years, to prevent unwanted creep effects. Based on the creep-relaxation effects, the long term compressive strength of EPS is set on 0,3 x short term compression strength.
To determine the design value of the long-term compressive strength, $\sigma_{10;perm;d}$, according to EN 1997-1 a material factor must be taken into account: γ_m = 1,1.
Example: EPS 100: $\sigma_{10;perm;d}$ =0,3*100/1,1 = 27,3 [kPa].
Values are given in Table 15.

Modulus of elasticity

Assuming that EPS in CEA applications will have a maximum deformation of 1%, the relation of the short term tangent modulus applies, as given in Figure 24.
In formula: E_t = 0.045_ - 3 [MPa]. As a result of that the calculation values used in Europe are given in Table 15.



Figuur 3: Relatie tangentmodulus/volumieke massa.

Figure 24 Short term tangent modulus

Compressive strength under cyclic load

Based on extensive studies it has been concluded that, with a relative light permanent loading at the top (15 [kN/m²]) 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 the Duskov [1] 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 1,1 (e.g. for EPS 100: $\sigma_{10;cycl;d}$ = 35/ 1,1 = 31,8 kPa).

For road building usually ~~Apart from~~ the test method EN 13793 is used. ~~which is the usual one for road building in case of any defined property for dynamic resistance and referred to in EN 13163, i~~In the EPS standard for civil engineering applications (EN 14933) another test method, SP 2687, a dynamic load test has been developed for railroad applications in the Nordic countries [27] is taken in.

Table 15: EPS properties for CEA

EPS product type according to EN 14933							
Description	Symbol	Unit	EPS type				
			EPS 60	**EPS 100**	**EPS 150**	**EPS 200**	**EPS 250**
Declared short term compression strength	σε=10%	[kPa]	60	100	150	200	250
Design short term compression strength	σε=10%;d	[kPa]	54,5	90,9	136,5	181,5	227,3
Modus of elasticity	E_t;$E_{dyn.}$	[kPa]	4000	6000	8000	10000	12000
Declared long term compression strength	σε=10%;perm	[kPa]	18	30	45	60	75
Design long term compression strength	σε=10%;perm;d	[kPa]	16,4	27,3	40,9	54,5	68,2
Declared strength under cycling loading	σε=10%;cycl	[kPa]	21	35	52,5	70	87,5
Design strength under cycling loading	σε=10%;cycl;d	[kPa]	19,1	31,8	47,7	63,6	79,5

[1] Duškov, Milan: EPS as a light weight sub-base material; 1997 Delft NL

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.

Mechanical characteristics for ETICS applications are listed from 3.15 to 3.20

3.15 Mechanical resistance and stability of the system

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 quantity of mechanical fixings. ~~amount of needed anchors.~~

3.16 Tensile strength of the reinforcement

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.

3.17 Resistance to impact

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]).

3.18 Resistance to penetration

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

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

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.

3.20 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 render system (the finishing layers like the key coat, finishing coat and decorative coat) ~~material~~ on the base coat. This claus~~es~~ explains the conditioning according EN 1062-11, which is needed for the determination of the durability and adhesion of the finishing material.

Moisture behaviour is listed from 3.20 to 3.26

3.21 Water absorption

EPS has a good resistance against water absorption. Due to tests required for ETICS, also the short term water absorption, even by partial immersion, is mentioned in the EPS standards.
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 (see 3.1).
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 8: Thermal conductivity in relationship to moisture content according ISO 10456.* and *Table 9.*

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.

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

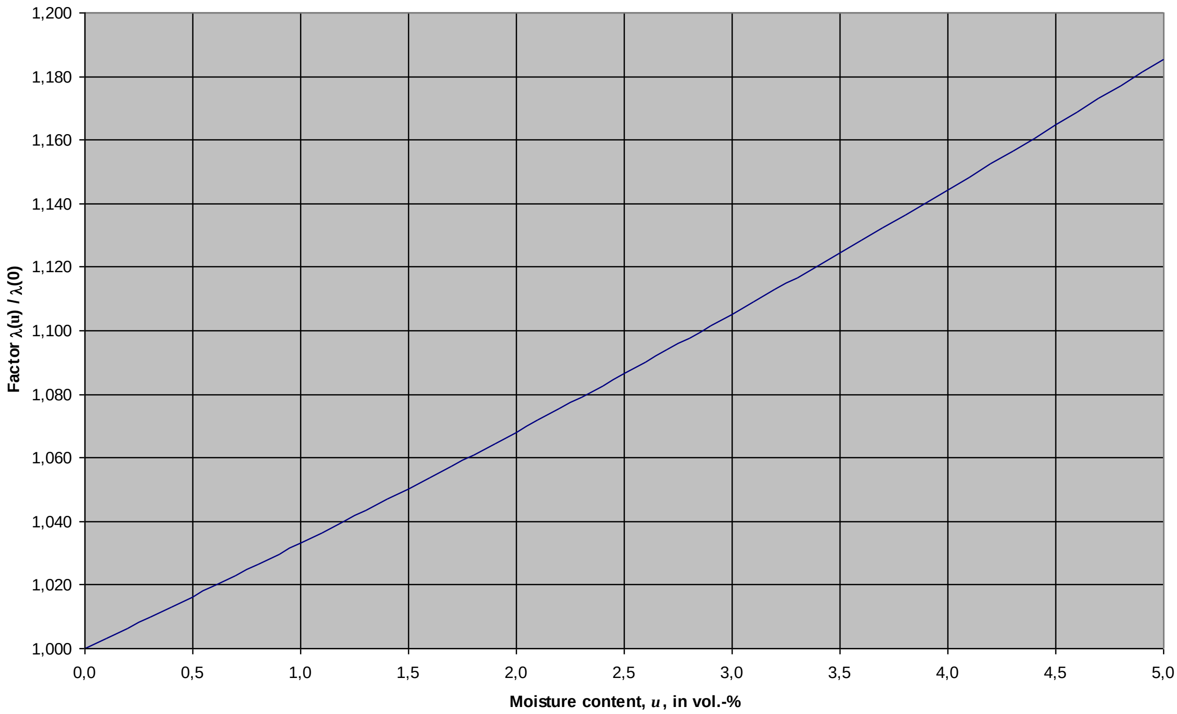


Figure 15: Change of thermal conductivity with moisture ref. [49].

Table 8: 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

Example

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 12*) 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 9: 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 *Table 9*.

3.22 Long term water absorption by immersion

For some applications the long term water absorption is required. This can be measured for partial or total immersion. Both possibilities are described in EN 12087.

3.23 Long term water absorption by diffusion

For some applications, see reference ~~(see~~ [45]~~)~~ long term water absorption by diffusion must be declared. This shall be determined in accordance with EN 12088. The long-term water absorption by diffusion is not only used as an accelerated test but can also be used for classification.

3.24 Freeze thaw resistance

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 0 °C. 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 ºC. 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].

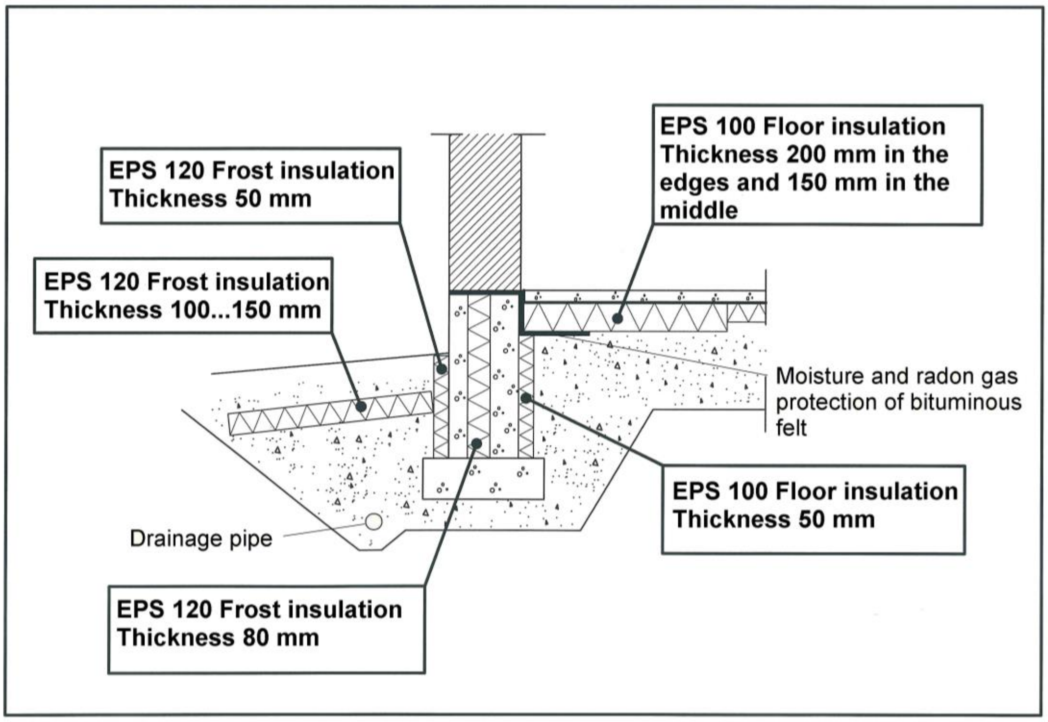


Figure 16:
Example of how to use EPS frost and floor insulation materials in ground slab structures.

Conclusion:

- 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 %

3.25 Water vapour transmission

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.

3.26 Water vapour diffusion resistance factor

The water vapour diffusion resistance factor is used to calculate water vapour condensation inside a construction. For more details see Table 10: Tabulated values of water vapour diffusion resistance factors and water vapour permeability.
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)]

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

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

Due to this calculation table D.2 in EN 13163 has to be slightly revised as given in Table 10.

Table 10: 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, EPS SD	20 to 40	0,015 to 0,030

3.27 *Liquid water permeability of the system surface*

Listed in EN 13499 only. Liquid water permeability shall be determined in accordance with EN 1062-3. No test result shall be greater than 0,5 [kg/(m².h^{0,5})]. If the base coat complies with this requirement the finishing material need not be tested.

3.28 Characteristics for floating floors are listed in 3.27 and 3.28

When EPS is used in floating floors, characteristics must be determined according to different test methods compared to determination of other EPS characteristics.

3.29 Dynamic stiffness

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.

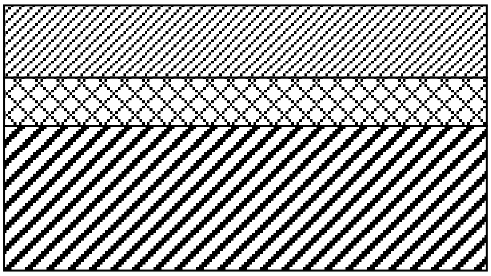


Figure 17: Example of a ceiling construction with a floating floor.

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

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

where

m' is the mass per unit area of the floor and
m'_0 is 1 [kg/m]

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

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] = 40 [dB]

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] = 38 [dB].

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 sound insulation. A draft (prEN 17237) is under ~~being~~ developmented ~~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 11*)
K_K = Correction for the percentage adhesive surface (see *Table 12*)
K_T = Correction for the evaluated sound insulation level of the carrier wall (see *Table 13*)

Table 11: 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 12: Correction for the percentage adhesive surface

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

Table 13: 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]

3.30 Compressibility

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 must be ~~have to~~ measured first.

$$c = d_L - d_B$$

No test result shall exceed the values for nominal compressibility plus tolerance of test results given in Table 8 for the declared level.

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.

3.31 Apparent density

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.

3.32 Release of dangerous substances

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 approach,
- focussed on the intended application of construction products,
- restricted to the normal use of construction products.

CEN has been requested to develop procedures and test methods of for the relevant release scenarios (emissions into indoor air, release into soil, ground water and surface water, radiation etc.) by the EC Mandate M 366.

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].

Some documents were already published by CEN TC 351:

- CEN/TR 16220 Construction products. Assessment of release of dangerous substances. Complement to sampling
- CEN/TS 16516 Construction products - Assessment of release of dangerous substances - Determination of emissions into indoor air
- CEN/TR 16496 Construction Products - Assessment of release of dangerous substances

Use of harmonised horizontal assessment methods. CEN TC 351 has- drafted two sets of procedures to determine the release of these "Regulated Dangerous Substances (RDS)" and the EC has funded TC 351 with budget for ruggedness testing of these procedures. Until the procedures have been verified, ~~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).

On request of DG Enterprise under the CPR EUMEPS has submitted a draft proposal –as part of CEN TC 88_ to prove that EPS fulfils all the requirements on release and emissions Europe wide.

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.

3.33 Continuous glowing combustion

Due to Mandate 367 (2005) this clause was placed in all standards, only as a placeholder, since no EN test method was available. An EN test method has been developed. Mandate 367 was ~~has been~~ amended in 2016 and only products that exhibit this phenomenon need to be tested. This clause will therefore be deleted from EPS standards (in the next revision).
~~, meaning that this clause can be deleted from the EPS standards (in the next revision).~~

Characteristics specific for building equipment and industrial installations are listed in 3.33 to 3.35

3.34 Maximum service temperature

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.

3.35 Minimum service temperature

The minimum service temperature must be determined when a product is applied at low temperatures. No harmonised EN test method is developed, because apparently different insulation materials react differently at ~~on~~ low temperatures. To determine the minimum service temperature a test method that is applicable for plastic insulation materials will be ~~is~~ put into those the standards ~~for plastic insulation materials~~ in an Annex, explaining the way to test the thermal conductivity and dimensions before and after the test..

3.36 Trace quantities of water soluble ions and pH

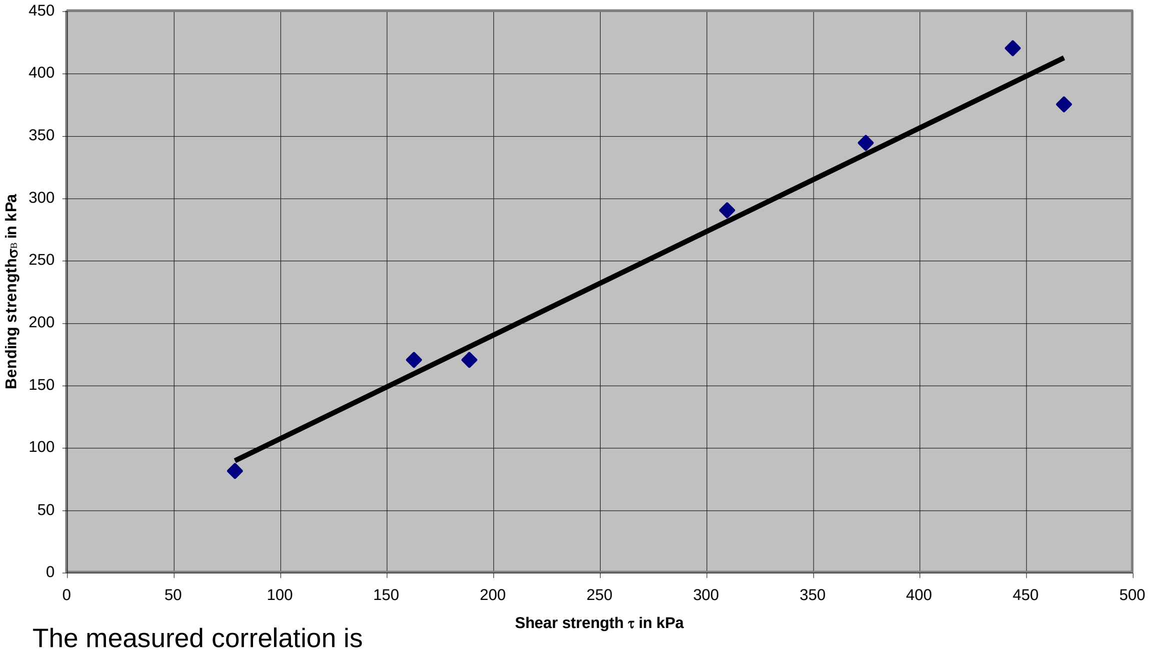
In certain applications a limit can be put to trace quantities of water soluble chloride, fluoride, silicate and sodium ions. A test method to determine those quantities and measuring the pH is developed (EN 13468).

The additional characteristics listed in 3.36 to 3.45 do not appear in the standards, but are useful.

3.37 Correlation between bending and tensile strength

The following correlation between bending strength and tensile strength was measured FIW.

Figure 18: Correlation between bending and tensile strength.



The measured correlation is

$\sigma_b = 0,83\tau + 23,6$ [kPa]

3.38 *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.

3.39 *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 *Table 14.*

Table 14: 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 products ~~board~~	42	parallel	$6,4 \cdot 10^{-5}$
		perpendicular	$6,7 \cdot 10^{-5}$

3.40 Hygroscopic expansion coefficient

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

3.41 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.

3.42 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 15* 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 15 shows the resistance of expanded foam to the most important chemical substances.

Table 15: 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.

3.43 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].

3.44 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 %.

3.45 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 regarding the sustainability of construction works. CEN TC 350 was established.

The following documents were already published by CEN TC 350:
- EN 15643-1 Sustainability of construction works - Sustainability assessment of buildings - General framework
- EN 15643-2 Sustainability of construction works - Assessment of buildings - Framework for the assessment of environmental performance
- EN 15643-3 Sustainability of construction works - Assessment of buildings - Framework for the assessment of social performance
- EN 15643-4 Sustainability of construction works. Assessment of buildings. - Framework for the assessment of economic performance
- EN 15804+A1 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
- EN 15978 Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method.

EN 15804 + A1 provides core product category rules (PCR) for Type III environmental declarations for any construction product and construction service. It provides a structure to ensure that all Environmental Product Declarations (EPD) of construction products, construction services and construction processes are derived, verified and presented in a harmonised way. EPD provide the data to assess the sustainability of construction works.

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.

4. Application and calculation

4.1 Eurocodes calculation rules for EPS

Introduction

In this clause the calculation rules of expanded polystyrene (EPS) are given for EPS in geotechnical/ civil engineering applications [57].

Design rules

A lot of nonofficial, voluntary design rules in the EU are used (e.g. FGSV, CROW and NRRL guidelines). With Eurocodes into force designers and engineers are bound to fundamental approaches, as agreed within CEN. Design rules were voluntary; now the Eurocodes are mandatory and legal. This clause describes general rules as a help to design the required EPS properties.

Loadings

Loadings of own weight and imposed dead loads can be derived from Eurocodes; for EPS a design value of 50 [kg/m³] is mostly taken into account, independent of the dry mass but eventual water uptake included. The higher the density, the lower the water uptake, thus resulting in the average of 50 [kg/m³]. For traffic (cyclic) loads idem from Eurocodes.

Loading factors

For safety class RC1 (the most used class) permanent loads a loading factor of $\gamma_{F;G}$ = 1,08 has to be applied; for traffic load a loading factor of $\gamma_{F;Q}$ = 1,35 (EN 1997 Annex A3 Table A3, collection A1 with a reduction of 0,9) has to be applied.
For safety class RC2 permanent loads a loading factor of $\gamma_{F;G}$ = 1,2 has to be applied; for traffic load a loading factor of $\gamma_{F;Q}$ = 1,5.
In case of a possibility of floating other factors have to be used; for favourable loads is a factor of 0,9 valid; see EN 1997-1.

5. Design criteria

- *Ultimate Limit state (STR) short term* Loading combination: Multiply the dead and imposed load with their respective loading factors and compare it with the short term design compressive strength $\sigma_{10;d}$ (e.g. 90,9 kPa for EPS 100).
- *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 compare it with the long term design strength $\sigma_{10;perm;d}$ (e.g. 27,3 [kPa] for EPS 100).
- *Ultimate Limit state (GEO) cyclic loads* Loading: Multiply the cyclic load with the factor γ_Q = 1,35 (in case of RC1) and compare it with the design cyclic strength $\sigma_{10;cycl;d}$ (e.g. 31,8 [kPa] for EPS 100).
- *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, taking into account a missing pressure equalising layer.

Example 1: Calculation typical Dutch polder road

As an example a typical road in the “Polders’ in the western part of the Netherlands is taken.
Construction:
Depth (removing peat soil): 1,4 [m]; Highest groundwater level 40 [cm] under ground level: applied EPS 100 blocks 2 [m] high; 0,5 [m] sand/gravel; 0,15 [m] asphalt.
Safety class RC1
Hardenigscalculation shows a variable/cyclic loading of 15 [kPa] imposed on the EPS.

Cross section typical Polderroad NL

Loadings:
Permanent loads (γ=1,08)

0,15 [m] asphalt bitumen layers	0,15 * 2100 [kg/m³] =	3,1 [kN/m²]
0,50 [m] gravel/sand	0,50 * 1800 [kg/m³] =	9,0 [kN/m²]
2,0 m EPS 100	2,00 * 50 [kg/m³] =	1,0 [kN/m²]
	P	= 13,1 [kN/m²]

Traffic load (γ =1,35)
Cyclic and uniformly distributed on EPS = 15,0 [kN/m²]

Loading combinations:

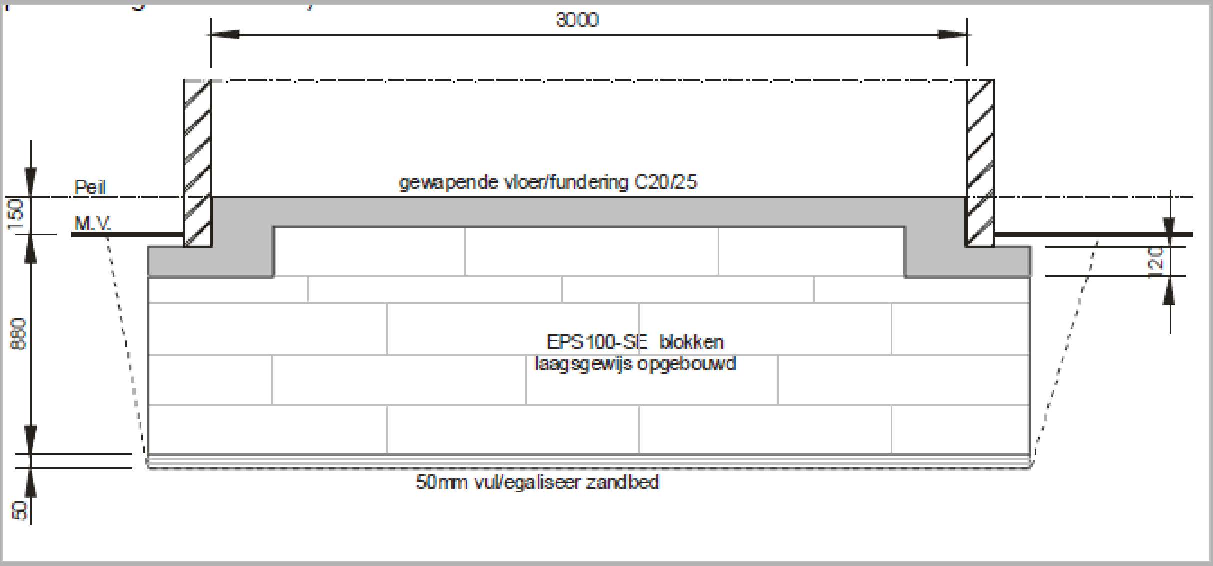
*STR- short:*1,08 * 13,1 + 1,35 * 15	= 34,40 [kPa] < 90,9 OK
STR-permanent 1,08 * 13,1	= 14,15 [kPa] < 27,3 OK
GEO-Cyclic 1,35 * 15	= 20,25 [kPa] < 31,8 OK
Floating (1,4 – 0,4) * 1,1, * 10 – 0,9 * 13,1	= 11- 11,8 OK (just enough)

Conclusion: The product properties of EPS 100 fulfil the performance requirements.
In this case even EPS 60 would have been sufficient, but for practical reasons EPS 100 was chosen.

Example 2: Calculation cycle barn in dwelling area

Description

A cycle barn, dimensions 2,70 * 3,20 [m]; height 2,40 [m]; 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:

1,08 * 108 + 1,35 * 10 = 130,4 [kN].

STR-permanent

1,08 * 108 + 1,35* 4 = 122,04 [kN]

Design values:

Applied is EPS100 with $\sigma_{10;d}$ = 90,9 [kPa] and $\sigma_{10;perm;d}$ = 31,8 [kPa]

Length of the foundation : 3,50 [m]; width: 3,0 [m]; surface: 10,50 [m²]

STR-short gives: 130,4 / 10,50 = 12,41 [kPa] < 90,9 OK

STR- long gives: 122,04 / 10,50 = 11,62 [kPa] < 31,8 OK

Floating possible?

The max GWL is 0,15 [m] below upper side EPS; total floating force: 0,73 [m] * 10,50 [m²] * 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)

5.1 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	

5.2 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

5.3 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 works and/or the relevant construction-part. Per aspect a “tabulated building rule” is given.
To be replaced by the Bbl as part of the Omgevingswet in 2022.
CPR rules are above the National Regulation. A published ETA is proof in compliance to the Dutch building regulation.

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 mark assurance, KOMO-certified and to be accepted by local authorities as if expected to fulfil the requirements.

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.

<u>Slovakia</u>

STN 72 722-1 Thermal insulation products for buildings. Part 1: Types of building structures and application codes
This standard specifies the types of building structures and codes which are used for thermal insulation products in building construction. This standard applies to thermal insulation products by standards STN EN 13162 to STN EN 13171.
The informative Annex A provides an overview of the performance of thermal insulation products of brand, units and reference of the regulations.

STN 72 722-2 Thermal insulation products for building applications. Part 2: Factory made products of expanded polystyrene (EPS). Intended use
This standard specifies the class or level of the feature that the product has achieved to demonstrate his fitness for the intended use, while respecting the basic requirements for construction works. Applies for the purposes of the design and building of works under special regulations for the usual types of structures and the use category.
This standard complements STN EN 13163.
This standard also applies to products used for sound insulation and determines the sound isolation characteristics which are evaluated according STN 73 0532
This standard also applies to products used in prefabricated thermal insulation systems and composite panels and includes performances of systems containing these products.

STN 73 2901 Performance of External thermal insulation composite systems (ETICS)
This standard specifies the technical requirements for the manufacture of external thermal insulation composite systems (ETICS) with thermal insulation based on expanded (foamed) polystyrene (EPS), mineral wool (MW) and appropriately based on other thermal insulation for example. phenolic foam (PF), polyurethane (PU) with a finished plaster or plaster with paint, bonded to the substrate using adhesive or adhesive and expansion anchors supplied by the manufacturer on the market as a complete system. ETICS provides primarily thermal protection of buildings and ~~their~~ protection against climatic influences. It does not ensure the airtightness of the thermal building structure, which is ~~achieved by~~ the responsibility of the contractor of the construction works before applying the ~~when making~~ ETICS.

<u>Spain</u> Spain has no additional rules in the application field of EPS.

<u>Sweden</u> 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.

5.4 European EPS Types

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 placed 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. Manufacturers 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 (e..g. sandwich panels); these are often called "commodity EPS products".

Table 16: 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 17: 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.

Application

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 18: 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.

6. Quality marks

6.1 New developments

The CPR states very clearly that CE marking and DoP are the only and legal expressions of the "quality" of a product.
With quality is meant that the performance of a product meets at least the declaration by the manufacturer.
The most used system ~~for AVCP~~ for EPS is AVCP system 3, where the manufacturer is responsible for his declaration (DoP). ~~has the most responsibility~~. According to the CPR, there is no room for voluntary quality certification systems when a product falls under a harmonised standard and a AVCP system 3. For kits (e.g. ETICS) and other systems (1, 1^+ and 2^+) the certification rules are given for ~~in~~ the kit or system and therefore are not voluntary.
According to the CPR, in the CE marking the manufacturer is only allowed to declare the essential characteristics as mentioned in the Mandate (and repeated in Annex ZA) ~~and DoP only the essential characteristics as mentioned in the Mandate (repeated in Annex ZA) must be declared.~~
This leaves a manufacturer to have a good Manufacturer's Literature in which he can declare any (non-Essential) characteristic that is needed for the specific application and not mentioned in Annex ZA or DoP. ~~CE.~~
Almost all EN standards cover only products. For those products CE marking and a DoP are enough for free trade (as entree to the local market). DoP's are checked in regulatory sense to be able to use the product in a specific ~~as well as~~ application in the various member states.
The level of the requirements (including safety factors) is set in all member states, leaving the responsibility to the manufacturer to deliver products with the required performance.
Also the possibility for voluntary certification exists, but only for those characteristics that are not to be given in the harmonised standard for CE marking and DoP.
Since this regulation is not clear or understood in all member states, all voluntary certification schemes are temporarily left out of the Whitebook.

7. Voluntary quality marks

7.1 Key mark system

This system can be used for e.g. ETICS

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10. Alphabetic register

A

B

C

D

E

F

G

H

I

K

L

M

N

O

P

R

S

T

V

W

11. Annex A Tables

Table 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.

Table A.2: Abbreviations

AoC	Attestation of conformity
ASTM	American Society for Testing and Materials (American standardisation body)
AVCP	Assessment and Verification of the Constancy of Performance
BR	Basic Requirement
CEA	Civil Engineering Application
CEN	European Committee for Standardisation (Comité Européen de Normalisation)
CPD	Construction Products Directive
CPR	Construction Products Regulation
CUAP	Common Unique Acceptance Procedure
DIBt	Deutsches Institut für Bautechnik (German Regulator Body)
DOA	Date of Acceptance
DoC	Declaration of Conformity
DoP	Declaration of Performance
DOW	Date of Withdrawal
EEA	European Economic Area
EC	European Commission
EN	European Norm (European Standard)
EoC	Evaluation of Conformity
ER	Essential Requirement
EOTA	European Organisation for Technical Assessment ~~Approval~~s
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
ITT	~~InNitial~~ Initial Type Testing
LFS	Lateral Flame Spread
MRA	Mutual Recognition Agreements
PECA	Protocol to the European Agreement on Conformity Assessment
prEN	provisional European Norm (European standard)
PTD	Product Type Determination
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)
VCP	Verification of the Constancy of Performance
VTT	Finish Technical Research Centre ~~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.

12. Specific guidance for manufacturers

This part of the White book contains specific guidance to EPS converters and is not published on the EUMEPS website.

1 Organisation of factory production control (FPC)

1.1 General

The factory Production Control according to the EN product standards might be more severe than it was in previous national specifications. The FPC is detailed in all EPS standards. Manufacturers having a quality management system according ISO 9001 or ISO 9002 can fulfil the general provisions for FPC. Before FPC starts, before a product is allowed to be placed on the market, a product must be tested initially: Product Type Determination (PTD).

1.2 Required Documents

For the appropriate AVCP the manufacturer needs the following documents (depending on the EPS standard):

EN 13163
EN 13172
EN 13787
EN 13499
EN 13950
EN 14309
EN 14933
EN 15037-4
EN 15037-5
EN 16025-1
EN 16801-1

Furthermore all testing standards are needed which are referred to in these standards as far as properties falling under FPC are concerned.

Helpful information are to be found in:

ISO 12491 – *Statistical methods for quality control of building materials and components*
ISO 12576-1 – *Thermal insulation – Insulating materials and products for buildings – Conformity control systems*

1.3 Properties to be tested under FPC

The properties which have to be tested under FPC are to be found in table B.1 and B.2 of EN 13163 and EN 14933 and table A.1 and A.2 of EN 13499 and EN 14309. Properties that will be declared have to be tested prior to placing on the market (PTD). If a manufacturer does not have the right testing equipment, the PTD can be performed by a notified body.

After placing a product on the market a manufacturer has to perform a continuous surveillance. The tables listed above give the required frequency. When a known relationship is established, the manufacture may also perform indirect testing.
A combination of direct and indirect testing leads to a much lower frequency of the direct testing.
When the results on FPC measurements are within certain limits, the frequency of testing also can be lowered; rules are given in EN 13172.

1.3.1 Thermal conductivity

The investment on testing equipment is recommended to obtain optimum results from the statistical evaluation. Lower values of thermal conductivity due to a larger amount of test results may also lead to a more economic production. The investment of about € 30.000 is high but not compulsory.

1.3.2 Testing machine

The investment of a testing machine is recommended to measure bending strength, compressive stress at 10 % deformation, tensile strength and compressibility – but is not compulsory.

1.3.3 Ignitability

The ignitability has to be tested according EN ISO 11925-2. The test method is similar to the B2 test according DIN 4102 which is widely used by EPS producers. For materials which soften such ~~are melting~~ as EPS, a modified moveable sample mounting is needed.

An upgrade to the B2 test is available. ~~A n~~ New testing equipment costs between about € 8.000 to € 11.000.

1.3.4 Dynamic stiffness

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.
When products are be grouped, certain tests have to be performed: for the lowest thickness only the dynamic stiffness must be determined and for the highest thickness only the compressibility. All other thicknesses in that group do not need be tested.

Example for testing (when grouping):

Thickness [mm]	Class	Test
40	SD10 - CP3	SD10
50	SD10 - CP3	None
60	SD10 - CP3	CP3

2 Design and grouping of product types

2.1 Design

2.1.1 General

Since most of the relevant EPS properties relate to density, the manufacturer should test and record the appropriate correlations. With this knowledge he is able to produce a product with a certain density having a certain set of properties.

This set of product properties may be found in (application related) national regulations or by obtaining guidance from *Table 18* of this White Book.

2.1.2 Thermal conductivity

The calculation of $\lambda_{90,90}$ is well described in Annex A of the EPS standards. It means that the lambda value has to be declared over a period of one year (the last year) every three months. In case there are not 10 measurements available over the one year period, this period may be extended up to three years. Statistical treatment starts at a minimum of 10 measurements.

In most cases the calculation will be performed on a PC and therefore an equation to calculate the k factor is more convenient than to use a table. The equation below for 90 % fractile (p) and a 90 % confidence level ($1 - \alpha$) is applicable only if more than 100 measurements (n) are available.

$$k_{n,p,1-\alpha} = \frac{2(n-1)}{2(n-1) - z_{1-\alpha}^2} \left(z_p + z_{1-\alpha} \sqrt{\frac{2(n-1) + n z_p^2 - z_{1-\alpha}^2}{2n(n-1)}} \right)$$

The value z is the fractile of the standardized normal distribution, which can be calculated with the EXCEL command NORMSINV(p) (German: STANDNORMINV(p)) respectively NORMSINV($1 - \alpha$).

For lower numbers of measurements than 100, Table 1 may be used and incorporated e. g. in an EXCEL file. If the table contains n in the first column (A) and the tabulated k factors in the second column the EXCEL command VLOOKUP(n;A1:Bn;2) (German SVERWEIS(…)) may be used to obtain the appropriate k factor.

Table 1 : $k_{\text{n, p, 1}}$ values for n = 10 through n = 99.

	$k_{\text{n, p, 1}}$ values								
n	*n* = 10	*n* = 20	*n* = 30	*n* = 40	*n* = 50	*n* = 60	*n* = 70	*n* = 80	*n* = 90
0	2,07	1,77	1,66	1,60	1,56	1,54	1,52	1,51	1,49
1	2,01	1,75	1,65	1,60	1,56	1,54	1,52	1,50	1,49
2	1,97	1,74	1,64	1,59	1,56	1,54	1,52	1,50	1,48
3	1,93	1,73	1,63	1,59	1,56	1,54	1,52	1,50	1,48
4	1,90	1,71	1,63	1,58	1,55	1,54	1,52	1,50	1,48
5	1,87	1,70	1,62	1,58	1,55	1,53	1,52	1,50	1,48
6	1,84	1,69	1,62	1,58	1,55	1,53	1,51	1,50	1,48
7	1,82	1,68	1,61	1,57	1,55	1,53	1,51	1,49	1,48
8	1,80	1,67	1,60	1,57	1,55	1,53	1,51	1,49	1,47
9	1,78	1,66	1,60	1,56	1,54	1,53	1,51	1,49	1,47

The declared value of thermal conductivity depend on the mean value of the measurements, the standard deviation and the number of measurements. The distribution is the factor which has great influence on the declared value. To avoid a wide distribution the values should be measured at similar conditions as thickness, density, raw material, production process etc.
If the minimum density of a certain product is designed as a production parameter according 3.5.1 the statistical treatment described above shall be taken from a certain density only.

Example

The values of thermal conductivity collected in Table 2 have been measured.

Table 2 Measured values of thermal conductivity

Counter *i*	**Measured thermal conductivity λ_i [mW/mK]**
1	32,6
2	31,9
3	33,0
4	32,8
5	32,2
6	33,3
7	31,9
8	32,4
9	32,7
10	32,3
11	32,2
12	32,8
13	32,6
14	32,1
15	31,8
16	32,7
17	32,3
18	32,8
19	31,7
20	32,1
21	32,0
22	32,1
23	32,5

Number of measurements: $n = 23$

Mean value	λ_{mean} = 0,03238 [W/m·K]
Estimated standard deviation	s_λ = 0,00042 [W/m·K]
k factor	k = 1,73
Declared thickness	d_N = 50 [mm]

The thermal conductivity, $\lambda_{90,90}$, with a fractile of 90 % of the production and a confidence level of 90 % is calculated as follows:

$\lambda_{90,90} = \lambda_{mean} + k \cdot s_\lambda$
$\lambda_{90,90}$ = 0,03238 [W/m·K] + 1,73 · 0,00042 [W/m·K]
$\lambda_{90,90}$ = 0,0331 [W/m·K]

To obtain the declared thermal conductivity, λ_D , the $\lambda_{90,90}$ has to be rounded upwards.

λ_D = 0,034 [W/m·K]
To calculate the thermal resistance use the declared thickness and the declared thermal conductivity.

$R = d_N / \lambda_D$
R = 0,050 [m] / 0,034 [W/m·K]
R = 1,471 [m²·K/W]

To obtain the declared thermal resistance the R value has to be rounded downwards and declared in steps of 0,05 [m²·K/W] (see clause 4.2.1 of EN 13163).

R_D = 1,45 [m²·K/W]

If thermal conductivity is the target of the design the appropriate density may be determined according to the relevant tables in the EPS standards. In most cases the producer will obtain a more favourable approach if he is measuring his own (raw material related) correlation between thermal conductivity and density.

Details on how to calculate the regression curve are given in A.3.2. Taking into account the density distribution see A.3.5.1.

2.1.3 Compressive stress at 10 % deformation

In many cases a product has to fulfil a certain value of compressive stress at 10 % deformation. The relationship between compressive stress at 10% deformation and density is described in B.2.2 of EN 13163. This relationship can be used to predict the minimum density needed for the intended compressive stress at 10% deformation. The determination of compressive stress at 10% deformation is merely a product characterisation.
In practical cases, often a certain load is required which the EPS product has to withstand over a longer period. The relationship between compressive stress at 10 % deformation and the long term compression behaviour is given in D.2 of EN 13163.

> Example
>
> An EPS product shall have a long term compressive behaviour ($\sigma_{2\%,50a}$) of 50 kPa and a maximum deformation of 2 % after 50 years.
>
> According D.2 is
>
> $\sigma_{2\%,50a} = 0{,}30 * \sigma_{10\%}$
>
> and the appropriate compressive stress at 10 % deformation ($\sigma_{10\%}$) is calculated
>
> $\sigma_{10\%} = \sigma_{2\%,50a} / 0{,}30 = 50 \text{ kPa} / 0{,}30 = \underline{167 \text{ [kPa]}}$
>
> Annex B of EN 13163 contains the general correlation between $\sigma_{10\%}$ and the density (ρ).

Since this is a statistical evaluation the distribution of the density inside the block (a moulded block) the distribution of the block weight (or weight per moulded item) shall be taken into account, too. For details see clause 3.5.1 of this document.

2.2 Grouping

2.2.1 General

Products of identical or similar property values may be grouped for PTD, FPC, and/or statistical evaluations. This grouping offers costs savings on the one hand but includes the risk of failing if only one product fails.
Concerning statistical evaluations (for thermal conductivity) it should ~~has to~~ be noted that a larger standard deviation may be obtained if products of different densities are ~~will be~~ grouped and the property is density related. That is why the manufacturer should decide which procedure will lead to the more favourable results:

big group with a large number of measurement results and higher standard deviation
or
small group with a small number of measurements and a lower standard deviation.

Footnote a of Annex B, Table B.1 in EN 13163 contains the expression *production unit* and *production line*. An EPS plant should be regarded as one production unit. A production line is a line where either blocks or shapes are moulded or a continuous moulding line. That means that products from different plants cannot be grouped.

Products from different production lines can be grouped for those properties that do not differ due to the production process (block, shape moulded, continuous).

The properties taken from the EPS standards for which grouping may be applicable are listed in *Table 3*.

Table 3: Properties which may be grouped.

Property
Thermal conductivity at 10 [°C]
Thermal conductivity at full temperature range [W/m·K]
Bending strength [kPa]
Reaction to fire [Euroclass]
Compressive stress at 10 % deformation [kPa]
Tensile strength [kPa]
Dynamic elasticity modulus to determine dynamic stiffness
Release of dangerous substances (at present no tests)

2.2.2 Thermal conductivity

Grouping different products of e.g. different densities concerning thermal conductivity to obtain one declared value is possible. To fulfil for every product the likelihood that 90 % of the measured values of thermal conductivity are equal or lower than the declared value it is not possible to calculate the 90/90 value from the entire group. The 90/90 value is rather to determine from the product of the lowest density and this value may be taken for other products of a higher density as well. Again in this case the manufacturer should choose the most favourable procedure of grouping.

2.2.3 Reaction to fire

If a manufacturer is using flame retarded raw materials from different producers he may group his products concerning a certain Euro class, if the raw materials are certified (see also note h of table A.2 in EN 14309). Products falling in Euro class F may be grouped anyway.

3 Indirect testing

3.1 General

Methods for indirect testing are given in the tables for Factory Production Control in the EPS standards. The possibility of indirect testing is always combined with the direct test but the frequency of the direct test is much lower.

In cases where a continuous surveillance by a third party is involved the direct test result may be taken from the testing body and the manufacturer has to perform the indirect test only. In those cases the manufacturer may save the costs for the testing equipment.

3.2 Thermal conductivity

The tables for Factory Production Control in the EPS standards contain four possibilities to test thermal conductivity.

First possibility
The direct test once per 24 hours is recommended for manufacturers having their own testing equipment only.

Second possibility
The second possibility requires one direct measurement of thermal conductivity once per 3 month and density or weight per moulded item once per two hours. Taking into account that most manufacturers have block weights automatically recorded it is even possible to calculate the real mean value and the real standard deviation of the block weight (instead of estimated values). To measure e.g. block weights, to use a λ/ρ correlation and to check the thermal conductivity with this actions requires in addition a known correlation between block weight and apparent density according EN 1602. Therefore ~~next to~~ the dimensions of the block the average water content must be known.
The most difficult task of this option is to calculate a specific correlation between measured thermal conductivity and density, ρ. It is recommended to have at least 20 direct test results before calculating the regression according the correlation below:

$\lambda_{mean} = b_0 + b_1 * \rho + b_2 / \rho$

To calculate the unknown parameters b_0, b_1 and b_2 use

$$D = \begin{vmatrix} \sum_{i=1}^{n}(1/\rho_i)^2 & \sum_{i=1}^{n}(1/\rho_i) & n \\ \sum_{i=1}^{n}(1/\rho_i) & n & \sum_{i=1}^{n}\rho_i \\ n & \sum_{i=1}^{n}\rho_i & \sum_{i=1}^{n}\rho_i^2 \end{vmatrix} \qquad D_1 = \begin{vmatrix} \sum_{i=1}^{n}(\lambda_i/\rho_i) & \sum_{i=1}^{n}(1/\rho_i) & n \\ \sum_{i=1}^{n}\lambda_i & n & \sum_{i=1}^{n}\rho_i \\ \sum_{i=1}^{n}(\lambda_i\cdot\rho_i) & \sum_{i=1}^{n}(\rho_i) & \sum_{i=1}^{n}\rho_i^2 \end{vmatrix}$$

$$D_2 = \begin{vmatrix} \sum_{i=1}^{n}(1/\rho_i)^2 & \sum_{i=1}^{n}(\lambda_i/\rho_i) & n \\ \sum_{i=1}^{n}(1/\rho_i) & \sum_{i=1}^{n}\lambda_i & \sum_{i=1}^{n}\rho_i \\ n & \sum_{i=1}^{n}(\lambda_i\cdot\rho_i) & \sum_{i=1}^{n}\rho_i^2 \end{vmatrix} \qquad D_3 = \begin{vmatrix} \sum_{i=1}^{n}(1/\rho_i)^2 & \sum_{i=1}^{n}(1/\rho_i) & \sum_{i=1}^{n}(\lambda_i/\rho_i) \\ \sum_{i=1}^{n}(1/\rho_i) & n & \sum_{i=1}^{n}\lambda_i \\ n & \sum_{i=1}^{n}\rho_i & \sum_{i=1}^{n}(\lambda_i\cdot\rho_i) \end{vmatrix}$$

and

$b_0 = D_1/D$
$b_1 = D_2/D$
$b_2 = D_3/D$

With these equations it is possible to determine the mean curve. Much more difficult is to determine the prediction curve of a 90 % confidence level for the approach given above.
For experts which are familiar with statistics the calculation method is briefly described as follows. Although the following equation does not look extremely difficult the calculation method is rather complicated and takes a lot of time. That is why specific software is offered by GSH, Germany (www.gueteschutz-hartschaum.de).

The equation to calculate the prediction curve is as follows:

$$\lambda_{u,o}(\rho_0) = b_0 / \rho_0 + b_1 + b_2\rho_0 \pm t_{f,1-\alpha} \cdot s \cdot \sqrt{1 + \vec{\rho}^T \cdot C \cdot \vec{\rho}}$$

The used equation $\lambda_{mean} = b_0 + b_1 * \rho + b_2 / \rho$ does not fit very well for EPS products made from infra-red absorbent raw materials, e. g. Neopor. In cases where this raw material is used the following more precise equation should be used: **Is there a newer version? To be checked with GSH**

$$\lambda_{mean} = b_0 + b_1 \cdot \rho + \frac{b_2}{b_3 + b_4 \cdot \rho}$$

To calculate the regression and particularly the upper confidence curve is much more complicated than the solution described before.

Third possibility
The third possibility was created for those manufacturers having no normative testing equipment for thermal conductivity. They may use this test apparatus once per week and check it by a direct test every three month.

Fourth possibility
The fourth possibility is similar to the first one but does not require statistical evaluations. Instead of manufacturer related curves the approach given in clause B.2.3 of EN 13163 shall be used. From the equation B.4 the thermal conductivity can be calculated from the density. In cases for non-infra-red absorbing EPS ("white") where the density shall be calculated from a certain thermal conductivity use the following equation:

$$\rho_a \approx \frac{-0{,}027174 W/mK - \lambda_{pred}}{1{,}03486 \cdot 10^{-4} Wm^2/kgK} + \sqrt{\left(\frac{0{,}027174 W/mK - \lambda_{pred}}{1{,}03486 \cdot 10^{-4} Wm^2/kgK}\right)^2 - \left(\frac{0{,}173606 Wkg/m^4K}{5{,}1743 \cdot 10^{-5} Wm^2/kgK}\right)}$$

Thickness effect
Due to the heat transfer mechanism in an EPS board a certain part is due to radiation. The heat transfer covered by radiation decreases with mass per area. That is why thin boards of a low density have a slightly different thermal conductivity to thick boards. To exclude the so called thickness effect it is recommended to calculate the statistical evaluation (90%,90% or regression) from a thickness of 50 [mm] only. For cases where conversion of thermal conductivity from one thickness to another is needed, table B.3 of EN 13163 may be used, or the equation given in paragraph of the Whitebook.

Example

The measured thermal conductivity of an EPS board of a thickness of 30 mm and a low density is 0,045 [W/mK]. The thermal conductivity of the same product at a thickness of 200 [mm] shall be determined.

$\lambda_i = \lambda'_i / L$
λ_i = 0,045 [W/mK] / 0,92 = 0,049 [W/mK]

The board of a thickness of 200 [mm] will have a thermal conductivity of 0,049 [W/mK].
The thickness effect of equal or less than 2% is negligible and needs not be taken into account.

3.3 *Bending strength*

In table B.1 of EN 13163 there is an indirect ‘manufacturer’s method’ allowed to test the bending strength. As ‘manufacturer’s method’ the following procedure may be useful particular for a continuous surveillance:

Put an entire board on two linear supports of a certain (depends on the thickness, see EN 12089) distance. Put a linear load (depends on the limit value which has to be proven) in the middle of the board. If the board breaks the test is negative.

3.4 *Reaction to fire*

No indirect test method is available.

3.5 *Compressive stress at 10 % deformation*

The compressive stress has to be measured directly once per day. In cases where no testing machine is available at the manufacturer’s lab one of the two possibilities may be used.

First possibility

The first possibility requires one direct measurement of compressive stress once per 3 month and density or weight per moulded item once per two hours. Taking into account that most manufacturers have block weights automatically recorded it is even possible to calculate the real mean value and the real standard deviation of the block weight (instead of estimated values). To measure e.g. block weights, to use a σ_{10}/ρ correlation and to check the compressive stress at 10% deformation with this actions requires in addition a known correlation between block weight and apparent density according EN 1602. Therefore next to the dimensions of the block the average water content must be known. The calculation of a specific correlation between measured compressive stress and density, ρ is much easier than calculating the lambda approach. It is recommended to have at least 20 direct test results before calculating the regression according the correlation below:

$$\sigma_{10,i} = b_0 + b_1\rho_i$$

The following example explains the calculation method for the mean and the prediction curve. The measured values are indicated in the second and third column of Table 4. Grey cells contain calculated values as indicated in the heading of the appropriate column.

Example

Table 4 Measured values of density and compressive stress and further calculated terms

i [1]	ρ_i [kg/m³]	$\sigma_{10,i}$ [kPa]	$(\rho_i - \overline{\rho})$ [kg/m³]	$(\rho_i - \overline{\rho})^2$ [kg²/m⁶]	$(\sigma_{10,i} - \overline{\sigma})$ [kPa]	$(\sigma_{10,i} - \overline{\sigma})^2$ [kPa²]	$(\rho_i - \overline{\rho})(\sigma_{10,i} - \overline{\sigma}$ [kg·kPa/m³]	$\hat{\sigma}_i = b_0 +$ [kPa]	$(\sigma_{10,i} - \hat{\sigma})^2$ [kPa]
1	17,9	110	-5,3	28,1	-37,2	1.381,4	197,0	96,6	178,8
2	18,7	99	-4,5	20,3	-48,2	2.320,0	216,8	104,3	27,6
3	20,2	125	-3,0	9,0	-22,2	491,4	66,5	118,6	41,5
4	23,1	120	-0,1	0,0	-27,2	738,0	2,7	146,2	687,1
5	29,0	217	5,8	33,6	69,8	4.876,7	405,0	202,5	211,1
6	30,3	212	7,1	50,4	64,8	4.203,4	460,3	214,9	8,2
	Σ = 139,2	Σ = 883,0	Σ = 0,0	Σ = 17.383	Σ = 0,0	Σ = 14.010,8	Σ = 1.348,3		Σ = 1.154,3

Number of measurements, *n* = 6

$$\bar{\rho} = \frac{\sum_{i=1}^{n} \rho_i}{n} = 139{,}2 kg/m^3 \big/ 6 = 23{,}2 kg/m^3$$

$$\bar{\sigma} = \frac{\sum_{i=1}^{n} \sigma_{10,i}}{n} = 833{,}0 kPa \big/ 6 = 147{,}2 kPa$$

$$b_1 = \frac{\sum_{i=1}^{n} (\rho_i - \bar{\rho})(\sigma_{10,i} = \bar{\sigma})}{\sum_{i=1}^{n} (\rho_i - \bar{\rho})^2} = \frac{1.348{,}3 kg \cdot kPa/m^3}{141{,}4 kg^2/m^6} = 9{,}5354 kPa \cdot m^3/kg$$

$$b_0 \equiv \bar{\sigma} - b_1 \cdot \bar{\rho} = 147{,}2 kPa - 9{,}5354 kPa \cdot m^3/kg \cdot 23{,}2 kg/m^3 = -74{,}054 kPa$$

With the parameters b_0 and b_1 it is possible to calculate

$$\hat{\sigma}_i = b_0 + b_1 \rho_i = -74{,}054 + 9{,}5354 \rho_i$$

and to determine the mean curve, see .....The standard deviation, s_σ, will be calculated from the deviation of the measured compressive stress, σ_i, and the approximated compressive stress, $\hat{\sigma}$:

$$s_\sigma = \sqrt{\frac{1}{n-2} \sum_{i=1}^{n} (\sigma_{10,i} - \hat{\sigma})^2} = \sqrt{\frac{1}{6-2} \cdot 1.154{,}3} = 17{,}0 kPa$$

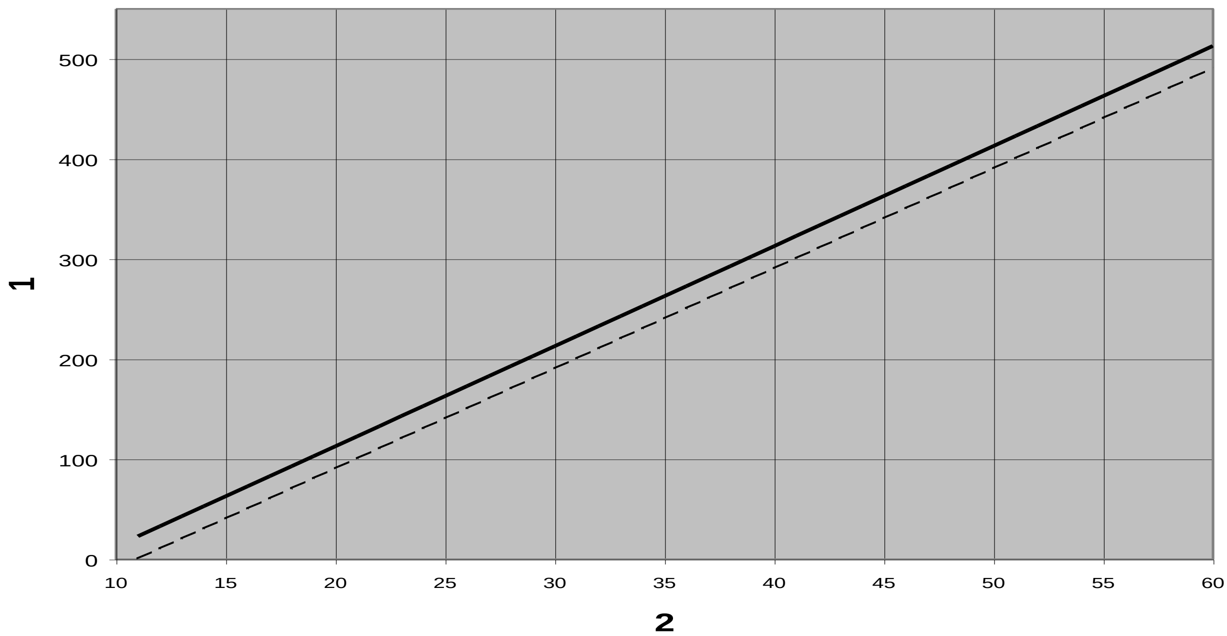
To calculated the one sided prediction interval for a new measured value with a confidence level of $1 - \alpha = 0{,}90$ the fractile of the t distribution, $t_{n-2;\,1-\alpha}$,is needed, too. This value may be taken from tables (give reference) or calculated with the EXCEL command TINV(2α;$n-2$) respectively TINV(0,20;4). For this example $t_{n-2;\,1-\alpha} = 1{,}5321$. Now it is possible to calculate the lower prediction curve, $\sigma_u(\rho_u)$, with the following equation:

$$\sigma_u(\rho_0) = b_0 + b_1 \rho_0 + t_{n-2,1-a} \cdot s_\sigma \cdot \sqrt{1 + \frac{1}{n} + \frac{(\rho_0 - \bar{\rho})^2}{\sum_{i=1}^{n} (\rho_i - \bar{\rho})^2}}$$

It is obvious that the term of the root is increasing in accordance with the difference of ρ_0 and $\bar{\rho}$ and therefore the distance between the prediction curve and the mean curve will increase at the ends.
To produce the values for the mean and the prediction curve it is recommended to use a new table. The increment of the density should be smaller and constant to obtain a smooth prediction curve. An example is given in Table 5.

Table 5: From density calculated values of compressive stress and the values for the lower prediction curve.

Counter	ρ_0 **[kg/m³]**	$\hat{\sigma}_i = b_0 + b_1\rho_0$ **[kPa]**	$\sigma_u(\rho_0)$ **[kPa]**
1.	18	97,6	67,2324
2.	19	107,1	77,5200
3.	20	116,7	87,6613
4.	21	126,2	97,6469
5.	22	135,7	107,4695
6.	23	145,3	117,1239
7.	24	154,8	126,6082
8.	25	164,3	135,9232
9.	26	173,9	145,0727
10.	27	183,4	154,0634
11.	28	192,9	162,9038
12.	29	202,5	171,6041
13.	30	212,0	180,1754
14.	31	221,5	188,6289



Key

1 Compressive stress σ_{10} [kPa]
2 Apparent density ρ_a [kg/m³]
_______ Compressive stress
------------ Predicted compressive stress

Figure 1: Determined correlation between compressive stress and density.

<u>Second possibility</u>
The direct measurement of compressive stress in this case is required once per year only. At the same time density or weight per moulded item has to be measured 1 per 2 hours. To determine the declared compressive stress the manufacturer has to use the correlation given in the annex for Factory Production Control in the EPS standards where the predicted curve has to be used. To calculate σ_{10} the equation

$\sigma_{10} = 10{,}0 \cdot \rho - 109{,}1$ [kPa] and to calculate density the equation

$\rho = 10{,}91$ kg/m³ $+ 0{,}1 \cdot \sigma_{10}$ have to be used.

3.5.1 Determination of the total variance of the density

The lower prediction curve in Table 5 provides the density which is needed for a certain minimum value of compressive stress. Since the mean density of a block and the density of boards cut from one block having a normal distribution ($\sigma_{\rho\ block}$,$s_{\rho\ board}$), too, it is needed to determine the entire standard deviation.

$$s_{\rho,total} = \sqrt{\sigma^2_{\rho,block} + s^2_{\rho,board.}}$$

In a factory where all block weights are recorded automatically the real standard deviation, for which the symbol σ is used, is known. Since the standard deviation of the density distribution inside a block is determined from a certain number of blocks this value is estimated (symbol s). The minimum density obtained from, ρ_0, has to be converted into a foamed density, ρ_{foam}, as a production parameter.

$$\rho_{foam} = \rho_0 + k * s_{\rho,\ total}$$

If all block densities are known due to automatically record process the k factor may be chosen for $n = \propto$.

4 Treatment of outliers

An outlier is a measured value of a normal distributed property which deviates a lot from the mean value. These outliers should be omitted if they fulfil the following criteria. If the number of measurements is smaller than 30 the test according Table 1 shall be used.

Table 1: Limit values, Z_n, and equations to determine outliers for n < 30.

Number of tests, n	Limit value, Z_n, for a confidence level of 95 %	Equations to determine outliers: down	Equations to determine outliers: up
3 4 5 6 7	0,941 0,765 0,642 0,560 0,507	$X = \frac{x_2 - x_1}{x_n - x_1}$	$X = \frac{x_n - x_{n-1}}{x_n - x_1}$
8 9 10	0,554 0,512 0,477	$X = \frac{x_2 - x_1}{x_{n-1} - x_1}$	$X = \frac{x_n - x_{n-1}}{x_n - x_2}$
11 12 13	0,576 0,546 0,521	$X = \frac{x_3 - x_1}{x_{n-1} - x_1}$	$X = \frac{x_n - x_{n-2}}{x_n - x_2}$
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29	0,546 0,525 0,507 0,490 0,475 0,462 0,450 0,440 0,430 0,421 0,413 0,406 0,399 0,393 0,387 0,381	$X = \frac{x_3 - x_1}{x_{n-2} - x_1}$	$X = \frac{x_n - x_{n-2}}{x_n - x_3}$

To test a value which is suspected to be an outlier the measured values have to be put in an ascending order, beginning with the lowest value x_1 and ending with the highest value x_n. If the lowest value is suspected to be an outlier use the equations in Table 1, column *down*. If the greatest value is suspected to be an outlier use the equations in column *up* of the same table. Which equation of a column has to be chosen depends on the number of measurements n. The tested value has to be accepted if $X \leq Z_n$ and has to be rejected if $X > Z_n$.

Example

The measured values of the thermal conductivity of a product are given in Table 2.

Table 2: Measured values of thermal conductivity of one product in an ascending order.

Number *n*	**Measured thermal conductivity, λ_i, in [W/mK]**
1	0,0330
2	0,0355
3	0,0357
4	0,0360
5	0,0361
6	0,0361
7	0,0363
8	0,0368
9	0,0369
10	0,0370

The lowest value, λ_1 = 0,0330 [W/mK], shall be tested as outlier.

Z_n = 0,477 (taken from Table 1)

$$X = \frac{\lambda_2 - \lambda_1}{\lambda_{n-1} - \lambda_1} = \frac{\lambda_2 - \lambda_1}{\lambda_9 - \lambda_1} = \frac{0{,}0355 - 0{,}0330}{0{,}0369 - 0{,}0330} = \frac{0{,}0025}{0{,}0039} = 0{,}641$$

Because $X > Z_n$ the value λ_1 is identified as outlier and has to be omitted.

If n is equal or greater than 30 the Z_n values according to Table 3 shall be used.

Table 3: Limit values, Z_n, and equations to determine outliers for $n \geq 30$.

Number of tests, *n*	**Limit value, Z_n, for a confidence level of 95 %**
30	2,745
35	2,811
40	2,866
45	2,914
50	2,956
55	2,992
60	3,025
65	3,055
70	3,082
75	3,107
80	3,130
85	3,151
90	3,171
95	3,189
100	3,207
105	3,224
110	3,239
115	3,254
120	3,267
125	3,281
130	3,294
135	3,306
140	3,318
145	3,328

Lower values may be accepted if $Z_n \leq \frac{\bar{x} - x_1}{s}$ and rejected if $Z_n > \frac{\bar{x} - x_1}{s}$

Example

The measured values of compressive stress of a product are given in Table *4*.

Table 4: Measured values of compressive stress of one product in an ascending order.

Number *n*	**Measured compressive stress, σ_i, in [kPa]**
1	176
2	180
3	180
4	182
5	182
6	183
7	185
8	185
9	185
10	186
11	186
12	188
13	188
14	189
15	190
16	191
17	191
18	193
19	194
20	195
21	195
22	195
23	196
24	197
25	199
26	199
27	199
28	200
29	200
30	201
31	202
32	204
33	204
34	205
35	229

The highest value, σ_{35} = 229 [kPa], shall be tested as outlier.

Z_n = 2,811 (taken from Table 3)

The mean is:

$$\overline{\sigma} = \frac{1}{n}\sum \sigma_i = 192{,}6kPa$$

The estimated standard deviation is

$$s_\sigma = \sqrt{\frac{1}{n-1}\sum(\sigma_i - \overline{\sigma})^2} = 8{,}9kPa$$

$$X = \frac{\sigma_n - \overline{\sigma}}{s_\sigma} = \frac{\sigma_{35} - \overline{\sigma}}{s_\sigma} = \frac{229kPa - 192{,}6kPa}{8{,}9kPa} = 4{,}09$$

Because X > Z_n the highest value of 2 [kPa] is an outlier and has not to be accepted.

To determine outliers of measured pairs of values (used to calculate a regression) a statistical concept according to the kind of regression has to be chosen. Since this approach is rather difficult a simplified estimation is given below.

If a regression $\hat{y} = f(x)$ is determined from measured values of x_i and y_i, the distances between y_i and $\hat{y}_i$ may be determined. These distances can be treated as shown before to check whether a certain value is an outlier or not.

The values of compressive stress at 10 % deformation and density are taken from Figure 1 and treated in Table 5. The values of compressive stress are given in an ascend order.

Example

Table 5: Measured values of compressive stress and density to determine outliers.

Counter i [1]) [1]	$\sigma_{10,I}$ [kPa]	ρ_I [kg/m³]	$\hat{\sigma}_{10,i}$ [kPa]	$\Delta\sigma_i = \lvert\hat{\sigma}_{10,i} - \sigma_{10,i}\rvert$ [kPa]
5	99	18,7	104,3	5,3
2	110	17,9	96,6	13,4
6	120	23,1	146,2	26,2
3	125	20,2	118,6	6,4
4	212	30,3	214,9	2,9
1	217	29,0	202,5	14,5

[1]) The numbering follows the values of the distances in the fifth column.

It shall be clarified now whether the distance $\Delta\sigma_6$ = 26,2 [kPa] is an outlier. Therefore the following equation has to be chosen

$$X = \frac{\Delta\sigma_6 - \Delta\sigma_5}{\Delta\sigma_6 - \Delta\sigma_1} = \frac{26{,}2 - 5{,}3}{26{,}2 + 14{,}5} = 0{,}77$$

Since the result of 0,77 is greater than 0,560 (taken from Table 1) the value might be seen as an outlier.

5 Traceability

The traceability of a product is required by the EPS standards and EN 13172 (clause 5.6) and should be described in the quality manual.
The minimum requirements for the identification according clause ZA.3 of the Annex ZA in EN 13163 are:
- the product itself,
- the plant of production,
- the year of production.

Not required by the standards, but recommended in addition is that the manufacturer installs means to trace:
- the production line,
- the batch,
- the raw material used.

These facts should be known if a product fails and the manufacturer is attempting to improve the quality.

6 Case of dispute

6.1 General

Properties which are evaluated by a statistical approach are more difficult to check than properties where a limit value is given. If a single product does not fulfil the indicated property, e.g. the thermal conductivity, it is still possible that the whole batch fulfils the 90 % fractile. To avoid a huge number of tests which are very expensive and time consuming a simplified procedure in case of complaint is described in Annex F of EN 13172.

6.2 Evidence of the test

The figures come from the ISO/DIS 2859-1.2 „Sampling procedures for inspection by attributes - Part 1: Sampling plans indexed by acceptable quality level (AQL) for lot-by-lot inspection". Obviously measuring thermal conductivity is a check of variables instead of attributes. To go for „variables" ISO 3951 may be used but it is much more complicated and does not lead to an easy approach. If the result of a thermal conductivity measurement will be transformed from the figure to a „YES" or „NO" answer (YES means the requirement is fulfilled, NO means the requirement is not fulfilled), again it is an attribute test. So in this case the ISO 2859-1 is applicable (see clause 3.1.3).

How to reach the link between 90 % fractile and 90 % confidence level to ISO 2859? The acceptable quality level (AQL) is similar to the fractile value of the production and 90 % fractile (of lambda values equal or smaller than the declared value) means an AQL level of 10 (= 10 % nonconforming results). The confidence level refers to the average and to the standard deviation of a number of measurements and cannot be taken into account in such a simplified procedure.
In addition it would be complicated and confusing to take into account the lot size and therefore the *sample size code letter* (see clause 13.4).

The decision about the acceptance will be made in two steps and therefore the tables 3 of ISO/DIS 2859-1.2 are applicable. In this case table 3C (reduced inspection) has been chosen because the other tables require too many measurements. The first indication in the column of an AQL level 10 in table 3C means:

1. Step: 2 results derived from 2 measurements have to fulfil the required value. If both measurements do not fulfil the requirements the lot has to be rejected. If only one measurement does not fulfil the declared value, a second procedure starts.

2. Step: 2 additional measurements are required. In total no more than one measurement shall exceed the required value otherwise the product fails.

The procedure in EN 13172 deviates from the approach in ISO 2859, but with the cumulated result after the second step it comes to the same decision.

An overview of the procedure is given in figure A.2.

This procedure is under discussion and may be changed soon.

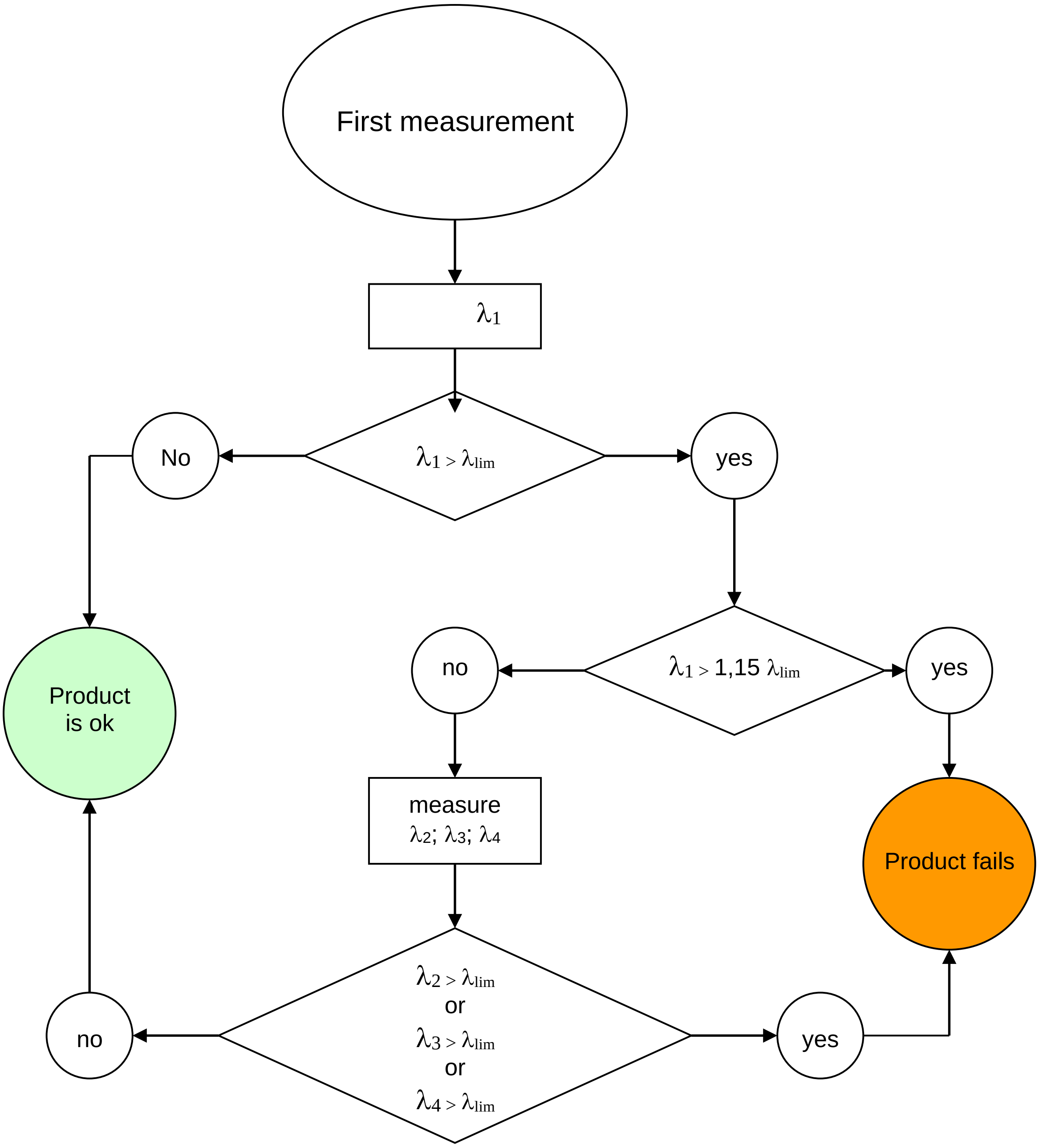


Figure A. 2: Flow chart for the procedure in case of dispute.