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Technical Specification No.5

Determination of the R_{CS} – d_S

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1 Preamble

The service compression strength (R_{CS}) and the normal service deformation (d_S) are defined in standard NF P 75-401-1 (DTU guideline 45.1) - Thermal insulation of refrigerated buildings and rooms with regulated climate.

The modulus of service elasticity E_S is defined in standard NF P 11-213-1 (DTU guideline 13.3) - Paving: Design, calculation and production.

These characteristics are required in the case of installation of the insulation under paving according to DTU guideline 13.3, under waterproofing according to the DTU guidelines for series 43 or in refrigerated buildings according to DTU guideline 45.1.

2 Method of determination

2.1 Principle

The service resistance R_{CS} is determined based on use of the stress/deformation curve obtained during compression testing at a speed of imposed strain performed in accordance with standard NF EN 826.

Throughout this Technical Specification, the symbol σ is used for stress (kPa) and the symbol ε for deformation (in %). The stress/deformation curve is therefore considered to be: $\sigma = f(\varepsilon)$.

The number and dimensions of the test specimens are defined in the corresponding product standard for the compression test at 10% deformation.

The critical resistance R_C, service resistance R_{CS} and normal service deformation d_S are defined based on the stress/deformation curve according to the procedure defined below depending on the type of curve obtained.

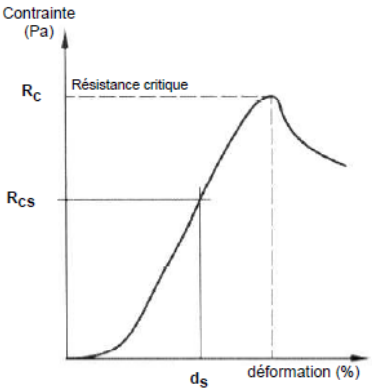
2.2 Use of the curve

2.2.1 Tangent with the steepest slope and origin of the deformations

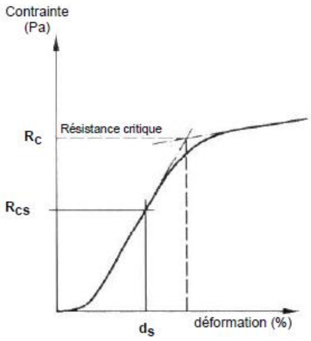
Based on the curve $\sigma = f(\varepsilon)$, we can define the tangent at the first point of inflexion of the curve, i.e. the tangent to the curve having the steepest slope.

The origin of the deformations is taken at the intersection between this tangent and the abscissa axis, marked d_0. Then, by d is meant the deformation brought back to the shifted origin d_0: $d = \varepsilon - d_0$.

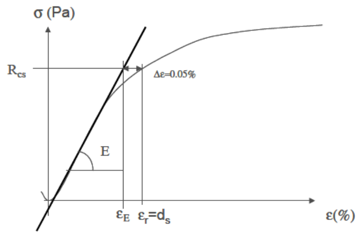
2.2.2 Types of curves



Type 1 curve



Type 2 curve



Type 3 curve

Type 1:	Type 1 curves are characterised by a peak corresponding to the critical resistance (R_C) or the maximum stress (σ_m) before the 10% deformation.
Type 2:	Type 2 curves have two linear zones, the first corresponding to the "elastic" part and the second to the "plastic" part, the R_C corresponds to the intersection of the 2 tangents (at the origin and at 10%)
Type 3:	Type 3 curves only have one linear zone corresponding to the elastic part. The second part of the curve does not include a maximum before the 10% deformation and is not linear.

2.2.3 Determination of the R_{CS} – d_S for type 1 and 2 curves

2.2.3.1 Thermal insulation products other than those based on cellular glass

Where *d* is the deformation for a stress of $0.6\ R_C$.

Thus:

1. If $d < 2\ \%$ then $R_{CS} = 0{,}6 \cdot R_C$ and $d_S = d$
2. If $d \geq 2\ \%$ then $R_{CS} = f(d = 2\ \%)$ and $d_S = 2\ \%$

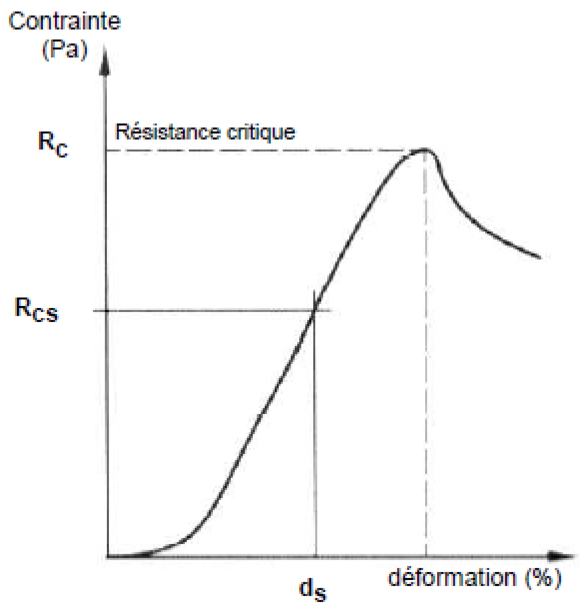


Figure 1: Type 1 curve

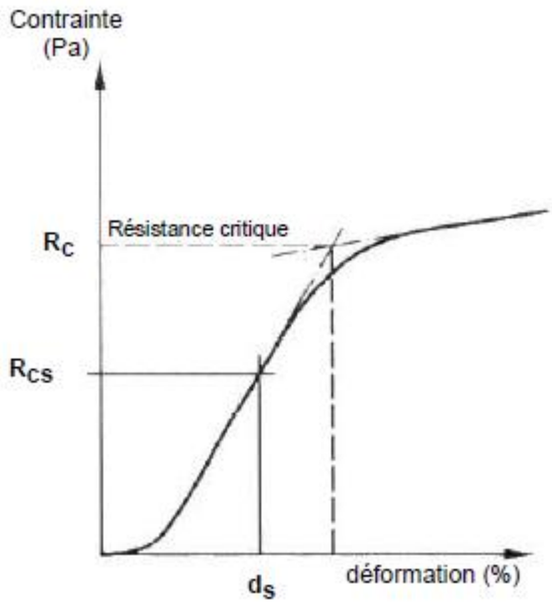


Figure 2: Type 2 curve

2.2.3.2 Thermal insulation products based on cellular glass coated in bitumen

The same method of determination is used as in paragraph 2.2.3.1, replacing the thresholds with the following values:

1. $R_{CS} = 0{,}4 \cdot R_C$ and $d_S \leq 0{,}5\ mm$ if hot bitumen is applied in the workshop,
2. $R_{CS} = 0{,}34 \cdot R_C$ and $d_S \leq 0{,}5\ mm$ if hot bitumen is applied on the worksite.

2.2.4 Determination of the R_{CS} – d_S for type 3 curves

For type 3 curves, the R_{CS} is defined from the stress/deformation curve by measuring its deviation from the modulus line limited to 0.05%:

$$\Delta\varepsilon = \varepsilon_r - \varepsilon_E = 0.05\%$$

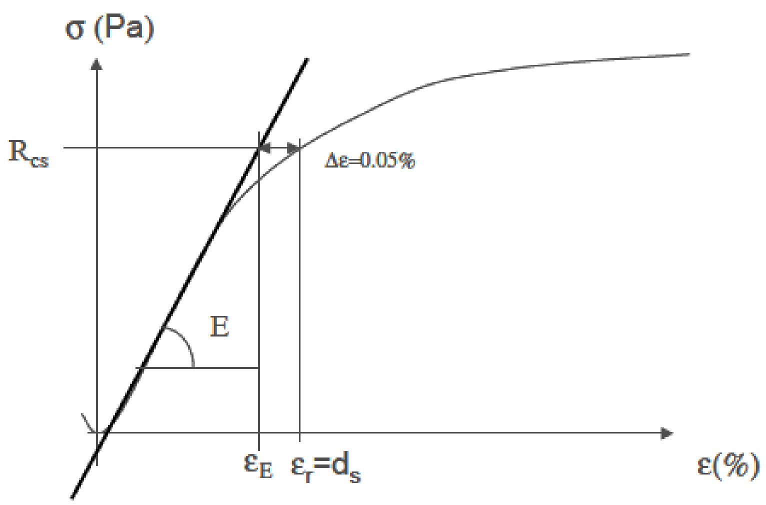


Figure 3: Type 3 curve

3 Expression of the declared values

The values for R_{CS}, $d_{S,min}$ and $d_{S,max}$ are expressed using a fractile 90 associated with a level of confidence of 90%:

$$R_{CS,(90,90)} = R_{CS,moy} - k \cdot \sigma_{R_{CS}}$$

$$d_{S,min,(90,90)} = d_{S,moy} - k \cdot \sigma_{d_S}$$

$$d_{S,max,(90,90)} = min\left[\left(d_{S,moy} + k \cdot \sigma_{d_S}\right) ; 2\ \%\right]$$

The declared value of R_{CS} is expressed after rounding to the nearest 5 kPa.

The declared value of d_S is expressed after rounding to the nearest 0.1% for $d_{S,min}$ and $d_{S,max}$.

For multi-sites, the R_{CS} and d_s are calculated based on the values from all of the plants. The rule for rounding to the nearest 0.1% is then applied.

In the context of the application of standard NF EN ISO 10456, some values for k for a unilateral tolerance interval of 90% with a level of confidence of 90% are given below:

Number of samples measured	k
10	2.07
12	1.97
14	1.90
16	1.84
18	1.80
20	1.77
25	1.70
30	1.66
35	1.62
40	1.60
45	1.58
50	1.56
100	1.47
300	1.39

4 Certification process

4.1 Initial examination

The manufacturer determines the values declared for R_{CS}, $d_{S,min}$ and $d_{S,max}$ for the product. These are calculated using the results of tests resulting from at least 4 different manufacturing dates.

The declaration of ds min and ds max is determined by the calculation of a fractile 90-90 and rounded to the nearest 0.1%. For multi-sites, the RCS and ds are calculated based on the values from all of the plants. The rule for rounding to the nearest 0.1% is then applied.

The lead member checks the calculation of the fractile established and performs tests on 2 samples. Sampling depends on the range of thicknesses, the range of densities and the different levels of declared compression stress at 10%.

4.2 Compliance criteria

The 2 results for R_{CS} must be greater than or equal to the declared value.

The 2 results for d_S must be less than the declared value for $d_{S,max}$.

4.3 Factory production control

Self-checks shall be performed at the rate of *at least* one test per day of manufacturing and the distribution of the checks must be representative of all the production. A test result is defined in compliance with the applicable provisions of the product standard for the compression test at 10%. When the compression stress at 10% (CS(10)) for the product is declared and checked, the frequency of control of the service compression strength is identical to that of the compression stress at 10%.

The fractile established using the self-check test results is checked at least every 3 months using the results of tests obtained over a sliding window which shall not exceed 1 year.

The fractile $d_{S,max}$ calculated for each plant must be less than the declared $d_{S,max}$.

An indirect test may be performed on condition that a correlation is established according to the same procedure as that defined in the product standard for compression performance (CS/10).

5 Modulus of service elasticity

The modulus of service elasticity may by certified based on the certified values for R_{CS}, $d_{S,min}$ and $d_{S,max}$.

The modulus E_S is determined as follows:

$$E_S = 0,6 \cdot \frac{R_{CS}}{d_S}$$

With: $d_S = \frac{d_{S,min} + d_{S,max}}{2}$