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 DTU 45.1 P1-1 and NF DTU 45.1 P1-2 (april 2023) - Thermal insulation of refrigerated buildings and rooms with regulated climate.

The modulus of service elasticity E_S is defined in standard NF DTU 13.3 P1-1-1 (december 2021) - Paving: Design, calculation and execution.

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 to compression R_{CS} is determined based on use of the stress/strain curve obtained through the determination of the behaviour at a speed of imposed strain performed during a test in accordance with standard NF EN 826.

In this Technical Specification, the symbol σ is used for stress (kPa) and the symbol ε for strain (deformation) (in %). The stress/strain 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 test of determination of compression behaviour.

From the stress/strain curve, the critical resistance R_C, the service resistance R_{CS}, and the conventional service strain d_S are determined according to the following method and depending of the type of curve obtained.

2.2 Use of the curve

2.2.1 Tangent with the steepest slope and origin of the strain axis

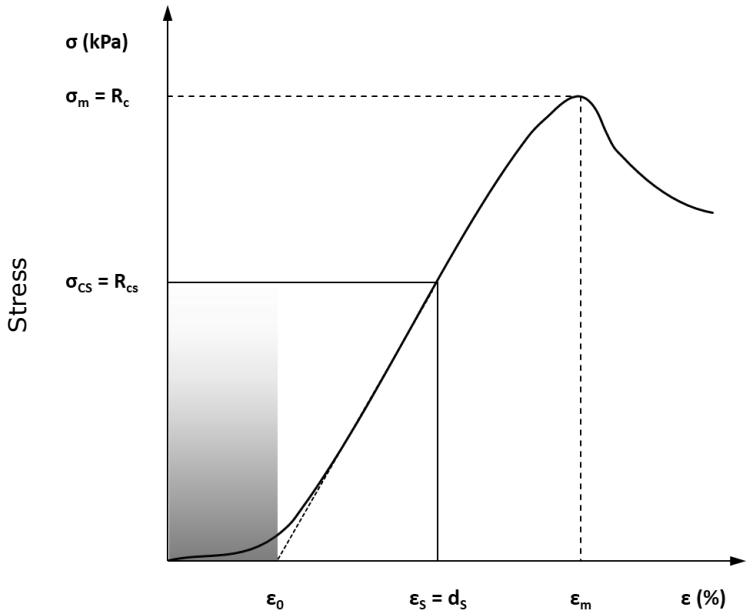
From the $\sigma=f(\varepsilon)$ curve, the tangent to the first point of inflexion of the curve, that is the tangent which has the steepest slope to the curve, is determined.

The origin of the strain axis is taken at the intersection of the abovementioned tangent and the abscissa axis, indicated as ε_0. The ε value is the strain relative to the shifted origin ε_0. Hence the relative strain at point ε_0 is 0%.

2.2.2 Curve Types

2.2.2.1 Type 1 curve

Type 1 curves are characterised by a peak (inflexion point) or a break point within less than a 10% relative strain, corresponding to the critical resistance (R_C) defined as the maximum compression stress σ_m.



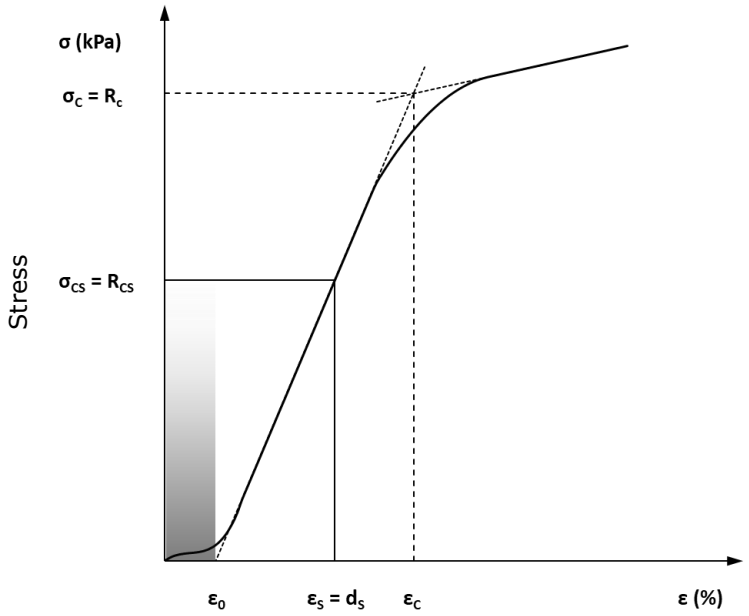
Strain, relative to the shifted origin ε_0 = 0%

Symbols :

ε_0	Point of 0% relative strain, determined using the straight line of highest slope that is tangent to σ(ε)
ε_m	Relative strain at maximum resistance σ_m
ε_S	Conventional service strain, defined as equal to d_S
σ_m	Maximum compression stress, defined as equal to the critical resistance R_C.
σ_{CS}	Conventional service stress, defined as equal to the service resistance to stress R_{CS}.

2.2.2.2 Type 2 curves

Type 2 curves have two linear zones, the first corresponding to the "elastic" part and the second to the "plastic" part, the R_C value corresponds to the intersection of the 2 tangents (at the origin and at 10%)



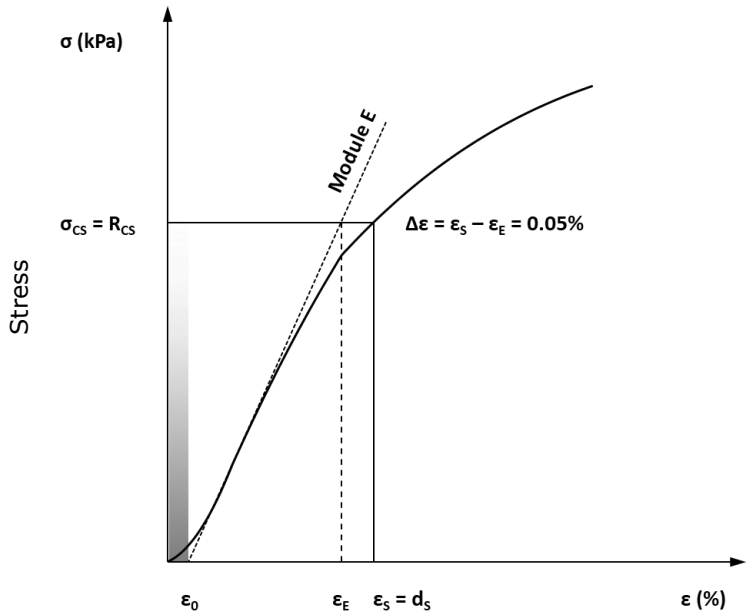
Strain, relative to the shifted origin ε_0 = 0%

Symbols :

ε_0	Point of 0% relative strain, determined using the straight line of highest slope that is tangent to σ(ε)
ε_m	Relative strain at maximum resistance σ_m
ε_S	Conventional service strain, defined as equal to d_S
σ_m	Maximum compression stress, defined as equal to the critical resistance R_C.
σ_{CS}	Conventional service stress, defined as equal to the service resistance to stress R_{CS}.

2.2.2.3 Type 3 curves

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.



Strain, relative to the shifted origin ε_0 = 0%

Symbols :

ε_0	Point of 0% relative strain, determined using the straight line of highest slope that is tangent to σ(ε), taken between an ε strain comprised from 0.30% to 0.75%.
ε_E	Relative strain for a linear σ stress.
ε_S	Conventional service strain, defined as equal to d_S.
σ_{CS}	Conventional service stress, defined as equal to the service resistance to stress R_{CS}
Δε	Difference between the relative strain of the σ(ε) curve, and the tangent defining Young's Modulus E defined in accordance to the EN 826.

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

The relative ε deformation, for a stress of 0,6 R_C is considered. R_{CS} and d_S are defined as below :

Case 1 : If ε < 2% then R_{CS} = 0,6 x R_C and $d_S = \varepsilon = \varepsilon_S$

Case 2 : If ε ≥ 2% then $R_{CS} = \sigma(\varepsilon = 2\%)$ eand d_S = 2%

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:

R_{CS} = 0,6 x σ_m and the shift $X_S \leq 0,5$ mm of the cellular glass-bitumen complex.

with $\varepsilon_S = \frac{X_S}{e_i} 100$

where e_i is the initial thickness of the sample.

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

For type 3 curves, the tangent to the first point of inflexion is determined, that is, the tangent to the curve for a strain ε comprised between 0.30% and 0.75%. The service resistance to stress R_{CS} is defined as the y-value of the curve when its difference Δε with the tangent is 0.05% where $\Delta\varepsilon = \varepsilon_S - \varepsilon_E$.

Case 1 :	If ε < 2%	then R_{CS} = σ(ε where Δε = 0,05%)	and $d_S = \varepsilon = \varepsilon_S$
Case 2 :	If ε ≥ 2%	then R_{CS} = σ(ε = 2%)	and d_S = 2%

3 Expression of the certified 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%: (Note : « moy » stands for « ave », or average)

$$R_{CS(90/90)} = R_{CS,moy} - k \times s_{R_{CS}}$$

$$d_{S,min(90/90)} = d_{S,moy} - k \times s_{d_S}$$

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

where s_i is the standard deviation for an i sample.

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

The d_S values, for $d_{S,min}$ and $d_{S,max}$, are expressed after rounding to the nearest 0.1% . They are certified to the nearest 0.1%.

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	Number of samples measured	k
4	3,19	20	1,77
5	2,74	25	1,70
6	2,49	30	1,66
7	2,33	35	1,62
8	2,22	40	1,60
9	2,13	45	1,58
10	2,07	50	1,56
12	1,97	100	1,47
14	1,90	200	1,40
16	1,84	500	1,36
18	1,80	1000	1,34

4 Certification process

4.1 Initial examination

4.1.1 Determination of the R_{CS} – d_S by the manufacturer

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 certified values of $R_{CS,}$ $d_{S,min}$ et $d_{S,max}$ are determined using a 90/90 fractile-based calculation.

Whenever several production units or lines are assessed simultaneously, the $R_{CS,}$ $d_{S,min}$ and $d_{S,max}$ values are calculated from the values of the units, or lines wholetogether, using at least 2 measurements per unit, or per line. The rounding rules defined in §3 are applicable.

Whenever the manufacturer wishes to extend the certification of R_{CS}-d_S to new production units or lines, the $R_{CS,}$ $d_{S,min}$ and $d_{S,max}$ values are calculated using the values obtained from all the units or lines.

Whenever the manufacturer wishes to extend the certification of R_{CS}-d_S to new thicknesses (minimum and/or maximum), the manufacturer includes the measurements obtained on these thicknesses in the 90/90 fractile-based calculation.

4.1.2 Verifications performed by the pilot

The pilot verifies the fractile-based calculation made by the manufacturer, and performs test on 2 samples taken for each production unit or line included in the request. The sampling depends on the thicknesses, density, and the different stress and strain levels certified. Whenever several ranges of R_{CS}-d_S are certified, each range is verified separately. The minimum and maximum thicknesses are always verified.

Whenever the manufacturer wishes to exrend the certification to new maximum and/or minimum thicknesses, the verification performed by the pilot is done on each corresponding minimum and/or maximum thickness.

Whenver any revision is performed, the test results performed by the pilot are valid up to 5 years after the date ot the test, providing no modification on the corresponding product since then.

4.1.3 Compliance criteria

Criteria on the fractile-based calculation performed by the manufacturer :

- The certified R_{CS} must be less or equal to $R_{CS(90/90)}$
- The certified $d_{S,min}$ must be above or equal to $d_{S,min(90/90)}$
- The certified $d_{S,max}$ must be above or equal to $d_{S,max(90/90)}$

Special case of an extension of R_{CS}-d_S certification to new production unit(s) or line(s) : If less than 10 test results from 10 different batches are included in the fractile-based calculation, then each of these test results must also be compliant with the certified values.

Criteria on the test results obtained in the pilot laboratory :

Critère sur les résultats obtenus au laboratoire pilote :

- Each individual R_{CS} test result must be above or equal to the certified value.
- Each individual d_S test result must be less than or equal to the certified $d_{S,max}$ value.

The rounding rules defined in §3 are applicable.

4.2 Factory production control

4.2.1 Frequency of 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.

4.2.2 Verification of the certified values

The fractiles of $R_{CS,}$ $d_{S,min}$ and $d_{S,max}$, established using the self-check test results is checked at least every 3 months using the results of tests obtained within the previous 12 months. Whenever less than 10 test results are available, this duration can be extended to a maximum of 3 years until 10 results are available. The product and the production conditions should not have been modified significantly over the whole duration.

Whenever several production units or lines are certified, the fractiles are calculated using the results of the production units or lines wholetogether. Alternatively, the manufacturer may calculate each fractile of each individual unit or line separately. In any case, the manufacturer's documentation, as defined in §3.2.5 of the General Guidelines, must state whichever method is used. If a modification is requested, it can only be performed if the fractiles are compliant using the current method. Any modification of the method should be declared to the ACERMI pilot.

The rounding rules defined in §3 are applicable.

4.2.3 Compliance criteria

The calculated $R_{CS\ (90,90)}$ fractile value must be above or equal to the certified value.

The calculated $d_{S,max(90/90)}$ fractile value must be less than or equal to the certified $d_{S,max}$ value.

In the general case where the fractiles are calculated from test results of the production units or lines wholetogether :

- For each production unit or line for which less than 10 test results obtained from 10 different batches are included in the 90/90 fractile-based calculation, then each individual result must be compliant regarding the certified value.

In case of non-conformity, fractiles are calculated separately for each individual production line or unit, in order to identify whichever unit or line do not pass, and to perform dedicated corrective actions. Once the non-conformity is treated, the fractiles may be calculated from all units or lines wholetogether. In any case, the modification of the calculation method can not be considered as a corrective action for the purpose of responding to a non-conformity of the statistical calculation.

4.2.4 Indirect test

Performing an indirect test is possible, providing a correlation is demonstrated according to the same principles as the ones defined in the product standard for a stress or compressive resistance (CS(10\Y)).

5 Service modulus of elasticity

The service modulus of elasticity may be certified from the R_{CS}, $d_{S,min}$ and $d_{S,max}$ values.

The E_S Modulus is determined as follows :

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

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

The result is expressed in MPa rounded to the nearest 0,1 MPa, for instance E_S = 3,65 MPa is rounded as E_S = 3,7 MPa.