Subject	**Conductivity of normal weight concrete at elevated temperatures**
Clause N°/ Subclause N° / Annex	EN1992-1-2 Section 3.3.3 EN1994-1-2 Clauses 3.3.2 (9) and (10)

Reason for change

In actual version of EC, EN1992 and EN1994 proposed at the beginning two different curves for thermal conductivity at elevated temperatures and finally an interval of values is adopted but giving the possibility to take any specific curve within the interval in the scope of national annex (NDP). This situation has led to many curves across Europe.

Original content

Section 3.3.3 in EN 1992-1-2 (2004)

(1) The thermal conductivity λ_c of concrete may be determined between lower and upper limit values, given in (2) below.

Note 1: The value of thermal conductivity may be set by the National annex within the range defined by lower and upper limit.

Note 2: Annex A is compatible with the lower limit. The remaining clauses of this part 1-2 are independent of the choice of thermal conductivity. For high strength concrete, see 6.3.

(2) The upper limit of thermal conductivity λ c of normal weight concrete may be determined from:

$\lambda_c = 2 - 0{,}2451\ (\theta / 100) + 0{,}0107\ (\theta / 100)^2$ W/m K for 20°C ≤ θ ≤ 1200°C

where θ is the concrete temperature.

The lower limit of thermal conductivity λ_c of normal weight concrete may be determined from:

$\lambda_c = 1{,}36 - 0{,}136\ (\theta / 100) + 0{,}0057\ (\theta / 100)^2$ W/m K for 20°C ≤ θ ≤ 1200°C

where θ is the concrete temperature.

(3) The variation of the upper limit and lower limit of thermal conductivity with temperature is illustrated in Figure 3.7.

Section 3.3.2 in EN 1994-1-2 (2005)

(9) The thermal conductivity λ_c of normal weight concrete may be determined between the lower and upper limits given in (10).

NOTE 1: The value of thermal conductivity may be set by the National Annex within the range defined by the lower and upper limits.

NOTE 2: The upper limit has been derived from tests of steel-concrete composite structural elements. The use of the upper limit is recommended.

(10) The upper limit of thermal conductivity λ_c of normal weight concrete may be determined from:

$\lambda_c = 2 - 0{,}2451\ (\theta / 100) + 0{,}0107\ (\theta / 100)^2$ W/m K for 20°C ≤ θ ≤ 1200°C (3.6a)

where θ is the concrete temperature.

The lower limit of thermal conductivity λ_c of normal weight concrete may be determined from:

$\lambda_c = 1{,}36 - 0{,}136\ (\theta / 100) + 0{,}0057\ (\theta / 100)^2$ W/m K for 20°C ≤ θ ≤ 1200°C (3.6b)

where θ is the concrete temperature.

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Change

The thermal conductivity λ_c of concrete may be determined from :

For $\theta \leq 140°C$: $\lambda_c = 2 - 0{,}2451\ (\theta / 100) + 0{,}0107\ (\theta / 100)^2$ W/m K

For $140 < \theta < 160°C$: $\lambda_c = -\ 0{,}02604\ \theta + 5{,}324$ W/m K

For $\theta \leq 140°C$ $\lambda_c = 1{,}36 - 0{,}136\ (\theta / 100) + 0{,}0057\ (\theta / 100)^2$ W/m K

where θ is the concrete temperature.

Background information

1) Annex A presents the choice regarding thermal conductivity which have been made in different Member States.

2) Annex B presents the analysis of EN 1992-1-2 tabulated data taking into account upper, lower and the new thermal conductivity curve. The upper thermal conductivity curve does not suit with the tabulated data given for the isolation analysis. This is inconsistent with the note given in section 5.1 (1) in EN 1992-1-2 which states:
"*The tables have been developed on an empirical basis confirmed by experience and theoretical evaluation of tests. The data is derived from approximate conservative assumptions for the more common structural elements and is valid for the whole range of thermal conductivity in 3.3.* "

3) A detailed analysis of existing fire tests has been performed and comparative numerical investigations have been carried on.

   The fire tests which have been analysed are the following:

Reference number	**Type of element**	**aggregates types**	**Mineralogy**	**Laboratory**	**Date of the test**	**Concrete Strength (@ fire test day)**
Test 1	slab - 20 cm	siliceous		CERIB	14 June 2016	36 MPa (cylinders)
Test 1	slab - 20 cm	calcareous		CERIB	14 June 2016	43 MPa (cylinders)
Test 2	slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	41 MPa (cylinders)
Test 2	slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	47 MPa (cylinders)
Test 2	slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	44 MPa (cylinders)
Test 2	slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	44 MPa (cylinders)
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	48 MPa (cylinders)
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	48 MPa (cylinders)
Test 3	slab - 15 cm	siliceous	flint	CERIB	18 April 2016	28 MPa (cylinders)
Test 3	slab - 10 cm	siliceous	flint	CERIB	18 April 2016	28 MPa (cylinders)
Test 3	slab - 15 cm	siliceous	granite	CERIB	18 April 2016	49 MPa (cylinders)
Test 3	slab - 10 cm	siliceous		CERIB	18 April 2016	49 MPa (cylinders)
Test 3	slab - 10 cm	calcareous		CERIB	18 April 2016	54 MPa (cylinders)
Test 3	slab - 15 cm	calcareous		CERIB	18 April 2016	54 MPa (cylinders)
Test 4	wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	57 MPa (cubes)
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	68 MPa (cubes)

draft

Reference number	Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	Concrete Strength (@ fire test day)
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	78 MPa (cubes)
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	84 MPa (cubes)
Test 6	1 column	siliceous		IBMB	27 January 2015	*72 MPa (cubes)*
Test 7	1 column	siliceous		IBMB	30 January 2015	*72 MPa (cubes)*
Test 8	1 wall	siliceous		IBMB	29 March 2017	*35 MPa (cylinders)*

Table 1 : Reference tests for the analysis

The corresponding excel files giving all the results are part of the background information and are publicly available.

4) Criteria for analysis

In 2002, HGF has formulated three possible criteria for validation:

- ✓ 1 / the calculation result shall not be on the unsafe side by more than 15% of the reference result,
- ✓ 2 / a maximum of 20 % of individual calculation results shall be on the unsafe side,
- ✓ 3 / the mean value of all percentage differences between calculation results and reference results shall be on the safe side.

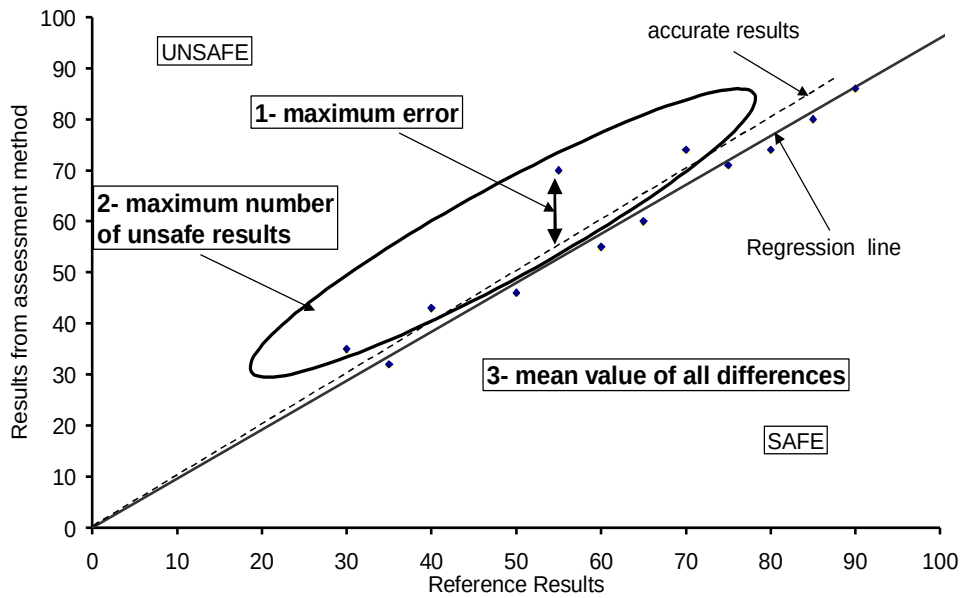

Figure 1 : possible criteria for validation given within the HGF in 2002

And it has been stated during TC CEN TC 250/special meeting 15th May 2002 that process of validation was difficult due to:

- ✓ the accuracy of test results (Nature of aggregates, moisture content (average and gradient), actual location of thermocouples, way of fixing thermocouples, accuracy to follow the (ISO) curve in tests
- ✓ the accuracy of calculation results (heat flux at exposed side (convection and radiation coefficients), moisture migration (mass transfer modeling), heat transfer through element (plain or with cavity), thermal resistance between structural steel and concrete

In 2017, in order to make up for these difficulties, the following recommendations have been adopted :

- ✓ A minimum of two thermocouples for one point should be used to get more representative values
- ✓ The homogeneity of the heat exposure should be checked and the thermocouples trees should be selected accordingly (if the plate thermometers differs locally from the conventional heating curve, then the corresponding thermocouples trees should be disregarded if the calculation considers only the conventional heating curve)
- ✓ The scatter from different concrete mixes is covered by the different experiments

Moreover, a detailed analysis of the previous criteria led to the conclusions that some new criteria should be made available in order to calibrate the thermal conductivity curve. Indeed in 2002 no criterion was dedicated to the accuracy of the model and the third criterion was improper in the sense that a bigger weight was given to the low temperatures. The following diagram illustrates this drawback. Likewise, it should be noticed that the values of these three 2002 criteria are not given in the background documentation.

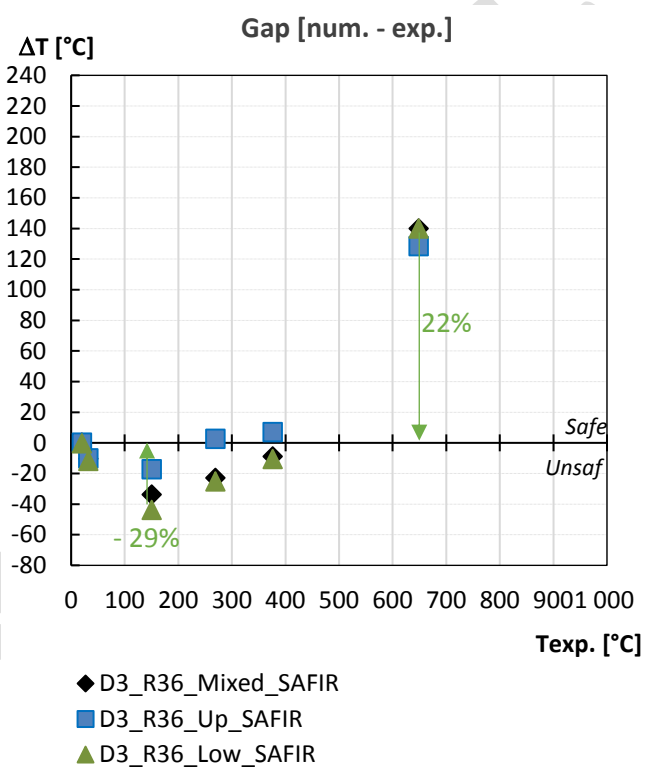

Figure 2 : illustration of the 3rd criteria given in 2002, ΔT is the difference between calculation result and experimental result, percentage differences are given for the low curve

Thus some new criteria have been established :an accuracy criterion ❶ and a safety criterion ❷

$$❶ \sqrt{\frac{\sum_{i=1}^{n}(T_{exp,i}-T_{cal,i})^2}{\sum_{i=1}^{n}(T_{exp,i})^2}}$$

It gives the accuracy of the model versus the experimental results, the best the model is, the smaller is the value, so this criterion should be minimized

$$❷ \frac{\sum_{i=1}^{n}(T_{cal,i}-T_{exp,i})}{\sum_{i=1}^{n}\sqrt{(T_{cal,i}-T_{exp,i})^2}}$$

when equal to -1, then all the results are on the unsafe side, when equal to +1, then all the results are on the safe side, when >0, the sum of the differences between calculation result and experimental result is on the safe side.

An illustration of the use of these criteria is given in Annex B. The objective is to minimize criterion ❶ and to have a positive value for the criterion ❷.

This criterion allows to take into account the whole history of the test (from the beginning to the end) and the results are not used only at specific time duration like 30, 60, 90 or 120 minutes.

There is a necessity to focus on the reinforcement area (R analysis) and the isolation analysis (I analysis). Regulations are mainly based on requirements from R30 to R120, thus for slabs, positions at 2, 3 and 4 cm have been considered for the reinforcement area (1 cm for R30 has been disregarded, taking into account the fact that the temperature is overestimated near the exposed surface).

Standard fire resistance	Minimum dimensions (mm)			
	slab thickness h_s (mm)	axis-distance *a*		
		one way	two way: $l_y/l_x \leq 1,5$	two way: $1,5 < l_y/l_x \leq 2$
1	2	3	4	5
REI 30	60	10*	10*	10*
REI 60	80	20	10*	15*
REI 90	100	30	15*	20
REI 120	120	40	20	25
REI 180	150	55	30	40
REI 240	175	65	40	50

Table 2 : section 5.7.2 Table 5.8 from EN 1992-1-2 (2004)

The following tables summarises all the obtained results (see Annex D).

R Analysis	**Accuracy criterion ❶**			**Safety criterion ❷**		
	Upper	Mixed	Lower	Upper	Mixed	Lower
All tests	0.143	0.10	0.11	0.83	0.45	0.43
Calcareous	0.151	0.11	0.11	0.97	0.85	0.79
Siliceous	0.139	0.10	0.11	0.76	0.25	0.25

I Analysis	**Accuracy criterion ❶**			**Safety criterion ❷**		
	Upper	Mixed	Lower	Upper	Mixed	Lower
All tests	0.77	0.54	0.46	0.57	0.29	0.11
Calcareous	1.05	0.74	0.49	0.67	0.62	0.37
Siliceous	0.62	0.42	0.44	0.52	0.11	-0.04

For R analysis, the mixed, lower and upper curves give similar performances in terms of accuracy.

For I analysis, the lower curve suits better when considering all the results and calcareous aggregates but this is not the case for siliceous aggregates and furthermore, in this case we obtain a negative safety criterion. Then lower curve can not be selected. The upper curve gives the worst accuracy criterion.

5) Conclusion

Taking into account all the previous statements, and in order to have in any case, whatever is the aggregate type a positive safety criterion, the mixed curve is provisionally selected for the thermal conductivity of concrete. If complementary tests are made available in the next coming months, they will be analysed in the same way.

Ease of use justification

The fact to have one unique curve in EN 1992-1-2 and EN 1994-1-2 will allow to delete one NDP. Thus it leads to a better harmonisation between countries and will facilitate the fire design from one country to another one.

draft

Annex A – Thermal conductivity choice in different member States

Country	EN 1992-1-2	EN 1994-1-2
Germany	upper limit	
France	mixed curve	
Norway	lower limit	not specified
Spain	upper limit	
Poland	upper limit	
Sweden	lower limit	
UK	lower limit	upper limit
Denmark	not specified	reference to EN 1992-1-2
Austria	lower limit	upper limit
Belgium	lower limit for calcareous aggregates average curve for siliceous aggregates	
Switzerland	upper limit	

draft

Annex B – Tabulated data analysis with different thermal conductivity curves

RESISTANCE ANALYSIS

§ 5.7.2, table 5.8 column 3 "one way"

	slab depth (mm)	axis distance	time before 500°C @axis distance upper curve	time before 500°C @axis distance new mixed curve	time before 500°C @axis distance lower curve
REI 30	60	10	30	30	30
REI 60	80	20	**54**	**58**	**58**
REI 90	100	30	**87**	95	95
REI 120	120	40	128	140	140
REI 180	150	55	202	222	222
REI 240	175	65	>240	>240	>240

ISOLATION ANALYSIS

Siliceous aggregates §5.4.1 Table 5.3

	slab depth (mm)	time before 160°C @unexposed side upper curve	time before 160°C @unexposed side new mixed curve	time before 160°C @unexposed side lower curve
REI 30	60	37	46	47
REI 60	80	**59**	75	76
REI 90	100	**87**	113	114
REI 120	120	122	159	161
REI 180	150	186	>240	>240
REI 240	175	>240	>240	>240

Calcareous aggregates §5.4.1 Table 5.3 + §5.4.1 (2)

	slab depth (mm)	time before 160°C @unexposed side upper curve	time before 160°C @unexposed side new mixed curve	time before 160°C @unexposed side lower curve
REI 30	54	32	39	39
REI 60	72	**49**	62	63
REI 90	90	**73**	93	94
REI 120	108	**100**	130	132
REI 180	135	**152**	200	202
REI 240	157,5	**206**	>240	>240

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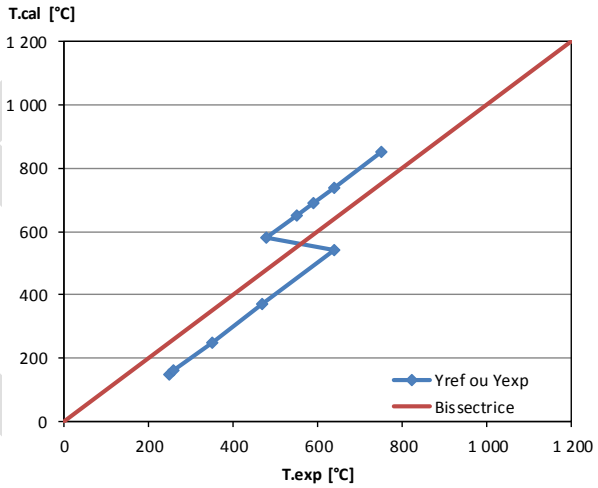
Annex C - Illustration of the new global criteria

Change value

[°C]		[°C]				
Cal.	Exp.	Cal.	Exp.			
Ycal ou Ycomp	Yref ou Yexp	Ycal ou Ycomp	Yref ou Yexp	Ycal-Yref	(Ycal-Yref)²	√[(Ycal-Yref)²]
148	248	148	248	- 100,00	10 000,00	100,00
160	260	160	260	- 100,00	10 000,00	100,00
250	350	250	350	- 100,00	10 000,00	100,00
370	470	370	470	- 100,00	10 000,00	100,00
540	640	540	640	- 100,00	10 000,00	100,00
580	479	580	479	101,00	10 201,00	101,00
650	550	650	550	100,00	10 000,00	100,00
690	590	690	590	100,00	10 000,00	100,00
740	640	740	640	100,00	10 000,00	100,00
850	750	850	750	100,00	10 000,00	100,00



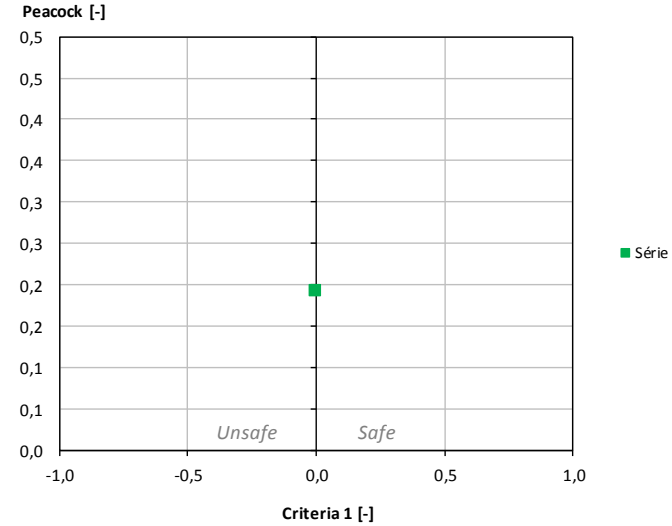
Peacock

A = Σ(Yref-Ycomp)²				100 201,00	
B = Σ(Yref)²		2734245			
√[A/B] =		0,19			

Critère 1

A = Σ(Ycal-Yref)	1,00		1,00		
B = Σ√[(Ycal-Yref)²]	1 001,00				1 001,00
A/B =	0,0009990	0,0009990			

criteria 1	0,19143
criteria 2	0,00100

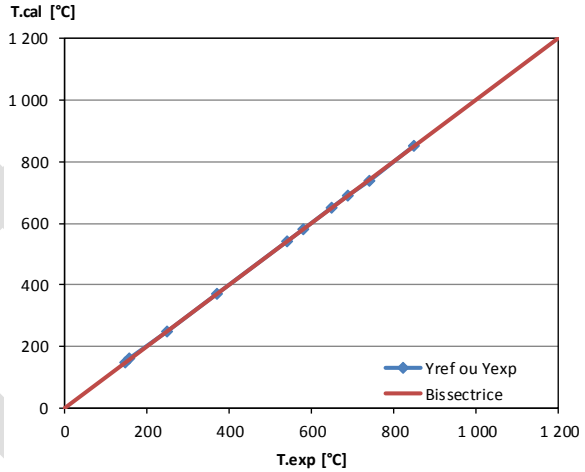


Peacock evaluation with °C unit

draft

Change value

[°C]		[°C]				
Cal.	Exp.	Cal.	Exp.			
Ycal ou Ycomp	Yref ou Yexp	Ycal ou Ycomp	Yref ou Yexp	Ycal-Yref	(Ycal-Yref)²	√[(Ycal-Yref)²]
148	147	148	147	1,00	1,00	1,00
160	159	160	159	1,00	1,00	1,00
250	249	250	249	1,00	1,00	1,00
370	369	370	369	1,00	1,00	1,00
540	539	540	539	1,00	1,00	1,00
580	579	580	579	1,00	1,00	1,00
650	649	650	649	1,00	1,00	1,00
690	689	690	689	1,00	1,00	1,00
740	739	740	739	1,00	1,00	1,00
850	849	850	849	1,00	1,00	1,00



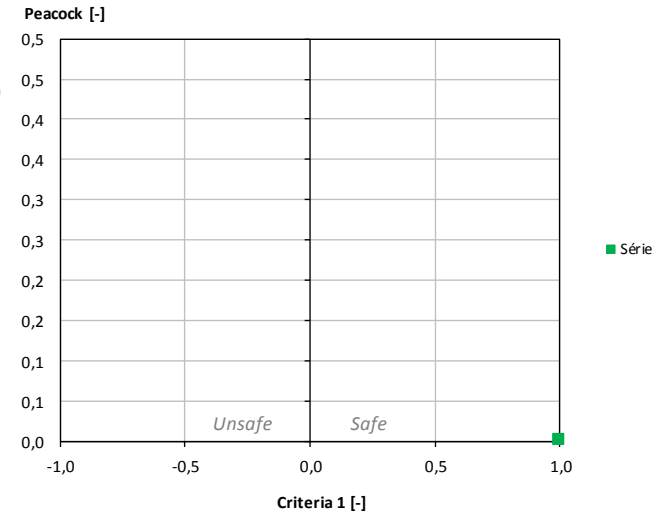
Peacock

A = Σ(Yref-Ycomp)²				10,00	
B = Σ(Yref)²		3033658			
√[A/B] =		0,00			

Critère 1

A = Σ(Ycal-Yref)	10,00		10,00		
B = Σ√[(Ycal-Yref)²]	10,00				10,00
A/B =	1,0000000	1,0000000			

criteria 1	0,00182
criteria 2	1,00000

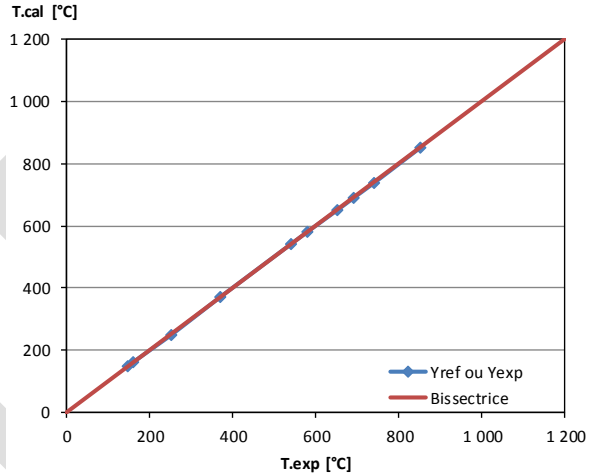


Peacock evaluation with °C unit

draft

Change value

[°C]		[°C]				
Cal.	Exp.	Cal.	Exp.			
Ycal ou Ycomp	Yref ou Yexp	Ycal ou Ycomp	Yref ou Yexp	Ycal-Yref	(Ycal-Yref)²	√[(Ycal-Yref)²]
148	149	148	149	- 1,00	1,00	1,00
160	161	160	161	- 1,00	1,00	1,00
250	251	250	251	- 1,00	1,00	1,00
370	371	370	371	- 1,00	1,00	1,00
540	541	540	541	- 1,00	1,00	1,00
580	581	580	581	- 1,00	1,00	1,00
650	651	650	651	- 1,00	1,00	1,00
690	691	690	691	- 1,00	1,00	1,00
740	741	740	741	- 1,00	1,00	1,00
850	851	850	851	- 1,00	1,00	1,00



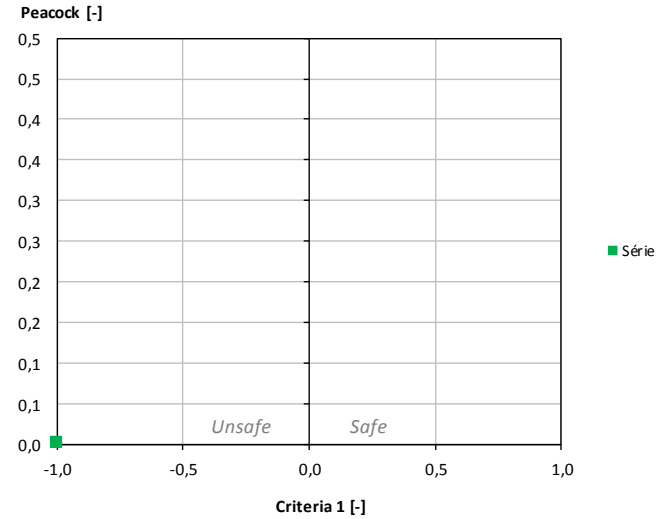
Peacock

A = Σ(Yref-Ycomp)²				10,00	
B = Σ(Yref)²		3053570			
√[A/B] =		0,00			

Critère 1

A = Σ(Ycal-Yref)	- 10,00		- 10,00		
B = Σ√[(Ycal-Yref)²]	10,00				10,00
A/B =	- 1,0000000	- 1,0000000			

criteria 1	0,00181
criteria 2	-1,00000



Peacock evaluation with °C unit

draft

Annex D – Criteria analysis

R Analysis

Reference number	Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper cur	General criteria mix curve	General criteria low curve
Test 1	**slab - 20 cm**	**siliceous**		**CERIB**	**14 June 2016**	0,04	0,05	0,07	0,26	-0,73	-0,81	0,000416	-0,001825	-0,003969
Test 1	slab - 20 cm	calcareous		CERIB	14 June 2016	0,11	0,06	0,06	0,91	0,62	0,14	0,011011	0,002232	0,000504
Test 2	slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	0,07	0,03	0,04	1	0,58	0,75	0,0049	0,000522	0,0012
Test 2	slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	0,15	0,1	0,09	1	0,99	0,99	0,0225	0,0099	0,008019
Test 2	slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,2	0,15	0,14	0,99	0,97	0,95	0,0396	0,021825	0,01862
Test 2	slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,14	0,1	0,11	0,99	0,95	0,95	0,019404	0,0095	0,011495
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,18	0,14	0,14	1	0,99	0,99	0,0324	0,019404	0,019404
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,19	0,15	0,15	1	0,99	0,97	0,0361	0,022275	0,021825
Test 3	slab - 15 cm	siliceous	flint	CERIB	18 April 2016	0,09	0,05	0,06	0,99	0,79	0,85	0,008019	0,001975	0,00306
Test 3	slab - 10 cm	siliceous	flint	CERIB	18 April 2016	0,13	0,08	0,07	0,99	0,96	0,91	0,016731	0,006144	0,004459
Test 3	slab - 15 cm	siliceous	granite	CERIB	18 April 2016	0,02	0,02	0,03	0,53	-0,53	-0,24	0,000212	-0,000212	-0,000216
Test 3	slab - 10 cm	siliceous		CERIB	18 April 2016	0,1	0,05	0,05	0,99	0,86	0,82	0,0099	0,00215	0,00205
Test 3	slab - 10 cm	calcareous		CERIB	18 April 2016	0,18	0,12	0,12	0,98	0,92	0,91	0,031752	0,013248	0,013104
Test 3	slab - 15 cm	calcareous		CERIB	18 April 2016	0,06	0,04	0,04	0,95	0,51	0,6	0,00342	0,000816	0,00096
Test 4	wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	0,04	0,04	0,04	0,71	0,1	-0,07	0,001136	0,00016	-0,000112
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,2	0,18	0,2	0,5	-0,01	-0,03	0,02	-0,000324	-0,0012
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,29	0,23	0,25	0,76	0,04	-0,01	0,063916	0,002116	-0,000625
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,27	0,23	0,24	0,72	0,05	0,02	0,052488	0,002645	0,001152
Test 6	1 column	siliceous		IBMB	27 January 2015	0,37	0,24	0,266	1	1	0,99	0,1369	0,0576	0,07004844
Test 7	1 column	siliceous		IBMB	30 January 2015	0,16	0,06	0,08	0,86	0,35	0,39	0,022016	0,00126	0,002496
Test 8	1 wall	siliceous		IBMB	29 March 2017	0,021	0,068	0,058	0,287	-0,997	-0,997	0,00012657	-0,00461013	-0,00335391
					AVERAGE	**0,143**	**0,10**	**0,11**	**0,83**	**0,45**	**0,43**	**0,025**	**0,008**	**0,008**

Reference number	Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper cur	General criteria mix curve	General criteria low curve
Test 1	slab - 20 cm	calcareous		CERIB	14 June 2016	0,11	0,06	0,06	0,91	0,62	0,14	0,011011	0,002232	0,000504
Test 2	slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,2	0,15	0,14	0,99	0,97	0,95	0,0396	0,021825	0,01862
Test 2	slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,14	0,1	0,11	0,99	0,95	0,95	0,019404	0,0095	0,011495
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,18	0,14	0,14	1	0,99	0,99	0,0324	0,019404	0,019404
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,19	0,15	0,15	1	0,99	0,97	0,0361	0,022275	0,021825
Test 3	slab - 10 cm	calcareous		CERIB	18 April 2016	0,18	0,12	0,12	0,98	0,92	0,91	0,031752	0,013248	0,013104
Test 3	slab - 15 cm	calcareous		CERIB	18 April 2016	0,06	0,04	0,04	0,95	0,51	0,6	0,00342	0,000816	0,00096
					AVERAGE	**0,151**	**0,11**	**0,11**	**0,97**	**0,85**	**0,79**	**0,025**	**0,013**	**0,012**

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Reference number	Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper cur	General criteria mix curve	General criteria low curve
Test 1	**slab - 20 cm**	**siliceous**		**CERIB**	**14 June 2016**	0,04	0,05	0,07	0,26	-0,73	-0,81	0,000416	-0,001825	-0,003969
Test 2	slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	0,07	0,03	0,04	1	0,58	0,75	0,0049	0,000522	0,0012
Test 2	slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	0,15	0,1	0,09	1	0,99	0,99	0,0225	0,0099	0,008019
Test 3	slab - 15 cm	siliceous	flint	CERIB	18 April 2016	0,09	0,05	0,06	0,99	0,79	0,85	0,008019	0,001975	0,00306
Test 3	slab - 10 cm	siliceous	flint	CERIB	18 April 2016	0,13	0,08	0,07	0,99	0,96	0,91	0,016731	0,006144	0,004459
Test 3	slab - 15 cm	siliceous	granite	CERIB	18 April 2016	0,02	0,02	0,03	0,53	-0,53	-0,24	0,000212	-0,000212	-0,000216
Test 3	slab - 10 cm	siliceous		CERIB	18 April 2016	0,1	0,05	0,05	0,99	0,86	0,82	0,0099	0,00215	0,00205
Test 4	wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	0,04	0,04	0,04	0,71	0,1	-0,07	0,001136	0,00016	-0,000112
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,2	0,18	0,2	0,5	-0,01	-0,03	0,02	-0,000324	-0,0012
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,29	0,23	0,25	0,76	0,04	-0,01	0,063916	0,002116	-0,000625
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,27	0,23	0,24	0,72	0,05	0,02	0,052488	0,002645	0,001152
Test 6	1 column	siliceous		IBMB	27 January 2015	0,37	0,24	0,266	1	1	0,99	0,1369	0,0576	0,07004844
Test 7	1 column	siliceous		IBMB	30 January 2015	0,16	0,06	0,08	0,86	0,35	0,39	0,022016	0,00126	0,002496
Test 8	1 wall	siliceous		IBMB	29 March 2017	0,021	0,068	0,058	0,287	-0,997	-0,997	0,00012657	-0,00461013	-0,00335391
					AVERAGE	**0,139**	**0,10**	**0,11**	**0,76**	**0,25**	**0,25**	**0,026**	**0,006**	**0,006**

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In the following table, a double check has been performed for the coloured lines.

Reference number	Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper cur	General criteria mix curve	General criteria low curve
Test 1	**slab - 20 cm**	**siliceous**		**CERIB**	**14 June 2016**	0,04	0,05	0,07	0,26	-0,73	-0,81	0,000416	-0,001825	-0,003969
Test 1	slab - 20 cm	calcareous		CERIB	14 June 2016	0,11	0,06	0,06	0,91	0,62	0,14	0,011011	0,002232	0,000504
Test 2	slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	0,07	0,03	0,04	1	0,58	0,75	0,0049	0,000522	0,0012
Test 2	slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	0,15	0,1	0,09	1	0,99	0,99	0,0225	0,0099	0,008019
Test 2	slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,2	0,15	0,14	0,99	0,97	0,95	0,0396	0,021825	0,01862
Test 2	slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,141	0,11	0,111	0,992	0,968	0,957	0,01972195	0,0117128	0,0117912
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,197	0,158	0,16	1	0,998	0,995	0,038809	0,02491407	0,025472
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,19	0,15	0,15	1	0,99	0,97	0,0361	0,022275	0,021825
Test 3	slab - 15 cm	siliceous	flint	CERIB	18 April 2016	0,09	0,05	0,06	0,99	0,79	0,85	0,008019	0,001975	0,00306
Test 3	slab - 10 cm	siliceous	flint	CERIB	18 April 2016	0,091	0,053	0,055	0,991	0,952	0,922	0,00820647	0,00267417	0,00278905
Test 3	slab - 15 cm	siliceous	granite	CERIB	18 April 2016	0,036	0,02	0,023	0,936	0,251	0,253	0,00121306	0,0001004	0,00013384
Test 3	slab - 10 cm	siliceous		CERIB	18 April 2016	0,05	0,015	0,017	0,992	0,65	0,582	0,00248	0,00014625	0,0001682
Test 3	slab - 10 cm	calcareous		CERIB	18 April 2016	0,18	0,12	0,12	0,98	0,92	0,91	0,031752	0,013248	0,013104
Test 3	slab - 15 cm	calcareous		CERIB	18 April 2016	0,06	0,04	0,04	0,95	0,51	0,6	0,00342	0,000816	0,00096
Test 4	wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	0,047	0,037	0,037	0,933	0,054	0,241	0,002061	7,3926E-05	0,00032993
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,2	0,18	0,2	0,5	-0,01	-0,03	0,02	-0,000324	-0,0012
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,29	0,23	0,25	0,76	0,04	-0,01	0,063916	0,002116	-0,000625
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,27	0,23	0,24	0,72	0,05	0,02	0,052488	0,002645	0,001152
Test 6	1 column	siliceous		IBMB	27 January 2015	0,37	0,24	0,266	1	1	0,99	0,1369	0,0576	0,07004844
Test 7	1 column	siliceous		IBMB	30 January 2015	0,16	0,06	0,08	0,86	0,35	0,39	0,022016	0,00126	0,002496
Test 8	1 wall	siliceous		IBMB	29 March 2017	0,021	0,068	0,058	0,287	-0,997	-0,997	0,00012657	-0,00461013	-0,00335391
					AVERAGE	**0,141**	**0,10**	**0,11**	**0,86**	**0,47**	**0,46**	**0,025**	**0,008**	**0,008**

Reference number	Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper cur	General criteria mix curve	General criteria low curve
Test 1	slab - 20 cm	calcareous		CERIB	14 June 2016	0,11	0,06	0,06	0,91	0,62	0,14	0,011011	0,002232	0,000504
Test 2	slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,2	0,15	0,14	0,99	0,97	0,95	0,0396	0,021825	0,01862
Test 2	slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,141	0,11	0,111	0,992	0,968	0,957	0,01972195	0,0117128	0,0117912
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,197	0,158	0,16	1	0,998	0,995	0,038809	0,02491407	0,025472
Test 2	slab - 12 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,19	0,15	0,15	1	0,99	0,97	0,0361	0,022275	0,021825
Test 3	slab - 10 cm	calcareous		CERIB	18 April 2016	0,18	0,12	0,12	0,98	0,92	0,91	0,031752	0,013248	0,013104
Test 3	slab - 15 cm	calcareous		CERIB	18 April 2016	0,06	0,04	0,04	0,95	0,51	0,6	0,00342	0,000816	0,00096
					AVERAGE	**0,154**	**0,11**	**0,11**	**0,97**	**0,85**	**0,79**	**0,026**	**0,014**	**0,013**

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Reference number	Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper cur	General criteria mix curve	General criteria low curve
Test 1	**slab - 20 cm**	**siliceous**		**CERIB**	**14 June 2016**	0,04	0,05	0,07	0,26	-0,73	-0,81	0,000416	-0,001825	-0,003969
Test 2	slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	0,07	0,03	0,04	1	0,58	0,75	0,0049	0,000522	0,0012
Test 2	slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	0,15	0,1	0,09	1	0,99	0,99	0,0225	0,0099	0,008019
Test 3	slab - 15 cm	siliceous	flint	CERIB	18 April 2016	0,09	0,05	0,06	0,99	0,79	0,85	0,008019	0,001975	0,00306
Test 3	slab - 10 cm	siliceous	flint	CERIB	18 April 2016	0,091	0,053	0,055	0,991	0,952	0,922	0,00820647	0,00267417	0,00278905
Test 3	slab - 15 cm	siliceous	granite	CERIB	18 April 2016	0,036	0,02	0,023	0,936	0,251	0,253	0,00121306	0,0001004	0,00013384
Test 3	slab - 10 cm	siliceous		CERIB	18 April 2016	0,05	0,015	0,017	0,992	0,65	0,582	0,00248	0,00014625	0,0001682
Test 4	wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	0,047	0,037	0,037	0,933	0,054	0,241	0,002061	7,3926E-05	0,00032993
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,2	0,18	0,2	0,5	-0,01	-0,03	0,02	-0,000324	-0,0012
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,29	0,23	0,25	0,76	0,04	-0,01	0,063916	0,002116	-0,000625
Test 5	slab - 30 cm	siliceous	granite	SP	16 October 2007	0,27	0,23	0,24	0,72	0,05	0,02	0,052488	0,002645	0,001152
Test 6	1 column	siliceous		IBMB	27 January 2015	0,37	0,24	0,266	1	1	0,99	0,1369	0,0576	0,07004844
Test 7	1 column	siliceous		IBMB	30 January 2015	0,16	0,06	0,08	0,86	0,35	0,39	0,022016	0,00126	0,002496
Test 8	1 wall	siliceous		IBMB	29 March 2017	0,021	0,068	0,058	0,287	-0,997	-0,997	0,00012657	-0,00461013	-0,00335391
					AVERAGE	**0,135**	**0,10**	**0,11**	**0,80**	**0,28**	**0,30**	**0,025**	**0,005**	**0,006**

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Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper curve	General criteria mix curve	General criteria low curve
slab - 20 cm	siliceous		CERIB	14 June 2016	0,18	0,19	0,25	-0,73	-0,74	-0,82	-0,023652	-0,026714	-0,05125
slab - 20 cm	calcareous		CERIB	14 June 2016	0,13	0,14	0,19	-0,47	-0,5	-0,71	-0,007943	-0,0098	-0,025631
slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	0,59	0,28	0,15	1	1	0,64	0,3481	0,0784	0,0144
slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	1,28	0,92	0,88	1	1	1	1,6384	0,8464	0,7744
slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	1,76	1,33	0,27	1	1	0,97	3,0976	1,7689	0,070713
slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,56	0,24	0,19	0,93	0,8	0,08	0,291648	0,04608	0,002888
slab - 15 cm	siliceous	flint	CERIB	18 April 2016	0,64	0,34	0,31	0,79	0,53	-0,02	0,323584	0,061268	-0,001922
slab - 10 cm	siliceous	flint	CERIB	18 April 2016	0,97	0,68	0,64	0,97	0,94	0,88	0,912673	0,434656	0,360448
slab - 15 cm	siliceous	granite	CERIB	18 April 2016	0,23	0,07	0,17	0,86	-0,76	-0,96	0,045494	-0,003724	-0,027744
slab - 10 cm	siliceous		CERIB	18 April 2016	1,43	1,06	1,02	0,98	0,96	0,92	2,004002	1,078656	0,957168
slab - 10 cm	calcareous		CERIB	18 April 2016	1,95	1,44	1,38	0,99	0,98	0,94	3,764475	2,032128	1,790136
slab - 15 cm	calcareous		CERIB	18 April 2016	0,87	0,57	0,44	0,89	0,82	0,56	0,673641	0,266418	0,108416
wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	0,16	0,07	0,22	0,71	-0,97	-1	0,018176	-0,004753	-0,0484
1 wall	siliceous		IBMB	29 March 2017	0,096	0,169	0,333	-0,94	-0,97	-0,99	-0,00866304	-0,02770417	-0,10978011
				AVERAGE	**0,77**	**0,54**	**0,46**	**0,57**	**0,29**	**0,11**	**0,93**	**0,47**	**0,27**

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Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper curve	General criteria mix curve	General criteria low curve
slab - 20 cm	calcareous		CERIB	14 June 2016	0,13	0,14	0,19	-0,47	-0,5	-0,71	-0,007943	-0,0098	-0,025631
slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	1,76	1,33	0,27	1	1	0,97	3,0976	1,7689	0,070713
slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,56	0,24	0,19	0,93	0,8	0,08	0,291648	0,04608	0,002888
slab - 10 cm	calcareous		CERIB	18 April 2016	1,95	1,44	1,38	0,99	0,98	0,94	3,764475	2,032128	1,790136
slab - 15 cm	calcareous		CERIB	18 April 2016	0,87	0,57	0,44	0,89	0,82	0,56	0,673641	0,266418	0,108416
				AVERAGE	**1,05**	**0,74**	**0,49**	**0,67**	**0,62**	**0,37**	**1,56**	**0,82**	**0,39**

Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper curve	General criteria mix curve	General criteria low curve
slab - 20 cm	siliceous		CERIB	14 June 2016	0,18	0,19	0,25	-0,73	-0,74	-0,82	-0,023652	-0,026714	-0,05125
slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	0,59	0,28	0,15	1	1	0,64	0,3481	0,0784	0,0144
slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	1,28	0,92	0,88	1	1	1	1,6384	0,8464	0,7744
slab - 15 cm	siliceous	flint	CERIB	18 April 2016	0,64	0,34	0,31	0,79	0,53	-0,02	0,323584	0,061268	-0,001922
slab - 10 cm	siliceous	flint	CERIB	18 April 2016	0,97	0,68	0,64	0,97	0,94	0,88	0,912673	0,434656	0,360448
slab - 15 cm	siliceous	granite	CERIB	18 April 2016	0,23	0,07	0,17	0,86	-0,76	-0,96	0,045494	-0,003724	-0,027744
slab - 10 cm	siliceous		CERIB	18 April 2016	1,43	1,06	1,02	0,98	0,96	0,92	2,004002	1,078656	0,957168
wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	0,16	0,07	0,22	0,71	-0,97	-1	0,018176	-0,004753	-0,0484
1 wall	siliceous		IBMB	29 March 2017	0,096	0,169	0,333	-0,94	-0,97	-0,99	-0,00866304	-0,02770417	-0,10978011
				AVERAGE	**0,62**	**0,42**	**0,44**	**0,52**	**0,11**	**-0,04**	**0,58**	**0,27**	**0,21**

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In the following table, a double check has been performed for the coloured lines.

Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper curve	General criteria mix curve	General criteria low curve
slab - 20 cm	siliceous		CERIB	14 June 2016	0,18	0,19	0,25	-0,73	-0,74	-0,82	-0,023652	-0,026714	-0,05125
slab - 20 cm	calcareous		CERIB	14 June 2016	0,13	0,14	0,19	-0,47	-0,5	-0,71	-0,007943	-0,0098	-0,025631
slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	0,59	0,28	0,15	1	1	0,64	0,3481	0,0784	0,0144
slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	1,28	0,92	0,88	1	1	1	1,6384	0,8464	0,7744
slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	1,76	1,33	0,27	1	1	0,97	3,0976	1,7689	0,070713
slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,679	0,324	0,19	0,95	0,87	-0,954	0,43798895	0,09132912	-0,0344394
slab - 15 cm	siliceous	flint	CERIB	18 April 2016	0,64	0,34	0,31	0,79	0,53	-0,02	0,323584	0,061268	-0,001922
slab - 10 cm	siliceous	flint	CERIB	18 April 2016	0,252	0,073	0,084	0,909	0,571	0,136	0,05772514	0,00304286	0,00095962
slab - 15 cm	siliceous	granite	CERIB	18 April 2016	0,353	0,073	0,102	0,946	0,624	-0,731	0,11788011	0,0033253	-0,00760532
slab - 10 cm	siliceous		CERIB	18 April 2016	0,512	0,292	0,287	0,951	0,881	0,77	0,24929894	0,07511758	0,06342413
slab - 10 cm	calcareous		CERIB	18 April 2016	1,95	1,44	1,38	0,99	0,98	0,94	3,764475	2,032128	1,790136
slab - 15 cm	calcareous		CERIB	18 April 2016	0,87	0,57	0,44	0,89	0,82	0,56	0,673641	0,266418	0,108416
wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	0,231	0,056	0,163	0,9	-0,913	-1	0,0480249	-0,00286317	-0,026569
1 wall	siliceous		IBMB	29 March 2017	0,096	0,169	0,333	-0,94	-0,97	-0,99	-0,00866304	-0,02770417	-0,10978011
				AVERAGE	**0,68**	**0,44**	**0,36**	**0,58**	**0,37**	**-0,01**	**0,77**	**0,37**	**0,18**

Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper curve	General criteria mix curve	General criteria low curve
slab - 20 cm	calcareous		CERIB	14 June 2016	0,13	0,14	0,19	-0,47	-0,5	-0,71	-0,007943	-0,0098	-0,025631
slab - 10 cm	calcareous	limestone Beauce	CERIB	15 April 2016	1,76	1,33	0,27	1	1	0,97	3,0976	1,7689	0,070713
slab - 15 cm	calcareous	limestone Beauce	CERIB	15 April 2016	0,679	0,324	0,19	0,95	0,87	-0,954	0,43798895	0,09132912	-0,0344394
slab - 10 cm	calcareous		CERIB	18 April 2016	1,95	1,44	1,38	0,99	0,98	0,94	3,764475	2,032128	1,790136
slab - 15 cm	calcareous		CERIB	18 April 2016	0,87	0,57	0,44	0,89	0,82	0,56	0,673641	0,266418	0,108416
				AVERAGE	**1,08**	**0,76**	**0,49**	**0,67**	**0,63**	**0,16**	**1,59**	**0,83**	**0,38**

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Type of element	aggregates types	Mineralogy	Laboratory	Date of the test	❶ accuracy criteria upper curve	❶ accuracy criteria mix curve	❶ accuracy criteria low curve	❷ Safety criteria upper curve	❷ Safety criteria mix curve	❷ Safety criteria low curve	General criteria upper curve	General criteria mix curve	General criteria low curve
slab - 20 cm	siliceous		CERIB	14 June 2016	0,18	0,19	0,25	-0,73	-0,74	-0,82	-0,023652	-0,026714	-0,05125
slab - 15 cm	siliceous	basalt	CERIB	15 April 2016	0,59	0,28	0,15	1	1	0,64	0,3481	0,0784	0,0144
slab - 10 cm	siliceous	basalt	CERIB	15 April 2016	1,28	0,92	0,88	1	1	1	1,6384	0,8464	0,7744
slab - 15 cm	siliceous	flint	CERIB	18 April 2016	0,64	0,34	0,31	0,79	0,53	-0,02	0,323584	0,061268	-0,001922
slab - 10 cm	siliceous	flint	CERIB	18 April 2016	0,252	0,073	0,084	0,909	0,571	0,136	0,05772514	0,00304286	0,00095962
slab - 15 cm	siliceous	granite	CERIB	18 April 2016	0,353	0,073	0,102	0,946	0,624	-0,731	0,11788011	0,0033253	-0,00760532
slab - 10 cm	siliceous		CERIB	18 April 2016	0,512	0,292	0,287	0,951	0,881	0,77	0,24929894	0,07511758	0,06342413
wall - 14 cm	silico-calcareous	60% calcareous	CERIB	23 September 2015	0,231	0,056	0,163	0,9	-0,913	-1	0,0480249	-0,00286317	-0,026569
1 wall	siliceous		IBMB	29 March 2017	0,096	0,169	0,333	-0,94	-0,97	-0,99	-0,00866304	-0,02770417	-0,10978011
				AVERAGE	**0,46**	**0,27**	**0,28**	**0,54**	**0,22**	**-0,11**	**0,31**	**0,11**	**0,07**

Prepared by Fabienne Robert (member of PT HGF and convenor of CEN TC 250/SC2/WG1/TG5) in collaboration with Jochen Zehfuss (member of CEN TC 250/SC2/WG1/TG5) and Robert Jansson McNamee (member of CEN TC 250/SC2/WG1/TG5) with data and modelling provided by IBMB Braunschweig, CERIB, SP.

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