fib Symposium2025
Antibes - France
Concrete Structures :
extend lifespan, limit impacts

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Durability performance of several concrete compositions including low carbon footprint concretes

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and

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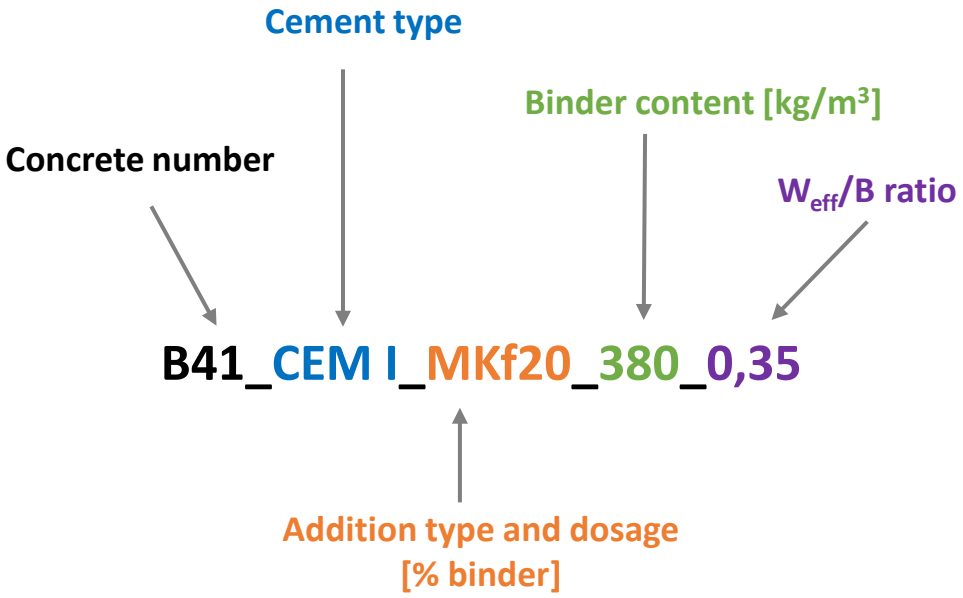
11 concrete mixes in XS3m and XC4

XC4 exposure : Epernon

XS3m exposure : La Rochelle

Concretes



❑ Concrete mix

B01_CEM I_280_0.62

B02_CEM I_V30_330_0.52

B04_CEM III/A_290_0.61

B05_CEM I_S60_310_0.57

B07_CEM I_L41_450_0.42

B31_CEM III/A_385_0.4

B36_CEM V/A_ (S-V)_365_0.46

B37_CEM V/A_(S-V)_370_0.45

B38_CEM I_V8_390_0.5

B40_CEM I_Qz30_370_0.47

B41_CEM I_MKf20_380_0.35

CO_2 footprint of constituents

Constituent	CO_2 footprint [$kgCO_2eq/t$]	Source
Sand and gravel	2.6	UNPG[A]
CEM II/A-LL 52.5R	636	France Ciment[B]
CEM III/A 52.5 L CE PM ES CP1	334	France Ciment[B]
CEM I 52.5 N	748	France Ciment[B]
CEM V/A(S-V) 42.5 CE PM ES	475	France Ciment[B]
Metakaolin	170	Supplier data
Fly Ash	42	Supplier data
Blst furnace slag	104	Supplier data
Silica fume	354	Supplier data
Siliceous addition	120	Supplier data
Limestone	28	CCA Europe[C]
Superplsticizer	1530	EFCA[D]
Effective water	0.136	ADEME[E]

[A] Union Nationale des Producteurs de Granulats. 2017.«Module d'information environnementale de la production de granulats à partir de roches massives».

[B] France Ciment. 2025. Accessed January 27. https://www.france-ciment.fr/enjeux/ciments-bas-carbone/

[C] CCA Europe. 2021. «Dry ground calcium carbonate (GCC-Dry) Fine - Sector EPD»

[D] European Federation of Concrete Admixtures Associations a.i.s.b.i., «Concrete admixtures: Plasticizers and Superplasticizers» Institut Bauen und Umwelt E.V. (IBU), 2015

[E] Groupe de travail Bilan GES de l'Astee, «Eau de réseau» ADEME. Accessed January 27. https://prod-basecarbonesolo.ademe-dri.fr.

FD P 18-483-2 (2025) « Ecodesign of concrete structures – Part 2: Specification of concrete for structures with reduced carbon impact »

- GWR (Global Warming potential Reduction) classes

$$\text{« GWR »} = 100 \times \left(1 - \frac{\text{Global Warming Potential of the concrete}}{\text{Global Warming Potential of Reference concrete}} \right)$$

The total GWP value of 1 m3 of concrete takes into account:
- the constituents (excluding reinforcement/reinforcement)
- the transportation of the constituents to the production site
- the concrete production up to the mixer outlet

The total GWP value must be derived from either:
- a verified FDES configurator (see INIES program)
- a verified FDES (see INIES program)
- a calculation tool compliant with NF EN 15804+A2/CN with periodic critical review by an independent third party

Value of Global Warming potential of Reference concrete (in $kgCO_2/m^3$) depending to the exposure classes, compressive strength classes and design service life

R_c	DUP	XC1	XC2	XC3	XC4	XS1	XS2	XS3	XD1	XD2	XD3	XF1	XF2	XF3	XF4	XA1	XA2	XA3
C20/25	50	219	219															
C25/30	50	219	219	235	235				235			235	252					
	100	235	235															
C30/37	50	235	235	235[a)]	235[a)]	276	276		235[a)]	276		235[a)]	274	274	285	276		
	100	235	235	252	276	276	276		276	276		276	292	318	318	276		
C35/45	50	276	276	276	276	276	276	292	276	276	292	276	300	301	301	276	292	
	100	276	276	276	276	276	276	292	276	276	292	276	300	323	323	276	292	
C40/50	50 et 100	318	318	318	318	318	318	318	318	318	318	318	330	330	330	318	318	318
C45/55	50 et 100	336	336	336	336	336	336	336	336	336	336	336	346	346	346	336	336	336
C50/60	50 et 100	354	354	354	354	354	354	354	354	354	354	354	366	366	366	354	354	354
C55/67	50 et 100	356	356	356	356	356	356	356	356	356	356	356	367	367	367	356	356	356
C60/75	50 et 100	357	357	357	357	357	357	357	357	357	357	357	368	368	368	357	357	357

a) Valeur portée à 252 pour les bétons précontraints

FD P 18-483-2 (2025) « Ecodesign of concrete structures – Part 2: Specification of concrete for structures with reduced carbon impact »

- GWR (Global Warming potential Reduction) classes

GWR Classes (Design service life 50 years)	Reduction (%)
GWR0	≤ 9
GWR1	10-19
GWR2	20-29
GWR3	30-39
GWR4	40-49
GWR5	50-59
GWR6	60-69
GWR7	≥ 70

CO_2 reduction class of concretes

Complying with prescriptive provision (deemed-to-satisfy values) in EN 206 and French National Annex (NA.F.1, 2022)

Concrete	XC4	XS3m	CO_2 footprint [$kgCO_2eq/m^3$]	GWR for XC4 structure in Epernon according to French guideline FD P18-483-2	GWR for XS3m structure in La Rochelle according to French guideline FD P18-483-2	Carbon footprint / Compressive strength [$kgCO_2eq/m^3/MPa$]
B01_CEM I_280_0.62	YES	NO	222	0	2	8.3
B02_CEM I_V30_330_0.52	YES	NO	179	2	3	4.2
B04_CEM III/A_290_0.61	YES	NO	139	4	5	2.6
B05_CEM I_S60_310_0.57	NO	NO	114	5	6	2.3
B07_CEM I_L41_450_0.42	NO	NO	223	0	0	5.5
B31_CEM III/A_385_0.4	YES	YES	187	2	3	2.4
B36_CEM V/A_ (S-V)_365_0.46	YES	YES	183	2	3	3.0
B37_CEM V/A_(S-V)_370_0.45	YES	YES	183	2	3	2.3
B38_CEM I_V8_390_0.5	YES	YES	288	-	0	2.8
B40_CEM I_Qz30_370_0.47	NO	NO	213	0	2	4.8
B41_CEM I_Mkf20_380_0.35	YES	YES	273	-	0	3.1

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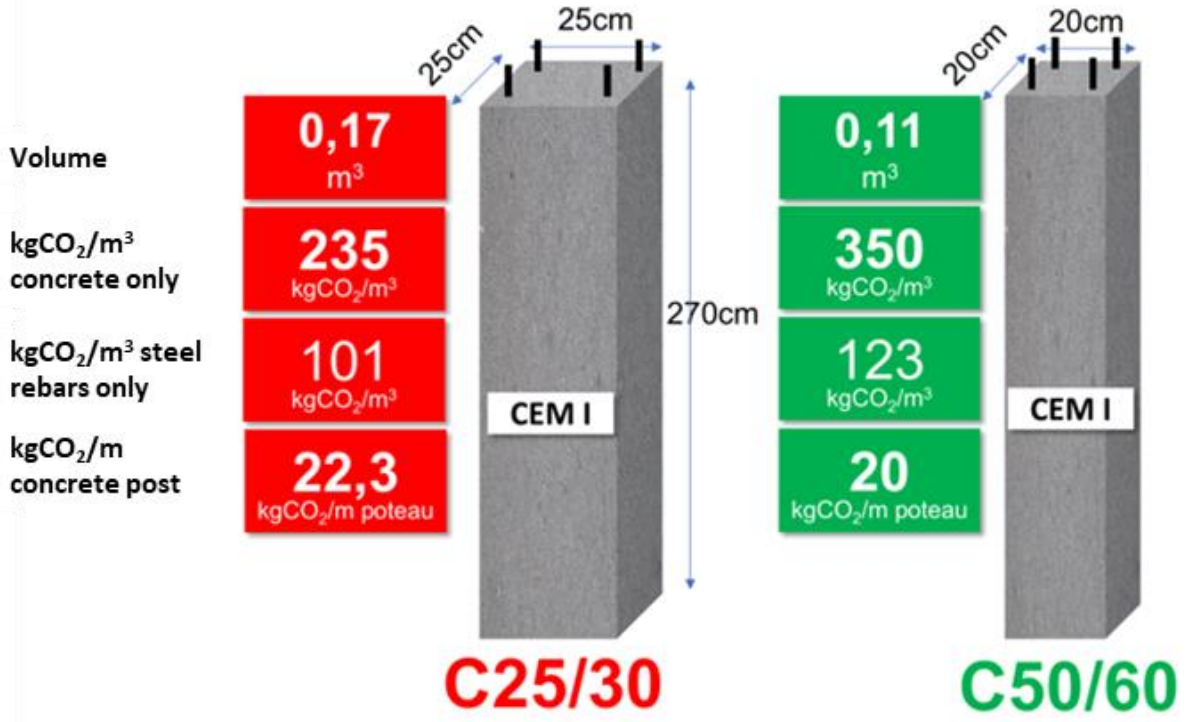
When the **functional unit** is previously dimensioned, the reference to a GWR reduction class is understood as integrating all the solutions corresponding to one of the following two cases:

Case 1 :

A structure meeting the dimensions as previously defined and whose **concrete meets at least the GWR reduction class requirement**.

Case 2 :

A structure whose **dimensioning optimization** is such that the reduction of impact on climate change at the scale of the functional unit is at least equivalent to case 1 (specified GWR reduction class) **regardless of the GWR class of the concrete(s)** used (GWP of the optimized structure less than or equal to that of the basic structure)

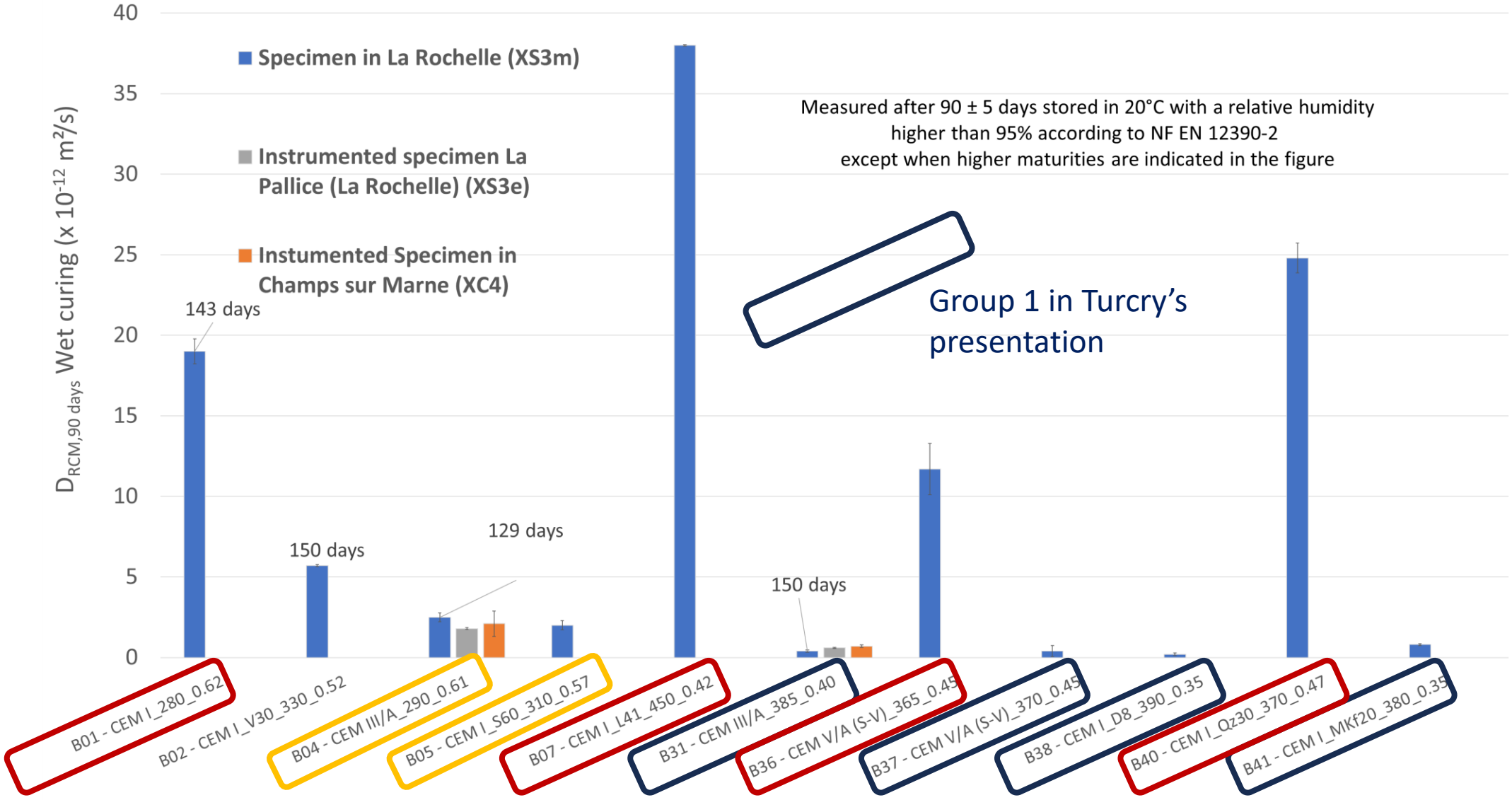


Durability properties of the 11 concretes measured at 90 days

Name	Binder content (kg/m^3)	W/B-W/C (-)	φ (%)	D_{RCM} (10^{-12} m^2/s)	α_M (-)	ρ_0 (Ω.m)
B01	CEM I (280) + L (50)	0.60-0.60	16.3	26.0	0.30	55
B02	CEM I (231) + FA (98)	0.54-0.77	17.0	12.5	0.60	96
B04	CEM III A (280) + L (50)	0.61-0.61	16.7	3.3	0.43	*91*
B05	CEM I (122) + BFS (184)	0.58-1.44	19.0	3.6	0.42	215
B07	CEM I (267) + L (188)	0.41-0.71	15.8	41.2	0.30	42
B31	CEM III A (383)	0.40-0.40	11.7	1.5	0.43	461
B36	CEM V (363)	0.45-0.45	19.3	11.5	0.59	93
B37	CEM V (374)	0.45-0.45	13.0	1.1	0.59	333
B38	CEM I (354) + SF (30)	0.35-0.38	9.9	0.3	0.39	276
B40	CEM I (261) + SA (112)	0.48-0.68	16.0	24.2	0.30	43
B41	CEM I (302) + MK (76)	0.35-0.44	10.6	1.1	0.30	*210*

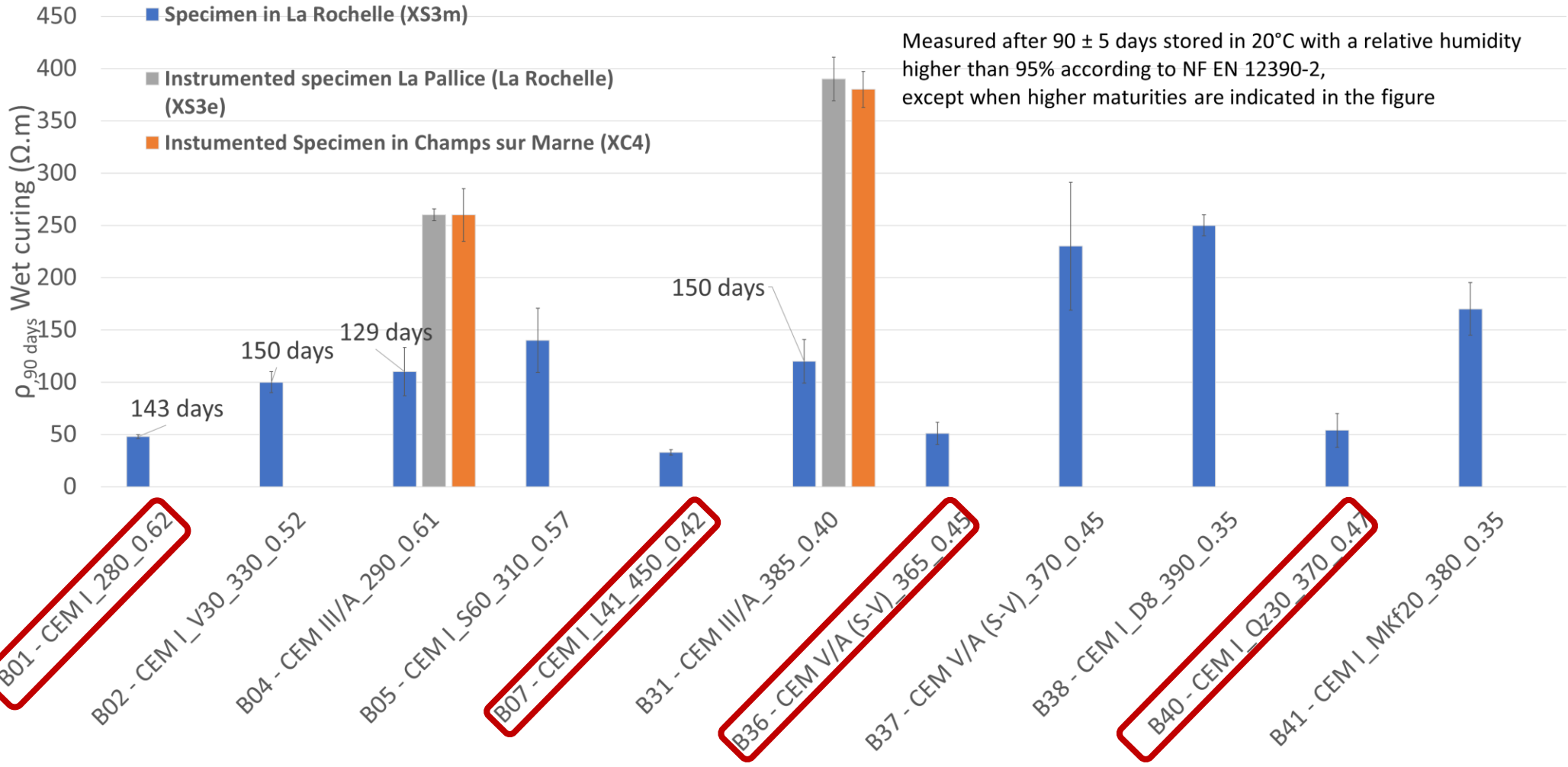
Migration coefficient measured on 11 concretes at 90 days

(except when maturities are precised in the figure)

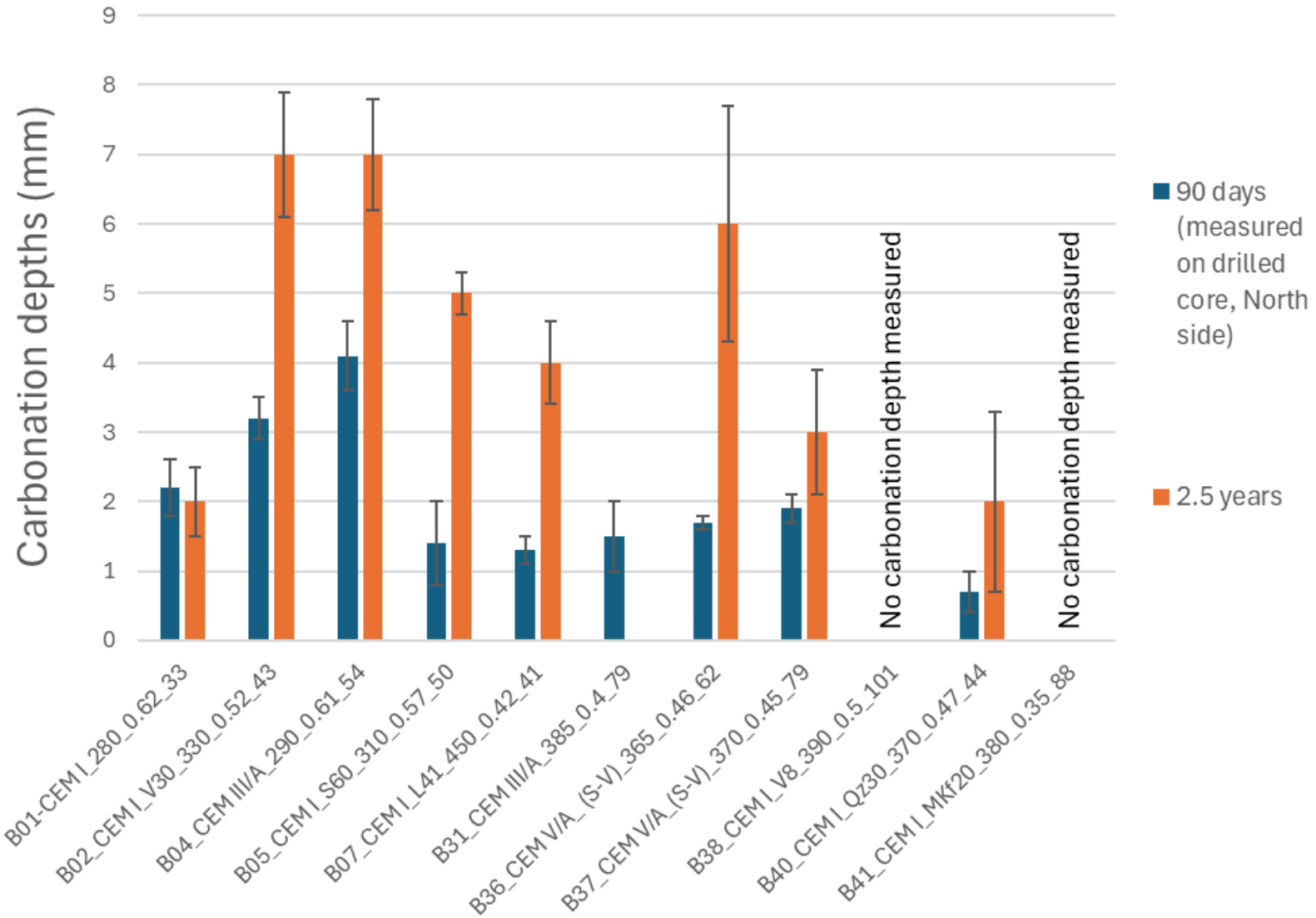


Electrical resistivity measured on 11 concretes at 90 days

(except when maturities are precised in the figure)



Carbonation depth measured on the 11 concretes

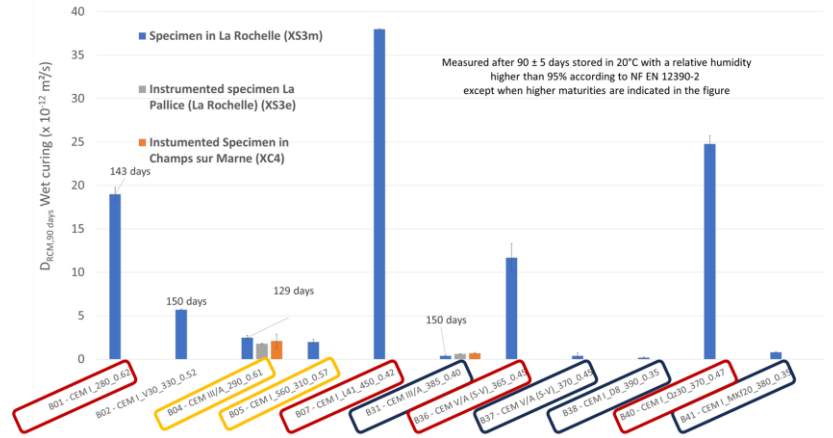


Conclusions

- **In XC4 environment**, according to both the **carbonation rate measured in laboratory** on similar concrete during PerfDub Project and the **carbonation depth obtained after 2,5 years of exposition**, the following concretes **could lead to signs of corrosion** during the twenty years of this study, especially when considering 10 mm of cover concrete:

- **B02_CEM I_V30_330_0.52** → Complying with deemed-to-satisfy values (prescriptive provison)
  → But **high carbonation rate**
- **B04_CEM III/A_290_0.61** → Complying with deemed-to-satisfy values (prescriptive provision)
  → But **high carbonation rate**
- **B05_CEM I_S60_310_0.57** → **Not** complying with deemed-to-satisfy values (prescriptive provision)
  → **High carbonation rate**
- **B36_CEM V/A_ (S-V)_365_0.46** → Complying with deemed-to-satisfy values (prescriptive provision)
  → But **high carbonation rate**, high aggregates porosity, high concrete porosity
- **B40_CEM I_Qz30_370_0.47** → **Not** complying with deemed-to-satisfy values (prescrtive provision)
  → And **high carbonation rate**

Conclusions



- In **XS3m environment**, according to the **performances of cover concrete**, the following concretes **could lead to signs of corrosion** during the twenty years of this study, especially when considering 10 mm of cover concrete:
  - **B01_CEM I_280_0.62** → **Not** complying with deemed-to-satisfy values (prescriptive provision) → **High D_{rcm}**
  - **B07_CEM I_L41_450_0.42** → **Not** complying with deemed-to-satisfy values (prescriptive provision) → **High D_{rcm}**
  - **B36_CEM V/A_ (S-V)_365_0.46** → Complying with deemed-to-satisfy values (prescriptive provision) → **High D_{rcm}, high aggregates porosity, high concrete porosity**
  - **B40_CEM I_Qz30_370_0.47** → **Not** complying with deemed-to-satisfy values (prescriptive provision) → **High D_{rcm}**
  - **B02_CEM I_V30_330_0.52 (to a lesser extent)** → **Not** complying with deemed-to-satisfy values (prescriptive provision) → **High D_{rcm}**

Conclusions and Outlook

- **Results based on durability properties of the concrete measured in laboratory and general indicators seem to be in line with :**
  - **Predictive simulations made with PerfDuB model**
  - **On-site observations and corrosion measurement**

- **Chloride content profiles are being compiled from samples to verify the first tendencies**