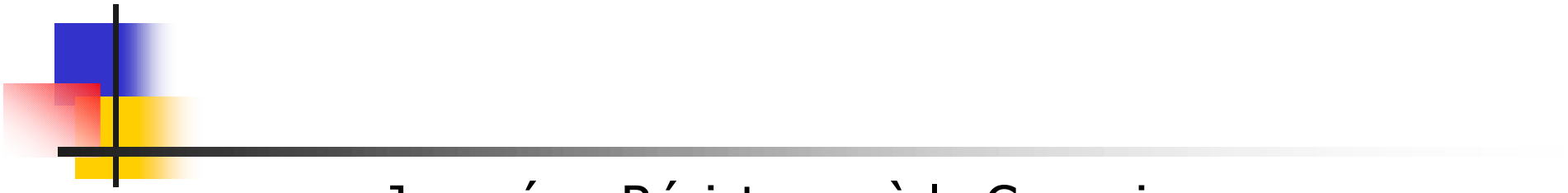
Quel(s) vieillissement(s) accéléré(s) pour simuler le vieillissement naturel ?



Journée : Résistance à la Corrosion

Méthodes d'investigation & Revêtements protecteurs

CRM, Liège, 22 mai 2008

Une organisation CoRI-CRM-Materia Nova

Hugues De Deurwaerder

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Introduction

- Questions
  - Correlation between accelerated tests & field testing ?
  - Which accelerated weathering for which climate ?
- Literature : "*In spite of several reports showing low correlation between the Salt Spray test & field exposure, the Salt Spray is still often used for testing paints*"
  - Nevertheless it is the more used artificial weathering

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Introduction

- Requirements for accelerated weathering
  - Produce results in relatively short time
  - Correlation with exterior exposure
  - Simulate multiple stress conditions
  - Validity for variety of materials
  - Reproducibility & repeatability
  - Practical, affordable equipment

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Automotive : corrosion resistance

- Daf
  - Salt spray & Tropical
- BMW
  - Cyclic corrosion test
    - M : salt spray
    - T to F : tropical (8h) then room temperature
    - Week-end : room temperature
  - Condensation water climatic testing
  - Out-door weathering test
  - CASS ($CuCl_2$-acetic acid salt spray test)

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Automotive : corrosion resistance

- Volvo
  - 5 tests

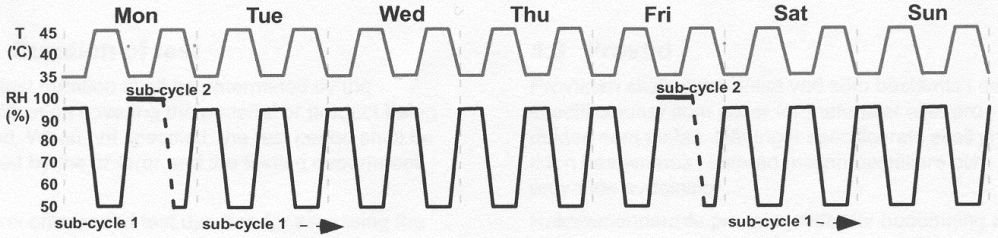

Fig 4a

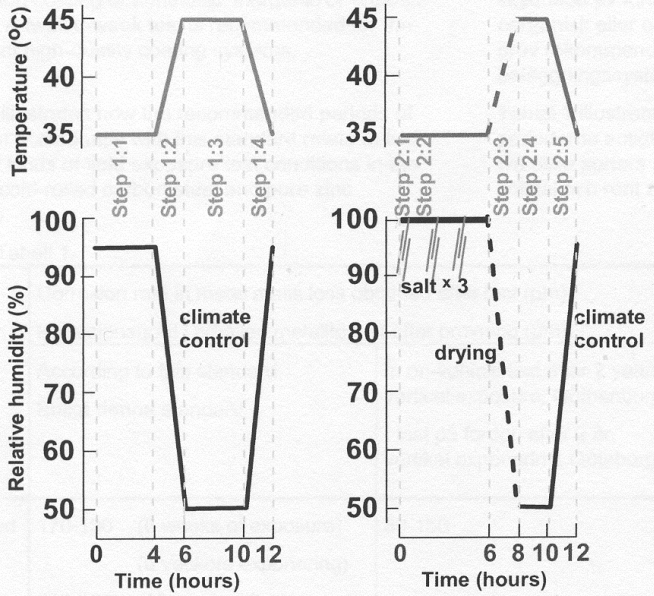

Fig 4b

Fig 4c

Fig 4a Complete one-week climate cycle
Komplett enveckas klimatcykel

Fig 4b Sub-cycle 1: 12-hour programme with controlled temperature and humidity ramps
Delcykel 1: tolvtimmars program med styrd temperatur- och fuktighetsvariation

Fig 4c Sub-cycle 2: 12-hour programme with repeated application of salt solution (wet phase) followed by drying and climate control
Delcykel 2: tolvtimmars program med upprepad applicering av saltlösning (våtfas) följt av torkning och klimatstyrning

Automotive : corrosion resistance

- Renault
  - Week 1 : Salt spray
  - Week 2, 3, 4 & 5 : 8 h tropical + 16 h room T°
  - Week 6 : 48 h at 20 ± 1°C & between 60 & 65 % RH

- ♠ each car manufacturer has its own test
- No test at T° < 0°C
- Evaluation N of Sweden or S of Italy or Spain

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ISO 12944/1 ♠ 8

- Paints & Varnishes – "*Corrosion protection of steel structures by protective paint systems*"
  - *Main overall international standard for surface protection*
  - Part 2 : classification of environments
    - C1 : very low
    - C2 : low
    - C3 : mean
    - C4 : high
    - C5-I : very high (industrial)
    - C5-M : very high (marine)
    - Im1 : fresh water, Im2 : seawater, Im3 : underground
  - Durability : L (2♠5y), M (5♠15y), H (>15y)

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- Part 5 : protective paint systems

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Tableau A.3 — Systèmes de peinture pour la catégorie de corrosivité C3

Les systèmes de peinture indiqués dans le tableau ci-dessous ne sont que des exemples. D'autres systèmes de peinture sont possibles s'ils présentent la même efficacité.
Si l'on utilise ces exemples, il faut s'assurer que les systèmes choisis ont les qualités requises pour obtenir la durabilité indiquée lorsque la peinture est appliquée selon les spécifications. Voir aussi 5.7.

Système de peinture n°	Degré de préparation de surface[1]		Couche(s) primaire(s)				Couche finale, y compris la (les) couche(s) intermédiaire(s)			Système de peinture		Durabilité probable (voir 5.5 et ISO 12944-1)		
	St 2	Sa 2½	Liant[8]	Type de primaire[2]	Nombre de couches	NDFT[3] µm	Liant[8]	Nombre de couches	NDFT[3] µm	Nombre de couches	NDFT totale[3] µm	Low	Medium	High
S3.01	x		AK	Misc.	2	80	AK	1	40	3	120			
S3.02		x			1-2	80		1	40	2-3	120			
S3.03	x				2	80		1-2	80	3-4	160			
S3.04		x			1-2	80		1-2	80	2-4	160			
S3.05	x				1-2	80		2-3	120	3-5	200			
S3.06		x			1-2	80		2-3	120	3-5	200			
S3.07		x			1-2	80	AY, CR, PVC[4]	2-3	120	3-5	200			
S3.08		x			1-2	80		2-3	160	3-5	240			
S3.09		x			1-2	80	BIT[4]	2	160	3-4	240			
S3.10		x	AY, CR, PVC		1-2	80		2	160	3-4	240			
S3.11	x				2	80	AY, CR, PVC	1-2	80	3-4	160			
S3.12		x			1-2	80		1-2	80	2-4	160			
S3.13		x			1-2	80		2-3	120	3-5	200			
S3.14		x			1-2	80		2-3	160	3-5	240			
S3.15		x	EP		1	160	AY	1	40	2	200			
S3.16		x			1-2	80	EP, PUR[5]	1	40	2-3	120			
S3.17		x			1-2	80		1-2	80	2-4	160			
S3.18		x			1-2	80		2-3	120	3-5	200			
S3.19		x			1-2	80		2-3	160	3-5	240			
S3.20		x	EP, PUR	Zn (R)	1-2	80	–	–	–	1-2	80			
S3.21		x	EP, PUR[6]		1	40	EP, PUR[5]	1-2	120	2-3	160			
S3.22		x			1	40		2-3	160	3-4	200			
S3.23		x			1	40	AY, CR, PVC	1-2	120	2-3	160			
S3.24		x			1	40		2-3	160	3-4	200			
S3.25		x	ESI[7]		1	80	–	–	–	1	80			
S3.26		x			1	80	AY, CR, PVC	1-2	80	2-3	160			
S3.27		x			1	80		2-3	120	3-4	200			
S3.28		x			1	80	EP, PUR[5]	1-2	80	2-3	160			
S3.29		x			1	80		2-3	120	3-4	200			

Liants de peintures pour couche(s) primaire(s)			Peintures (liquide)		
			Composants		À l'eau
			1 comp.	2 comp.	
AK	=	Alkyde	x		x
CR	=	Caoutchouc chloré	x		
PVC	=	Polychlorure de vinyle	x		
AY	=	Acrylique	x		x
EP	=	Époxy		x	x
ESI	=	Éthylsilicate		x	
PUR	=	Polyuréthane	x		

Liants de peinture pour couche(s) primaire(s)			Peintures (liquide)		
			Composants		À l'eau
			1 comp.	2 comp.	
AK	=	Alkyde	x		x
CR	=	Caoutchouc chloré	x		
PVC	=	Polychlorure de vinyle	x		
AY	=	Acrylique	x		x
EP	=	Époxy		x	x
PUR	=	Polyuréthane	x	x	
BIT	=	Bitume	x		

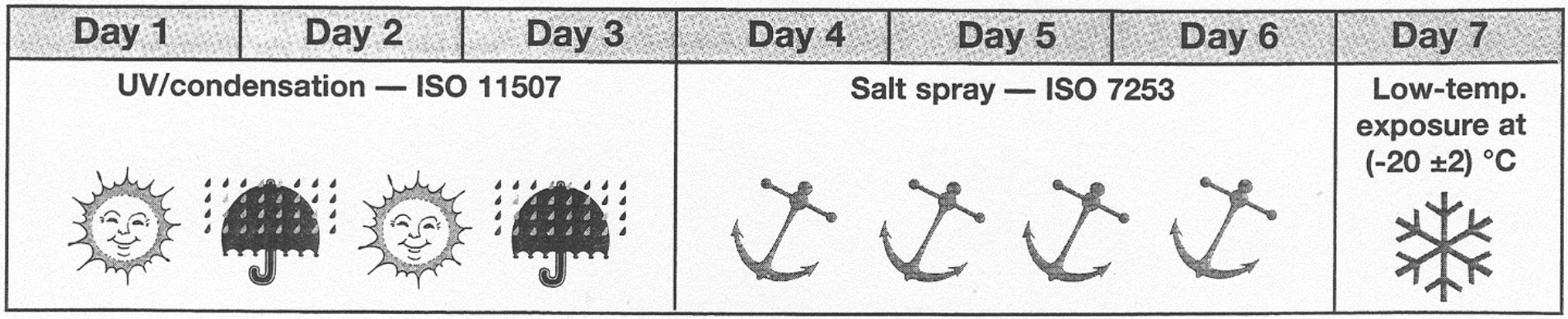
ISO 12944/ 1 ♠ 8

- Part 6 : laboratory performances test methods

		Chemical Resistance	Immersion	Tropical	Salt Spray
		2812-1	2812-2	6270	7253
C4	L	-	-	120	240
	M	-	-	240	480
	H	-	-	480	720
C5-I	L	168	-	240	480
	M	168	-	480	720
	H	168	-	720	1440
C5-M	L	-	-	240	480
	M	-	-	480	720
	H	-	-	720	1440

"Heavy-duty coating systems for offshore service"

- ISO 12944 ♠ ISO 20340
- 25 X ♠ 4200 h (6 months)
  - 1800 h U.V./condensation
  - 1800 h salt spray
  - 600 h freezing



Qualicoat

- Aluminium window frames
  - Acetic acid salt spray test
- Powder coatings
  - Acetic acid salt spray test
  - Tropical
  - Kesternich (SO_2)
  - Sun Test
  - Florida exposure

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Accelerated tests ↔ 5 y offshore

- Norsok M 501 : cyclic with drying, U.V.
- Volvo test : cyclic with drying, no U.V.
- Mebon Prohesion test : continuous
- Salt Spray : continuous

- 5 y at Snorre (N)

- Norsok & Volvo better r (≈ 0.76 for 9 coatings) to the results from 5 y field test

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CoRI's Results

- Materials
  - Waterborne 2K epoxy + latex of low Tg
    - P1 = 0%
    - P2 = 9%
    - P3 = 15%
    - P4 = 23%

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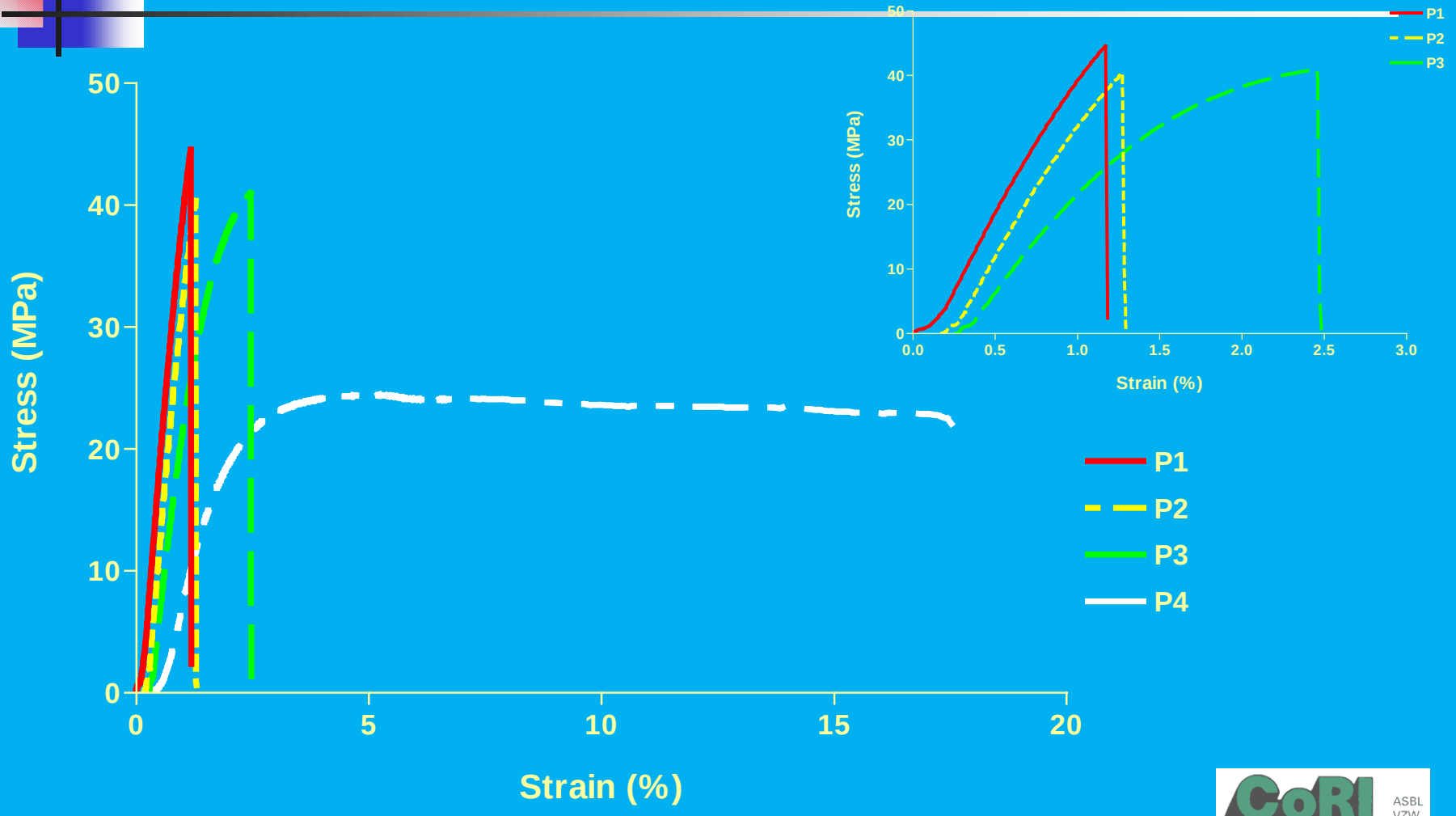
Mechanical Properties



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CoRI's Results

- Tropical – 40°C, 97% r.h.
  - continuous $\Rightarrow$ no difference in protection after $\approx$ 2 weeks
- Cycles : tropical / drying
  - M to F from 09:00 to 16:00 : 40°C and 97% r.h.
  - M to F from 16:00 to 09:00 : drying
  - Weekend : drying

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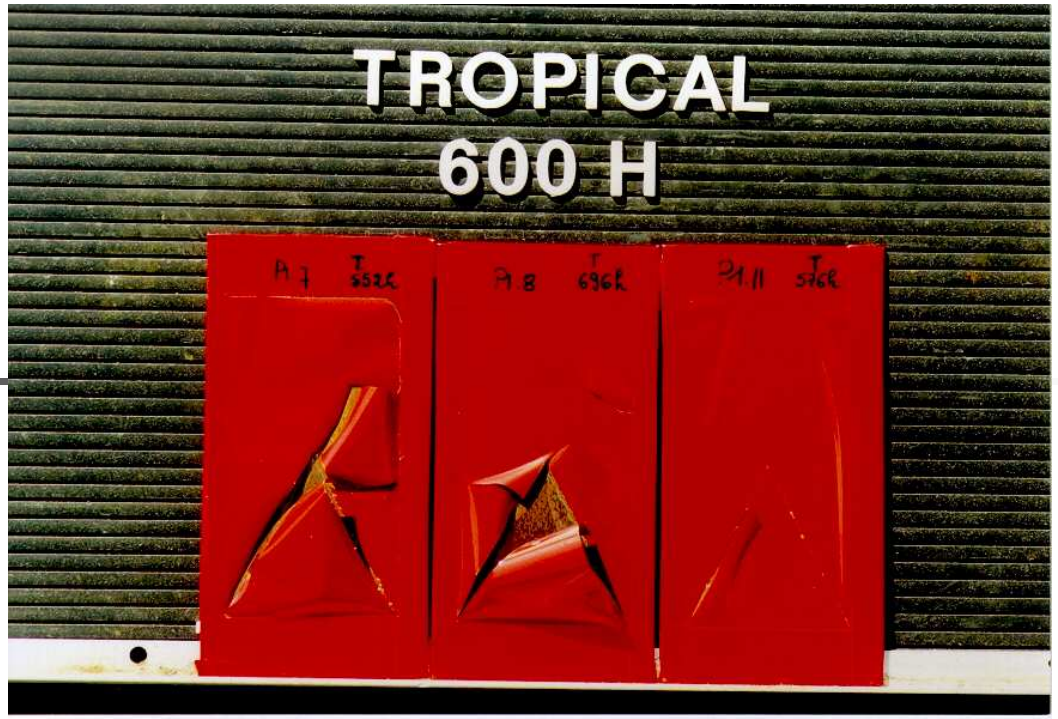

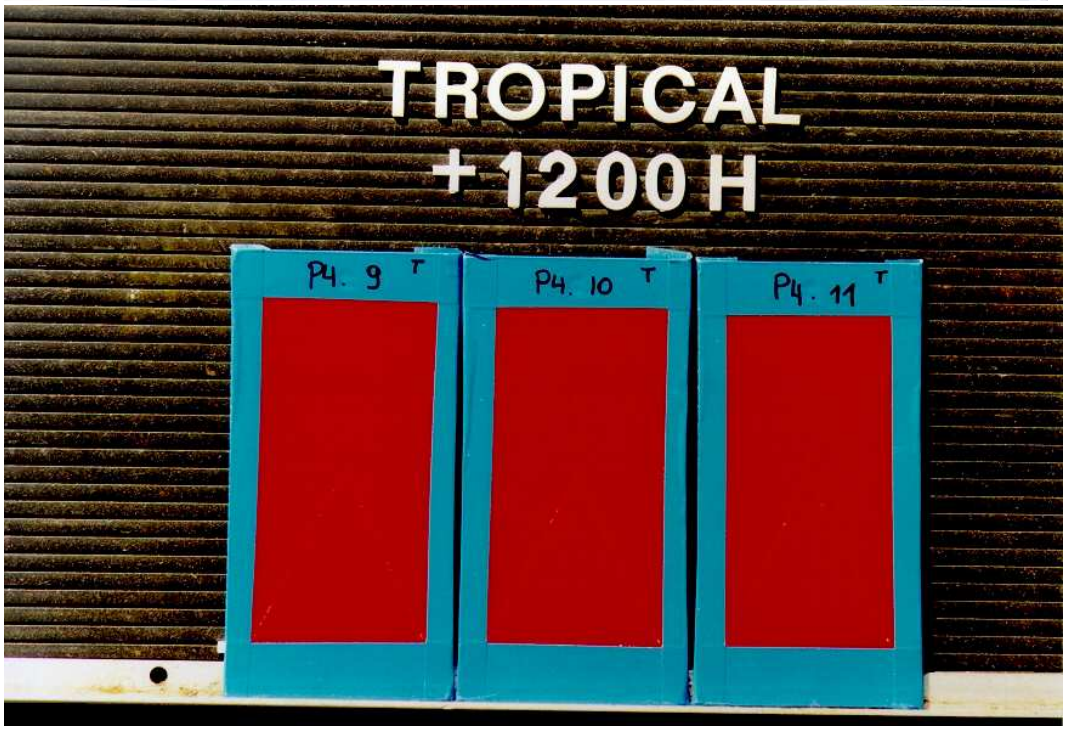

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CoRI Result's

- outdoor $\Rightarrow$ T and r.h. variations
  - heavy rains at $\approx$ 10°C
  - humid periods at $\approx$ 0°C
  - dry periods at $\approx$ -5°C
  - snow
  - long spell of fine weather

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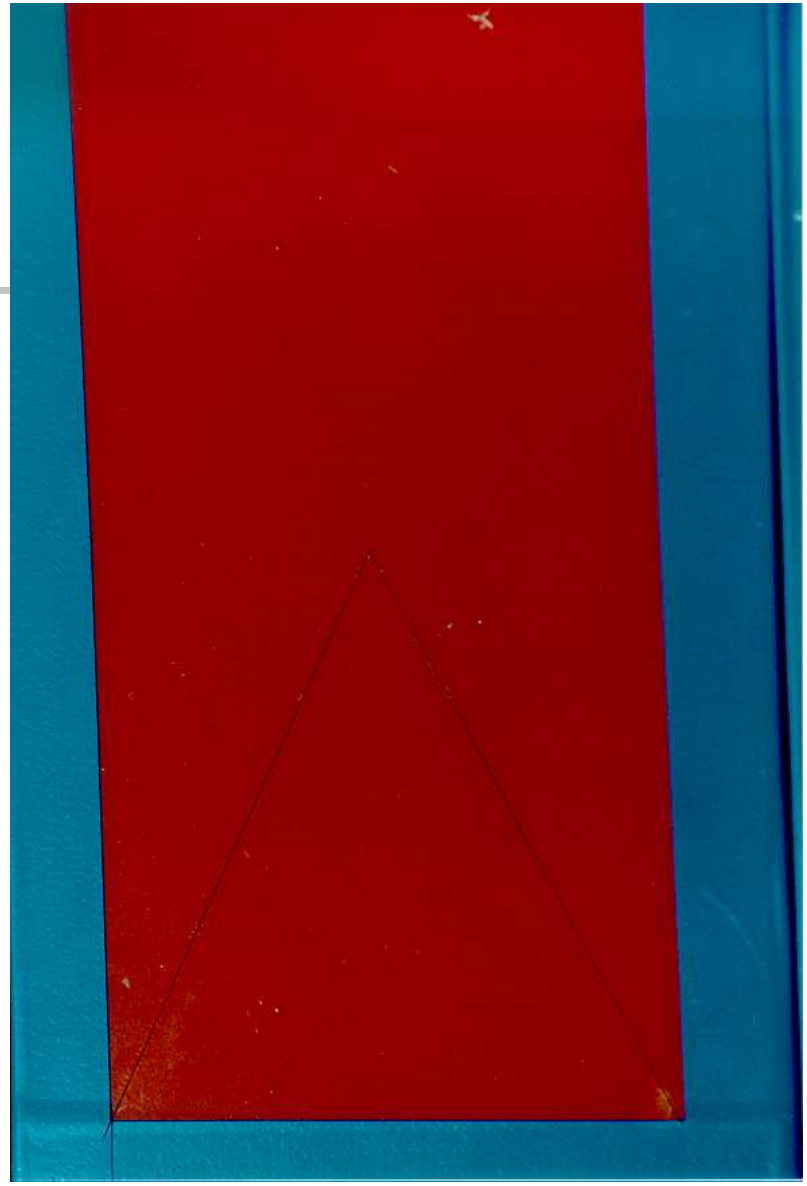

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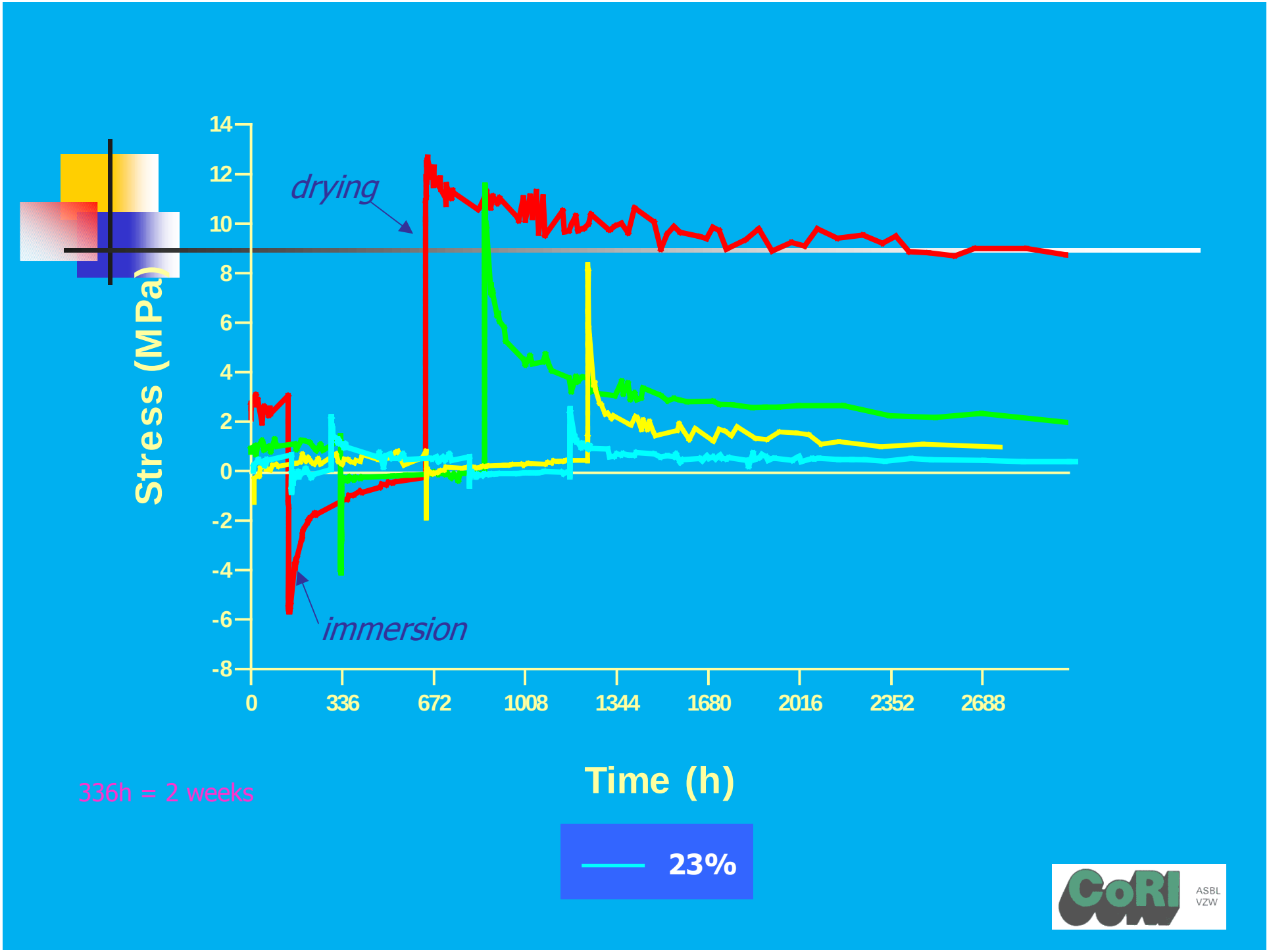
drying
immersion
Stress (MPa)
14
12
10
8
6
4
2
0
-2
-4
-6
-8
0
336
672
1008
1344
1680
2016
2352
2688
Time (h)
336h = 2 weeks
23%
CoRI
ASBL
VZW

Climate : Influencing parameters

- Radiation
  - Chemical (photo)degradation by U.V.
- Temperature
  - Corrosion is an electrochemical process
    - & of T° & of rate of electrochemical reaction
  - T° < 0°C
    - ♠ paints becomes brittle (! T_g)
    - ♠ expansion of water : mechanical damage

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Climate : influencing parameters

- Humidity
- Corrosive atmosphere
  - NaCl
  - SO_2
  - NO_x
  - Cl_2
- Climate : mixture of all these parameters

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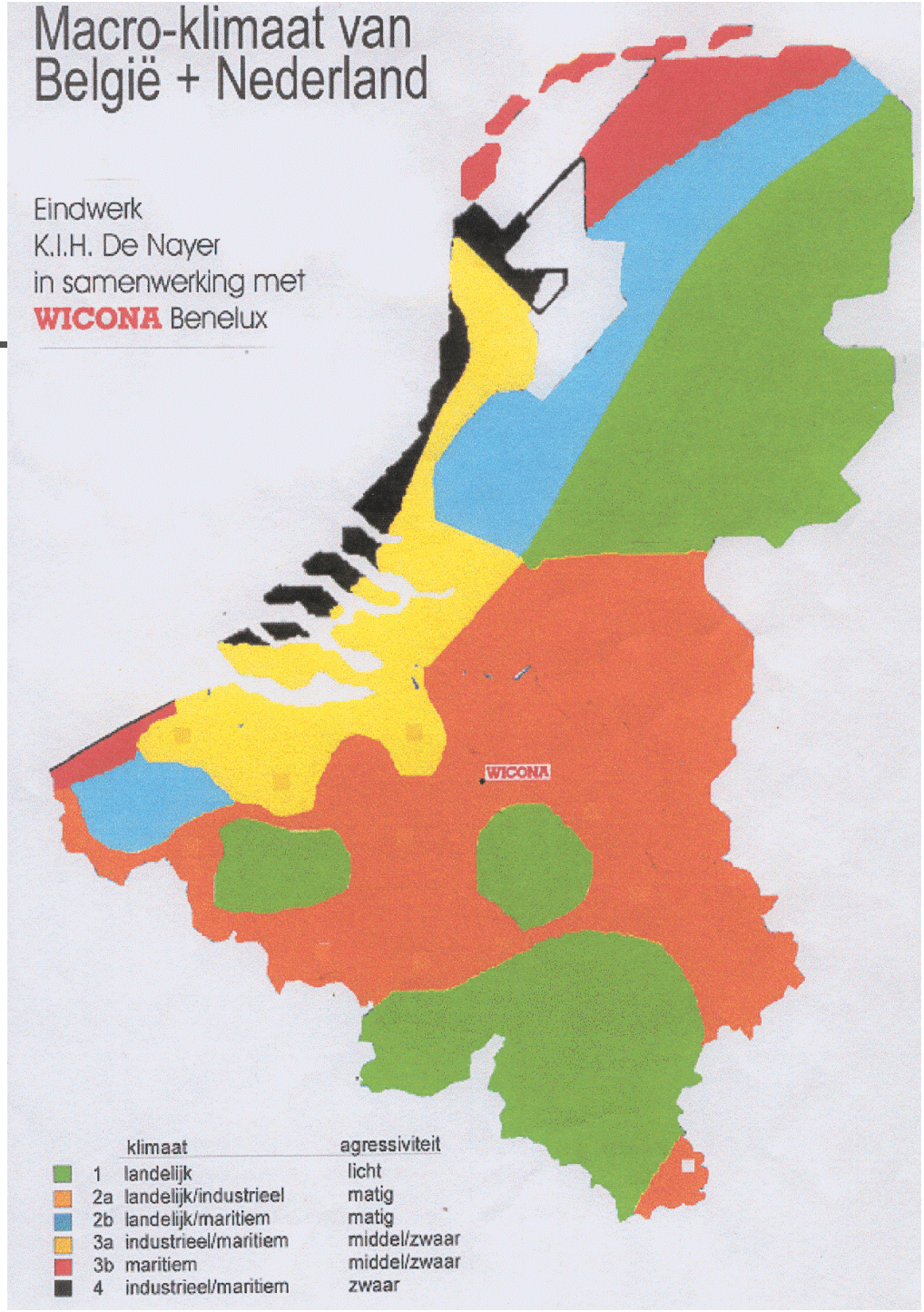

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Conclusions

- Each single method simulates a single stress factor
- Salt spray
  - Many coatings are selected based on inappropriate test with a resultant likelihood of early & catastrophic failure
  - Manufacturer have formulated coatings that will provide best performances in Salt Spray rather than outdoor

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Conclusions

- No single accelerated weathering mimics the climate : Climate is not constant, Seasons, ...
- There is no single test appropriate for testing all materials in all environments
- Coatings are the most stressed during transitions (hot/cold, wet/dry), not during steady-state conditions
- Test to be carried out depends on the climate
- ISO 12944

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Conclusions

- Cyclic tests have shown very high potential for improving coating evaluation & may offer best correlation
  - **But which cyclic methods ???**

- Scratched or not ?

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Thank you for listening

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