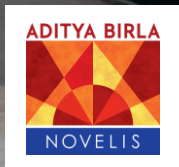


Road Exposure Corrosion Evaluation of Aluminum Alloys for Automotive Applications

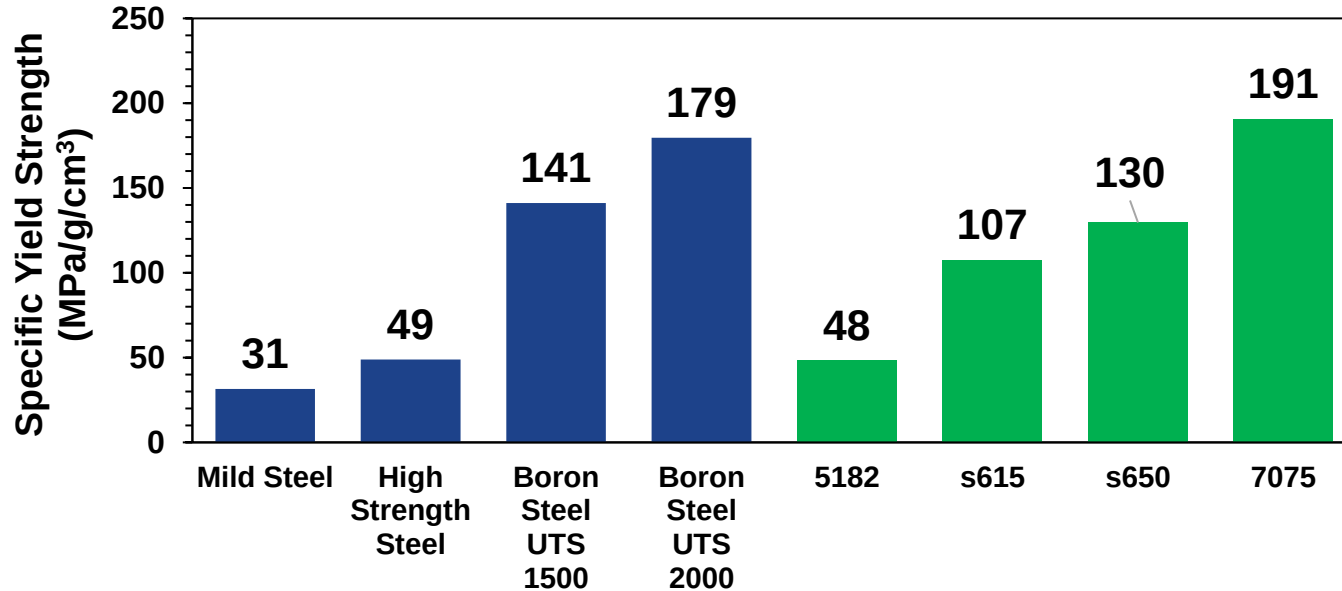
Ganesh Bhaskaran, Kevin Ryan, Yudie Yuan, Shanshan Wang, John Ho, Mary Lyn Lim
Novelis Global Research and Technology Center, Kennesaw GA, USA



This work was done in collaboration with NRC-Canada
Automotive Corrosion Symposium | April 11, 2024

Novelis

Why high strength aluminum for automotive?



If bending stiffness is maintained in a direct substitution of aluminum for steel, the aluminum component will be about half the weight of the steel component

Door Project



17.9kg



-46% weight

9.7kg



B Pillar Project



10.0 (-13.3kg)

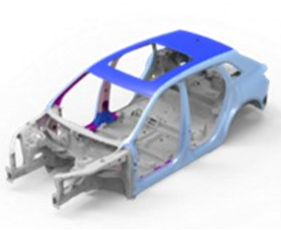


-35% to -50% weight

6.5kg



Top Hat Project



194kg

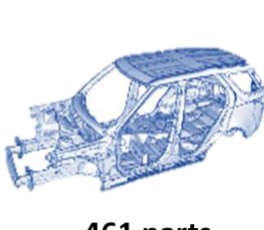


-42% weight

113kg



Joining Project



461 parts
5193 RSWs



-37% joints

399 parts
3264 SPRs



LMDV Project



SIV BIW 874kg
Vehicle 2,450kg



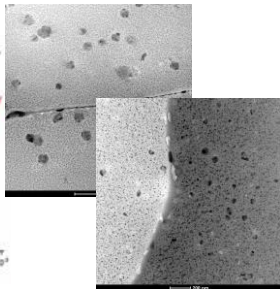
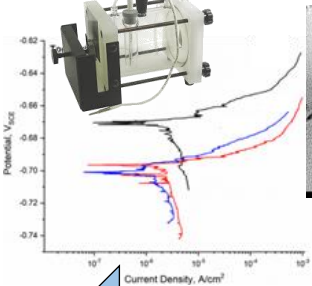
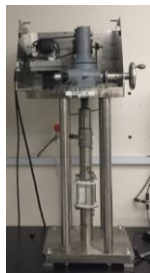
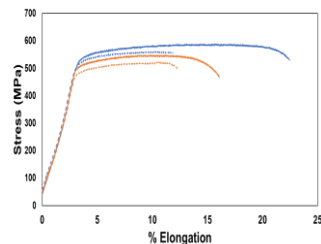
-47% weight

AIV BIW 461kg
Vehicle 1,908kg

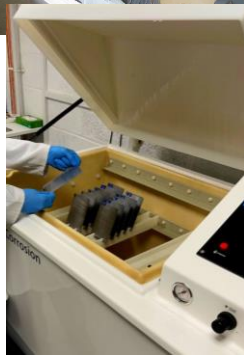
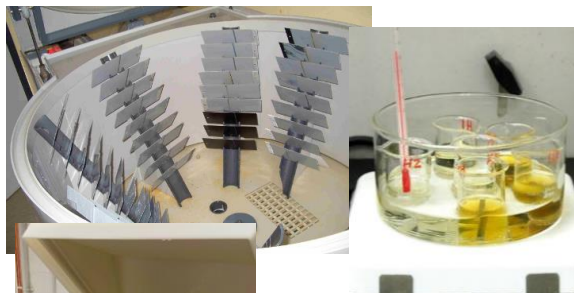


Details of Alুমobility technical projects & White Papers can be found on the website by scanning the QR Code

Material Property Characterization



Laboratory Accelerated Corrosion Testing



Field Corrosion Performance



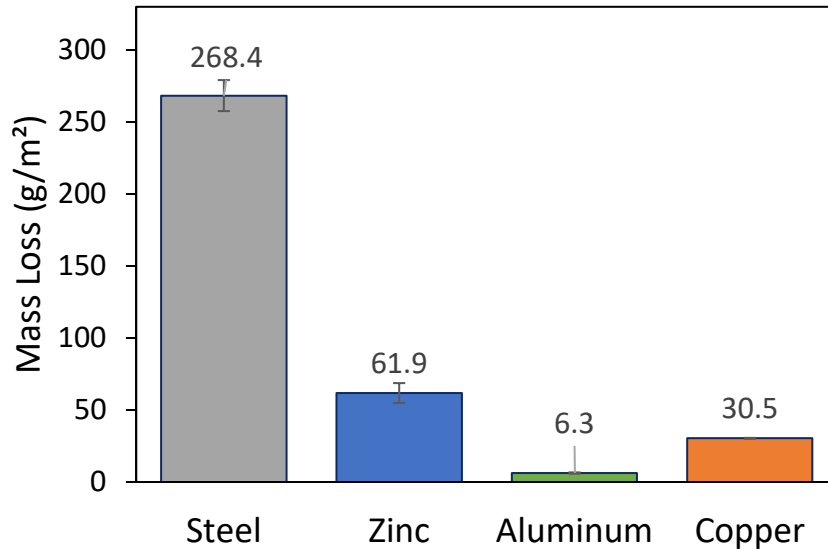
Correlate road exposure and laboratory accelerated testing considering material properties

- Partnered with Industrial research facility of NRC-Canada, based in Saguenay, Quebec
 - 2-year long study
 - Wet underbody environment (worst case scenario)
- 440 test coupons of 6xxx and 7XXX alloys
 - Mounted under a 53 ft truck trailer that traveled a total of over 360,000 km across Canada
 - Evaluated SCC, filiform corrosion, and mixed material corrosion performance
- Various sensors installed under the truck:
 - Relative humidity/temperature sensor
 - Time of wetness (TOW) sensor
 - Metal-surface temperature sensor



Corrosion of Aluminum vs. Steel

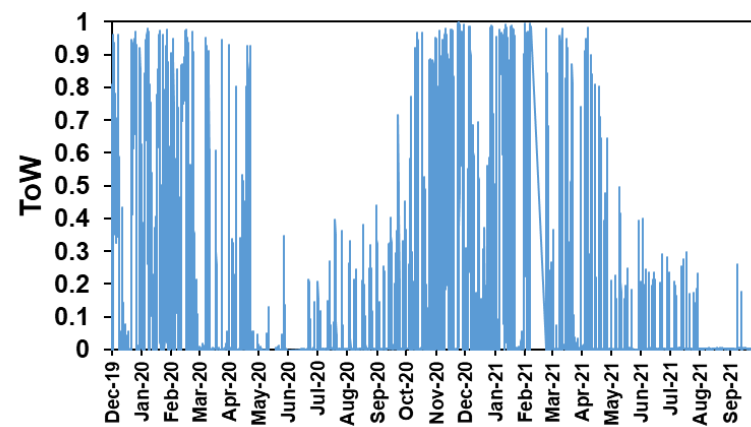
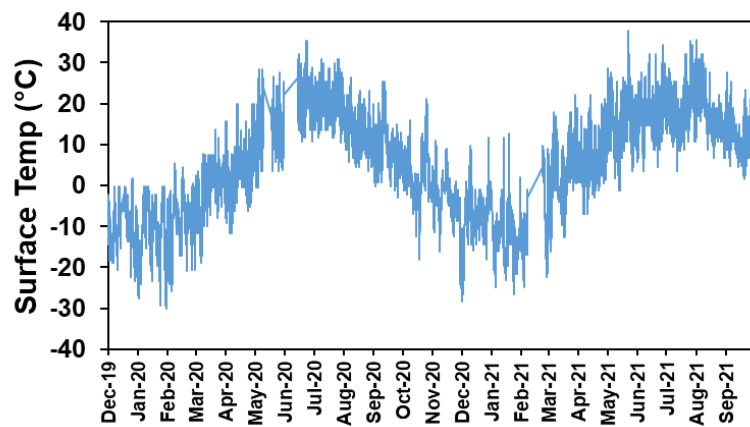
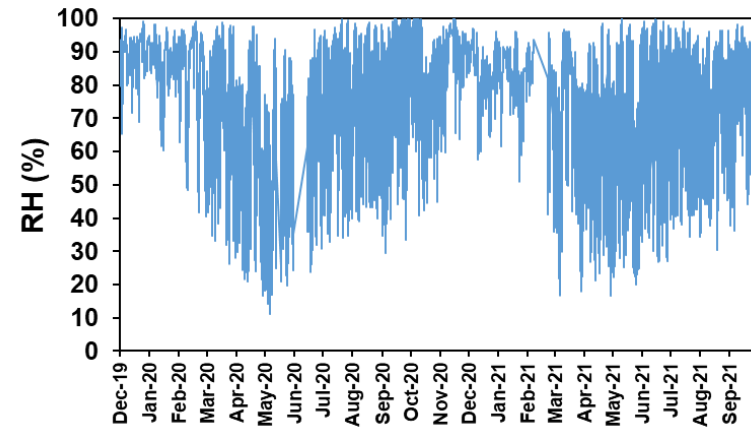
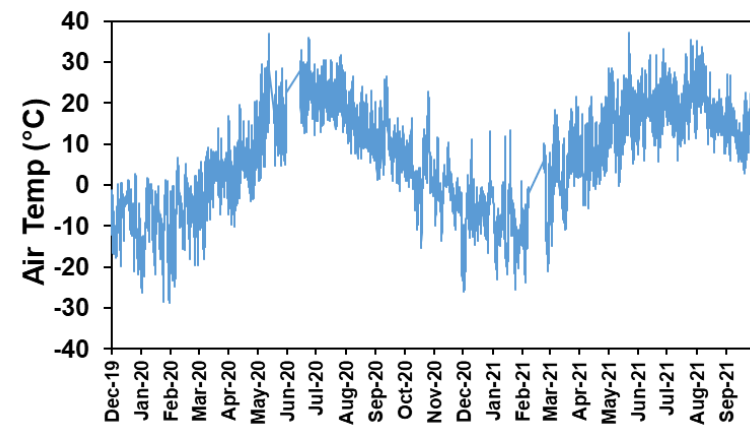
Exposed to Canadian Weather
Feb 2020 to Jan 2021



ISO 9223		Mass Loss in First Year (g/m²)			
Categories of Corrosivity		Carbon Steel		Aluminum	
		Min.	Max.	Min.	Max.
C1	"Very Low"	0	10	Negligible	
C2	"Low"	10	200	0	0.6
C3	"Medium"	200	400	0.6	2
C4	"High"	400	650	2	5
C5	"Very High"	650	1500	5	10
CX	"Extreme"	1500	5500	10	> 10

Road exposure environment is representative of very high corrosivity for aluminum

Environmental Conditions over the Exposure Period



		Joint Corrosion				Filiform Corrosion E-coated		Stress Corrosion Cracking				
								Bare		Pretreated + E-coated		
		Resistance Spot Welded		Self-Piercing Riveted				Constant Stress Frame		4-Point Bending Frame		
Alloy	Temper	Bare	Zr PT + Ecoated	Bare	Zr PT + Ecoated	ZnP PT	Zr PT	80% YS	No Stress	80%YS	No Scribe	Scribe
s615	T4	✓	✓	✓	✓	⚡	✓	⚡	⚡	⚡	⚡	⚡
	T6	✓	✓	✓	✓	⚡	✓	⚡	⚡	⚡	⚡	⚡
s650	T4	✓	✓	✓	✓	⚡	✓	⚡	⚡	⚡	⚡	⚡
	T6	✓	✓	✓	✓	⚡	✓	⚡	⚡	⚡	⚡	⚡
7075	T6	⚡	⚡	⚡	⚡	⤵	✓	✓	✓	✓	✓	✓
	T6+PB	⚡	⚡	⚡	⚡	✓	✓	✓	✓	✓	⚡	⚡
	T73	⚡	⚡	⚡	⚡	✓	✓	✓	✓	✓	✓	✓

Joint Corrosion

- S615 (0.6% Cu)
- S650 (0.9% Cu)

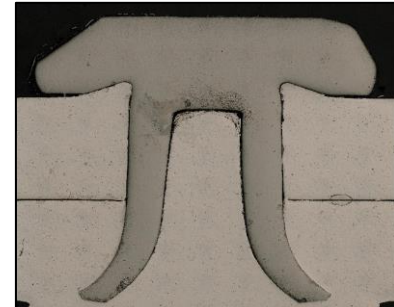
- T4+PB
- T6+PB

- SPR
- RSW

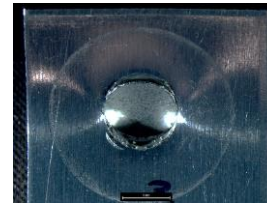
- Bare
- Zr PT + Ecoat

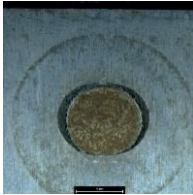
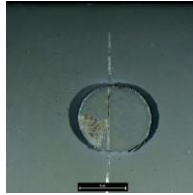
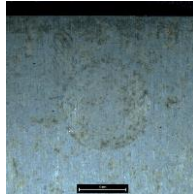
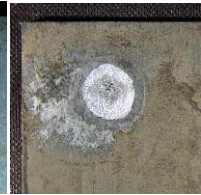
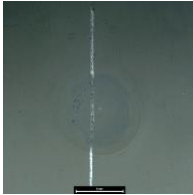
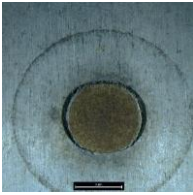
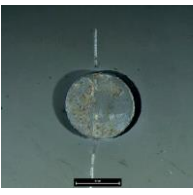
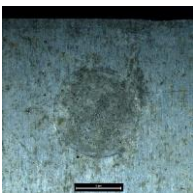
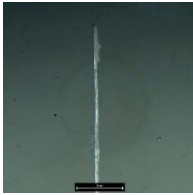


Resistance Spot Weld (**RSW**)

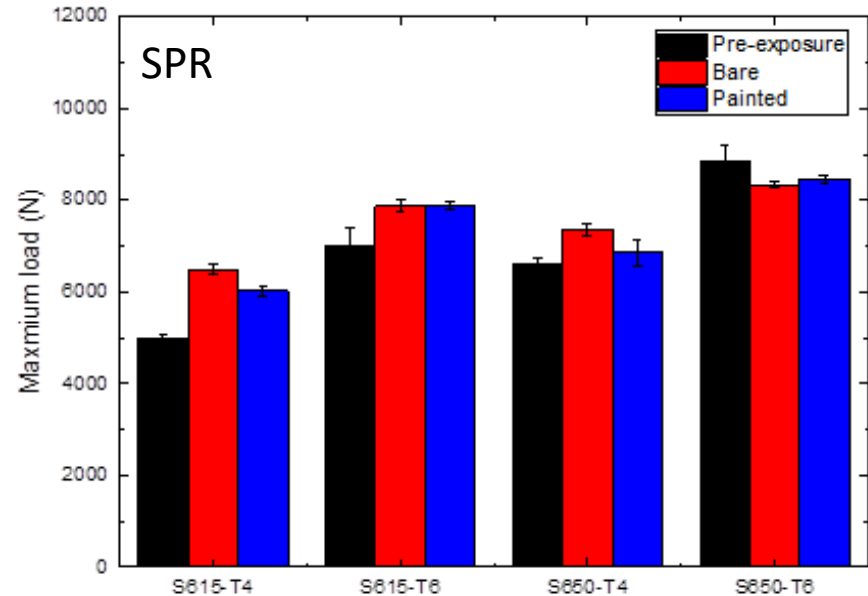
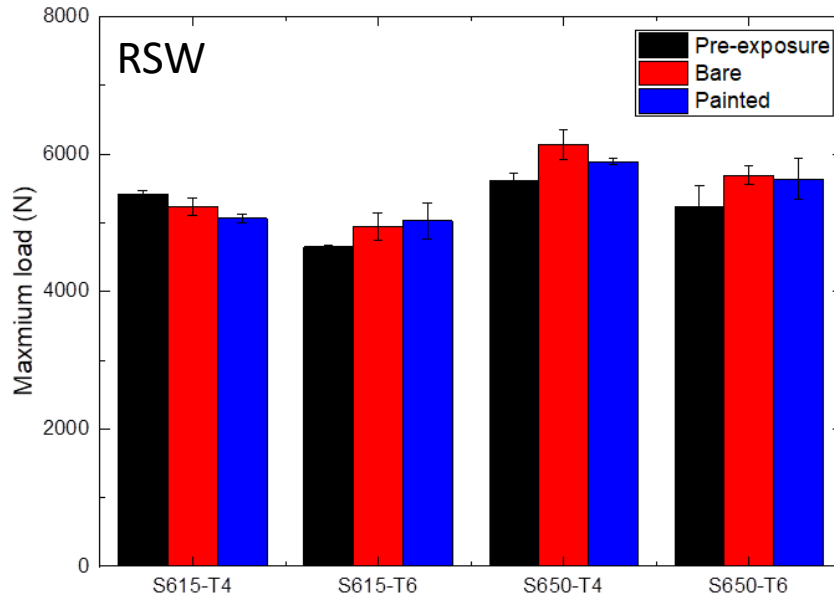


Self-Piercing Rivet (**SPR**)



	Self Piercing Riveted				Resistance Spot Welded			
	Bare		Coated		Bare		Coated	
s615-T4+PB								
s650-T4+PB								

- All the assemblies survived the 2 year road exposure
- Galvanically driven corrosion observed around bare weld/rivet region
- Relative to bare, coated samples show reduced corrosion in this area



- No significant drop in residual strength of post exposure welded and riveted joints
- E-coating does not appear to influence the residual strength

Filiform Corrosion

- S615 (0.6% Cu)
- S650 (0.9% Cu)

- T4+PB
- T6+PB

- Zr PT + Ecoat

- 7075

- T6+PB
- T73+PB

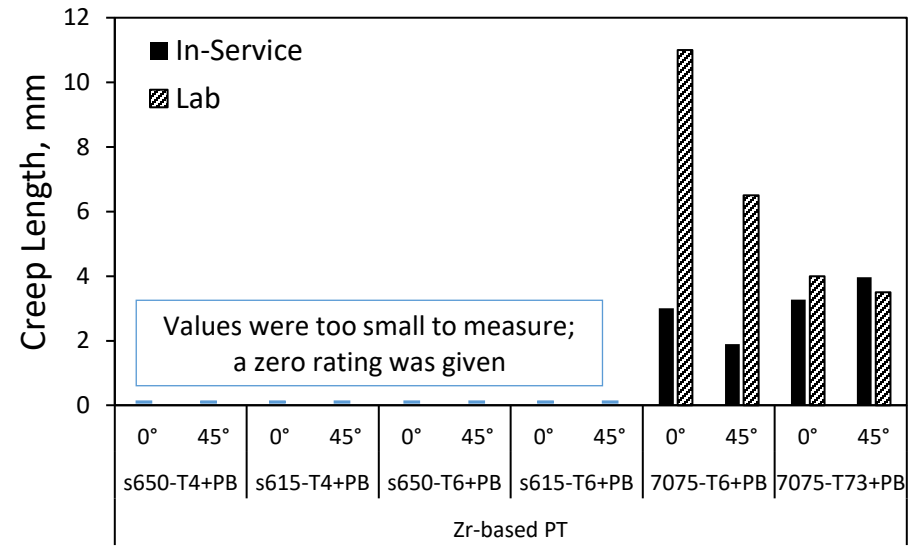
- Zr PT + Ecoat
- Zn Phos PT + Ecoat

Lab Test:

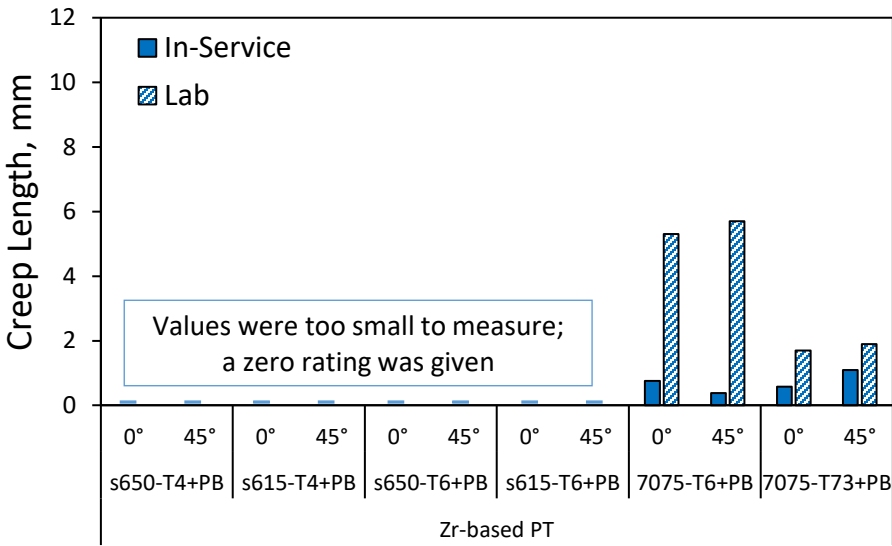
Acidic cyclic corrosion
6 week exposure



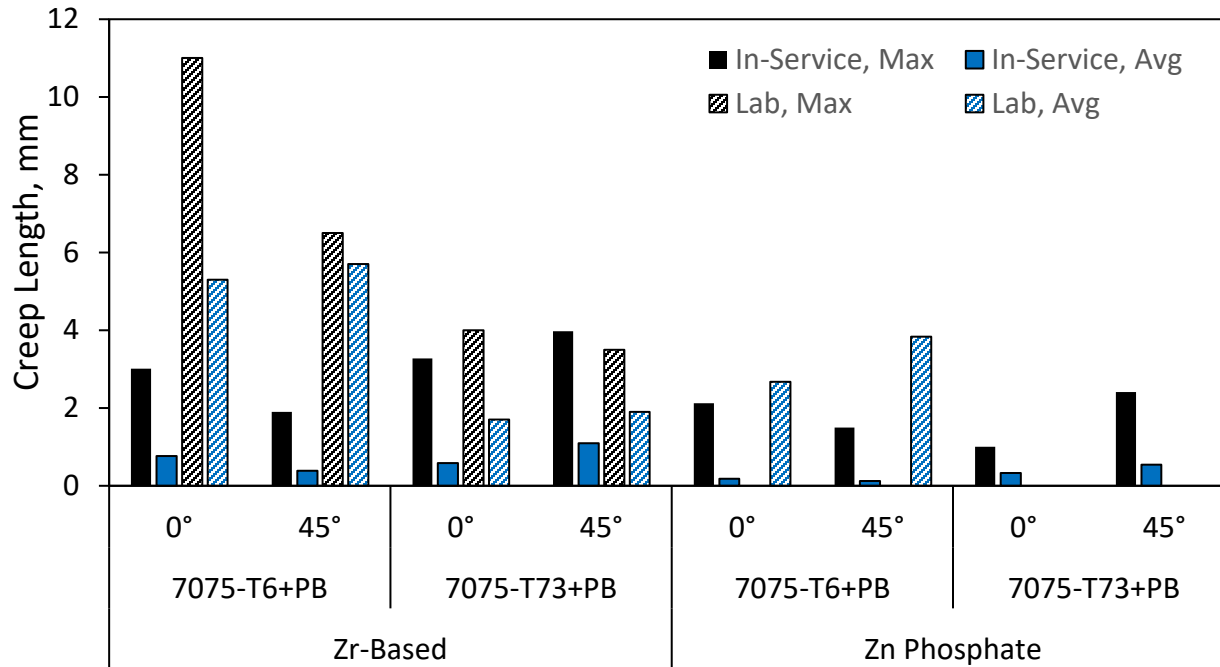
Maximum Creep Length



Average Creep Length



- Both 6xxx and 7xxx samples show acceptable performance in in-service environment
- Relative to 6xxx, 7xxx coated samples exhibited higher scribe creep length



- Lab testing typically resulted in more severe filiform corrosion than the road exposure
- Relative to the Zr-based PT, Zn phosphate performed better on 7075

Stress Corrosion Cracking

- 7075

- T6
- T6+PB
- T73+PB

- Bare
- Zn Phos + Ecoat

Lab Test: ASTM G47

Specimens held at:

- 80% of yield stress
- Baseline: unstressed

Cyclic environment:

- 10 min in 3.5 wt.% NaCl
- 50 min in air
- 40 day exposure



Passing Criteria: Survive 40 day exposure
 $\geq 80\%$ residual strength

Stress Corrosion Cracking Evaluation

Stress Corrosion Cracking

- 7075

- T6
- T6+PB
- T73+PB

- Bare
- Zn Phos PT + Ecoat

Constant Stress



4-Point Bending



Alloy	Bare Metal			PT w/ ZnP		Bare Metal
	Constant Stress Frame (Dog bone)		4-Point Bending (1" x 4")	4-Point Bending (1" x 4")		Constant Strain
	80% YS Road Exposure (Days)	0 (Unstressed) Road Exposure (Days)	80% YS Road Exposure (Days)	80% YS No Scribe (Days)	80% YS With Scribe (Days)	80% YS Lab (Days)
7075-T6						
7075-T6+PB						
7075-T73						

Stress Corrosion Cracking Evaluation

Stress Corrosion Cracking

- 7075

- T6
- T6+PB
- T73+PB

- Bare
- Zn Phos + Ecoat

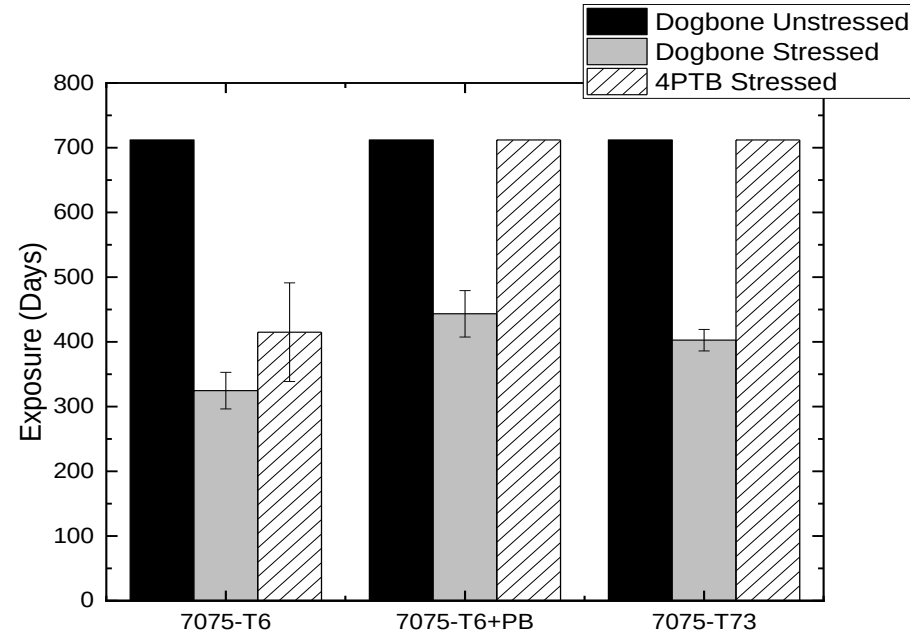
Constant Stress



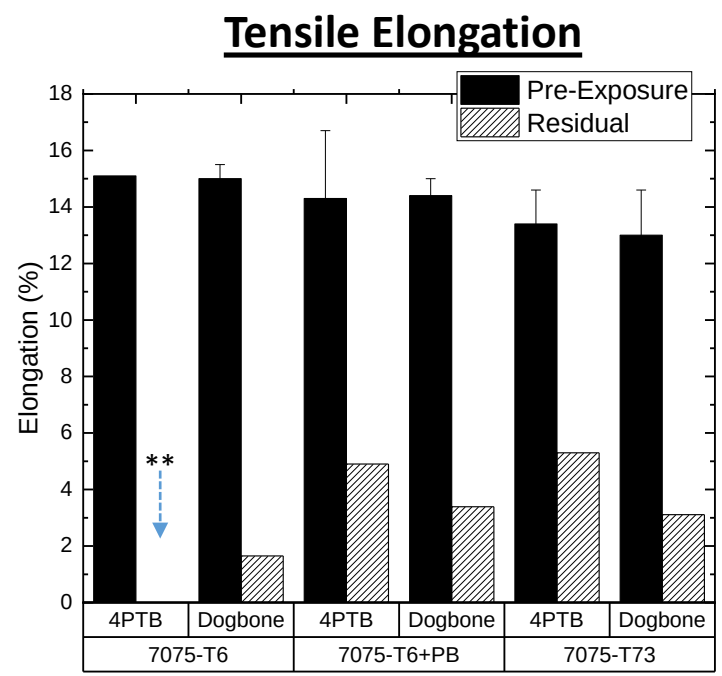
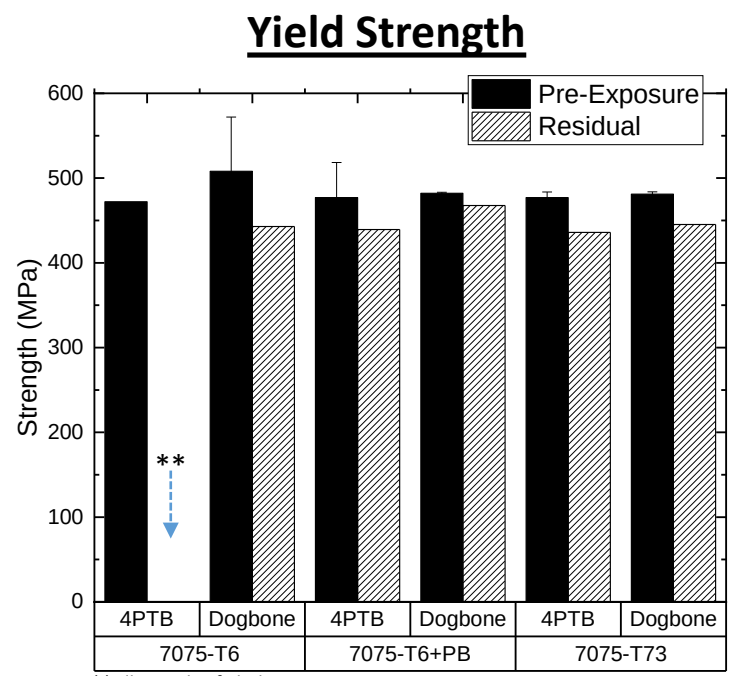
4-Point Bending



Alloy/ Temper	Bare Metal			PT w/ ZnP		Bare Metal
	Constant Stress Frame (Dog bone)		4-Point Bending (1" x 4")	4-Point Bending (1" x 4")		Constant Strain
	80% YS Road Exposure (Days)	0 (Unstressed) Road Exposure (Days)	80% YS Road Exposure (Days)	80% YS No Scribe (Days)	80% YS With Scribe (Days)	80% YS Lab (Days)
7075-T6	299, 355, 320	>712	459, 175, 327	>712	>712	40
7075-T6+PB	484, 430, 416	>712	>712	n/a	n/a	40
7075-T73	416, 408, 384	>712	>712	>712	>712	40



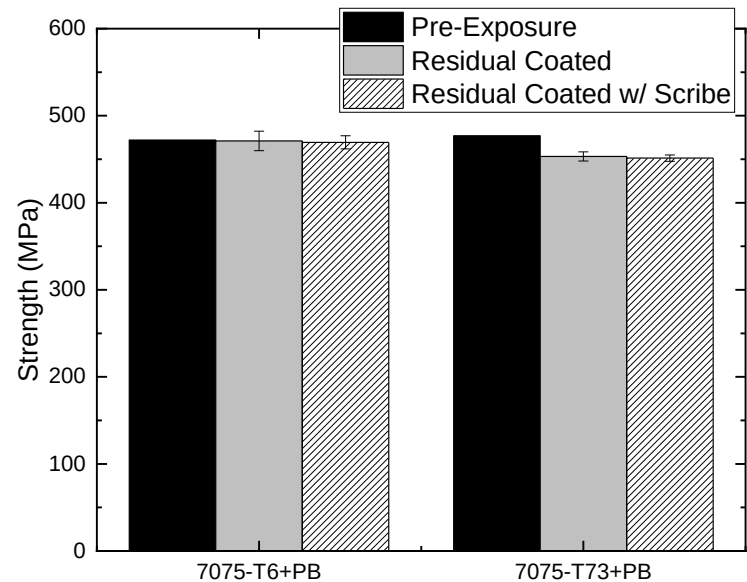
- Irrespective of temper, all the unstressed samples survived the duration of exposure
- Mode of stress application influences susceptibility to SCC
- Paint baked/overaged temper offers improved SCC resistance over the standard T6



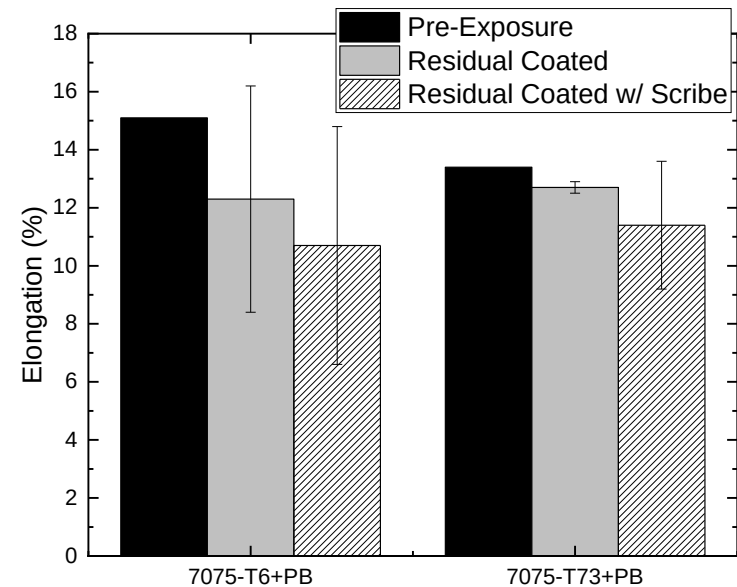
**All samples failed

The combined stress application and road exposure reduced the residual elongation without impacting the residual strength

Yield Strength



Tensile Elongation



Protection from coatings rendered smaller drop in elongation relative to the bare samples

Joint corrosion performance of high strength 6XXX alloys s615 and s650

- All RSW and SPR joint test coupons **passed** the full 2-year road-exposure in harsh Canadian winters, without drop in residual strength

Filiform corrosion performance of high strength 6XXX and ultra-high strength 7XXX alloys

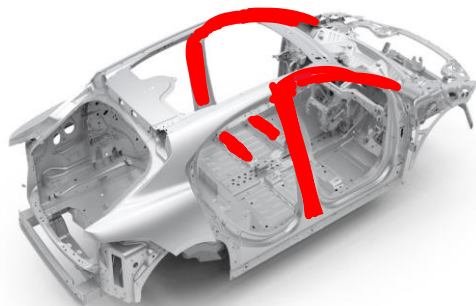
- All test coupons (6XXX and 7XXX) **passed** the full 2-year road-exposure
- For 7XXX, FFC results after full road-exposure are better than the lab test results

Stress corrosion cracking performance of ultra-high strength 7XXX alloys

- Simulated service temper (T6+PB) and over-aged temper (T73) for s701 (AA7075) showed better SCC performance than peak-aged temper (T6)
- Zn phosphate + e-coating improves the SCC resistance of AA7075 alloys

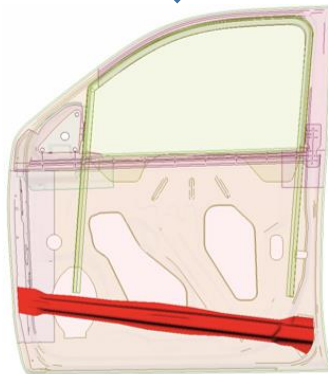
Low Corrosion Applications

- Floor Reinforcements
- Roof Rails
- A Pillar Reinforcement
- B Pillar Reinforcement



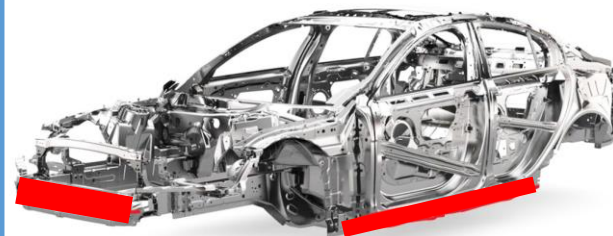
Intermediate Corrosion Applications

- Door Intrusion Beams



High Corrosion Applications

- Rockers
- Front & Rear Bumpers
- Underbody



- Key learnings are being used to improve Phase III road exposure testing in collaboration with NRC-Canada
- Initiated Phase III testing – on test until March 2025
 - Press hardened steel included, as a key reference material
 - Varying environmental severity
 - Varying mechanical load for SCC samples (use more realistic load levels)
 - Accelerated laboratory testing being run in parallel to establish correlation



THANK YOU!

For additional details please contact:
Marylyn.lim@novelis.vom