

Effects of wet dry cycling environment on bond deterioration at interface of CFRP and corroded steel

CAI, Lianheng
Structural Design Laboratory, Kyushu University

YANG, Muye
Structural Design Laboratory, Kyushu University

Kainuma, Shigenobu
Structural Design Laboratory, Kyushu University

<https://hdl.handle.net/2324/7238319>

出版情報 : 2024-03-09. 土木学会西部支部
バージョン :
権利関係 :



Effects of wet-dry cycling environment on bond deterioration at interface of CFRP and corroded steel

Lianheng CAI, Muye YANG, Shigenobu KAINUMA

Structural Design Lab.

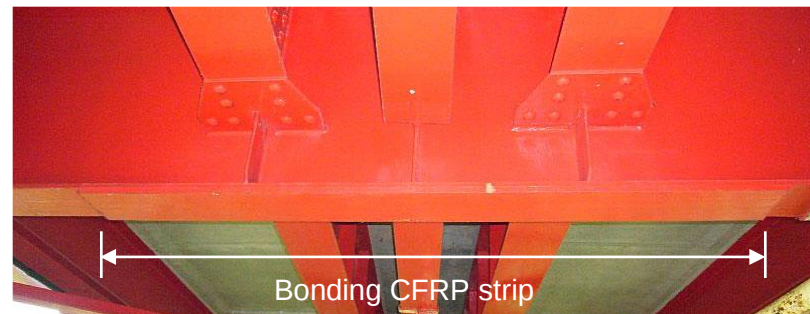
Kyushu University



九州大学

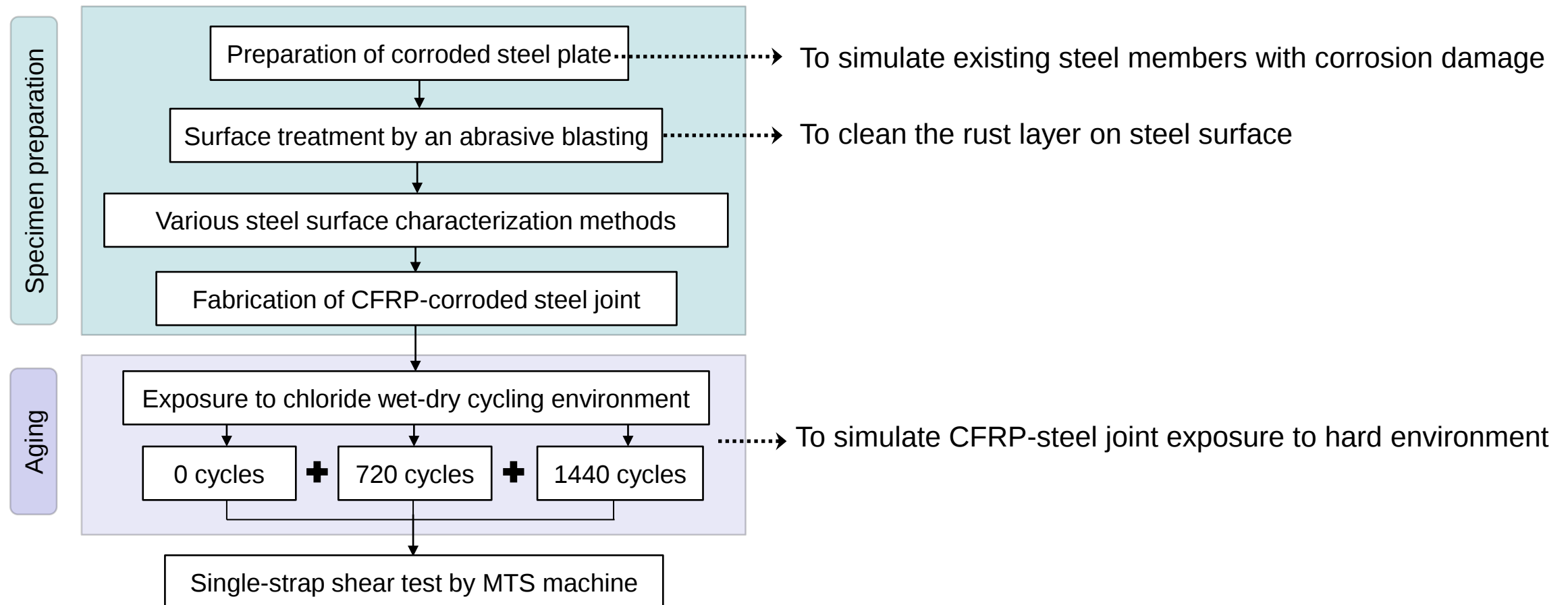
Background

CFRP strip has been proven effective for repairing existing steel members.



Purpose

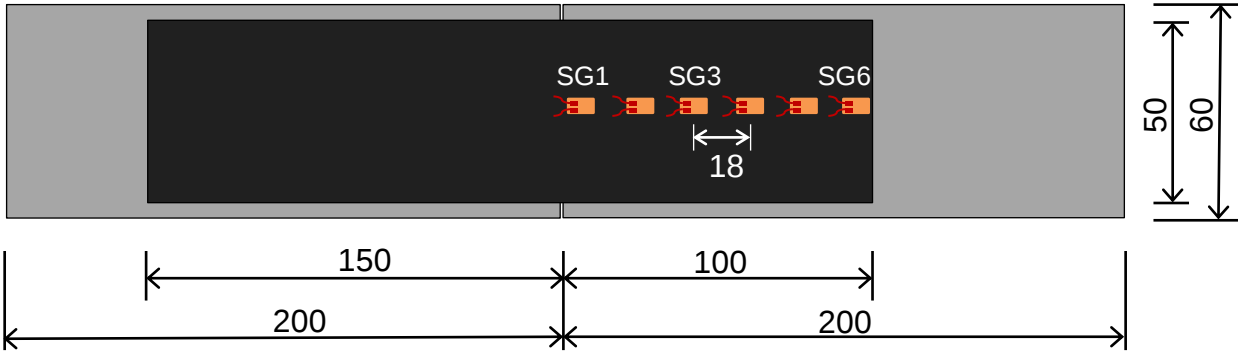
To evaluate the interfacial durability of CFRP-corroded steel joint under harsh environment.



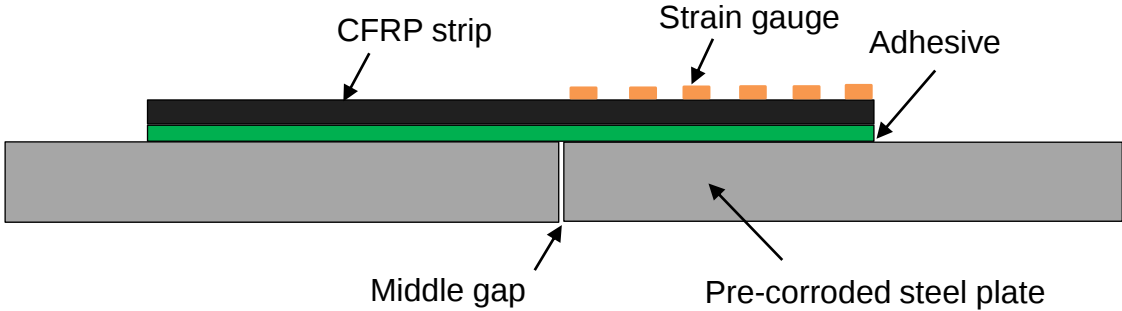
Design of specimen

Specimen ID	Pre-corrosion level of steel	Surface treatment method	Number of wet-dry cycles (WDCs) of CFRP/steel joint	Repetition
CFA0	JIS K5600-7-9, Cycle A 60 days	Abrasive blasting	0	3
CFA720			720	
CFA1440			1440	

Front view



Side view



Preparation of corroded steel plate

Cyclic corrosion test



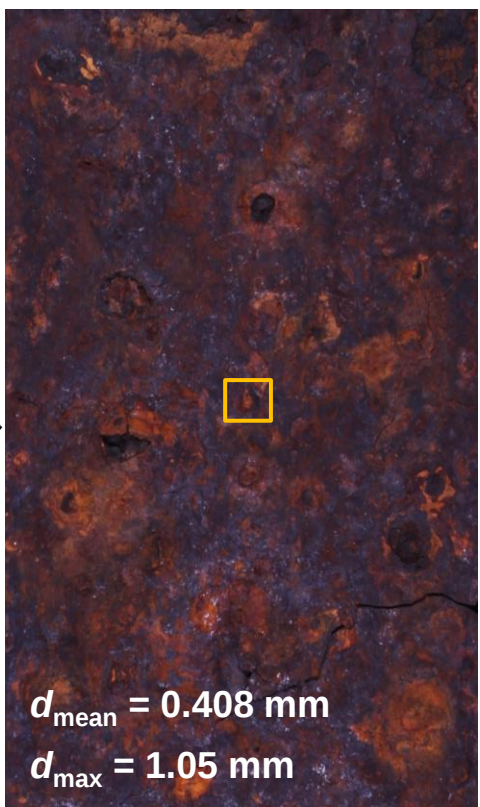
Salt fog spraying
 $35 \pm 1^\circ\text{C}$, 95%RH
 2 hrs

Wetting
 $60 \pm 1^\circ\text{C}$, 20%RH
 4 hrs

Drying
 $50 \pm 1^\circ\text{C}$, 95%RH
 2 hrs

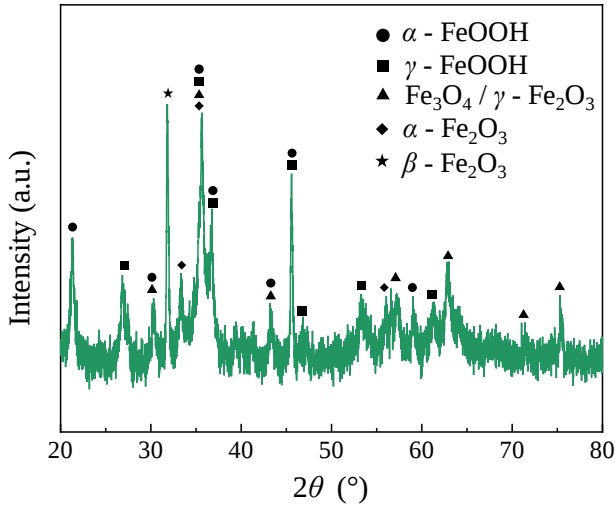
(Ref. JIS K5600-7-9, Cycle A)

After 60 days



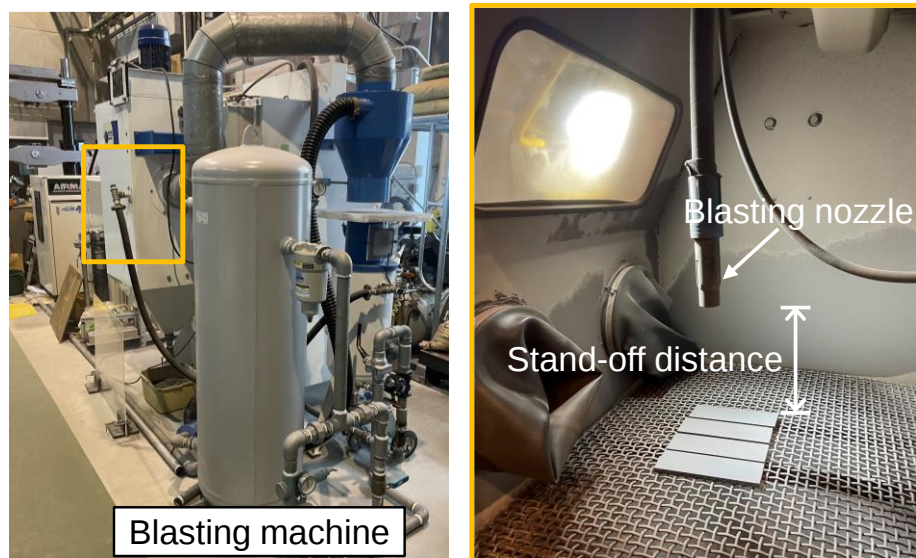
$d_{\text{mean}} = 0.408 \text{ mm}$
 $d_{\text{max}} = 1.05 \text{ mm}$

60 mm



Surface treatment method

■ Air-driven abrasive blasting work



- Abrasives: garnet particles #80
- Pressure: 0.7 MPa
- Jet angle: 90°
- Stand-off distance: 300 mm

■ Detailed information of abrasives

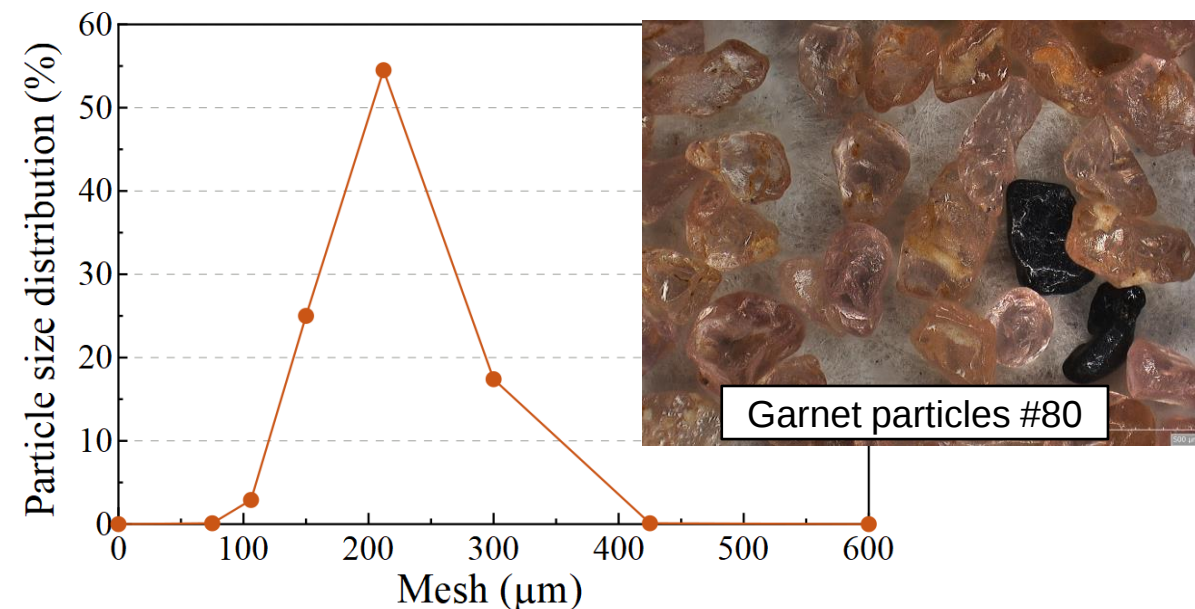
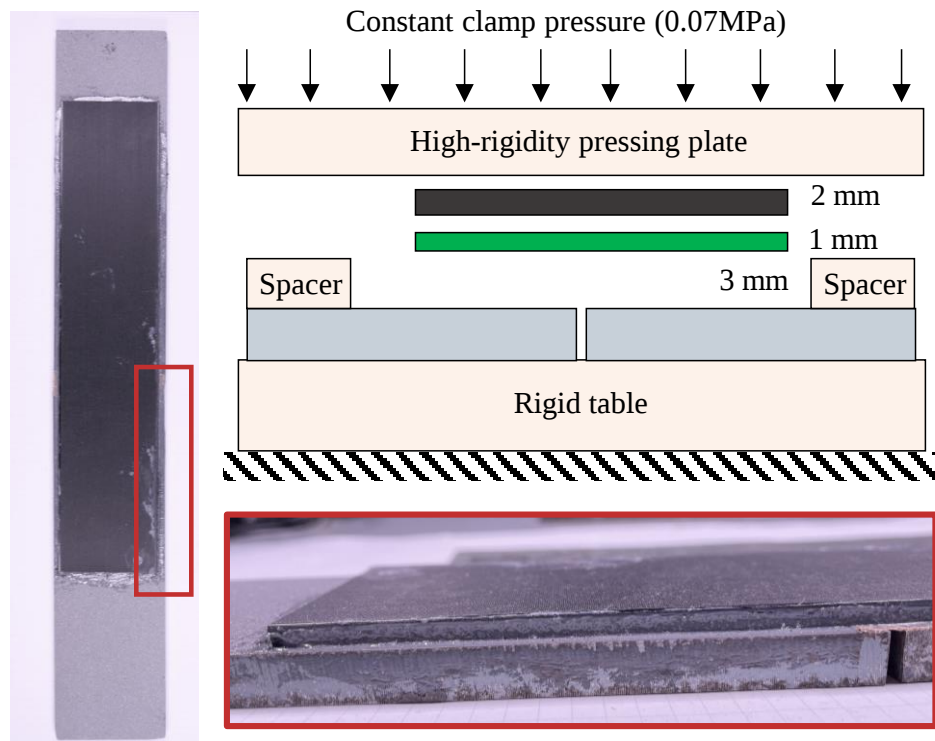


Table. Chemical composition of garnet particles (unit: wt.%)

Abrasive particles	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	TiO ₂
Garnet #80	33.4	20.0	33.8	2.30	5.64	3.43

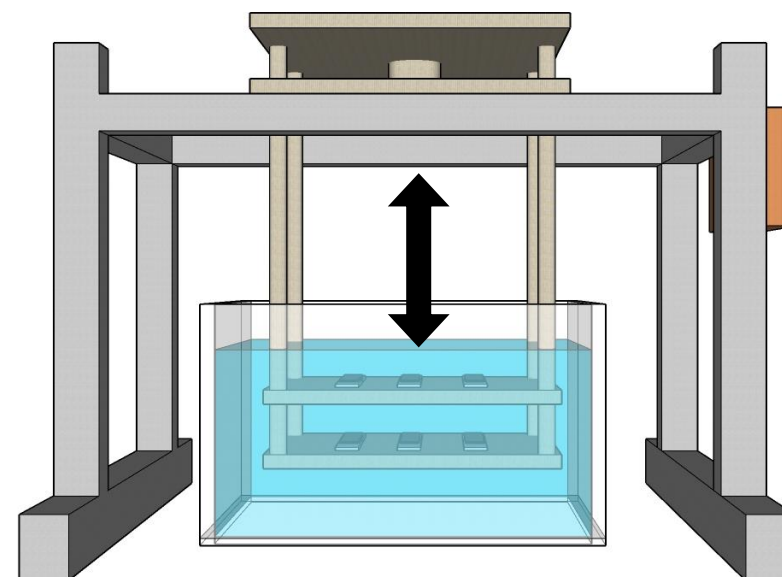
Joint fabrication & Environmental exposure

■ Fabrication process



■ Wet-drying cycling environment

Various aging periods: 0, 720, 1440 cycles



1 cycle = wetting (10 min) + drying (50 min)

Results — Failure modes

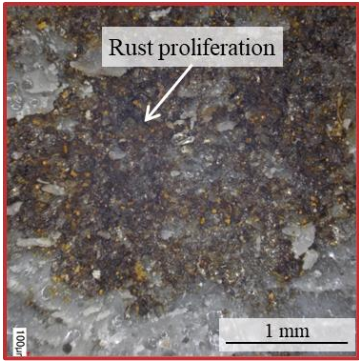
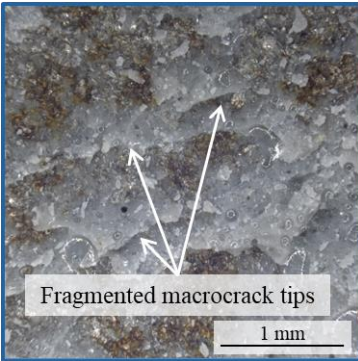
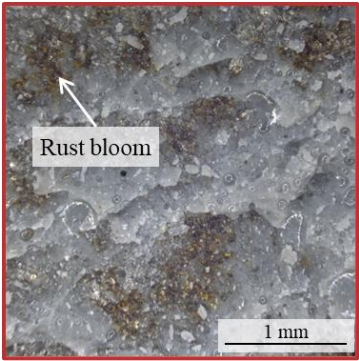
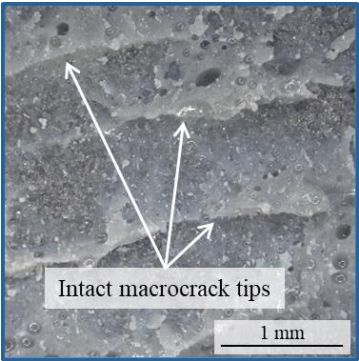
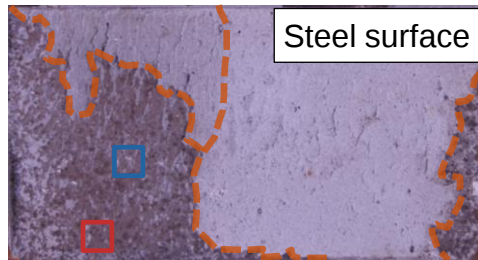
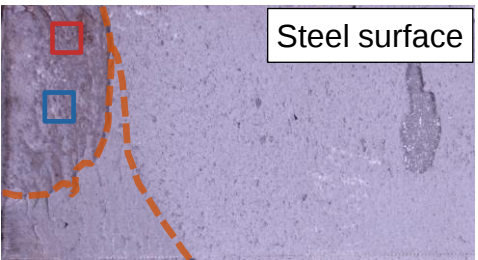
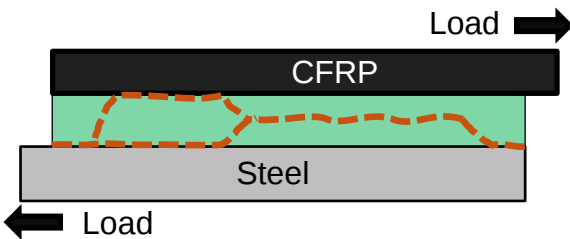
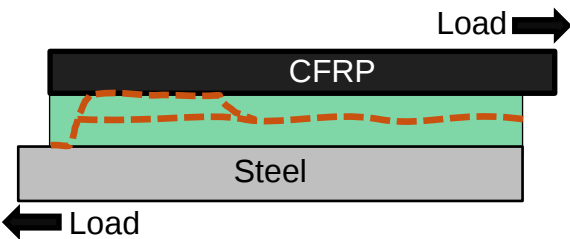
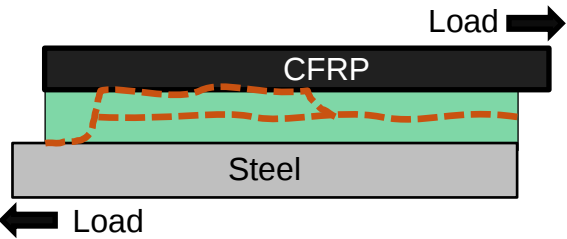
720 WDCs

1440 WDCs

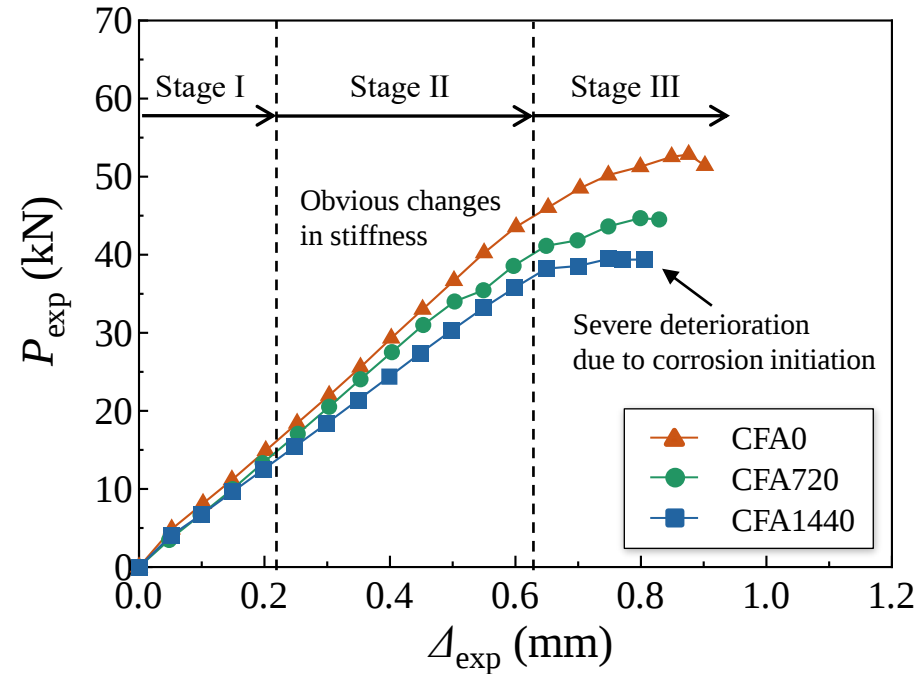
CFA0

CFA720

CFA1440



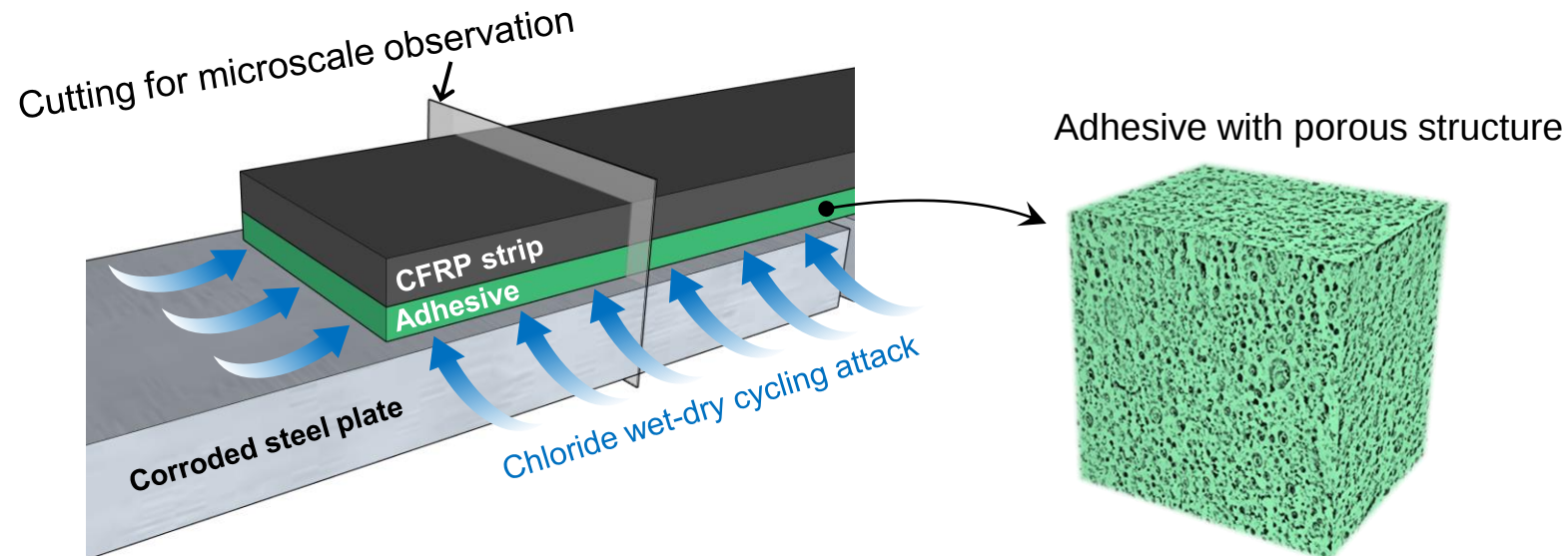
Results — Load-displacement curve



■ Three distinct stages present various interfacial stress behavior of bonded joints.

■ Number of wet-dry cycles $\uparrow$ $\Rightarrow$ Stiffness $\downarrow$ Capacity $\downarrow$ Plasticity $\uparrow$

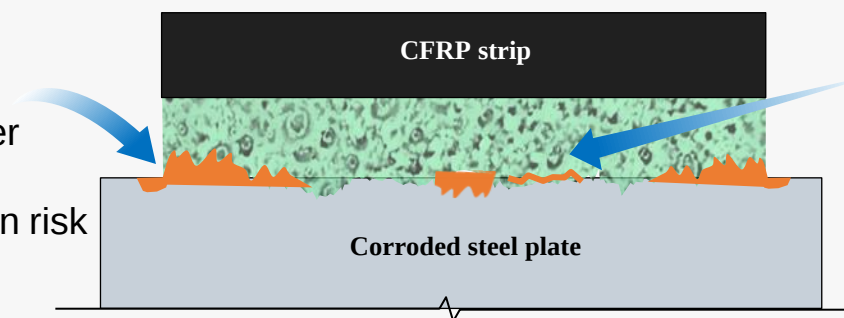
Results — Deterioration mechanism



Observation of cross section

External factors:

- Stagnant saltwater
- Capillary action
- Galvanic corrosion risk

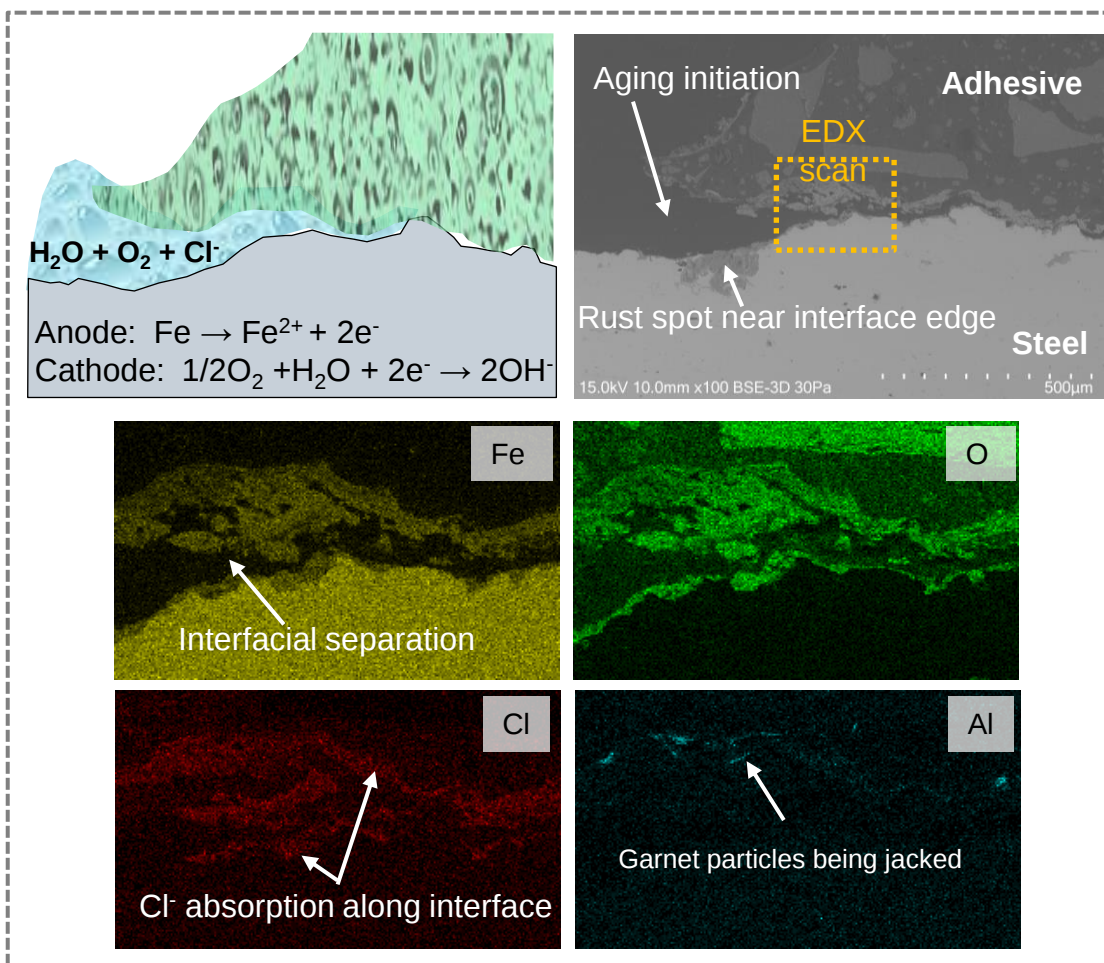


Internal factors:

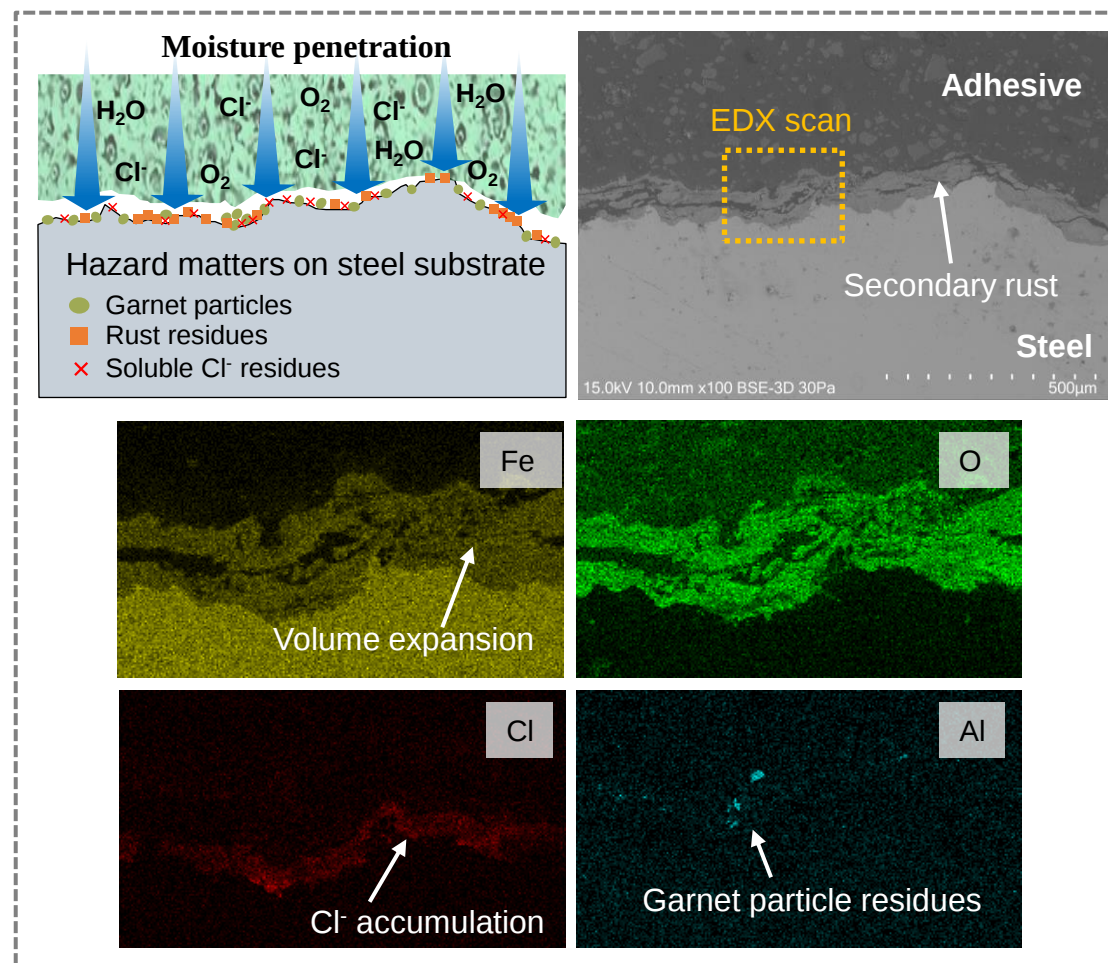
- Moisture penetration
- Hazard matters on steel substrate, including:
 - Abrasive particles (herein, garnet)
 - Rust residues
 - Soluble Cl^- residues
 - ...

Results — Deterioration mechanism

External factor



Internal factor



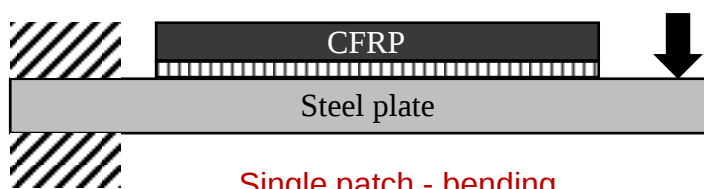
Conclusions

- ✓ There is an **undesirable shift** in the triggering failure mode at the ends.
- ✓ As the aging period increased, an **obvious reduction** was observed in the joint stiffness and capacity.
- ✓ Deterioration mechanism encompassed **“foreign attacks”** and **“domestic unrest”**.
 - **“foreign attacks”**: external factors, marked by corrosion at the bonding edges and inward capillary diffusion of chloride ions.
 - **“domestic unrest”**: internal factors, exemplified by the development of those adherent chloride/rust residues, weakening steel-adhesive bonds, and risk of separation.

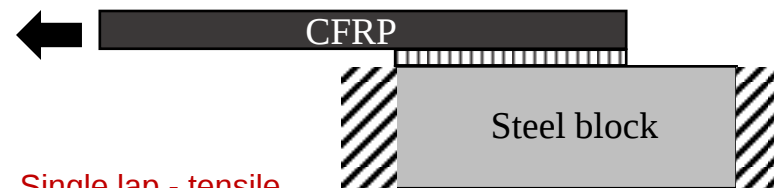
Thanks for Listening !



Bonded joint configurations of CFRP and steel



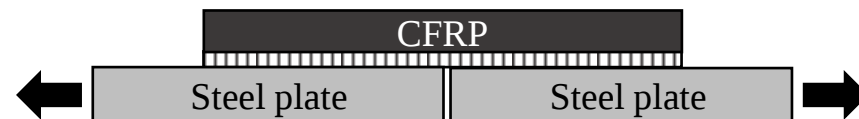
Single patch - bending



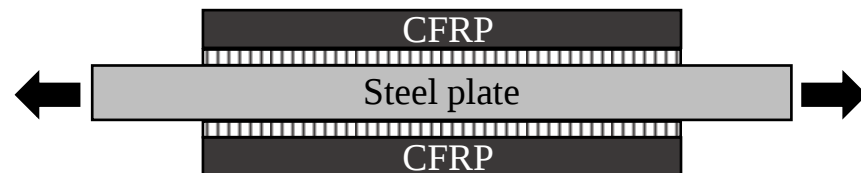
Single lap - tensile



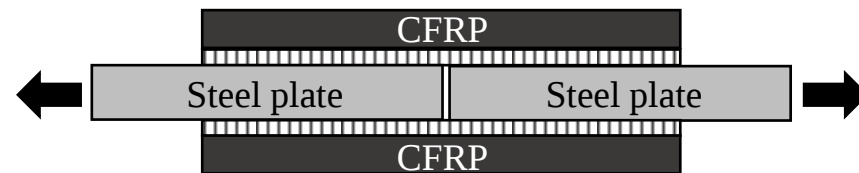
Single patch - tensile



Single strap - tensile



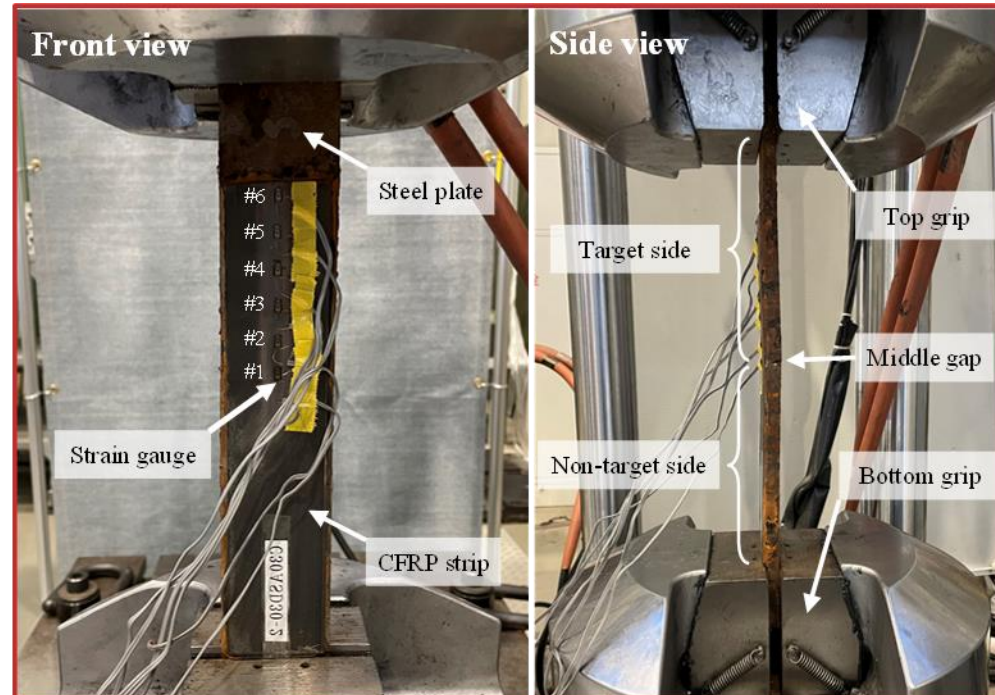
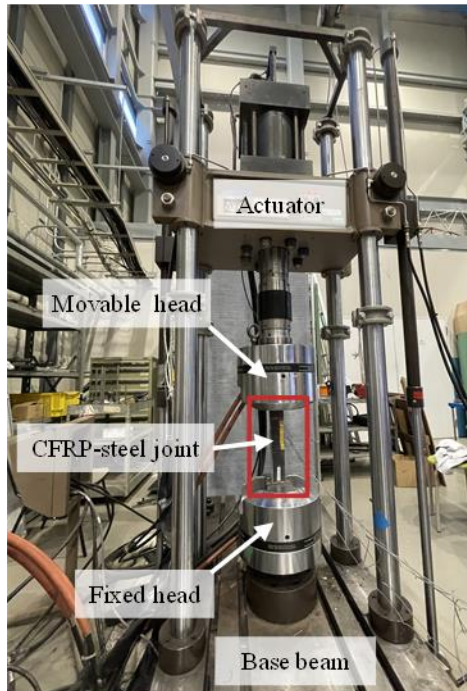
Double patch - tensile



Double strap - tensile

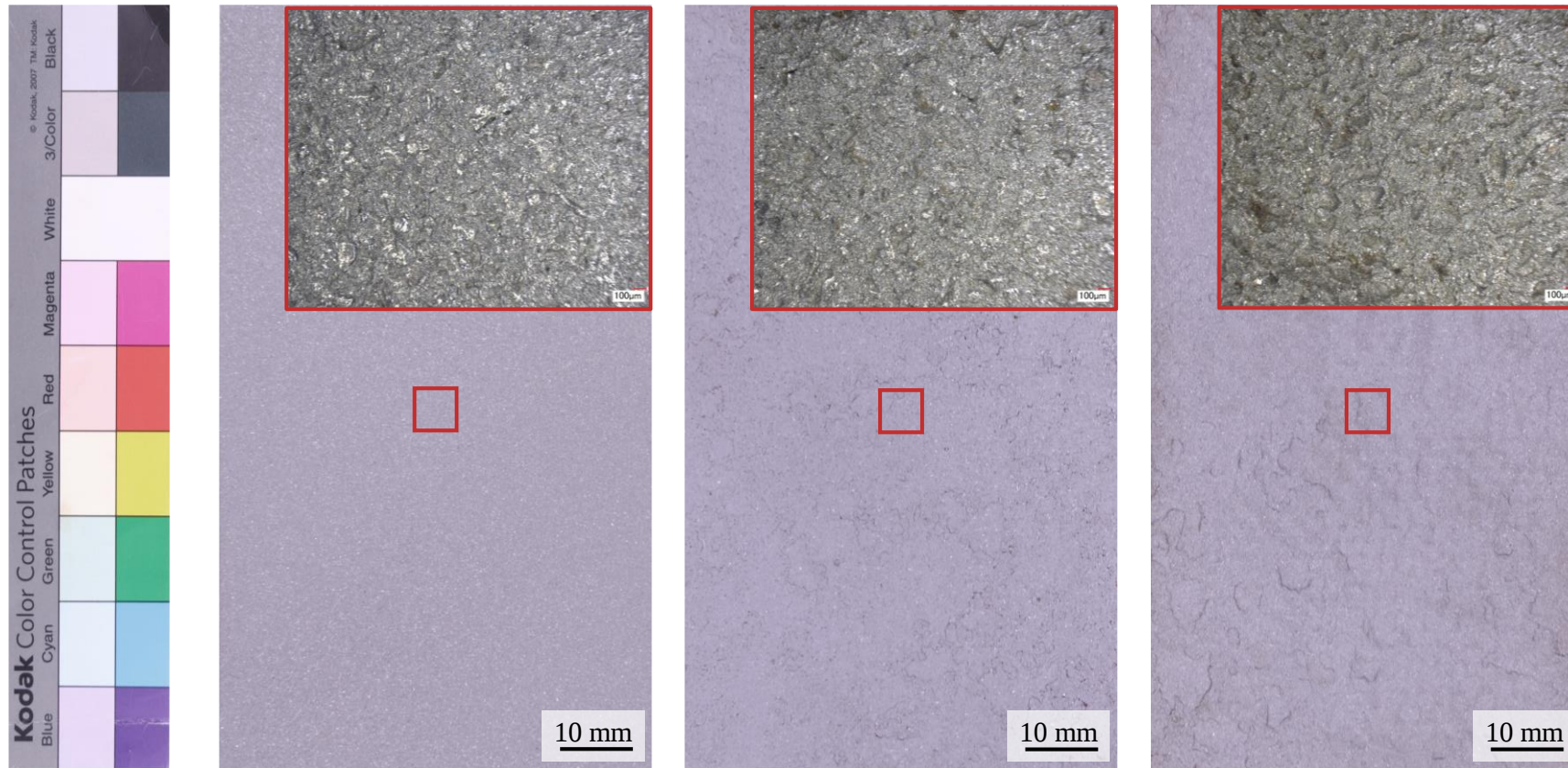
Test setup

- Monotonic uniaxial loading
- Preloading test conducted with a peak value set at 10% P_u
- Displacement control, speed: 0.3 mm/min
- Data record: external load, displacement, CFRP strain



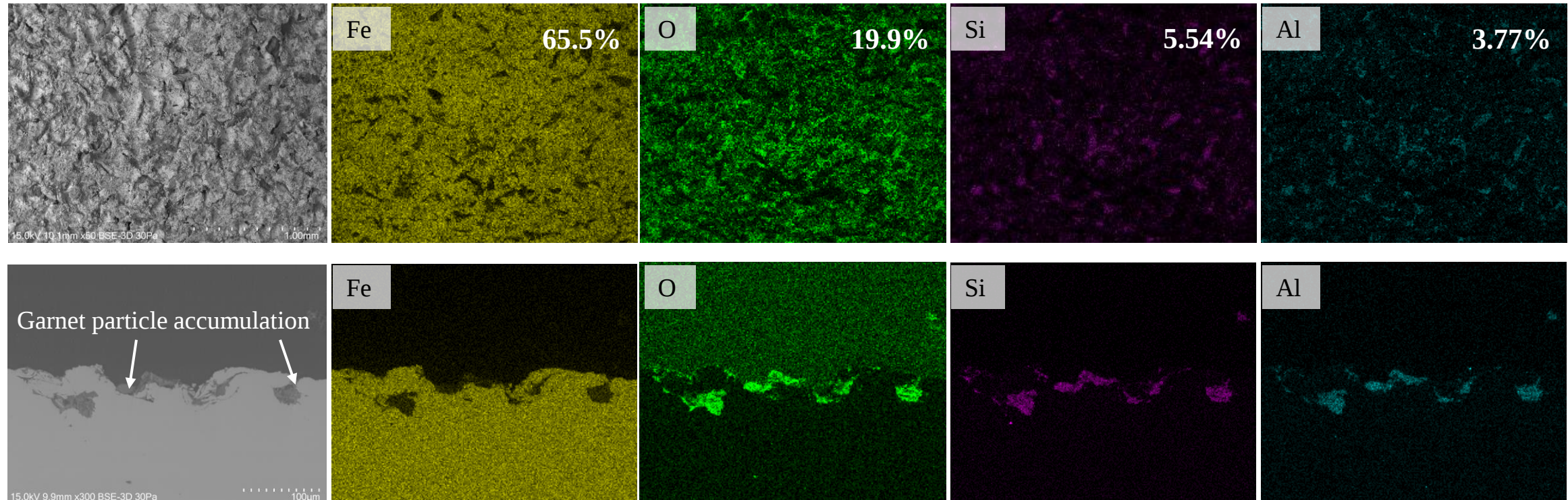
Steel surface characterization ①

■ Observation



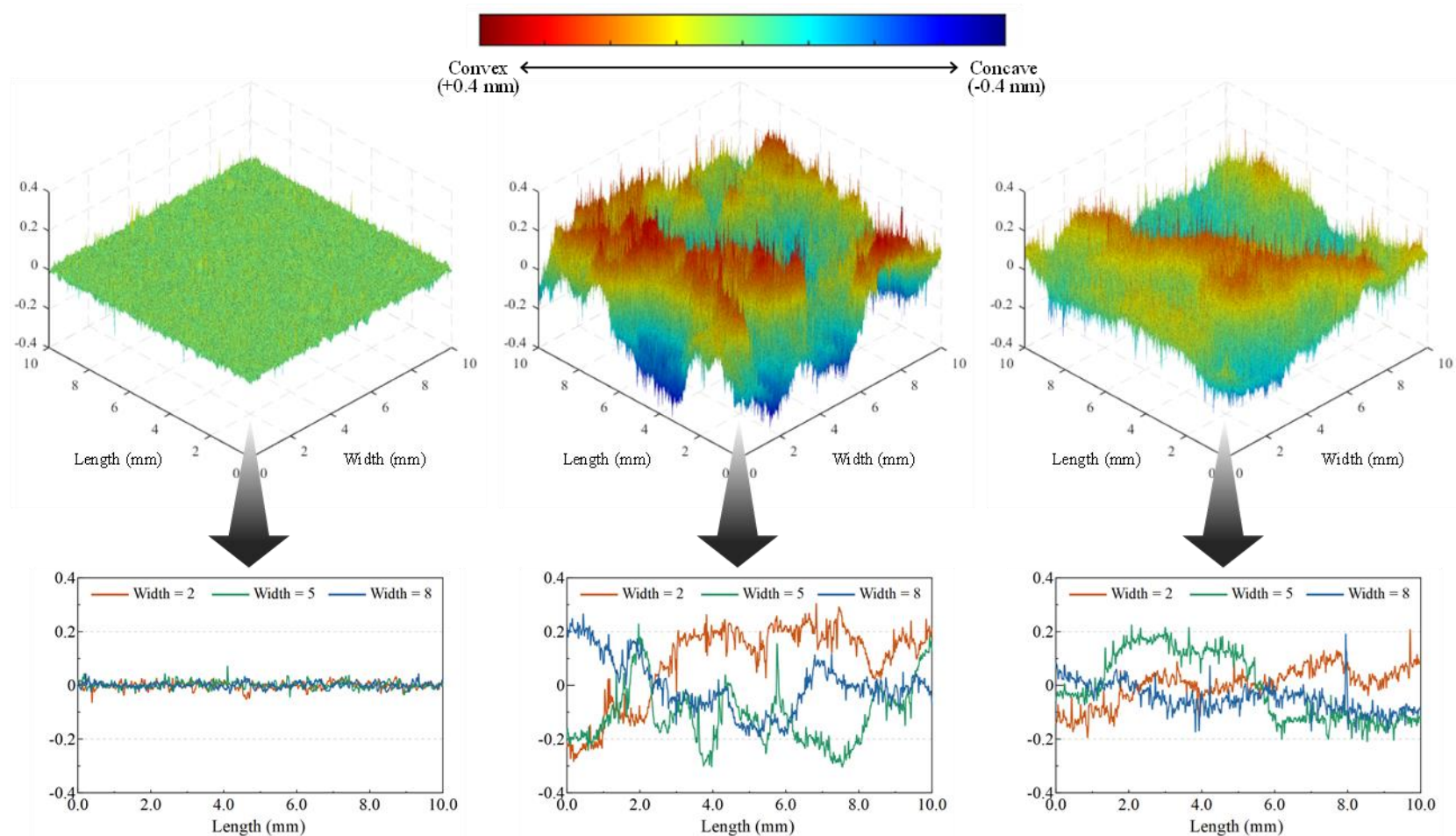
Steel surface characterization ②

■ Analysis of SEM-EDX



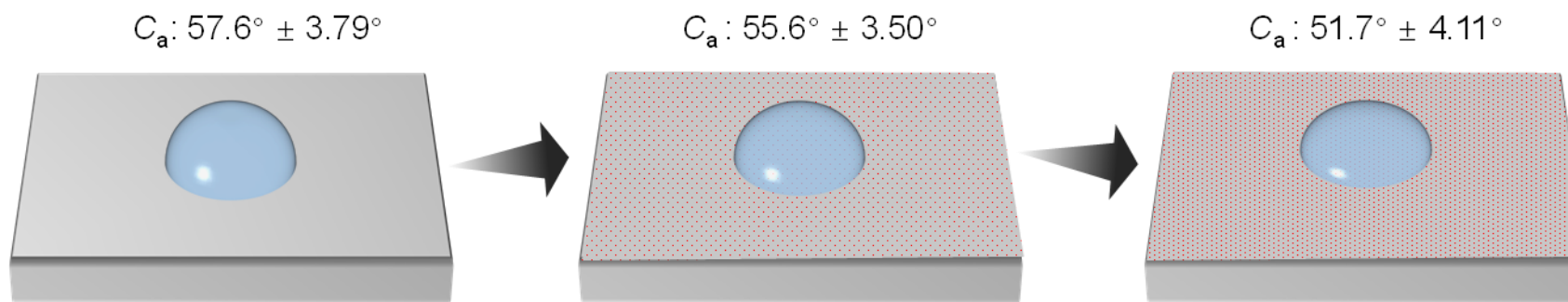
Steel surface characterization ③

■ Surface topography



Steel surface characterization ④

■ Soluble salt retention & Contact angle



Specimen ID	Element content (%)		Profile/surface roughness (μm)						r	D_b	C_a ($^\circ$)	w_s ($\text{mg}\cdot\text{m}^{-2}$)
	Fe	O	R_a	R_q	R_z	S_a	S_q	S_z				
C0FA0	71.5	14.2	9.39	12.3	77.7	8.66	11.3	103	1.23	1.28	57.6	~50
C0FA720												
C0FA1440												
C1FA0	69.6	16.7	33.0	41.7	245	29.4	38.7	294	1.30	1.31	55.6	507
C1FA720												
C1FA1440												
C2FA0	65.5	19.9	21.5	28.2	196	17.6	22.6	187	1.31	1.32	51.7	1,117
C2FA720												
C2FA1440												