Deliverable 4

Testing Protocol and Material Specifications for Basalt Fiber Reinforced Polymer Bars

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Chapter 1

Chemical, Physical, and Material Properties of Rebar and Components After Exposure to Aggressive Environments

1.1 Introduction

It is the goal of this deliverable to list the performance evaluation of BFRP rebars after exposing them to aggressive environments for 300 days at 60 °C. Several physical, mechanical, and chemical tests were executed for each rebar sample, raw material, and exposure solution after exposure to various combinations of saline and alkaline environments. Accordingly, this deliverable focuses on three major aspects: 1) the characterization of exposure solutions, 2) the characterization of BFRP rebar components, and 3) the characterization of BFRP rebar specimens.

1.2 Properties of Exposure Environments after 300 Day Exposure

This section presents the chemical properties of all exposure environments used in the research to expose rebars and rebar components.

1.2.1 pH

The pH of the chemical environments was measured after 300 days of exposure. Tables 1.1, 1.2, and 1.3 below shows the pH data of environments in which rebars, resins, and fibers were

exposed.

Table 1.1: pH Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						pH			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$	$\vee$	μ	σ
A	Epoxy	1	300	4	0	3.52	3.58	3.55	0.03
B	Vinyl Ester	1	300	4	0	4.25	4.29	4.27	0.02
C	Epoxy	1	300	4	0	3.80	3.82	3.81	0.01
A	Epoxy	1	300	4	200	3.48	3.52	3.50	0.02
B	Vinyl Ester	1	300	4	200	4.26	4.32	4.29	0.03
C	Epoxy	1	300	4	200	3.71	3.75	3.73	0.02
A	Epoxy	1	300	4	20000	3.46	3.52	3.49	0.03
B	Vinyl Ester	1	300	4	20000	4.35	4.41	4.38	0.03
C	Epoxy	1	300	4	20000	3.66	3.68	3.67	0.01
A	Epoxy	1	300	4	SeaWater	3.41	3.45	3.43	0.02
B	Vinyl Ester	1	300	4	SeaWater	4.47	4.48	4.47	0.01
C	Epoxy	1	300	4	SeaWater	3.57	3.59	3.58	0.01
A	Epoxy	2	300	4	0	3.39	3.45	3.42	0.03
B	Vinyl Ester	2	300	4	0	4.30	4.34	4.32	0.02
C	Epoxy	2	300	4	0	3.72	3.75	3.74	0.02
A	Epoxy	2	300	4	200	3.42	3.48	3.45	0.03
B	Vinyl Ester	2	300	4	200	4.31	4.35	4.33	0.02
C	Epoxy	2	300	4	200	3.65	3.66	3.65	0.01
A	Epoxy	2	300	4	20000	3.51	3.55	3.53	0.02
B	Vinyl Ester	2	300	4	20000	4.34	4.36	4.35	0.01
C	Epoxy	2	300	4	20000	3.58	3.65	3.62	0.04
A	Epoxy	2	300	4	SeaWater	3.46	3.49	3.47	0.02
B	Vinyl Ester	2	300	4	SeaWater	4.42	4.43	4.42	0.01
C	Epoxy	2	300	4	SeaWater	3.52	3.58	3.55	0.03
A	Epoxy	1	300	7	0	6.72	6.78	6.75	0.03
B	Vinyl Ester	1	300	7	0	7.15	7.21	7.18	0.03
C	Epoxy	1	300	7	0	6.80	6.82	6.81	0.01
A	Epoxy	1	300	7	200	6.61	6.65	6.63	0.02
B	Vinyl Ester	1	300	7	200	7.18	7.24	7.21	0.03
C	Epoxy	1	300	7	200	6.77	6.79	6.78	0.01
A	Epoxy	1	300	7	20000	6.60	6.62	6.61	0.01
B	Vinyl Ester	1	300	7	20000	7.26	7.32	7.29	0.03
C	Epoxy	1	300	7	20000	6.65	6.70	6.68	0.02
A	Epoxy	1	300	7	SeaWater	6.43	6.51	6.47	0.04
B	Vinyl Ester	1	300	7	SeaWater	7.34	7.40	7.37	0.03

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Table 1.1: pH Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						pH			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$	$\vee$	μ	σ
C	Epoxy	1	300	7	SeaWater	6.56	6.59	6.57	0.02
A	Epoxy	2	300	7	0	6.53	6.55	6.54	0.01
B	Vinyl Ester	2	300	7	0	7.40	7.46	7.43	0.03
C	Epoxy	2	300	7	0	6.55	6.61	6.58	0.03
A	Epoxy	2	300	7	200	6.31	6.33	6.32	0.01
B	Vinyl Ester	2	300	7	200	7.43	7.51	7.47	0.04
C	Epoxy	2	300	7	200	6.53	6.54	6.53	0.01
A	Epoxy	2	300	7	20000	6.25	6.26	6.26	0.01
B	Vinyl Ester	2	300	7	20000	7.53	7.57	7.55	0.02
C	Epoxy	2	300	7	20000	6.33	6.37	6.35	0.02
A	Epoxy	2	300	7	SeaWater	6.21	6.25	6.23	0.02
B	Vinyl Ester	2	300	7	SeaWater	7.61	7.65	7.63	0.02
C	Epoxy	2	300	7	SeaWater	6.29	6.33	6.31	0.02
A	Epoxy	1	300	10	0	9.83	9.89	9.86	0.03
B	Vinyl Ester	1	300	10	0	10.29	10.37	10.33	0.04
C	Epoxy	1	300	10	0	9.86	9.89	9.88	0.02
A	Epoxy	1	300	10	200	9.71	9.78	9.74	0.04
B	Vinyl Ester	1	300	10	200	10.45	10.51	10.48	0.03
C	Epoxy	1	300	10	200	9.76	9.78	9.77	0.01
A	Epoxy	1	300	10	20000	9.61	9.64	9.62	0.02
B	Vinyl Ester	1	300	10	20000	10.56	10.60	10.58	0.02
C	Epoxy	1	300	10	20000	9.67	9.71	9.69	0.02
A	Epoxy	1	300	10	SeaWater	9.44	9.50	9.47	0.03
B	Vinyl Ester	1	300	10	SeaWater	10.60	10.66	10.63	0.03
C	Epoxy	1	300	10	SeaWater	9.54	9.55	9.54	0.01
A	Epoxy	2	300	10	0	9.72	9.74	9.73	0.01
B	Vinyl Ester	2	300	10	0	10.29	10.35	10.32	0.03
C	Epoxy	2	300	10	0	9.74	9.78	9.76	0.02
A	Epoxy	2	300	10	200	9.50	9.54	9.52	0.02
B	Vinyl Ester	2	300	10	200	10.35	10.39	10.37	0.02
C	Epoxy	2	300	10	200	9.71	9.72	9.71	0.01
A	Epoxy	2	300	10	20000	9.45	9.47	9.46	0.01
B	Vinyl Ester	2	300	10	20000	10.46	10.47	10.46	0.01
C	Epoxy	2	300	10	20000	9.46	9.50	9.48	0.02
A	Epoxy	2	300	10	SeaWater	9.36	9.43	9.39	0.04
B	Vinyl Ester	2	300	10	SeaWater	10.48	10.56	10.52	0.04
C	Epoxy	2	300	10	SeaWater	9.42	9.45	9.43	0.02

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Table 1.1: pH Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						pH			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$	$\vee$	μ	σ
A	Epoxy	1	300	13	0	11.38	11.44	11.41	0.03
B	Vinyl Ester	1	300	13	0	12.25	12.29	12.27	0.02
C	Epoxy	1	300	13	0	11.81	11.82	11.82	0.01
A	Epoxy	1	300	13	200	11.35	11.39	11.37	0.02
B	Vinyl Ester	1	300	13	200	12.40	12.48	12.44	0.04
C	Epoxy	1	300	13	200	11.74	11.75	11.74	0.01
A	Epoxy	1	300	13	20000	11.28	11.36	11.32	0.04
B	Vinyl Ester	1	300	13	20000	12.44	12.46	12.45	0.01
C	Epoxy	1	300	13	20000	11.53	11.56	11.55	0.02
A	Epoxy	1	300	13	SeaWater	11.24	11.30	11.27	0.03
B	Vinyl Ester	1	300	13	SeaWater	12.59	12.67	12.63	0.04
C	Epoxy	1	300	13	SeaWater	11.50	11.54	11.52	0.02
A	Epoxy	2	300	13	0	11.29	11.32	11.31	0.02
B	Vinyl Ester	2	300	13	0	12.42	12.46	12.44	0.02
C	Epoxy	2	300	13	0	11.76	11.78	11.77	0.01
A	Epoxy	2	300	13	200	11.23	11.29	11.26	0.03
B	Vinyl Ester	2	300	13	200	12.45	12.49	12.47	0.02
C	Epoxy	2	300	13	200	11.67	11.71	11.69	0.02
A	Epoxy	2	300	13	20000	11.14	11.20	11.17	0.03
B	Vinyl Ester	2	300	13	20000	12.53	12.55	12.54	0.01
C	Epoxy	2	300	13	20000	11.23	11.26	11.25	0.02
A	Epoxy	2	300	13	SeaWater	11.09	11.15	11.12	0.03
B	Vinyl Ester	2	300	13	SeaWater	12.58	12.65	12.61	0.04
C	Epoxy	2	300	13	SeaWater	11.44	11.47	11.46	0.02

Table 1.2: pH Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					pH			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$	$\vee$	μ	σ
A	Epoxy	300	4	0	3.83	3.89	3.86	0.03
B	Vinyl Ester	300	4	0	3.80	3.88	3.84	0.04
A	Epoxy	300	4	200	3.80	3.86	3.83	0.03

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Table 1.2: pH Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					pH			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$	$\vee$	μ	σ
B	Vinyl Ester	300	4	200	3.73	3.77	3.75	0.02
A	Epoxy	300	4	20000	3.76	3.82	3.79	0.03
B	Vinyl Ester	300	4	20000	3.64	3.70	3.67	0.03
A	Epoxy	300	4	SeaWater	3.71	3.77	3.74	0.03
B	Vinyl Ester	300	4	SeaWater	3.61	3.69	3.65	0.04
A	Epoxy	300	7	0	6.62	6.68	6.65	0.03
B	Vinyl Ester	300	7	0	6.50	6.58	6.54	0.04
A	Epoxy	300	7	200	6.54	6.62	6.58	0.04
B	Vinyl Ester	300	7	200	6.47	6.51	6.49	0.02
A	Epoxy	300	7	20000	6.49	6.55	6.52	0.03
B	Vinyl Ester	300	7	20000	6.42	6.43	6.42	0.01
A	Epoxy	300	7	SeaWater	6.44	6.48	6.46	0.02
B	Vinyl Ester	300	7	SeaWater	6.35	6.39	6.37	0.02
A	Epoxy	300	10	0	9.53	9.61	9.57	0.04
B	Vinyl Ester	300	10	0	9.49	9.57	9.53	0.04
A	Epoxy	300	10	200	9.49	9.51	9.50	0.01
B	Vinyl Ester	300	10	200	9.42	9.46	9.44	0.02
A	Epoxy	300	10	20000	9.39	9.45	9.42	0.03
B	Vinyl Ester	300	10	20000	9.29	9.37	9.33	0.04
A	Epoxy	300	10	SeaWater	9.35	9.39	9.37	0.02
B	Vinyl Ester	300	10	SeaWater	9.25	9.29	9.27	0.02
A	Epoxy	300	13	0	12.59	12.61	12.60	0.01
B	Vinyl Ester	300	13	0	12.54	12.60	12.57	0.03
A	Epoxy	300	13	200	12.54	12.58	12.56	0.02
B	Vinyl Ester	300	13	200	12.53	12.57	12.55	0.02
A	Epoxy	300	13	20000	12.50	12.54	12.52	0.02
B	Vinyl Ester	300	13	20000	12.46	12.48	12.47	0.01
A	Epoxy	300	13	SeaWater	12.46	12.52	12.49	0.03
B	Vinyl Ester	300	13	SeaWater	12.42	12.48	12.45	0.03

Table 1.3: pH Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					pH			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$	$\vee$	μ	σ
A	Sized	300	4	0	4.23	4.29	4.26	0.03
B	Sized	300	4	0	4.22	4.24	4.23	0.01
C	Sized	300	4	0	4.30	4.34	4.32	0.02
A	Sized	300	4	200	4.33	4.34	4.34	0.01
B	Sized	300	4	200	4.32	4.33	4.32	0.01
C	Sized	300	4	200	4.36	4.38	4.37	0.01
A	Sized	300	4	20000	4.55	4.63	4.59	0.04
B	Sized	300	4	20000	4.54	4.55	4.54	0.01
C	Sized	300	4	20000	4.53	4.57	4.55	0.02
A	Sized	300	4	SeaWater	4.58	4.64	4.61	0.03
B	Sized	300	4	SeaWater	4.56	4.57	4.57	0.01
C	Sized	300	4	SeaWater	4.58	4.62	4.60	0.02
A	Unsized	300	4	0	4.36	4.37	4.36	0.01
B	Unsized	300	4	0	4.32	4.36	4.34	0.02
A	Unsized	300	4	200	4.37	4.45	4.41	0.04
B	Unsized	300	4	200	4.34	4.38	4.36	0.02
A	Unsized	300	4	20000	4.46	4.50	4.48	0.02
B	Unsized	300	4	20000	4.35	4.39	4.37	0.02
A	Unsized	300	4	SeaWater	4.44	4.50	4.47	0.03
B	Unsized	300	4	SeaWater	4.42	4.48	4.45	0.03
A	Sized	300	7	0	7.32	7.36	7.34	0.02
B	Sized	300	7	0	7.29	7.33	7.31	0.02
C	Sized	300	7	0	7.35	7.36	7.36	0.01
A	Sized	300	7	200	7.47	7.55	7.51	0.04
B	Sized	300	7	200	7.43	7.49	7.46	0.03
C	Sized	300	7	200	7.54	7.56	7.55	0.01
A	Sized	300	7	20000	7.54	7.62	7.58	0.04
B	Sized	300	7	20000	7.51	7.52	7.51	0.01
C	Sized	300	7	20000	7.63	7.66	7.64	0.02
A	Sized	300	7	SeaWater	7.63	7.69	7.66	0.03
B	Sized	300	7	SeaWater	7.55	7.56	7.55	0.01
C	Sized	300	7	SeaWater	7.73	7.75	7.74	0.01
A	Unsized	300	7	0	7.35	7.43	7.39	0.04
B	Unsized	300	7	0	7.24	7.25	7.24	0.01
A	Unsized	300	7	200	7.44	7.48	7.46	0.02
B	Unsized	300	7	200	7.29	7.33	7.31	0.02
A	Unsized	300	7	20000	7.44	7.52	7.48	0.04

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Table 1.3: pH Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					pH			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$	$\vee$	μ	σ
B	Unsized	300	7	20000	7.35	7.43	7.39	0.04
A	Unsized	300	7	SeaWater	7.48	7.56	7.52	0.04
B	Unsized	300	7	SeaWater	7.37	7.45	7.41	0.04
A	Sized	300	10	0	10.25	10.29	10.27	0.02
B	Sized	300	10	0	10.24	10.25	10.24	0.01
C	Sized	300	10	0	10.69	10.73	10.71	0.02
A	Sized	300	10	200	10.42	10.43	10.43	0.01
B	Sized	300	10	200	10.35	10.39	10.37	0.02
C	Sized	300	10	200	10.80	10.82	10.81	0.01
A	Sized	300	10	20000	10.50	10.54	10.52	0.02
B	Sized	300	10	20000	10.44	10.45	10.44	0.01
C	Sized	300	10	20000	10.85	10.87	10.86	0.01
A	Sized	300	10	SeaWater	10.63	10.67	10.65	0.02
B	Sized	300	10	SeaWater	10.57	10.58	10.57	0.01
C	Sized	300	10	SeaWater	10.86	10.91	10.89	0.03
A	Unsized	300	10	0	10.25	10.33	10.29	0.04
B	Unsized	300	10	0	10.14	10.20	10.17	0.03
A	Unsized	300	10	200	10.32	10.36	10.34	0.02
B	Unsized	300	10	200	10.20	10.21	10.20	0.01
A	Unsized	300	10	20000	10.33	10.41	10.37	0.04
B	Unsized	300	10	20000	10.22	10.30	10.26	0.04
A	Unsized	300	10	SeaWater	10.39	10.45	10.42	0.03
B	Unsized	300	10	SeaWater	10.33	10.37	10.35	0.02
A	Sized	300	13	0	12.45	12.49	12.47	0.02
B	Sized	300	13	0	12.44	12.45	12.44	0.01
C	Sized	300	13	0	12.61	12.65	12.63	0.02
A	Sized	300	13	200	12.59	12.63	12.61	0.02
B	Sized	300	13	200	12.57	12.61	12.59	0.02
C	Sized	300	13	200	12.76	12.77	12.77	0.01
A	Sized	300	13	20000	12.61	12.65	12.63	0.02
B	Sized	300	13	20000	12.61	12.62	12.62	0.01
C	Sized	300	13	20000	12.79	12.83	12.81	0.02
A	Sized	300	13	SeaWater	12.65	12.69	12.67	0.02
B	Sized	300	13	SeaWater	12.62	12.68	12.65	0.03
C	Sized	300	13	SeaWater	12.88	12.89	12.88	0.01
A	Unsized	300	13	0	12.42	12.46	12.44	0.02
B	Unsized	300	13	0	12.29	12.34	12.31	0.03

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Table 1.3: pH Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					pH			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$	$\vee$	μ	σ
A	Unsized	300	13	200	12.43	12.49	12.46	0.03
B	Unsized	300	13	200	12.37	12.38	12.37	0.01
A	Unsized	300	13	20000	12.58	12.59	12.58	0.01
B	Unsized	300	13	20000	12.50	12.56	12.53	0.03
A	Unsized	300	13	SeaWater	12.62	12.68	12.65	0.03
B	Unsized	300	13	SeaWater	12.60	12.66	12.63	0.03

The change in pH of exposure environments after the exposure period was calculated and the data was plotted in the following Figures 1.1, 1.2, and 1.3.

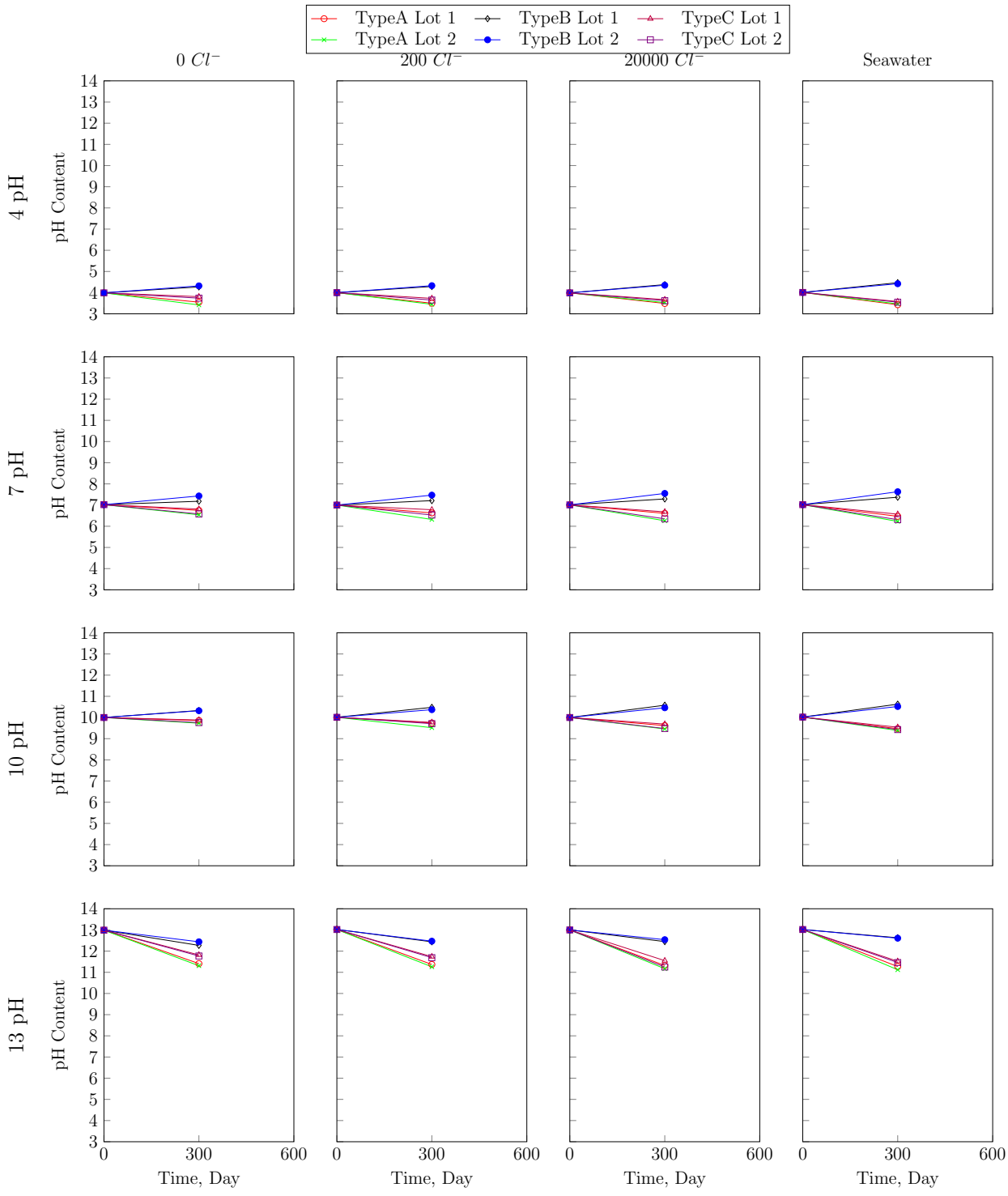

Figure 1.1: pH of environments after exposure of rebars

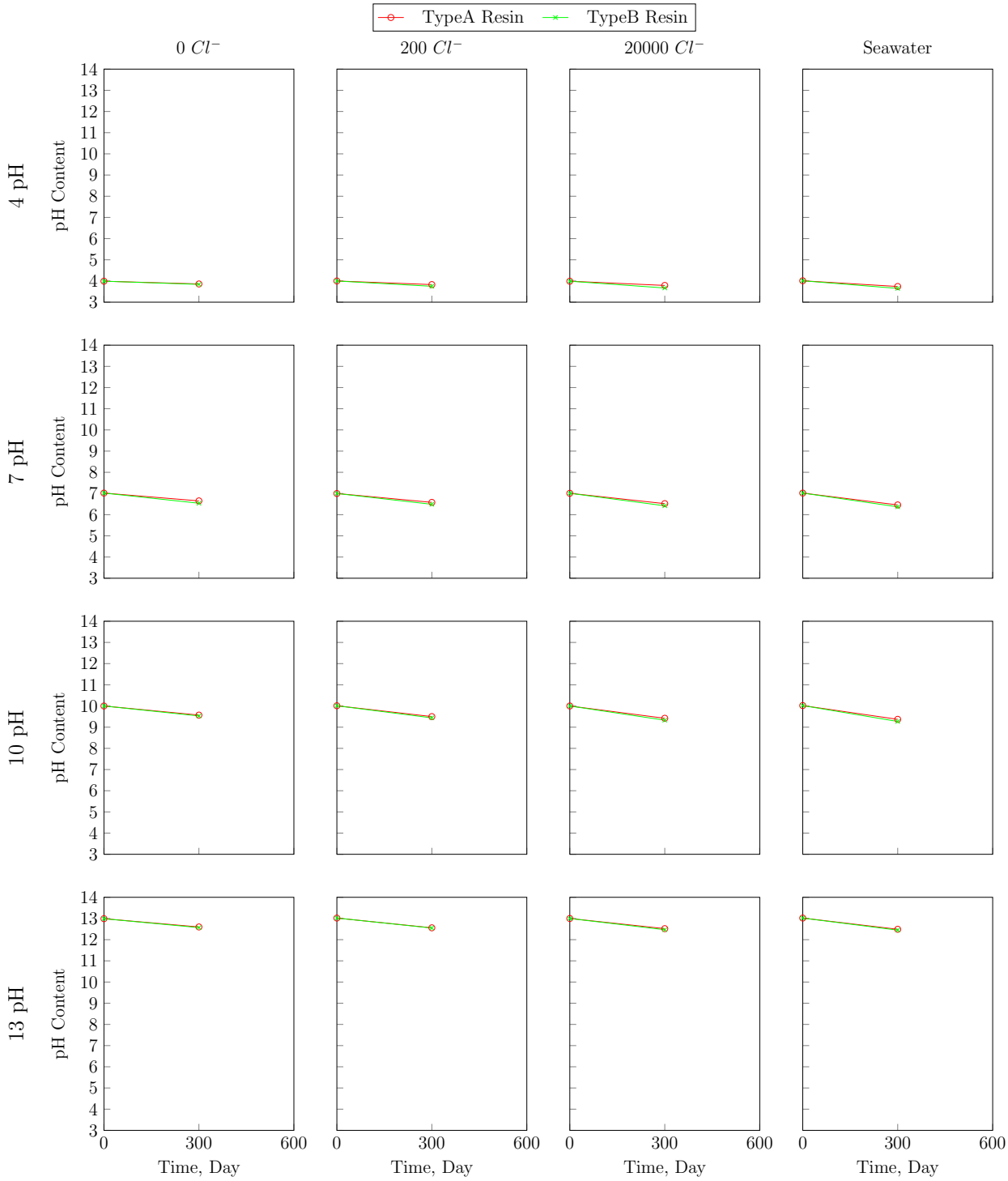

Figure 1.2: pH of environments after exposure of resins

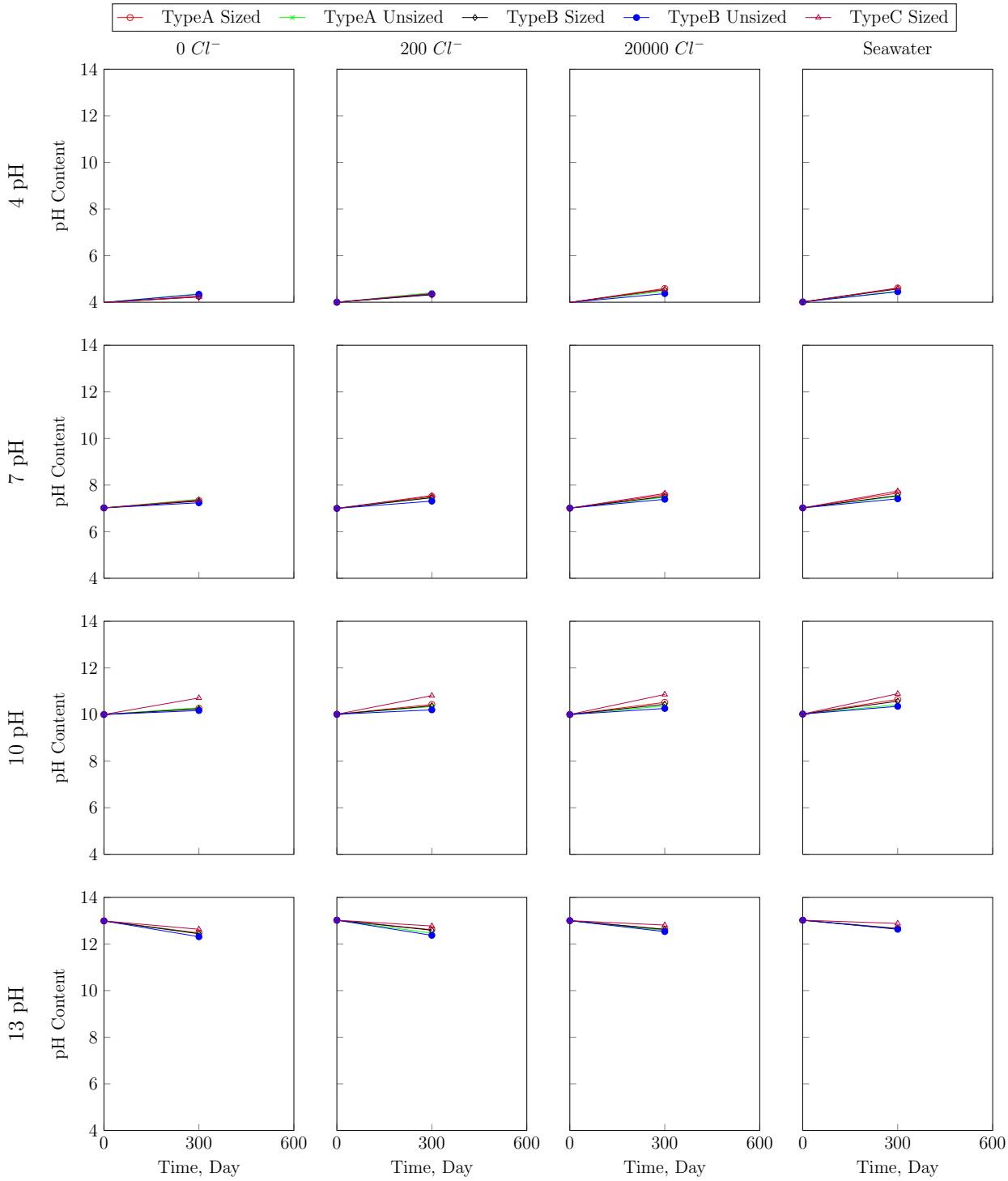

Figure 1.3: pH of environments after exposure of sized and naked fibers

1.2.2 Salinity

Salinity of the chemical environments was measured after 300 days of exposure. Tables 1.4, 1.5, and 1.6 below shows the salinity data of environments in which rebars, resins, and fibers were exposed.

Table 1.4: Salinity Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Salinity			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	30.09	31.24	30.67	0.58
B	Vinyl Ester	1	300	4	0	55.51	57.82	56.67	1.15
C	Epoxy	1	300	4	0	45.09	46.24	45.67	0.58
A	Epoxy	1	300	4	200	360.14	363.19	361.67	1.53
B	Vinyl Ester	1	300	4	200	371.00	375.00	373.00	2.00
C	Epoxy	1	300	4	200	380.14	383.19	381.67	1.53
A	Epoxy	1	300	4	20000	33 400.00	33 420.00	33 410.00	10.00
B	Vinyl Ester	1	300	4	20000	33 407.56	33 419.11	33 413.33	5.77
C	Epoxy	1	300	4	20000	33 590.00	33 610.00	33 600.00	10.00
A	Epoxy	1	300	4	SeaWater	34 218.17	34 268.50	34 243.33	25.17
B	Vinyl Ester	1	300	4	SeaWater	35 708.06	35 738.61	35 723.33	15.28
C	Epoxy	1	300	4	SeaWater	34 408.17	34 458.50	34 433.33	25.17
A	Epoxy	2	300	4	0	20.59	24.75	22.67	2.08
B	Vinyl Ester	2	300	4	0	69.09	70.24	69.67	0.58
C	Epoxy	2	300	4	0	54.27	57.73	56.00	1.73
A	Epoxy	2	300	4	200	349.51	351.82	350.67	1.15
B	Vinyl Ester	2	300	4	200	349.51	351.82	350.67	1.15
C	Epoxy	2	300	4	200	410.35	415.65	413.00	2.65
A	Epoxy	2	300	4	20000	33 010.00	33 030.00	33 020.00	10.00
B	Vinyl Ester	2	300	4	20000	33 282.68	33 317.32	33 300.00	17.32
C	Epoxy	2	300	4	20000	33 153.54	33 206.46	33 180.00	26.46
A	Epoxy	2	300	4	SeaWater	33 128.17	33 178.50	33 153.33	25.17
B	Vinyl Ester	2	300	4	SeaWater	34 495.85	34 537.48	34 516.67	20.82
C	Epoxy	2	300	4	SeaWater	34 023.54	34 076.46	34 050.00	26.46
A	Epoxy	1	300	7	0	41.51	43.82	42.67	1.15
B	Vinyl Ester	1	300	7	0	42.27	45.73	44.00	1.73
C	Epoxy	1	300	7	0	56.51	58.82	57.67	1.15
A	Epoxy	1	300	7	200	372.81	375.86	374.33	1.53
B	Vinyl Ester	1	300	7	200	387.00	389.00	388.00	1.00
C	Epoxy	1	300	7	200	392.81	395.86	394.33	1.53
A	Epoxy	1	300	7	20000	33 218.06	33 248.61	33 233.33	15.28
B	Vinyl Ester	1	300	7	20000	33 413.54	33 466.46	33 440.00	26.46
C	Epoxy	1	300	7	20000	33 408.06	33 438.61	33 423.33	15.28
A	Epoxy	1	300	7	SeaWater	34 292.52	34 334.15	34 313.33	20.82
B	Vinyl Ester	1	300	7	SeaWater	34 420.00	34 440.00	34 430.00	10.00
C	Epoxy	1	300	7	SeaWater	34 482.52	34 524.15	34 503.33	20.82
A	Epoxy	2	300	7	0	32.51	34.82	33.67	1.15
B	Vinyl Ester	2	300	7	0	29.09	30.24	29.67	0.58
C	Epoxy	2	300	7	0	65.36	69.98	67.67	2.31
A	Epoxy	2	300	7	200	362.81	365.86	364.33	1.53

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Table 1.4: Salinity Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Salinity			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	2	300	7	200	363.81	366.86	365.33	1.53
C	Epoxy	2	300	7	200	454.25	458.41	456.33	2.08
A	Epoxy	2	300	7	20000	33 241.79	33 264.88	33 253.33	11.55
B	Vinyl Ester	2	300	7	20000	32 963.54	33 016.46	32 990.00	26.46
C	Epoxy	2	300	7	20000	33 301.79	33 324.88	33 313.33	11.55
A	Epoxy	2	300	7	SeaWater	33 402.52	33 444.15	33 423.33	20.82
B	Vinyl Ester	2	300	7	SeaWater	34 267.56	34 279.11	34 273.33	5.77
C	Epoxy	2	300	7	SeaWater	34 312.68	34 347.32	34 330.00	17.32
A	Epoxy	1	300	10	0	34.36	38.98	36.67	2.31
B	Vinyl Ester	1	300	10	0	58.81	61.86	60.33	1.53
C	Epoxy	1	300	10	0	49.36	53.98	51.67	2.31
A	Epoxy	1	300	10	200	371.14	374.19	372.67	1.53
B	Vinyl Ester	1	300	10	200	379.25	383.41	381.33	2.08
C	Epoxy	1	300	10	200	391.14	394.19	392.67	1.53
A	Epoxy	1	300	10	20000	33 261.39	33 291.94	33 276.67	15.28
B	Vinyl Ester	1	300	10	20000	33 630.00	33 670.00	33 650.00	20.00
C	Epoxy	1	300	10	20000	33 451.39	33 481.94	33 466.67	15.28
A	Epoxy	1	300	10	SeaWater	35 021.79	35 044.88	35 033.33	11.55
B	Vinyl Ester	1	300	10	SeaWater	35 091.79	35 114.88	35 103.33	11.55
C	Epoxy	1	300	10	SeaWater	35 211.79	35 234.88	35 223.33	11.55
A	Epoxy	2	300	10	0	34.51	36.82	35.67	1.15
B	Vinyl Ester	2	300	10	0	27.14	30.19	28.67	1.53
C	Epoxy	2	300	10	0	49.18	51.49	50.33	1.15
A	Epoxy	2	300	10	200	370.25	374.41	372.33	2.08
B	Vinyl Ester	2	300	10	200	362.09	363.24	362.67	0.58
C	Epoxy	2	300	10	200	450.59	454.75	452.67	2.08
A	Epoxy	2	300	10	20000	33 506.08	33 600.59	33 553.33	47.26
B	Vinyl Ester	2	300	10	20000	33 308.17	33 358.50	33 333.33	25.17
C	Epoxy	2	300	10	20000	33 805.12	33 828.21	33 816.67	11.55
A	Epoxy	2	300	10	SeaWater	33 831.39	33 861.94	33 846.67	15.28
B	Vinyl Ester	2	300	10	SeaWater	35 151.79	35 174.88	35 163.33	11.55
C	Epoxy	2	300	10	SeaWater	35 380.00	35 400.00	35 390.00	10.00
A	Epoxy	1	300	13	0	2529.59	2533.75	2531.67	2.08
B	Vinyl Ester	1	300	13	0	1564.51	1566.82	1565.67	1.15
C	Epoxy	1	300	13	0	2769.59	2773.75	2771.67	2.08
A	Epoxy	1	300	13	200	3333.25	3337.41	3335.33	2.08
B	Vinyl Ester	1	300	13	200	1937.27	1940.73	1939.00	1.73
C	Epoxy	1	300	13	200	3335.25	3339.41	3337.33	2.08
A	Epoxy	1	300	13	20000	22 400.00	22 440.00	22 420.00	20.00
B	Vinyl Ester	1	300	13	20000	28 981.79	29 004.88	28 993.33	11.55
C	Epoxy	1	300	13	20000	22 590.00	22 630.00	22 610.00	20.00
A	Epoxy	1	300	13	SeaWater	25 572.52	25 614.15	25 593.33	20.82
B	Vinyl Ester	1	300	13	SeaWater	29 822.78	29 883.88	29 853.33	30.55
C	Epoxy	1	300	13	SeaWater	25 762.52	25 804.15	25 783.33	20.82
A	Epoxy	2	300	13	0	2384.55	2392.12	2388.33	3.79
B	Vinyl Ester	2	300	13	0	1801.00	1805.00	1803.00	2.00
C	Epoxy	2	300	13	0	2969.59	2973.75	2971.67	2.08
A	Epoxy	2	300	13	200	3330.25	3334.41	3332.33	2.08
B	Vinyl Ester	2	300	13	200	2299.14	2302.19	2300.67	1.53

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Table 1.4: Salinity Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Salinity			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	13	200	3221.59	3225.75	3223.67	2.08
A	Epoxy	2	300	13	20000	22 230.00	22 250.00	22 240.00	10.00
B	Vinyl Ester	2	300	13	20000	28 708.06	28 738.61	28 723.33	15.28
C	Epoxy	2	300	13	20000	23 911.39	23 941.94	23 926.67	15.28
A	Epoxy	2	300	13	SeaWater	25 291.39	25 321.94	25 306.67	15.28
B	Vinyl Ester	2	300	13	SeaWater	31 518.06	31 548.61	31 533.33	15.28
C	Epoxy	2	300	13	SeaWater	27 143.54	27 196.46	27 170.00	26.46

Table 1.5: Salinity Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Salinity			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	17.76	18.91	18.33	0.58
B	Vinyl Ester	300	4	0	24.81	27.86	26.33	1.53
A	Epoxy	300	4	200	351.76	352.91	352.33	0.58
B	Vinyl Ester	300	4	200	345.81	348.86	347.33	1.53
A	Epoxy	300	4	20000	33 681.39	33 711.94	33 696.67	15.28
B	Vinyl Ester	300	4	20000	33 590.00	33 610.00	33 600.00	10.00
A	Epoxy	300	4	SeaWater	34 761.39	34 791.94	34 776.67	15.28
B	Vinyl Ester	300	4	SeaWater	35 018.06	35 048.61	35 033.33	15.28
A	Epoxy	300	7	0	17.00	19.00	18.00	1.00
B	Vinyl Ester	300	7	0	23.76	24.91	24.33	0.58
A	Epoxy	300	7	200	358.00	360.00	359.00	1.00
B	Vinyl Ester	300	7	200	359.09	360.24	359.67	0.58
A	Epoxy	300	7	20000	33 728.06	33 758.61	33 743.33	15.28
B	Vinyl Ester	300	7	20000	34 100.89	34 112.44	34 106.67	5.77
A	Epoxy	300	7	SeaWater	35 090.89	35 102.44	35 096.67	5.77
B	Vinyl Ester	300	7	SeaWater	34 558.06	34 588.61	34 573.33	15.28
A	Epoxy	300	10	0	6.81	9.86	8.33	1.53
B	Vinyl Ester	300	10	0	7.09	8.24	7.67	0.58
A	Epoxy	300	10	200	349.14	352.19	350.67	1.53
B	Vinyl Ester	300	10	200	346.18	348.49	347.33	1.15
A	Epoxy	300	10	20000	33 695.12	33 718.21	33 706.67	11.55
B	Vinyl Ester	300	10	20000	33 595.85	33 637.48	33 616.67	20.82

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Table 1.5: Salinity Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Salinity			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	10	SeaWater	36 258.06	36 288.61	36 273.33	15.28
B	Vinyl Ester	300	10	SeaWater	34 970.00	34 990.00	34 980.00	10.00
A	Epoxy	300	13	0	4340.89	4352.44	4346.67	5.77
B	Vinyl Ester	300	13	0	4257.56	4269.11	4263.33	5.77
A	Epoxy	300	13	200	4664.51	4666.82	4665.67	1.15
B	Vinyl Ester	300	13	200	4628.09	4629.24	4628.67	0.58
A	Epoxy	300	13	20000	39 978.06	40 008.61	39 993.33	15.28
B	Vinyl Ester	300	13	20000	37 941.39	37 971.94	37 956.67	15.28
A	Epoxy	300	13	SeaWater	43 713.94	43 786.06	43 750.00	36.06
B	Vinyl Ester	300	13	SeaWater	38 703.94	38 776.06	38 740.00	36.06

Table 1.6: Salinity Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Salinity			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	15.02	19.64	17.33	2.31
B	Sized	300	4	0	28.76	29.91	29.33	0.58
C	Sized	300	4	0	19.02	23.64	21.33	2.31
A	Sized	300	4	200	342.59	346.75	344.67	2.08
B	Sized	300	4	200	350.09	351.24	350.67	0.58
C	Sized	300	4	200	344.59	348.75	346.67	2.08
A	Sized	300	4	20000	33 251.39	33 281.94	33 266.67	15.28
B	Sized	300	4	20000	33 425.12	33 448.21	33 436.67	11.55
C	Sized	300	4	20000	33 361.39	33 391.94	33 376.67	15.28
A	Sized	300	4	SeaWater	34 221.39	34 251.94	34 236.67	15.28
B	Sized	300	4	SeaWater	33 932.78	33 993.88	33 963.33	30.55
C	Sized	300	4	SeaWater	34 331.39	34 361.94	34 346.67	15.28
A	Unsized	300	4	0	11.76	12.91	12.33	0.58
B	Unsized	300	4	0	15.14	18.19	16.67	1.53
A	Unsized	300	4	200	344.81	347.86	346.33	1.53
B	Unsized	300	4	200	346.81	349.86	348.33	1.53
A	Unsized	300	4	20000	33 305.85	33 347.48	33 326.67	20.82

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Table 1.6: Salinity Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Salinity			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	4	20000	33 417.56	33 429.11	33 423.33	5.77
A	Unsized	300	4	SeaWater	34 482.68	34 517.32	34 500.00	17.32
B	Unsized	300	4	SeaWater	34 198.06	34 228.61	34 213.33	15.28
A	Sized	300	7	0	11.09	12.24	11.67	0.58
B	Sized	300	7	0	22.00	24.00	23.00	1.00
C	Sized	300	7	0	15.09	16.24	15.67	0.58
A	Sized	300	7	200	352.00	354.00	353.00	1.00
B	Sized	300	7	200	354.09	355.24	354.67	0.58
C	Sized	300	7	200	354.00	356.00	355.00	1.00
A	Sized	300	7	20000	33 785.85	33 827.48	33 806.67	20.82
B	Sized	300	7	20000	33 381.55	33 451.79	33 416.67	35.12
C	Sized	300	7	20000	33 895.85	33 937.48	33 916.67	20.82
A	Sized	300	7	SeaWater	34 000.89	34 012.44	34 006.67	5.77
B	Sized	300	7	SeaWater	34 575.47	34 651.19	34 613.33	37.86
C	Sized	300	7	SeaWater	34 110.89	34 122.44	34 116.67	5.77
A	Unsized	300	7	0	21.00	23.00	22.00	1.00
B	Unsized	300	7	0	24.76	25.91	25.33	0.58
A	Unsized	300	7	200	363.27	366.73	365.00	1.73
B	Unsized	300	7	200	354.76	355.91	355.33	0.58
A	Unsized	300	7	20000	33 630.00	33 650.00	33 640.00	10.00
B	Unsized	300	7	20000	33 731.39	33 761.94	33 746.67	15.28
A	Unsized	300	7	SeaWater	34 268.06	34 298.61	34 283.33	15.28
B	Unsized	300	7	SeaWater	34 308.06	34 338.61	34 323.33	15.28
A	Sized	300	10	0	7.81	10.86	9.33	1.53
B	Sized	300	10	0	12.25	16.41	14.33	2.08
C	Sized	300	10	0	11.81	14.86	13.33	1.53
A	Sized	300	10	200	351.51	353.82	352.67	1.15
B	Sized	300	10	200	352.76	353.91	353.33	0.58
C	Sized	300	10	200	353.51	355.82	354.67	1.15
A	Sized	300	10	20000	34 160.89	34 172.44	34 166.67	5.77
B	Sized	300	10	20000	34 032.52	34 074.15	34 053.33	20.82
C	Sized	300	10	20000	34 270.89	34 282.44	34 276.67	5.77
A	Sized	300	10	SeaWater	35 002.68	35 037.32	35 020.00	17.32
B	Sized	300	10	SeaWater	35 331.55	35 401.79	35 366.67	35.12
C	Sized	300	10	SeaWater	35 112.68	35 147.32	35 130.00	17.32
A	Unsized	300	10	0	13.14	16.19	14.67	1.53
B	Unsized	300	10	0	11.76	12.91	12.33	0.58

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Table 1.6: Salinity Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Salinity			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	10	200	355.81	358.86	357.33	1.53
B	Unsized	300	10	200	352.09	353.24	352.67	0.58
A	Unsized	300	10	20000	33 827.56	33 839.11	33 833.33	5.77
B	Unsized	300	10	20000	33 870.24	33 916.43	33 893.33	23.09
A	Unsized	300	10	SeaWater	35 865.85	35 907.48	35 886.67	20.82
B	Unsized	300	10	SeaWater	35 511.79	35 534.88	35 523.33	11.55
A	Sized	300	13	0	3677.56	3689.11	3683.33	5.77
B	Sized	300	13	0	3268.17	3318.50	3293.33	25.17
C	Sized	300	13	0	3797.56	3809.11	3803.33	5.77
A	Sized	300	13	200	4001.27	4004.73	4003.00	1.73
B	Sized	300	13	200	3830.15	3837.18	3833.67	3.51
C	Sized	300	13	200	4010.27	4013.73	4012.00	1.73
A	Sized	300	13	20000	34 140.00	34 160.00	34 150.00	10.00
B	Sized	300	13	20000	34 724.52	34 788.81	34 756.67	32.15
C	Sized	300	13	20000	34 250.00	34 270.00	34 260.00	10.00
A	Sized	300	13	SeaWater	35 306.41	35 393.59	35 350.00	43.59
B	Sized	300	13	SeaWater	35 826.12	35 887.22	35 856.67	30.55
C	Sized	300	13	SeaWater	35 416.41	35 503.59	35 460.00	43.59
A	Unsized	300	13	0	3080.24	3126.43	3103.33	23.09
B	Unsized	300	13	0	3397.56	3409.11	3403.33	5.77
A	Unsized	300	13	200	3535.00	3541.00	3538.00	3.00
B	Unsized	300	13	200	3835.12	3841.55	3838.33	3.21
A	Unsized	300	13	20000	34 581.39	34 611.94	34 596.67	15.28
B	Unsized	300	13	20000	34 742.52	34 784.15	34 763.33	20.82
A	Unsized	300	13	SeaWater	35 484.00	35 582.66	35 533.33	49.33
B	Unsized	300	13	SeaWater	35 960.00	35 980.00	35 970.00	10.00

For a better understanding, change in the salinity content of the environments was plotted in graphs in Figure 1.4, 1.5, and 1.6.

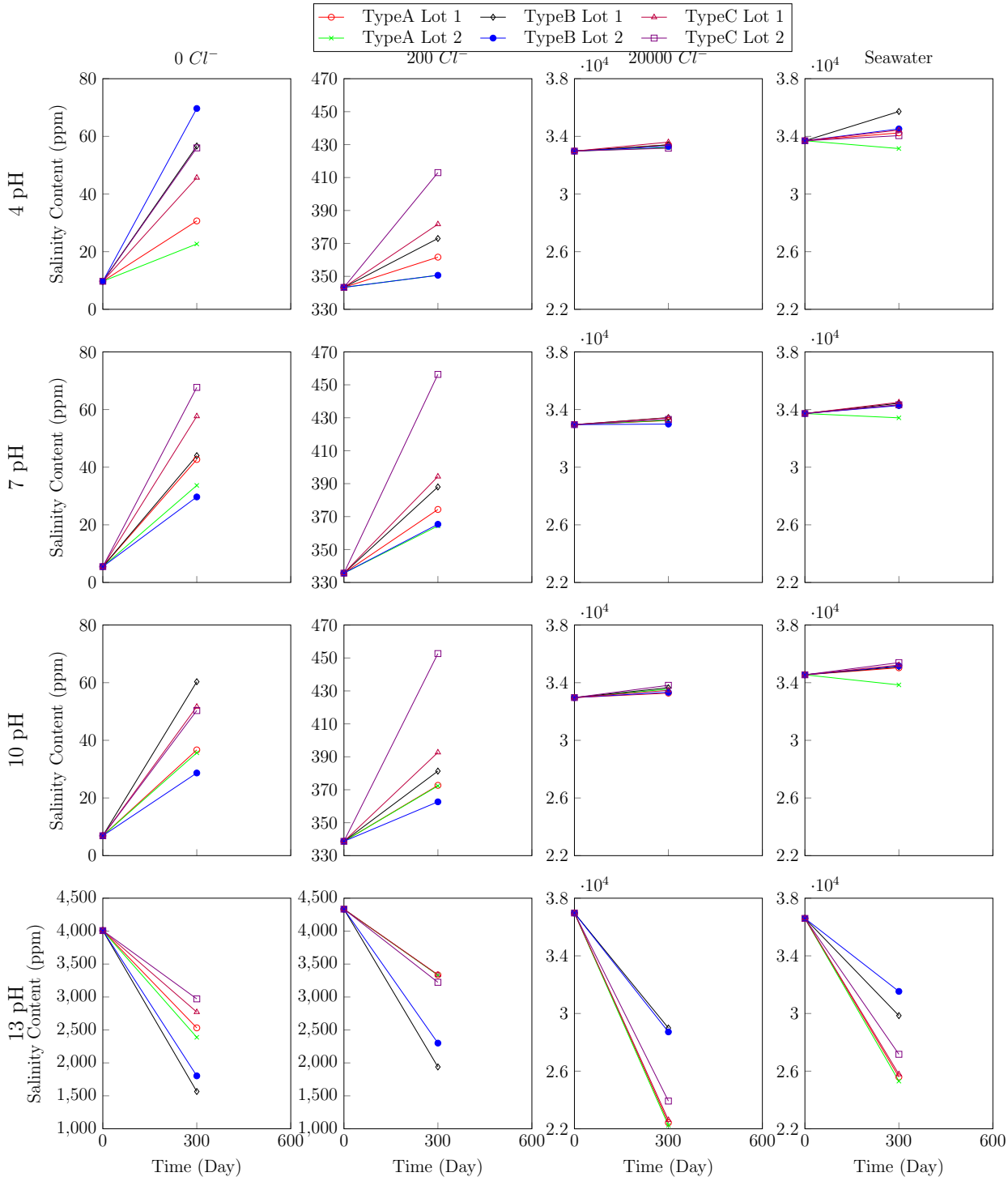

Figure 1.4: Salinity of environments after exposure of rebars

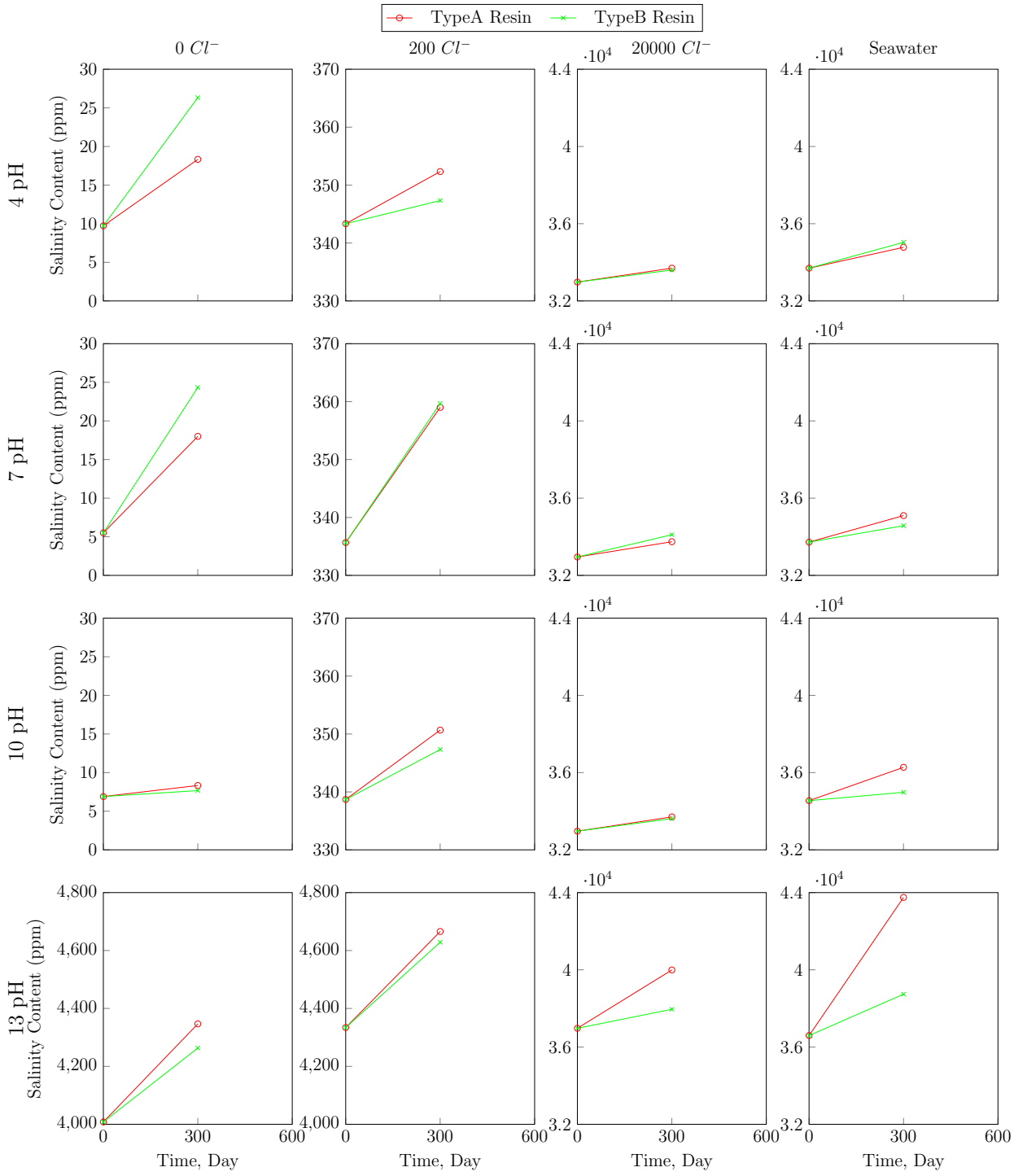

Figure 1.5: Salinity of environments after exposure of resins

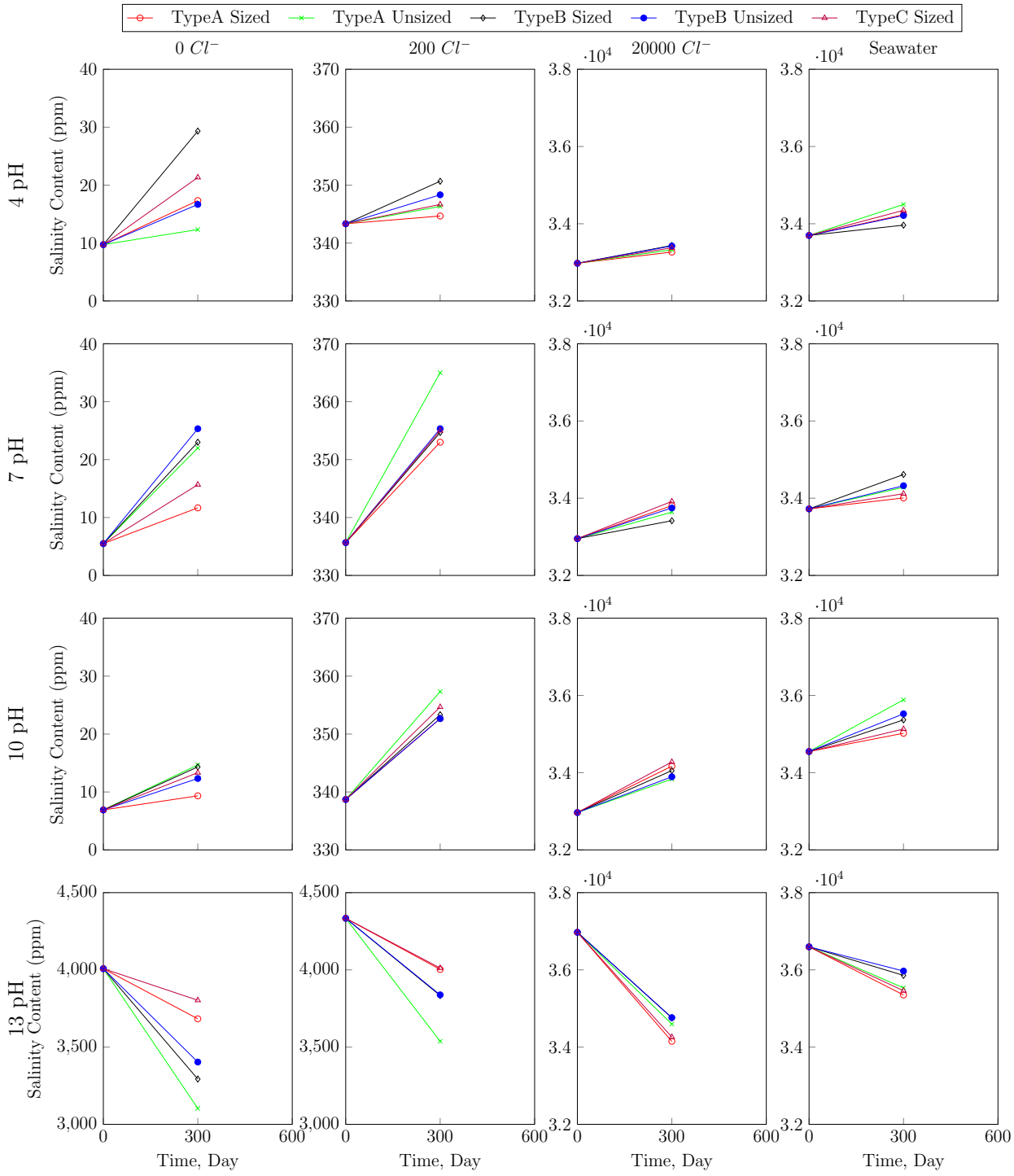

Figure 1.6: Salinity of environments after exposure of sized and unsized fibers

1.2.3 Dissolved oxygen (DO)

DO of the chemical environments was measured after 300 days of exposure. Tables 1.7, 1.8, and 1.9 below shows the DO data of environments in which rebars, resins, and fibers were exposed.

Table 1.7: Dissolved Oxygen Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Dissolved Oxygen			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	8.66	8.70	8.68	0.02
B	Vinyl Ester	1	300	4	0	8.70	8.73	8.72	0.02
C	Epoxy	1	300	4	0	8.65	8.71	8.68	0.03
A	Epoxy	1	300	4	200	8.60	8.64	8.62	0.02
B	Vinyl Ester	1	300	4	200	8.64	8.78	8.71	0.07
C	Epoxy	1	300	4	200	8.59	8.62	8.60	0.02
A	Epoxy	1	300	4	20000	8.51	8.52	8.52	0.01
B	Vinyl Ester	1	300	4	20000	8.65	8.66	8.65	0.01
C	Epoxy	1	300	4	20000	8.48	8.54	8.51	0.03
A	Epoxy	1	300	4	SeaWater	8.47	8.53	8.50	0.03
B	Vinyl Ester	1	300	4	SeaWater	8.50	8.56	8.53	0.03
C	Epoxy	1	300	4	SeaWater	8.40	8.42	8.41	0.01
A	Epoxy	2	300	4	0	8.51	8.59	8.55	0.04
B	Vinyl Ester	2	300	4	0	8.68	8.80	8.74	0.06
C	Epoxy	2	300	4	0	8.38	8.48	8.43	0.05
A	Epoxy	2	300	4	200	8.47	8.50	8.48	0.02
B	Vinyl Ester	2	300	4	200	8.70	8.71	8.71	0.01
C	Epoxy	2	300	4	200	8.41	8.43	8.42	0.01
A	Epoxy	2	300	4	20000	8.38	8.43	8.41	0.03
B	Vinyl Ester	2	300	4	20000	8.66	8.72	8.69	0.03
C	Epoxy	2	300	4	20000	8.38	8.39	8.39	0.01
A	Epoxy	2	300	4	SeaWater	8.26	8.29	8.28	0.02
B	Vinyl Ester	2	300	4	SeaWater	8.45	8.55	8.50	0.05
C	Epoxy	2	300	4	SeaWater	7.67	7.74	7.70	0.04
A	Epoxy	1	300	7	0	8.66	8.68	8.67	0.01
B	Vinyl Ester	1	300	7	0	8.67	8.77	8.72	0.05
C	Epoxy	1	300	7	0	8.60	8.64	8.62	0.02

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Table 1.7: Dissolved Oxygen Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Dissolved Oxygen			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	7	200	8.57	8.61	8.59	0.02
B	Vinyl Ester	1	300	7	200	8.67	8.75	8.71	0.04
C	Epoxy	1	300	7	200	8.49	8.55	8.52	0.03
A	Epoxy	1	300	7	20000	8.52	8.53	8.52	0.01
B	Vinyl Ester	1	300	7	20000	8.62	8.64	8.63	0.01
C	Epoxy	1	300	7	20000	8.44	8.48	8.46	0.02
A	Epoxy	1	300	7	SeaWater	8.41	8.43	8.42	0.01
B	Vinyl Ester	1	300	7	SeaWater	8.51	8.52	8.51	0.01
C	Epoxy	1	300	7	SeaWater	8.33	8.35	8.34	0.01
A	Epoxy	2	300	7	0	8.46	8.52	8.49	0.03
B	Vinyl Ester	2	300	7	0	8.70	8.74	8.72	0.02
C	Epoxy	2	300	7	0	8.37	8.43	8.40	0.03
A	Epoxy	2	300	7	200	8.37	8.43	8.40	0.03
B	Vinyl Ester	2	300	7	200	8.68	8.71	8.70	0.02
C	Epoxy	2	300	7	200	8.34	8.43	8.39	0.05
A	Epoxy	2	300	7	20000	8.30	8.36	8.33	0.03
B	Vinyl Ester	2	300	7	20000	8.64	8.65	8.65	0.01
C	Epoxy	2	300	7	20000	8.31	8.33	8.32	0.01
A	Epoxy	2	300	7	SeaWater	8.20	8.23	8.21	0.02
B	Vinyl Ester	2	300	7	SeaWater	8.49	8.51	8.50	0.01
C	Epoxy	2	300	7	SeaWater	7.38	7.42	7.40	0.02
A	Epoxy	1	300	10	0	8.62	8.69	8.66	0.03
B	Vinyl Ester	1	300	10	0	8.68	8.74	8.71	0.03
C	Epoxy	1	300	10	0	8.47	8.54	8.50	0.04
A	Epoxy	1	300	10	200	8.56	8.61	8.58	0.03
B	Vinyl Ester	1	300	10	200	8.68	8.73	8.70	0.03
C	Epoxy	1	300	10	200	8.37	8.44	8.41	0.03
A	Epoxy	1	300	10	20000	8.41	8.49	8.45	0.04
B	Vinyl Ester	1	300	10	20000	8.55	8.67	8.61	0.06
C	Epoxy	1	300	10	20000	8.30	8.37	8.34	0.03
A	Epoxy	1	300	10	SeaWater	8.04	8.08	8.06	0.02
B	Vinyl Ester	1	300	10	SeaWater	8.48	8.52	8.50	0.02

Continued on next page ...

Table 1.7: Dissolved Oxygen Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Dissolved Oxygen			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	1	300	10	SeaWater	8.20	8.24	8.22	0.02
A	Epoxy	2	300	10	0	8.35	8.42	8.38	0.04
B	Vinyl Ester	2	300	10	0	8.64	8.65	8.65	0.01
C	Epoxy	2	300	10	0	8.37	8.40	8.39	0.02
A	Epoxy	2	300	10	200	8.27	8.31	8.29	0.02
B	Vinyl Ester	2	300	10	200	8.64	8.65	8.65	0.01
C	Epoxy	2	300	10	200	8.35	8.36	8.36	0.01
A	Epoxy	2	300	10	20000	8.19	8.26	8.22	0.04
B	Vinyl Ester	2	300	10	20000	8.55	8.63	8.59	0.04
C	Epoxy	2	300	10	20000	8.22	8.34	8.28	0.06
A	Epoxy	2	300	10	SeaWater	8.05	8.12	8.09	0.04
B	Vinyl Ester	2	300	10	SeaWater	8.44	8.49	8.46	0.02
C	Epoxy	2	300	10	SeaWater	7.34	7.35	7.34	0.01
A	Epoxy	1	300	13	0	8.62	8.63	8.62	0.01
B	Vinyl Ester	1	300	13	0	8.67	8.68	8.68	0.01
C	Epoxy	1	300	13	0	7.88	7.92	7.90	0.02
A	Epoxy	1	300	13	200	8.44	8.48	8.46	0.02
B	Vinyl Ester	1	300	13	200	8.62	8.70	8.66	0.04
C	Epoxy	1	300	13	200	7.80	7.82	7.81	0.01
A	Epoxy	1	300	13	20000	8.13	8.16	8.14	0.02
B	Vinyl Ester	1	300	13	20000	8.56	8.64	8.60	0.04
C	Epoxy	1	300	13	20000	7.70	7.72	7.71	0.01
A	Epoxy	1	300	13	SeaWater	7.56	7.61	7.58	0.03
B	Vinyl Ester	1	300	13	SeaWater	8.44	8.50	8.47	0.03
C	Epoxy	1	300	13	SeaWater	7.52	7.58	7.55	0.03
A	Epoxy	2	300	13	0	7.74	7.80	7.77	0.03
B	Vinyl Ester	2	300	13	0	8.61	8.64	8.63	0.02
C	Epoxy	2	300	13	0	8.24	8.34	8.29	0.05
A	Epoxy	2	300	13	200	7.68	7.70	7.69	0.01
B	Vinyl Ester	2	300	13	200	8.56	8.57	8.57	0.01
C	Epoxy	2	300	13	200	8.25	8.28	8.27	0.02
A	Epoxy	2	300	13	20000	7.56	7.61	7.59	0.02

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Table 1.7: Dissolved Oxygen Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Dissolved Oxygen			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	2	300	13	20000	8.52	8.58	8.55	0.03
C	Epoxy	2	300	13	20000	8.13	8.16	8.14	0.02
A	Epoxy	2	300	13	SeaWater	7.46	7.51	7.49	0.03
B	Vinyl Ester	2	300	13	SeaWater	8.44	8.46	8.45	0.01
C	Epoxy	2	300	13	SeaWater	7.06	7.16	7.11	0.05

Table 1.8: Dissolved Oxygen Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Dissolved Oxygen			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	8.74	8.76	8.75	0.01
B	Vinyl Ester	300	4	0	8.67	8.75	8.71	0.04
A	Epoxy	300	4	200	8.66	8.74	8.70	0.04
B	Vinyl Ester	300	4	200	8.68	8.69	8.69	0.01
A	Epoxy	300	4	20000	8.65	8.67	8.66	0.01
B	Vinyl Ester	300	4	20000	8.63	8.68	8.66	0.03
A	Epoxy	300	4	SeaWater	8.47	8.48	8.47	0.01
B	Vinyl Ester	300	4	SeaWater	8.47	8.55	8.51	0.04
A	Epoxy	300	7	0	8.71	8.75	8.73	0.02
B	Vinyl Ester	300	7	0	8.67	8.68	8.67	0.01
A	Epoxy	300	7	200	8.66	8.69	8.68	0.02
B	Vinyl Ester	300	7	200	8.63	8.69	8.66	0.03
A	Epoxy	300	7	20000	8.63	8.66	8.64	0.02
B	Vinyl Ester	300	7	20000	8.64	8.67	8.65	0.02
A	Epoxy	300	7	SeaWater	8.45	8.47	8.46	0.01
B	Vinyl Ester	300	7	SeaWater	8.45	8.55	8.50	0.05
A	Epoxy	300	10	0	8.65	8.70	8.67	0.03

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Table 1.8: Dissolved Oxygen Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Dissolved Oxygen			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	300	10	0	8.62	8.68	8.65	0.03
A	Epoxy	300	10	200	8.61	8.65	8.63	0.02
B	Vinyl Ester	300	10	200	8.65	8.68	8.66	0.02
A	Epoxy	300	10	20000	8.60	8.62	8.61	0.01
B	Vinyl Ester	300	10	20000	8.60	8.66	8.63	0.03
A	Epoxy	300	10	SeaWater	8.40	8.52	8.46	0.06
B	Vinyl Ester	300	10	SeaWater	8.46	8.48	8.47	0.01
A	Epoxy	300	13	0	8.66	8.67	8.67	0.01
B	Vinyl Ester	300	13	0	8.61	8.67	8.64	0.03
A	Epoxy	300	13	200	8.62	8.63	8.62	0.01
B	Vinyl Ester	300	13	200	8.60	8.66	8.63	0.03
A	Epoxy	300	13	20000	8.54	8.64	8.59	0.05
B	Vinyl Ester	300	13	20000	8.56	8.58	8.57	0.01
A	Epoxy	300	13	SeaWater	8.44	8.47	8.45	0.02
B	Vinyl Ester	300	13	SeaWater	8.45	8.49	8.47	0.02

Table 1.9: Dissolved Oxygen Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Dissolved Oxygen			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	8.73	8.74	8.74	0.01
B	Sized	300	4	0	8.77	8.78	8.77	0.01
C	Sized	300	4	0	8.68	8.72	8.70	0.02
A	Sized	300	4	200	8.70	8.73	8.71	0.02
B	Sized	300	4	200	8.67	8.68	8.68	0.01
C	Sized	300	4	200	8.62	8.65	8.64	0.02

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Table 1.9: Dissolved Oxygen Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Dissolved Oxygen			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	20000	8.68	8.70	8.69	0.01
B	Sized	300	4	20000	8.60	8.67	8.63	0.04
C	Sized	300	4	20000	8.59	8.61	8.60	0.01
A	Sized	300	4	SeaWater	8.51	8.54	8.52	0.02
B	Sized	300	4	SeaWater	8.52	8.54	8.53	0.01
C	Sized	300	4	SeaWater	8.55	8.57	8.56	0.01
A	Unsized	300	4	0	8.74	8.75	8.75	0.01
B	Unsized	300	4	0	8.72	8.76	8.74	0.02
A	Unsized	300	4	200	8.69	8.73	8.71	0.02
B	Unsized	300	4	200	8.71	8.73	8.72	0.01
A	Unsized	300	4	20000	8.63	8.70	8.67	0.04
B	Unsized	300	4	20000	8.67	8.71	8.69	0.02
A	Unsized	300	4	SeaWater	8.46	8.50	8.48	0.02
B	Unsized	300	4	SeaWater	8.50	8.52	8.51	0.01
A	Sized	300	7	0	8.73	8.75	8.74	0.01
B	Sized	300	7	0	8.67	8.73	8.70	0.03
C	Sized	300	7	0	8.68	8.69	8.68	0.01
A	Sized	300	7	200	8.66	8.69	8.68	0.02
B	Sized	300	7	200	8.65	8.69	8.67	0.02
C	Sized	300	7	200	8.59	8.61	8.60	0.01
A	Sized	300	7	20000	8.64	8.70	8.67	0.03
B	Sized	300	7	20000	8.60	8.64	8.62	0.02
C	Sized	300	7	20000	8.51	8.55	8.53	0.02
A	Sized	300	7	SeaWater	8.47	8.48	8.47	0.01
B	Sized	300	7	SeaWater	8.46	8.54	8.50	0.04
C	Sized	300	7	SeaWater	8.48	8.50	8.49	0.01
A	Unsized	300	7	0	8.74	8.75	8.74	0.01
B	Unsized	300	7	0	8.71	8.77	8.74	0.03
A	Unsized	300	7	200	8.68	8.69	8.69	0.01
B	Unsized	300	7	200	8.70	8.71	8.70	0.01

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Table 1.9: Dissolved Oxygen Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Dissolved Oxygen			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	7	20000	8.61	8.69	8.65	0.04
B	Unsized	300	7	20000	8.67	8.69	8.68	0.01
A	Unsized	300	7	SeaWater	8.42	8.47	8.45	0.03
B	Unsized	300	7	SeaWater	8.47	8.55	8.51	0.04
A	Sized	300	10	0	8.70	8.72	8.71	0.01
B	Sized	300	10	0	8.67	8.68	8.68	0.01
C	Sized	300	10	0	8.60	8.63	8.61	0.02
A	Sized	300	10	200	8.65	8.69	8.67	0.02
B	Sized	300	10	200	8.66	8.67	8.67	0.01
C	Sized	300	10	200	8.51	8.54	8.53	0.02
A	Sized	300	10	20000	8.62	8.70	8.66	0.04
B	Sized	300	10	20000	8.60	8.64	8.62	0.02
C	Sized	300	10	20000	8.47	8.49	8.48	0.01
A	Sized	300	10	SeaWater	8.44	8.48	8.46	0.02
B	Sized	300	10	SeaWater	8.46	8.50	8.48	0.02
C	Sized	300	10	SeaWater	8.37	8.41	8.39	0.02
A	Unsized	300	10	0	8.70	8.72	8.71	0.01
B	Unsized	300	10	0	8.69	8.77	8.73	0.04
A	Unsized	300	10	200	8.67	8.69	8.68	0.01
B	Unsized	300	10	200	8.67	8.72	8.70	0.03
A	Unsized	300	10	20000	8.63	8.67	8.65	0.02
B	Unsized	300	10	20000	8.66	8.67	8.66	0.01
A	Unsized	300	10	SeaWater	8.44	8.46	8.45	0.01
B	Unsized	300	10	SeaWater	8.48	8.53	8.51	0.02
A	Sized	300	13	0	8.65	8.66	8.66	0.01
B	Sized	300	13	0	8.65	8.69	8.67	0.02
C	Sized	300	13	0	8.57	8.59	8.58	0.01
A	Sized	300	13	200	8.64	8.67	8.66	0.02
B	Sized	300	13	200	8.65	8.68	8.66	0.02
C	Sized	300	13	200	8.48	8.51	8.49	0.02

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Table 1.9: Dissolved Oxygen Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Dissolved Oxygen			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	13	20000	8.61	8.71	8.66	0.05
B	Sized	300	13	20000	8.58	8.61	8.60	0.02
C	Sized	300	13	20000	8.38	8.41	8.40	0.02
A	Sized	300	13	SeaWater	8.41	8.51	8.46	0.05
B	Sized	300	13	SeaWater	8.42	8.50	8.46	0.04
C	Sized	300	13	SeaWater	8.30	8.34	8.32	0.02
A	Unsized	300	13	0	8.67	8.69	8.68	0.01
B	Unsized	300	13	0	8.69	8.74	8.71	0.02
A	Unsized	300	13	200	8.63	8.67	8.65	0.02
B	Unsized	300	13	200	8.70	8.72	8.71	0.01
A	Unsized	300	13	20000	8.64	8.65	8.64	0.01
B	Unsized	300	13	20000	8.58	8.65	8.62	0.04
A	Unsized	300	13	SeaWater	8.42	8.45	8.43	0.02
B	Unsized	300	13	SeaWater	8.46	8.54	8.50	0.04

For a better understanding, change in the DO content of the environments was plotted in graphs in Figure 1.7, 1.8, and 1.9. It can be seen that dissolved oxygen content of environments has decreased overtime.

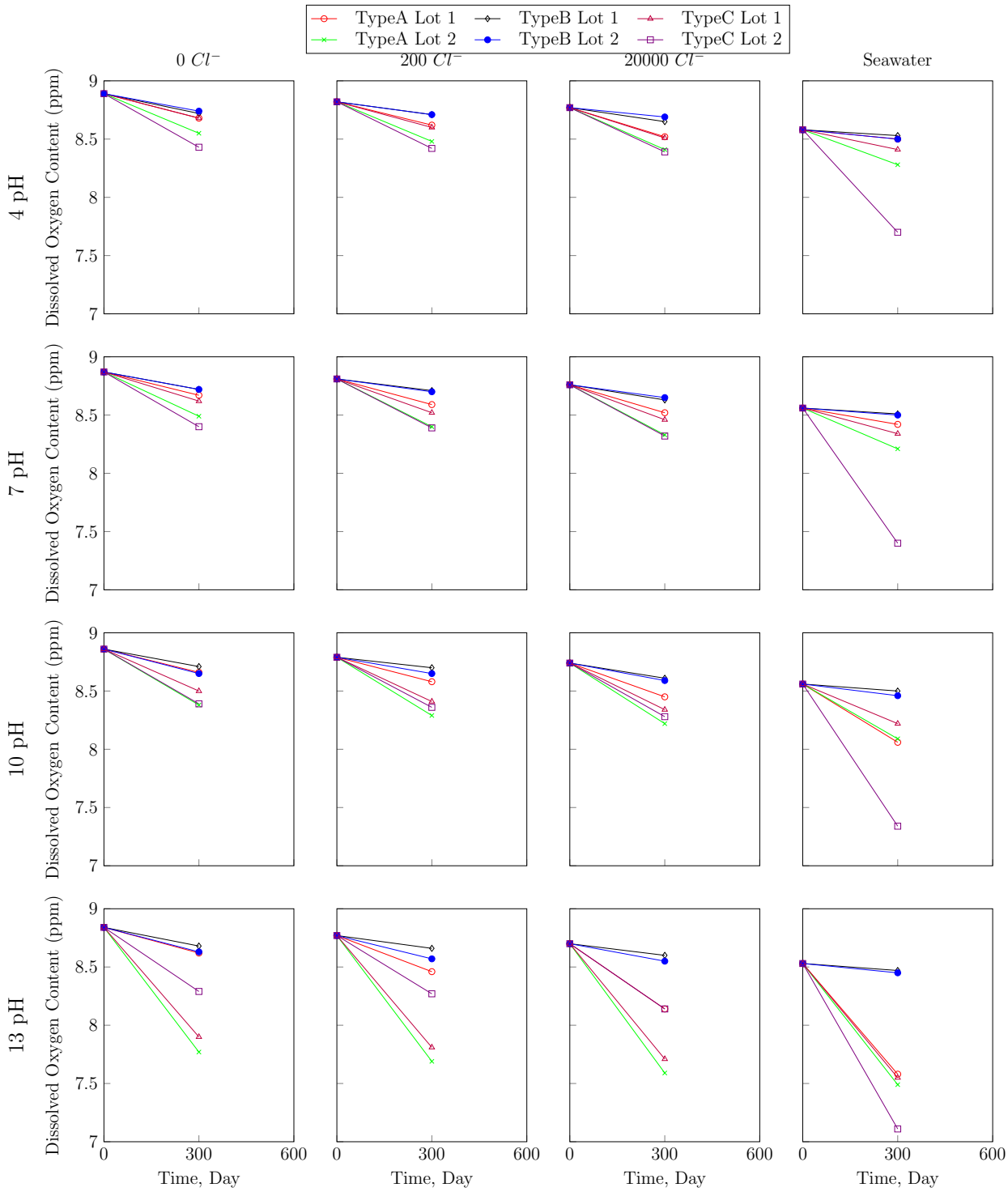

Figure 1.7: Dissolved oxygen concentration of environments after exposure of rebars

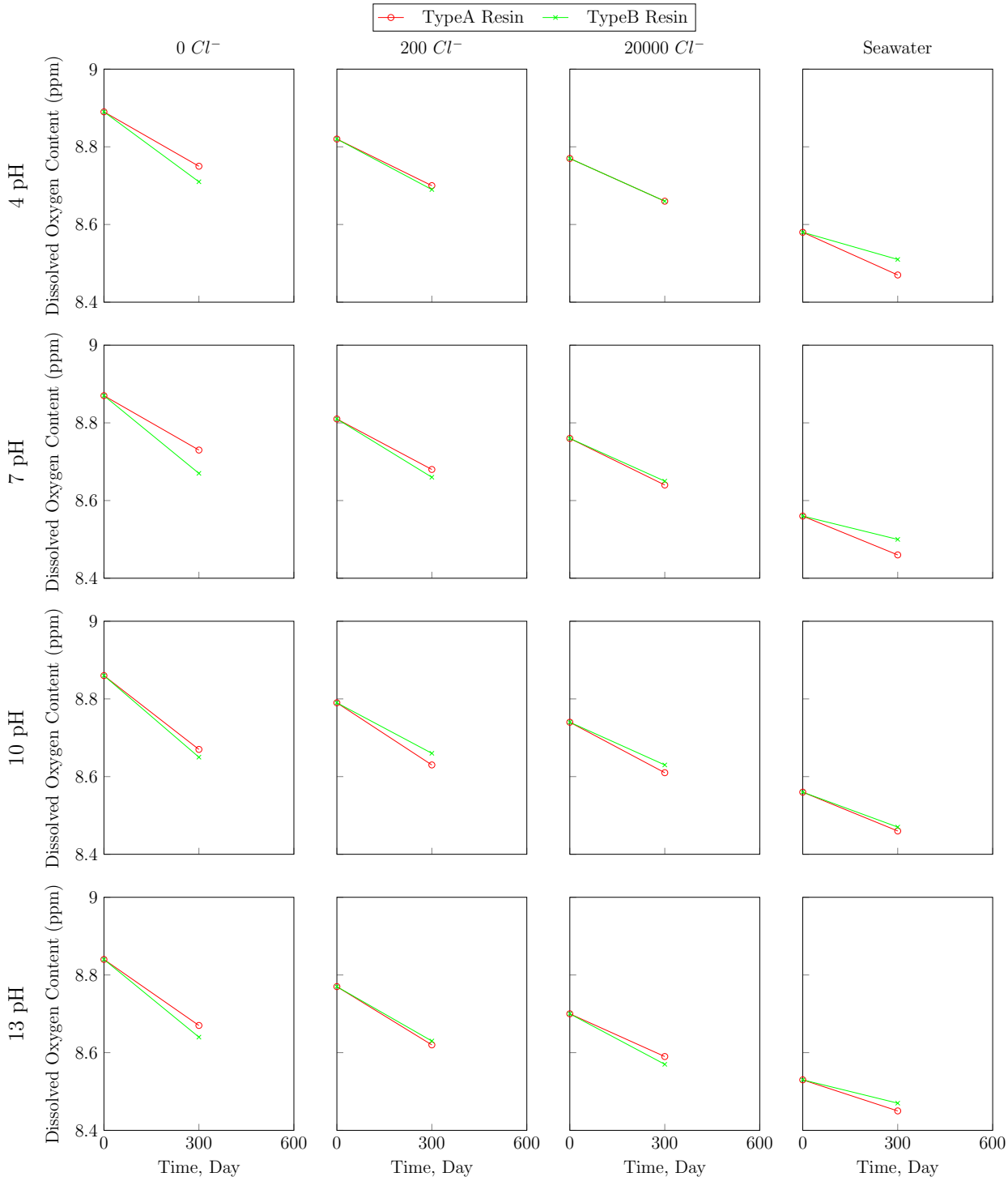

Figure 1.8: Dissolved oxygen concentration of environments after exposure of resins

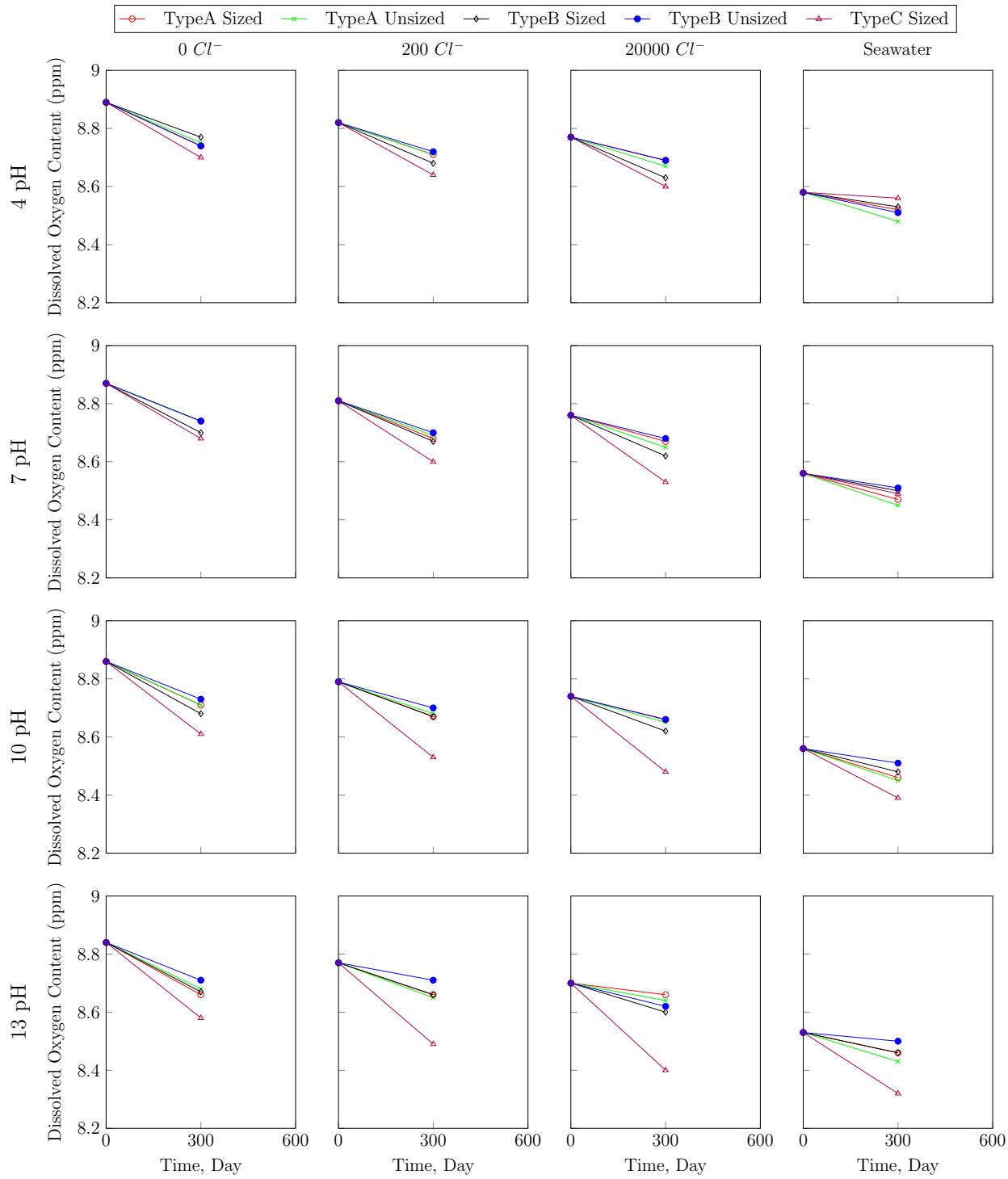

Figure 1.9: Dissolved oxygen concentration of environments after exposure of sized and unsized fibers

1.2.4 Alkalinity

Alkalinity of the chemical environments was measured after 300 days of exposure. Tables 1.10, 1.11, and 1.12 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.10: Alkalinity Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Alkalinity as $CaCO_3$			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	−13.20	−13.01	−13.11	0.09
B	Vinyl Ester	1	300	4	0	−2.41	−2.35	−2.38	0.03
C	Epoxy	1	300	4	0	−11.62	−11.45	−11.53	0.08
A	Epoxy	1	300	4	200	−14.59	−14.45	−14.52	0.07
B	Vinyl Ester	1	300	4	200	−2.10	−2.06	−2.08	0.02
C	Epoxy	1	300	4	200	−12.84	−12.72	−12.78	0.06
A	Epoxy	1	300	4	20000	−16.32	−15.86	−16.09	0.23
B	Vinyl Ester	1	300	4	20000	−1.92	−0.48	−1.20	0.72
C	Epoxy	1	300	4	20000	−14.37	−13.96	−14.16	0.20
A	Epoxy	1	300	4	SeaWater	−19.03	−18.87	−18.95	0.08
B	Vinyl Ester	1	300	4	SeaWater	−0.75	−0.05	−0.40	0.35
C	Epoxy	1	300	4	SeaWater	−16.74	−16.60	−16.67	0.07
A	Epoxy	2	300	4	0	−23.64	−19.02	−21.33	2.31
B	Vinyl Ester	2	300	4	0	−2.22	−1.80	−2.01	0.21
C	Epoxy	2	300	4	0	−20.33	−16.36	−18.35	1.99
A	Epoxy	2	300	4	200	−20.23	−18.67	−19.45	0.78
B	Vinyl Ester	2	300	4	200	−2.00	−1.60	−1.80	0.20
C	Epoxy	2	300	4	200	−17.40	−16.06	−16.73	0.67
A	Epoxy	2	300	4	20000	−15.56	−15.16	−15.36	0.20
B	Vinyl Ester	2	300	4	20000	−2.13	−1.07	−1.60	0.53
C	Epoxy	2	300	4	20000	−13.38	−13.04	−13.21	0.17
A	Epoxy	2	300	4	SeaWater	−14.22	−13.76	−13.99	0.23
B	Vinyl Ester	2	300	4	SeaWater	−0.78	−0.55	−0.67	0.12

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Table 1.10: Alkalinity Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Alkalinity as $CaCO_3$			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	4	SeaWater	−12.23	−11.84	−12.03	0.20
A	Epoxy	1	300	7	0	0.71	1.92	1.31	0.60
B	Vinyl Ester	1	300	7	0	3.68	5.18	4.43	0.75
C	Epoxy	1	300	7	0	0.75	2.01	1.38	0.63
A	Epoxy	1	300	7	200	0.99	1.45	1.22	0.23
B	Vinyl Ester	1	300	7	200	5.16	6.30	5.73	0.57
C	Epoxy	1	300	7	200	1.04	1.52	1.28	0.24
A	Epoxy	1	300	7	20000	0.80	1.28	1.04	0.24
B	Vinyl Ester	1	300	7	20000	6.07	6.57	6.32	0.25
C	Epoxy	1	300	7	20000	0.84	1.35	1.09	0.25
A	Epoxy	1	300	7	SeaWater	57.07	58.51	57.79	0.72
B	Vinyl Ester	1	300	7	SeaWater	73.21	74.17	73.69	0.48
C	Epoxy	1	300	7	SeaWater	59.92	61.44	60.68	0.76
A	Epoxy	2	300	7	0	0.66	1.43	1.05	0.38
B	Vinyl Ester	2	300	7	0	3.89	5.45	4.67	0.78
C	Epoxy	2	300	7	0	0.70	1.52	1.11	0.41
A	Epoxy	2	300	7	200	0.23	1.41	0.82	0.59
B	Vinyl Ester	2	300	7	200	5.44	6.62	6.03	0.59
C	Epoxy	2	300	7	200	0.24	1.50	0.87	0.63
A	Epoxy	2	300	7	20000	0.40	0.59	0.49	0.09
B	Vinyl Ester	2	300	7	20000	6.38	6.90	6.64	0.26
C	Epoxy	2	300	7	20000	0.42	0.62	0.52	0.10
A	Epoxy	2	300	7	SeaWater	52.28	52.96	52.62	0.34
B	Vinyl Ester	2	300	7	SeaWater	78.58	79.13	78.86	0.27

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Table 1.10: Alkalinity Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Alkalinity as $CaCO_3$			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	7	SeaWater	55.42	56.14	55.78	0.36
A	Epoxy	1	300	10	0	5.89	6.33	6.11	0.22
B	Vinyl Ester	1	300	10	0	14.90	15.30	15.10	0.20
C	Epoxy	1	300	10	0	6.19	6.65	6.42	0.23
A	Epoxy	1	300	10	200	5.20	5.26	5.23	0.03
B	Vinyl Ester	1	300	10	200	18.54	18.90	18.72	0.18
C	Epoxy	1	300	10	200	5.46	5.52	5.49	0.03
A	Epoxy	1	300	10	20000	4.44	4.87	4.65	0.21
B	Vinyl Ester	1	300	10	20000	23.47	23.57	23.52	0.05
C	Epoxy	1	300	10	20000	4.66	5.11	4.89	0.22
A	Epoxy	1	300	10	SeaWater	98.97	100.57	99.77	0.80
B	Vinyl Ester	1	300	10	SeaWater	122.95	124.46	123.71	0.75
C	Epoxy	1	300	10	SeaWater	103.92	105.60	104.76	0.84
A	Epoxy	2	300	10	0	5.41	5.59	5.50	0.09
B	Vinyl Ester	2	300	10	0	14.90	15.03	14.97	0.06
C	Epoxy	2	300	10	0	5.73	5.93	5.83	0.10
A	Epoxy	2	300	10	200	4.31	4.47	4.39	0.08
B	Vinyl Ester	2	300	10	200	16.54	16.90	16.72	0.18
C	Epoxy	2	300	10	200	4.56	4.74	4.65	0.09
A	Epoxy	2	300	10	20000	3.64	4.07	3.85	0.21
B	Vinyl Ester	2	300	10	20000	19.07	19.17	19.12	0.05
C	Epoxy	2	300	10	20000	3.86	4.31	4.08	0.23
A	Epoxy	2	300	10	SeaWater	94.87	96.70	95.78	0.92
B	Vinyl Ester	2	300	10	SeaWater	120.24	122.21	121.22	0.98

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Table 1.10: Alkalinity Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Alkalinity as $CaCO_3$			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	10	SeaWater	100.56	102.50	101.53	0.97
A	Epoxy	1	300	13	0	166.25	182.42	174.33	8.08
B	Vinyl Ester	1	300	13	0	957.00	973.00	965.00	8.00
C	Epoxy	1	300	13	0	167.25	183.51	175.38	8.13
A	Epoxy	1	300	13	200	127.54	134.46	131.00	3.46
B	Vinyl Ester	1	300	13	200	1395.98	1407.35	1401.67	5.69
C	Epoxy	1	300	13	200	128.56	135.54	132.05	3.49
A	Epoxy	1	300	13	20000	117.18	119.49	118.33	1.15
B	Vinyl Ester	1	300	13	20000	1456.85	1477.15	1467.00	10.15
C	Epoxy	1	300	13	20000	118.35	120.68	119.52	1.17
A	Epoxy	1	300	13	SeaWater	373.57	436.43	405.00	31.43
B	Vinyl Ester	1	300	13	SeaWater	4141.51	4195.82	4168.67	27.15
C	Epoxy	1	300	13	SeaWater	378.87	438.18	408.53	29.66
A	Epoxy	2	300	13	0	104.09	119.24	111.67	7.57
B	Vinyl Ester	2	300	13	0	1397.00	1413.00	1405.00	8.00
C	Epoxy	2	300	13	0	104.93	120.19	112.56	7.63
A	Epoxy	2	300	13	200	84.87	115.13	100.00	15.13
B	Vinyl Ester	2	300	13	200	1508.31	1520.36	1514.33	6.03
C	Epoxy	2	300	13	200	85.72	116.28	101.00	15.28
A	Epoxy	2	300	13	20000	79.25	83.41	81.33	2.08
B	Vinyl Ester	2	300	13	20000	1776.85	1797.15	1787.00	10.15
C	Epoxy	2	300	13	20000	80.20	84.42	82.31	2.11
A	Epoxy	2	300	13	SeaWater	320.02	383.31	351.67	31.64
B	Vinyl Ester	2	300	13	SeaWater	4093.19	4129.48	4111.33	18.15

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Table 1.10: Alkalinity Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Alkalinity as $CaCO_3$			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	13	SeaWater	324.50	388.68	356.59	32.09

Table 1.11: Alkalinity Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Alkalinity as $CaCO_3$			
Manuf. Type	Resin Type	Exposure Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	−7.95	−7.59	−7.77	0.18
B	Vinyl Ester	300	4	0	−8.92	−7.96	−8.44	0.48
A	Epoxy	300	4	200	−8.59	−8.45	−8.52	0.07
B	Vinyl Ester	300	4	200	−10.20	−10.15	−10.17	0.02
A	Epoxy	300	4	20000	−11.13	−10.42	−10.77	0.36
B	Vinyl Ester	300	4	20000	−12.51	−12.37	−12.44	0.07
A	Epoxy	300	4	SeaWater	−12.91	−12.86	−12.89	0.02
B	Vinyl Ester	300	4	SeaWater	−14.73	−14.51	−14.62	0.11
A	Epoxy	300	7	0	0.71	1.78	1.25	0.53
B	Vinyl Ester	300	7	0	0.29	1.62	0.95	0.67
A	Epoxy	300	7	200	0.44	1.76	1.10	0.66
B	Vinyl Ester	300	7	200	0.04	1.36	0.70	0.66
A	Epoxy	300	7	20000	0.54	1.01	0.77	0.24
B	Vinyl Ester	300	7	20000	−0.39	0.90	0.25	0.64
A	Epoxy	300	7	SeaWater	55.27	55.93	55.60	0.33
B	Vinyl Ester	300	7	SeaWater	53.48	54.15	53.81	0.34
A	Epoxy	300	10	0	5.53	5.89	5.71	0.18
B	Vinyl Ester	300	10	0	5.08	5.44	5.26	0.18
A	Epoxy	300	10	200	3.95	4.37	4.16	0.21
B	Vinyl Ester	300	10	200	3.65	4.13	3.89	0.24
A	Epoxy	300	10	20000	3.64	4.07	3.85	0.21
B	Vinyl Ester	300	10	20000	3.30	3.58	3.44	0.14
A	Epoxy	300	10	SeaWater	94.67	95.84	95.25	0.58
B	Vinyl Ester	300	10	SeaWater	92.41	93.58	93.00	0.59
A	Epoxy	300	13	0	2137.00	2153.00	2145.00	8.00
B	Vinyl Ester	300	13	0	2085.56	2097.78	2091.67	6.11
A	Epoxy	300	13	200	2003.98	2015.35	2009.67	5.69
B	Vinyl Ester	300	13	200	1943.98	1955.35	1949.67	5.69
A	Epoxy	300	13	20000	1887.37	1915.96	1901.67	14.29
B	Vinyl Ester	300	13	20000	1847.37	1875.96	1861.67	14.29
A	Epoxy	300	13	SeaWater	3954.43	3992.24	3973.33	18.90
B	Vinyl Ester	300	13	SeaWater	3927.76	3965.57	3946.67	18.90

Table 1.12: Alkalinity Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Alkalinity as $CaCO_3$			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	−2.40	−2.21	−2.31	0.09
B	Sized	300	4	0	−2.60	−2.55	−2.57	0.02
C	Sized	300	4	0	−2.16	−1.99	−2.08	0.08
A	Sized	300	4	200	−2.14	−2.08	−2.11	0.03
B	Sized	300	4	200	−2.34	−2.24	−2.29	0.05
C	Sized	300	4	200	−1.93	−1.87	−1.90	0.03
A	Sized	300	4	20000	−1.86	−1.69	−1.77	0.08
B	Sized	300	4	20000	−2.84	−1.83	−2.33	0.50
C	Sized	300	4	20000	−1.67	−1.52	−1.60	0.07
A	Sized	300	4	SeaWater	−1.30	−0.65	−0.97	0.33
B	Sized	300	4	SeaWater	−1.57	−0.96	−1.27	0.31
C	Sized	300	4	SeaWater	−1.17	−0.58	−0.88	0.29
A	Unsized	300	4	0	−2.07	−1.82	−1.95	0.13
B	Unsized	300	4	0	−2.20	−2.15	−2.17	0.02
A	Unsized	300	4	200	−2.03	−1.59	−1.81	0.22
B	Unsized	300	4	200	−2.14	−2.12	−2.13	0.01
A	Unsized	300	4	20000	−2.20	−1.98	−2.09	0.11
B	Unsized	300	4	20000	−2.13	−1.07	−1.60	0.53
A	Unsized	300	4	SeaWater	−1.60	−0.80	−1.20	0.40
B	Unsized	300	4	SeaWater	−1.50	−1.04	−1.27	0.23
A	Sized	300	7	0	4.69	4.89	4.79	0.10
B	Sized	300	7	0	3.78	5.33	4.55	0.77
C	Sized	300	7	0	4.93	5.14	5.03	0.10
A	Sized	300	7	200	6.75	7.13	6.94	0.19
B	Sized	300	7	200	5.43	6.61	6.02	0.59
C	Sized	300	7	200	7.08	7.49	7.29	0.20
A	Sized	300	7	20000	7.00	7.27	7.13	0.13
B	Sized	300	7	20000	6.61	7.12	6.87	0.25
C	Sized	300	7	20000	7.35	7.63	7.49	0.14
A	Sized	300	7	SeaWater	78.84	80.07	79.46	0.62
B	Sized	300	7	SeaWater	77.11	77.57	77.34	0.23
C	Sized	300	7	SeaWater	82.78	84.08	83.43	0.65
A	Unsized	300	7	0	3.87	5.39	4.63	0.76
B	Unsized	300	7	0	3.71	5.27	4.49	0.78
A	Unsized	300	7	200	5.43	6.62	6.02	0.59
B	Unsized	300	7	200	5.27	6.43	5.85	0.58
A	Unsized	300	7	20000	6.30	6.81	6.55	0.26

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Table 1.12: Alkalinity Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Alkalinity as $CaCO_3$			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	7	20000	6.19	6.70	6.44	0.26
A	Unsized	300	7	SeaWater	76.00	77.34	76.67	0.67
B	Unsized	300	7	SeaWater	73.81	75.16	74.48	0.68
A	Sized	300	10	0	15.48	15.79	15.63	0.16
B	Sized	300	10	0	13.98	14.04	14.01	0.03
C	Sized	300	10	0	16.25	16.58	16.42	0.16
A	Sized	300	10	200	18.78	19.06	18.92	0.14
B	Sized	300	10	200	14.86	17.99	16.43	1.56
C	Sized	300	10	200	19.72	20.01	19.87	0.15
A	Sized	300	10	20000	22.89	24.34	23.61	0.73
B	Sized	300	10	20000	18.85	20.57	19.71	0.86
C	Sized	300	10	20000	24.03	25.56	24.79	0.76
A	Sized	300	10	SeaWater	123.63	124.69	124.16	0.53
B	Sized	300	10	SeaWater	122.24	122.62	122.43	0.19
C	Sized	300	10	SeaWater	129.81	130.92	130.37	0.55
A	Unsized	300	10	0	14.74	15.03	14.89	0.14
B	Unsized	300	10	0	10.90	11.30	11.10	0.20
A	Unsized	300	10	200	15.27	15.64	15.45	0.19
B	Unsized	300	10	200	12.95	13.26	13.11	0.16
A	Unsized	300	10	20000	16.64	17.38	17.01	0.37
B	Unsized	300	10	20000	14.67	14.77	14.72	0.05
A	Unsized	300	10	SeaWater	118.20	119.73	118.97	0.76
B	Unsized	300	10	SeaWater	116.84	117.93	117.38	0.54
A	Sized	300	13	0	1535.01	1568.32	1551.67	16.65
B	Sized	300	13	0	1445.56	1457.78	1451.67	6.11
C	Sized	300	13	0	1542.69	1576.16	1559.43	16.74
A	Sized	300	13	200	2115.68	2128.99	2122.33	6.66
B	Sized	300	13	200	2095.98	2107.35	2101.67	5.69
C	Sized	300	13	200	2128.37	2141.77	2135.07	6.70
A	Sized	300	13	20000	2187.69	2216.97	2202.33	14.64
B	Sized	300	13	20000	2118.00	2140.00	2129.00	11.00
C	Sized	300	13	20000	2203.01	2232.49	2217.75	14.74
A	Sized	300	13	SeaWater	4220.00	4260.00	4240.00	20.00
B	Sized	300	13	SeaWater	4165.56	4243.77	4204.67	39.11
C	Sized	300	13	SeaWater	4232.66	4272.78	4252.72	20.06
A	Unsized	300	13	0	1443.91	1478.09	1461.00	17.09
B	Unsized	300	13	0	1085.56	1097.78	1091.67	6.11

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Table 1.12: Alkalinity Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Alkalinity as $CaCO_3$			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	13	200	1499.73	1522.27	1511.00	11.27
B	Unsized	300	13	200	1195.98	1207.35	1201.67	5.69
A	Unsized	300	13	20000	2079.72	2111.61	2095.67	15.95
B	Unsized	300	13	20000	2118.00	2140.00	2129.00	11.00
A	Unsized	300	13	SeaWater	4177.51	4231.82	4204.67	27.15
B	Unsized	300	13	SeaWater	4124.43	4164.90	4144.67	20.23

For a better understanding, change in the alkalinity content of the environments was plotted in graphs in Figure 1.10, 1.11, and 1.12. It can be seen that the alkalinity of all environments has decreased except for 13pH environments. This would be expected even if the -OH ions were being consumed since pH 13 has a 1000 times higher -OH content so the same net consumption would not be noticeable.

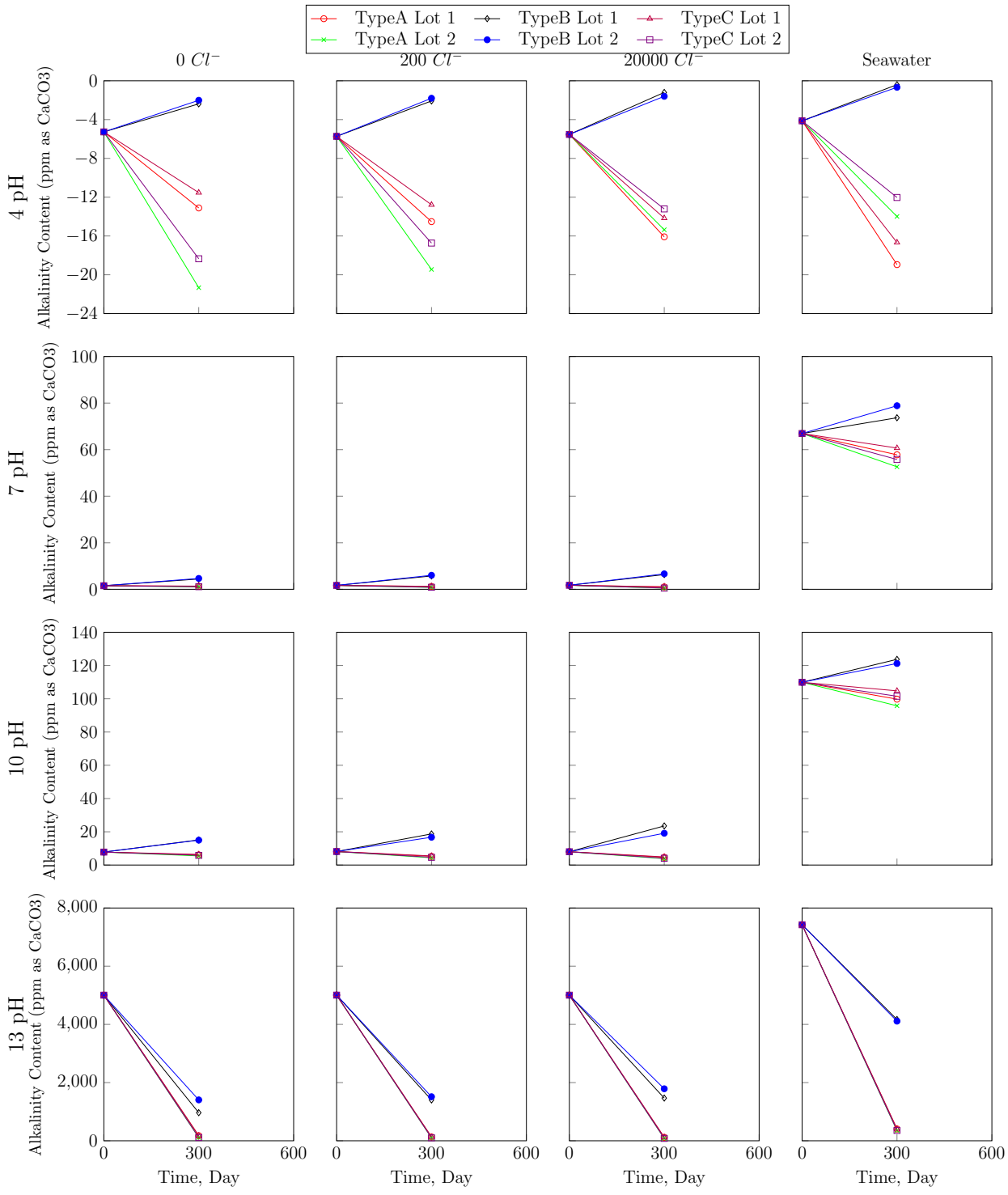

Figure 1.10: Alkalinity of environments after exposure of rebars

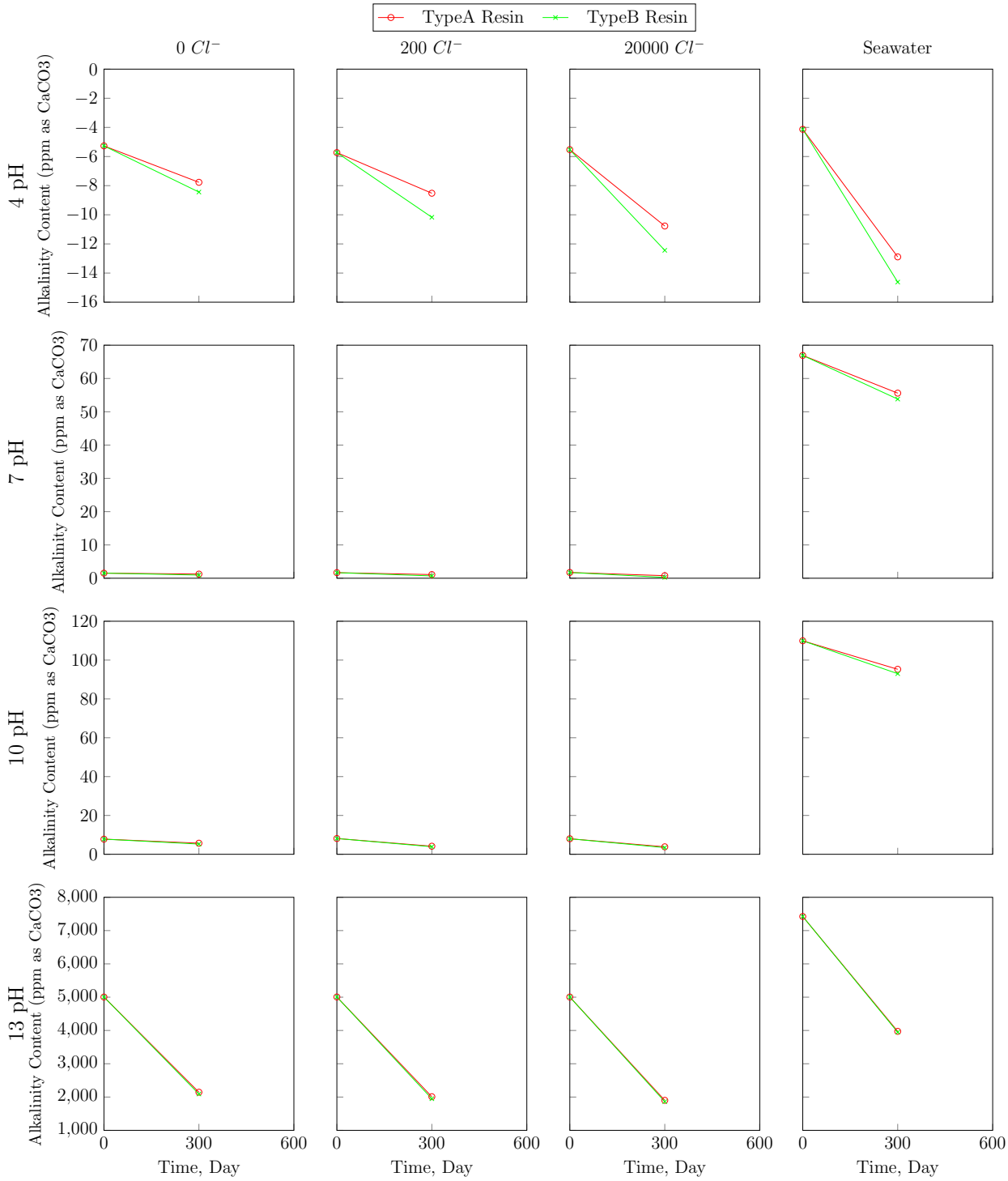

Figure 1.11: Alkalinity of environments after exposure of resins

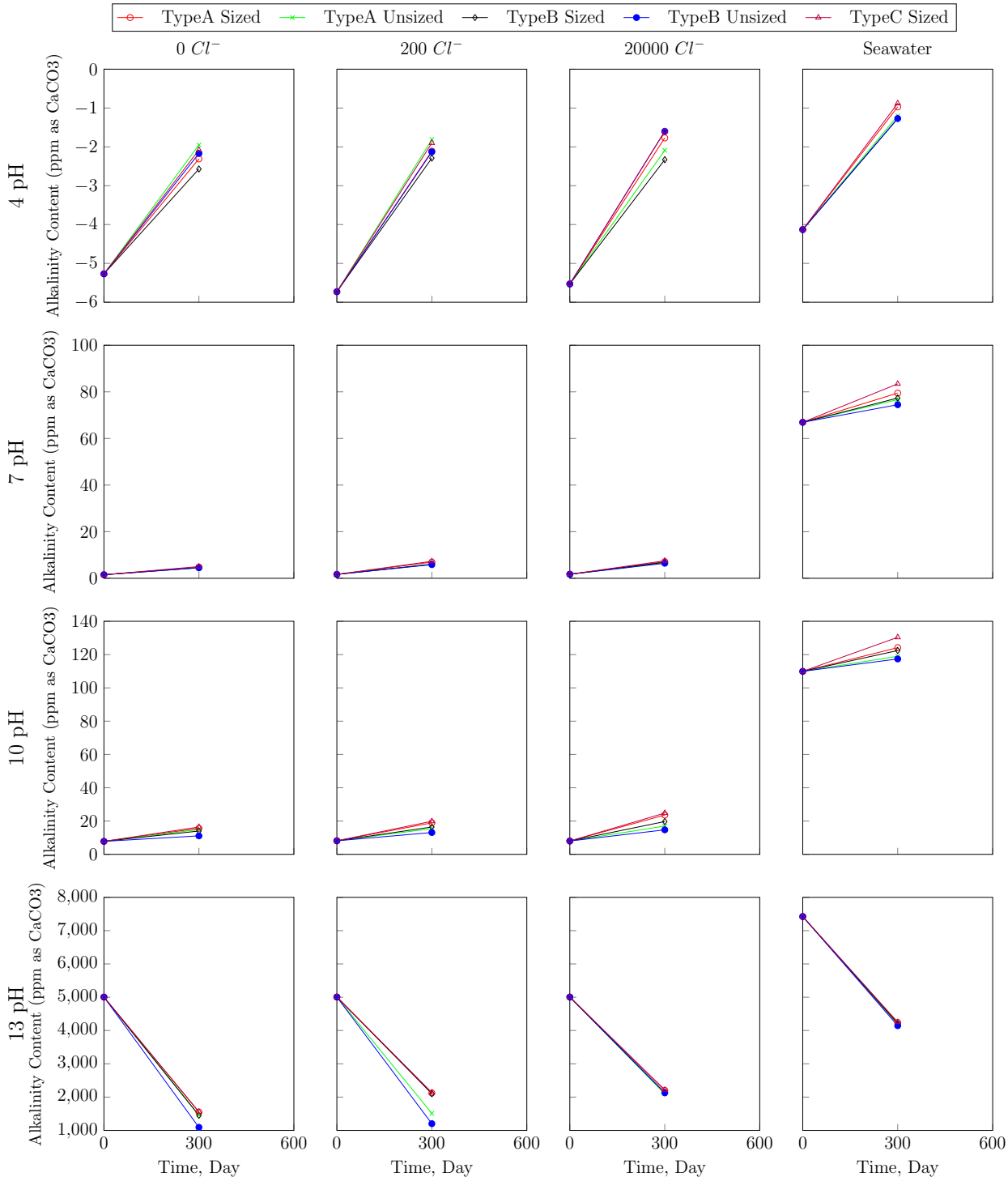

Figure 1.12: Alkalinity of environments after exposure of sized and unsized fibers

1.2.5 Anions

Chloride

Chloride content of the chemical environments was measured after 300 days of exposure. Tables 1.13, 1.14, and 1.15 below shows the Chloride data of environments in which rebars, resins, and fibers were exposed.

Table 1.13: Chloride Ion Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Chloride Ion			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	0.40	0.42	0.41	0.01
B	Vinyl Ester	1	300	4	0	0.48	0.54	0.51	0.03
C	Epoxy	1	300	4	0	0.52	0.55	0.53	0.01
A	Epoxy	1	300	4	200	214.52	214.60	214.56	0.04
B	Vinyl Ester	1	300	4	200	204.61	207.33	205.97	1.36
C	Epoxy	1	300	4	200	220.95	221.04	220.99	0.04
A	Epoxy	1	300	4	20000	19 965.12	19 988.21	19 976.67	11.55
B	Vinyl Ester	1	300	4	20000	19 911.19	19 975.48	19 943.33	32.15
C	Epoxy	1	300	4	20000	19 985.08	20 008.20	19 996.64	11.56
A	Epoxy	1	300	4	SeaWater	19 789.41	19 883.92	19 836.67	47.26
B	Vinyl Ester	1	300	4	SeaWater	19 861.79	19 884.88	19 873.33	11.55
C	Epoxy	1	300	4	SeaWater	19 809.20	19 903.81	19 856.50	47.31
A	Epoxy	2	300	4	0	0.36	0.39	0.37	0.02
B	Vinyl Ester	2	300	4	0	0.12	0.15	0.14	0.02
C	Epoxy	2	300	4	0	0.44	0.47	0.46	0.02
A	Epoxy	2	300	4	200	205.76	205.82	205.79	0.03
B	Vinyl Ester	2	300	4	200	203.59	204.47	204.03	0.44
C	Epoxy	2	300	4	200	211.52	211.58	211.55	0.03
A	Epoxy	2	300	4	20000	19 945.85	19 987.48	19 966.67	20.82
B	Vinyl Ester	2	300	4	20000	19 922.52	19 964.15	19 943.33	20.82
C	Epoxy	2	300	4	20000	19 975.77	20 017.46	19 996.62	20.85
A	Epoxy	2	300	4	SeaWater	19 796.41	19 883.59	19 840.00	43.59
B	Vinyl Ester	2	300	4	SeaWater	19 808.19	19 868.47	19 838.33	30.14
C	Epoxy	2	300	4	SeaWater	19 826.11	19 913.41	19 869.76	43.65
A	Epoxy	1	300	7	0	0.30	0.36	0.33	0.03
B	Vinyl Ester	1	300	7	0	0.35	0.42	0.39	0.04
C	Epoxy	1	300	7	0	0.39	0.47	0.43	0.04
A	Epoxy	1	300	7	200	211.65	211.68	211.67	0.02
B	Vinyl Ester	1	300	7	200	206.53	207.03	206.78	0.25
C	Epoxy	1	300	7	200	218.00	218.03	218.02	0.02
A	Epoxy	1	300	7	20000	19 920.00	19 940.00	19 930.00	10.00
B	Vinyl Ester	1	300	7	20000	19 925.85	19 967.48	19 946.67	20.82
C	Epoxy	1	300	7	20000	19 939.92	19 959.94	19 949.93	10.01
A	Epoxy	1	300	7	SeaWater	19 803.94	19 876.06	19 840.00	36.06
B	Vinyl Ester	1	300	7	SeaWater	19 812.68	19 847.32	19 830.00	17.32
C	Epoxy	1	300	7	SeaWater	19 823.75	19 895.93	19 859.84	36.09
A	Epoxy	2	300	7	0	0.35	0.37	0.36	0.01
B	Vinyl Ester	2	300	7	0	0.27	0.29	0.28	0.01

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Table 1.13: Chloride Ion Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Chloride Ion			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	7	0	0.42	0.45	0.44	0.01
A	Epoxy	2	300	7	200	204.61	204.71	204.66	0.05
B	Vinyl Ester	2	300	7	200	203.49	204.17	203.83	0.34
C	Epoxy	2	300	7	200	210.34	210.44	210.39	0.05
A	Epoxy	2	300	7	20000	19 912.92	19 993.75	19 953.33	40.41
B	Vinyl Ester	2	300	7	20000	19 914.11	19 949.23	19 931.67	17.56
C	Epoxy	2	300	7	20000	19 942.79	20 023.74	19 983.26	40.48
A	Epoxy	2	300	7	SeaWater	19 832.52	19 874.15	19 853.33	20.82
B	Vinyl Ester	2	300	7	SeaWater	19 801.55	19 871.79	19 836.67	35.12
C	Epoxy	2	300	7	SeaWater	19 862.27	19 903.96	19 883.11	20.85
A	Epoxy	1	300	10	0	0.61	0.65	0.63	0.02
B	Vinyl Ester	1	300	10	0	0.25	0.31	0.28	0.03
C	Epoxy	1	300	10	0	0.80	0.85	0.82	0.03
A	Epoxy	1	300	10	200	205.26	205.30	205.28	0.02
B	Vinyl Ester	1	300	10	200	206.07	207.53	206.80	0.73
C	Epoxy	1	300	10	200	211.41	211.46	211.43	0.02
A	Epoxy	1	300	10	20000	19 894.17	19 985.83	19 940.00	45.83
B	Vinyl Ester	1	300	10	20000	19 913.94	19 986.06	19 950.00	36.06
C	Epoxy	1	300	10	20000	19 914.07	20 005.81	19 959.94	45.87
A	Epoxy	1	300	10	SeaWater	19 825.47	19 901.19	19 863.33	37.86
B	Vinyl Ester	1	300	10	SeaWater	19 821.50	19 871.83	19 846.67	25.17
C	Epoxy	1	300	10	SeaWater	19 845.30	19 921.09	19 883.20	37.90
A	Epoxy	2	300	10	0	0.83	0.87	0.85	0.02
B	Vinyl Ester	2	300	10	0	0.50	0.53	0.51	0.02
C	Epoxy	2	300	10	0	1.01	1.06	1.04	0.02
A	Epoxy	2	300	10	200	206.58	206.64	206.61	0.03
B	Vinyl Ester	2	300	10	200	201.61	202.42	202.02	0.40
C	Epoxy	2	300	10	200	212.37	212.42	212.40	0.03
A	Epoxy	2	300	10	20000	19 898.81	19 974.53	19 936.67	37.86
B	Vinyl Ester	2	300	10	20000	19 908.17	19 958.50	19 933.33	25.17
C	Epoxy	2	300	10	20000	19 928.66	20 004.49	19 966.57	37.92
A	Epoxy	2	300	10	SeaWater	19 840.00	19 880.00	19 860.00	20.00
B	Vinyl Ester	2	300	10	SeaWater	19 815.47	19 891.19	19 853.33	37.86
C	Epoxy	2	300	10	SeaWater	19 869.76	19 909.82	19 889.79	20.03
A	Epoxy	1	300	13	0	0.39	0.43	0.41	0.02
B	Vinyl Ester	1	300	13	0	0.45	0.51	0.48	0.03
C	Epoxy	1	300	13	0	0.51	0.56	0.54	0.03
A	Epoxy	1	300	13	200	212.15	212.19	212.17	0.02
B	Vinyl Ester	1	300	13	200	204.60	205.73	205.16	0.57
C	Epoxy	1	300	13	200	218.51	218.55	218.53	0.02
A	Epoxy	1	300	13	20000	19 917.15	20 009.52	19 963.33	46.19
B	Vinyl Ester	1	300	13	20000	19 912.78	19 973.88	19 943.33	30.55
C	Epoxy	1	300	13	20000	19 937.06	20 029.53	19 983.30	46.23
A	Epoxy	1	300	13	SeaWater	19 821.53	19 881.81	19 851.67	30.14
B	Vinyl Ester	1	300	13	SeaWater	19 807.80	19 865.53	19 836.67	28.87
C	Epoxy	1	300	13	SeaWater	19 841.35	19 901.69	19 871.52	30.17
A	Epoxy	2	300	13	0	0.48	0.51	0.49	0.02
B	Vinyl Ester	2	300	13	0	0.60	0.67	0.63	0.03
C	Epoxy	2	300	13	0	0.58	0.62	0.60	0.02

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Table 1.13: Chloride Ion Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Chloride Ion			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	2	300	13	200	207.87	207.91	207.89	0.02
B	Vinyl Ester	2	300	13	200	203.01	204.80	203.90	0.90
C	Epoxy	2	300	13	200	213.69	213.74	213.71	0.02
A	Epoxy	2	300	13	20000	19 911.19	19 975.48	19 943.33	32.15
B	Vinyl Ester	2	300	13	20000	19 901.70	19 984.97	19 943.33	41.63
C	Epoxy	2	300	13	20000	19 941.05	20 005.44	19 973.25	32.19
A	Epoxy	2	300	13	SeaWater	19 852.52	19 894.15	19 873.33	20.82
B	Vinyl Ester	2	300	13	SeaWater	19 800.81	19 875.86	19 838.33	37.53
C	Epoxy	2	300	13	SeaWater	19 882.30	19 923.99	19 903.14	20.85

Table 1.14: Chloride Ion Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Chloride Ion			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	0.57	0.62	0.60	0.03
B	Vinyl Ester	300	4	0	0.17	0.28	0.22	0.06
A	Epoxy	300	4	200	203.60	204.77	204.19	0.59
B	Vinyl Ester	300	4	200	205.06	206.04	205.55	0.49
A	Epoxy	300	4	20000	19 912.68	19 947.32	19 930.00	17.32
B	Vinyl Ester	300	4	20000	19 931.39	19 961.94	19 946.67	15.28
A	Epoxy	300	4	SeaWater	19 848.06	19 878.61	19 863.33	15.28
B	Vinyl Ester	300	4	SeaWater	19 815.47	19 891.19	19 853.33	37.86
A	Epoxy	300	7	0	0.61	0.65	0.63	0.02
B	Vinyl Ester	300	7	0	0.09	0.16	0.13	0.04
A	Epoxy	300	7	200	204.99	205.03	205.01	0.02
B	Vinyl Ester	300	7	200	202.47	204.82	203.65	1.17
A	Epoxy	300	7	20000	19 912.52	19 954.15	19 933.33	20.82
B	Vinyl Ester	300	7	20000	19 918.21	19 988.45	19 953.33	35.12
A	Epoxy	300	7	SeaWater	19 802.78	19 863.88	19 833.33	30.55
B	Vinyl Ester	300	7	SeaWater	19 821.50	19 871.83	19 846.67	25.17
A	Epoxy	300	10	0	0.73	0.77	0.75	0.02
B	Vinyl Ester	300	10	0	0.41	0.50	0.45	0.05
A	Epoxy	300	10	200	205.43	206.74	206.08	0.65
B	Vinyl Ester	300	10	200	205.40	206.39	205.90	0.49

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Table 1.14: Chloride Ion Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Chloride Ion			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	10	20000	19 921.50	19 971.83	19 946.67	25.17
B	Vinyl Ester	300	10	20000	19 938.06	19 968.61	19 953.33	15.28
A	Epoxy	300	10	SeaWater	19 843.54	19 896.46	19 870.00	26.46
B	Vinyl Ester	300	10	SeaWater	19 807.34	19 906.00	19 856.67	49.33
A	Epoxy	300	13	0	0.37	0.41	0.39	0.02
B	Vinyl Ester	300	13	0	0.23	0.39	0.31	0.08
A	Epoxy	300	13	200	208.92	210.07	209.49	0.58
B	Vinyl Ester	300	13	200	200.99	207.16	204.07	3.08
A	Epoxy	300	13	20000	19 901.50	19 951.83	19 926.67	25.17
B	Vinyl Ester	300	13	20000	19 901.50	19 951.83	19 926.67	25.17
A	Epoxy	300	13	SeaWater	19 838.06	19 868.61	19 853.33	15.28
B	Vinyl Ester	300	13	SeaWater	19 830.24	19 876.43	19 853.33	23.09

Table 1.15: Chloride Ion Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Chloride Ion			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	0.11	0.12	0.11	0.01
B	Sized	300	4	0	0.11	0.13	0.12	0.01
C	Sized	300	4	0	0.13	0.14	0.14	0.01
A	Sized	300	4	200	204.94	205.00	204.97	0.03
B	Sized	300	4	200	203.48	204.51	203.99	0.51
C	Sized	300	4	200	209.04	209.10	209.07	0.03
A	Sized	300	4	20000	19 888.81	19 964.53	19 926.67	37.86
B	Sized	300	4	20000	19 935.85	19 977.48	19 956.67	20.82
C	Sized	300	4	20000	19 928.58	20 004.46	19 966.52	37.94
A	Sized	300	4	SeaWater	19 803.94	19 876.06	19 840.00	36.06
B	Sized	300	4	SeaWater	19 791.19	19 855.48	19 823.33	32.15
C	Sized	300	4	SeaWater	19 843.55	19 915.81	19 879.68	36.13
A	Unsized	300	4	0	0.40	0.44	0.42	0.02
B	Unsized	300	4	0	0.16	0.19	0.17	0.02
A	Unsized	300	4	200	204.96	204.98	204.97	0.01

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Table 1.15: Chloride Ion Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Chloride Ion			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	4	200	202.00	203.02	202.51	0.51
A	Unsized	300	4	20000	19 931.39	19 961.94	19 946.67	15.28
B	Unsized	300	4	20000	19 929.11	19 964.23	19 946.67	17.56
A	Unsized	300	4	SeaWater	19 798.81	19 874.53	19 836.67	37.86
B	Unsized	300	4	SeaWater	19 798.23	19 878.44	19 838.33	40.10
A	Sized	300	7	0	0.14	0.18	0.16	0.02
B	Sized	300	7	0	0.11	0.15	0.13	0.02
C	Sized	300	7	0	0.17	0.21	0.19	0.02
A	Sized	300	7	200	207.77	207.82	207.79	0.02
B	Sized	300	7	200	202.86	204.14	203.50	0.64
C	Sized	300	7	200	211.93	211.97	211.95	0.02
A	Sized	300	7	20000	19 886.41	19 973.59	19 930.00	43.59
B	Sized	300	7	20000	19 950.89	19 962.44	19 956.67	5.77
C	Sized	300	7	20000	19 926.18	20 013.54	19 969.86	43.68
A	Sized	300	7	SeaWater	19 843.54	19 896.46	19 870.00	26.46
B	Sized	300	7	SeaWater	19 803.94	19 876.06	19 840.00	36.06
C	Sized	300	7	SeaWater	19 883.23	19 936.25	19 909.74	26.51
A	Unsized	300	7	0	0.24	0.27	0.26	0.02
B	Unsized	300	7	0	0.11	0.17	0.14	0.03
A	Unsized	300	7	200	207.39	207.43	207.41	0.02
B	Unsized	300	7	200	203.53	205.25	204.39	0.86
A	Unsized	300	7	20000	19 932.52	19 974.15	19 953.33	20.82
B	Unsized	300	7	20000	19 939.11	19 974.23	19 956.67	17.56
A	Unsized	300	7	SeaWater	19 796.41	19 883.59	19 840.00	43.59
B	Unsized	300	7	SeaWater	19 832.09	19 877.91	19 855.00	22.91
A	Sized	300	10	0	0.30	0.36	0.33	0.03
B	Sized	300	10	0	0.09	0.12	0.10	0.02
C	Sized	300	10	0	0.36	0.44	0.40	0.04
A	Sized	300	10	200	207.02	207.06	207.04	0.02
B	Sized	300	10	200	202.76	204.42	203.59	0.83
C	Sized	300	10	200	211.16	211.20	211.18	0.02
A	Sized	300	10	20000	19 935.85	19 977.48	19 956.67	20.82
B	Sized	300	10	20000	19 948.06	19 978.61	19 963.33	15.28
C	Sized	300	10	20000	19 975.72	20 017.44	19 996.58	20.86
A	Sized	300	10	SeaWater	19 789.41	19 883.92	19 836.67	47.26
B	Sized	300	10	SeaWater	19 861.39	19 891.94	19 876.67	15.28
C	Sized	300	10	SeaWater	19 828.99	19 923.69	19 876.34	47.35

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Table 1.15: Chloride Ion Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Chloride Ion			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	10	0	0.25	0.29	0.27	0.02
B	Unsized	300	10	0	0.14	0.18	0.16	0.02
A	Unsized	300	10	200	206.04	206.09	206.06	0.03
B	Unsized	300	10	200	203.62	205.72	204.67	1.05
A	Unsized	300	10	20000	19 910.00	19 950.00	19 930.00	20.00
B	Unsized	300	10	20000	19 952.68	19 987.32	19 970.00	17.32
A	Unsized	300	10	SeaWater	19 823.94	19 896.06	19 860.00	36.06
B	Unsized	300	10	SeaWater	19 820.24	19 866.43	19 843.33	23.09
A	Sized	300	13	0	0.52	0.59	0.56	0.03
B	Sized	300	13	0	0.14	0.15	0.15	0.01
C	Sized	300	13	0	0.63	0.71	0.67	0.04
A	Sized	300	13	200	207.02	207.43	207.23	0.21
B	Sized	300	13	200	202.62	204.29	203.45	0.84
C	Sized	300	13	200	211.16	211.58	211.37	0.21
A	Sized	300	13	20000	19 921.19	19 985.48	19 953.33	32.15
B	Sized	300	13	20000	19 931.39	19 961.94	19 946.67	15.28
C	Sized	300	13	20000	19 961.03	20 025.45	19 993.24	32.21
A	Sized	300	13	SeaWater	19 804.17	19 895.83	19 850.00	45.83
B	Sized	300	13	SeaWater	19 789.41	19 883.92	19 836.67	47.26
C	Sized	300	13	SeaWater	19 843.78	19 935.62	19 889.70	45.92
A	Unsized	300	13	0	0.28	0.32	0.30	0.02
B	Unsized	300	13	0	0.11	0.19	0.15	0.04
A	Unsized	300	13	200	208.95	209.03	208.99	0.04
B	Unsized	300	13	200	201.85	204.48	203.16	1.32
A	Unsized	300	13	20000	19 935.85	19 977.48	19 956.67	20.82
B	Unsized	300	13	20000	19 960.75	19 985.92	19 973.33	12.58
A	Unsized	300	13	SeaWater	19 805.47	19 881.19	19 843.33	37.86
B	Unsized	300	13	SeaWater	19 842.52	19 884.15	19 863.33	20.82

For a better understanding, change in the chloride content of the environments was plotted in graphs in Figure 1.13, 1.14, and 1.15. It can be seen that the chloride content of all samples has increased except for the 20000ppm synthetic solution.

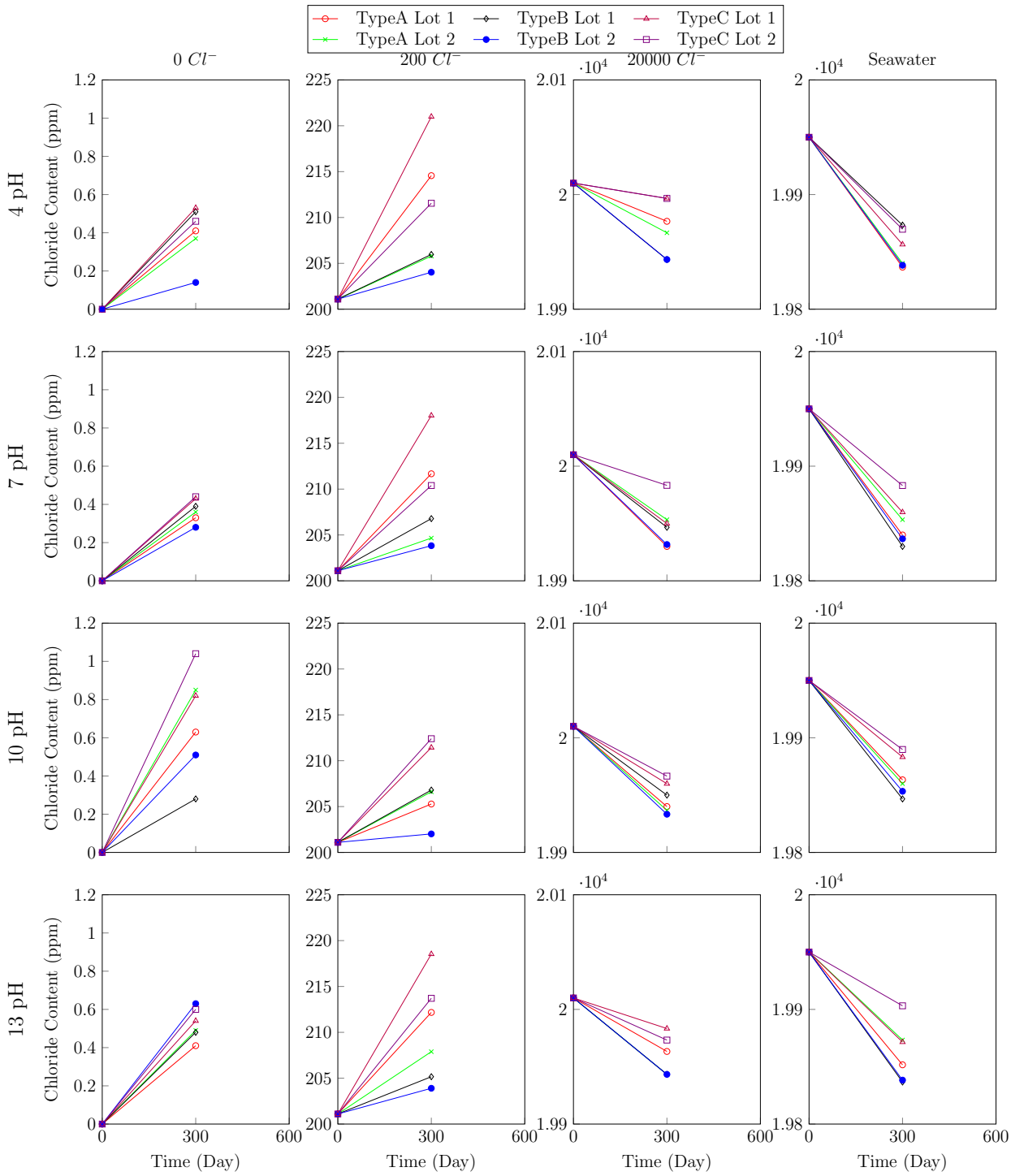

Figure 1.13: Chloride concentration of all environments after exposure of rebars

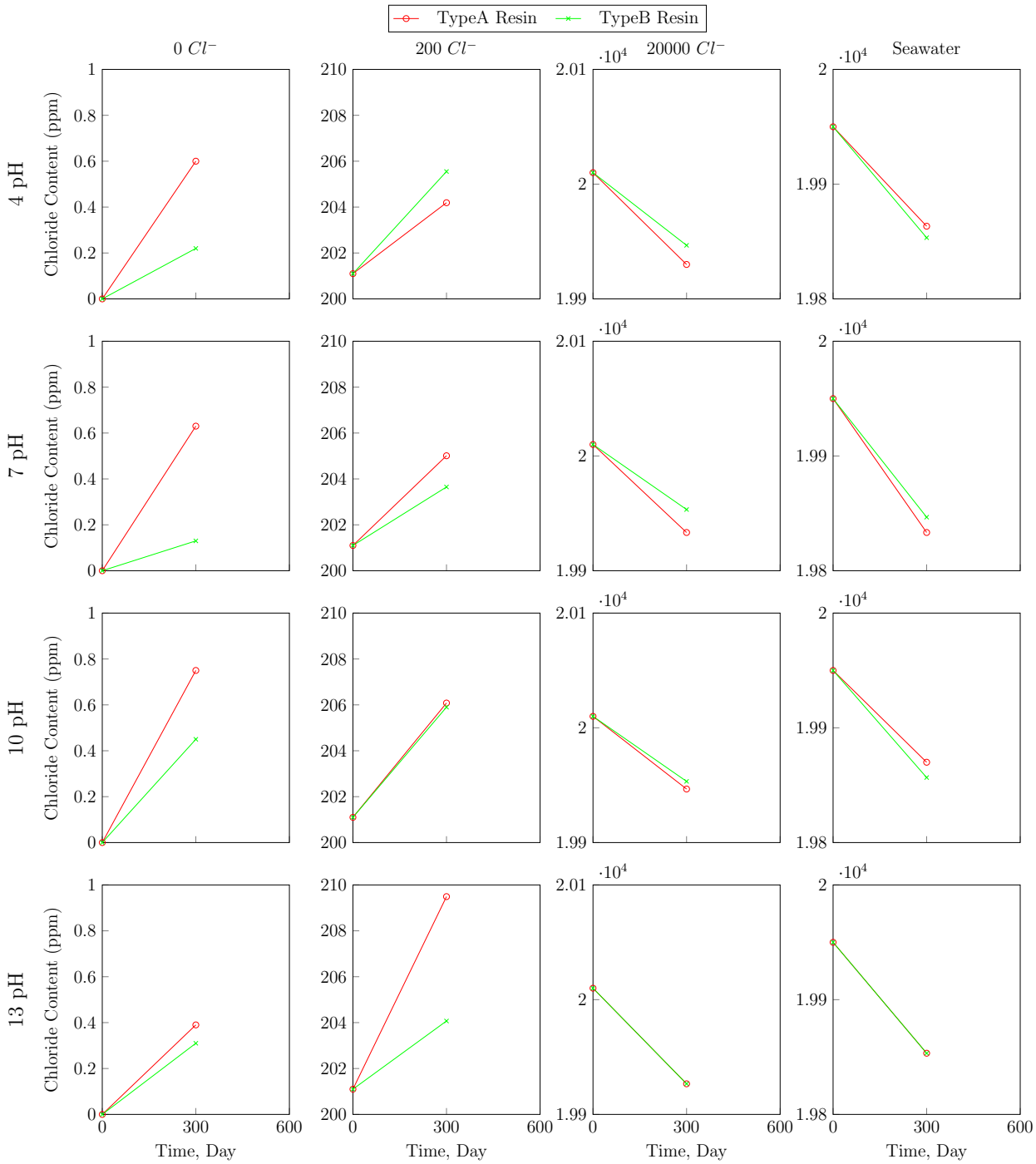

Figure 1.14: Chloride concentration of all environments after exposure of resins

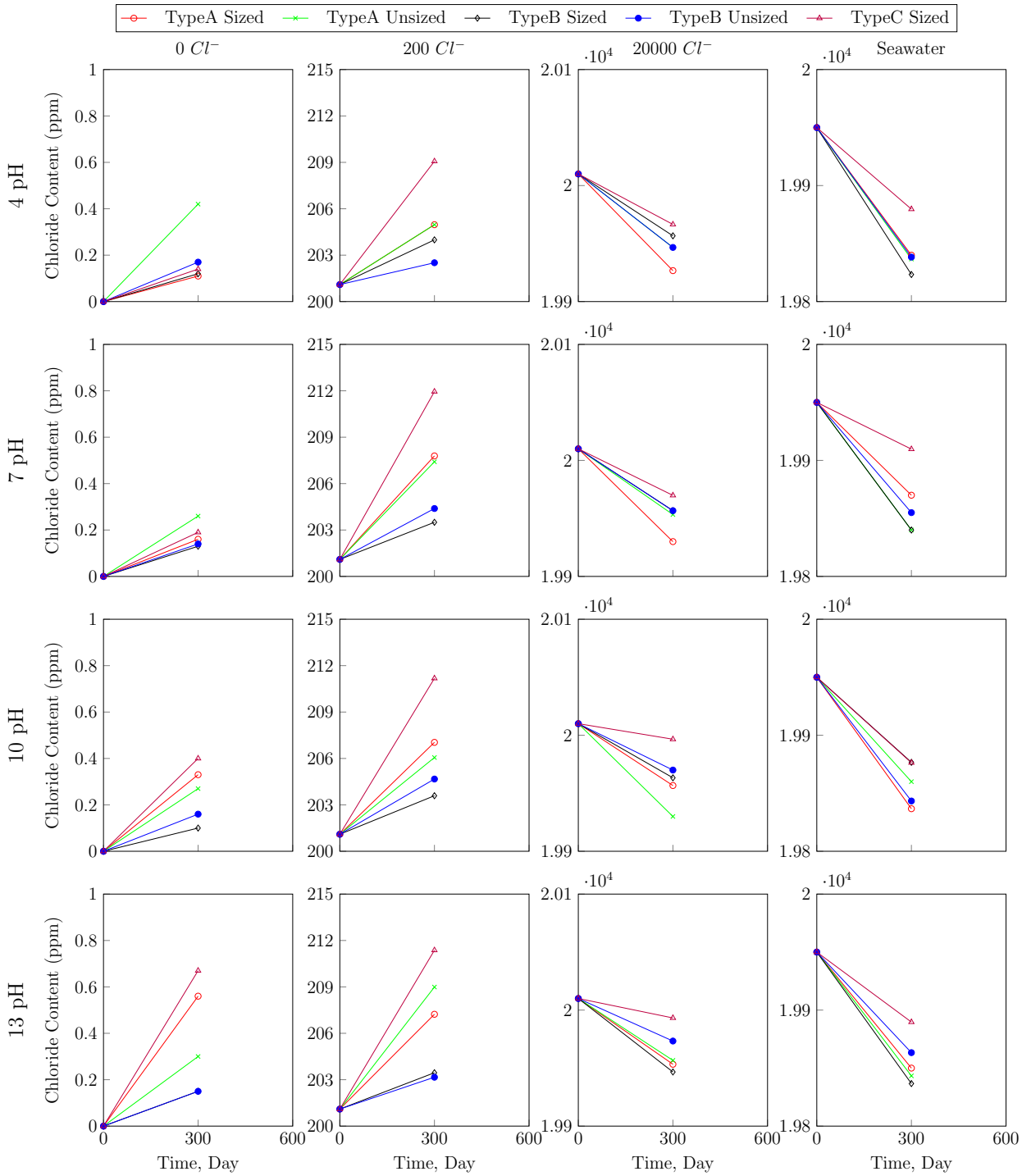

Figure 1.15: Chloride concentration of all environments after exposure of sized and unsized fibers

Sulfate

Sulfate content of the chemical environments was measured after 300 days of exposure. Tables 1.16, 1.17, and 1.18 below shows the sulfate data of environments in which rebars, resins, and fibers were exposed.

Table 1.16: Sulfate Ion Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Sulfate Ion			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	8.75	8.78	8.77	0.02
B	Vinyl Ester	1	300	4	0	7.24	7.46	7.35	0.11
C	Epoxy	1	300	4	0	11.11	11.15	11.13	0.02
A	Epoxy	1	300	4	200	8.37	8.42	8.40	0.03
B	Vinyl Ester	1	300	4	200	7.81	8.01	7.91	0.10
C	Epoxy	1	300	4	200	10.63	10.70	10.66	0.03
A	Epoxy	1	300	4	20000	8.16	8.21	8.19	0.03
B	Vinyl Ester	1	300	4	20000	7.67	8.20	7.94	0.27
C	Epoxy	1	300	4	20000	10.37	10.43	10.40	0.03
A	Epoxy	1	300	4	SeaWater	2493.81	2569.53	2531.67	37.86
B	Vinyl Ester	1	300	4	SeaWater	2540.12	2563.21	2551.67	11.55
C	Epoxy	1	300	4	SeaWater	2498.79	2574.67	2536.73	37.94
A	Epoxy	2	300	4	0	8.30	8.33	8.31	0.02
B	Vinyl Ester	2	300	4	0	7.35	7.97	7.66	0.31
C	Epoxy	2	300	4	0	10.79	10.83	10.81	0.02
A	Epoxy	2	300	4	200	7.96	8.00	7.98	0.02
B	Vinyl Ester	2	300	4	200	7.09	7.77	7.43	0.34
C	Epoxy	2	300	4	200	10.35	10.40	10.37	0.03
A	Epoxy	2	300	4	20000	8.16	8.20	8.18	0.02
B	Vinyl Ester	2	300	4	20000	7.33	8.03	7.68	0.35
C	Epoxy	2	300	4	20000	10.60	10.66	10.63	0.03
A	Epoxy	2	300	4	SeaWater	2535.00	2555.00	2545.00	10.00
B	Vinyl Ester	2	300	4	SeaWater	2554.16	2575.17	2564.67	10.50
C	Epoxy	2	300	4	SeaWater	2542.61	2562.67	2552.64	10.03
A	Epoxy	1	300	7	0	0.44	0.48	0.46	0.02
B	Vinyl Ester	1	300	7	0	0.20	0.28	0.24	0.04
C	Epoxy	1	300	7	0	0.55	0.61	0.58	0.03
A	Epoxy	1	300	7	200	0.64	0.68	0.66	0.02
B	Vinyl Ester	1	300	7	200	0.57	0.63	0.60	0.03
C	Epoxy	1	300	7	200	0.81	0.86	0.83	0.03
A	Epoxy	1	300	7	20000	0.71	0.74	0.73	0.02

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Table 1.16: Sulfate Ion Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Sulfate Ion			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	1	300	7	20000	0.44	0.49	0.46	0.02
C	Epoxy	1	300	7	20000	0.90	0.94	0.92	0.02
A	Epoxy	1	300	7	SeaWater	2497.41	2591.92	2544.67	47.26
B	Vinyl Ester	1	300	7	SeaWater	2556.73	2579.27	2568.00	11.27
C	Epoxy	1	300	7	SeaWater	2502.40	2597.11	2549.76	47.35
A	Epoxy	2	300	7	0	0.75	0.79	0.77	0.02
B	Vinyl Ester	2	300	7	0	0.47	0.56	0.51	0.05
C	Epoxy	2	300	7	0	0.97	1.02	1.00	0.03
A	Epoxy	2	300	7	200	0.65	0.68	0.66	0.02
B	Vinyl Ester	2	300	7	200	0.67	0.71	0.69	0.02
C	Epoxy	2	300	7	200	0.84	0.88	0.86	0.02
A	Epoxy	2	300	7	20000	0.91	0.96	0.93	0.02
B	Vinyl Ester	2	300	7	20000	0.57	0.75	0.66	0.09
C	Epoxy	2	300	7	20000	1.18	1.24	1.21	0.03
A	Epoxy	2	300	7	SeaWater	2510.52	2552.15	2531.33	20.82
B	Vinyl Ester	2	300	7	SeaWater	2536.85	2578.48	2557.67	20.82
C	Epoxy	2	300	7	SeaWater	2518.05	2559.81	2538.93	20.88
A	Epoxy	1	300	10	0	0.18	0.21	0.19	0.02
B	Vinyl Ester	1	300	10	0	0.86	0.91	0.89	0.03
C	Epoxy	1	300	10	0	0.23	0.26	0.25	0.02
A	Epoxy	1	300	10	200	0.23	0.26	0.25	0.02
B	Vinyl Ester	1	300	10	200	0.71	0.79	0.75	0.04
C	Epoxy	1	300	10	200	0.29	0.33	0.31	0.02
A	Epoxy	1	300	10	20000	0.33	0.36	0.35	0.02
B	Vinyl Ester	1	300	10	20000	0.25	0.31	0.28	0.03
C	Epoxy	1	300	10	20000	0.42	0.46	0.44	0.02
A	Epoxy	1	300	10	SeaWater	2500.00	2540.00	2520.00	20.00
B	Vinyl Ester	1	300	10	SeaWater	2556.16	2573.17	2564.67	8.50
C	Epoxy	1	300	10	SeaWater	2505.00	2545.08	2525.04	20.04
A	Epoxy	2	300	10	0	0.53	0.55	0.54	0.01
B	Vinyl Ester	2	300	10	0	0.79	0.87	0.83	0.04
C	Epoxy	2	300	10	0	0.69	0.72	0.70	0.01
A	Epoxy	2	300	10	200	0.48	0.50	0.49	0.01
B	Vinyl Ester	2	300	10	200	0.59	0.67	0.63	0.04
C	Epoxy	2	300	10	200	0.62	0.65	0.64	0.01
A	Epoxy	2	300	10	20000	0.58	0.61	0.59	0.02
B	Vinyl Ester	2	300	10	20000	0.35	0.37	0.36	0.01

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Table 1.16: Sulfate Ion Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Sulfate Ion			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	10	20000	0.75	0.79	0.77	0.02
A	Epoxy	2	300	10	SeaWater	2511.79	2534.88	2523.33	11.55
B	Vinyl Ester	2	300	10	SeaWater	2568.83	2593.17	2581.00	12.17
C	Epoxy	2	300	10	SeaWater	2519.32	2542.48	2530.90	11.58
A	Epoxy	1	300	13	0	0.46	0.50	0.48	0.02
B	Vinyl Ester	1	300	13	0	0.51	0.58	0.55	0.04
C	Epoxy	1	300	13	0	0.58	0.64	0.61	0.03
A	Epoxy	1	300	13	200	0.45	0.48	0.46	0.02
B	Vinyl Ester	1	300	13	200	0.55	0.62	0.58	0.03
C	Epoxy	1	300	13	200	0.57	0.61	0.59	0.02
A	Epoxy	1	300	13	20000	0.45	0.48	0.46	0.02
B	Vinyl Ester	1	300	13	20000	0.43	0.47	0.45	0.02
C	Epoxy	1	300	13	20000	0.57	0.61	0.59	0.02
A	Epoxy	1	300	13	SeaWater	2547.17	2597.50	2572.33	25.17
B	Vinyl Ester	1	300	13	SeaWater	2539.56	2551.11	2545.33	5.77
C	Epoxy	1	300	13	SeaWater	2552.26	2602.69	2577.48	25.22
A	Epoxy	2	300	13	0	0.44	0.46	0.45	0.01
B	Vinyl Ester	2	300	13	0	0.61	0.65	0.63	0.02
C	Epoxy	2	300	13	0	0.57	0.60	0.59	0.01
A	Epoxy	2	300	13	200	0.33	0.36	0.35	0.02
B	Vinyl Ester	2	300	13	200	0.34	0.42	0.38	0.04
C	Epoxy	2	300	13	200	0.43	0.47	0.45	0.02
A	Epoxy	2	300	13	20000	0.54	0.58	0.56	0.02
B	Vinyl Ester	2	300	13	20000	0.53	0.59	0.56	0.03
C	Epoxy	2	300	13	20000	0.71	0.76	0.73	0.03
A	Epoxy	2	300	13	SeaWater	2554.12	2577.21	2565.67	11.55
B	Vinyl Ester	2	300	13	SeaWater	2561.65	2581.68	2571.67	10.02
C	Epoxy	2	300	13	SeaWater	2561.78	2584.95	2573.36	11.58

Table 1.17: Sulfate Ion Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Sulfate Ion			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	7.67	7.76	7.71	0.05
B	Vinyl Ester	300	4	0	7.55	7.88	7.71	0.17
A	Epoxy	300	4	200	8.18	8.21	8.20	0.02
B	Vinyl Ester	300	4	200	7.07	7.91	7.49	0.42
A	Epoxy	300	4	20000	7.73	7.80	7.77	0.04
B	Vinyl Ester	300	4	20000	7.49	8.55	8.02	0.53
A	Epoxy	300	4	SeaWater	2554.16	2575.17	2564.67	10.50
B	Vinyl Ester	300	4	SeaWater	2582.56	2594.11	2588.33	5.77
A	Epoxy	300	7	0	0.66	0.71	0.68	0.02
B	Vinyl Ester	300	7	0	0.72	0.78	0.75	0.03
A	Epoxy	300	7	200	0.80	0.86	0.83	0.03
B	Vinyl Ester	300	7	200	0.59	0.65	0.62	0.03
A	Epoxy	300	7	20000	0.42	0.45	0.44	0.02
B	Vinyl Ester	300	7	20000	0.51	0.56	0.54	0.03
A	Epoxy	300	7	SeaWater	2571.14	2599.52	2585.33	14.19
B	Vinyl Ester	300	7	SeaWater	2571.70	2586.97	2579.33	7.64
A	Epoxy	300	10	0	0.85	0.92	0.89	0.04
B	Vinyl Ester	300	10	0	0.31	0.39	0.35	0.04
A	Epoxy	300	10	200	0.69	0.72	0.71	0.02
B	Vinyl Ester	300	10	200	0.33	0.41	0.37	0.04
A	Epoxy	300	10	20000	0.33	0.36	0.35	0.02
B	Vinyl Ester	300	10	20000	0.59	0.67	0.63	0.04
A	Epoxy	300	10	SeaWater	2565.12	2588.21	2576.67	11.55
B	Vinyl Ester	300	10	SeaWater	2566.39	2596.94	2581.67	15.28
A	Epoxy	300	13	0	0.70	0.75	0.72	0.02
B	Vinyl Ester	300	13	0	0.50	0.54	0.52	0.02
A	Epoxy	300	13	200	0.69	0.71	0.70	0.01
B	Vinyl Ester	300	13	200	0.75	0.77	0.76	0.01
A	Epoxy	300	13	20000	0.25	0.29	0.27	0.02
B	Vinyl Ester	300	13	20000	0.53	0.57	0.55	0.02
A	Epoxy	300	13	SeaWater	2549.89	2561.44	2555.67	5.77
B	Vinyl Ester	300	13	SeaWater	2556.32	2582.35	2569.33	13.01

Table 1.18: Sulfate Ion Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Sulfate Ion			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	8.00	8.06	8.03	0.03
B	Sized	300	4	0	7.66	7.79	7.72	0.07
C	Sized	300	4	0	9.99	10.08	10.04	0.04
A	Sized	300	4	200	7.66	7.71	7.68	0.03
B	Sized	300	4	200	7.18	7.73	7.46	0.28
C	Sized	300	4	200	9.57	9.64	9.60	0.03
A	Sized	300	4	20000	7.34	7.38	7.36	0.02
B	Sized	300	4	20000	7.11	8.11	7.61	0.50
C	Sized	300	4	20000	9.17	9.22	9.20	0.03
A	Sized	300	4	SeaWater	2526.39	2556.94	2541.67	15.28
B	Sized	300	4	SeaWater	2570.93	2588.40	2579.67	8.74
C	Sized	300	4	SeaWater	2539.02	2569.73	2554.38	15.35
A	Unsized	300	4	0	7.68	7.80	7.74	0.06
B	Unsized	300	4	0	7.09	8.03	7.56	0.47
A	Unsized	300	4	200	7.41	7.49	7.45	0.04
B	Unsized	300	4	200	7.52	7.95	7.74	0.21
A	Unsized	300	4	20000	7.08	7.13	7.10	0.03
B	Unsized	300	4	20000	7.19	7.43	7.31	0.12
A	Unsized	300	4	SeaWater	2536.39	2566.94	2551.67	15.28
B	Unsized	300	4	SeaWater	2566.39	2596.94	2581.67	15.28
A	Sized	300	7	0	0.53	0.55	0.54	0.01
B	Sized	300	7	0	0.38	0.46	0.42	0.04
C	Sized	300	7	0	0.66	0.69	0.68	0.01
A	Sized	300	7	200	0.31	0.35	0.33	0.02
B	Sized	300	7	200	0.45	0.66	0.56	0.11
C	Sized	300	7	200	0.39	0.44	0.42	0.03
A	Sized	300	7	20000	0.57	0.60	0.58	0.02
B	Sized	300	7	20000	0.17	0.24	0.21	0.03
C	Sized	300	7	20000	0.71	0.75	0.73	0.02
A	Sized	300	7	SeaWater	2553.12	2576.21	2564.67	11.55
B	Sized	300	7	SeaWater	2579.55	2587.12	2583.33	3.79
C	Sized	300	7	SeaWater	2565.89	2589.09	2577.49	11.60

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Table 1.18: Sulfate Ion Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Sulfate Ion			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	7	0	0.67	0.71	0.69	0.02
B	Unsized	300	7	0	0.22	0.28	0.25	0.03
A	Unsized	300	7	200	0.61	0.66	0.64	0.03
B	Unsized	300	7	200	0.18	0.23	0.20	0.03
A	Unsized	300	7	20000	0.44	0.47	0.46	0.02
B	Unsized	300	7	20000	0.52	0.58	0.55	0.03
A	Unsized	300	7	SeaWater	2519.55	2589.79	2554.67	35.12
B	Unsized	300	7	SeaWater	2571.89	2583.44	2577.67	5.77
A	Sized	300	10	0	0.48	0.51	0.49	0.02
B	Sized	300	10	0	0.36	0.64	0.50	0.14
C	Sized	300	10	0	0.60	0.64	0.62	0.02
A	Sized	300	10	200	0.71	0.77	0.74	0.03
B	Sized	300	10	200	0.08	0.85	0.47	0.38
C	Sized	300	10	200	0.89	0.96	0.93	0.03
A	Sized	300	10	20000	0.21	0.27	0.24	0.03
B	Sized	300	10	20000	0.07	0.17	0.12	0.05
C	Sized	300	10	20000	0.27	0.33	0.30	0.03
A	Sized	300	10	SeaWater	2530.70	2545.97	2538.33	7.64
B	Sized	300	10	SeaWater	2577.17	2585.50	2581.33	4.16
C	Sized	300	10	SeaWater	2543.35	2558.70	2551.03	7.68
A	Unsized	300	10	0	0.54	0.58	0.56	0.02
B	Unsized	300	10	0	0.37	0.45	0.41	0.04
A	Unsized	300	10	200	0.25	0.31	0.28	0.03
B	Unsized	300	10	200	0.24	0.25	0.25	0.01
A	Unsized	300	10	20000	0.15	0.17	0.16	0.01
B	Unsized	300	10	20000	0.35	0.41	0.38	0.03
A	Unsized	300	10	SeaWater	2525.85	2567.48	2546.67	20.82
B	Unsized	300	10	SeaWater	2579.30	2594.04	2586.67	7.37
A	Sized	300	13	0	0.26	0.27	0.26	0.01
B	Sized	300	13	0	0.32	0.41	0.37	0.05
C	Sized	300	13	0	0.32	0.34	0.33	0.01
A	Sized	300	13	200	0.68	0.72	0.70	0.02

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Table 1.18: Sulfate Ion Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Sulfate Ion			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Sized	300	13	200	0.68	0.80	0.74	0.06
C	Sized	300	13	200	0.84	0.90	0.87	0.03
A	Sized	300	13	20000	0.23	0.29	0.26	0.03
B	Sized	300	13	20000	0.10	0.11	0.11	0.01
C	Sized	300	13	20000	0.29	0.36	0.33	0.03
A	Sized	300	13	SeaWater	2560.79	2583.88	2572.33	11.55
B	Sized	300	13	SeaWater	2577.35	2582.65	2580.00	2.65
C	Sized	300	13	SeaWater	2573.59	2596.80	2585.20	11.60
A	Unsized	300	13	0	0.49	0.53	0.51	0.02
B	Unsized	300	13	0	0.32	0.34	0.33	0.01
A	Unsized	300	13	200	0.36	0.40	0.38	0.02
B	Unsized	300	13	200	0.64	0.69	0.67	0.02
A	Unsized	300	13	20000	0.14	0.16	0.15	0.01
B	Unsized	300	13	20000	0.45	0.54	0.50	0.05
A	Unsized	300	13	SeaWater	2541.68	2576.32	2559.00	17.32
B	Unsized	300	13	SeaWater	2572.58	2588.75	2580.67	8.08

For a better understanding, change in the sulfate content of the environments was plotted in graphs in Figure 1.16, 1.17, and 1.18. It can be seen that sulfate concentration of all samples has increased except the seawater samples.

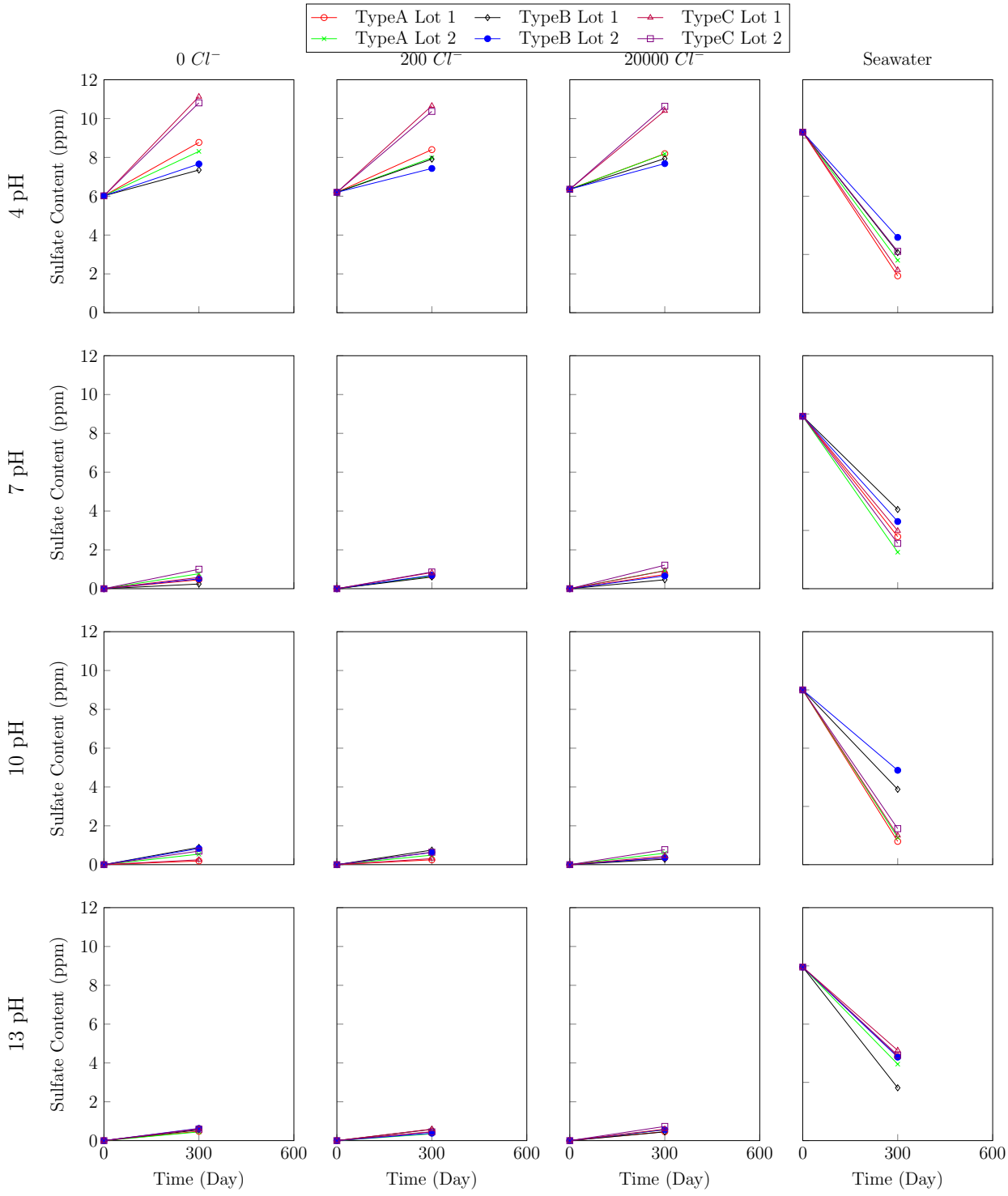

Figure 1.16: Sulfate concentration of all environments after exposure of rebars

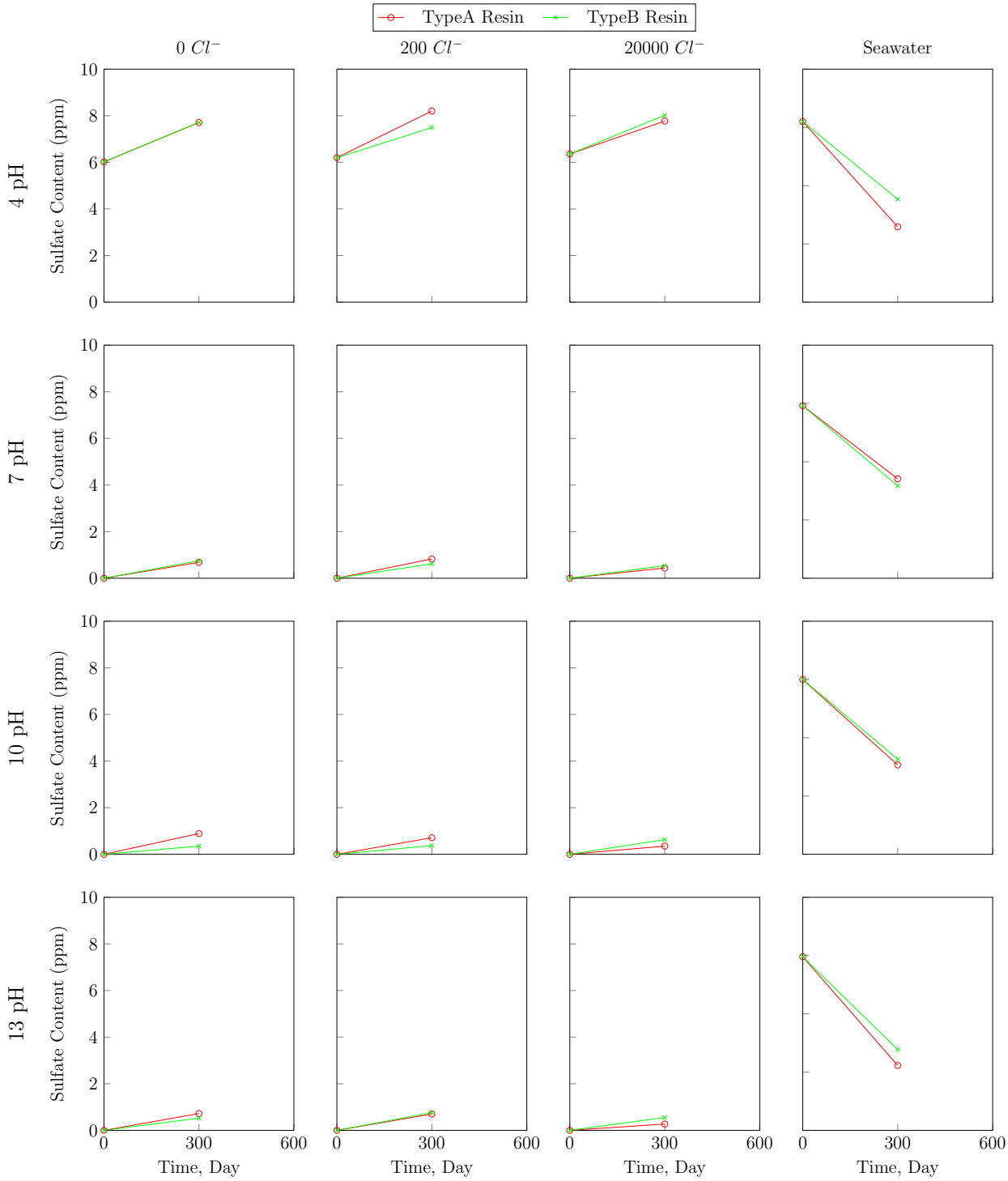

Figure 1.17: Sulfate concentration of all environments after exposure of resins

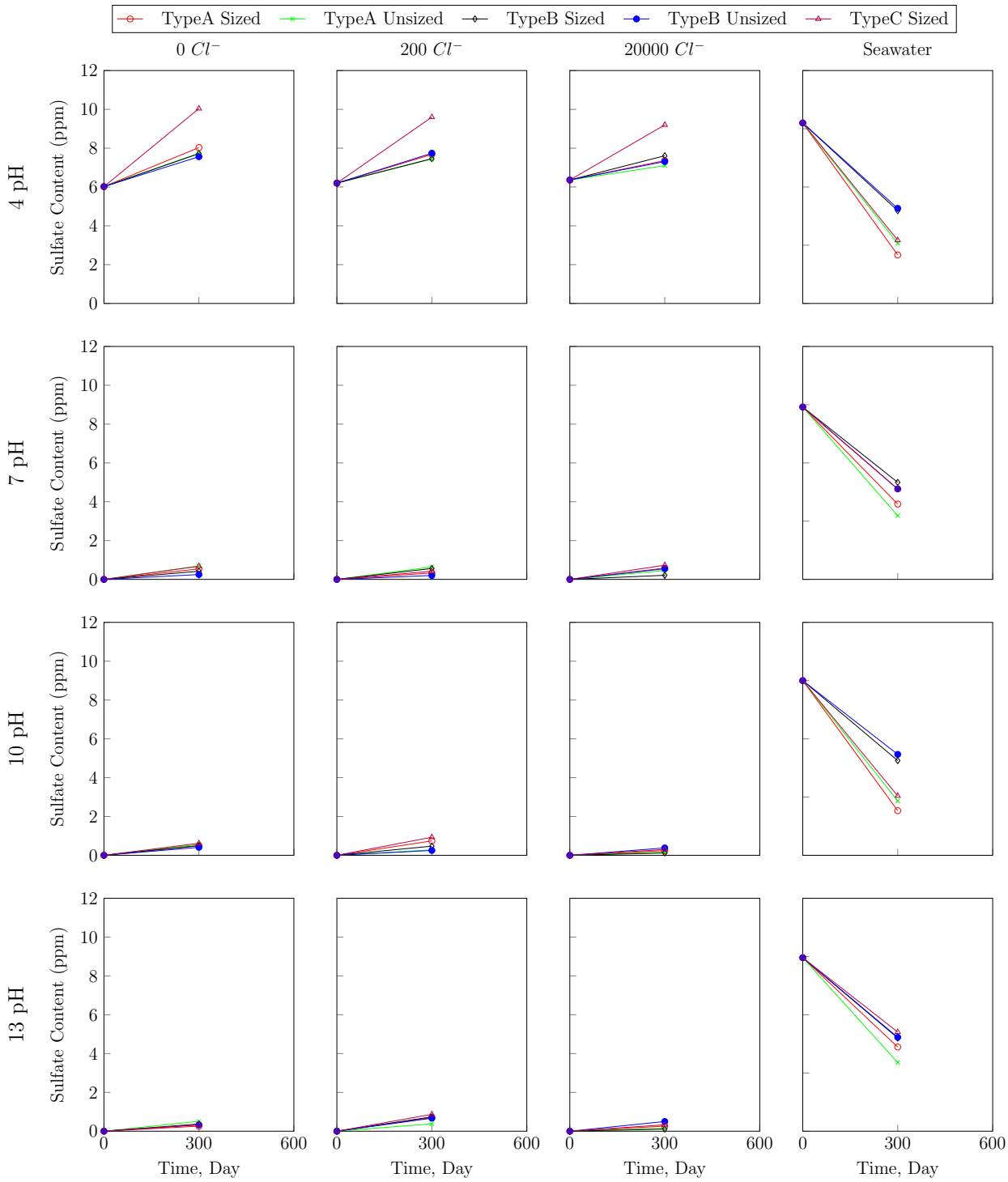

Figure 1.18: Sulfate concentration of all environments after exposure of sized and unsized fibers

1.2.6 Metals

Metals such as Aluminum, Calcium, Chromium, Iron, Magnesium, Potassium, Silicon, and Sodium were measured after 300 days of exposure and the results are tabulated in this subsection.

Aluminum

Aluminum content of the chemical environments was measured after 300 days of exposure. Tables 1.19, 1.20, and 1.21 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.19: Aluminum Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Aluminum			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	12.30	13.11	12.71	0.41
B	Vinyl Ester	1	300	4	0	8.75	9.15	8.95	0.20
C	Epoxy	1	300	4	0	16.65	17.66	17.15	0.51
A	Epoxy	1	300	4	200	15.30	18.95	17.13	1.83
B	Vinyl Ester	1	300	4	200	10.51	12.32	11.42	0.90
C	Epoxy	1	300	4	200	20.84	25.40	23.12	2.28
A	Epoxy	1	300	4	20000	20.26	22.38	21.32	1.06
B	Vinyl Ester	1	300	4	20000	12.97	14.02	13.49	0.52
C	Epoxy	1	300	4	20000	27.46	30.10	28.78	1.32
A	Epoxy	1	300	4	SeaWater	29.20	30.99	30.09	0.89
B	Vinyl Ester	1	300	4	SeaWater	17.69	18.57	18.13	0.44
C	Epoxy	1	300	4	SeaWater	39.51	41.74	40.62	1.12
A	Epoxy	2	300	4	0	17.63	18.45	18.04	0.41
B	Vinyl Ester	2	300	4	0	10.12	10.59	10.36	0.23
C	Epoxy	2	300	4	0	21.08	22.23	21.65	0.57
A	Epoxy	2	300	4	200	23.84	27.53	25.69	1.85
B	Vinyl Ester	2	300	4	200	12.17	14.25	13.21	1.04
C	Epoxy	2	300	4	200	28.24	33.41	30.83	2.58
A	Epoxy	2	300	4	20000	32.62	34.75	33.68	1.07
B	Vinyl Ester	2	300	4	20000	15.00	16.21	15.61	0.60
C	Epoxy	2	300	4	20000	38.93	41.91	40.42	1.49
A	Epoxy	2	300	4	SeaWater	49.05	50.86	49.95	0.90
B	Vinyl Ester	2	300	4	SeaWater	20.45	21.47	20.96	0.51
C	Epoxy	2	300	4	SeaWater	58.68	61.21	59.94	1.26

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Table 1.19: Aluminum Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Aluminum			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	7	0	15.74	18.51	17.12	1.38
B	Vinyl Ester	1	300	7	0	11.21	12.58	11.89	0.68
C	Epoxy	1	300	7	0	21.39	24.84	23.12	1.73
A	Epoxy	1	300	7	200	16.99	25.19	21.09	4.10
B	Vinyl Ester	1	300	7	200	11.85	15.91	13.88	2.03
C	Epoxy	1	300	7	200	23.35	33.60	28.48	5.13
A	Epoxy	1	300	7	20000	26.48	29.16	27.82	1.34
B	Vinyl Ester	1	300	7	20000	16.73	18.05	17.39	0.66
C	Epoxy	1	300	7	20000	35.88	39.23	37.56	1.67
A	Epoxy	1	300	7	SeaWater	35.00	38.57	36.79	1.79
B	Vinyl Ester	1	300	7	SeaWater	21.01	22.78	21.90	0.88
C	Epoxy	1	300	7	SeaWater	47.43	51.90	49.66	2.23
A	Epoxy	2	300	7	0	23.27	26.05	24.66	1.39
B	Vinyl Ester	2	300	7	0	12.97	14.55	13.76	0.79
C	Epoxy	2	300	7	0	27.64	31.54	29.59	1.95
A	Epoxy	2	300	7	200	27.92	36.20	32.06	4.14
B	Vinyl Ester	2	300	7	200	13.71	18.40	16.05	2.34
C	Epoxy	2	300	7	200	32.67	44.27	38.47	5.80
A	Epoxy	2	300	7	20000	43.16	45.87	44.51	1.35
B	Vinyl Ester	2	300	7	20000	19.35	20.88	20.11	0.77
C	Epoxy	2	300	7	20000	51.52	55.31	53.42	1.89
A	Epoxy	2	300	7	SeaWater	60.00	63.61	61.80	1.80
B	Vinyl Ester	2	300	7	SeaWater	24.30	26.34	25.32	1.02
C	Epoxy	2	300	7	SeaWater	71.64	76.69	74.16	2.53
A	Epoxy	1	300	10	0	18.77	21.04	19.91	1.14
B	Vinyl Ester	1	300	10	0	13.07	14.20	13.64	0.56
C	Epoxy	1	300	10	0	25.45	28.30	26.88	1.42
A	Epoxy	1	300	10	200	25.05	26.92	25.99	0.93
B	Vinyl Ester	1	300	10	200	16.41	17.34	16.87	0.46
C	Epoxy	1	300	10	200	33.91	36.25	35.08	1.17
A	Epoxy	1	300	10	20000	30.22	37.45	33.83	3.61
B	Vinyl Ester	1	300	10	20000	19.10	22.67	20.88	1.79
C	Epoxy	1	300	10	20000	41.16	50.19	45.67	4.52
A	Epoxy	1	300	10	SeaWater	40.93	47.11	44.02	3.09
B	Vinyl Ester	1	300	10	SeaWater	24.37	27.42	25.89	1.53
C	Epoxy	1	300	10	SeaWater	55.57	63.28	59.43	3.86
A	Epoxy	2	300	10	0	27.92	30.21	29.07	1.15

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Table 1.19: Aluminum Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Aluminum			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	2	300	10	0	15.13	16.43	15.78	0.65
C	Epoxy	2	300	10	0	33.27	36.49	34.88	1.61
A	Epoxy	2	300	10	200	39.08	40.96	40.02	0.94
B	Vinyl Ester	2	300	10	200	18.99	20.05	19.52	0.53
C	Epoxy	2	300	10	200	46.70	49.34	48.02	1.32
A	Epoxy	2	300	10	20000	51.16	58.46	54.81	3.65
B	Vinyl Ester	2	300	10	20000	22.09	26.22	24.15	2.06
C	Epoxy	2	300	10	20000	60.66	70.88	65.77	5.11
A	Epoxy	2	300	10	SeaWater	71.72	77.95	74.83	3.12
B	Vinyl Ester	2	300	10	SeaWater	28.18	31.70	29.94	1.76
C	Epoxy	2	300	10	SeaWater	85.44	94.17	89.80	4.36
A	Epoxy	1	300	13	0	23.24	29.41	26.33	3.09
B	Vinyl Ester	1	300	13	0	16.26	19.32	17.79	1.53
C	Epoxy	1	300	13	0	31.68	39.40	35.54	3.86
A	Epoxy	1	300	13	200	31.47	35.13	33.30	1.83
B	Vinyl Ester	1	300	13	200	20.44	22.25	21.35	0.90
C	Epoxy	1	300	13	200	42.67	47.24	44.96	2.28
A	Epoxy	1	300	13	20000	36.19	43.50	39.84	3.65
B	Vinyl Ester	1	300	13	20000	22.48	26.10	24.29	1.81
C	Epoxy	1	300	13	20000	49.22	58.35	53.79	4.57
A	Epoxy	1	300	13	SeaWater	49.23	51.91	50.57	1.34
B	Vinyl Ester	1	300	13	SeaWater	28.74	30.07	29.40	0.66
C	Epoxy	1	300	13	SeaWater	66.60	69.95	68.27	1.67
A	Epoxy	2	300	13	0	35.84	42.08	38.96	3.12
B	Vinyl Ester	2	300	13	0	18.82	22.34	20.58	1.76
C	Epoxy	2	300	13	0	42.39	51.12	46.75	4.36
A	Epoxy	2	300	13	200	50.11	53.80	51.95	1.85
B	Vinyl Ester	2	300	13	200	23.65	25.74	24.69	1.04
C	Epoxy	2	300	13	200	59.76	64.92	62.34	2.58
A	Epoxy	2	300	13	20000	61.65	69.03	65.34	3.69
B	Vinyl Ester	2	300	13	20000	26.01	30.18	28.09	2.09
C	Epoxy	2	300	13	20000	73.24	83.58	78.41	5.17
A	Epoxy	2	300	13	SeaWater	85.63	88.34	86.98	1.35
B	Vinyl Ester	2	300	13	SeaWater	33.23	34.76	33.99	0.77
C	Epoxy	2	300	13	SeaWater	102.48	106.27	104.38	1.89

Table 1.20: Aluminum Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Aluminum			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	4	SeaWater	1.55	1.95	1.75	0.20
B	Vinyl Ester	300	4	SeaWater	1.62	1.82	1.72	0.10
A	Epoxy	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	7	SeaWater	1.49	2.09	1.79	0.30
B	Vinyl Ester	300	7	SeaWater	1.54	1.94	1.74	0.20
A	Epoxy	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	10	SeaWater	1.72	1.92	1.82	0.10
B	Vinyl Ester	300	10	SeaWater	1.57	1.97	1.77	0.20
A	Epoxy	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	300	13	SeaWater	1.75	1.95	1.85	0.10
B	Vinyl Ester	300	13	SeaWater	1.65	1.95	1.8	0.15

Table 1.21: Aluminum Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Aluminum			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	2.62	2.84	2.73	0.11

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Table 1.21: Aluminum Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Aluminum			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Sized	300	4	0	1.91	2.11	2.01	0.10
C	Sized	300	4	0	2.96	3.21	3.08	0.13
A	Sized	300	4	200	2.73	3.75	3.24	0.51
B	Sized	300	4	200	2.11	3.01	2.56	0.45
C	Sized	300	4	200	3.08	4.24	3.66	0.58
A	Sized	300	4	20000	3.69	4.29	3.99	0.30
B	Sized	300	4	20000	2.76	3.28	3.02	0.26
C	Sized	300	4	20000	4.17	4.84	4.51	0.33
A	Sized	300	4	SeaWater	6.65	7.15	6.90	0.25
B	Sized	300	4	SeaWater	3.83	4.27	4.05	0.22
C	Sized	300	4	SeaWater	7.51	8.08	7.80	0.28
A	Unsized	300	4	0	2.26	2.55	2.41	0.14
B	Unsized	300	4	0	1.81	2.02	1.91	0.11
A	Unsized	300	4	200	2.23	3.51	2.87	0.64
B	Unsized	300	4	200	2.01	2.95	2.48	0.47
A	Unsized	300	4	20000	3.18	3.92	3.55	0.37
B	Unsized	300	4	20000	2.62	3.17	2.89	0.27
A	Unsized	300	4	SeaWater	3.62	4.08	3.85	0.23
B	Unsized	300	4	SeaWater	5.87	6.50	6.18	0.31
A	Sized	300	7	0	3.06	3.84	3.45	0.39
B	Sized	300	7	0	2.33	3.01	2.67	0.34
C	Sized	300	7	0	3.46	4.34	3.90	0.44
A	Sized	300	7	200	2.96	5.26	4.11	1.15
B	Sized	300	7	200	2.10	4.12	3.11	1.01
C	Sized	300	7	200	3.34	5.95	4.64	1.30
A	Sized	300	7	20000	4.40	5.16	4.78	0.38
B	Sized	300	7	20000	3.56	4.22	3.89	0.33
C	Sized	300	7	20000	4.98	5.83	5.40	0.43
A	Sized	300	7	SeaWater	7.17	8.17	7.67	0.50
B	Sized	300	7	SeaWater	4.45	5.33	4.89	0.44
C	Sized	300	7	SeaWater	8.10	9.23	8.67	0.57
A	Unsized	300	7	0	2.56	3.53	3.04	0.48

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Table 1.21: Aluminum Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Aluminum			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	7	0	2.19	2.90	2.55	0.36
A	Unsized	300	7	200	2.20	5.08	3.64	1.44
B	Unsized	300	7	200	1.96	4.08	3.02	1.06
A	Unsized	300	7	20000	3.78	4.72	4.25	0.47
B	Unsized	300	7	20000	3.37	4.06	3.71	0.35
A	Unsized	300	7	SeaWater	6.26	7.51	6.89	0.63
B	Unsized	300	7	SeaWater	4.19	5.12	4.66	0.46
A	Sized	300	10	0	3.58	4.22	3.90	0.32
B	Sized	300	10	0	2.78	3.34	3.06	0.28
C	Sized	300	10	0	4.05	4.77	4.41	0.36
A	Sized	300	10	200	4.96	5.48	5.22	0.26
B	Sized	300	10	200	3.55	4.01	3.78	0.23
C	Sized	300	10	200	5.60	6.19	5.90	0.30
A	Sized	300	10	20000	4.97	6.99	5.98	1.01
B	Sized	300	10	20000	3.78	5.56	4.67	0.89
C	Sized	300	10	20000	5.61	7.90	6.76	1.15
A	Sized	300	10	SeaWater	7.45	9.19	8.32	0.87
B	Sized	300	10	SeaWater	5.02	6.54	5.78	0.76
C	Sized	300	10	SeaWater	8.42	10.38	9.40	0.98
A	Unsized	300	10	0	3.04	3.84	3.44	0.40
B	Unsized	300	10	0	2.63	3.22	2.93	0.29
A	Unsized	300	10	200	4.30	4.96	4.63	0.33
B	Unsized	300	10	200	3.44	3.93	3.69	0.24
A	Unsized	300	10	20000	4.07	6.60	5.33	1.27
B	Unsized	300	10	20000	3.53	5.40	4.47	0.93
A	Unsized	300	10	SeaWater	6.41	8.57	7.49	1.08
B	Unsized	300	10	SeaWater	4.72	6.31	5.51	0.80
A	Sized	300	13	0	4.14	5.88	5.01	0.87
B	Sized	300	13	0	3.23	4.75	3.99	0.76
C	Sized	300	13	0	4.68	6.64	5.66	0.98
A	Sized	300	13	200	5.64	6.66	6.15	0.51
B	Sized	300	13	200	4.33	5.23	4.78	0.45

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Table 1.21: Aluminum Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Aluminum			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Sized	300	13	200	6.37	7.53	6.95	0.58
A	Sized	300	13	20000	5.98	8.04	7.01	1.03
B	Sized	300	13	20000	4.53	6.33	5.43	0.90
C	Sized	300	13	20000	6.76	9.08	7.92	1.16
A	Sized	300	13	SeaWater	9.56	10.32	9.94	0.38
B	Sized	300	13	SeaWater	6.23	6.89	6.56	0.33
C	Sized	300	13	SeaWater	10.81	11.66	11.23	0.43
A	Unsized	300	13	0	3.35	5.51	4.43	1.08
B	Unsized	300	13	0	3.04	4.64	3.84	0.80
A	Unsized	300	13	200	4.82	6.10	5.46	0.64
B	Unsized	300	13	200	4.21	5.16	4.68	0.47
A	Unsized	300	13	20000	4.98	7.55	6.27	1.28
B	Unsized	300	13	20000	4.23	6.12	5.18	0.95
A	Unsized	300	13	SeaWater	8.67	9.62	9.14	0.47
B	Unsized	300	13	SeaWater	5.91	6.61	6.26	0.35

For a better understanding, change in the Aluminum content of the environments was plotted in graphs in Figure 1.19, 1.20, and 1.21. It can be seen that the Aluminum concentration has decreased in all environments except the environments that had resin samples.

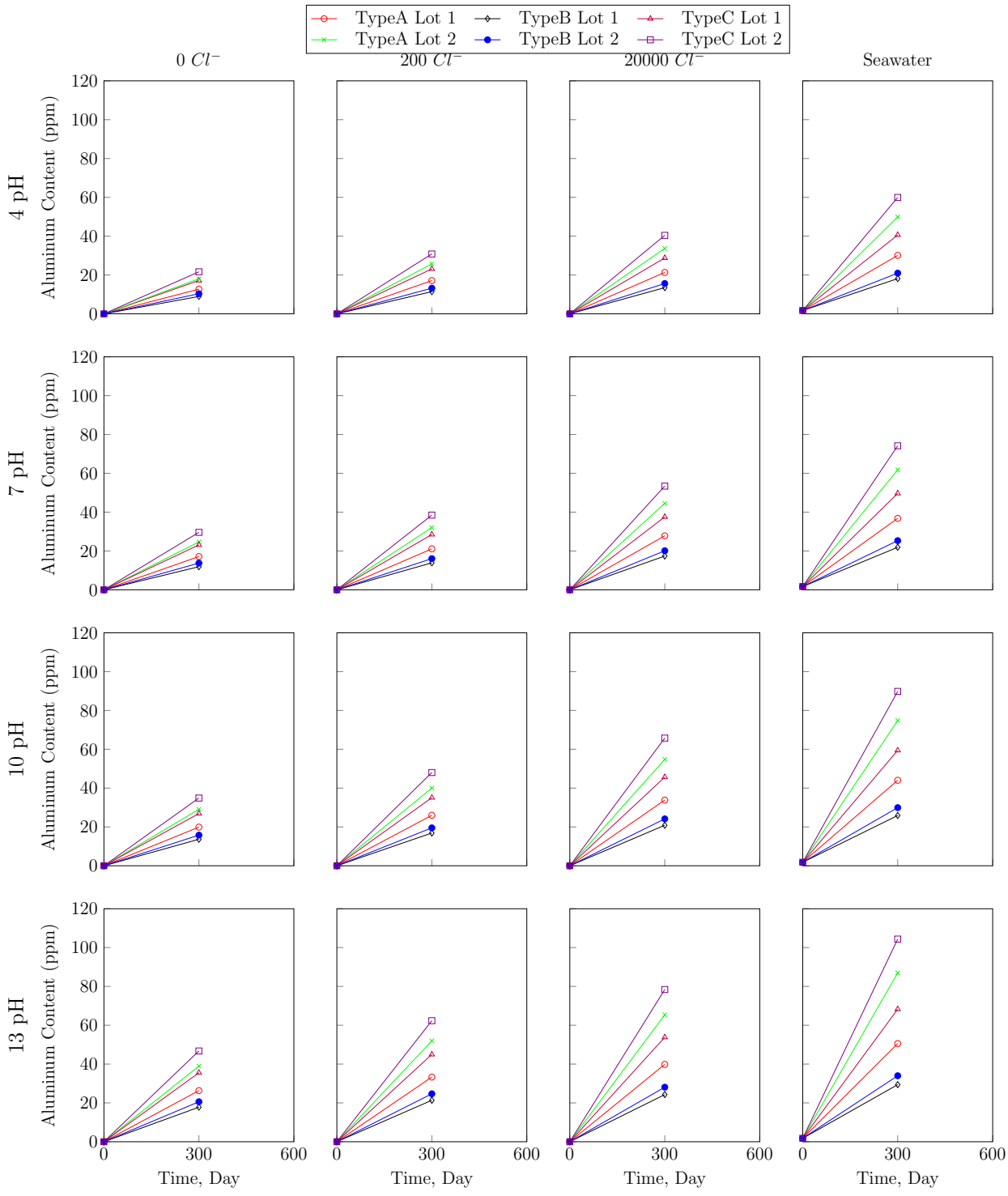

Figure 1.19: Aluminum concentration of all environments after exposure of rebars

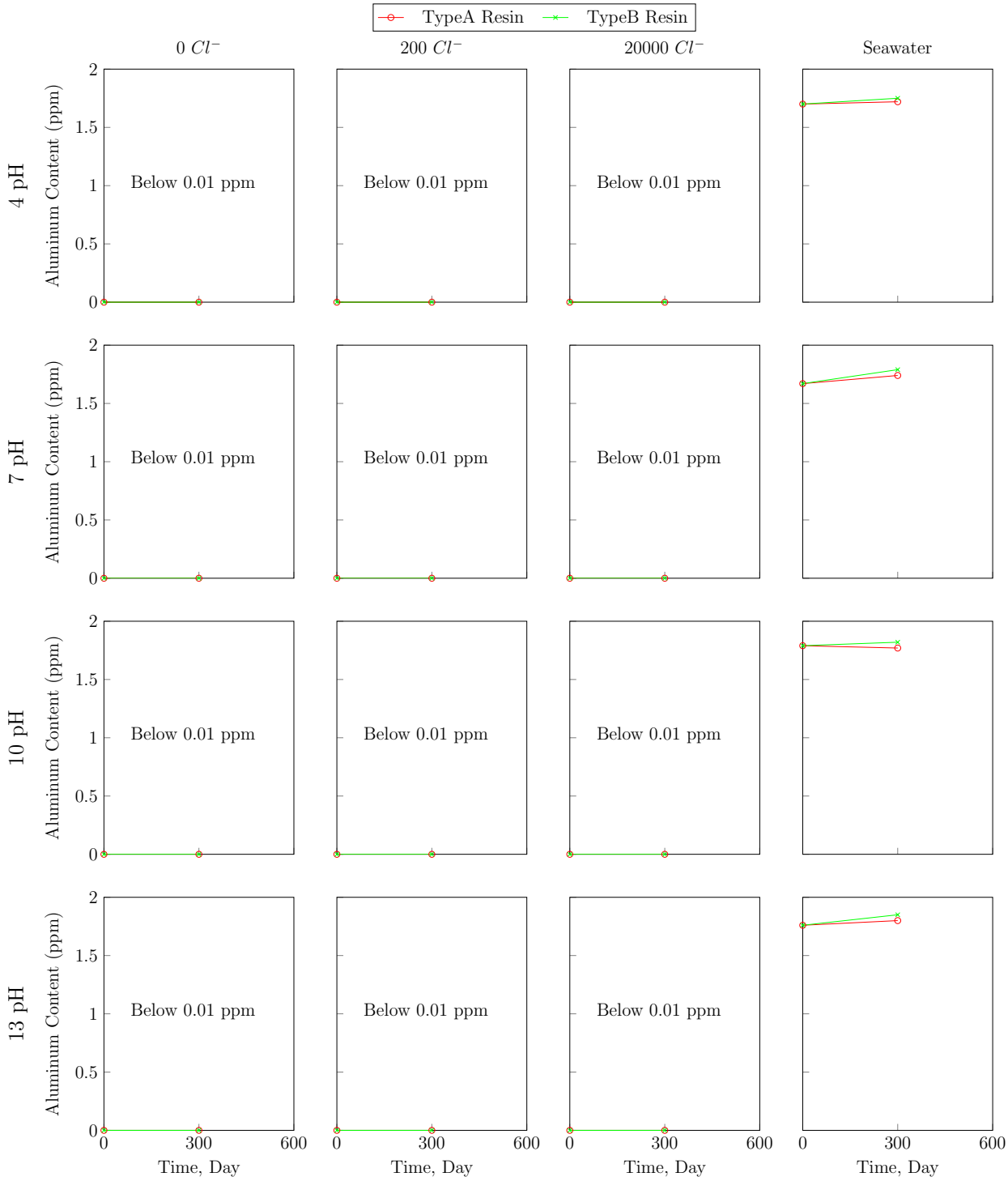

Figure 1.20: Aluminum concentration of all environments after exposure of resins

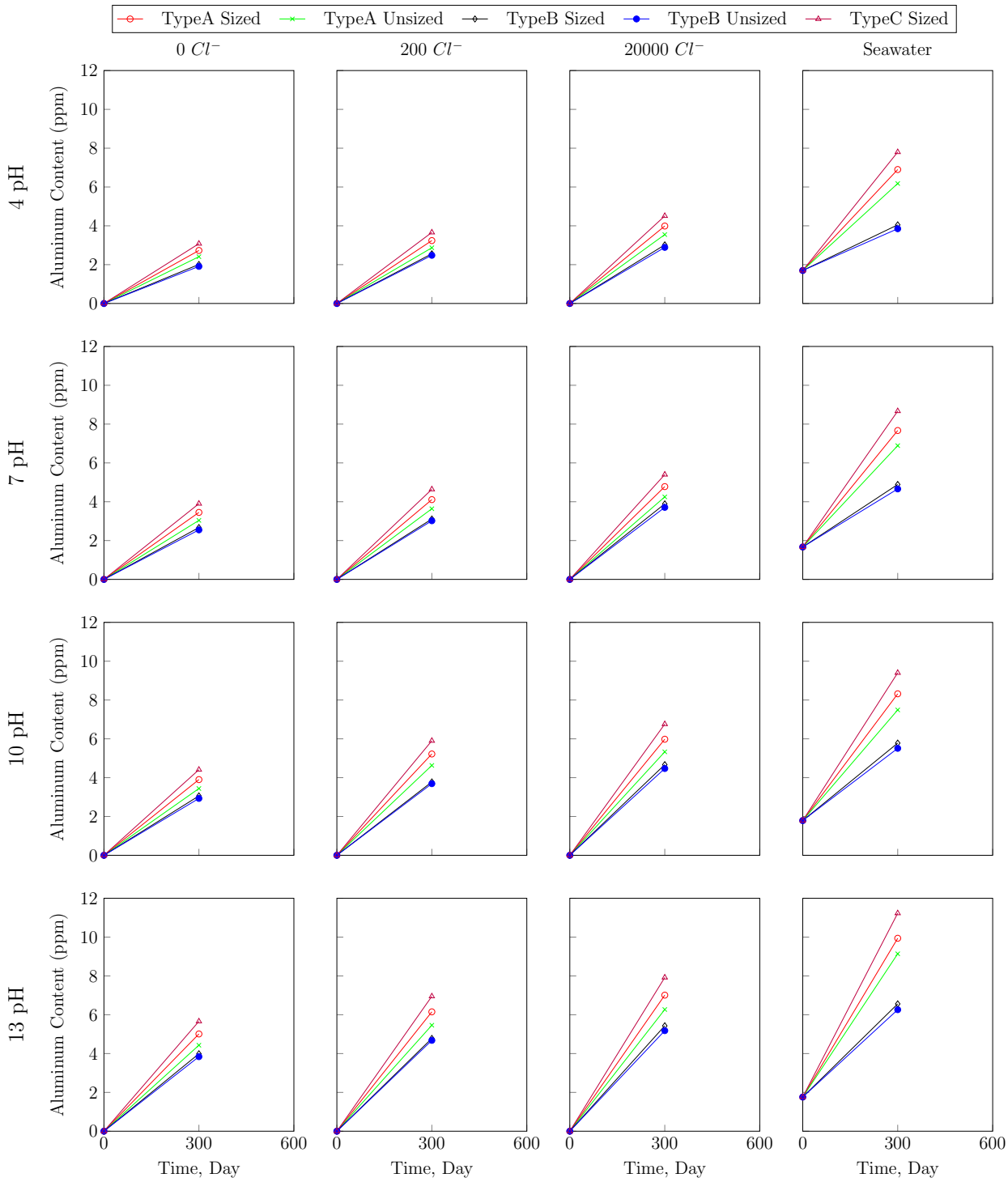

Figure 1.21: Aluminum concentration of all environments after exposure of sized and unsized fibers

Calcium

Calcium content of the chemical environments was measured after 300 days of exposure. Tables 1.22, 1.23, and 1.24 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.22: Calcium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Calcium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	2.92	3.05	2.99	0.07
B	Vinyl Ester	1	300	4	0	2.09	2.12	2.10	0.01
C	Epoxy	1	300	4	0	3.45	3.63	3.54	0.09
A	Epoxy	1	300	4	200	3.04	3.97	3.51	0.46
B	Vinyl Ester	1	300	4	200	2.38	2.55	2.47	0.09
C	Epoxy	1	300	4	200	3.54	4.78	4.16	0.62
A	Epoxy	1	300	4	20000	7.42	9.40	8.41	0.99
B	Vinyl Ester	1	300	4	20000	5.73	6.10	5.92	0.19
C	Epoxy	1	300	4	20000	8.63	11.29	9.96	1.33
A	Epoxy	1	300	4	SeaWater	509.82	516.68	513.25	3.43
B	Vinyl Ester	1	300	4	SeaWater	501.73	507.45	504.59	2.86
C	Epoxy	1	300	4	SeaWater	522.76	534.11	528.44	5.67
A	Epoxy	2	300	4	0	7.56	8.28	7.92	0.36
B	Vinyl Ester	2	300	4	0	5.35	5.38	5.36	0.01
C	Epoxy	2	300	4	0	9.70	10.62	10.16	0.46
A	Epoxy	2	300	4	200	6.75	11.83	9.29	2.54
B	Vinyl Ester	2	300	4	200	6.19	6.39	6.29	0.10
C	Epoxy	2	300	4	200	8.70	15.15	11.92	3.22
A	Epoxy	2	300	4	20000	16.84	27.73	22.28	5.45
B	Vinyl Ester	2	300	4	20000	14.87	15.29	15.08	0.21
C	Epoxy	2	300	4	20000	26.13	31.05	28.59	2.46
A	Epoxy	2	300	4	SeaWater	533.51	541.23	537.37	3.86
B	Vinyl Ester	2	300	4	SeaWater	534.14	540.63	537.39	3.24
C	Epoxy	2	300	4	SeaWater	550.55	564.45	557.50	6.95
A	Epoxy	1	300	7	0	2.80	3.33	3.07	0.26
B	Vinyl Ester	1	300	7	0	2.11	2.21	2.16	0.05
C	Epoxy	1	300	7	0	3.28	3.99	3.64	0.35
A	Epoxy	1	300	7	200	3.97	5.57	4.77	0.80
B	Vinyl Ester	1	300	7	200	2.72	2.94	2.83	0.11
C	Epoxy	1	300	7	200	3.43	4.62	4.02	0.59
A	Epoxy	1	300	7	20000	8.65	13.67	11.16	2.51

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Table 1.22: Calcium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Calcium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	1	300	7	20000	7.38	8.32	7.85	0.47
C	Epoxy	1	300	7	20000	9.85	16.59	13.22	3.37
A	Epoxy	1	300	7	SeaWater	520.07	524.70	522.38	2.32
B	Vinyl Ester	1	300	7	SeaWater	511.64	515.50	513.57	1.93
C	Epoxy	1	300	7	SeaWater	535.01	540.67	537.84	2.83
A	Epoxy	2	300	7	0	6.68	9.58	8.13	1.45
B	Vinyl Ester	2	300	7	0	5.45	5.56	5.50	0.06
C	Epoxy	2	300	7	0	8.59	12.28	10.43	1.84
A	Epoxy	2	300	7	200	7.40	13.93	10.67	3.27
B	Vinyl Ester	2	300	7	200	7.09	7.35	7.22	0.13
C	Epoxy	2	300	7	200	9.54	17.83	13.69	4.15
A	Epoxy	2	300	7	20000	25.77	33.36	29.57	3.79
B	Vinyl Ester	2	300	7	20000	19.48	20.55	20.02	0.53
C	Epoxy	2	300	7	20000	31.72	44.17	37.94	6.23
A	Epoxy	2	300	7	SeaWater	544.33	549.54	546.93	2.61
B	Vinyl Ester	2	300	7	SeaWater	544.76	549.14	546.95	2.19
C	Epoxy	2	300	7	SeaWater	563.96	570.88	567.42	3.46
A	Epoxy	1	300	10	0	3.18	3.44	3.31	0.13
B	Vinyl Ester	1	300	10	0	2.30	2.35	2.33	0.02
C	Epoxy	1	300	10	0	3.74	4.10	3.92	0.18
A	Epoxy	1	300	10	200	4.28	5.60	4.94	0.66
B	Vinyl Ester	1	300	10	200	3.35	3.60	3.48	0.12
C	Epoxy	1	300	10	200	4.97	6.74	5.85	0.89
A	Epoxy	1	300	10	20000	9.06	15.00	12.03	2.97
B	Vinyl Ester	1	300	10	20000	7.91	9.02	8.47	0.56
C	Epoxy	1	300	10	20000	10.27	18.25	14.26	3.99
A	Epoxy	1	300	10	SeaWater	519.18	532.69	525.93	6.76
B	Vinyl Ester	1	300	10	SeaWater	511.43	522.69	517.06	5.63
C	Epoxy	1	300	10	SeaWater	533.25	549.74	541.50	8.24
A	Epoxy	2	300	10	0	8.04	9.49	8.76	0.73
B	Vinyl Ester	2	300	10	0	5.91	5.96	5.93	0.03
C	Epoxy	2	300	10	0	10.33	12.17	11.25	0.92
A	Epoxy	2	300	10	200	9.46	16.72	13.09	3.63
B	Vinyl Ester	2	300	10	200	8.72	9.01	8.86	0.14
C	Epoxy	2	300	10	200	12.20	21.41	16.80	4.61
A	Epoxy	2	300	10	20000	25.55	38.22	31.89	6.34
B	Vinyl Ester	2	300	10	20000	20.96	22.22	21.59	0.63

Continued on next page ...

Table 1.22: Calcium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Calcium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	10	20000	33.55	48.30	40.92	7.37
A	Epoxy	2	300	10	SeaWater	543.05	558.25	550.65	7.60
B	Vinyl Ester	2	300	10	SeaWater	544.28	557.06	550.67	6.39
C	Epoxy	2	300	10	SeaWater	561.18	581.38	571.28	10.10
A	Epoxy	1	300	13	0	2.90	5.54	4.22	1.32
B	Vinyl Ester	1	300	13	0	2.72	3.22	2.97	0.25
C	Epoxy	1	300	13	0	3.23	6.78	5.00	1.77
A	Epoxy	1	300	13	200	4.89	10.17	7.53	2.64
B	Vinyl Ester	1	300	13	200	4.80	5.79	5.30	0.50
C	Epoxy	1	300	13	200	6.44	11.40	8.92	2.48
A	Epoxy	1	300	13	20000	14.93	17.83	16.38	1.45
B	Vinyl Ester	1	300	13	20000	11.25	11.79	11.52	0.27
C	Epoxy	1	300	13	20000	17.46	21.35	19.41	1.95
A	Epoxy	1	300	13	SeaWater	521.23	536.11	528.67	7.44
B	Vinyl Ester	1	300	13	SeaWater	513.55	525.95	519.75	6.20
C	Epoxy	1	300	13	SeaWater	535.24	553.39	544.31	9.08
A	Epoxy	2	300	13	0	3.93	18.45	11.19	7.26
B	Vinyl Ester	2	300	13	0	7.30	7.86	7.58	0.28
C	Epoxy	2	300	13	0	5.15	23.58	14.36	9.21
A	Epoxy	2	300	13	200	12.43	27.48	19.96	7.52
B	Vinyl Ester	2	300	13	200	12.95	14.07	13.51	0.56
C	Epoxy	2	300	13	200	21.02	30.20	25.61	4.59
A	Epoxy	2	300	13	20000	35.41	51.39	43.40	7.99
B	Vinyl Ester	2	300	13	20000	29.07	29.69	29.38	0.31
C	Epoxy	2	300	13	20000	52.09	59.30	55.70	3.60
A	Epoxy	2	300	13	SeaWater	545.15	561.89	553.52	8.37
B	Vinyl Ester	2	300	13	SeaWater	546.49	560.57	553.53	7.04
C	Epoxy	2	300	13	SeaWater	563.13	585.37	574.25	11.12

Table 1.23: Calcium Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Calcium			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	4	0	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	4	200	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	4	200	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	4	20000	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	4	20000	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	4	SeaWater	458.38	460.46	459.42	1.04
B	Vinyl Ester	300	4	SeaWater	456.94	461.46	459.2	2.26
A	Epoxy	300	7	0	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	7	0	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	7	200	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	7	200	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	7	20000	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	7	20000	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	7	SeaWater	465.93	469.27	467.6	1.67
B	Vinyl Ester	300	7	SeaWater	465.62	469.12	467.37	1.75
A	Epoxy	300	10	0	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	10	0	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	10	200	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	10	200	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	10	20000	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	10	20000	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	10	SeaWater	468.74	472.82	470.78	2.04
B	Vinyl Ester	300	10	SeaWater	468.45	472.63	470.54	2.09
A	Epoxy	300	13	0	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	13	0	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	13	200	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	13	200	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	13	20000	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	13	20000	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	13	SeaWater	471.73	474.73	473.23	1.50
B	Vinyl Ester	300	13	SeaWater	471.88	474.1	472.99	1.11

Table 1.24: Calcium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Calcium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	0.85	0.88	0.87	0.01
B	Sized	300	4	0	0.78	0.80	0.79	0.01
C	Sized	300	4	0	0.95	0.99	0.97	0.02
A	Sized	300	4	200	0.92	1.11	1.02	0.09

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Table 1.24: Calcium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Calcium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Sized	300	4	200	0.85	1.00	0.92	0.08
C	Sized	300	4	200	1.03	1.25	1.14	0.11
A	Sized	300	4	20000	2.24	2.64	2.44	0.20
B	Sized	300	4	20000	2.05	2.38	2.22	0.17
C	Sized	300	4	20000	2.49	2.97	2.73	0.24
A	Sized	300	4	SeaWater	473.51	479.60	476.56	3.05
B	Sized	300	4	SeaWater	464.67	469.75	467.21	2.54
C	Sized	300	4	SeaWater	483.32	490.76	487.04	3.72
A	Unsized	300	4	0	0.75	0.77	0.76	0.01
B	Unsized	300	4	0	0.70	0.72	0.71	0.01
A	Unsized	300	4	200	0.81	0.98	0.89	0.08
B	Unsized	300	4	200	0.76	0.91	0.83	0.08
A	Unsized	300	4	20000	1.97	2.32	2.14	0.17
B	Unsized	300	4	20000	1.83	2.16	1.99	0.16
A	Unsized	300	4	SeaWater	466.72	472.09	469.41	2.68
B	Unsized	300	4	SeaWater	460.02	465.05	462.54	2.52
A	Sized	300	7	0	0.84	0.94	0.89	0.05
B	Sized	300	7	0	0.76	0.85	0.81	0.04
C	Sized	300	7	0	0.93	1.06	1.00	0.06
A	Sized	300	7	200	1.05	1.29	1.17	0.12
B	Sized	300	7	200	0.96	1.16	1.06	0.10
C	Sized	300	7	200	1.16	1.45	1.31	0.14
A	Sized	300	7	20000	2.73	3.74	3.23	0.50
B	Sized	300	7	20000	2.52	3.36	2.94	0.42
C	Sized	300	7	20000	3.01	4.23	3.62	0.61
A	Sized	300	7	SeaWater	482.98	487.09	485.03	2.06
B	Sized	300	7	SeaWater	473.81	477.24	475.52	1.72
C	Sized	300	7	SeaWater	493.19	498.22	495.71	2.51
A	Unsized	300	7	0	0.74	0.83	0.78	0.05
B	Unsized	300	7	0	0.68	0.77	0.73	0.04
A	Unsized	300	7	200	0.92	1.13	1.03	0.10
B	Unsized	300	7	200	0.86	1.05	0.95	0.10
A	Unsized	300	7	20000	2.40	3.29	2.85	0.44
B	Unsized	300	7	20000	2.23	3.06	2.65	0.41
A	Unsized	300	7	SeaWater	475.95	479.57	477.76	1.81
B	Unsized	300	7	SeaWater	469.07	472.47	470.77	1.70
A	Sized	300	10	0	0.93	0.99	0.96	0.03
B	Sized	300	10	0	0.85	0.89	0.87	0.02
C	Sized	300	10	0	1.04	1.11	1.07	0.03
A	Sized	300	10	200	1.30	1.56	1.43	0.13
B	Sized	300	10	200	1.19	1.41	1.30	0.11
C	Sized	300	10	200	1.44	1.77	1.60	0.16
A	Sized	300	10	20000	2.89	4.08	3.49	0.59
B	Sized	300	10	20000	2.68	3.67	3.17	0.50
C	Sized	300	10	20000	3.18	4.63	3.91	0.72
A	Sized	300	10	SeaWater	482.33	494.34	488.33	6.01
B	Sized	300	10	SeaWater	473.75	483.76	478.76	5.01
C	Sized	300	10	SeaWater	491.75	506.40	499.08	7.33
A	Unsized	300	10	0	0.82	0.87	0.84	0.02

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Table 1.24: Calcium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Calcium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	10	0	0.76	0.81	0.78	0.02
A	Unsized	300	10	200	1.14	1.38	1.26	0.12
B	Unsized	300	10	200	1.06	1.28	1.17	0.11
A	Unsized	300	10	20000	2.55	3.59	3.07	0.52
B	Unsized	300	10	20000	2.36	3.34	2.85	0.49
A	Unsized	300	10	SeaWater	475.72	486.29	481.01	5.29
B	Unsized	300	10	SeaWater	469.01	478.92	473.97	4.95
A	Sized	300	13	0	0.96	1.49	1.22	0.26
B	Sized	300	13	0	0.89	1.33	1.11	0.22
C	Sized	300	13	0	1.05	1.69	1.37	0.32
A	Sized	300	13	200	1.65	2.71	2.18	0.53
B	Sized	300	13	200	1.54	2.42	1.98	0.44
C	Sized	300	13	200	1.80	3.09	2.44	0.64
A	Sized	300	13	20000	4.46	5.04	4.75	0.29
B	Sized	300	13	20000	4.07	4.56	4.32	0.24
C	Sized	300	13	20000	4.96	5.67	5.32	0.35
A	Sized	300	13	SeaWater	484.26	497.48	490.87	6.61
B	Sized	300	13	SeaWater	475.74	486.76	481.25	5.51
C	Sized	300	13	SeaWater	493.60	509.74	501.67	8.07
A	Unsized	300	13	0	0.85	1.31	1.08	0.23
B	Unsized	300	13	0	0.78	1.22	1.00	0.22
A	Unsized	300	13	200	1.46	2.39	1.92	0.46
B	Unsized	300	13	200	1.35	2.22	1.79	0.44
A	Unsized	300	13	20000	3.92	4.43	4.18	0.26
B	Unsized	300	13	20000	3.64	4.12	3.88	0.24
A	Unsized	300	13	SeaWater	477.69	489.33	483.51	5.82
B	Unsized	300	13	SeaWater	470.98	481.89	476.43	5.46

For a better understanding, change in the Calcium content of the environments was plotted in graphs in Figure 1.22, 1.23, and 1.24. It can be seen that the Calcium content has increased in all environments except the environments that had resin samples.

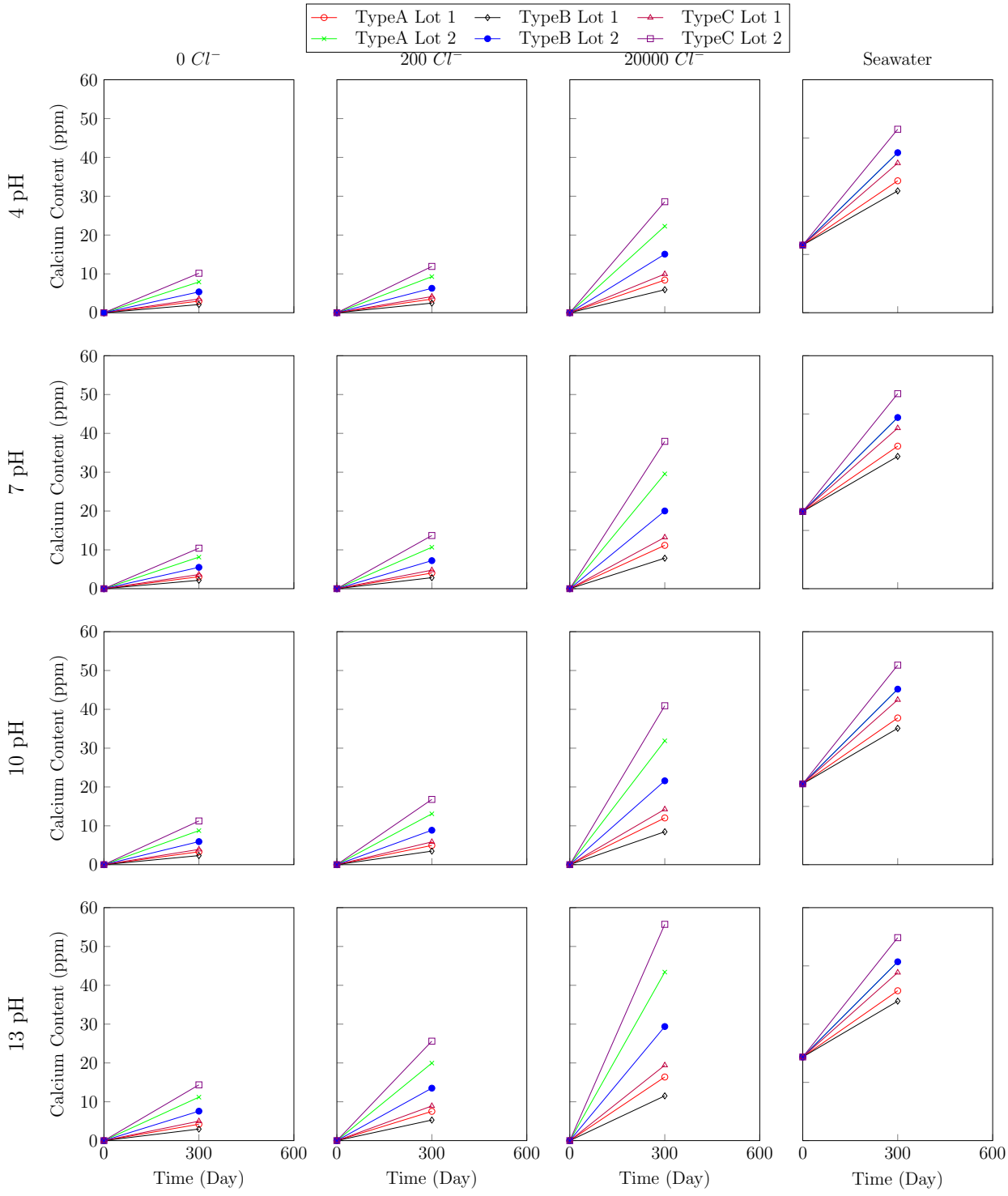

Figure 1.22: Calcium concentration of all environments after exposure of rebars

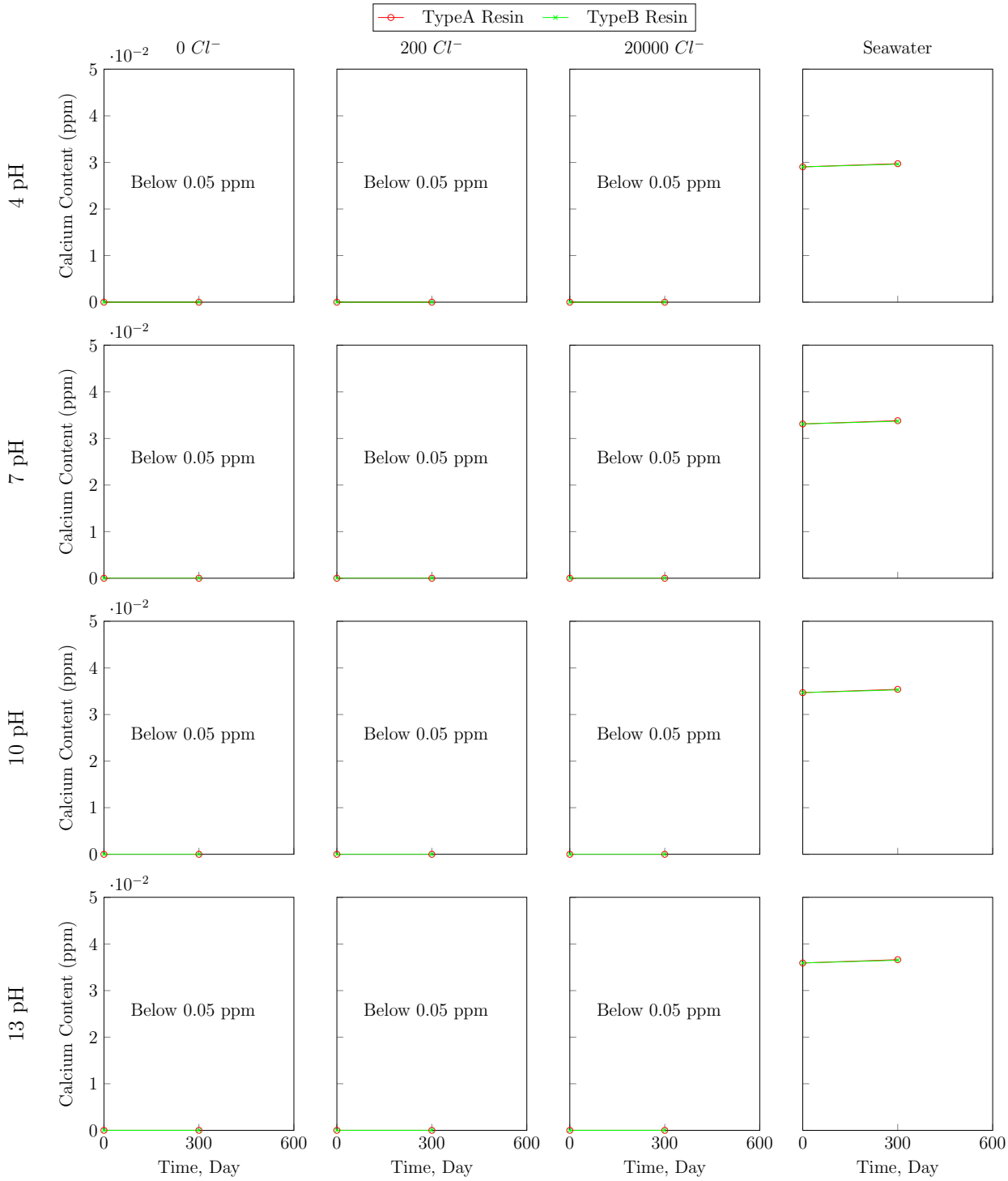

Figure 1.23: Calcium concentration of all environments after exposure of resins

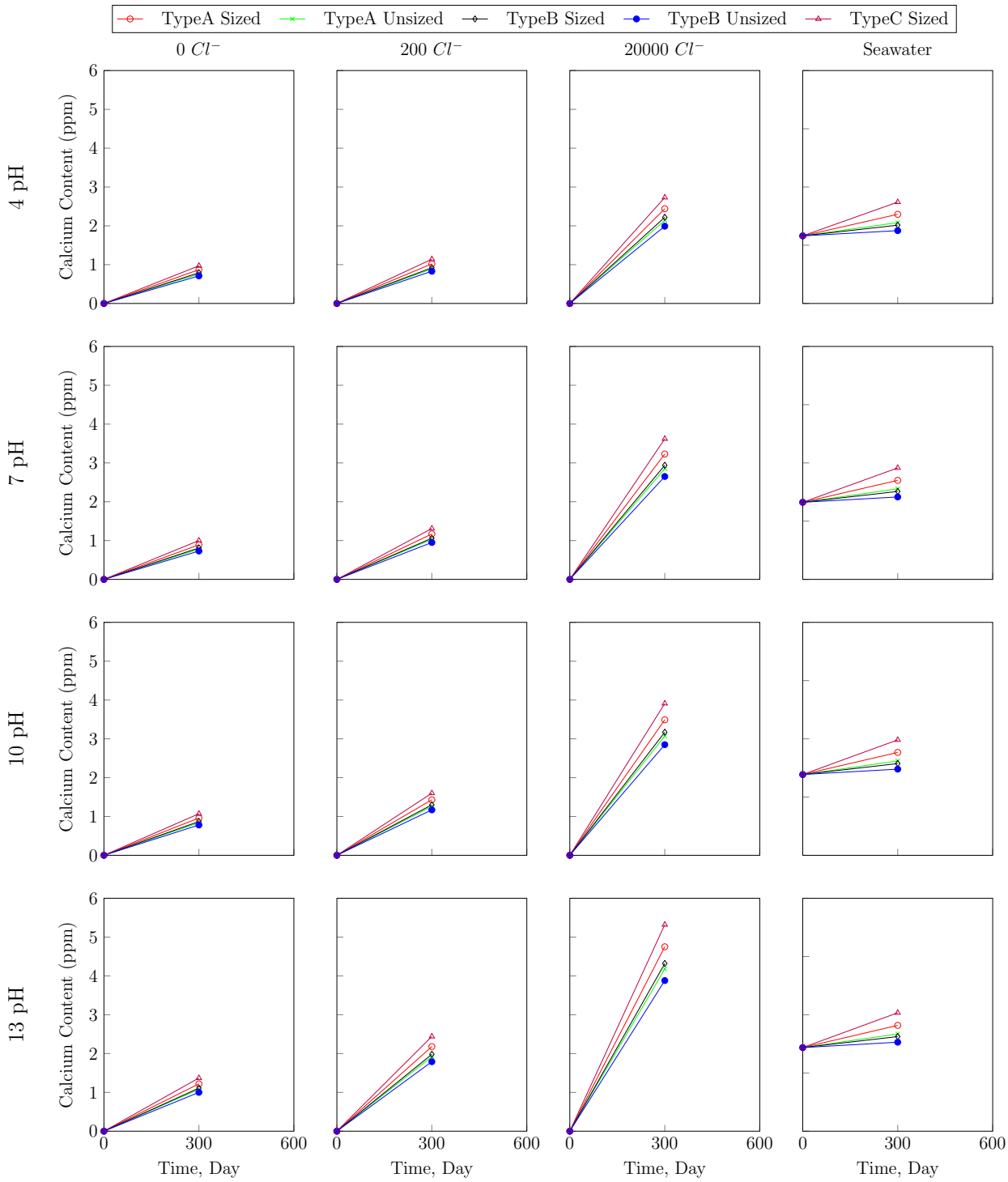

Figure 1.24: Calcium concentration of all environments after exposure of sized and unsized fibers

Chromium

Chromium content of the chemical environments was measured after 300 days of exposure. Tables 1.25, 1.26, and 1.27 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.25: Chromium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Chromium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0

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Table 1.25: Chromium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Chromium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	1	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	1	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	1	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0

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Table 1.25: Chromium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Chromium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	2	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	2	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	2	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Epoxy	2	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0

Table 1.26: Chromium Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Chromium			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Epoxy	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0

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Table 1.26: Chromium Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Chromium			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Vinyl Ester	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0

Table 1.27: Chromium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Chromium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	4	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0

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Table 1.27: Chromium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Chromium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	7	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	10	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0

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Table 1.27: Chromium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Chromium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Sized	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Sized	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
C	Sized	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.0
A	Unsized	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0
B	Unsized	300	13	SeaWater	Below 0.01	Below 0.01	Below 0.01	0.0

For a better understanding, change in the Chromium content of the environments was plotted in graphs in Figure 1.25, 1.26, and 1.27. It can be seen that the Chromium concentration has not changed over time in all exposure environments.

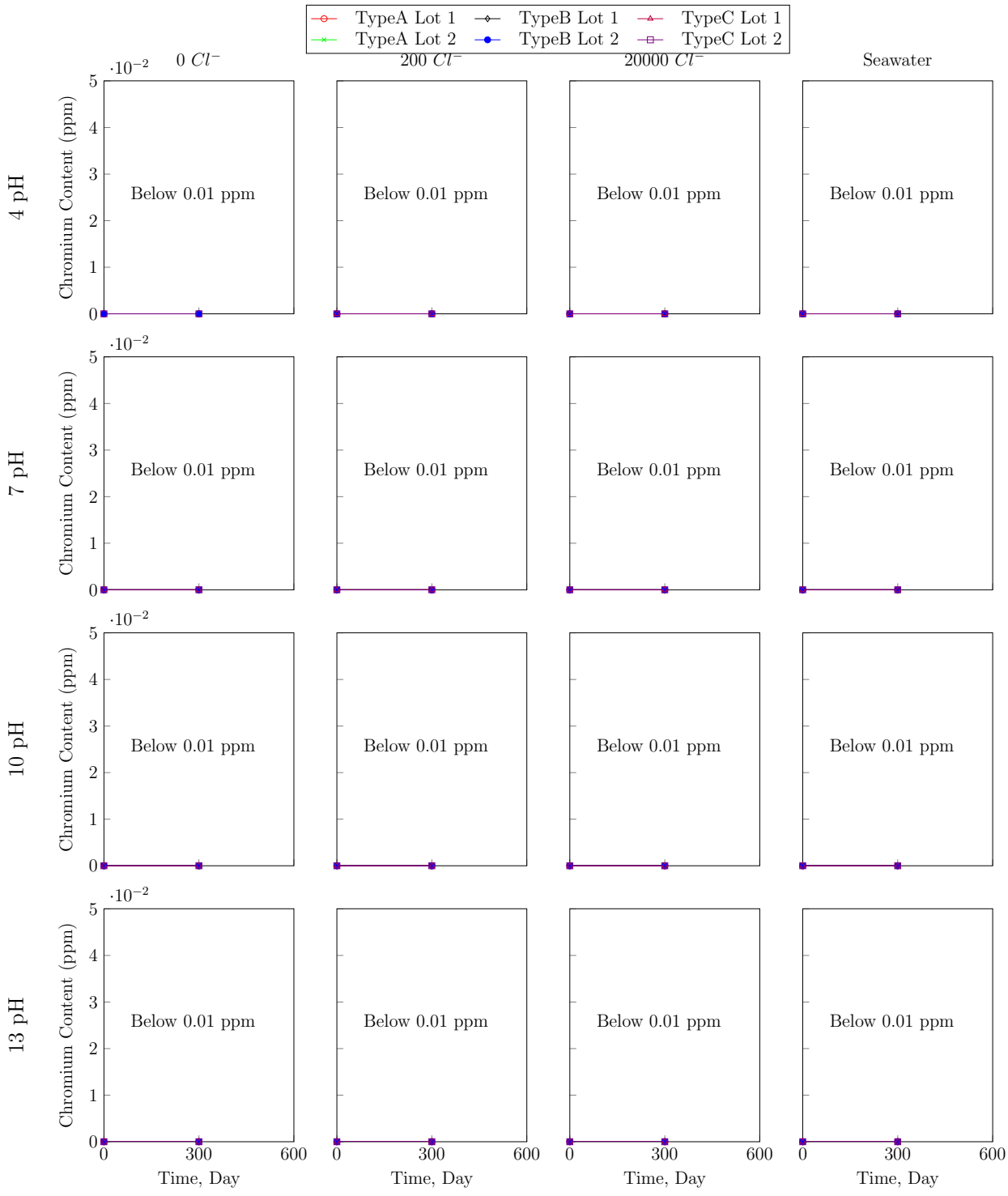

Figure 1.25: Chromium concentration of all environments after exposure of rebars

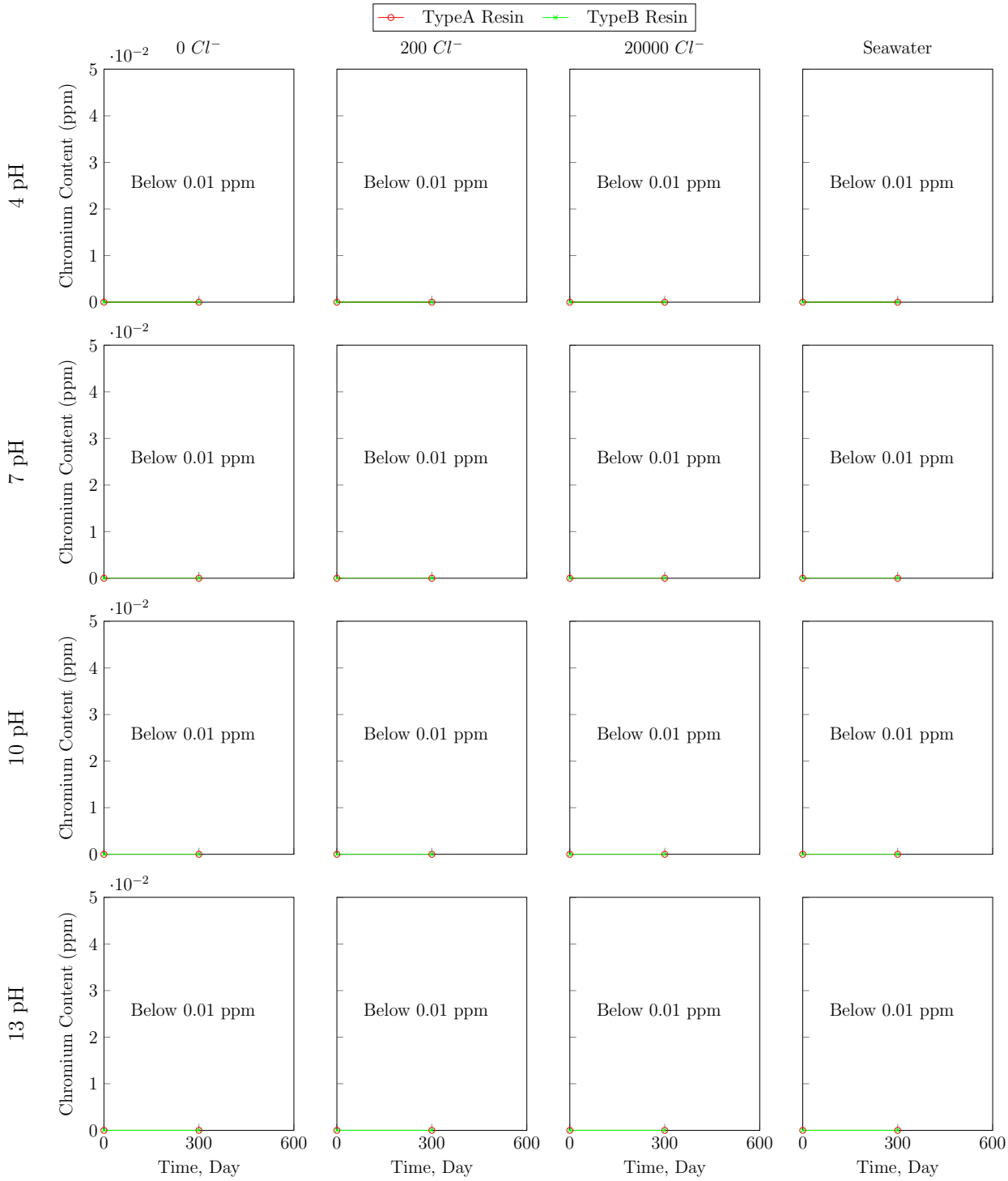

Figure 1.26: Chromium concentration of all environments after exposure of resins

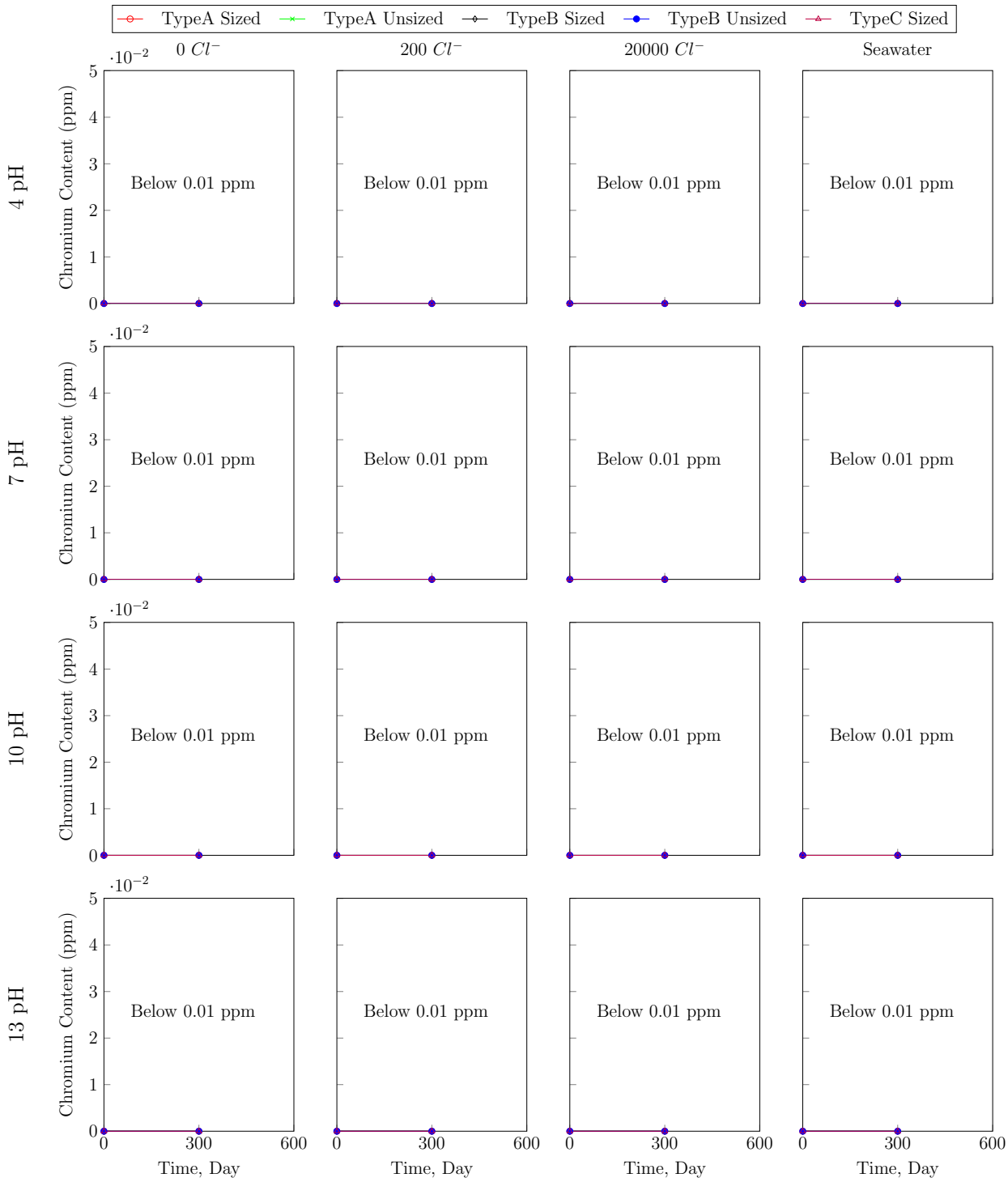

Figure 1.27: Chromium concentration of all environments after exposure of sized and unsized fibers

Iron

Iron content of the chemical environments was measured after 300 days of exposure. Tables 1.28, 1.29, and 1.30 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.28: Iron Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Iron			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	4.71	4.78	4.74	0.04
B	Vinyl Ester	1	300	4	0	3.32	3.35	3.34	0.01
C	Epoxy	1	300	4	0	6.12	6.21	6.16	0.04
A	Epoxy	1	300	4	200	5.64	6.13	5.89	0.25
B	Vinyl Ester	1	300	4	200	3.82	4.03	3.92	0.10
C	Epoxy	1	300	4	200	7.36	7.95	7.65	0.30
A	Epoxy	1	300	4	20000	14.37	15.42	14.90	0.53
B	Vinyl Ester	1	300	4	20000	9.21	9.64	9.43	0.22
C	Epoxy	1	300	4	20000	18.73	20.00	19.36	0.64
A	Epoxy	1	300	4	SeaWater	16.58	21.31	18.95	2.36
B	Vinyl Ester	1	300	4	SeaWater	10.45	12.38	11.41	0.96
C	Epoxy	1	300	4	SeaWater	21.79	27.47	24.63	2.84
A	Epoxy	2	300	4	0	6.68	6.78	6.73	0.05
B	Vinyl Ester	2	300	4	0	5.05	5.10	5.07	0.02
C	Epoxy	2	300	4	0	7.67	7.81	7.74	0.07
A	Epoxy	2	300	4	200	9.68	10.64	10.16	0.48
B	Vinyl Ester	2	300	4	200	5.79	6.13	5.96	0.17
C	Epoxy	2	300	4	200	8.47	9.19	8.83	0.36
A	Epoxy	2	300	4	20000	22.77	24.30	23.53	0.77
B	Vinyl Ester	2	300	4	20000	13.95	14.69	14.32	0.37
C	Epoxy	2	300	4	20000	26.04	28.09	27.06	1.03
A	Epoxy	2	300	4	SeaWater	28.02	34.88	31.45	3.43
B	Vinyl Ester	2	300	4	SeaWater	15.70	18.97	17.34	1.63
C	Epoxy	2	300	4	SeaWater	31.58	40.76	36.17	4.59
A	Epoxy	1	300	7	0	4.80	5.08	4.94	0.14
B	Vinyl Ester	1	300	7	0	3.37	3.49	3.43	0.06
C	Epoxy	1	300	7	0	6.25	6.59	6.42	0.17
A	Epoxy	1	300	7	200	6.53	7.17	6.85	0.32
B	Vinyl Ester	1	300	7	200	4.38	4.64	4.51	0.13
C	Epoxy	1	300	7	200	8.52	9.29	8.91	0.38
A	Epoxy	1	300	7	20000	18.68	21.37	20.03	1.34

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Table 1.28: Iron Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Iron			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	1	300	7	20000	11.97	13.06	12.52	0.55
C	Epoxy	1	300	7	20000	24.42	27.64	26.03	1.61
A	Epoxy	1	300	7	SeaWater	23.93	26.33	25.13	1.20
B	Vinyl Ester	1	300	7	SeaWater	14.47	15.45	14.96	0.49
C	Epoxy	1	300	7	SeaWater	31.23	34.10	32.67	1.44
A	Epoxy	2	300	7	0	6.91	7.32	7.11	0.20
B	Vinyl Ester	2	300	7	0	5.11	5.31	5.21	0.10
C	Epoxy	2	300	7	0	7.90	8.45	8.18	0.27
A	Epoxy	2	300	7	200	9.95	10.87	10.41	0.46
B	Vinyl Ester	2	300	7	200	6.63	7.07	6.85	0.22
C	Epoxy	2	300	7	200	11.36	12.59	11.97	0.62
A	Epoxy	2	300	7	20000	30.10	33.98	32.04	1.94
B	Vinyl Ester	2	300	7	20000	18.08	19.94	19.01	0.93
C	Epoxy	2	300	7	20000	34.24	39.45	36.85	2.60
A	Epoxy	2	300	7	SeaWater	40.47	43.95	42.21	1.74
B	Vinyl Ester	2	300	7	SeaWater	21.89	23.55	22.72	0.83
C	Epoxy	2	300	7	SeaWater	46.21	50.88	48.55	2.33
A	Epoxy	1	300	10	0	5.33	5.47	5.40	0.07
B	Vinyl Ester	1	300	10	0	3.67	3.73	3.70	0.03
C	Epoxy	1	300	10	0	6.94	7.10	7.02	0.08
A	Epoxy	1	300	10	200	8.17	8.88	8.52	0.35
B	Vinyl Ester	1	300	10	200	5.39	5.68	5.54	0.14
C	Epoxy	1	300	10	200	10.66	11.51	11.08	0.42
A	Epoxy	1	300	10	20000	20.29	23.47	21.88	1.59
B	Vinyl Ester	1	300	10	20000	12.86	14.15	13.51	0.65
C	Epoxy	1	300	10	20000	26.54	30.35	28.44	1.91
A	Epoxy	1	300	10	SeaWater	28.65	35.78	32.22	3.56
B	Vinyl Ester	1	300	10	SeaWater	17.50	20.40	18.95	1.45
C	Epoxy	1	300	10	SeaWater	37.60	46.16	41.88	4.28
A	Epoxy	2	300	10	0	7.78	7.99	7.88	0.10
B	Vinyl Ester	2	300	10	0	5.57	5.67	5.62	0.05
C	Epoxy	2	300	10	0	8.93	9.20	9.07	0.14
A	Epoxy	2	300	10	200	12.62	13.64	13.13	0.51
B	Vinyl Ester	2	300	10	200	8.17	8.65	8.41	0.24
C	Epoxy	2	300	10	200	14.41	15.78	15.10	0.69
A	Epoxy	2	300	10	20000	33.14	37.75	35.44	2.30
B	Vinyl Ester	2	300	10	20000	19.42	21.61	20.51	1.10

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Table 1.28: Iron Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Iron			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	10	20000	37.68	43.84	40.76	3.08
A	Epoxy	2	300	10	SeaWater	49.60	59.93	54.77	5.17
B	Vinyl Ester	2	300	10	SeaWater	26.32	31.25	28.78	2.46
C	Epoxy	2	300	10	SeaWater	56.06	69.91	62.98	6.92
A	Epoxy	1	300	13	0	6.29	7.70	6.99	0.71
B	Vinyl Ester	1	300	13	0	4.44	5.01	4.73	0.29
C	Epoxy	1	300	13	0	8.25	9.94	9.09	0.85
A	Epoxy	1	300	13	200	11.76	14.58	13.17	1.41
B	Vinyl Ester	1	300	13	200	7.86	9.02	8.44	0.58
C	Epoxy	1	300	13	200	15.42	18.81	17.12	1.69
A	Epoxy	1	300	13	20000	29.38	30.93	30.16	0.78
B	Vinyl Ester	1	300	13	20000	18.07	18.70	18.39	0.32
C	Epoxy	1	300	13	20000	38.27	40.13	39.20	0.93
A	Epoxy	1	300	13	SeaWater	40.54	46.89	43.71	3.18
B	Vinyl Ester	1	300	13	SeaWater	24.12	26.71	25.41	1.30
C	Epoxy	1	300	13	SeaWater	53.01	60.63	56.82	3.81
A	Epoxy	2	300	13	0	9.33	11.37	10.35	1.02
B	Vinyl Ester	2	300	13	0	6.69	7.67	7.18	0.49
C	Epoxy	2	300	13	0	10.53	13.27	11.90	1.37
A	Epoxy	2	300	13	200	18.50	22.59	20.54	2.05
B	Vinyl Ester	2	300	13	200	11.85	13.80	12.82	0.98
C	Epoxy	2	300	13	200	20.88	26.36	23.62	2.74
A	Epoxy	2	300	13	20000	48.33	50.58	49.46	1.13
B	Vinyl Ester	2	300	13	20000	27.39	28.47	27.93	0.54
C	Epoxy	2	300	13	20000	55.37	58.38	56.88	1.51
A	Epoxy	2	300	13	SeaWater	60.58	69.79	65.18	4.60
B	Vinyl Ester	2	300	13	SeaWater	36.40	40.79	38.59	2.20
C	Epoxy	2	300	13	SeaWater	68.79	81.13	74.96	6.17

Table 1.29: Iron Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Iron			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	4	0	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	4	200	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	4	200	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	4	20000	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	4	20000	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	4	SeaWater	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	4	SeaWater	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	7	0	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	7	0	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	7	200	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	7	200	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	7	20000	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	7	20000	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	7	SeaWater	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	7	SeaWater	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	10	0	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	10	0	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	10	200	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	10	200	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	10	20000	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	10	20000	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	10	SeaWater	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	10	SeaWater	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	13	0	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	13	0	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	13	200	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	13	200	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	13	20000	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	13	20000	Below 0.05	Below 0.05	Below 0.05	0.0
A	Epoxy	300	13	SeaWater	Below 0.05	Below 0.05	Below 0.05	0.0
B	Vinyl Ester	300	13	SeaWater	Below 0.05	Below 0.05	Below 0.05	0.0

Table 1.30: Iron Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Iron			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	0.94	0.96	0.95	0.01

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Table 1.30: Iron Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Iron			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Sized	300	4	0	0.74	0.76	0.75	0.01
C	Sized	300	4	0	1.05	1.08	1.06	0.01
A	Sized	300	4	200	1.40	1.56	1.48	0.08
B	Sized	300	4	200	0.81	0.95	0.88	0.07
C	Sized	300	4	200	1.56	1.75	1.66	0.09
A	Sized	300	4	20000	2.83	3.19	3.01	0.18
B	Sized	300	4	20000	1.96	2.26	2.11	0.15
C	Sized	300	4	20000	3.17	3.57	3.37	0.20
A	Sized	300	4	SeaWater	5.53	7.15	6.34	0.81
B	Sized	300	4	SeaWater	1.88	3.22	2.55	0.67
C	Sized	300	4	SeaWater	6.19	8.01	7.10	0.91
A	Unsized	300	4	0	0.88	0.91	0.89	0.01
B	Unsized	300	4	0	0.69	0.71	0.70	0.01
A	Unsized	300	4	200	1.31	1.51	1.41	0.10
B	Unsized	300	4	200	0.76	0.91	0.84	0.08
A	Unsized	300	4	20000	2.67	3.10	2.88	0.21
B	Unsized	300	4	20000	1.89	2.22	2.06	0.17
A	Unsized	300	4	SeaWater	5.17	7.08	6.12	0.96
B	Unsized	300	4	SeaWater	1.80	3.27	2.53	0.74
A	Sized	300	7	0	0.93	1.03	0.98	0.05
B	Sized	300	7	0	0.73	0.81	0.77	0.04
C	Sized	300	7	0	1.04	1.15	1.10	0.05
A	Sized	300	7	200	1.45	1.67	1.56	0.11
B	Sized	300	7	200	0.92	1.10	1.01	0.09
C	Sized	300	7	200	1.63	1.87	1.75	0.12
A	Sized	300	7	20000	3.32	4.24	3.78	0.46
B	Sized	300	7	20000	2.42	3.18	2.80	0.38
C	Sized	300	7	20000	3.72	4.75	4.23	0.51
A	Sized	300	7	SeaWater	6.60	7.42	7.01	0.41
B	Sized	300	7	SeaWater	3.00	3.68	3.34	0.34
C	Sized	300	7	SeaWater	7.39	8.31	7.85	0.46
A	Unsized	300	7	0	0.87	0.98	0.93	0.06

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Table 1.30: Iron Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Iron			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	7	0	0.68	0.76	0.72	0.04
A	Unsized	300	7	200	1.36	1.61	1.49	0.13
B	Unsized	300	7	200	0.87	1.06	0.96	0.10
A	Unsized	300	7	20000	3.09	4.17	3.63	0.54
B	Unsized	300	7	20000	2.35	3.19	2.77	0.42
A	Unsized	300	7	SeaWater	6.30	7.27	6.79	0.49
B	Unsized	300	7	SeaWater	2.95	3.70	3.33	0.37
A	Sized	300	10	0	1.09	1.13	1.11	0.02
B	Sized	300	10	0	0.81	0.85	0.83	0.02
C	Sized	300	10	0	1.22	1.27	1.24	0.03
A	Sized	300	10	200	1.77	2.01	1.89	0.12
B	Sized	300	10	200	1.14	1.34	1.24	0.10
C	Sized	300	10	200	1.98	2.25	2.12	0.14
A	Sized	300	10	20000	3.69	4.77	4.23	0.54
B	Sized	300	10	20000	2.57	3.47	3.02	0.45
C	Sized	300	10	20000	4.13	5.35	4.74	0.61
A	Sized	300	10	SeaWater	6.45	8.89	7.67	1.22
B	Sized	300	10	SeaWater	3.22	5.24	4.23	1.01
C	Sized	300	10	SeaWater	7.22	9.96	8.59	1.37
A	Unsized	300	10	0	1.02	1.08	1.05	0.03
B	Unsized	300	10	0	0.76	0.80	0.78	0.02
A	Unsized	300	10	200	1.08	1.30	1.19	0.11
B	Unsized	300	10	200	1.66	1.95	1.80	0.14
A	Unsized	300	10	20000	3.43	4.71	4.07	0.64
B	Unsized	300	10	20000	2.49	3.48	2.99	0.50
A	Unsized	300	10	SeaWater	5.97	8.86	7.42	1.44
B	Unsized	300	10	SeaWater	3.11	5.33	4.22	1.11
A	Sized	300	13	0	1.12	1.60	1.36	0.24
B	Sized	300	13	0	0.86	1.26	1.06	0.20
C	Sized	300	13	0	1.25	1.79	1.52	0.27
A	Sized	300	13	200	2.19	3.15	2.67	0.48
B	Sized	300	13	200	1.49	2.29	1.89	0.40

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Table 1.30: Iron Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Iron			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Sized	300	13	200	2.45	3.53	2.99	0.54
A	Sized	300	13	20000	5.62	6.16	5.89	0.27
B	Sized	300	13	20000	3.89	4.33	4.11	0.22
C	Sized	300	13	20000	6.30	6.89	6.60	0.30
A	Sized	300	13	SeaWater	7.66	9.84	8.75	1.09
B	Sized	300	13	SeaWater	4.77	6.57	5.67	0.90
C	Sized	300	13	SeaWater	8.58	11.02	9.80	1.22
A	Unsized	300	13	0	1.00	1.57	1.29	0.29
B	Unsized	300	13	0	0.78	1.22	1.00	0.22
A	Unsized	300	13	200	1.98	3.12	2.55	0.57
B	Unsized	300	13	200	1.39	2.27	1.83	0.44
A	Unsized	300	13	20000	5.36	5.99	5.68	0.31
B	Unsized	300	13	20000	3.83	4.32	4.07	0.24
A	Unsized	300	13	SeaWater	7.19	9.76	8.48	1.29
B	Unsized	300	13	SeaWater	4.62	6.60	5.61	0.99

For a better understanding, change in the Iron content of the environments was plotted in graphs in Figure 1.28, 1.29, and 1.30. It can be seen that the Iron content of all environments has increased except for the environments in which resin samples were exposed.

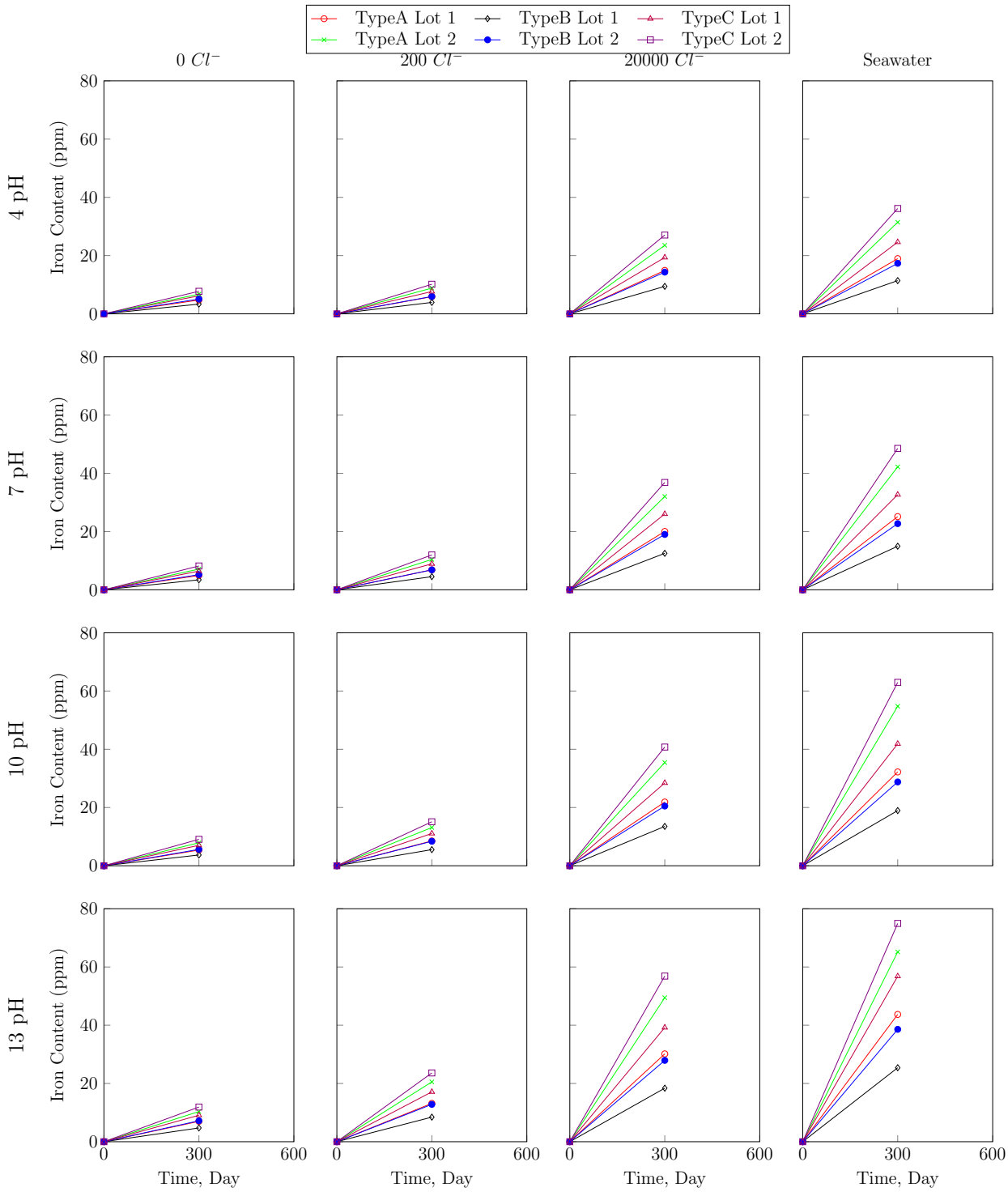

Figure 1.28: Iron concentration of all environments after exposure of rebars

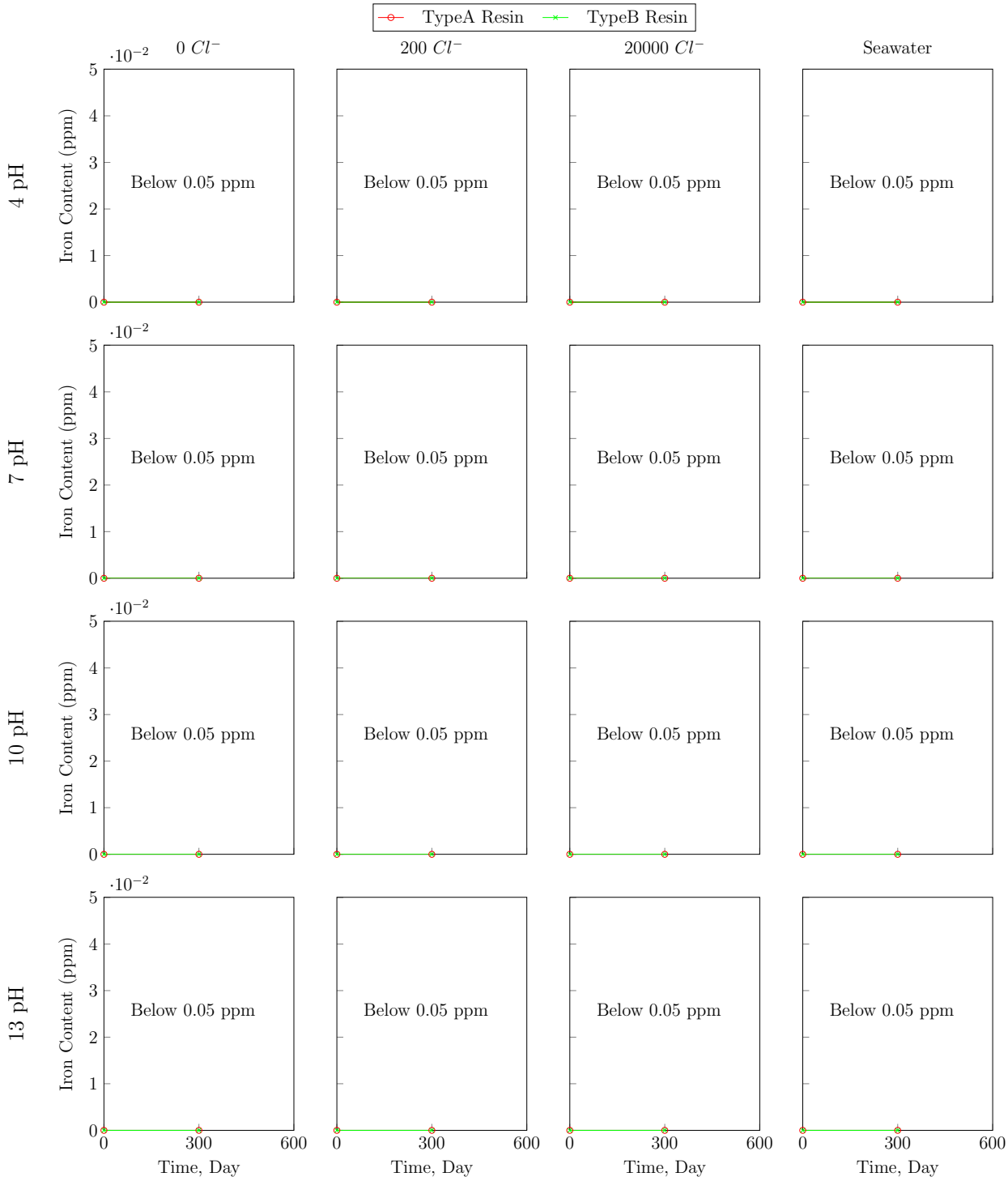

Figure 1.29: Iron concentration of all environments after exposure of resins

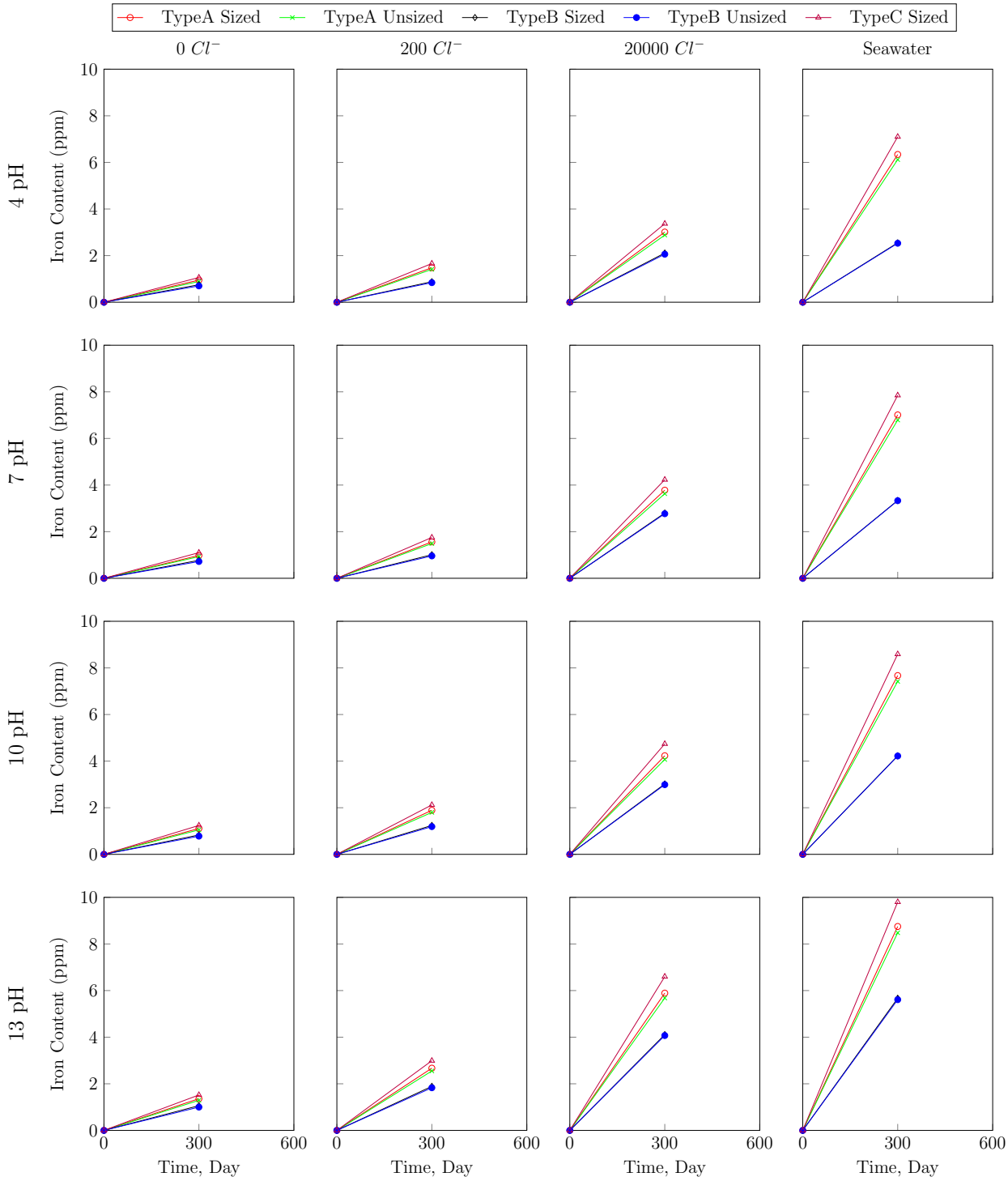

Figure 1.30: Iron concentration of all environments after exposure of sized and unsized fibers

Magnesium

Magnesium content of the chemical environments was measured after 300 days of exposure. Tables 1.31, 1.32, and 1.33 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.31: Magnesium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Magnesium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	4	SeaWater	1382.45	1392.89	1387.67	5.22
B	Vinyl Ester	1	300	4	SeaWater	1405.04	1414.14	1409.59	4.55
C	Epoxy	1	300	4	SeaWater	1395.75	1407.34	1401.55	5.79
A	Epoxy	2	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	4	SeaWater	1376.21	1386.45	1381.33	5.12
B	Vinyl Ester	2	300	4	SeaWater	1393.92	1405.72	1399.82	5.90
C	Epoxy	2	300	4	SeaWater	1383.81	1397.64	1390.73	6.91
A	Epoxy	1	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	7	SeaWater	1370.89	1380.01	1375.45	4.56
B	Vinyl Ester	1	300	7	SeaWater	1389.33	1407.17	1398.25	8.92
C	Epoxy	1	300	7	SeaWater	1384.14	1394.26	1389.20	5.06
A	Epoxy	2	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00

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Table 1.31: Magnesium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Magnesium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	7	SeaWater	1364.54	1374.50	1369.52	4.98
B	Vinyl Ester	2	300	7	SeaWater	1386.70	1396.26	1391.48	4.78
C	Epoxy	2	300	7	SeaWater	1372.11	1385.55	1378.83	6.72
A	Epoxy	1	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	10	SeaWater	1359.14	1373.34	1366.24	7.10
B	Vinyl Ester	1	300	10	SeaWater	1382.01	1393.35	1387.68	5.67
C	Epoxy	1	300	10	SeaWater	1372.02	1387.78	1379.90	7.88
A	Epoxy	2	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	10	SeaWater	1357.11	1368.69	1362.90	5.79
B	Vinyl Ester	2	300	10	SeaWater	1371.03	1386.79	1378.91	7.88
C	Epoxy	2	300	10	SeaWater	1364.35	1379.98	1372.17	7.82
A	Epoxy	1	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	1	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	1	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	1	300	13	SeaWater	1358.00	1365.12	1361.56	3.56
B	Vinyl Ester	1	300	13	SeaWater	1373.06	1386.90	1379.98	6.92
C	Epoxy	1	300	13	SeaWater	1371.23	1379.13	1375.18	3.95
A	Epoxy	2	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00

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Table 1.31: Magnesium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Magnesium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	2	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Vinyl Ester	2	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Epoxy	2	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Epoxy	2	300	13	SeaWater	1346.33	1359.89	1353.11	6.78
B	Vinyl Ester	2	300	13	SeaWater	1363.09	1381.33	1372.21	9.12
C	Epoxy	2	300	13	SeaWater	1353.16	1371.47	1362.32	9.15

Table 1.32: Magnesium Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Magnesium			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	0.0212	0.0218	0.0215	0.00
B	Vinyl Ester	300	4	0	0.0210	0.0214	0.0212	0.00
A	Epoxy	300	4	200	0.0203	0.0211	0.0207	0.00
B	Vinyl Ester	300	4	200	0.0202	0.0206	0.0204	0.00
A	Epoxy	300	4	20000	0.0215	0.0217	0.0216	0.00
B	Vinyl Ester	300	4	20000	0.0210	0.0216	0.0213	0.00
A	Epoxy	300	4	SeaWater	1452.47	1467.59	1460.03	7.56
B	Vinyl Ester	300	4	SeaWater	1453.54	1463.50	1458.52	4.98
A	Epoxy	300	7	0	0.0217	0.0223	0.0220	0.00
B	Vinyl Ester	300	7	0	0.0216	0.0218	0.0217	0.00
A	Epoxy	300	7	200	0.0202	0.0212	0.0207	0.00
B	Vinyl Ester	300	7	200	0.0201	0.0207	0.0204	0.00
A	Epoxy	300	7	20000	0.0211	0.0215	0.0213	0.00
B	Vinyl Ester	300	7	20000	0.0206	0.0214	0.0210	0.00
A	Epoxy	300	7	SeaWater	1473.97	1486.43	1480.20	6.23
B	Vinyl Ester	300	7	SeaWater	1468.81	1488.57	1478.69	9.88
A	Epoxy	300	10	0	0.0206	0.0214	0.0210	0.00
B	Vinyl Ester	300	10	0	0.0206	0.0208	0.0207	0.00
A	Epoxy	300	10	200	0.0197	0.0209	0.0203	0.00

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Table 1.32: Magnesium Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Magnesium			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	300	10	200	0.0199	0.0201	0.0200	0.00
A	Epoxy	300	10	20000	0.0203	0.0207	0.0205	0.00
B	Vinyl Ester	300	10	20000	0.0197	0.0207	0.0202	0.00
A	Epoxy	300	10	SeaWater	1468.61	1486.63	1477.62	9.01
B	Vinyl Ester	300	10	SeaWater	1469.22	1483.00	1476.11	6.89
A	Epoxy	300	13	0	0.0211	0.0215	0.0213	0.00
B	Vinyl Ester	300	13	0	0.0206	0.0214	0.0210	0.00
A	Epoxy	300	13	200	0.0210	0.0212	0.0211	0.00
B	Vinyl Ester	300	13	200	0.0207	0.0209	0.0208	0.00
A	Epoxy	300	13	20000	0.0205	0.0209	0.0207	0.00
B	Vinyl Ester	300	13	20000	0.0201	0.0207	0.0204	0.00
A	Epoxy	300	13	SeaWater	1493.83	1504.71	1499.27	5.44
B	Vinyl Ester	300	13	SeaWater	1488.88	1506.64	1497.76	8.88

Table 1.33: Magnesium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Magnesium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	4	SeaWater	1402.74	1416.52	1409.63	6.89
B	Sized	300	4	SeaWater	1416.15	1434.83	1425.49	9.34

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Table 1.33: Magnesium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Magnesium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Sized	300	4	SeaWater	1419.52	1433.58	1426.55	7.03
A	Unsized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	4	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	4	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	4	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	4	SeaWater	1415.10	1429.56	1422.33	7.23
B	Unsized	300	4	SeaWater	1425.49	1447.97	1436.73	11.24
A	Sized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	7	SeaWater	1394.23	1412.69	1403.46	9.23
B	Sized	300	7	SeaWater	1409.55	1425.15	1417.35	7.80
C	Sized	300	7	SeaWater	1410.89	1429.72	1420.30	9.41
A	Unsized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	7	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	7	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	7	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	7	SeaWater	1405.51	1427.53	1416.52	11.01
B	Unsized	300	7	SeaWater	1422.44	1436.00	1429.22	6.78
A	Sized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00

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Table 1.33: Magnesium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Magnesium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Sized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	10	SeaWater	1388.34	1402.56	1395.45	7.11
B	Sized	300	10	SeaWater	1395.13	1417.23	1406.18	11.05
C	Sized	300	10	SeaWater	1404.94	1419.45	1412.19	7.25
A	Unsized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	10	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	10	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	10	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	10	SeaWater	1393.88	1417.92	1405.90	12.02
B	Unsized	300	10	SeaWater	1406.36	1424.24	1415.30	8.94
A	Sized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Sized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
C	Sized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Sized	300	13	SeaWater	1377.49	1389.75	1383.62	6.13
B	Sized	300	13	SeaWater	1385.46	1406.10	1395.78	10.32
C	Sized	300	13	SeaWater	1393.97	1406.47	1400.22	6.25
A	Unsized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	13	0	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	13	200	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
B	Unsized	300	13	20000	Below 0.01	Below 0.01	Below 0.01	0.00
A	Unsized	300	13	SeaWater	1388.55	1407.01	1397.78	9.23
B	Unsized	300	13	SeaWater	1396.95	1415.17	1406.06	9.11

For a better understanding, change in the Magnesium content of the environments was plotted in graphs in Figure 1.31, 1.32, and 1.33. It can be seen that the Magnesium concentration in all environments has decreased except for the environments in which resin samples were

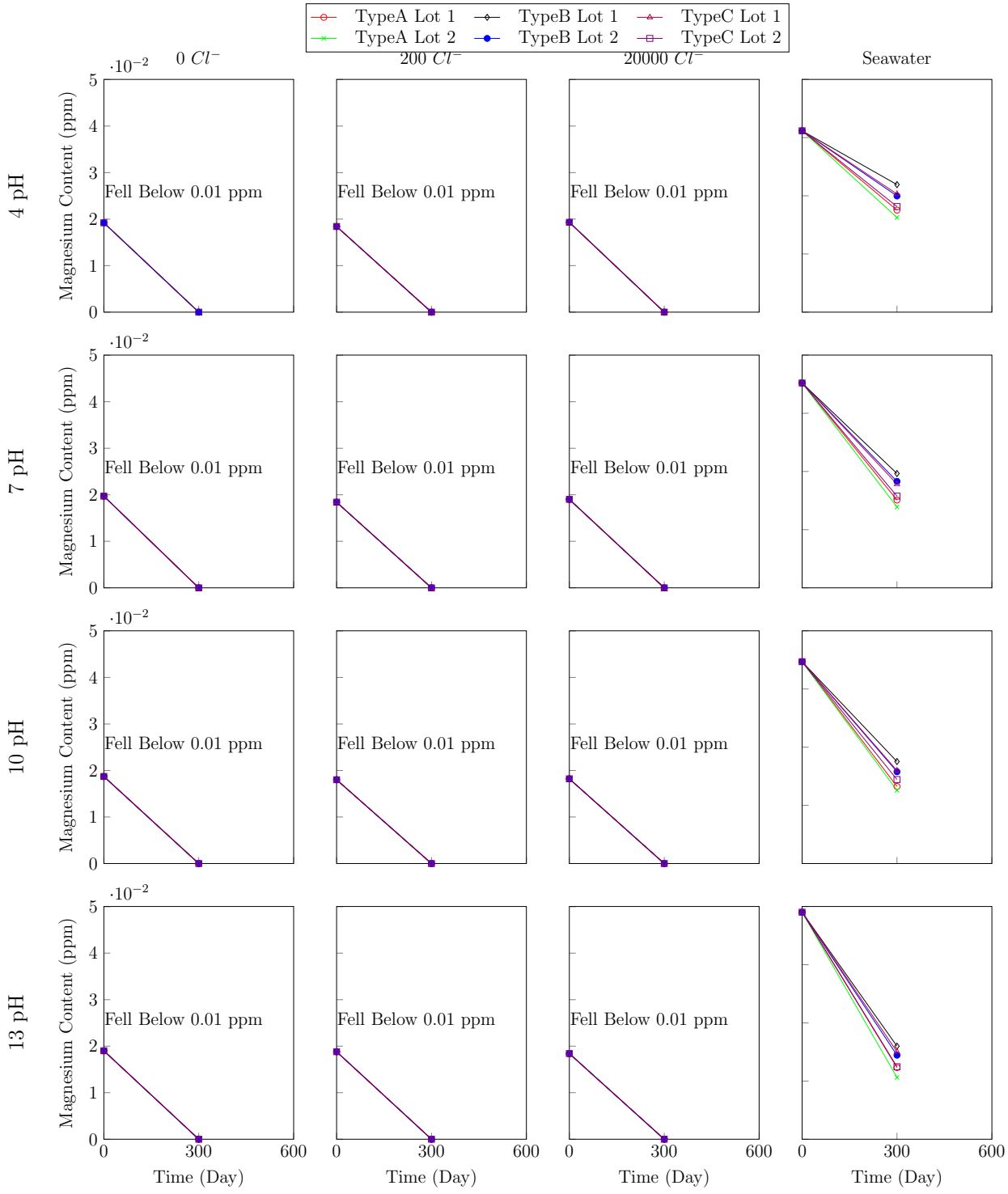

Figure 1.31: Magnesium concentration of all environments after exposure of rebars

exposed.

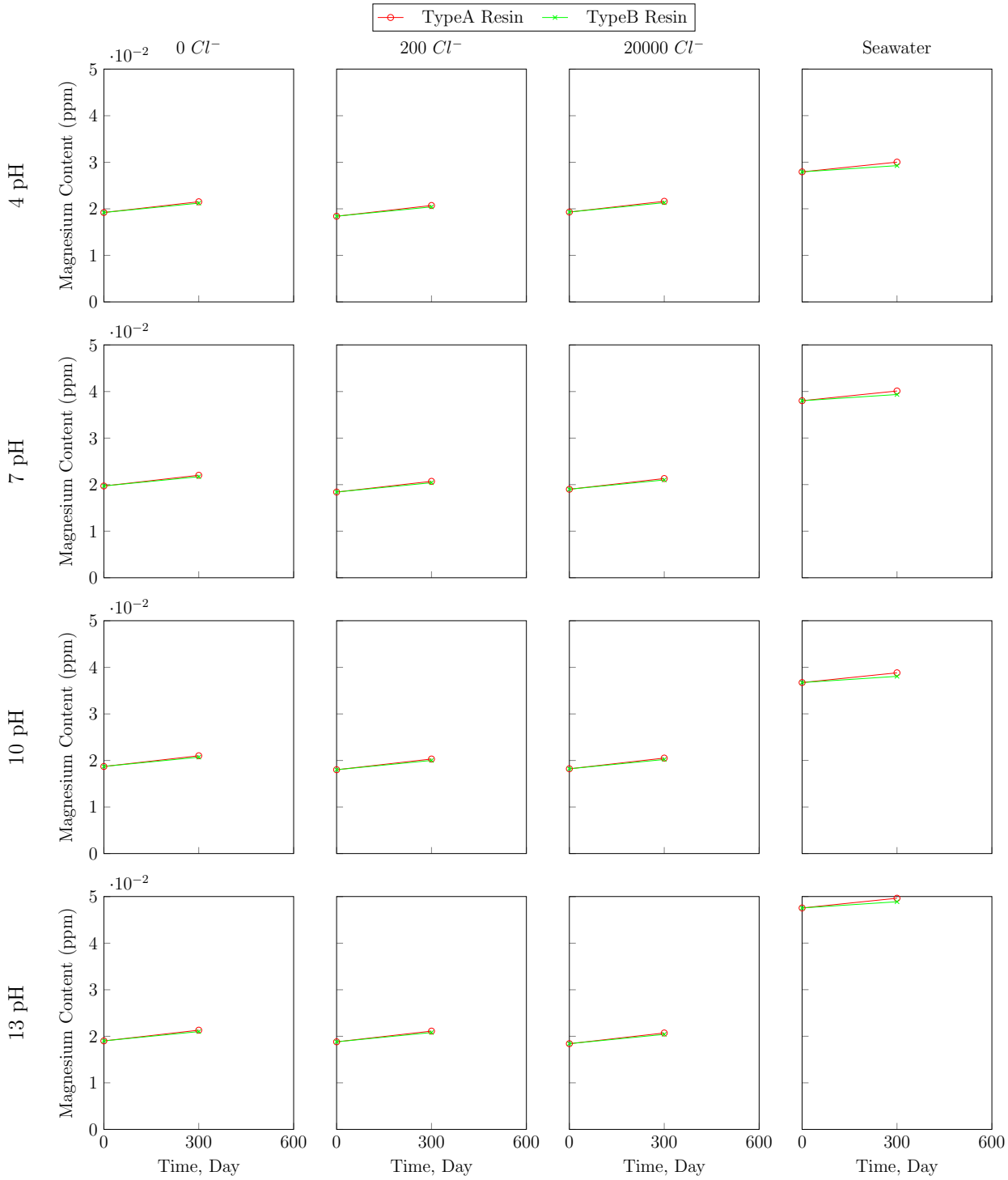

Figure 1.32: Magnesium concentration of all environments after exposure of resins

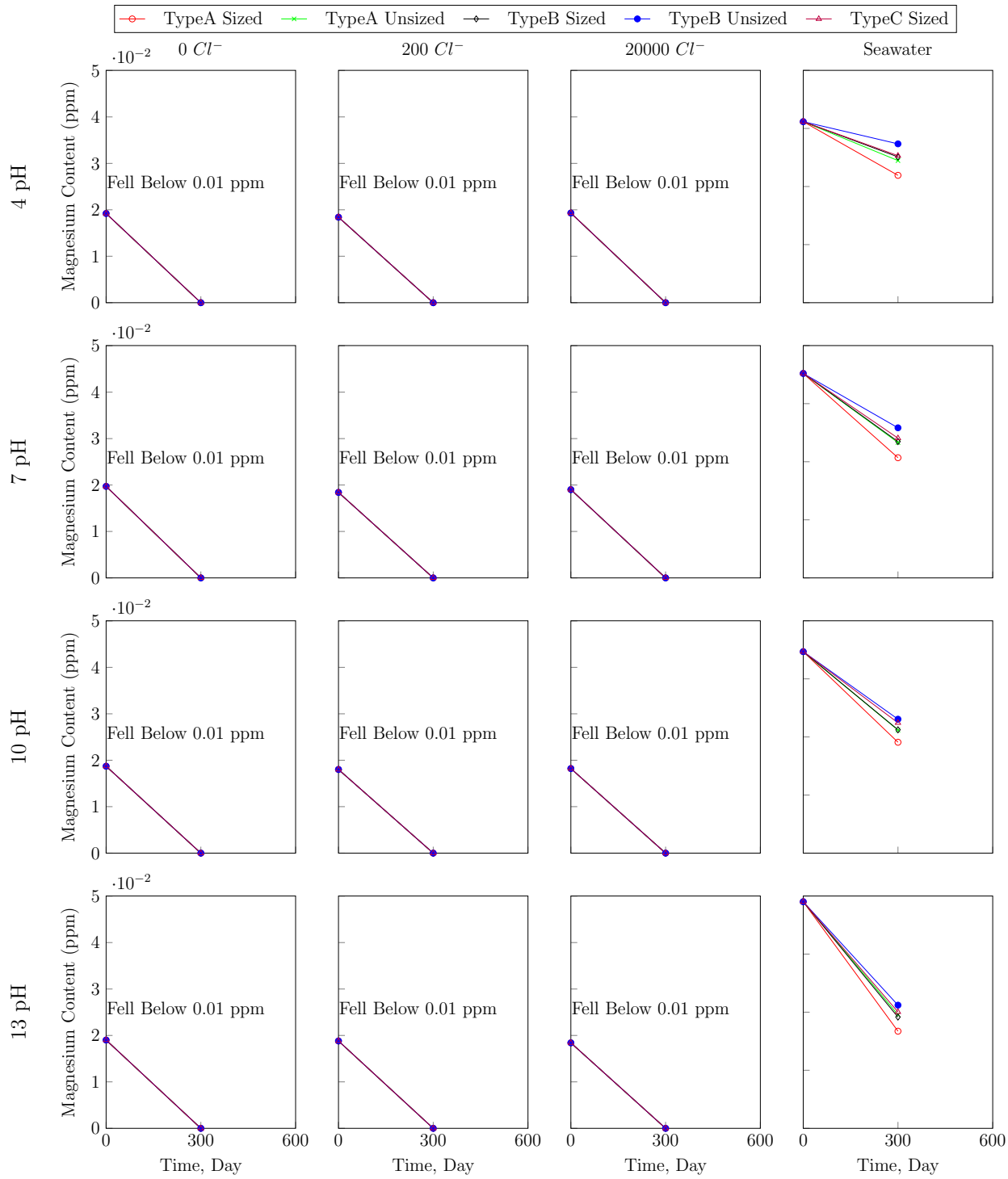

Figure 1.33: Magnesium concentration of all environments after exposure of sized and unsized fibers

Potassium

Potassium content of the chemical environments was measured after 300 days of exposure. Tables 1.34, 1.35, and 1.36 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.34: Potassium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Potassium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	0.08	0.08	0.08	0.00
B	Vinyl Ester	1	300	4	0	0.05	0.06	0.05	0.00
C	Epoxy	1	300	4	0	0.09	0.09	0.09	0.00
A	Epoxy	1	300	4	200	0.09	0.09	0.09	0.00
B	Vinyl Ester	1	300	4	200	0.06	0.07	0.06	0.00
C	Epoxy	1	300	4	200	0.10	0.10	0.10	0.00
A	Epoxy	1	300	4	20000	0.10	0.10	0.10	0.00
B	Vinyl Ester	1	300	4	20000	0.07	0.08	0.07	0.00
C	Epoxy	1	300	4	20000	0.11	0.12	0.12	0.00
A	Epoxy	1	300	4	SeaWater	408.56	420.80	414.68	6.12
B	Vinyl Ester	1	300	4	SeaWater	399.81	411.15	405.48	5.67
C	Epoxy	1	300	4	SeaWater	428.31	442.51	435.41	7.10
A	Epoxy	2	300	4	0	0.10	0.10	0.10	0.00
B	Vinyl Ester	2	300	4	0	0.06	0.06	0.06	0.00
C	Epoxy	2	300	4	0	0.14	0.14	0.14	0.00
A	Epoxy	2	300	4	200	0.11	0.12	0.12	0.00
B	Vinyl Ester	2	300	4	200	0.07	0.07	0.07	0.00
C	Epoxy	2	300	4	200	0.16	0.16	0.16	0.00
A	Epoxy	2	300	4	20000	0.13	0.13	0.13	0.00
B	Vinyl Ester	2	300	4	20000	0.08	0.08	0.08	0.00
C	Epoxy	2	300	4	20000	0.18	0.18	0.18	0.00
A	Epoxy	2	300	4	SeaWater	419.58	435.12	427.35	7.77
B	Vinyl Ester	2	300	4	SeaWater	402.26	420.30	411.28	9.02
C	Epoxy	2	300	4	SeaWater	431.66	452.95	442.30	10.64
A	Epoxy	1	300	7	0	0.08	0.08	0.08	0.00
B	Vinyl Ester	1	300	7	0	0.06	0.06	0.06	0.00
C	Epoxy	1	300	7	0	0.09	0.09	0.09	0.00
A	Epoxy	1	300	7	200	0.09	0.09	0.09	0.00
B	Vinyl Ester	1	300	7	200	0.07	0.07	0.07	0.00
C	Epoxy	1	300	7	200	0.10	0.11	0.11	0.00
A	Epoxy	1	300	7	20000	0.10	0.10	0.10	0.00

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Table 1.34: Potassium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Potassium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	1	300	7	20000	0.07	0.08	0.08	0.00
C	Epoxy	1	300	7	20000	0.12	0.12	0.12	0.00
A	Epoxy	1	300	7	SeaWater	416.35	429.91	423.13	6.78
B	Vinyl Ester	1	300	7	SeaWater	406.64	420.06	413.35	6.71
C	Epoxy	1	300	7	SeaWater	436.42	452.15	444.28	7.86
A	Epoxy	2	300	7	0	0.10	0.11	0.11	0.00
B	Vinyl Ester	2	300	7	0	0.06	0.06	0.06	0.00
C	Epoxy	2	300	7	0	0.15	0.15	0.15	0.00
A	Epoxy	2	300	7	200	0.12	0.12	0.12	0.00
B	Vinyl Ester	2	300	7	200	0.07	0.07	0.07	0.00
C	Epoxy	2	300	7	200	0.17	0.17	0.17	0.00
A	Epoxy	2	300	7	20000	0.13	0.13	0.13	0.00
B	Vinyl Ester	2	300	7	20000	0.08	0.08	0.08	0.00
C	Epoxy	2	300	7	20000	0.18	0.19	0.19	0.00
A	Epoxy	2	300	7	SeaWater	433.89	445.91	439.90	6.01
B	Vinyl Ester	2	300	7	SeaWater	407.65	429.67	418.66	11.01
C	Epoxy	2	300	7	SeaWater	447.06	463.53	455.29	8.23
A	Epoxy	1	300	10	0	0.08	0.08	0.08	0.00
B	Vinyl Ester	1	300	10	0	0.06	0.06	0.06	0.00
C	Epoxy	1	300	10	0	0.09	0.10	0.09	0.00
A	Epoxy	1	300	10	200	0.09	0.10	0.09	0.00
B	Vinyl Ester	1	300	10	200	0.07	0.07	0.07	0.00
C	Epoxy	1	300	10	200	0.11	0.11	0.11	0.00
A	Epoxy	1	300	10	20000	0.10	0.11	0.10	0.00
B	Vinyl Ester	1	300	10	20000	0.08	0.08	0.08	0.00
C	Epoxy	1	300	10	20000	0.12	0.12	0.12	0.00
A	Epoxy	1	300	10	SeaWater	423.11	441.53	432.32	9.21
B	Vinyl Ester	1	300	10	SeaWater	410.71	422.93	416.82	6.11
C	Epoxy	1	300	10	SeaWater	443.26	464.62	453.94	10.68
A	Epoxy	2	300	10	0	0.11	0.11	0.11	0.00
B	Vinyl Ester	2	300	10	0	0.06	0.07	0.06	0.00
C	Epoxy	2	300	10	0	0.15	0.15	0.15	0.00
A	Epoxy	2	300	10	200	0.12	0.12	0.12	0.00
B	Vinyl Ester	2	300	10	200	0.07	0.08	0.07	0.00
C	Epoxy	2	300	10	200	0.17	0.17	0.17	0.00
A	Epoxy	2	300	10	20000	0.13	0.14	0.14	0.00
B	Vinyl Ester	2	300	10	20000	0.08	0.08	0.08	0.00

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Table 1.34: Potassium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Potassium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	10	20000	0.19	0.19	0.19	0.00
A	Epoxy	2	300	10	SeaWater	437.29	449.27	443.28	5.99
B	Vinyl Ester	2	300	10	SeaWater	414.75	435.21	424.98	10.23
C	Epoxy	2	300	10	SeaWater	450.59	467.01	458.80	8.21
A	Epoxy	1	300	13	0	0.08	0.09	0.09	0.00
B	Vinyl Ester	1	300	13	0	0.06	0.07	0.06	0.00
C	Epoxy	1	300	13	0	0.10	0.10	0.10	0.00
A	Epoxy	1	300	13	200	0.09	0.10	0.10	0.00
B	Vinyl Ester	1	300	13	200	0.07	0.07	0.07	0.00
C	Epoxy	1	300	13	200	0.11	0.11	0.11	0.00
A	Epoxy	1	300	13	20000	0.10	0.11	0.11	0.00
B	Vinyl Ester	1	300	13	20000	0.08	0.08	0.08	0.00
C	Epoxy	1	300	13	20000	0.12	0.13	0.12	0.00
A	Epoxy	1	300	13	SeaWater	429.29	445.59	437.44	8.15
B	Vinyl Ester	1	300	13	SeaWater	413.26	431.28	422.27	9.01
C	Epoxy	1	300	13	SeaWater	449.86	468.77	459.31	9.45
A	Epoxy	2	300	13	0	0.11	0.12	0.11	0.00
B	Vinyl Ester	2	300	13	0	0.07	0.07	0.07	0.00
C	Epoxy	2	300	13	0	0.15	0.16	0.16	0.00
A	Epoxy	2	300	13	200	0.12	0.13	0.13	0.00
B	Vinyl Ester	2	300	13	200	0.07	0.08	0.08	0.00
C	Epoxy	2	300	13	200	0.17	0.18	0.18	0.00
A	Epoxy	2	300	13	20000	0.13	0.14	0.14	0.00
B	Vinyl Ester	2	300	13	20000	0.08	0.09	0.08	0.00
C	Epoxy	2	300	13	20000	0.19	0.20	0.19	0.00
A	Epoxy	2	300	13	SeaWater	442.33	462.11	452.22	9.89
B	Vinyl Ester	2	300	13	SeaWater	424.29	438.53	431.41	7.12
C	Epoxy	2	300	13	SeaWater	454.50	481.60	468.05	13.55

Table 1.35: Potassium Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Potassium			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	0.0069	0.0073	0.0071	0.00
B	Vinyl Ester	300	4	0	0.0069	0.0071	0.0070	0.00
A	Epoxy	300	4	200	0.0068	0.0074	0.0071	0.00
B	Vinyl Ester	300	4	200	0.0069	0.0071	0.0070	0.00
A	Epoxy	300	4	20000	0.0070	0.0072	0.0071	0.00
B	Vinyl Ester	300	4	20000	0.0068	0.0072	0.0070	0.00
A	Epoxy	300	4	SeaWater	375.86	388.32	382.09	6.23
B	Vinyl Ester	300	4	SeaWater	378.53	384.97	381.75	3.22
A	Epoxy	300	7	0	0.0066	0.0076	0.0071	0.00
B	Vinyl Ester	300	7	0	0.0067	0.0073	0.0070	0.00
A	Epoxy	300	7	200	0.0069	0.0073	0.0071	0.00
B	Vinyl Ester	300	7	200	0.0069	0.0071	0.0070	0.00
A	Epoxy	300	7	20000	0.0070	0.0072	0.0071	0.00
B	Vinyl Ester	300	7	20000	0.0068	0.0072	0.0070	0.00
A	Epoxy	300	7	SeaWater	387.58	399.14	393.36	5.78
B	Vinyl Ester	300	7	SeaWater	387.35	398.69	393.02	5.67
A	Epoxy	300	10	0	0.0069	0.0071	0.0070	0.00
B	Vinyl Ester	300	10	0	0.0067	0.0071	0.0069	0.00
A	Epoxy	300	10	200	0.0069	0.0073	0.0071	0.00
B	Vinyl Ester	300	10	200	0.0066	0.0074	0.0070	0.00
A	Epoxy	300	10	20000	0.0068	0.0074	0.0071	0.00
B	Vinyl Ester	300	10	20000	0.0069	0.0071	0.0070	0.00
A	Epoxy	300	10	SeaWater	384.14	392.80	388.47	4.33
B	Vinyl Ester	300	10	SeaWater	381.35	394.91	388.13	6.78
A	Epoxy	300	13	0	0.0071	0.0073	0.0072	0.00
B	Vinyl Ester	300	13	0	0.0070	0.0072	0.0071	0.00
A	Epoxy	300	13	200	0.0068	0.0074	0.0071	0.00
B	Vinyl Ester	300	13	200	0.0067	0.0073	0.0070	0.00
A	Epoxy	300	13	20000	0.0066	0.0074	0.0070	0.00
B	Vinyl Ester	300	13	20000	0.0064	0.0074	0.0069	0.00
A	Epoxy	300	13	SeaWater	391.25	400.59	395.92	4.67
B	Vinyl Ester	300	13	SeaWater	391.03	400.13	395.58	4.55

Table 1.36: Potassium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Potassium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	0.03	0.03	0.03	0.00
B	Sized	300	4	0	0.01	0.02	0.01	0.00
C	Sized	300	4	0	0.03	0.03	0.03	0.00
A	Sized	300	4	200	0.04	0.04	0.04	0.00
B	Sized	300	4	200	0.02	0.02	0.02	0.00
C	Sized	300	4	200	0.04	0.04	0.04	0.00
A	Sized	300	4	20000	0.04	0.05	0.05	0.00
B	Sized	300	4	20000	0.02	0.03	0.03	0.00
C	Sized	300	4	20000	0.05	0.05	0.05	0.00
A	Sized	300	4	SeaWater	391.33	411.35	401.34	10.01
B	Sized	300	4	SeaWater	388.20	398.00	393.10	4.90
C	Sized	300	4	SeaWater	402.37	424.39	413.38	11.01
A	Unsized	300	4	0	0.02	0.02	0.02	0.00
B	Unsized	300	4	0	0.01	0.01	0.01	0.00
A	Unsized	300	4	200	0.02	0.02	0.02	0.00
B	Unsized	300	4	200	0.01	0.01	0.01	0.00
A	Unsized	300	4	20000	0.02	0.03	0.03	0.00
B	Unsized	300	4	20000	0.01	0.01	0.01	0.00
A	Unsized	300	4	SeaWater	379.43	395.45	387.44	8.01
B	Unsized	300	4	SeaWater	379.43	384.09	381.76	2.33
A	Sized	300	7	0	0.03	0.03	0.03	0.00
B	Sized	300	7	0	0.02	0.02	0.02	0.00
C	Sized	300	7	0	0.03	0.03	0.03	0.00
A	Sized	300	7	200	0.04	0.04	0.04	0.00
B	Sized	300	7	200	0.02	0.02	0.02	0.00
C	Sized	300	7	200	0.04	0.04	0.04	0.00
A	Sized	300	7	20000	0.05	0.05	0.05	0.00
B	Sized	300	7	20000	0.03	0.03	0.03	0.00
C	Sized	300	7	20000	0.05	0.05	0.05	0.00
A	Sized	300	7	SeaWater	402.46	421.36	411.91	9.45
B	Sized	300	7	SeaWater	393.83	409.59	401.71	7.88
C	Sized	300	7	SeaWater	413.87	434.66	424.26	10.40
A	Unsized	300	7	0	0.02	0.02	0.02	0.00
B	Unsized	300	7	0	0.01	0.01	0.01	0.00
A	Unsized	300	7	200	0.02	0.02	0.02	0.00
B	Unsized	300	7	200	0.01	0.01	0.01	0.00
A	Unsized	300	7	20000	0.03	0.03	0.03	0.00

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Table 1.36: Potassium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Potassium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	7	20000	0.01	0.01	0.01	0.00
A	Unsized	300	7	SeaWater	387.67	405.11	396.39	8.72
B	Unsized	300	7	SeaWater	383.15	393.13	388.14	4.99
A	Sized	300	10	0	0.03	0.03	0.03	0.00
B	Sized	300	10	0	0.02	0.02	0.02	0.00
C	Sized	300	10	0	0.04	0.04	0.04	0.00
A	Sized	300	10	200	0.04	0.04	0.04	0.00
B	Sized	300	10	200	0.02	0.02	0.02	0.00
C	Sized	300	10	200	0.04	0.05	0.05	0.00
A	Sized	300	10	20000	0.05	0.05	0.05	0.00
B	Sized	300	10	20000	0.03	0.03	0.03	0.00
C	Sized	300	10	20000	0.05	0.06	0.05	0.00
A	Sized	300	10	SeaWater	408.10	426.56	417.33	9.23
B	Sized	300	10	SeaWater	398.41	416.43	407.42	9.01
C	Sized	300	10	SeaWater	419.69	440.00	429.85	10.15
A	Unsized	300	10	0	0.02	0.02	0.02	0.00
B	Unsized	300	10	0	0.01	0.01	0.01	0.00
A	Unsized	300	10	200	0.02	0.03	0.02	0.00
B	Unsized	300	10	200	0.01	0.01	0.01	0.00
A	Unsized	300	10	20000	0.03	0.03	0.03	0.00
B	Unsized	300	10	20000	0.01	0.02	0.01	0.00
A	Unsized	300	10	SeaWater	396.18	409.72	402.95	6.77
B	Unsized	300	10	SeaWater	387.14	397.26	392.20	5.06
A	Sized	300	13	0	0.03	0.04	0.04	0.00
B	Sized	300	13	0	0.02	0.02	0.02	0.00
C	Sized	300	13	0	0.04	0.04	0.04	0.00
A	Sized	300	13	200	0.04	0.05	0.04	0.00
B	Sized	300	13	200	0.02	0.03	0.02	0.00
C	Sized	300	13	200	0.05	0.05	0.05	0.00
A	Sized	300	13	20000	0.05	0.05	0.05	0.00
B	Sized	300	13	20000	0.03	0.03	0.03	0.00
C	Sized	300	13	20000	0.05	0.06	0.06	0.00
A	Sized	300	13	SeaWater	412.60	434.80	423.70	11.10
B	Sized	300	13	SeaWater	401.92	420.56	411.24	9.32
C	Sized	300	13	SeaWater	424.21	448.63	436.42	12.21
A	Unsized	300	13	0	0.02	0.03	0.02	0.00
B	Unsized	300	13	0	0.01	0.01	0.01	0.00

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Table 1.36: Potassium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Potassium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	13	200	0.02	0.03	0.03	0.00
B	Unsized	300	13	200	0.01	0.01	0.01	0.00
A	Unsized	300	13	20000	0.03	0.03	0.03	0.00
B	Unsized	300	13	20000	0.01	0.02	0.01	0.00
A	Unsized	300	13	SeaWater	400.32	415.66	407.99	7.67
B	Unsized	300	13	SeaWater	390.64	404.82	397.73	7.09

For a better understanding, change in the Potassium content of the environments was plotted in graphs in Figure 1.34, 1.35, and 1.36. It can be seen that the Potassium concentration in all environments has increased except for the environments in which resin samples were exposed.

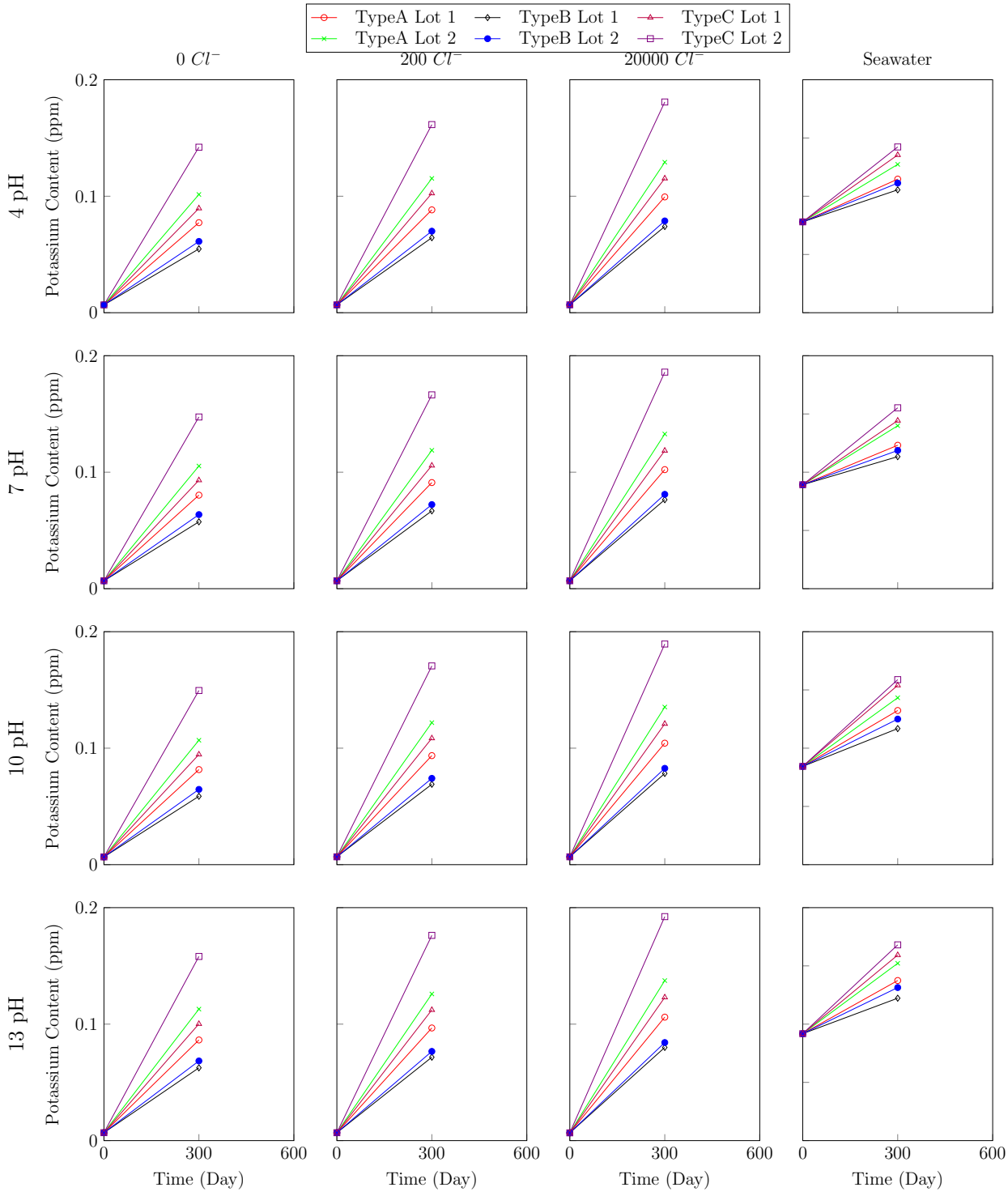

Figure 1.34: Potassium concentration of all environments after exposure of rebars

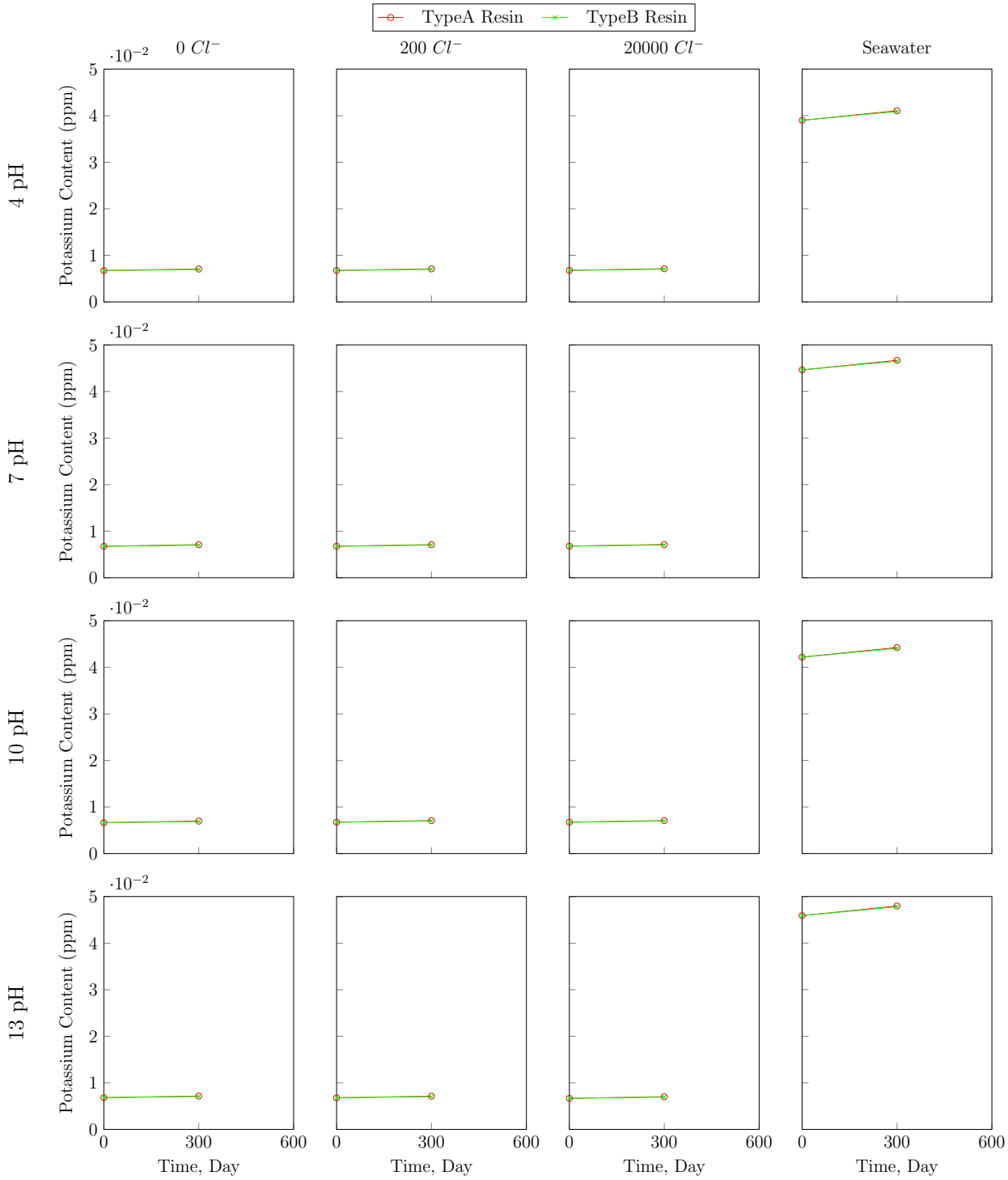

Figure 1.35: Potassium concentration of all environments after exposure of resins

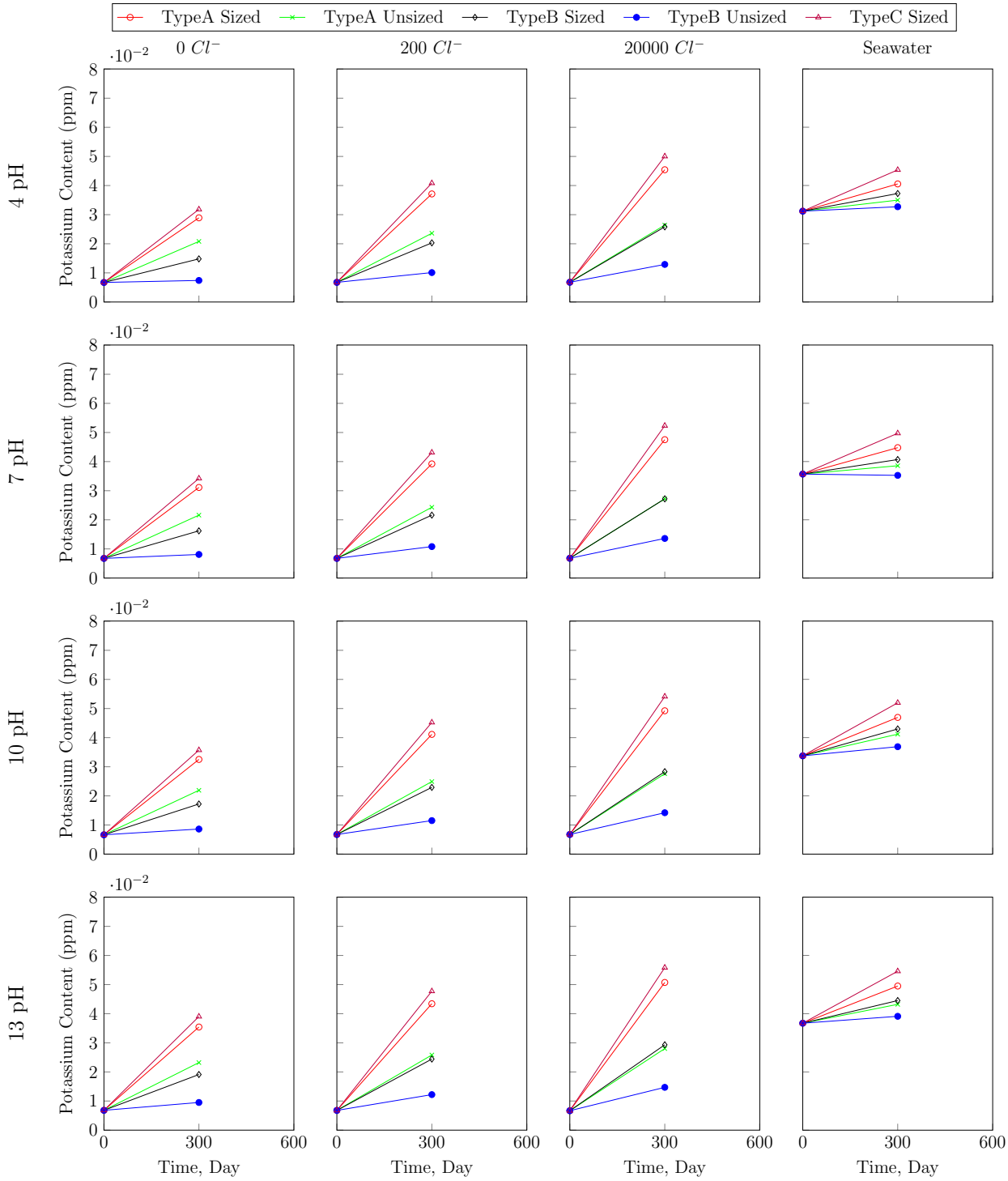

Figure 1.36: Potassium concentration of all environments after exposure of sized and unsized fibers

Silicon

Silicon content of the chemical environments was measured after 300 days of exposure. Tables 1.37, 1.38, and 1.39 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.37: Silicon Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Silicon			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	20.52	23.45	21.99	1.46
B	Vinyl Ester	1	300	4	0	14.76	16.21	15.48	0.72
C	Epoxy	1	300	4	0	27.85	31.51	29.68	1.83
A	Epoxy	1	300	4	200	25.80	30.53	28.17	2.37
B	Vinyl Ester	1	300	4	200	17.61	19.95	18.78	1.17
C	Epoxy	1	300	4	200	35.07	40.99	38.03	2.96
A	Epoxy	1	300	4	20000	33.04	34.07	33.56	0.52
B	Vinyl Ester	1	300	4	20000	20.98	21.49	21.24	0.26
C	Epoxy	1	300	4	20000	44.65	45.95	45.30	0.65
A	Epoxy	1	300	4	SeaWater	2.93	3.96	3.44	0.52
B	Vinyl Ester	1	300	4	SeaWater	3.29	3.80	3.54	0.26
C	Epoxy	1	300	4	SeaWater	2.84	4.18	3.51	0.67
A	Epoxy	2	300	4	0	29.74	32.70	31.22	1.48
B	Vinyl Ester	2	300	4	0	21.21	22.76	21.99	0.78
C	Epoxy	2	300	4	0	38.66	42.51	40.58	1.92
A	Epoxy	2	300	4	200	39.86	44.64	42.25	2.39
B	Vinyl Ester	2	300	4	200	26.91	29.43	28.17	1.26
C	Epoxy	2	300	4	200	51.82	58.04	54.93	3.11
A	Epoxy	2	300	4	20000	52.50	53.54	53.02	0.52
B	Vinyl Ester	2	300	4	20000	33.28	33.83	33.56	0.27
C	Epoxy	2	300	4	20000	68.25	69.60	68.92	0.68
A	Epoxy	2	300	4	SeaWater	2.95	3.99	3.47	0.52
B	Vinyl Ester	2	300	4	SeaWater	3.31	3.85	3.58	0.27
C	Epoxy	2	300	4	SeaWater	2.86	4.22	3.54	0.68
A	Epoxy	1	300	7	0	24.88	30.64	27.76	2.88
B	Vinyl Ester	1	300	7	0	17.85	20.71	19.28	1.43
C	Epoxy	1	300	7	0	33.87	41.08	37.48	3.60
A	Epoxy	1	300	7	200	30.62	32.60	31.61	0.99
B	Vinyl Ester	1	300	7	200	20.31	21.29	20.80	0.49
C	Epoxy	1	300	7	200	41.44	43.92	42.68	1.24
A	Epoxy	1	300	7	20000	37.51	41.21	39.36	1.85

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Table 1.37: Silicon Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Silicon			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	1	300	7	20000	23.69	25.52	24.60	0.92
C	Epoxy	1	300	7	20000	50.83	55.45	53.14	2.31
A	Epoxy	1	300	7	SeaWater	2.73	4.79	3.76	1.03
B	Vinyl Ester	1	300	7	SeaWater	3.37	4.39	3.88	0.51
C	Epoxy	1	300	7	SeaWater	2.49	5.18	3.84	1.34
A	Epoxy	2	300	7	0	37.06	42.89	39.98	2.91
B	Vinyl Ester	2	300	7	0	26.23	29.30	27.76	1.53
C	Epoxy	2	300	7	0	48.18	55.75	51.97	3.79
A	Epoxy	2	300	7	200	47.05	49.05	48.05	1.00
B	Vinyl Ester	2	300	7	200	31.09	32.14	31.61	0.53
C	Epoxy	2	300	7	200	61.17	63.77	62.47	1.30
A	Epoxy	2	300	7	20000	61.11	64.85	62.98	1.87
B	Vinyl Ester	2	300	7	20000	38.38	40.35	39.36	0.98
C	Epoxy	2	300	7	20000	79.45	84.31	81.88	2.43
A	Epoxy	2	300	7	SeaWater	2.77	4.85	3.81	1.04
B	Vinyl Ester	2	300	7	SeaWater	3.39	4.49	3.94	0.55
C	Epoxy	2	300	7	SeaWater	2.53	5.24	3.89	1.36
A	Epoxy	1	300	10	0	28.08	35.40	31.74	3.66
B	Vinyl Ester	1	300	10	0	19.93	23.55	21.74	1.81
C	Epoxy	1	300	10	0	38.28	47.42	42.85	4.57
A	Epoxy	1	300	10	200	34.52	40.03	37.27	2.75
B	Vinyl Ester	1	300	10	200	22.84	25.57	24.20	1.36
C	Epoxy	1	300	10	200	46.88	53.76	50.32	3.44
A	Epoxy	1	300	10	20000	42.63	47.27	44.95	2.32
B	Vinyl Ester	1	300	10	20000	26.60	28.90	27.75	1.15
C	Epoxy	1	300	10	20000	57.78	63.59	60.68	2.90
A	Epoxy	1	300	10	SeaWater	2.66	5.32	3.99	1.33
B	Vinyl Ester	1	300	10	SeaWater	3.36	4.68	4.02	0.66
C	Epoxy	1	300	10	SeaWater	2.34	5.80	4.07	1.73
A	Epoxy	2	300	10	0	42.65	50.04	46.34	3.69
B	Vinyl Ester	2	300	10	0	29.80	33.69	31.74	1.95
C	Epoxy	2	300	10	0	55.44	65.05	60.25	4.80
A	Epoxy	2	300	10	200	54.62	60.18	57.40	2.78
B	Vinyl Ester	2	300	10	200	35.81	38.74	37.27	1.47
C	Epoxy	2	300	10	200	71.01	78.24	74.62	3.62
A	Epoxy	2	300	10	20000	70.47	75.17	72.82	2.35
B	Vinyl Ester	2	300	10	20000	43.71	46.19	44.95	1.24

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Table 1.37: Silicon Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Silicon			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	10	20000	91.62	97.72	94.67	3.05
A	Epoxy	2	300	10	SeaWater	2.60	5.30	3.95	1.35
B	Vinyl Ester	2	300	10	SeaWater	3.38	4.80	4.09	0.71
C	Epoxy	2	300	10	SeaWater	2.28	5.78	4.03	1.75
A	Epoxy	1	300	13	0	35.63	37.61	36.62	0.99
B	Vinyl Ester	1	300	13	0	24.25	25.23	24.74	0.49
C	Epoxy	1	300	13	0	48.20	50.67	49.43	1.24
A	Epoxy	1	300	13	200	41.10	43.94	42.52	1.42
B	Vinyl Ester	1	300	13	200	26.55	27.96	27.25	0.70
C	Epoxy	1	300	13	200	55.62	59.17	57.40	1.77
A	Epoxy	1	300	13	20000	44.83	52.83	48.83	4.00
B	Vinyl Ester	1	300	13	20000	27.80	31.76	29.78	1.98
C	Epoxy	1	300	13	20000	60.92	70.93	65.92	5.00
A	Epoxy	1	300	13	SeaWater	2.62	5.46	4.04	1.42
B	Vinyl Ester	1	300	13	SeaWater	3.41	4.81	4.11	0.70
C	Epoxy	1	300	13	SeaWater	2.27	5.97	4.12	1.85
A	Epoxy	2	300	13	0	53.19	55.19	54.19	1.00
B	Vinyl Ester	2	300	13	0	36.09	37.14	36.62	0.53
C	Epoxy	2	300	13	0	69.15	71.75	70.45	1.30
A	Epoxy	2	300	13	200	64.89	67.76	66.33	1.43
B	Vinyl Ester	2	300	13	200	41.76	43.27	42.52	0.76
C	Epoxy	2	300	13	200	84.36	88.09	86.22	1.86
A	Epoxy	2	300	13	20000	76.04	84.13	80.09	4.04
B	Vinyl Ester	2	300	13	20000	46.70	50.96	48.83	2.13
C	Epoxy	2	300	13	20000	98.86	109.37	104.11	5.25
A	Epoxy	2	300	13	SeaWater	2.64	5.50	4.07	1.43
B	Vinyl Ester	2	300	13	SeaWater	3.37	4.89	4.13	0.76
C	Epoxy	2	300	13	SeaWater	2.29	6.02	4.15	1.86

Table 1.38: Silicon Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Silicon			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	4	0	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	4	200	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	4	200	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	4	20000	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	4	20000	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	4	SeaWater	2.97	4.99	3.98	1.01
B	Vinyl Ester	300	4	SeaWater	2.77	4.99	3.88	1.11
A	Epoxy	300	7	0	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	7	0	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	7	200	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	7	200	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	7	20000	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	7	20000	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	7	SeaWater	2.83	5.47	4.15	1.32
B	Vinyl Ester	300	7	SeaWater	3.03	5.07	4.05	1.02
A	Epoxy	300	10	0	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	10	0	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	10	200	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	10	200	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	10	20000	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	10	20000	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	10	SeaWater	3.30	5.46	4.38	1.08
B	Vinyl Ester	300	10	SeaWater	3.11	5.45	4.28	1.17
A	Epoxy	300	13	0	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	13	0	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	13	200	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	13	200	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	13	20000	Below 0.05	Below 0.05	Below 0.05	0.00
B	Vinyl Ester	300	13	20000	Below 0.05	Below 0.05	Below 0.05	0.00
A	Epoxy	300	13	SeaWater	3.26	5.60	4.43	1.17
B	Vinyl Ester	300	13	SeaWater	3.12	5.54	4.33	1.21

Table 1.39: Silicon Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Silicon			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	6.33	7.03	6.68	0.35
B	Sized	300	4	0	4.71	5.39	5.05	0.34

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Table 1.39: Silicon Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Silicon			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Sized	300	4	0	7.21	8.01	7.61	0.40
A	Sized	300	4	200	7.11	8.24	7.68	0.57
B	Sized	300	4	200	5.23	6.33	5.78	0.55
C	Sized	300	4	200	8.10	9.40	8.75	0.65
A	Sized	300	4	20000	8.32	8.57	8.44	0.12
B	Sized	300	4	20000	6.20	6.44	6.32	0.12
C	Sized	300	4	20000	9.48	9.77	9.63	0.14
A	Sized	300	4	SeaWater	3.14	3.38	3.26	0.12
B	Sized	300	4	SeaWater	3.10	3.34	3.22	0.12
C	Sized	300	4	SeaWater	3.18	3.46	3.32	0.14
A	Unsized	300	4	0	5.18	5.97	5.57	0.39
B	Unsized	300	4	0	3.89	4.72	4.30	0.41
A	Unsized	300	4	200	5.84	7.11	6.47	0.63
B	Unsized	300	4	200	4.30	5.64	4.97	0.67
A	Unsized	300	4	20000	7.05	7.32	7.19	0.14
B	Unsized	300	4	20000	5.34	5.63	5.49	0.15
A	Unsized	300	4	SeaWater	2.83	3.11	2.97	0.14
B	Unsized	300	4	SeaWater	2.60	2.89	2.74	0.15
A	Sized	300	7	0	7.12	8.50	7.81	0.69
B	Sized	300	7	0	5.23	6.57	5.90	0.67
C	Sized	300	7	0	8.12	9.69	8.91	0.79
A	Sized	300	7	200	8.05	8.52	8.29	0.24
B	Sized	300	7	200	6.00	6.46	6.23	0.23
C	Sized	300	7	200	9.18	9.72	9.45	0.27
A	Sized	300	7	20000	9.02	9.90	9.46	0.44
B	Sized	300	7	20000	6.64	7.50	7.07	0.43
C	Sized	300	7	20000	10.28	11.29	10.78	0.50
A	Sized	300	7	SeaWater	3.59	4.08	3.83	0.25
B	Sized	300	7	SeaWater	3.54	4.02	3.78	0.24
C	Sized	300	7	SeaWater	3.63	4.19	3.91	0.28
A	Unsized	300	7	0	5.77	7.31	6.54	0.77
B	Unsized	300	7	0	4.22	5.86	5.04	0.82
A	Unsized	300	7	200	6.74	7.27	7.00	0.27
B	Unsized	300	7	200	5.09	5.65	5.37	0.28
A	Unsized	300	7	20000	7.57	8.57	8.07	0.50
B	Unsized	300	7	20000	5.63	6.68	6.15	0.52
A	Unsized	300	7	SeaWater	3.23	3.78	3.50	0.28

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Table 1.39: Silicon Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Silicon			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	7	SeaWater	2.94	3.52	3.23	0.29
A	Sized	300	10	0	7.66	9.42	8.54	0.88
B	Sized	300	10	0	5.60	7.30	6.45	0.85
C	Sized	300	10	0	8.74	10.73	9.74	1.00
A	Sized	300	10	200	8.65	9.97	9.31	0.66
B	Sized	300	10	200	6.35	7.63	6.99	0.64
C	Sized	300	10	200	9.86	11.37	10.61	0.75
A	Sized	300	10	20000	9.86	10.97	10.41	0.56
B	Sized	300	10	20000	7.23	8.31	7.77	0.54
C	Sized	300	10	20000	11.24	12.50	11.87	0.63
A	Sized	300	10	SeaWater	3.78	4.41	4.09	0.32
B	Sized	300	10	SeaWater	3.72	4.34	4.03	0.31
C	Sized	300	10	SeaWater	3.82	4.54	4.18	0.36
A	Unsized	300	10	0	6.18	8.15	7.16	0.98
B	Unsized	300	10	0	4.48	6.56	5.52	1.04
A	Unsized	300	10	200	7.15	8.62	7.89	0.74
B	Unsized	300	10	200	5.26	6.82	6.04	0.78
A	Unsized	300	10	20000	8.28	9.53	8.90	0.62
B	Unsized	300	10	20000	6.12	7.43	6.78	0.66
A	Unsized	300	10	SeaWater	3.39	4.11	3.75	0.36
B	Unsized	300	10	SeaWater	3.07	3.83	3.45	0.38
A	Sized	300	13	0	9.20	9.68	9.44	0.24
B	Sized	300	13	0	6.89	7.35	7.12	0.23
C	Sized	300	13	0	10.49	11.03	10.76	0.27
A	Sized	300	13	200	9.89	10.57	10.23	0.34
B	Sized	300	13	200	7.34	8.00	7.67	0.33
C	Sized	300	13	200	11.28	12.05	11.66	0.39
A	Sized	300	13	20000	10.07	11.99	11.03	0.96
B	Sized	300	13	20000	7.29	9.15	8.22	0.93
C	Sized	300	13	20000	11.48	13.67	12.58	1.09
A	Sized	300	13	SeaWater	3.84	4.52	4.18	0.34
B	Sized	300	13	SeaWater	3.78	4.44	4.11	0.33
C	Sized	300	13	SeaWater	3.88	4.65	4.27	0.38
A	Unsized	300	13	0	7.67	8.21	7.94	0.27
B	Unsized	300	13	0	5.83	6.39	6.11	0.28
A	Unsized	300	13	200	8.31	9.07	8.69	0.38
B	Unsized	300	13	200	6.24	7.04	6.64	0.40

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Table 1.39: Silicon Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Silicon			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	13	20000	8.38	10.53	9.45	1.07
B	Unsized	300	13	20000	6.05	8.32	7.18	1.13
A	Unsized	300	13	SeaWater	3.72	4.48	4.10	0.38
B	Unsized	300	13	SeaWater	3.12	3.93	3.53	0.40

For a better understanding, change in the Silicon content of the environments was plotted in graphs in Figure 1.37, 1.38, and 1.39. It can be seen that the silicon concentration has increased in al exposure environments except the sea water environments and the exposure environments with resin samples.

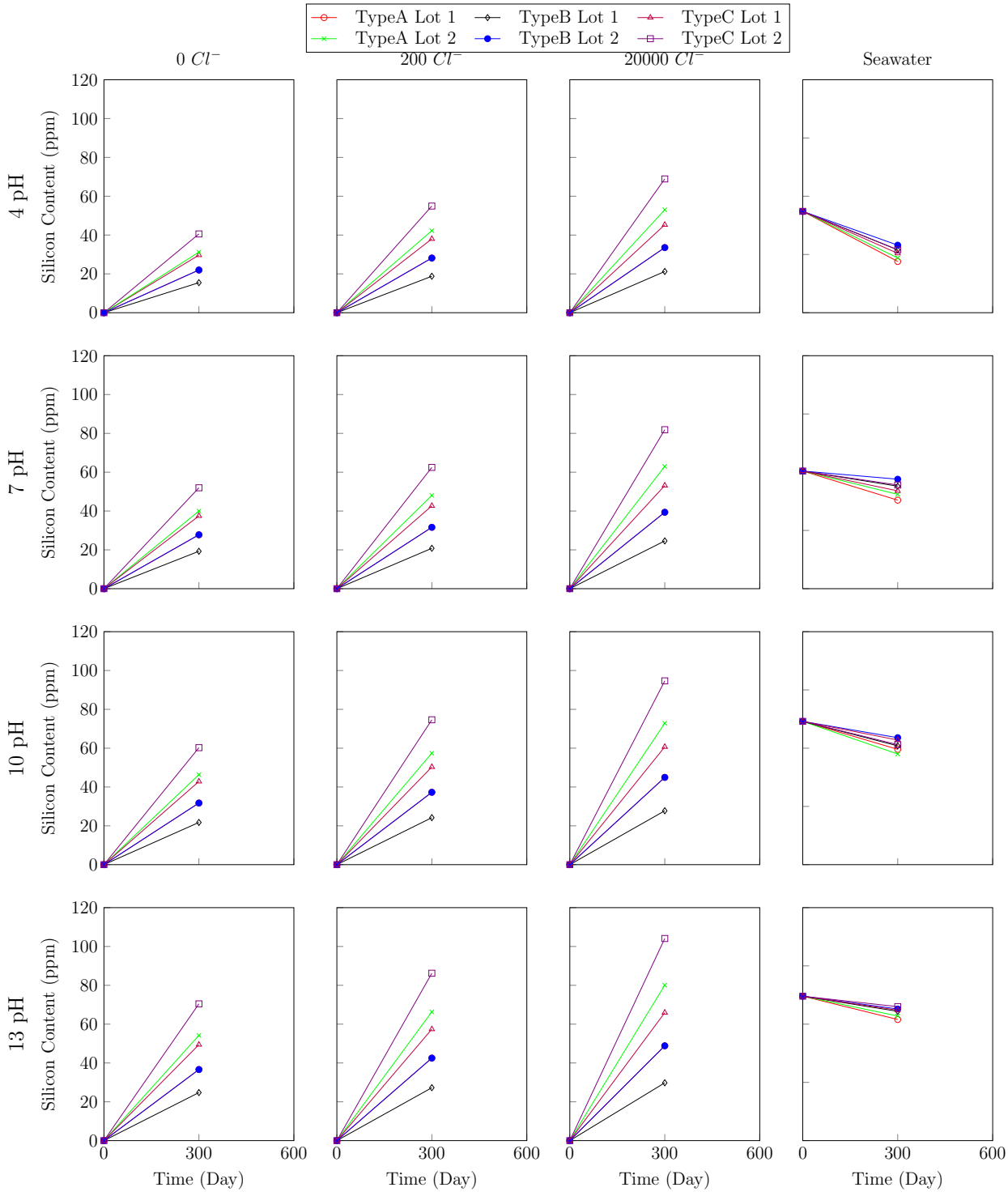

Figure 1.37: Silicon concentration of all environments after exposure of rebars

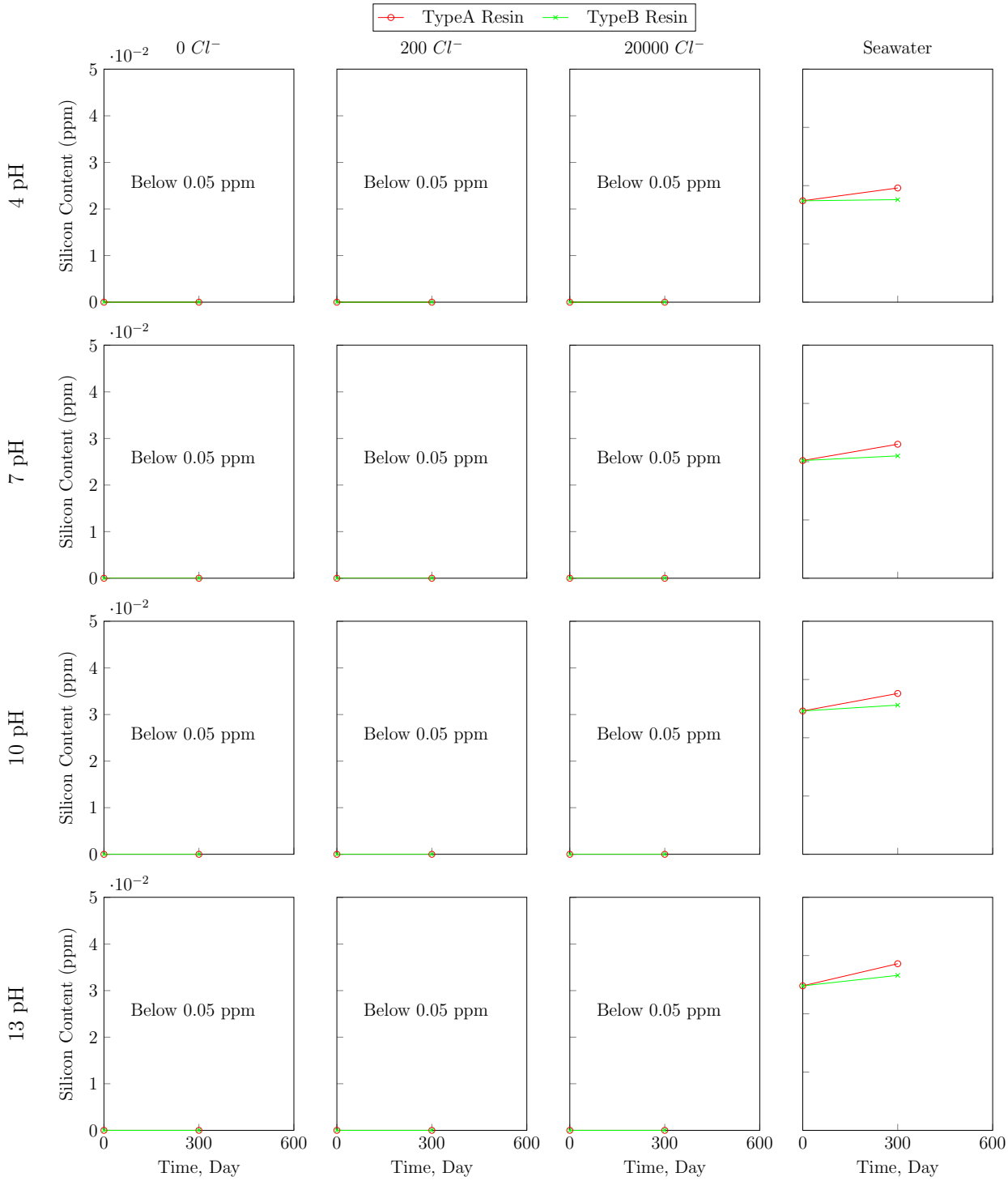

Figure 1.38: Silicon concentration of all environments after exposure of resins

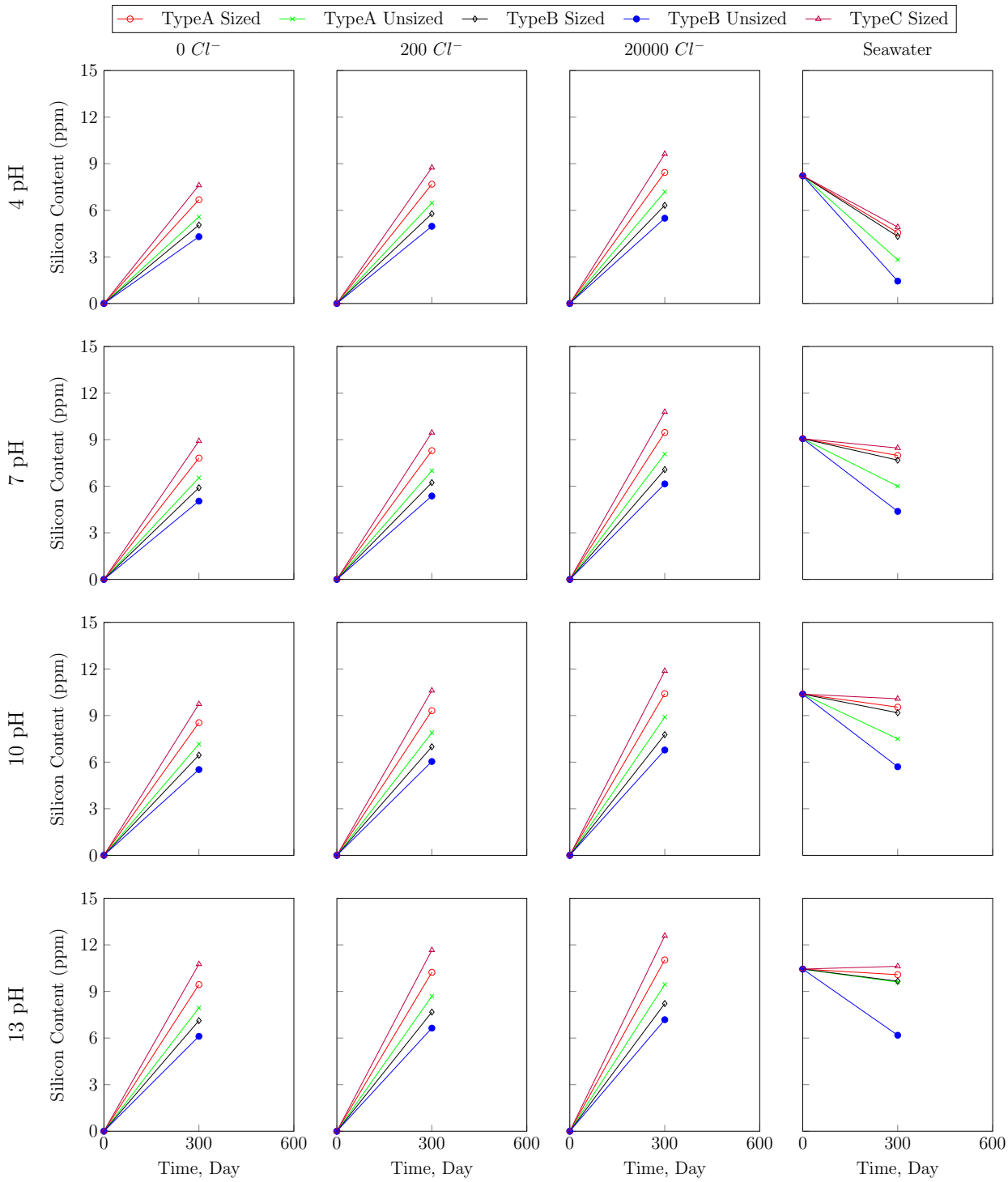

Figure 1.39: Silicon concentration of all environments after exposure of sized and unsized fibers

Sodium

Sodium content of the chemical environments was measured after 300 days of exposure. Tables 1.40, 1.41, and 1.42 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.40: Sodium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Sodium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	0.04	0.12	0.08	0.04
B	Vinyl Ester	1	300	4	0	0.04	0.12	0.08	0.04
C	Epoxy	1	300	4	0	0.05	0.09	0.07	0.02
A	Epoxy	1	300	4	200	113.27	122.23	117.75	4.48
B	Vinyl Ester	1	300	4	200	120.37	127.53	123.95	3.58
C	Epoxy	1	300	4	200	107.40	113.66	110.53	3.13
A	Epoxy	1	300	4	20000	13 158.61	13 206.70	13 182.66	24.04
B	Vinyl Ester	1	300	4	20000	13 166.35	13 212.15	13 189.25	22.90
C	Epoxy	1	300	4	20000	13 132.82	13 211.41	13 172.11	39.29
A	Epoxy	1	300	4	SeaWater	11 419.96	11 515.70	11 467.83	47.87
B	Vinyl Ester	1	300	4	SeaWater	11 440.83	11 506.31	11 473.57	32.74
C	Epoxy	1	300	4	SeaWater	11 420.26	11 497.06	11 458.66	38.40
A	Epoxy	2	300	4	0	0.06	0.08	0.07	0.01
B	Vinyl Ester	2	300	4	0	0.07	0.08	0.08	0.01
C	Epoxy	2	300	4	0	0.06	0.08	0.07	0.01
A	Epoxy	2	300	4	200	100.68	111.27	105.98	5.29
B	Vinyl Ester	2	300	4	200	109.53	113.58	111.55	2.02
C	Epoxy	2	300	4	200	94.59	104.36	99.48	4.88
A	Epoxy	2	300	4	20000	13 137.88	13 201.07	13 169.47	31.59
B	Vinyl Ester	2	300	4	20000	13 148.36	13 203.76	13 176.06	27.70
C	Epoxy	2	300	4	20000	13 119.92	13 197.96	13 158.94	39.02
A	Epoxy	2	300	4	SeaWater	11 415.74	11 496.99	11 456.36	40.63
B	Vinyl Ester	2	300	4	SeaWater	11 439.59	11 484.60	11 462.09	22.50
C	Epoxy	2	300	4	SeaWater	11 420.43	11 473.96	11 447.20	26.77
A	Epoxy	1	300	7	0	0.07	0.09	0.08	0.01
B	Vinyl Ester	1	300	7	0	0.07	0.09	0.08	0.01
C	Epoxy	1	300	7	0	0.06	0.09	0.08	0.01
A	Epoxy	1	300	7	200	115.41	123.48	119.44	4.03
B	Vinyl Ester	1	300	7	200	120.33	131.13	125.73	5.40
C	Epoxy	1	300	7	200	109.78	114.46	112.12	2.34
A	Epoxy	1	300	7	20000	13 226.76	13 281.74	13 254.25	27.49
B	Vinyl Ester	1	300	7	20000	13 224.37	13 297.39	13 260.88	36.51
C	Epoxy	1	300	7	20000	13 222.77	13 264.52	13 243.64	20.88
A	Epoxy	1	300	7	SeaWater	11 448.45	11 502.93	11 475.69	27.24
B	Vinyl Ester	1	300	7	SeaWater	11 461.40	11 501.47	11 481.43	20.04
C	Epoxy	1	300	7	SeaWater	11 434.48	11 498.55	11 466.51	32.03
A	Epoxy	2	300	7	0	0.07	0.08	0.08	0.01
B	Vinyl Ester	2	300	7	0	0.07	0.09	0.08	0.01
C	Epoxy	2	300	7	0	0.06	0.08	0.07	0.01
A	Epoxy	2	300	7	200	101.34	113.66	107.50	6.16
B	Vinyl Ester	2	300	7	200	109.54	116.77	113.16	3.61

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Table 1.40: Sodium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Sodium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	7	200	95.01	106.80	100.91	5.90
A	Epoxy	2	300	7	20000	13 211.72	13 270.27	13 240.99	29.27
B	Vinyl Ester	2	300	7	20000	13 215.62	13 279.62	13 247.62	32.00
C	Epoxy	2	300	7	20000	13 207.79	13 253.01	13 230.40	22.61
A	Epoxy	2	300	7	SeaWater	11 425.57	11 502.86	11 464.22	38.65
B	Vinyl Ester	2	300	7	SeaWater	11 439.46	11 500.44	11 469.95	30.49
C	Epoxy	2	300	7	SeaWater	11 414.32	11 495.77	11 455.04	40.73
A	Epoxy	1	300	10	0	0.78	3.35	2.07	1.29
B	Vinyl Ester	1	300	10	0	1.01	3.31	2.16	1.15
C	Epoxy	1	300	10	0	0.40	3.54	1.97	1.57
A	Epoxy	1	300	10	200	119.10	131.02	125.06	5.96
B	Vinyl Ester	1	300	10	200	124.90	138.38	131.64	6.74
C	Epoxy	1	300	10	200	111.58	123.20	117.39	5.81
A	Epoxy	1	300	10	20000	13 231.22	13 305.90	13 268.56	37.34
B	Vinyl Ester	1	300	10	20000	13 235.79	13 314.61	13 275.20	39.41
C	Epoxy	1	300	10	20000	13 232.51	13 283.38	13 257.95	25.43
A	Epoxy	1	300	10	SeaWater	11 452.66	11 533.82	11 493.24	40.58
B	Vinyl Ester	1	300	10	SeaWater	11 465.97	11 532.01	11 498.99	33.02
C	Epoxy	1	300	10	SeaWater	11 437.93	11 530.15	11 484.04	46.11
A	Epoxy	2	300	10	0	1.72	2.21	1.96	0.24
B	Vinyl Ester	2	300	10	0	1.73	2.38	2.06	0.32
C	Epoxy	2	300	10	0	1.75	2.00	1.87	0.12
A	Epoxy	2	300	10	200	106.53	118.57	112.55	6.02
B	Vinyl Ester	2	300	10	200	111.49	125.46	118.48	6.99
C	Epoxy	2	300	10	200	101.01	110.29	105.65	4.64
A	Epoxy	2	300	10	20000	13 231.20	13 279.39	13 255.29	24.09
B	Vinyl Ester	2	300	10	20000	13 232.61	13 291.24	13 261.92	29.31
C	Epoxy	2	300	10	20000	13 210.60	13 278.78	13 244.69	34.09
A	Epoxy	2	300	10	SeaWater	11 449.48	11 514.01	11 481.74	32.27
B	Vinyl Ester	2	300	10	SeaWater	11 454.28	11 520.70	11 487.49	33.21
C	Epoxy	2	300	10	SeaWater	11 446.36	11 498.76	11 472.56	26.20
A	Epoxy	1	300	13	0	2258.68	2283.44	2271.06	12.38
B	Vinyl Ester	1	300	13	0	2275.85	2298.29	2287.07	11.22
C	Epoxy	1	300	13	0	2250.21	2262.38	2256.30	6.09
A	Epoxy	1	300	13	200	2443.93	2462.04	2452.99	9.05
B	Vinyl Ester	1	300	13	200	2457.84	2482.72	2470.28	12.44
C	Epoxy	1	300	13	200	2426.72	2447.37	2437.04	10.33
A	Epoxy	1	300	13	20000	15 212.09	15 281.59	15 246.84	34.75
B	Vinyl Ester	1	300	13	20000	15 213.08	15 295.85	15 254.47	41.38
C	Epoxy	1	300	13	20000	15 200.33	15 268.96	15 234.64	34.32
A	Epoxy	1	300	13	SeaWater	13 810.73	13 877.87	13 844.30	33.57
B	Vinyl Ester	1	300	13	SeaWater	13 808.75	13 893.70	13 851.23	42.47
C	Epoxy	1	300	13	SeaWater	13 804.67	13 861.78	13 833.22	28.56
A	Epoxy	2	300	13	0	2233.15	2263.55	2248.35	15.20
B	Vinyl Ester	2	300	13	0	2258.92	2269.48	2264.20	5.28
C	Epoxy	2	300	13	0	2218.40	2249.07	2233.74	15.34
A	Epoxy	2	300	13	200	2415.64	2441.27	2428.46	12.82
B	Vinyl Ester	2	300	13	200	2414.22	2476.93	2445.58	31.35
C	Epoxy	2	300	13	200	2400.65	2424.70	2412.67	12.02

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Table 1.40: Sodium Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Sodium			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	2	300	13	20000	15 194.02	15 269.16	15 231.59	37.57
B	Vinyl Ester	2	300	13	20000	15 204.92	15 273.50	15 239.21	34.29
C	Epoxy	2	300	13	20000	15 182.93	15 255.88	15 219.41	36.47
A	Epoxy	2	300	13	SeaWater	13 785.86	13 875.05	13 830.46	44.60
B	Vinyl Ester	2	300	13	SeaWater	13 790.34	13 884.41	13 837.37	47.03
C	Epoxy	2	300	13	SeaWater	13 787.43	13 851.35	13 819.39	31.96

Table 1.41: Sodium Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Sodium			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	0.07	0.10	0.09	0.01
B	Vinyl Ester	300	4	0	0.07	0.10	0.09	0.02
A	Epoxy	300	4	200	135.50	151.51	143.50	8.01
B	Vinyl Ester	300	4	200	134.47	152.48	143.47	9.01
A	Epoxy	300	4	20000	13 182.77	13 256.50	13 219.63	36.86
B	Vinyl Ester	300	4	20000	13 175.52	13 258.46	13 216.99	41.47
A	Epoxy	300	4	SeaWater	11 483.04	11 516.96	11 500.00	16.96
B	Vinyl Ester	300	4	SeaWater	11 478.62	11 516.78	11 497.70	19.08
A	Epoxy	300	7	0	0.06	0.13	0.09	0.04
B	Vinyl Ester	300	7	0	0.05	0.13	0.09	0.04
A	Epoxy	300	7	200	138.45	152.68	145.56	7.11
B	Vinyl Ester	300	7	200	137.53	153.54	145.53	8.00
A	Epoxy	300	7	20000	13 265.03	13 317.82	13 291.43	26.39
B	Vinyl Ester	300	7	20000	13 259.08	13 318.46	13 288.77	29.69
A	Epoxy	300	7	SeaWater	11 484.06	11 531.71	11 507.88	23.82
B	Vinyl Ester	300	7	SeaWater	11 478.78	11 532.38	11 505.58	26.80
A	Epoxy	300	10	0	1.94	2.85	2.40	0.46
B	Vinyl Ester	300	10	0	1.88	2.91	2.40	0.51
A	Epoxy	300	10	200	143.35	161.46	152.41	9.06
B	Vinyl Ester	300	10	200	142.19	162.56	152.38	10.19
A	Epoxy	300	10	20000	13 266.33	13 345.23	13 305.78	39.45
B	Vinyl Ester	300	10	20000	13 258.74	13 347.50	13 303.12	44.38
A	Epoxy	300	10	SeaWater	11 500.47	11 550.48	11 525.48	25.01

Continued on next page ...

Table 1.41: Sodium Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Sodium			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	300	10	SeaWater	11 495.04	11 551.31	11 523.17	28.13
A	Epoxy	300	13	0	2310.44	2334.52	2322.48	12.04
B	Vinyl Ester	300	13	0	2308.47	2335.56	2322.01	13.55
A	Epoxy	300	13	200	2496.44	2520.60	2508.52	12.08
B	Vinyl Ester	300	13	200	2494.43	2521.61	2508.02	13.59
A	Epoxy	300	13	20000	15 245.41	15 333.81	15 289.61	44.20
B	Vinyl Ester	300	13	20000	15 236.82	15 336.27	15 286.55	49.73
A	Epoxy	300	13	SeaWater	13 846.44	13 919.83	13 883.13	36.70
B	Vinyl Ester	300	13	SeaWater	13 839.07	13 921.64	13 880.36	41.28

Table 1.42: Sodium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Sodium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	0.06	0.10	0.08	0.02
B	Sized	300	4	0	0.07	0.10	0.08	0.01
C	Sized	300	4	0	0.06	0.10	0.08	0.02
A	Sized	300	4	200	127.87	133.80	130.84	2.97
B	Sized	300	4	200	134.71	140.73	137.72	3.01
C	Sized	300	4	200	121.98	129.22	125.60	3.62
A	Sized	300	4	20000	13 154.57	13 237.14	13 195.85	41.29
B	Sized	300	4	20000	13 165.59	13 239.32	13 202.45	36.86
C	Sized	300	4	20000	13 141.93	13 228.67	13 185.30	43.37
A	Sized	300	4	SeaWater	11 460.32	11 498.31	11 479.31	19.00
B	Sized	300	4	SeaWater	11 468.09	11 502.01	11 485.05	16.96
C	Sized	300	4	SeaWater	11 446.95	11 493.30	11 470.13	23.17
A	Unsized	300	4	0	0.05	0.11	0.08	0.03
B	Unsized	300	4	0	0.06	0.10	0.08	0.02
A	Unsized	300	4	200	125.65	138.64	132.14	6.49
B	Unsized	300	4	200	134.83	143.37	139.10	4.27
A	Unsized	300	4	20000	13 167.80	13 234.46	13 201.13	33.33
B	Unsized	300	4	20000	13 167.39	13 248.08	13 207.74	40.35

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Table 1.42: Sodium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Sodium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	4	SeaWater	11 447.30	11 520.51	11 483.90	36.61
B	Unsized	300	4	SeaWater	11 465.56	11 513.73	11 489.65	24.08
A	Sized	300	7	0	0.04	0.12	0.08	0.04
B	Sized	300	7	0	0.05	0.12	0.09	0.04
C	Sized	300	7	0	0.03	0.13	0.08	0.05
A	Sized	300	7	200	126.75	138.68	132.71	5.97
B	Sized	300	7	200	133.59	145.81	139.70	6.11
C	Sized	300	7	200	120.13	134.68	127.41	7.28
A	Sized	300	7	20000	13 237.96	13 297.07	13 267.52	29.56
B	Sized	300	7	20000	13 247.76	13 300.54	13 274.15	26.39
C	Sized	300	7	20000	13 220.84	13 292.96	13 256.90	36.06
A	Sized	300	7	SeaWater	11 460.50	11 513.86	11 487.18	26.68
B	Sized	300	7	SeaWater	11 469.10	11 516.75	11 492.93	23.82
C	Sized	300	7	SeaWater	11 445.44	11 510.54	11 477.99	32.55
A	Unsized	300	7	0	0.01	0.16	0.08	0.08
B	Unsized	300	7	0	0.04	0.14	0.09	0.05
A	Unsized	300	7	200	126.85	141.23	134.04	7.19
B	Unsized	300	7	200	132.42	149.78	141.10	8.68
A	Unsized	300	7	20000	13 227.86	13 317.79	13 272.82	44.96
B	Unsized	300	7	20000	13 241.99	13 316.94	13 279.46	37.48
A	Unsized	300	7	SeaWater	11 460.35	11 523.20	11 491.77	31.42
B	Unsized	300	7	SeaWater	11 463.69	11 531.35	11 497.52	33.83
A	Sized	300	10	0	1.66	2.69	2.17	0.51
B	Sized	300	10	0	1.82	2.73	2.28	0.46
C	Sized	300	10	0	1.45	2.70	2.08	0.62
A	Sized	300	10	200	133.81	144.10	138.95	5.14
B	Sized	300	10	200	141.21	151.32	146.27	5.06
C	Sized	300	10	200	127.12	139.67	133.39	6.27
A	Sized	300	10	20000	13 237.66	13 326.03	13 281.84	44.18
B	Sized	300	10	20000	13 249.04	13 327.94	13 288.49	39.45
C	Sized	300	10	20000	13 237.32	13 305.12	13 271.22	33.90
A	Sized	300	10	SeaWater	11 476.73	11 532.75	11 504.74	28.01
B	Sized	300	10	SeaWater	11 485.49	11 535.51	11 510.50	25.01
C	Sized	300	10	SeaWater	11 461.37	11 529.71	11 495.54	34.17
A	Unsized	300	10	0	1.21	3.18	2.20	0.98
B	Unsized	300	10	0	1.65	2.95	2.30	0.65
A	Unsized	300	10	200	131.43	149.25	140.34	8.91

Continued on next page ...

Table 1.42: Sodium Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Sodium			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	10	200	140.55	154.91	147.73	7.18
A	Unsized	300	10	20000	13 251.77	13 322.54	13 287.16	35.38
B	Unsized	300	10	20000	13 250.79	13 336.82	13 293.80	43.02
A	Unsized	300	10	SeaWater	11 485.37	11 533.32	11 509.34	23.98
B	Unsized	300	10	SeaWater	11 479.59	11 550.61	11 515.10	35.51
A	Sized	300	13	0	2285.52	2302.48	2294.00	8.48
B	Sized	300	13	0	2304.13	2316.21	2310.17	6.04
C	Sized	300	13	0	2268.74	2289.44	2279.09	10.35
A	Sized	300	13	200	2466.23	2489.29	2477.76	11.53
B	Sized	300	13	200	2483.15	2507.31	2495.23	12.08
C	Sized	300	13	200	2453.59	2469.73	2461.66	8.07
A	Sized	300	13	20000	15 212.60	15 311.60	15 262.10	49.50
B	Sized	300	13	20000	15 225.53	15 313.93	15 269.73	44.20
C	Sized	300	13	20000	15 208.50	15 291.29	15 249.89	41.39
A	Sized	300	13	SeaWater	13 817.06	13 899.26	13 858.16	41.10
B	Sized	300	13	SeaWater	13 828.40	13 901.79	13 865.09	36.70
C	Sized	300	13	SeaWater	13 811.93	13 882.21	13 847.07	35.14
A	Unsized	300	13	0	2296.43	2314.51	2305.47	9.04
B	Unsized	300	13	0	2306.21	2323.37	2314.79	8.58
A	Unsized	300	13	200	2480.08	2500.23	2490.15	10.07
B	Unsized	300	13	200	2483.07	2517.38	2500.22	17.15
A	Unsized	300	13	20000	15 238.40	15 298.01	15 268.20	29.80
B	Unsized	300	13	20000	15 243.08	15 308.61	15 275.84	32.76
A	Unsized	300	13	SeaWater	13 818.82	13 908.59	13 863.70	44.88
B	Unsized	300	13	SeaWater	13 834.53	13 906.75	13 870.64	36.11

For a better understanding, change in the Sodium content of the environments was plotted in graphs in Figure 1.40, 1.41, and 1.42. It can be seen that the Sodium concentration of exposure environments has decreased except in the environments with resin samples.

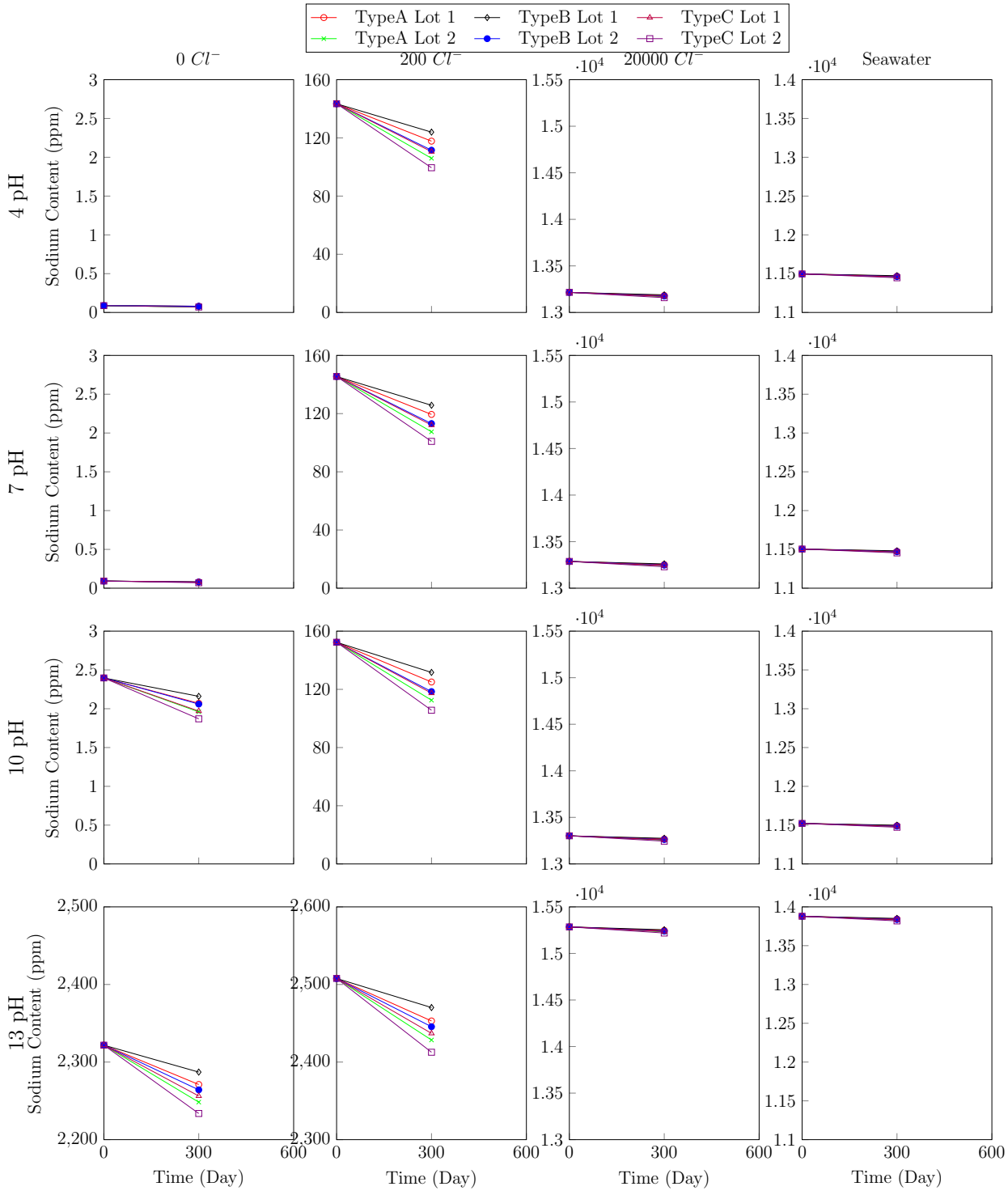

Figure 1.40: Sodium concentration of all environments after exposure of rebars

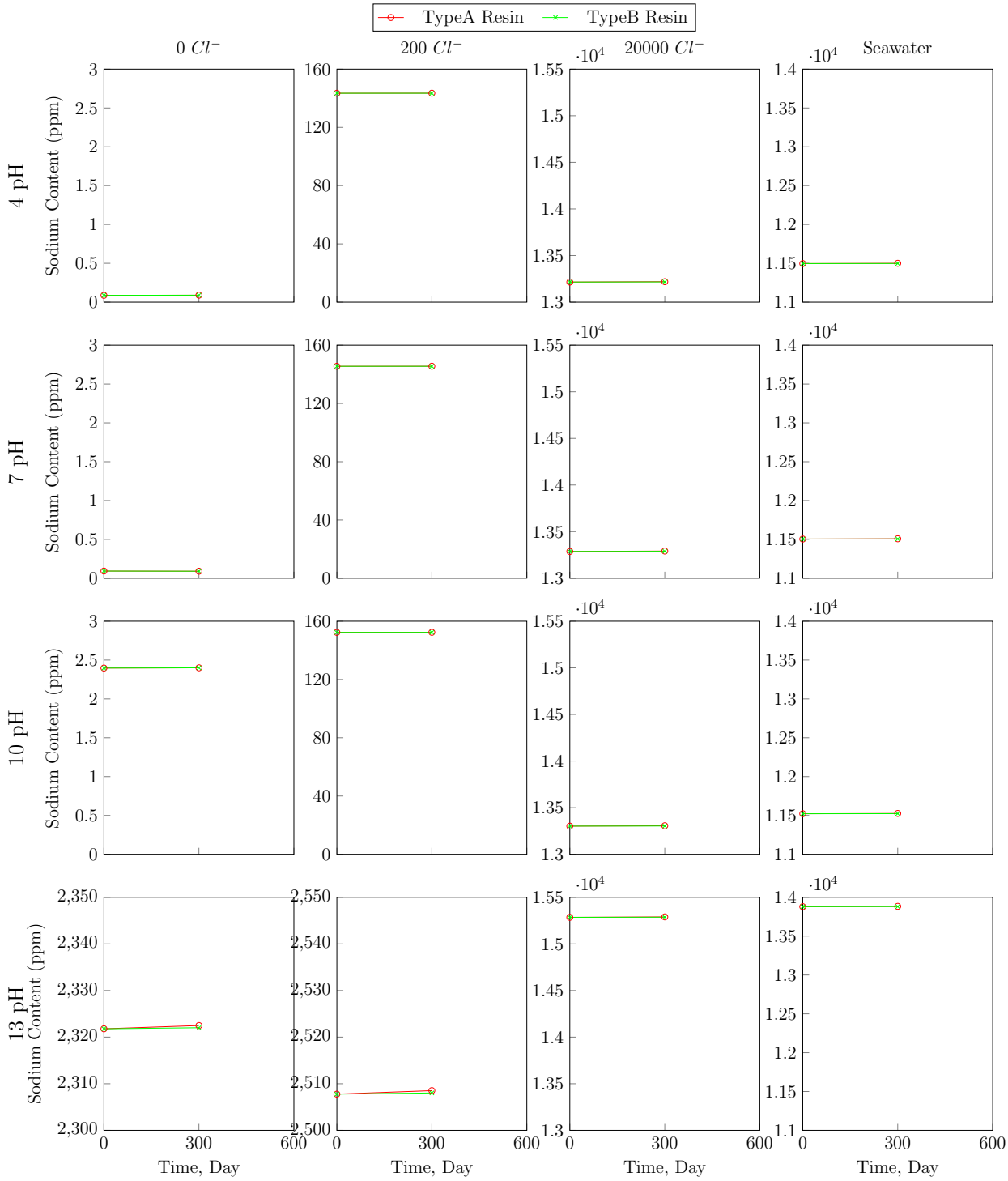

Figure 1.41: Sodium concentration of all environments after exposure of resins

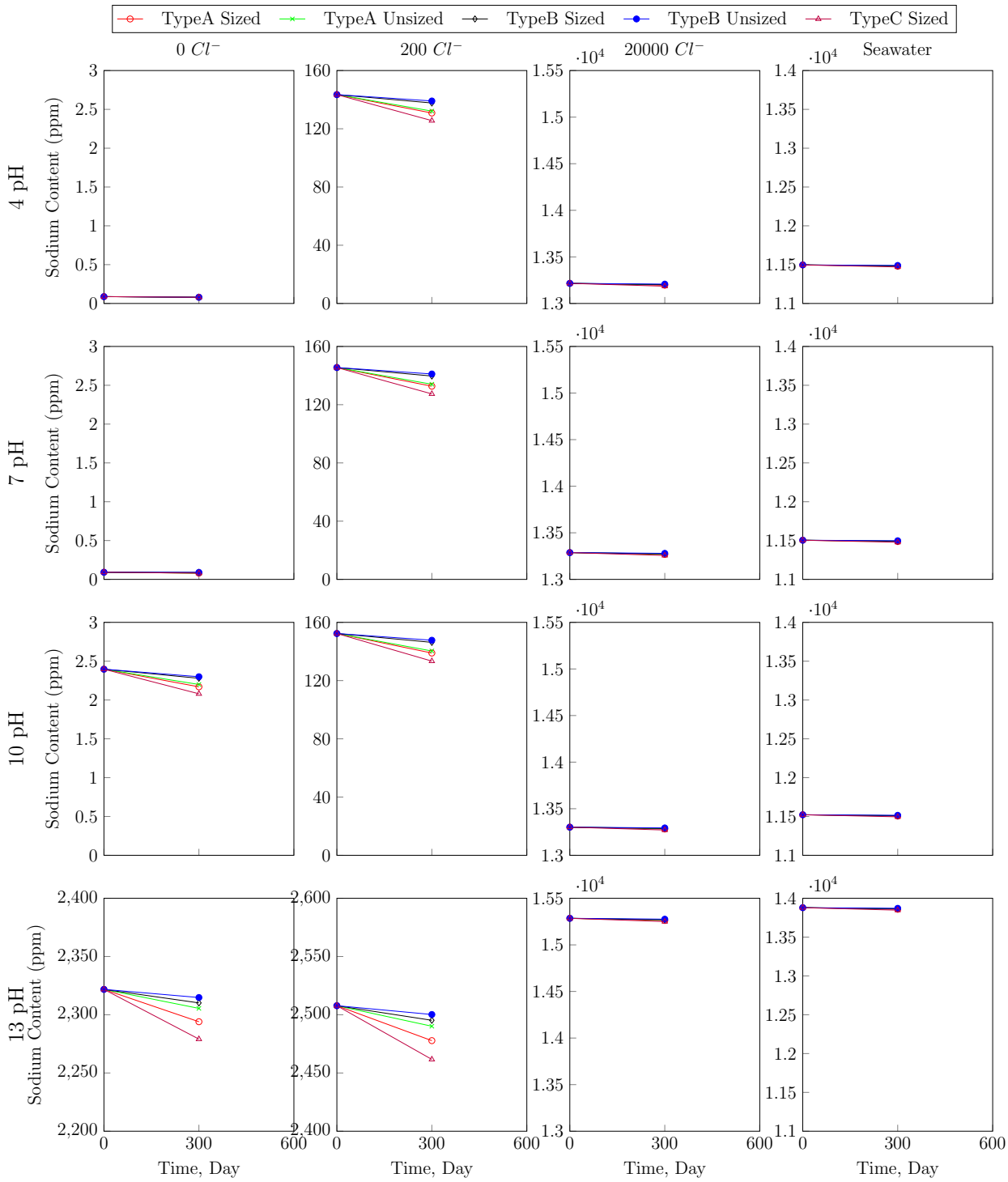

Figure 1.42: Sodium concentration of all environments after exposure of sized and unsized fibers

1.2.7 Total Organic Carbon (TOC)

TOC content of the chemical environments was measured after 300 days of exposure. Tables 1.43, 1.44, and 1.45 below shows the pH data of environments in which rebars, resins, and fibers were exposed.

Table 1.43: Total Organic Carbon Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Total Organic Carbon			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	1	300	4	0	60.65	62.20	61.42	0.77
B	Vinyl Ester	1	300	4	0	51.60	51.85	51.72	0.12
C	Epoxy	1	300	4	0	66.71	68.42	67.57	0.85
A	Epoxy	1	300	4	200	63.54	68.83	66.18	2.65
B	Vinyl Ester	1	300	4	200	56.45	57.14	56.80	0.34
C	Epoxy	1	300	4	200	69.89	75.71	72.80	2.91
A	Epoxy	1	300	4	20000	94.67	98.23	96.45	1.78
B	Vinyl Ester	1	300	4	20000	75.10	81.07	78.09	2.98
C	Epoxy	1	300	4	20000	104.14	108.06	106.10	1.96
A	Epoxy	1	300	4	SeaWater	102.50	103.78	103.14	0.64
B	Vinyl Ester	1	300	4	SeaWater	81.31	89.66	85.48	4.18
C	Epoxy	1	300	4	SeaWater	112.75	114.16	113.45	0.71
A	Epoxy	2	300	4	0	80.65	82.20	81.42	0.77
B	Vinyl Ester	2	300	4	0	68.60	68.85	68.72	0.12
C	Epoxy	2	300	4	0	90.33	92.06	91.20	0.87
A	Epoxy	2	300	4	200	83.54	88.83	86.18	2.65
B	Vinyl Ester	2	300	4	200	73.45	74.14	73.80	0.34
C	Epoxy	2	300	4	200	93.56	99.49	96.52	2.96
A	Epoxy	2	300	4	20000	114.67	118.23	116.45	1.78
B	Vinyl Ester	2	300	4	20000	92.10	98.07	95.09	2.98
C	Epoxy	2	300	4	20000	128.43	132.42	130.43	1.99
A	Epoxy	2	300	4	SeaWater	122.50	123.78	123.14	0.64
B	Vinyl Ester	2	300	4	SeaWater	98.31	106.66	102.48	4.18
C	Epoxy	2	300	4	SeaWater	137.20	138.64	137.92	0.72
A	Epoxy	1	300	7	0	66.02	66.68	66.35	0.33
B	Vinyl Ester	1	300	7	0	53.21	53.68	53.45	0.24
C	Epoxy	1	300	7	0	72.63	73.35	72.99	0.36
A	Epoxy	1	300	7	200	70.06	71.43	70.74	0.68
B	Vinyl Ester	1	300	7	200	57.78	58.08	57.93	0.15
C	Epoxy	1	300	7	200	77.06	78.57	77.81	0.75
A	Epoxy	1	300	7	20000	106.19	112.67	109.43	3.24

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Table 1.43: Total Organic Carbon Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Total Organic Carbon			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Vinyl Ester	1	300	7	20000	85.92	92.17	89.04	3.13
C	Epoxy	1	300	7	20000	116.80	123.94	120.37	3.57
A	Epoxy	1	300	7	SeaWater	113.86	124.83	119.34	5.49
B	Vinyl Ester	1	300	7	SeaWater	92.48	95.81	94.15	1.67
C	Epoxy	1	300	7	SeaWater	125.24	137.31	131.28	6.03
A	Epoxy	2	300	7	0	86.02	86.68	86.35	0.33
B	Vinyl Ester	2	300	7	0	70.21	70.68	70.45	0.24
C	Epoxy	2	300	7	0	96.35	97.08	96.72	0.37
A	Epoxy	2	300	7	200	90.06	91.43	90.74	0.68
B	Vinyl Ester	2	300	7	200	74.78	75.08	74.93	0.15
C	Epoxy	2	300	7	200	100.86	102.40	101.63	0.77
A	Epoxy	2	300	7	20000	126.19	132.67	129.43	3.24
B	Vinyl Ester	2	300	7	20000	102.92	109.17	106.04	3.13
C	Epoxy	2	300	7	20000	141.33	148.59	144.96	3.63
A	Epoxy	2	300	7	SeaWater	133.86	144.83	139.34	5.49
B	Vinyl Ester	2	300	7	SeaWater	109.48	112.81	111.15	1.67
C	Epoxy	2	300	7	SeaWater	149.92	162.21	156.07	6.14
A	Epoxy	1	300	10	0	70.35	72.04	71.19	0.85
B	Vinyl Ester	1	300	10	0	57.66	57.87	57.77	0.11
C	Epoxy	1	300	10	0	77.38	79.25	78.31	0.93
A	Epoxy	1	300	10	200	78.88	81.74	80.31	1.43
B	Vinyl Ester	1	300	10	200	65.45	66.05	65.75	0.30
C	Epoxy	1	300	10	200	86.76	89.92	88.34	1.58
A	Epoxy	1	300	10	20000	109.82	115.75	112.79	2.96
B	Vinyl Ester	1	300	10	20000	93.75	95.43	94.59	0.84
C	Epoxy	1	300	10	20000	120.81	127.32	124.06	3.26
A	Epoxy	1	300	10	SeaWater	123.73	129.14	126.44	2.71
B	Vinyl Ester	1	300	10	SeaWater	107.41	113.39	110.40	2.99
C	Epoxy	1	300	10	SeaWater	136.11	142.06	139.08	2.98
A	Epoxy	2	300	10	0	90.35	92.04	91.19	0.85
B	Vinyl Ester	2	300	10	0	74.66	74.87	74.77	0.11
C	Epoxy	2	300	10	0	101.19	103.09	102.14	0.95
A	Epoxy	2	300	10	200	121.94	125.35	123.64	1.70
B	Vinyl Ester	2	300	10	200	82.45	83.05	82.75	0.30
C	Epoxy	2	300	10	200	136.57	140.39	138.48	1.91
A	Epoxy	2	300	10	20000	129.82	135.75	132.79	2.96
B	Vinyl Ester	2	300	10	20000	110.75	112.43	111.59	0.84

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Table 1.43: Total Organic Carbon Test Statistical values for All Rebar Sample Groups

Sample Group						Statistical Values			
						Total Organic Carbon			
Manuf. Type	Resin Type	Lot No.	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
C	Epoxy	2	300	10	20000	145.40	152.04	148.72	3.32
A	Epoxy	2	300	10	SeaWater	181.20	182.03	181.62	0.41
B	Vinyl Ester	2	300	10	SeaWater	149.24	158.16	153.70	4.46
C	Epoxy	2	300	10	SeaWater	202.95	203.87	203.41	0.46
A	Epoxy	1	300	13	0	108.08	109.61	108.85	0.77
B	Vinyl Ester	1	300	13	0	97.69	98.37	98.03	0.34
C	Epoxy	1	300	13	0	118.89	120.57	119.73	0.84
A	Epoxy	1	300	13	200	118.34	126.79	122.57	4.22
B	Vinyl Ester	1	300	13	200	103.90	105.74	104.82	0.92
C	Epoxy	1	300	13	200	130.18	139.47	134.82	4.64
A	Epoxy	1	300	13	20000	148.39	152.62	150.51	2.11
B	Vinyl Ester	1	300	13	20000	120.60	128.08	124.34	3.74
C	Epoxy	1	300	13	20000	163.23	167.88	165.56	2.32
A	Epoxy	1	300	13	SeaWater	161.20	162.03	161.62	0.41
B	Vinyl Ester	1	300	13	SeaWater	131.96	134.77	133.37	1.41
C	Epoxy	1	300	13	SeaWater	177.33	178.23	177.78	0.45
A	Epoxy	2	300	13	0	128.08	129.61	128.85	0.77
B	Vinyl Ester	2	300	13	0	114.69	115.37	115.03	0.34
C	Epoxy	2	300	13	0	143.45	145.17	144.31	0.86
A	Epoxy	2	300	13	200	156.18	162.28	159.23	3.05
B	Vinyl Ester	2	300	13	200	120.90	122.74	121.82	0.92
C	Epoxy	2	300	13	200	174.93	181.76	178.34	3.42
A	Epoxy	2	300	13	20000	168.39	172.62	170.51	2.11
B	Vinyl Ester	2	300	13	20000	137.60	145.08	141.34	3.74
C	Epoxy	2	300	13	20000	188.60	193.33	190.97	2.37
A	Epoxy	2	300	13	SeaWater	181.20	182.03	181.62	0.41
B	Vinyl Ester	2	300	13	SeaWater	149.24	158.16	153.70	4.46
C	Epoxy	2	300	13	SeaWater	202.95	203.87	203.41	0.46

Table 1.44: Total Organic Carbon Test Statistical values for All Resin Sample Groups

Sample Group					Statistical Values			
					Total Organic Carbon			
Manuf. Type	Resin Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Epoxy	300	4	0	12.49	13.25	12.87	0.38
B	Vinyl Ester	300	4	0	10.58	10.80	10.69	0.11
A	Epoxy	300	4	200	34.89	35.31	35.10	0.21
B	Vinyl Ester	300	4	200	32.72	33.68	33.20	0.48
A	Epoxy	300	4	20000	38.98	41.36	40.17	1.19
B	Vinyl Ester	300	4	20000	35.70	39.39	37.54	1.84
A	Epoxy	300	4	SeaWater	54.77	57.50	56.14	1.36
B	Vinyl Ester	300	4	SeaWater	45.03	47.53	46.28	1.25
A	Epoxy	300	7	0	14.33	14.94	14.64	0.30
B	Vinyl Ester	300	7	0	11.90	12.02	11.96	0.06
A	Epoxy	300	7	200	14.82	15.63	15.22	0.41
B	Vinyl Ester	300	7	200	13.24	13.36	13.30	0.06
A	Epoxy	300	7	20000	37.08	37.55	37.32	0.23
B	Vinyl Ester	300	7	20000	28.54	29.96	29.25	0.71
A	Epoxy	300	7	SeaWater	41.52	42.25	41.89	0.36
B	Vinyl Ester	300	7	SeaWater	31.62	35.19	33.41	1.78
A	Epoxy	300	10	0	18.33	19.06	18.69	0.36
B	Vinyl Ester	300	10	0	14.49	14.68	14.59	0.09
A	Epoxy	300	10	200	22.45	23.15	22.80	0.35
B	Vinyl Ester	300	10	200	18.31	18.60	18.45	0.15
A	Epoxy	300	10	20000	39.77	40.99	40.38	0.61
B	Vinyl Ester	300	10	20000	31.40	32.67	32.03	0.64
A	Epoxy	300	10	SeaWater	44.94	46.03	45.49	0.54
B	Vinyl Ester	300	10	SeaWater	35.33	39.99	37.66	2.33
A	Epoxy	300	13	0	34.89	35.31	35.10	0.21
B	Vinyl Ester	300	13	0	32.72	33.68	33.20	0.48
A	Epoxy	300	13	200	38.98	41.36	40.17	1.19
B	Vinyl Ester	300	13	200	35.70	39.39	37.54	1.84
A	Epoxy	300	13	20000	54.77	57.50	56.14	1.36
B	Vinyl Ester	300	13	20000	45.03	47.53	46.28	1.25
A	Epoxy	300	13	SeaWater	63.05	65.00	64.03	0.98
B	Vinyl Ester	300	13	SeaWater	54.84	61.39	58.11	3.28

Table 1.45: Total Organic Carbon Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Total Organic Carbon			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Sized	300	4	0	16.96	18.15	17.56	0.60
B	Sized	300	4	0	14.01	14.05	14.03	0.02
C	Sized	300	4	0	20.35	21.78	21.07	0.71
A	Sized	300	4	200	18.54	22.86	20.70	2.16
B	Sized	300	4	200	16.60	17.20	16.90	0.30
C	Sized	300	4	200	22.24	27.43	24.84	2.59
A	Sized	300	4	20000	35.89	38.23	37.06	1.17
B	Sized	300	4	20000	25.60	27.51	26.55	0.96
C	Sized	300	4	20000	43.07	45.88	44.47	1.40
A	Sized	300	4	SeaWater	37.91	38.17	38.04	0.13
B	Sized	300	4	SeaWater	29.01	33.05	31.03	2.02
C	Sized	300	4	SeaWater	45.50	45.81	45.65	0.16
A	Unsized	300	4	0	7.24	9.71	8.48	1.23
B	Unsized	300	4	0	5.82	6.03	5.93	0.11
A	Unsized	300	4	200	13.25	13.63	13.44	0.19
B	Unsized	300	4	200	8.98	10.14	9.56	0.58
A	Unsized	300	4	20000	17.11	21.19	19.15	2.04
B	Unsized	300	4	20000	19.04	21.37	20.21	1.17
A	Unsized	300	4	SeaWater	22.79	23.84	23.31	0.52
B	Unsized	300	4	SeaWater	29.17	30.65	29.91	0.74
A	Sized	300	7	0	20.51	20.92	20.72	0.20
B	Sized	300	7	0	14.20	14.78	14.49	0.29
C	Sized	300	7	0	24.61	25.11	24.86	0.25
A	Sized	300	7	200	23.44	25.60	24.52	1.08
B	Sized	300	7	200	17.52	17.72	17.62	0.10
C	Sized	300	7	200	28.13	30.72	29.42	1.30
A	Sized	300	7	20000	37.96	44.26	41.11	3.15
B	Sized	300	7	20000	30.03	35.57	32.80	2.77
C	Sized	300	7	20000	45.56	53.11	49.33	3.78
A	Sized	300	7	SeaWater	41.12	51.79	46.46	5.33
B	Sized	300	7	SeaWater	33.61	33.88	33.74	0.14
C	Sized	300	7	SeaWater	49.35	62.14	55.75	6.40
A	Unsized	300	7	0	10.34	10.41	10.38	0.04
B	Unsized	300	7	0	7.41	11.36	9.39	1.97
A	Unsized	300	7	200	13.24	15.74	14.49	1.25
B	Unsized	300	7	200	10.49	11.52	11.01	0.51
A	Unsized	300	7	20000	19.00	19.81	19.40	0.40

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Table 1.45: Total Organic Carbon Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Total Organic Carbon			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
B	Unsized	300	7	20000	24.43	27.63	26.03	1.60
A	Unsized	300	7	SeaWater	24.13	27.91	26.02	1.89
B	Unsized	300	7	SeaWater	31.38	34.26	32.82	1.44
A	Sized	300	10	0	20.97	22.03	21.50	0.53
B	Sized	300	10	0	16.16	16.19	16.18	0.01
C	Sized	300	10	0	25.16	26.44	25.80	0.64
A	Sized	300	10	200	24.91	28.11	26.51	1.60
B	Sized	300	10	200	20.14	20.45	20.30	0.15
C	Sized	300	10	200	29.90	33.74	31.82	1.92
A	Sized	300	10	20000	38.68	44.14	41.41	2.73
B	Sized	300	10	20000	34.09	37.02	35.56	1.46
C	Sized	300	10	20000	46.41	52.97	49.69	3.28
A	Sized	300	10	SeaWater	47.78	52.12	49.95	2.17
B	Sized	300	10	SeaWater	44.97	46.51	45.74	0.77
C	Sized	300	10	SeaWater	57.34	62.54	59.94	2.60
A	Unsized	300	10	0	12.73	13.34	13.03	0.31
B	Unsized	300	10	0	10.28	10.88	10.58	0.30
A	Unsized	300	10	200	18.69	20.65	19.67	0.98
B	Unsized	300	10	200	12.64	15.51	14.07	1.44
A	Unsized	300	10	20000	26.84	31.21	29.02	2.18
B	Unsized	300	10	20000	29.67	32.19	30.93	1.26
A	Unsized	300	10	SeaWater	33.91	39.44	36.67	2.77
B	Unsized	300	10	SeaWater	35.58	38.94	37.26	1.68
A	Sized	300	13	0	42.13	43.37	42.75	0.62
B	Sized	300	13	0	37.65	38.02	37.83	0.18
C	Sized	300	13	0	50.55	52.05	51.30	0.75
A	Sized	300	13	200	48.33	54.46	51.40	3.06
B	Sized	300	13	200	37.76	42.79	40.27	2.51
C	Sized	300	13	200	58.00	65.35	61.67	3.67
A	Sized	300	13	20000	62.62	64.12	63.37	0.75
B	Sized	300	13	20000	50.17	57.99	54.08	3.91
C	Sized	300	13	20000	75.14	76.94	76.04	0.90
A	Sized	300	13	SeaWater	75.72	77.46	76.59	0.87
B	Sized	300	13	SeaWater	64.74	68.43	66.58	1.85
C	Sized	300	13	SeaWater	90.86	92.96	91.91	1.05
A	Unsized	300	13	0	31.29	34.74	33.01	1.73
B	Unsized	300	13	0	27.07	28.66	27.86	0.79

Continued on next page ...

Table 1.45: Total Organic Carbon Test Statistical values for All Fiber Sample Groups

Sample Group					Statistical Values			
					Total Organic Carbon			
Manuf. Type	Fiber Type	Exposure Period Days	pH	Cl^- ppm	$\wedge$ ppm	$\vee$ ppm	μ ppm	σ ppm
A	Unsized	300	13	200	37.78	39.74	38.76	0.98
B	Unsized	300	13	200	30.72	35.44	33.08	2.36
A	Unsized	300	13	20000	50.52	51.51	51.01	0.49
B	Unsized	300	13	20000	42.79	43.74	43.26	0.48
A	Unsized	300	13	SeaWater	58.16	61.77	59.96	1.81
B	Unsized	300	13	SeaWater	49.82	56.42	53.12	3.30

For a better understanding, change in the TOC content of the environments was plotted in graphs in Figure 1.43, 1.44, and 1.45. It can be seen that the total organic carbon content of all exposure environments has increased.

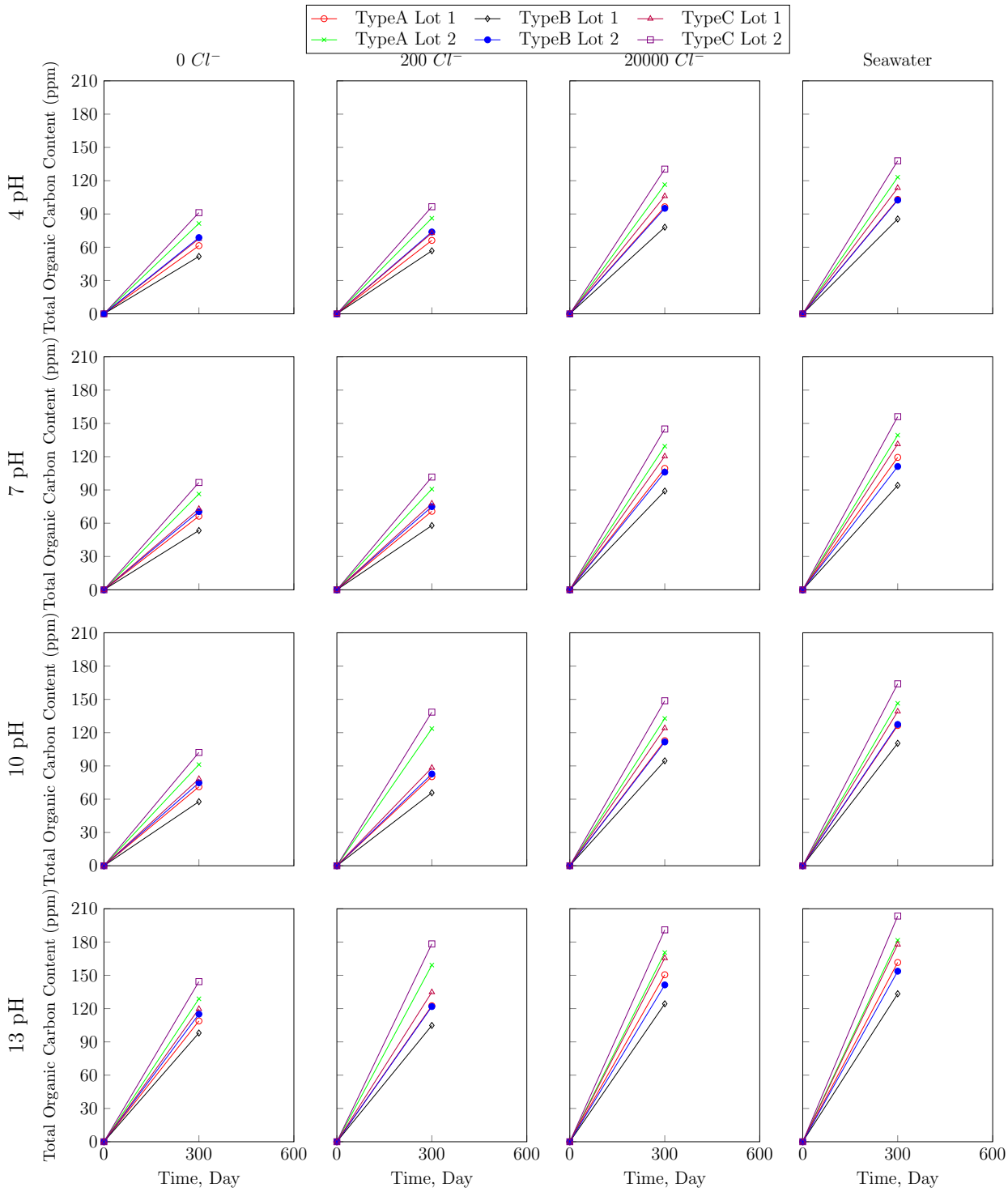

Figure 1.43: Total Organic Carbon concentration of all environments after exposure of rebars

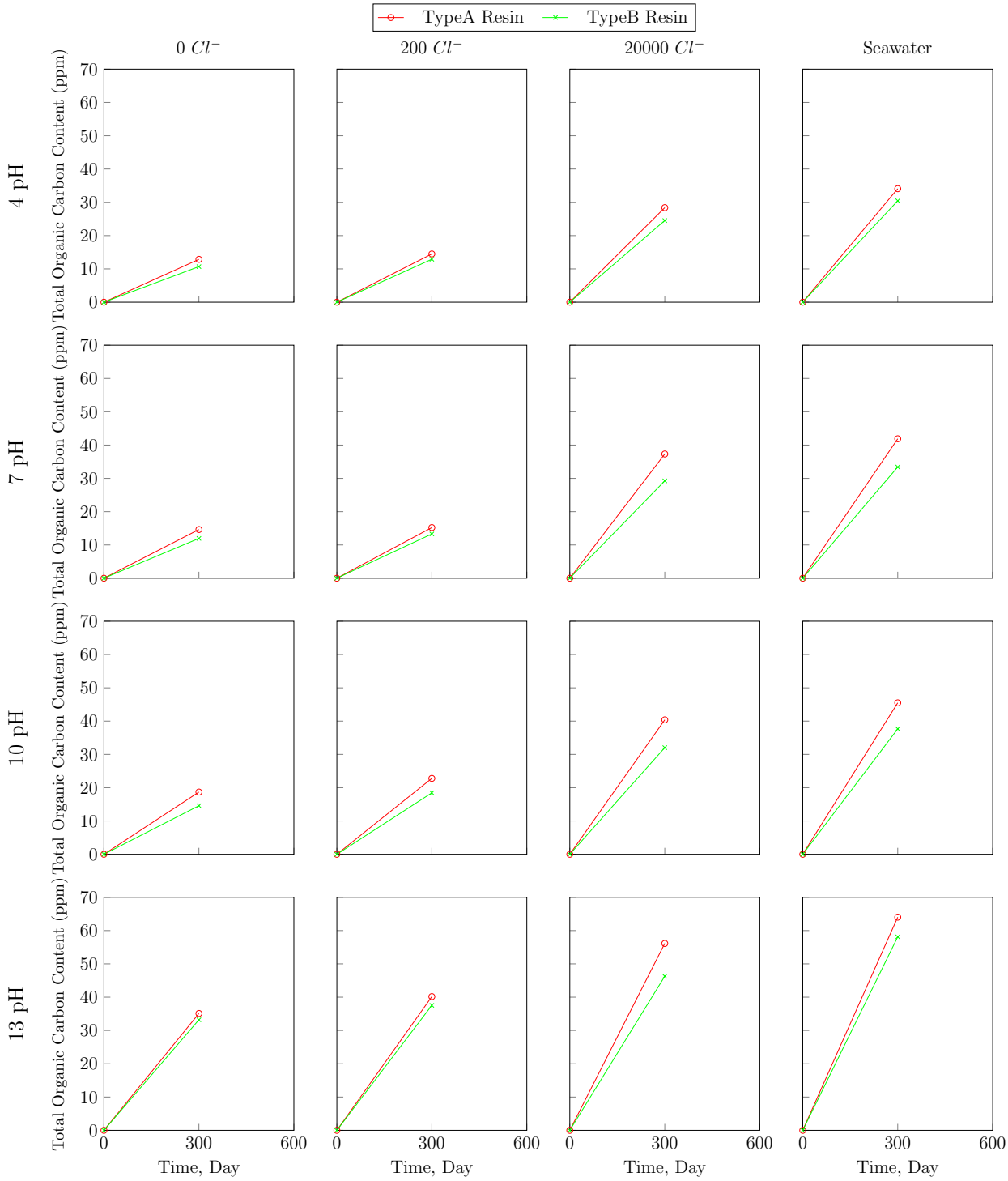

Figure 1.44: Total Organic Carbon concentration of all environments after exposure of resins

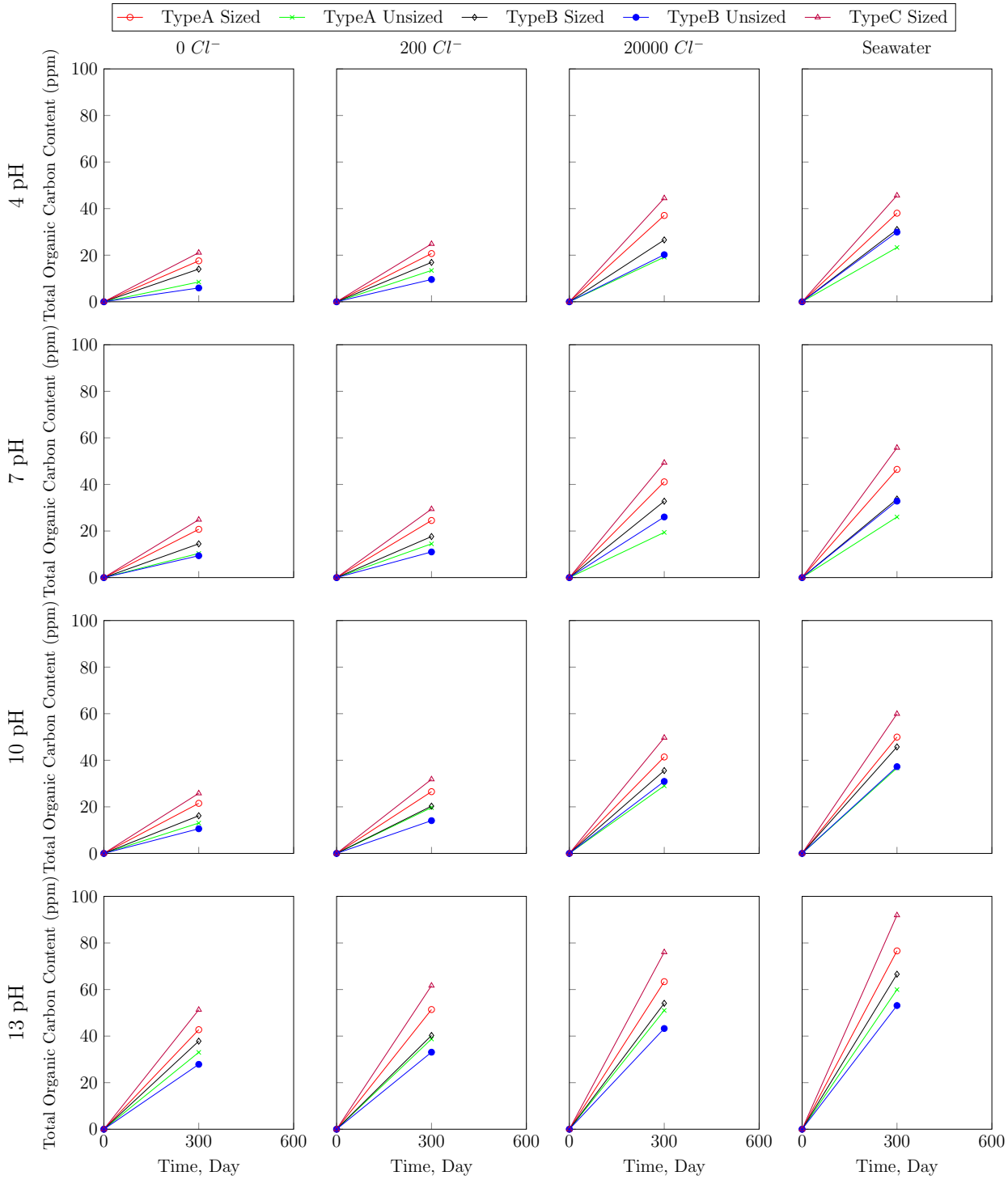

Figure 1.45: Total Organic Carbon concentration of all environments after exposure of sized and unsized fibers

1.3 Physical and Mechanical Properties of Components After Exposure to Aggressive Environments

In this section, the physical properties such as X-Ray fluorescence and mechanical properties such as tensile strength of rebar components is detailed.

1.3.1 Resin Tensile Test

The resins were tested according to the ASTM D 638 (ASTM-International, 2014) to evaluate the tensile properties. The recorded and processed data of the tensile strength test are shown in this section via graphs and table.

Load-Displacement Behavior

To compare the load-displacement behavior of the different resin samples and specimens, the graphs in Figures 1.46 and 1.47 plot the recorded test data. As shown, the x-axis of the graph represents the cross-head extension—which has to be interpreted with care because it includes the elastic deformation of the load frame and the test fixtures—and the y-axis indicates the applied and measured load. Figure 1.46, and 1.47 shows that, although the extension of both resins during the test was similar regardless of the conditioned environments, the peak load was much higher for Type A resin in comparison with Type B resin. All the tested resin specimens failed in similar fashion.

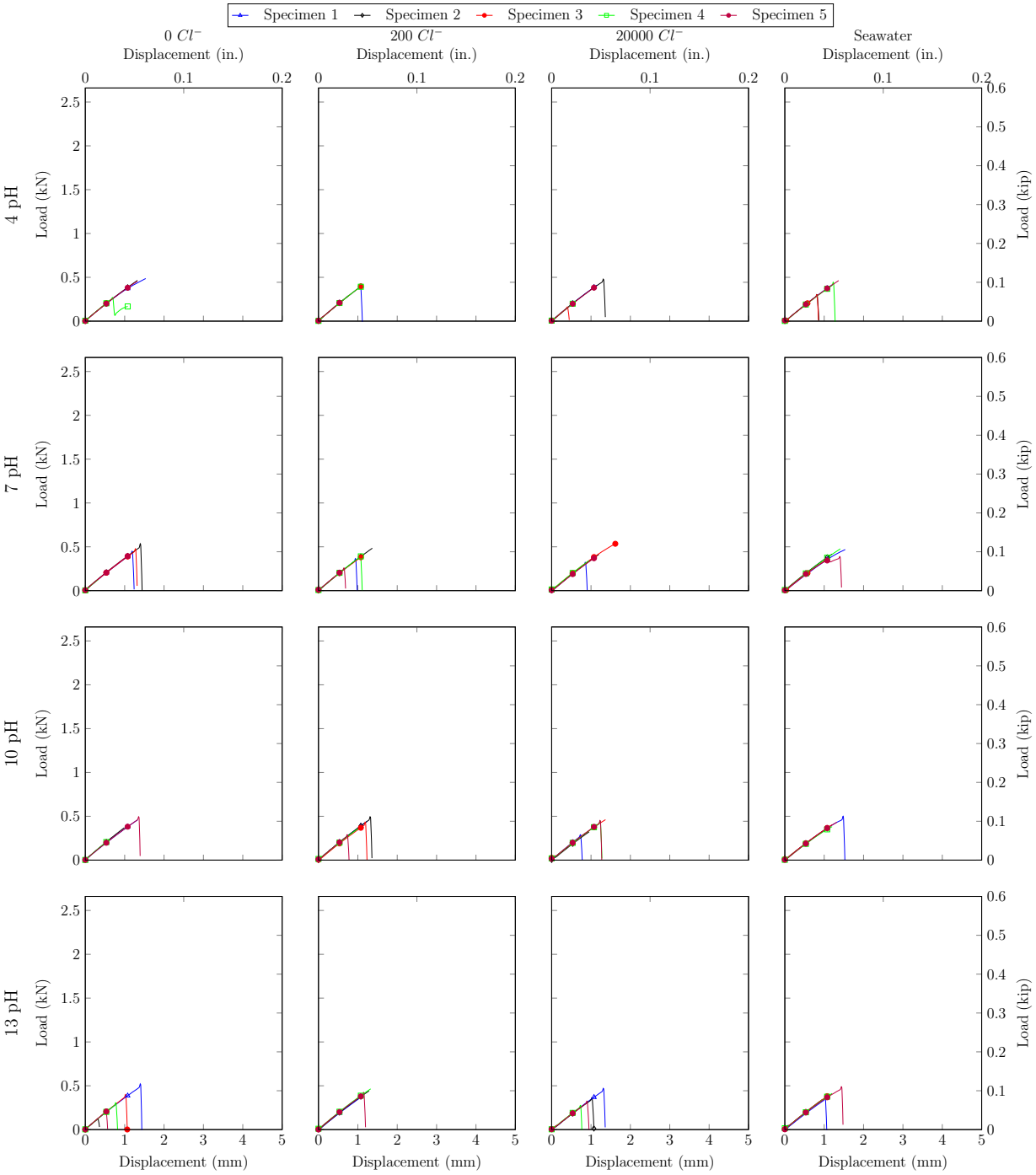

Figure 1.46: Tensile strength-displacement behavior of Type A Resin

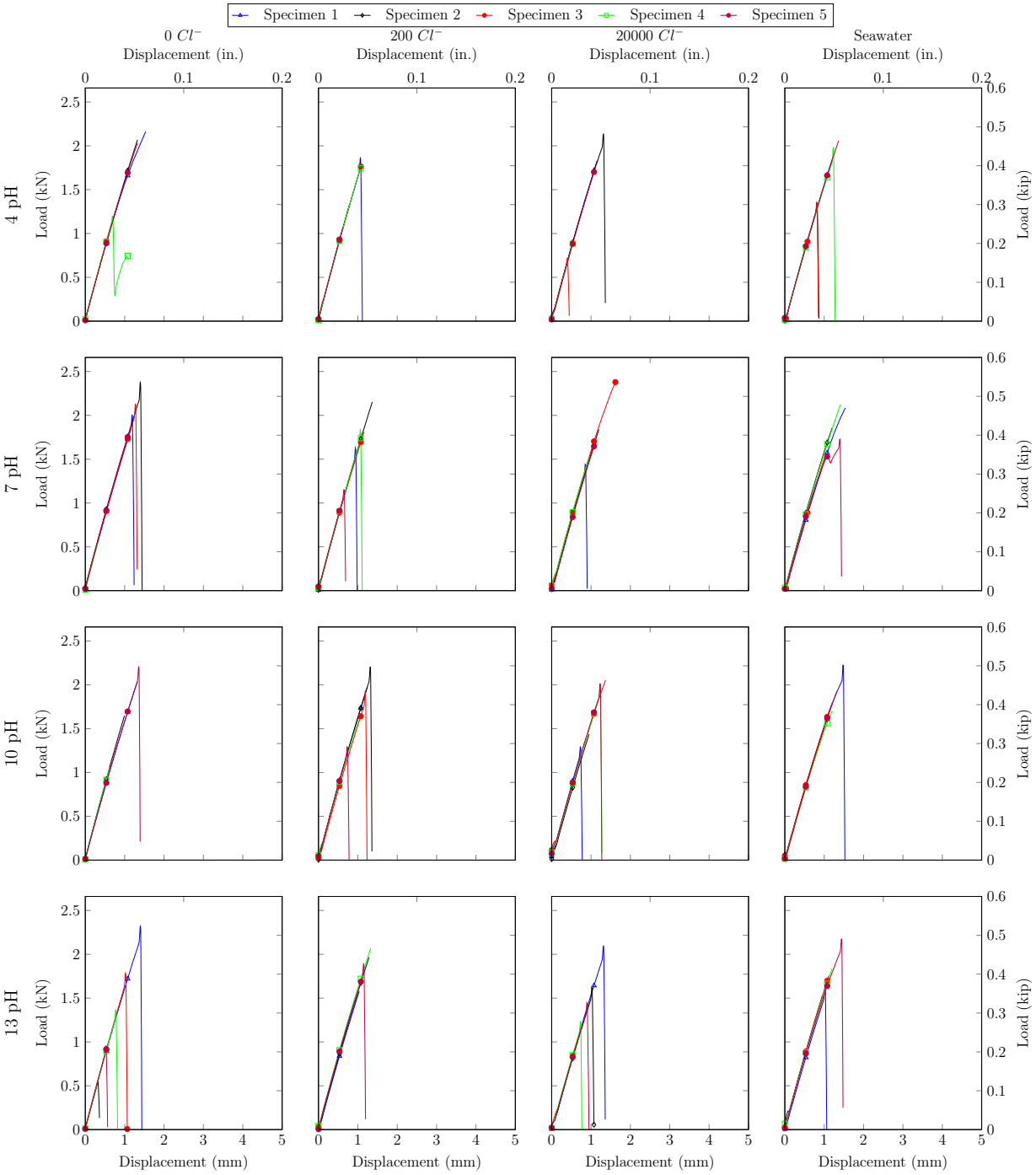

Figure 1.47: Tensile strength-displacement behavior of Type B Resin

Stress-Strain Behavior

The stress-strain behavior of the failed resins of all types was plotted to quantify and compare the elastic moduli of the tested resins. The data in Figures 1.48 and 1.49 were plotted to compare the stress-strain behavior of the different resin types. Accordingly, the x-axis shows the applied stress while the y-axis represents the outermost surface strain that was measured with an external extensometer. It can be seen in Figure 1.48 and 1.49 that stress-strain

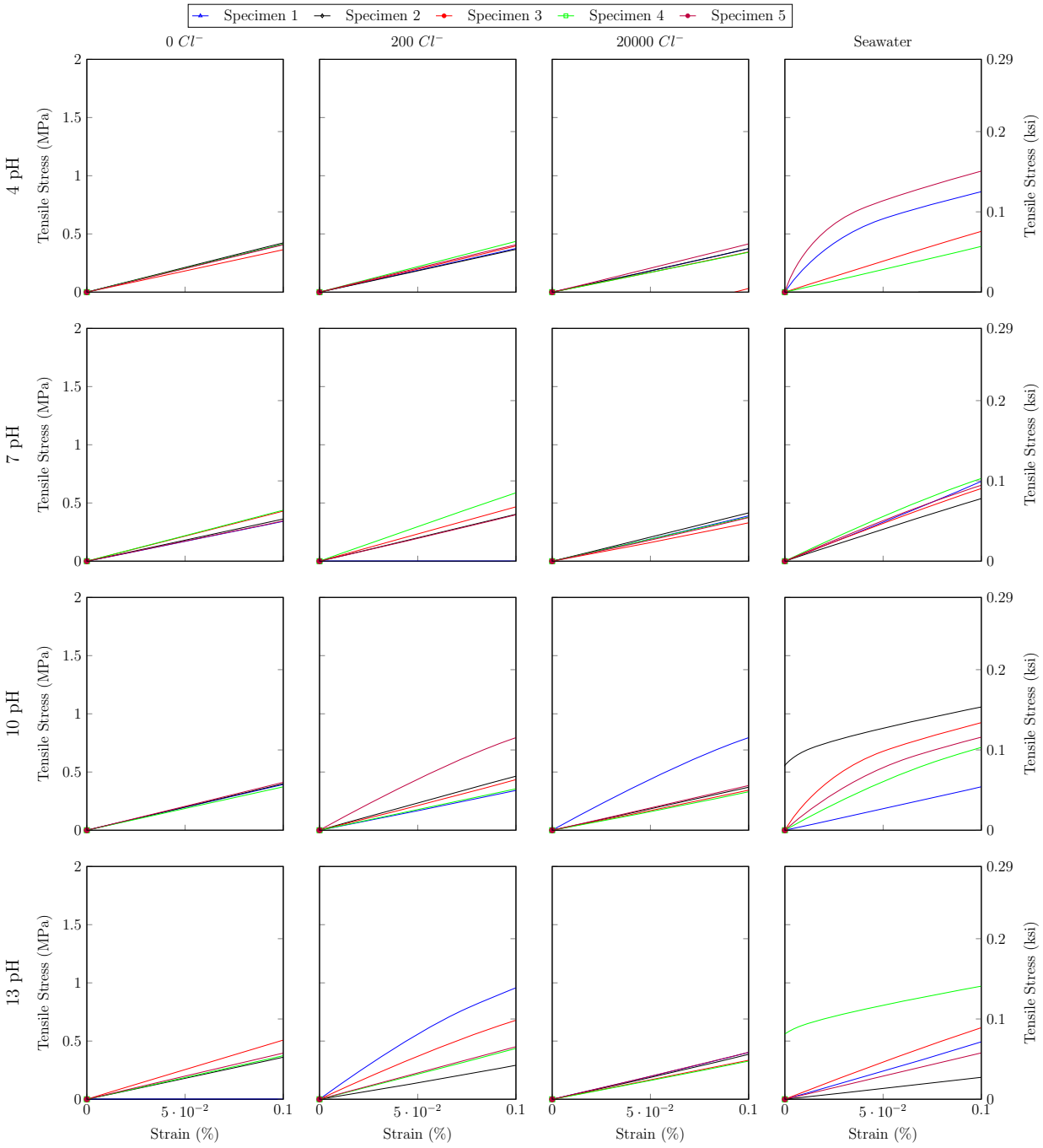

Figure 1.48: Tensile stress - Strain behavior of rebar Type A Resin

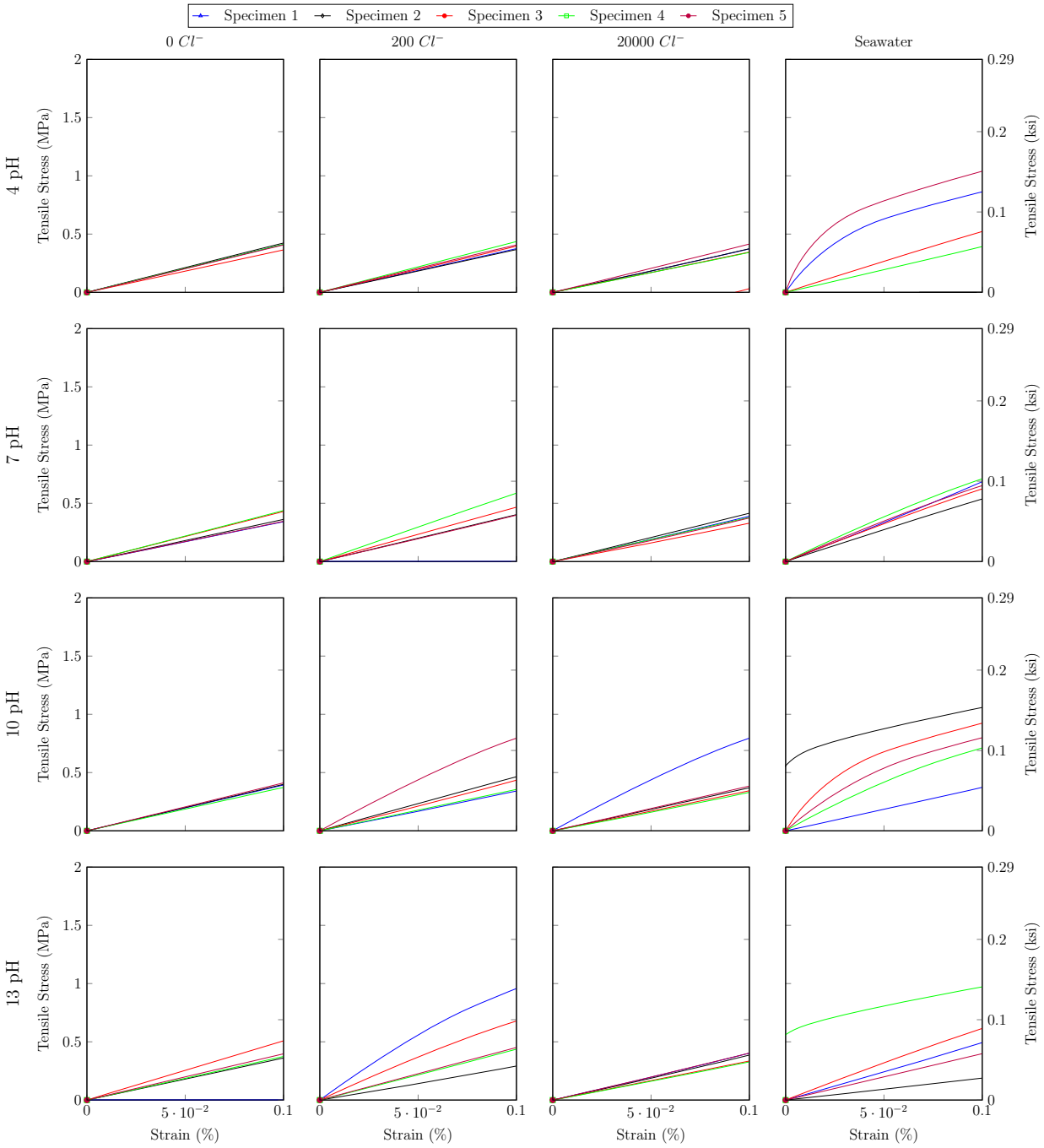

Figure 1.49: Tensile stress - Strain behavior of rebar Type B Resin

behavior of both resins are identical and linear until failure.

1.3.2 XRF Analysis on Fibers

XRF analysis was conducted on both naked and sized basalt fibers after exposure in aggressive environments. Tables 1.46 and 1.47 show the obtained data.

Table 1.46: XRF results of naked fibers after exposure in harsh environments for 300 days

Type Type	pH	Cl^-	Ca %	Ti %	Cr PPM	Mn %	Fe %	Cu PPM	Zn %	Sr %	Zr %	Mo PPM	Ag %	Ba %	Eu %	Mg %	Al %	S %	P %	S %	Cl %	K %
A	4	0	18.94	3.04	332.3	0.71	50.56	495.2	0.12	0.29	0.15	264.3	0.51		0.31	0.41	4.53	14.96	0.38	0.00	0.46	4.11
A	7	0	18.74	2.91	366.0	0.69	49.57	0.0	0.11	0.33	0.18	394.9	0.57	0.1	0.33	0.5	4.55	16.13	0.36	0.00	0.32	4.14
A	10	0	19.11	2.96	331.2	0.69	48.63	328.8	0.11	0.34	0.19	364.1	0.53	968.2	0.31	0.46	4.47	16.72	0.37	0.00	0.31	4.19
A	13	0	21.35	3.31	312.0	0.78	54.59	329.7	0.13	0.39	0.22	411.2	0.72	0.2	0.36	0.66	2.35	10.83	0.34	0.00	0.46	2.84
A	4	200	18.93	3.01	335.6	0.70	50.32	444.0	0.11	0.27	0.15	301.4	0.47	699.5	0.33	0.4	4.37	15.16	0.39	0.00	0.69	4.15
A	7	200	18.69	2.95	367.8	0.71	51.51	328.6	0.12	0.34	0.19	405.6	0.58	0.1	0.37	0.38	4.14	14.41	0.39	0.00	0.44	4.11
A	10	200	18.96	2.95	342.4	0.73	50.57	349.6	0.12	0.34	0.18	390.0	0.57	0.1	0.3	0.44	4.18	15.25	0.39	0.00	0.24	4.14
A	13	200	20.71	3.33	331.0	0.78	52.52	443.6	0.12	0.31	0.16	259.2	0.53	876.2	0.31	0.7	3.02	12.95	0.35	0.00	0.34	3.33
A	4	20000	18.58	2.90	297.7	0.67	48.07	398.5	0.11	0.3	0.16	324.6	0.55	924.9	0.29	0.38	4.04	13.78	0.36	0.00	5.13	4.09
A	7	20000	18.40	2.86	395.5	0.69	49.09	195.7	0.1	0.36	0.20	471.5	0.71	0.1	0.32	0.41	4.28	14.71	0.41	0.00	2.70	4.05
A	10	20000	17.35	2.80	369.5	0.71	51.17	0.0	0.13	0.41	0.24	569.8	1.27	0.2	0.32	777.4	1.83	6.37	0.42	0.00	12.57	3.58
A	13	20000	22.43	3.40	294.2	0.73	50.29	410.7	0.11	0.28	0.15	92.0	0.47	855.7	0.29	0.56	2.1	9.94	0.3	0.00	7.03	1.51
A	4	Seawater	18.31	2.80	360.5	0.67	48.28	299.9	0.11	0.35	0.19	473.3	0.78	0.1	0.28	0.33	3.45	11.78	0.4	0.50	7.03	4.01
A	7	Seawater	17.20	2.87	314.4	0.65	50.46	334.2	0.12	0.39	0.24	514.1	1.08	0.2	0.34	1.16	3.32	12.10	0.47	0.00	4.99	3.78
A	10	Seawater	18.28	2.94	339.9	0.67	48.03	380.3	0.11	0.28	0.15	348.7	0.61	0.1	0.29	1.19	3.89	14.02	0.34	0.00	4.50	4.10
A	13	Seawater	0.00	0.00	0.0	0.00	0	0.0	0	0	0.00	0.0	0	0.0	0	0	0	0.00	0	0.00	0.00	0.00
B	4	0	18.53	2.95	314.3	0.66	50.24	0.0	0.13	0.37	0.34	0.0	0.62	0.1	0.35	0.47	4.55	15.28	0.38	0.12	0.38	4.01
B	7	0	18.84	2.98	272.0	0.67	49.6	353.6	0.12	0.32	0.28	0.0	0.57		0.35	0.45	4.52	16.01	0.41	0.00	0.32	4.08
B	10	0	18.86	2.94	294.1	0.71	50.98	0.0	0.12	0.35	0.32	0.0	0.61	0.1	0.33	0.42	4.08	14.75	0.4	0.00	0.44	4.09
B	13	0	21.63	3.40	329.8	0.78	54.74	0.0	0.13	0.36	0.32	0.0	0.62	0.1	0.34	0.77	2.26	10.63	0.34	0.87	0.50	2.56
B	4	200	18.38	2.86	302.0	0.68	49.71	0.0	0.14	0.35	0.34	0.0	0.74	0.1	0.31	0.46	4.6	16.06	0.44	0.00	0.32	3.99
B	7	200	18.53	2.91	344.6	0.69	50.02	0.0	0.13	0.36	0.31	0.0	0.57	0.1	0.32	0.49	4.38	15.15	0.37	0.00	1.13	4.04
B	10	200	18.83	2.92	262.7	0.69	48.86	0.0	0.12	0.37	0.34	0.0	0.88	0.2	0.32	0.47	4.33	16.50	0.36	0.00	0.24	4.08
B	13	200	19.69	3.19	313.7	0.77	54.59	0.0	0.14	0.39	0.34	0.0	0.96	0.2	0.35	0.61	2.59	11.44	0.44	0.00	0.71	3.18
B	4	20000	18.90	2.94	246.2	0.66	49.19	350.5	0.11	0.29	0.27	0.0	0.56	818.3	0.32	0.53	4.09	14.39	0.37	0.00	2.86	4.03
B	7	20000	18.58	2.95	376.7	0.67	49.78	303.3	0.13	0.3	0.27	0.0	0.54		0.33	0.43	3.88	13.86	0.39	0.00	3.35	4.04
B	10	20000	17.64	2.96	263.4	0.67	49.86	0.0	0.12	0.34	0.33	0.0	0.67		0.33	1.65	3.81	13.73	0.39	0.12	3.01	3.92
B	13	20000	16.17	2.89	274.1	0.63	50.01	0.0	0.12	0.34	0.34	0.0	0.67	0.1	0.3	2.02	3.23	10.18	0.36	0.59	7.87	3.62
B	4	Seawater	18.15	2.72	301.1	0.66	46.71	261.2	0.12	0.38	0.37	0.0	0.82	0.2	0.28	0.32	3.5	13.21	0.4	0.00	7.69	3.99
B	7	Seawater	18.68	2.91	338.8	0.69	50.57	0.0	0.13	0.36	0.33	0.0	0.79	0.2	0.33	0.39	3.77	13.46	0.43	0.64	2.36	4.10
B	10	Seawater	23.47	3.24	258.6	0.67	49.86	353.3	0.11	0.3	0.25	0.0	0.45	822.8	0.28	0.4	2.01	9.96	0.22	0.53	7.44	0.90
B	13	Seawater	0.00	0.00	0.0	0.00	0	0.0	0	0	0.00	0.0	0	0.0	0	0	0	0.00	0	0.00	0.00	0.00

Table 1.47: XRF results of sized fibers after exposure in harsh environments for 300 days

Type Type	pH	Cl^-	Ca %	Ti %	Cr PPM	Mn %	Fe %	Cu PPM	Zn %	Sr %	Zr %	Mo PPM	Ag %	Ba %	Eu %	Mg %	Al %	Si %	P %	S %	Cl %	K %
A	4	0	19	2.99	305.5	0.7	49.73	430.9	0.11	0.29	0.15	287.5	0.52	887.5	0.32	0.45	4.34	16.05	0.36	0	0.23	4.15
A	7	0	19.79	3.08	385.9	0.71	49.07	439.5	0.12	0.27	0.14	226.5	0.58		0.31	0.38	4.1	15.69	0.64	0	0.29	4.31
A	10	0	19.18	2.99	326.9	0.69	48.76	360.1	0.1	0.28	0.14	284.4	0.52		0.33	0.53	4.5	16.65	0.35	0	0.23	4.26
A	13	0	21.31	3.3	333.5	0.73	49.53	397.7	983.7	0.28	0.15	256.3	0.5	838.9	0.33	1.18	3.51	14.45	0.33	0	0.43	3.35
A	4	200	19.05	2.95	326.2	0.68	48.26	0	0.11	0.34	0.18	350.8	0.64	0.11	0.32	0.54	4.59	16.83	0.36	0	0.38	4.17
A	7	200	19.88	3.11	377	0.7	47.64	333	897.3	0.19	927.1	186	0.45		0.3	0.51	4.41	16.37	0.38	0	1.06	4.37
A	10	200	19.45	3.01	296.4	0.71	49.37	404.9	0.1	0.28	0.15	283.3	0.57	941.5	0.31	0.49	4.24	15.8	0.4	0	0.26	4.3
A	13	200	20.86	3.27	346.3	0.76	52.15	432.9	0.11	0.28	0.14	227.8	0.46	718.3	0.33	0.76	3.14	13.29	0.34	0	0.23	3.34
A	4	20000	18.05	2.78	327.6	0.68	48.7	321.5	0.12	0.38	0.22	473.2	0.78	0.17	0.31	0.42	4.42	16.22	0.4	0	1.82	3.97
A	7	20000	19.02	2.96	371.8	0.66	46.88	0	0.1	0.29	0.16	305.6	0.6	0	0.33	0.53	4.73	17.4	0.33	0	1.33	4.18
A	10	20000	18.71	2.85	430.4	0.67	47.6	295.4	992.1	0.33	0.18	391.9	0.6	0.12	0.31	0.48	4.26	16.06	0.36	0	2.67	4.17
A	13	20000	20.17	3.14	309.2	0.74	51.66	338.5	0.11	0.36	0.19	254.8	0.69	0.13	0.36	0.44	2.1	9.44	0.33	0	7.28	2.45
A	4	Seawater	19.36	2.97	376.4	0.67	46.23	0	0.1	0.24	0.12	219.7	0.69	0	0.29	0.48	4.37	16.19	0.65	0	2.94	4.25
A	7	Seawater	18.47	2.88	307.6	0.7	49.38	330.9	0.11	0.34	0.18	367.8	0.61	0.1	0.29	0.72	3.95	14.8	0.36	0	2.46	4.1
A	10	Seawater	16.74	2.78	300.6	0.58	44.24	333.9	912.5	0.26	0.14	244	0.52	0	0.27	1.66	3.32	11.17	0.33	0.21	12.92	4.18
A	13	Seawater	26.11	3.33	308.1	0.55	43.58	304.4	724	1.12	550.8		0.38	0	0.23	0.83	0.97	6.2	0.29	0.64	14.43	0.89
B	4	0	18.45	2.84	308.4	0.69	49.99	405.1	0.12	0.32	0.29	0	0.65	939.9	0.31	0.39	3.93	14.09	0.42	0	2.86	4.04
B	7	0	18.67	2.9	317.1	0.69	49.24	0	0.12	0.37	0.34	0	0.67	0.14	0.32	0.5	4.46	16.16	0.36	0	0.51	4.06
B	10	0	18.56	2.86	292.9	0.71	50.05	380.7	0.13	0.34	0.31	0	0.61	973.2	0.31	0.51	4.27	15.53	0.39	0	0.76	4.08
B	13	0	22.24	3.45	294.8	0.73	50.97	0	0.11	0.24	0.2	0	0.45	0	0.33	1.01	2.86	12.47	0.38	565.3	1.34	2.82
B	4	200	18.6	2.92	274.8	0.66	48	242.7	0.12	0.34	0.31	0	0.59	0.11	0.31	0.6	4.82	16.95	0.34	0	0.79	4.05
B	7	200	17.71	2.65	300.3	0.66	47.16	458.7	0.16	0.42	0.37	0	0.83	0.13	0.3	0.53	5.01	18.71	0.58	0	0.35	3.88
B	10	200	18.69	2.93	291.7	0.68	49.1	363.8	0.12	0.31	0.27	0	0.56		0.34	0.52	4.38	16.16	0.37	0	1.02	4.08
B	13	200	20.4	3.2	251.6	0.77	54.74	0	0.14	0.4	0.38	0	0.73	0.17	0.35	0.63	2.63	11.49	0.37	0	0.37	2.8
B	4	20000	18.68	2.9	294	0.67	48.67	0	0.13	0.38	0.35	0	0.72	0.14	0.33	0.35	3.59	13.04	0.41	107.5	5.18	4.04
B	7	20000	18.58	2.84	373.2	0.67	48.01	365.1	0.12	0.32	0.28	0	0.57	923	0.32	0.34	3.95	14.14	0.48	0	4.71	4.1
B	10	20000	18.7	2.84	283.9	0.67	47.67	301.1	0.12	0.34	0.31	0	0.61	0.1	0.32	0.57	4.31	15.88	0.38	0	2.64	4.05
B	13	20000	23.51	3.28	234.2	0.66	50.94	278.4	890.7	0.3	0.26	0	0.45	864.8	0.31	0.4	2.17	10	0.25	835.6	6.02	0.81
B	4	Seawater	18.88	2.98	272.2	0.67	48.62	282.2	0.11	0.35	0.34	0	0.69	0.14	0.28	0.51	4.11	15.21	0.41	0	2.13	4.05
B	7	Seawater	18.47	2.95	308.9	0.67	48.72	0	0.13	0.35	0.31	0	0.73	0	0.33	1.16	3.83	14.42	0.47	996.6	2.81	4.05
B	10	Seawater	17.1	2.88	342.7	0.64	49.19	368.6	0.12	0.31	0.28	0	0.63	0	0.3	2.3	3.81	11.57	0.47	0.35	5.71	3.81
B	13	Seawater	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	4	0	19.16	3.02	361.9	0.69	377.5	47.76	0.17	0	0.55	17.25	0	4.17	0.28	0.55	4.95	17.25	0.31	0	0.28	4.17
C	7	0	19.82	3.15	395.8	0.71	415.5	48.86	0.13	0	0.42	15.87	0	4.3	0.34	0.42	4.38	15.87	0.42	0	0.24	4.3
C	10	0	18.96	3.04	311.2	0.69	367.6	49.43	0.13	0	0.39	15.09	0	4.17	0.32	0.39	4.28	15.09	0.43	0	1.55	4.17
C	13	0	17.55	2.87	337.7	0.73	0	53.43	0.34	0.17	0.18	7.64	0	3.76	0.32	0.18	2.22	7.64	0	0	8.08	3.76
C	4	200	18.84	2.94	480.5	0.66	491.4	48.07	0.31	0	0.39	16.49	0	4	0.32	0.39	4.56	16.49	0.63	0	0.37	4
C	7	200	18.96	2.92	467.2	0.66	321.7	46.15	0.22	0	0.44	16.82	0	4.1	0.31	0.44	4.28	16.82	0.61	0	2.41	4.1
C	10	200	17.99	2.86	362	0.69	368.2	50.21	0.15	0.11	1.09	13.42	0	3.97	0.32	1.09	3.64	13.42	0.41	0	3.28	3.97
C	13	200	20.29	3.09	370.2	0.69	0	48.75	0.23	0	0.53	15.62	0	3.84	0.37	0.53	3.82	15.62	0.45	0	0.26	3.84
C	4	20000	21.12	3.27	395	0.73	0	49.27	0.23	0	0.48	14.19	0	3.86	0.3	0.48	3.52	14.19	0.77	0	0.26	3.86
C	7	20000	20.81	3.12	367.8	0.72	433.3	48.48	0.18	0	0.55	14.61	0	3.65	0.33	0.55	3.42	14.61	0.46	0	1.85	3.65
C	10	20000	19.85	3.11	374.9	0.69	353.2	47.72	0.15	0	0.4	16.35	0	4.34	0.31	0.4	4.4	16.35	0.52	0	0.57	4.34
C	13	20000	18.39	2.96	364.2	0.67	0	49.85	0.28	0	0.15	11.54	0	3.9	0.35	0.15	3.53	11.54	0.66	0	5.41	3.9
C	4	Seawater	25.12	3.95	584.1	0.71	366.2	49.02	0.17	0	0.15	0	0	4.83	0.34	0.15	1.59	0	1.59	0	9.3	4.83
C	7	Seawater	19.36	2.96	397.2	0.66	410.2	46.33	0.2	0	0.48	17.68	0	4.11	0.33	0.48	4.73	17.68	0	0	0.65	4.11
C	10	Seawater	18.83	2.96	391.5	0.7	0	49.89	0.24	829.5	0.43	15.88	0	4.08	0.32	0.43	4.21	15.88	0.38	0	0.37	4.08

It can be seen that the fibers exposed to 13 pH-seawater environment degraded completely compared to other environments and least degradation was seen in fibers exposed 7pH environments.

1.4 Physical Properties of Rebars After Exposure to Aggressive Environments

1.4.1 XRF Analysis on Rebars

BFRP rebars were exposed to 16 different environments and XRF analysis was conducted on rebar samples after exposure to aggressive environments. Results obtained from the analysis are tabulated in Table 1.48 below. It can be seen that rebars exposed to 13pH-20000cl^- and 13pH-Seawater environments degraded more in comparison with rebars exposed to other environments.

Table 1.48: XRF results of rebars after exposure to aggressive environments for 300 days

Type	Lot #	pH	Cl^-	Ca %	T %	Cr PPM	Mn %	Fe %	Cu PPM	Zn %	Sr %	Zr %	Mo PPM	Ag %	Ba %	Eu %	Mg %	Al %	Si %	P %	S %	Cl %	K %
A	1	4	0	17.8	3.07	0.03	0.63	47.29	0.34	0.12	0.37	0.2	0.27	1.93	0.33	0.3	0.35	4.31	17.41	0.58	0.00	0.59	3.79
A	1	7	0	17.69	3.16	0.03	0.63	48.39	0.79	0.11	0.3	0.17	0.26	1.6	0.3	0.32	0.31	5.04	160.04	0.42	0.00	0.85	3.78
A	1	10	0	17.37	2.99	0.03	0.63	47.72	0.11	0.13	0.37	0.19	0.27	2.02	0.33	0.27	0.31	4.36	17.6	0.48	0.00	0.56	3.67
A	1	13	0	15.69	2.90	0.03	0.68	46.1	0.68	0.14	0.38	0.2	0.24	1.78	0.3	0.3	0.38	5.99	20.79	0.5	0.00	0.52	2.55
A	1	4	200	18.4	3.05	0.03	0.66	47.71	0	0.12	0.38	0.2	0.28	2.01	0.33	0.29	0.34	4.01	16.49	0.66	0.00	0.6	3.87
A	1	7	200	17.7	3.03	0.03	0.64	48.76	0.67	0.15	0.38	0.2	0.27	2.28	0.37	0.34	0.22	4.24	15.75	0.73	0.00	0.72	3.65
A	1	10	200	17.35	3.02	0.03	0.64	47.96	0.12	0.12	0.36	0.2	0.27	2.12	0	0.27	0.31	4.07	17.66	0.53	0.00	0.66	3.64
A	1	13	200	20.15	4.10	0.04	0.64	43.04	0.13	0.19	0.45	0.23	0.23	1.93	0.29	0.3	1.04	4.14	19.17	0.42	0.00	0.67	2.29
A	1	4	20000	14.79	2.39	0.02	0.52	38.71	0.26	0.93	0.29	0.15	0.21	1.5	0.28	0.22	0.17	2.44	10.89	0.45	0.00	23.21	3.19
A	1	7	20000	13.98	2.25	0.02	0.5	37.75	0.38	0.97	0.3	0.16	0.22	1.6	0.28	0.26	0.16	1.97	9.21	0.43	0.00	27.38	2.98
A	1	10	20000	14.92	2.39	0.02	0.53	39.14	0.35	0.82	0.23	0.12	0.19	1.28	0.24	0.24	0.2	2.57	10.09	0.37	0.00	23.76	3.23
A	1	13	20000	18.23	3.28	0.03	0.69	49.42	0.74	0.12	0.32	0.16	0.22	1.41	0.27	0.33	0.41	3.43	13.02	0.45	0.00	4.36	3.27
A	1	4	Seawater	17.07	2.69	0.02	0.58	43.08	0.59	0.12	0.32	0.16	0.21	1.5	0.25	0.28	0.35	3.24	12.91	0.44	0.00	12.49	3.73
A	1	7	Seawater	15.84	2.49	0.03	0.53	40.05	0.14	0.11	0.3	0.16	0.21	1.46	0.25	0.28	0.77	3.11	12.5	0.38	0.22	17.18	3.51
A	1	10	Seawater	13.99	2.91	0.03	0.54	43.88	0.62	0.12	0.33	0.18	0.24	1.64	0.27	0.27	2.07	2.91	8.79	0.43	0.41	17.29	3.13
A	1	13	Seawater	27.03	1.71	0.04	0.35	27.85	0.76	0.17	0.78	0.29	0.18	4.43	0.71	0.12	0.26	4.1	22.87	1.82	0.00	3.85	2.55
B	1	4	0	17.39	2.88	0.03	0.56	41.8	0.97	0.11	0.34	0.22	0.02	2.03	0.35	0.28	0.29	4.12	22.61	0.51	0.00	0.5	3.71
B	1	7	0	16.73	2.70	0.03	0.59	41.98	0.16	0.12	0.35	0.23	0.00	2.16	0.34	0.23	0.24	3.85	22.37	0.65	0.48	0.57	3.52
B	1	10	0	15.92	2.52	0.03	0.58	44.39	0.32	0.12	0.34	0.22	0.00	1.82	0.29	0.29	0.31	3.93	22.01	0.52	0.44	0.37	3.43
B	1	13	0	20.46	3.06	0.03	0.58	39.1	0.22	0.2	0.51	0.33	0.00	2.87	0.51	0.27	0.88	1.89	21.88	0.86	0.00	1.49	1.42
B	1	4	200	16.95	2.78	0.03	0.58	41.86	922.9	0.11	0.33	0.21	0.00	1.99	0.3	0.25	0.3	3.81	22.61	0.58	0.48	0.76	3.62
B	1	7	200	16.78	2.72	0.03	0.58	42.8	0.19	0.12	0.35	0.23	0.00	2.25	0.34	0.28	0.23	3.84	21.53	0.75	0.00	0.53	3.49
B	1	10	200	16.98	2.76	0.04	0.61	42.93	0.16	0.12	0.34	0.21	0.00	2	0.3	0.26	0.28	3.83	21.38	0.65	0.55	0.52	3.59
B	1	13	200	21.87	3.55	0.02	0.7	47.69	0.32	0.14	0.35	0.22	0.00	1.94	0.34	0.3	0.75	1.75	13.9	0.5	0.23	1.3	1.73
B	1	4	20000	17.75	2.85	0.03	0.58	41.69	0.46	1	0.32	0.2	0.00	1.8	0.29	0.27	0.26	3.11	16.56	0.44	0.30	7.52	3.82
B	1	7	20000	15.42	2.33	0.04	0.57	39.31	0.89	0.13	0.32	0.2	0.00	2.75	0	0.24	0.12	2.51	17.43	0	0.35	12.51	3.21
B	1	10	20000	16.79	2.52	0.03	0.54	37.63	0.57	0.1	0.29	0.2	0.00	1.99	0.35	0.24	0.32	3.32	23.34	0.32	0.98	5.07	3.66
B	1	13	20000	18.19	2.56	0.02	0.54	37.13	0.12	0.11	0.26	0.17	0.00	1.5	0.23	0.25	0.14	1	9.16	0.35	0.22	25.56	0.64
B	1	4	Seawater	16.11	2.47	0.02	0.52	38.43	0.46	0.92	0.29	0.18	0.00	1.65	0.32	0.29	0.31	2.52	12.55	0.44	1.01	17.2	3.48
B	1	7	Seawater	17.43	2.65	0.02	0.53	37.85	0.11	0.11	0.3	0.19	0.02	1.68	0.29	0.23	0.35	2.12	12.95	0.38	0.54	16.41	3.77
B	1	10	Seawater	10.13	2.00	0.02	0.37	31.39	0.61	0.78	0.24	0.15	0.00	1.4	0.23	0.2	0.99	0.94	7.67	0.34	1.27	38.36	2.42
B	1	13	Seawater	26.36	3.25	0.03	0.79	53.34	0.19	0.14	1.12	0.23	0.00	2.3	0.35	0.32	0.1	0.27	5.15	0.16	0.88	2.37	1.02
C	1	4	0	17.95	2.96	376.60	0.69	51.57	652.1	0.14	0.44	0.23	0.48	1.95	0.4	0.34	0.28	3.79	13.14	0.48	0.00	0.67	3.74
C	1	7	0	17.67	2.97	376.40	0.68	51.55	0.13	0.17	0.44	0.23	0.46	2.02	0.36	0.35	0.26	4.14	13.08	0.53	0.00	0.68	3.62
C	1	10	0	17.68	2.99	324.40	0.65	50.51	0.13	0.18	0.39	0.2	0.41	1.95	0.3	0.35	0.3	4.63	13.93	0.52	0.00	0.54	3.65
C	1	13	0	18.4	2.90	378.00	0.68	50.09	0.19	0.17	0.4	0.21	0.40	1.89	0.34	0.37	0.26	4.84	14.75	0.37	0.00	0.44	2.82
C	1	4	200	18.1	2.93	396.00	0.68	49.84	789.9	0.14	0.38	0.19	0.40	1.97	0.31	0.32	0.38	4.19	14.69	0.28	0.00	0.72	3.82
C	1	7	200	17.99	3.01	543.50	0.66	49.96	0.13	0.18	0.39	0.2	0.44	2.37	0	0.34	0.31	4.46	14.18	0	0.00	0.97	3.69
C	1	10	200	17.68	2.93	358.70	0.65	49.01	885.2	0.15	0.4	0.21	0.43	1.94	0.36	0.34	0.32	4.29	13.15	0.51	0.00	3.19	3.7
C	1	13	200	22.14	3.52	369.10	0.76	51.19	946.8	0.15	0.35	0.18	0.34	1.68	0.28	0.32	0.78	3.15	12.03	823.7	0.00	0.56	1.99
C	1	4	20000	15.43	2.36	282.60	0.54	40.89	536.3	0.11	0.32	0.16	0.32	1.55	0.25	0.27	0.19	2.43	8.26	0.41	0.00	22.73	3.3
C	1	7	20000	18.66	3.02	376.00	0.63	45.51	738.7	0.12	0.31	0.16	0.32	1.61	0.24	0.27	0.31	3.79	14.12	0.27	0.00	6.05	3.94
C	1	10	20000	18.24	2.98	372.60	0.74	56.02	0.13	0.18	0.49	0.26	0.52	2.17	0.41	0.37	818.1	1.88	0	0	0.00	10.93	3.77
C	1	13	20000	17.18	2.83	379.70	0.71	52.09	0.26	0.18	0.43	0.22	0.43	1.83	0.35	0.35	0.18	4.45	12.96	0.46	0.00	2.44	1.99
C	1	4	Seawater	18.18	2.86	294.30	0.63	45.74	0	0.12	0.34	0.18	0.38	1.59	0.29	0.3	0.38	3.51	11.76	0.48	0.00	8.85	3.83
C	1	7	Seawater	16.52	2.67	382.20	0.61	45.76	0.25	0.18	0.38	0.2	0.42	1.69	0.31	0.33	0.7	3.21	9.26	0	0.26	12.99	3.53
C	1	10	Seawater	15.69	3.35	455.90	0.68	57.38	0.16	0.19	0.49	0.26	0.49	2.23	0.4	0.37	1.43	1.56	0	0.43	0.00	10.79	3.28
C	1	13	Seawater	17.63	3.36	417.30	0.84	58.92	758.2	0.19	0.65	0.27	0.45	2.49	0.41	0.36	0.23	1.32	6.65	0.68	0.00	2.17	2.47

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Table 1.48: XRF results of rebars after exposure to aggressive environments for 300 days

Type	Lot #	pH	Cl^-	Ca %	T %	Cr PPM	Mn %	Fe %	Cu PPM	Zn %	Sr %	Zr %	Mo PPM	Ag %	Ba %	Eu %	Mg %	Al %	Si %	P %	S %	Cl %	K %
A	2	4	0	19.33	3.71	0.04	0.72	51.48	0.55	0.16	0.35	0.18	0.26	2.06	0	0.35	0.11	2.48	12.26	0.75	0.00	1.36	3.78
A	2	7	0	14.9	2.87	0.04	0.77	57.72	0	0.16	0.48	0.26	0.40	2.87	0.55	0.39	0.13	2.17	11.21	0.88	0.00	0.65	3.05
A	2	10	0	16.72	3.53	0.03	0.68	49.87	0.39	0.13	0.42	0.22	0.31	2.09	0.38	0.28	0.18	2.87	17.05	0.38	0.00	0.76	3.44
A	2	13	0	16.9	2.94	0.04	0.7	51.19	0.52	0.15	0.44	0.23	0.32	1.92	0.4	0.38	0.28	3.28	15.53	0.5	0.00	0.53	3.57
A	2	4	200	17.41	2.96	0.03	0.68	48.98	0.6	0.15	0.44	0.23	0.31	2.49	0.44	0.28	0.21	2.9	15.86	0.62	0.00	1.84	3.47
A	2	7	200	16.37	2.88	0.03	0.72	54.25	0	0.12	0.36	0.19	0.29	1.79	0.32	0.4	0.34	3.25	13.81	0.36	0.00	0.5	3.51
A	2	10	200	17.63	3.03	0.04	0.64	46.47	0.91	0.12	0.38	0.2	0.29	2.16	0.39	0.28	0.32	3.5	17.93	0.72	0.00	1.47	3.71
A	2	13	200	17.36	3.46	0.03	0.8	52.51	0.6	0.15	0.4	0.2	0.28	1.71	0.33	0.37	0.42	3.22	13.62	0.53	0.00	0.73	3.32
A	2	4	20000	12.37	2.33	0.02	0.43	30.95	0.21	0.83	0.24	0.13	0.17	1.28	0.23	0.21	957.3	1.22	6.61	0	0.00	40.35	2.57
A	2	7	20000	15.52	2.61	0.02	0.52	35.7	0	0.85	0.28	0.15	0.21	1.47	0.27	0.22	0.26	2.32	13.76	0.42	0.00	22.67	3.13
A	2	10	20000	16.89	2.99	0.02	0.59	42.56	0.33	1	0.29	0.15	0.22	1.37	0.27	0.27	0.29	2.75	11.77	0.37	0.00	15.13	3.56
A	2	13	20000	16.6	2.98	0.03	0.74	51.14	0.34	0.12	0.34	0.18	0.28	1.88	0.33	0.36	0.32	2.71	15.1	0.56	0.00	2.53	3.28
A	2	4	Seawater	16.9	3.03	0.02	0.58	41.2	0.23	0.95	0.31	0.17	0.22	1.51	0.3	0.27	0.45	2.73	14.41	0.4	0.00	13.08	3.71
A	2	7	Seawater	17.61	2.92	0.03	0.61	43.71	0	0.11	0.35	0.19	0.25	1.78	0.32	0.29	0.45	3.59	18.64	0.49	0.00	4.32	3.83
A	2	10	Seawater	15.07	2.37	0.03	0.5	36.69	0.23	0.9	0.28	0.15	0.20	1.46	0.28	0.22	0.4	1.79	11.19	0.36	0.37	24.79	3.31
A	2	13	Seawater	20.93	2.47	0.03	0.73	52.64	0.53	0.16	0.65	0.24	0.16	1.93	0.32	0.3	0.19	2.21	9.69	0.42	0.00	4.06	2.28
B	2	4	0	17.52	2.73	0.03	0.57	41.41	0.97	0.12	0.32	0.2	0.00	1.83	0.33	0.28	0.33	3.69	17.57	0.58	0.78	5.59	3.73
B	2	7	0	17.67	2.72	0.03	0.61	43.36	0.11	0.12	0.31	0.19	0.00	2.06	0	0.31	0.36	4.24	19.81	0	1.60	0.51	3.75
B	2	10	0	18.39	2.76	0.04	0.63	43.34	0.13	0.12	0.35	0.21	0.00	1.77	0.32	0.27	0.44	4.28	19.19	0.54	0.27	0.69	3.89
B	2	13	0	21.74	3.25	0.03	0.67	46.88	0.14	0.14	0.37	0.23	0.00	1.87	0.34	0.34	0.63	2.39	14.69	0.48	0.00	0.73	2.37
B	2	4	200	17.66	2.81	0.02	0.61	43.68	0.81	0.12	0.36	0.23	0.00	2	0.33	0.26	0.33	4.11	19.04	0.59	0.37	0.87	3.72
B	2	7	200	17.83	2.70	0.02	0.62	42.3	0.3	0.12	0.32	0.2	0.00	1.86	0.3	0.24	0.37	3.8	18.3	0.58	0.20	3.89	3.82
B	2	10	200	17.28	2.53	0.03	0.61	42.87	0.18	0.12	0.37	0.22	0.00	1.96	0.33	0.31	0.4	3.9	19.61	0.56	0.97	1.6	3.66
B	2	13	200	20.69	3.12	0.03	0.65	43.63	0.11	0.12	0.3	0.18	0.00	1.61	0.28	0.29	0.82	1.94	12.71	0.42	0.52	8.28	2.16
B	2	4	20000	16.3	2.47	0.02	0.46	32.96	0.43	0.77	0.23	0.15	0.01	1.49	0.24	0.22	0.35	3.54	16.47	0.48	0.00	19.09	3.5
B	2	7	20000	16.56	2.54	0.02	0.55	39.81	0.8	0.1	0.31	0.19	0.00	1.57	0.26	0.25	0.28	2.94	13.88	0.46	0.34	14.2	3.53
B	2	10	20000	16.98	2.53	0.02	0.55	38.74	0.71	0.93	0.31	0.19	0.00	1.52	0.26	0.27	0.3	3.27	16.91	0.45	0.30	11.68	3.65
B	2	13	20000	24.55	4.18	0.03	0.65	44.79	0.19	0.14	0.35	0.23	0.00	1.63	0.32	0.31	0.43	1.02	8.24	0.39	0.18	8.88	1.21
B	2	4	Seawater	17.01	2.64	0.03	0.59	41.66	0.55	0.95	0.33	0.2	0.00	1.63	0.3	0.27	0.39	2.87	13.4	0.47	0.88	11.08	3.88
B	2	7	Seawater	17.6	2.60	0.03	0.57	39.77	0.64	0.11	0.32	0.2	0.00	1.84	0.3	0.24	0.52	3.84	19.88	0.54	0.70	4.75	3.84
B	2	10	Seawater	12.38	2.30	0.03	0.46	37.23	0.97	0.99	0.3	0.19	0.00	1.6	0.25	0.25	1.29	1.3	7.98	0.5	0.99	27.75	2.87
B	2	13	Seawater	23.65	3.56	0.03	0.69	49.5	0.26	0.13	1.03	0.2	0.00	1.58	0.27	0.31	0.78	0.95	10.93	0.37	0.45	2.14	0.78
C	2	4	0	17.41	3.06	340.30	0.67	51.6	0.16	0.16	0.43	0.23	0.45	1.94	0.34	0.32	0.29	3.89	12.56	0.58	0.00	1.4	3.62
C	2	7	0	18.19	3.02	356.10	0.67	49.36	0.18	0.17	0.37	0.19	0.37	1.84	0	0.28	0.38	4.69	15.17	0	0.00	0.62	3.84
C	2	10	0	18.56	2.97	371.50	0.69	49.2	0.15	0.16	0.39	0.2	0.39	1.84	0.31	0.34	0.38	4.08	15.02	0.35	0.00	0.49	3.8
C	2	13	0	19.45	3.01	377.70	0.71	49.01	0.12	0.15	0.36	0.18	0.36	1.49	0.26	0.31	0.37	4.45	15.08	0	0.00	0.56	3.48
C	2	7	Seawater	18.27	3.07	336.50	0.65	49.31	0.13	0.16	0.39	0.2	0.40	1.77	0.32	0.34	0.31	4.52	14.5	0.47	0.00	0.7	3.82
C	2	4	200	18.14	2.97	412.30	0.66	48.9	0.2	0.18	0.36	0.18	0.35	1.8	0.3	0.31	0.39	4.87	15.31	0	0.00	0.58	3.81
C	2	7	200	18.32	3.03	355.50	0.65	47.49	0.14	0.17	0.34	0.18	0.37	1.71	0.27	0.33	0.4	5.26	16.12	0	0.00	0.69	3.85
C	2	10	200	19.24	2.99	373.60	0.77	53.33	0.11	0.21	0.43	0.23	0.45	1.73	0.33	0.34	0.43	3.14	11.91	0.46	0.00	0.5	2.71
C	2	13	200	17.69	2.85	312.30	0.63	47.29	692	0.13	0.36	0.19	0.38	1.62	0.3	0.3	0.35	4.01	13.06	0.47	0.00	5.9	3.76
C	2	4	20000	17.27	2.63	386.80	0.62	44.62	952.7	0.14	0.37	0.19	0.37	1.64	0.28	0.31	0.29	3.43	12.5	0.5	0.00	10.46	3.66
C	2	7	20000	17.98	2.75	388.00	0.62	44.03	772.7	0.14	0.33	0.17	0.33	1.58	0.24	0.31	0.42	3.63	13.55	0	384.20	9.3	3.86
C	2	10	20000	17.37	2.72	430.30	0.66	46.31	630.9	0.16	0.35	0.18	0.34	1.59	0.26	0.32	0.22	6.57	18.67	0	0.00	1.35	2.06
C	2	13	20000	17.55	2.66	324.50	0.54	39.46	497.6	0.11	0.28	0.14	0.28	1.45	0.24	0.3	0.4	3.28	11.57	0.36	0.12	16.79	3.84
C	2	4	Seawater	17.94	2.67	318.50	0.61	43.52	0.18	0.16	0.32	0.17	0.29	1.5	0.23	0.26	0.48	3.56	12.98	0.28	0.00	10.34	3.88
C	2	10	Seawater	16	2.85	380.40	0.61	48.92	0.14	0.15	0.39	0.21	0.42	1.8	0.35	0.34	2.42	3.52	9.38	0.51	0.00	7.97	3.36
C	2	13	Seawater	21.05	2.53	305.30	0.55	42.53	702.6	0.13	0.69	0.22	0.31	1.8	0.38	0.26		6.51	18.29	0.42	0.00	1.63	1.98

1.4.2 Glass Transition Temperature of Rebar Samples

Glass transition analysis on rebars was conducted using differential scanning calorimeter. Results obtained from the analysis are presented in the form of graphs in Figures 1.50, 1.51, 1.52, 1.53, 1.54, and 1.55. It can be seen in graphs that the glass transition temperature

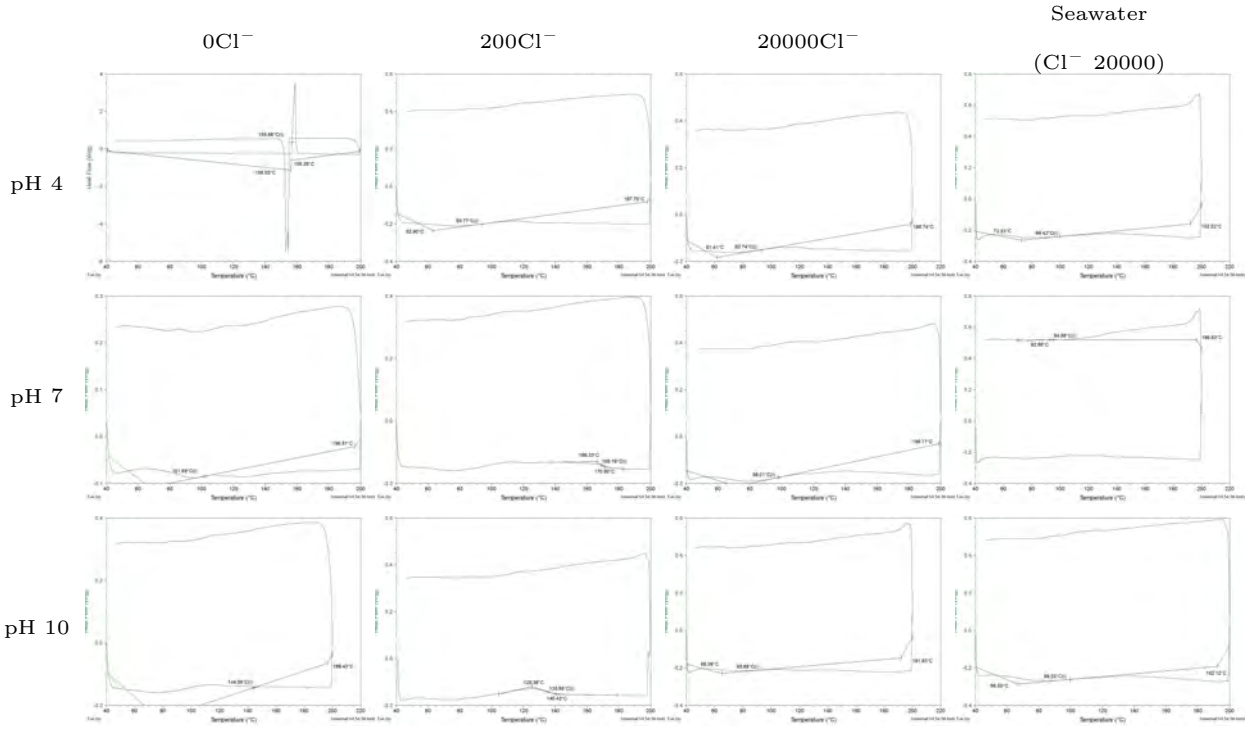

Figure 1.50: Glass transition temperature of exposed Type A Lot 1 rebars

of rebars differed between types but it was similar among the same type regardless of the production lot and exposure condition.

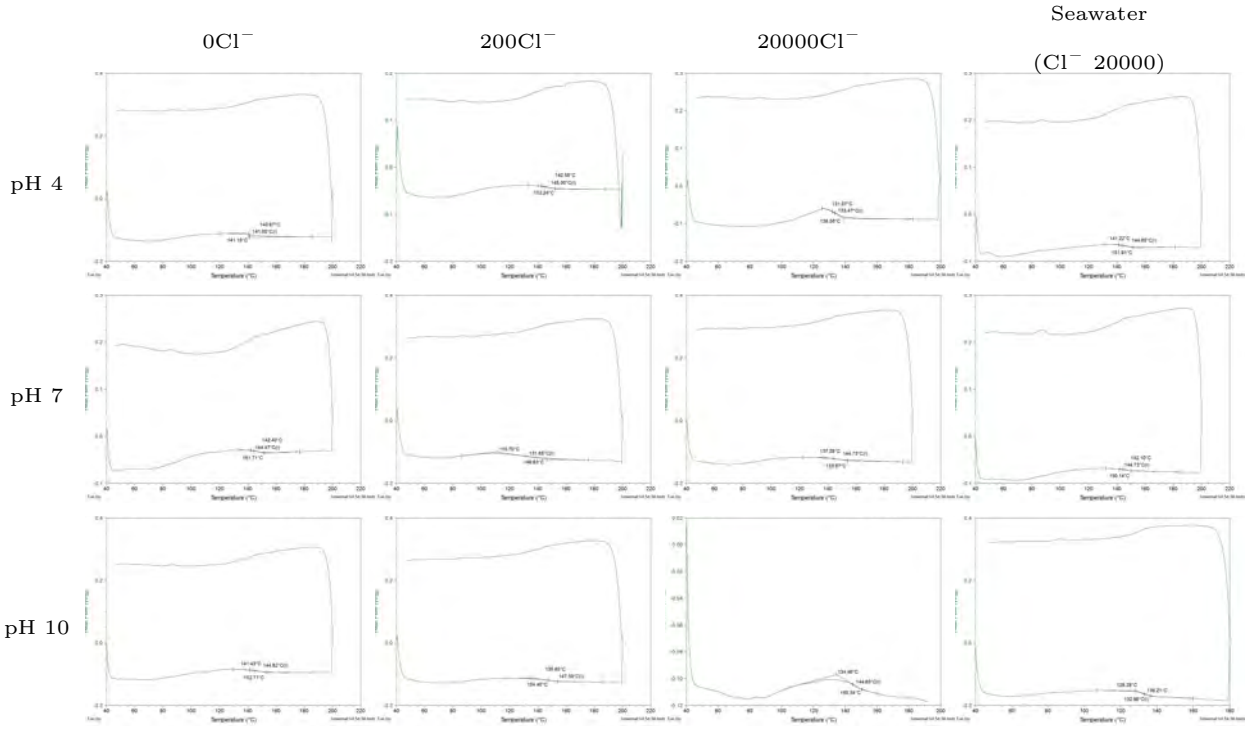

Figure 1.51: Glass transition temperature of exposed Type B Lot 1 rebars

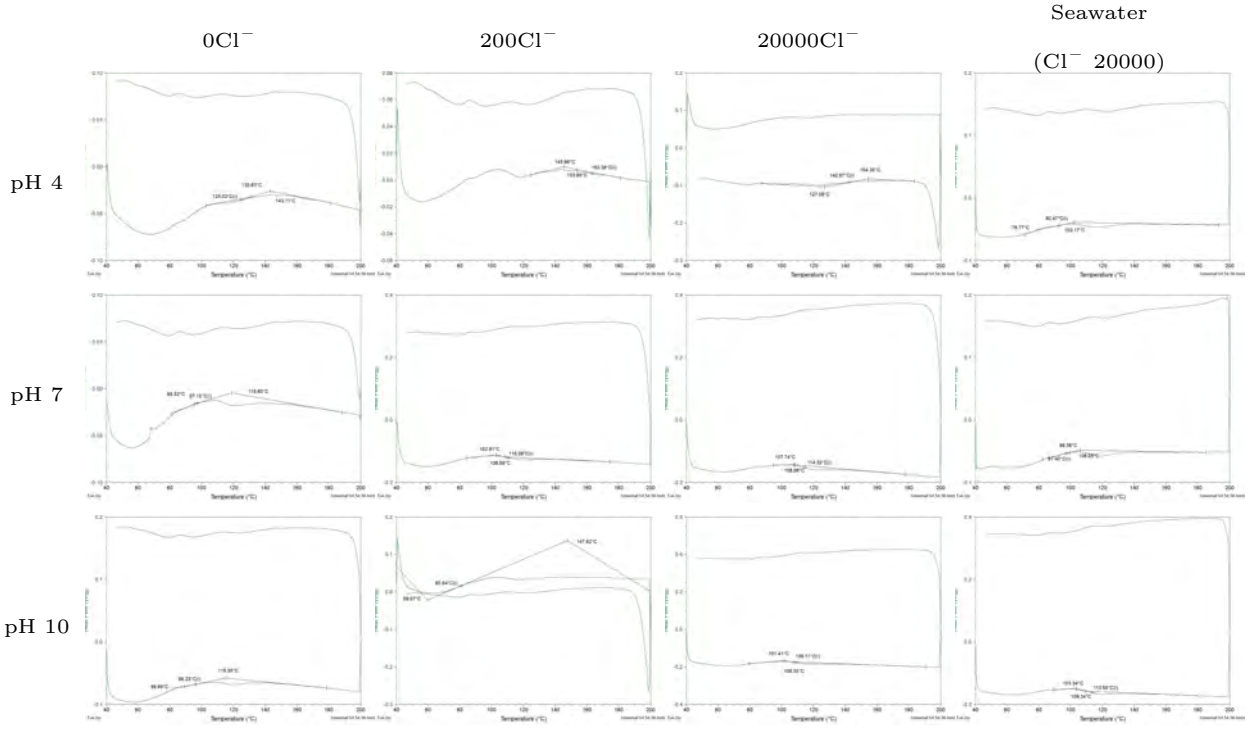

Figure 1.52: Glass transition temperature of exposed Type C Lot 1 rebars

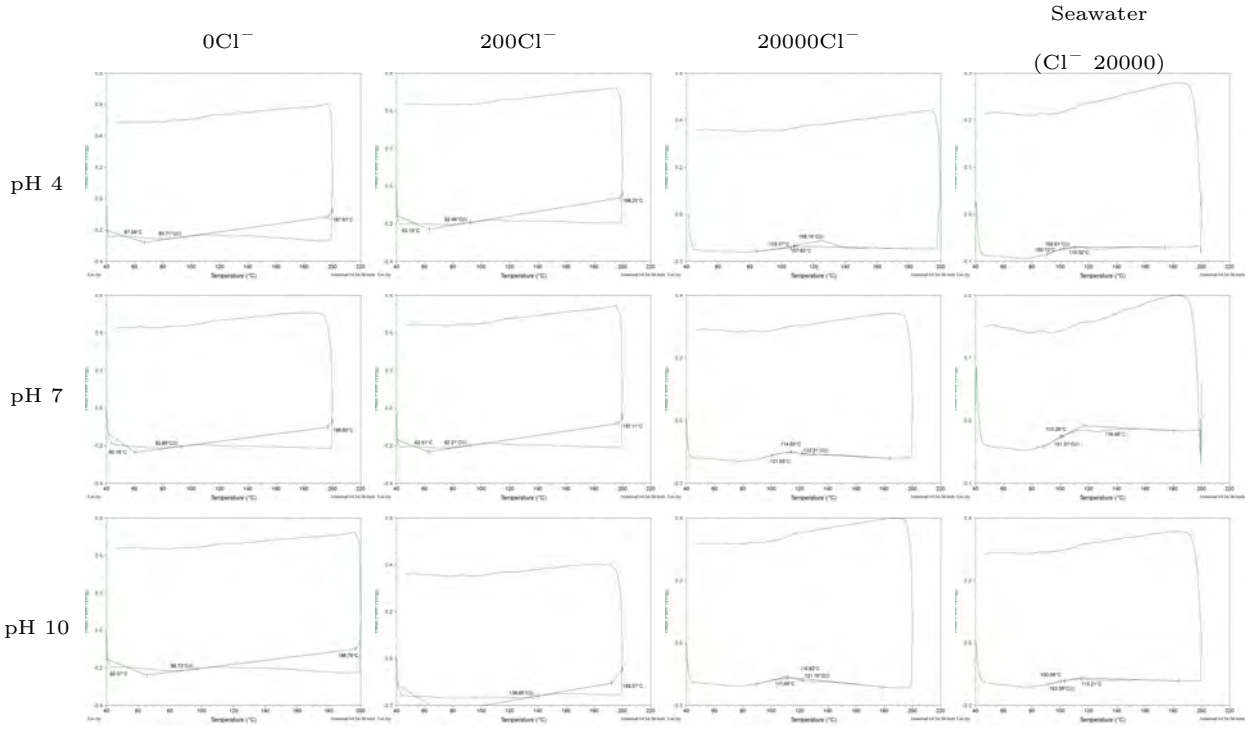

Figure 1.53: Glass transition temperature of exposed Type A Lot 2 rebars

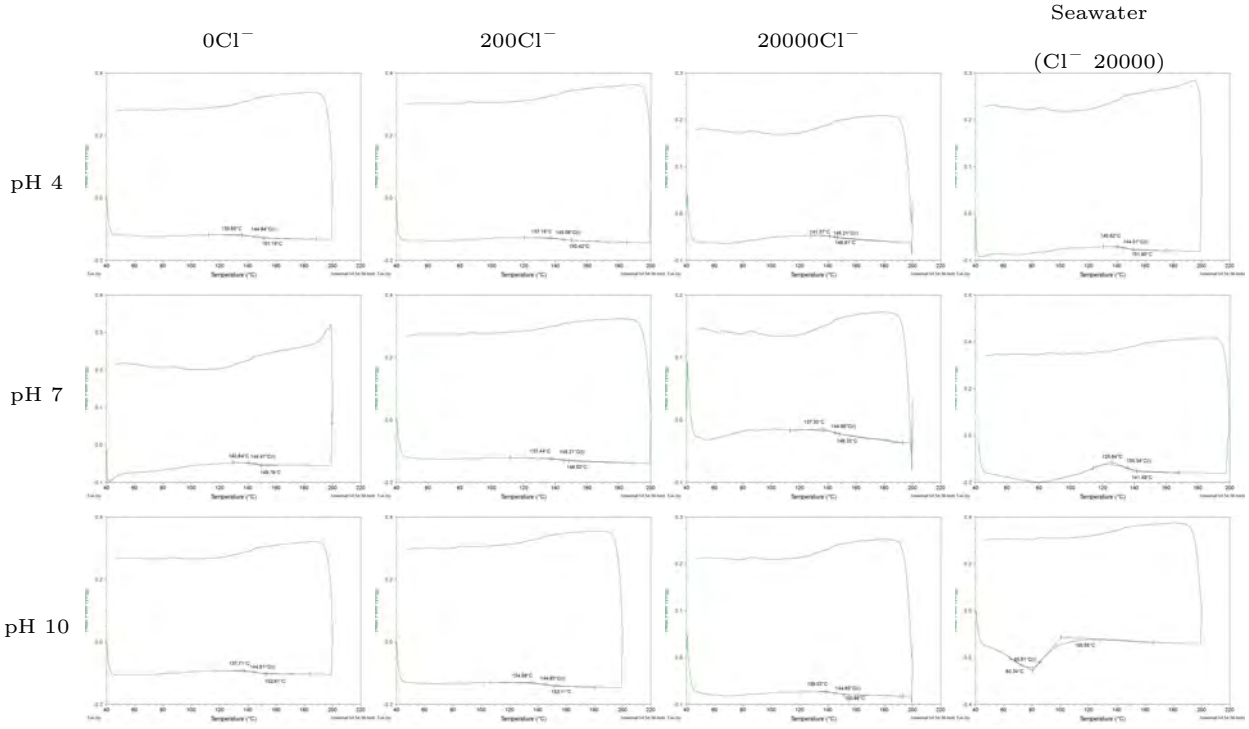

Figure 1.54: Glass transition temperature of exposed Type B Lot 2 rebars

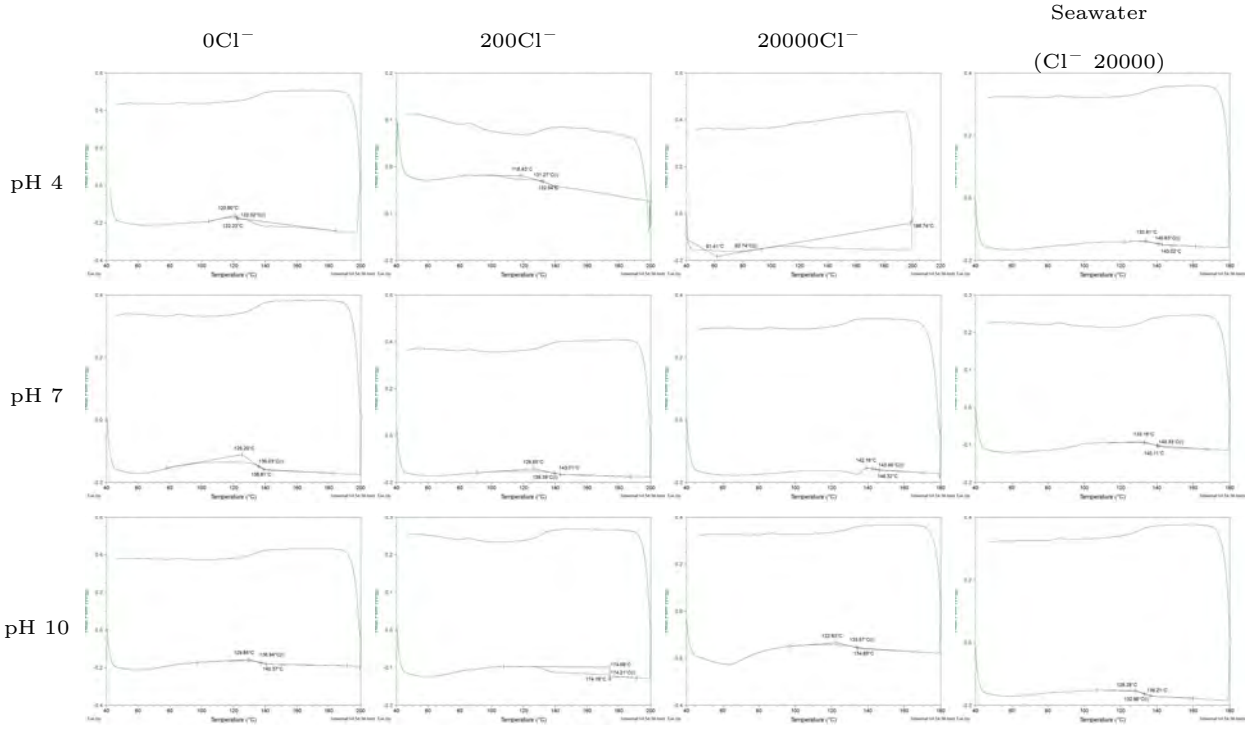

Figure 1.55: Glass transition temperature of exposed Type C Lot 2 rebars

1.5 Rebar Mechanical Properties

1.5.1 Transverse Shear Test

ASTM D 7617 (ASTM-International, 2012b) was used in the process of testing and analyzing the transverse shear strength of the rebars. Tested and processed data are plotted in the following sections 1.5.1 and 1.5.1.

Load-Displacement

The graphs plotted in Figures 1.56, 1.57, 1.58, 1.59, 1.60, and 1.61 show the load-displacement behavior recorded during the transverse shear tests of # 3 and # 5 rebars from all rebar types and exposure environments tested in this study. The x-axis of the graph represents the cross-head extension or the relative displacement between the edges of the directly sheared specimen, while the y-axis shows the measured force throughout the load application period.

The Graph in figure 1.56 shows a linear behavior until it reaches the ultimate failure load. It can be seen that # 5 sized rebar sustained higher load in comparison with # 3 rebars. It can be seen that rebars exposed to 4pH and 7pH sustained a consistent load while the extension of the rebars varied. The graph in Figure 1.57 shows a comparison between the load and the displacement for transverse shear strength of # 3 and # 5 rebars Lot 1 from Type B rebar. It can be seen that the graph had a linear behavior until it reached the ultimate failure load. All the rebars sizes sustained a consistent load with similar extension. The Graph in Figure 1.58 shows the load - displacement behavior of Type C rebars. Linearity can be seen until it reaches the ultimate failure load. It can be seen that # 5 sized rebar sustained higher load in comparison with # 3 rebars. The graph in Figure 1.59 presents a comparison between the load and the displacement for of transverse shear strength of # 3 and # 5 rebars from Type A from Lot 2. The graph shows a linear behavior until it reached approximately 90% of the ultimate failure load. The visualized data in Figure 1.60 show the load-displacement behavior for transverse shear strength of # 3 and # 5 rebars Lot 2 from Type B rebar. It can be seen that the material behaved linearly until approximately 90 % of the ultimate failure load was reached. All the # 3 rebars sustained a consistent load while # 5 rebars sustained same peak load but the extension of the rebars varied. The graph in Figure 1.61 shows a comparison between the load and the displacement for transverse shear strength of # 3 and # 5 rebars from Lot 2. The graph shows a linear behavior until it reached approximately 90% of the ultimate failure load.

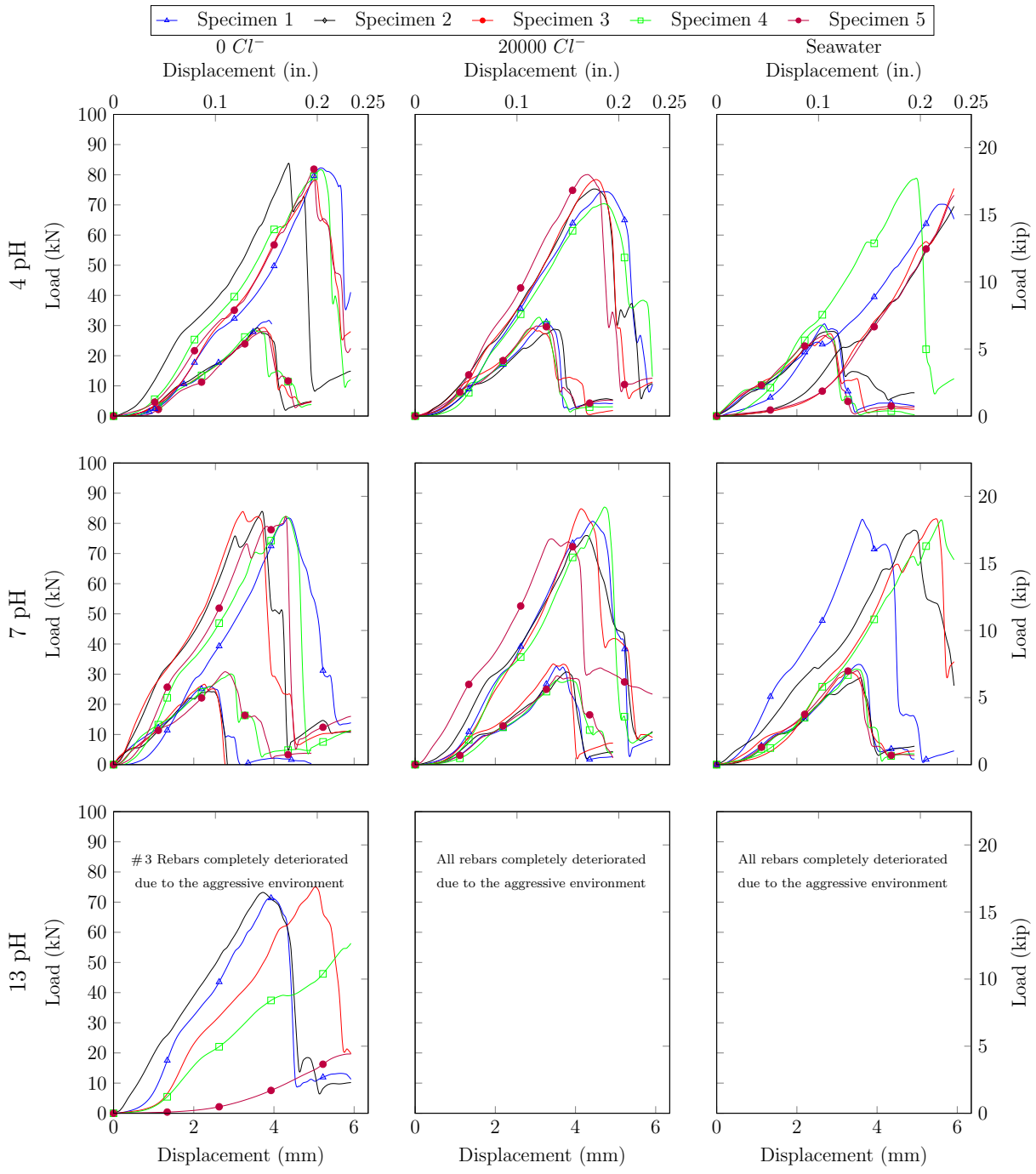

Figure 1.56: Transverse shear force - extension concentration of Type A Lot1 tested rebars

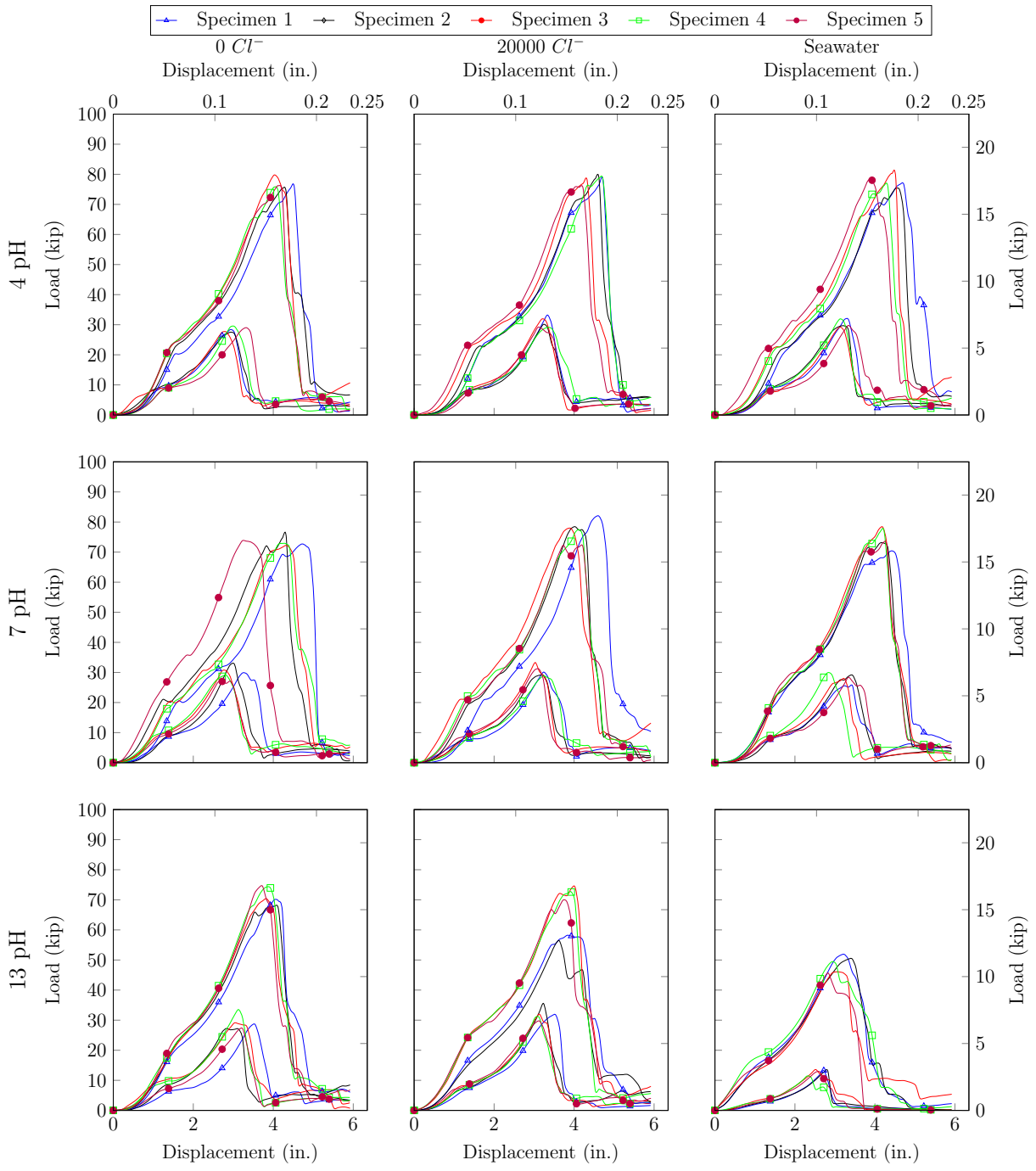

Figure 1.57: Transverse shear force - extension concentration of Type B Lot1 tested rebars

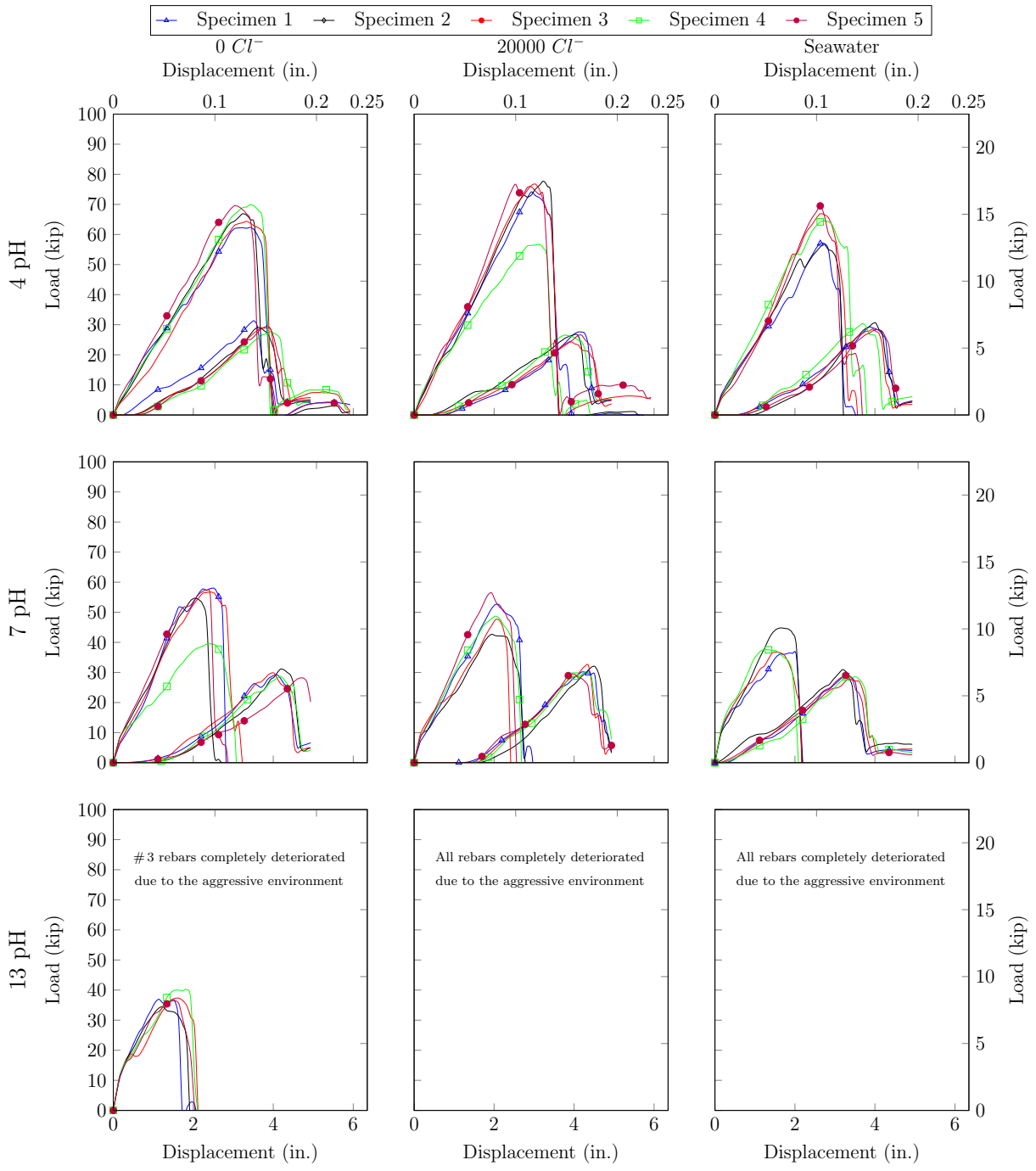

Figure 1.58: Transverse shear force - extension concentration of Type C Lot1 tested rebars

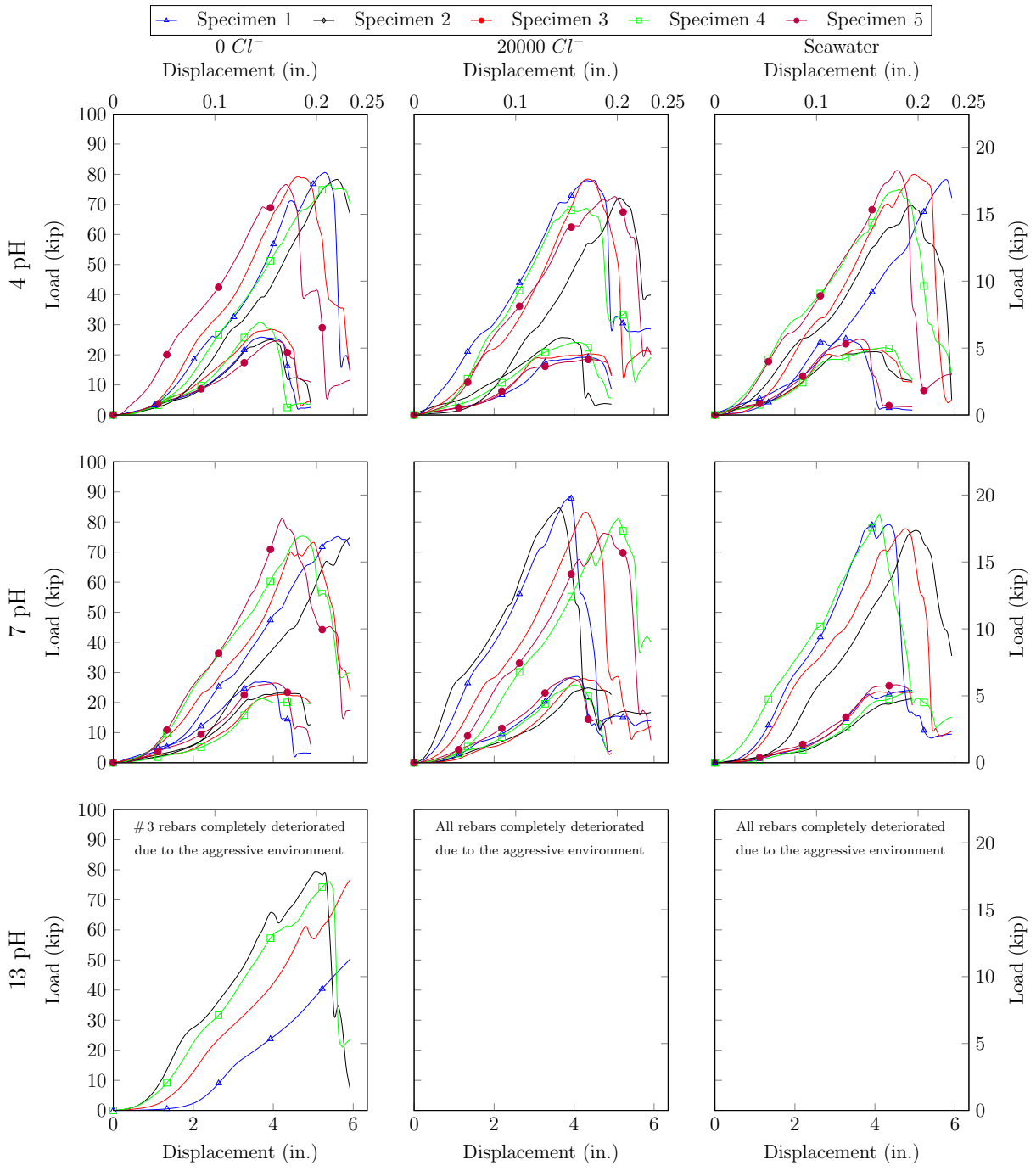

Figure 1.59: Transverse shear force - extension concentration of Type A Lot2 tested rebars

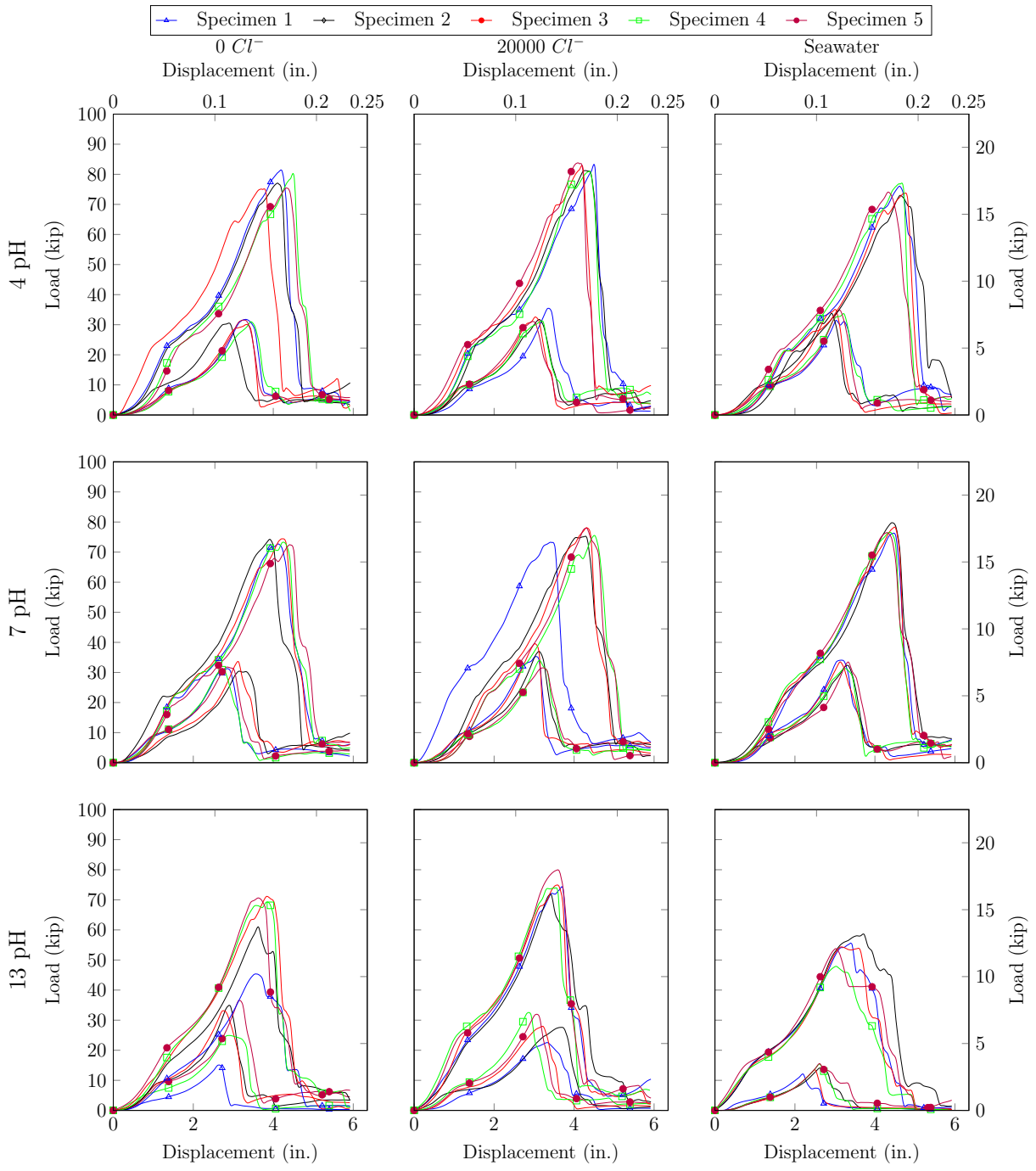

Figure 1.60: Transverse shear force - extension concentration of Type B Lot2 tested rebars

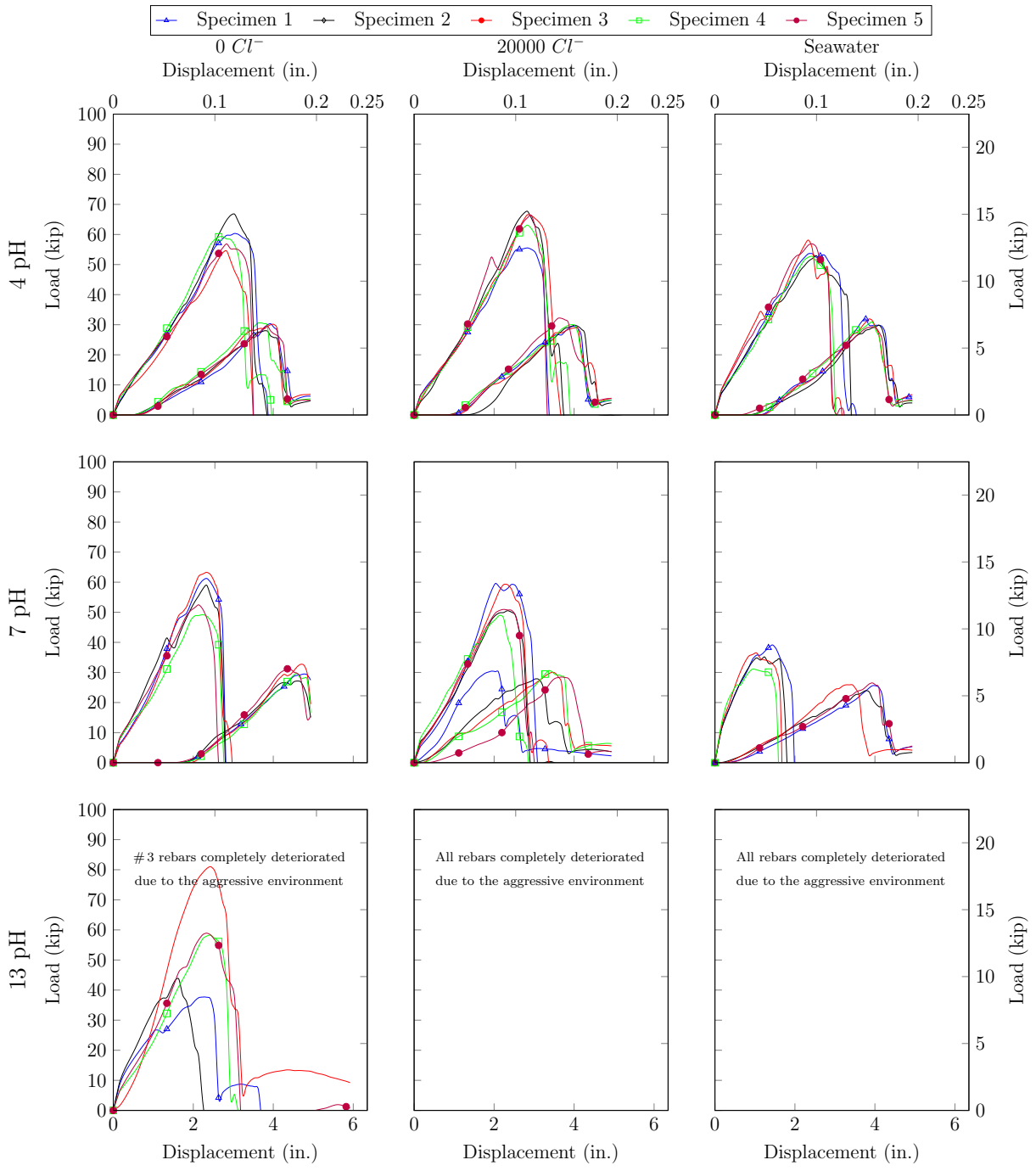

Figure 1.61: Transverse shear force - extension concentration of Type C Lot2 tested rebars

Transverse Stress-Displacement

The results obtained from the transverse test was properly reduced and analyzed. These results are shown via graphs and table. The graphs in Figures 1.62, 1.63, 1.64, 1.65, 1.66, and 1.67 compare the stress-displacement behavior of transverse shear test of # 3 and # 5 rebars from all rebar types that were tested for this research project. The data along the x-axis represents the cross-head extension or the direct shear displacement, while the y-axis signifies the measured shear stress.

The data in Figure 1.62 show that the material behaved nearly linearly until the ultimate failure load was reached. It can be seen in Figure 1.62 that the stress-strain behavior of all rebars was close but not identical—specifically, it varied significantly for rebar number # 5.

The graph in Figure 1.63 presents the stress-displacement behavior of transverse shear test of rebar Type B Lot 1. From the stress-strain behavior of rebar Type B as shown in Figure 1.63, it can be seen that the rebars underwent similar failure behavior. The graph in Figure 1.64 compares the stress - strain behavior of Type C rebar from Lot 1. It shows the linearity of tested rebar until the ultimate failure load was reached. It can be seen in Figure 1.64 that the stress-strain behavior of all rebars was close but not identical—specifically, it varied significantly for rebar number # 5. The graph in Figure 1.65 presents the stress-displacement behavior of transverse shear test of rebar Type A Lot 2. The graphs display a mostly linear behavior until the ultimate failure load was reached. Figure 1.66 shows the stress-displacement behavior of transverse shear test of rebar Type B Lot 2. It can be seen that the data represented a nearly linear behavior until the ultimate failure load was attained. The stress-displacement behavior of failed rebar specimen from both types from Lot 2 in Figures 1.65 and 1.66 show that, although the ultimate failure capacity of the rebars varied significantly, all the rebar samples failed in a identical manner. The graph in Figure 1.67 presents the stress-displacement behavior of transverse shear test of Lot 2 rebars from Type C manufacturer. From the stress-displacement behavior of rebar as shown in Figure 1.67, it can be seen that the rebars underwent similar failure behavior.

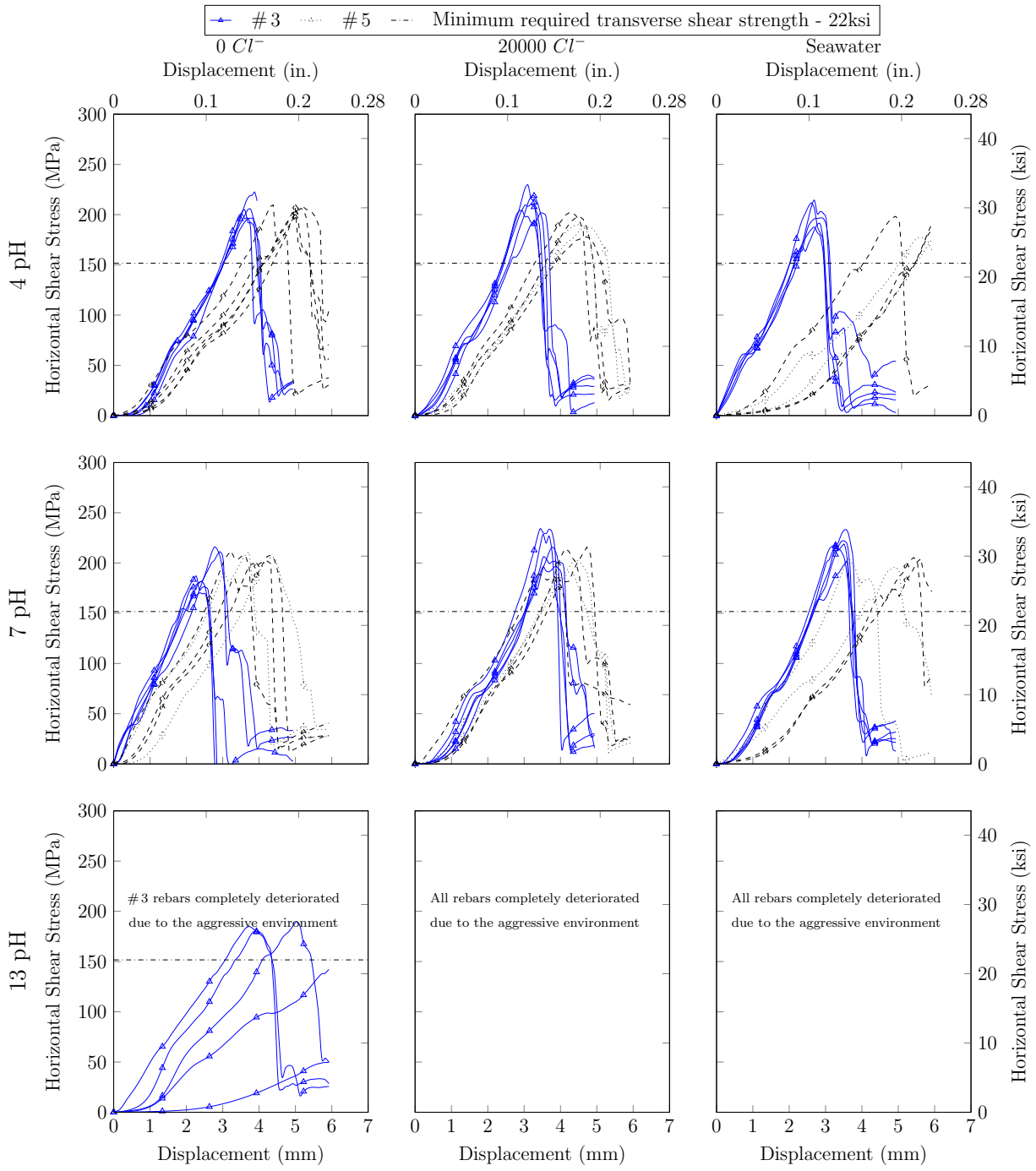

Figure 1.62: Transverse shear stress - extension concentration of Type A Lot1 tested rebars

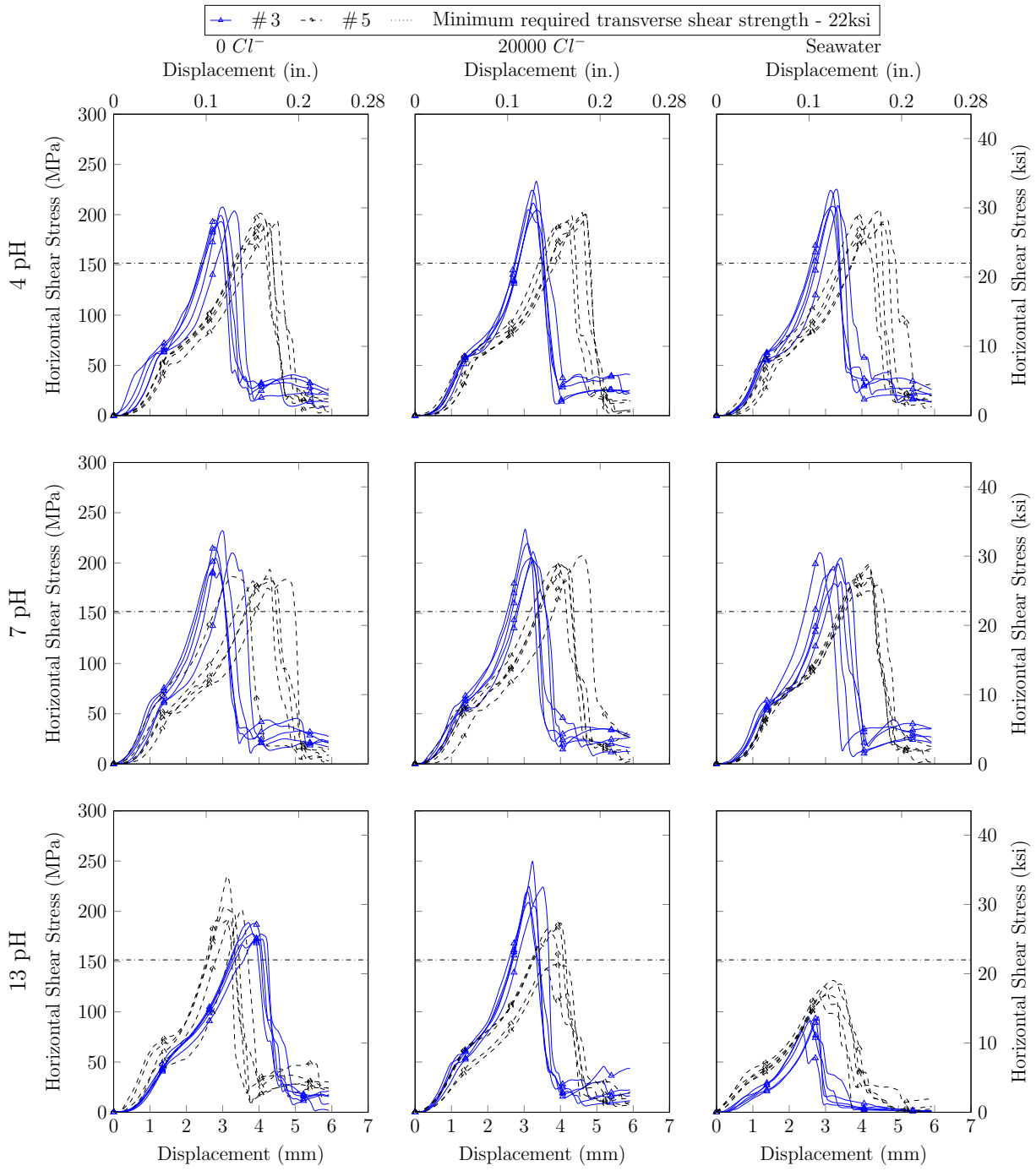

Figure 1.63: Transverse shear stress - extension concentration of Type B Lot1 tested rebars

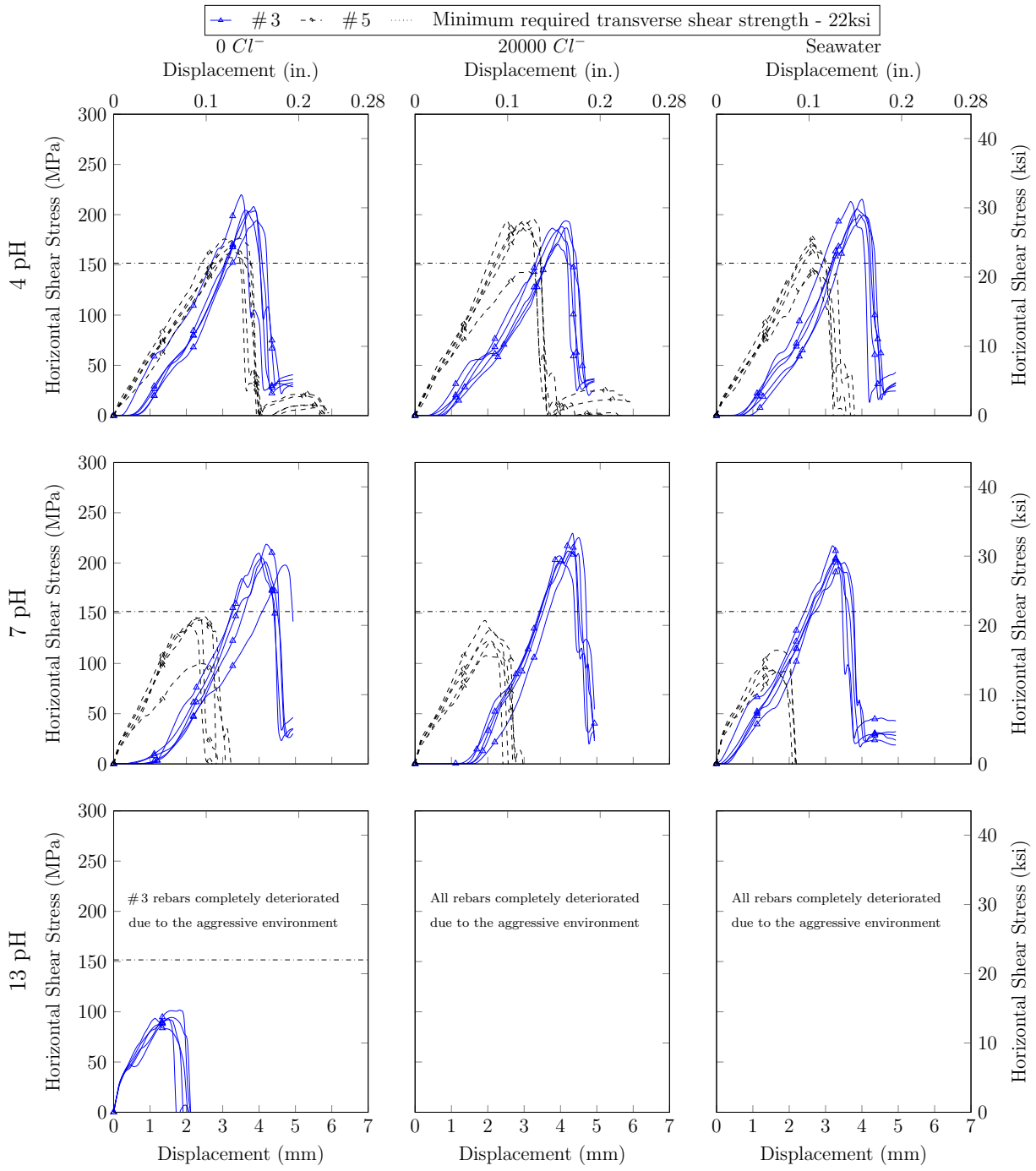

Figure 1.64: Transverse shear stress - extension concentration of Type C Lot1 tested rebars

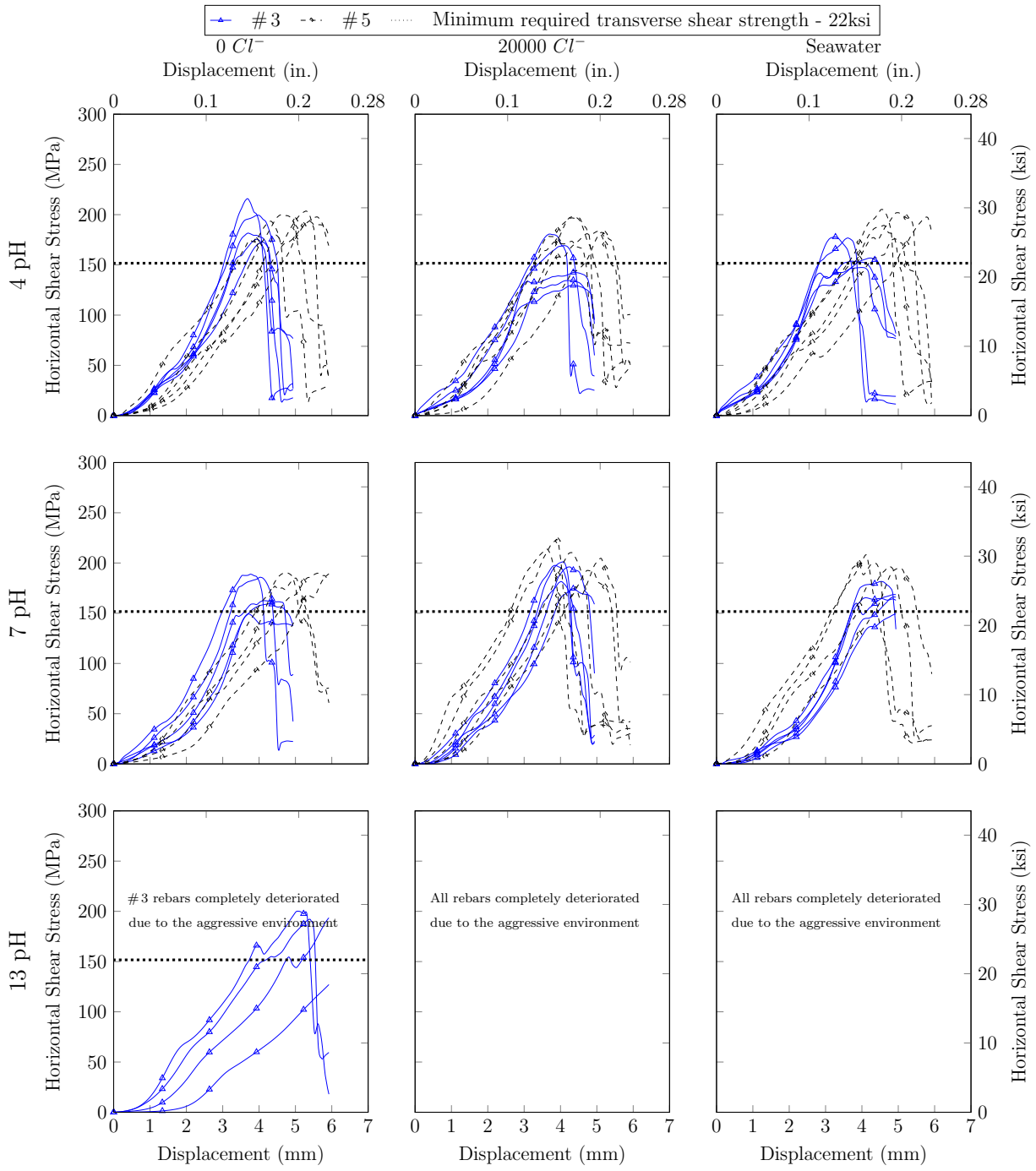

Figure 1.65: Transverse shear stress - extension concentration of Type A Lot2 tested rebars

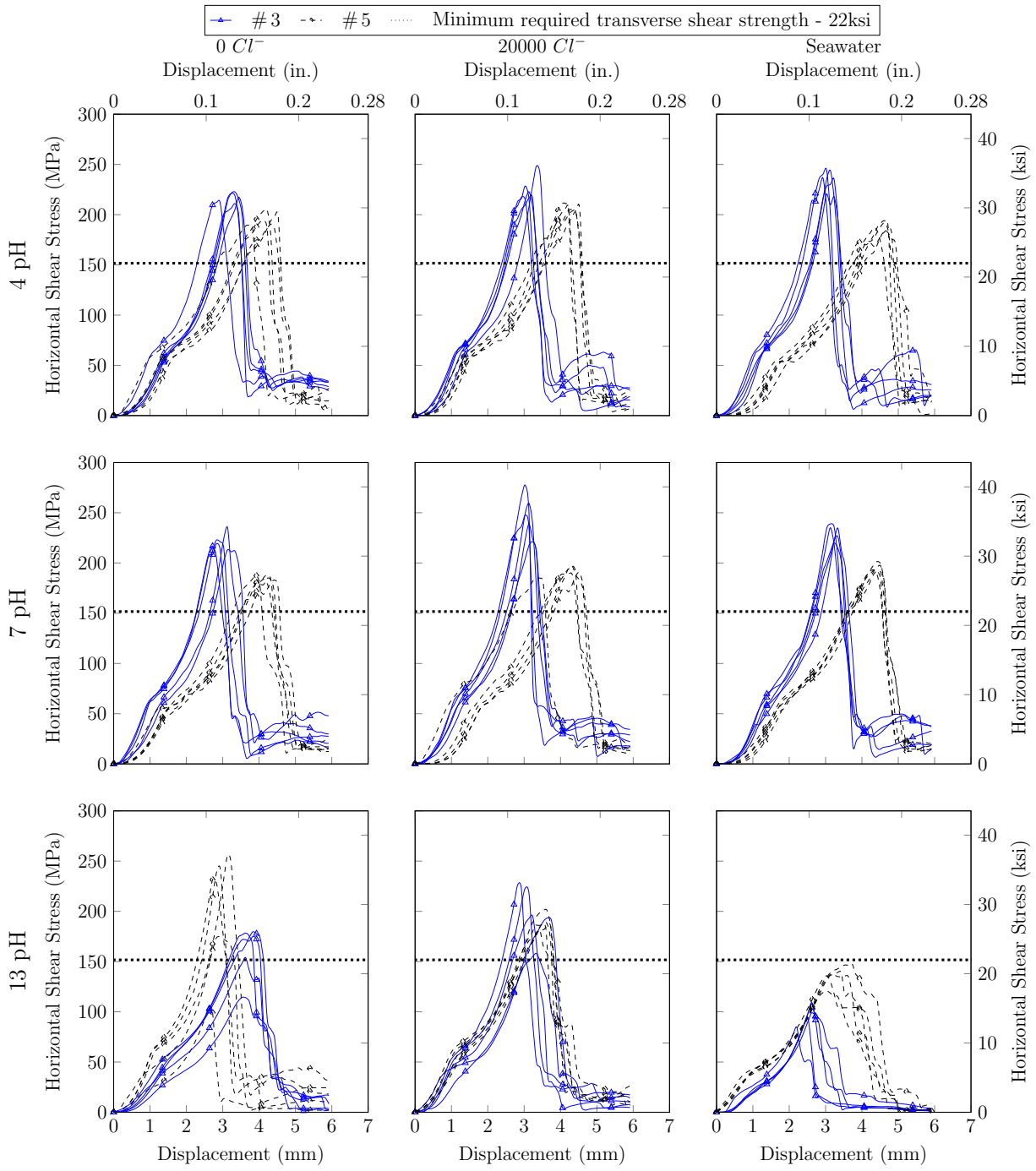

Figure 1.66: Transverse shear stress - extension concentration of Type B Lot2 tested rebars

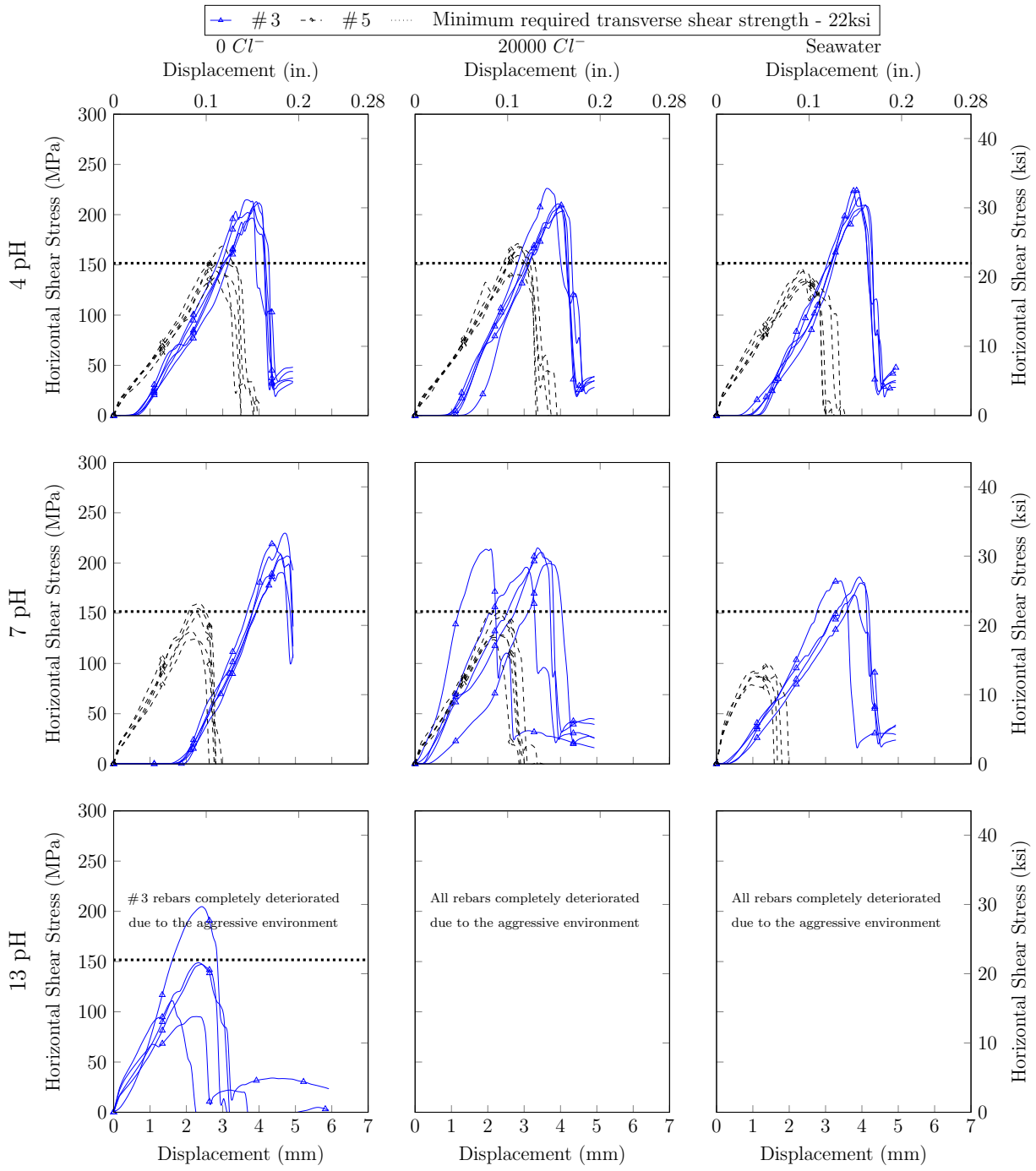

Figure 1.67: Transverse shear stress - extension concentration of Type C Lot2 tested rebars

1.5.2 Modes of Failure

To study the failure process, the failed BFRP rebars were analyzed in detail to observe the failure pattern of outer fibers and inner fibers.

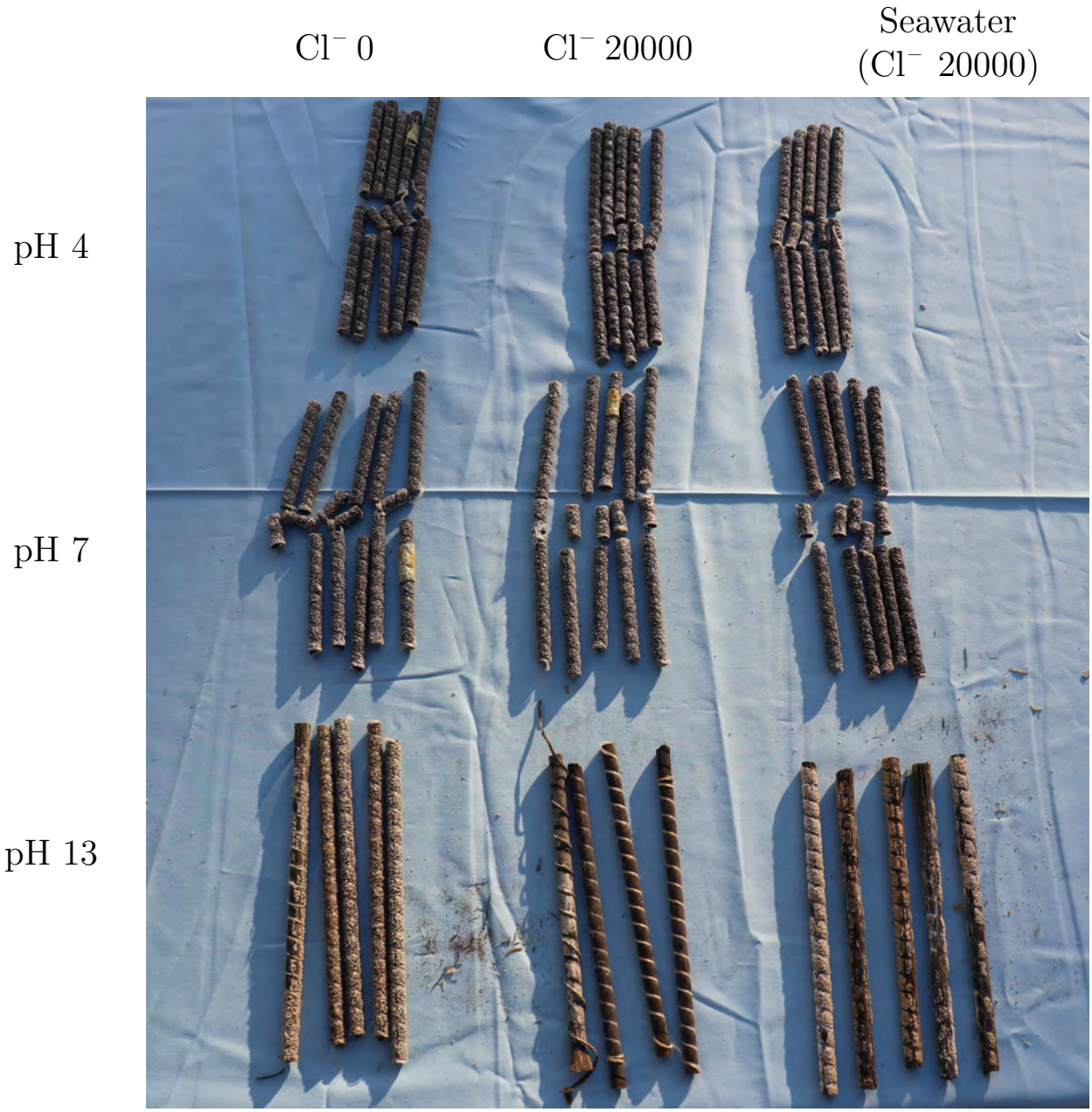

Figure 1.68: Transverse shear failure mode of Type A # 3 rebars

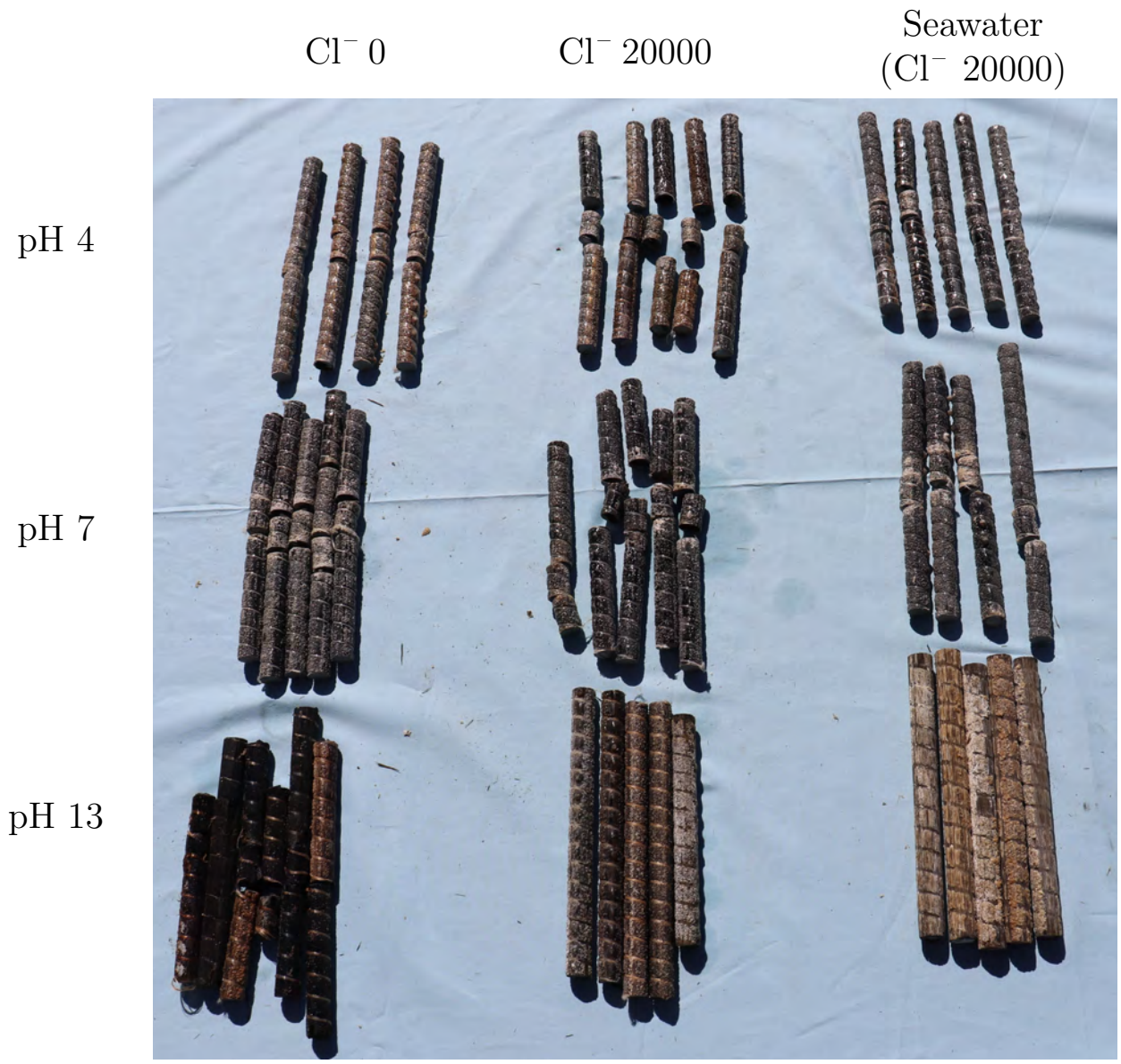

Figure 1.69: Transverse shear failure mode of Type A #5 rebars

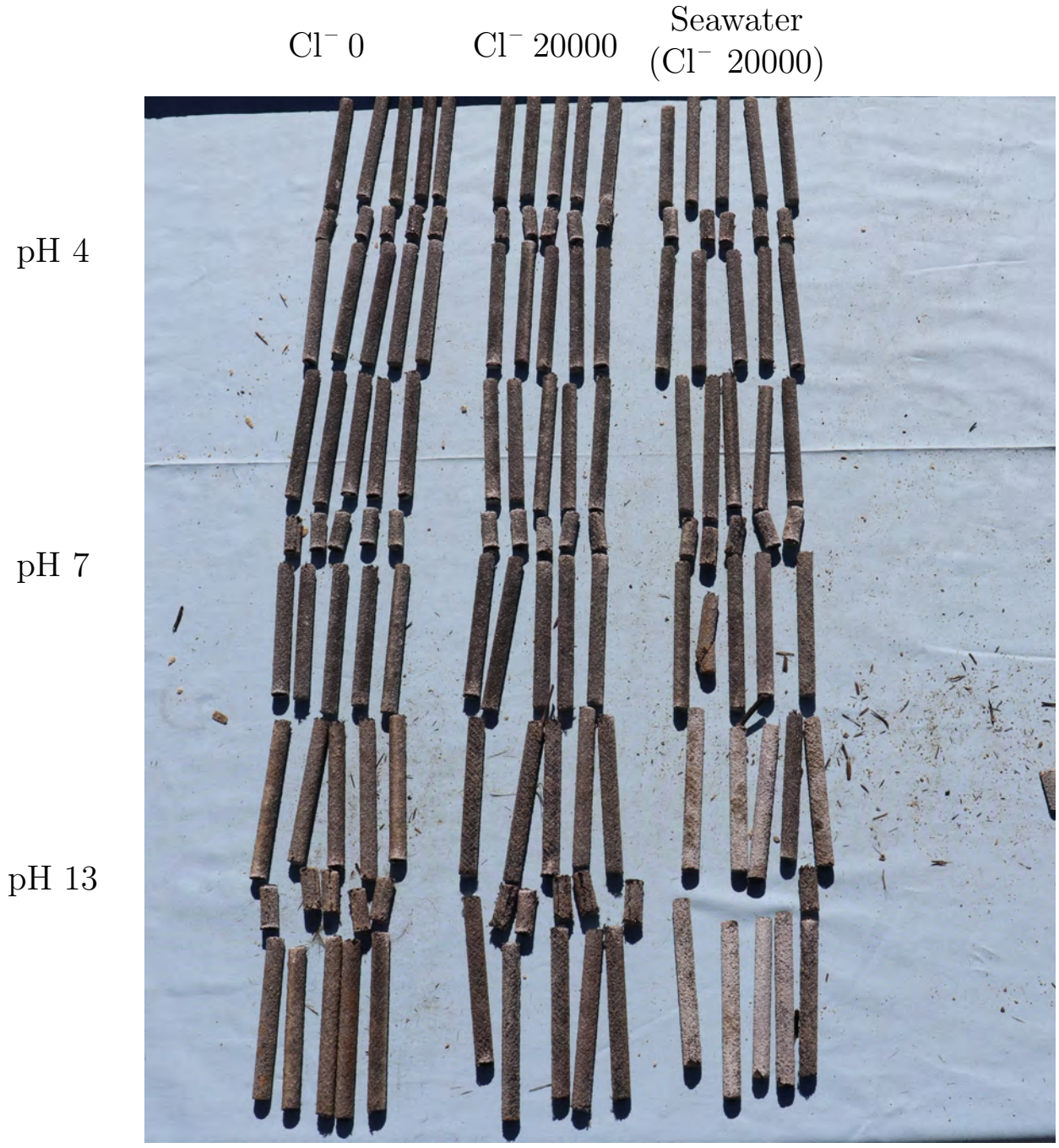

Figure 1.70: Transverse shear failure mode of Type B # 3 rebars

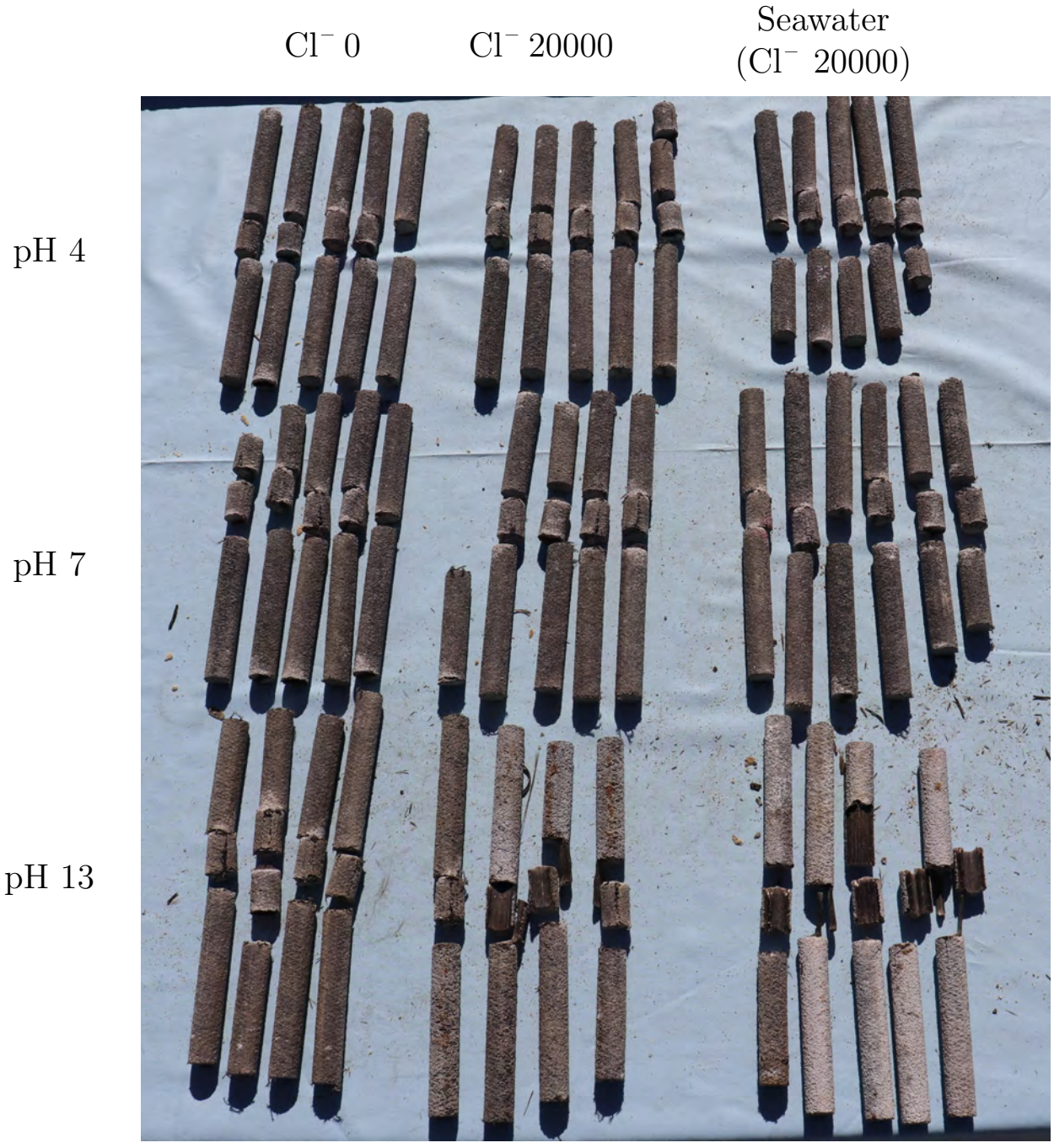

Figure 1.71: Transverse shear failure mode of Type B # 5 rebars

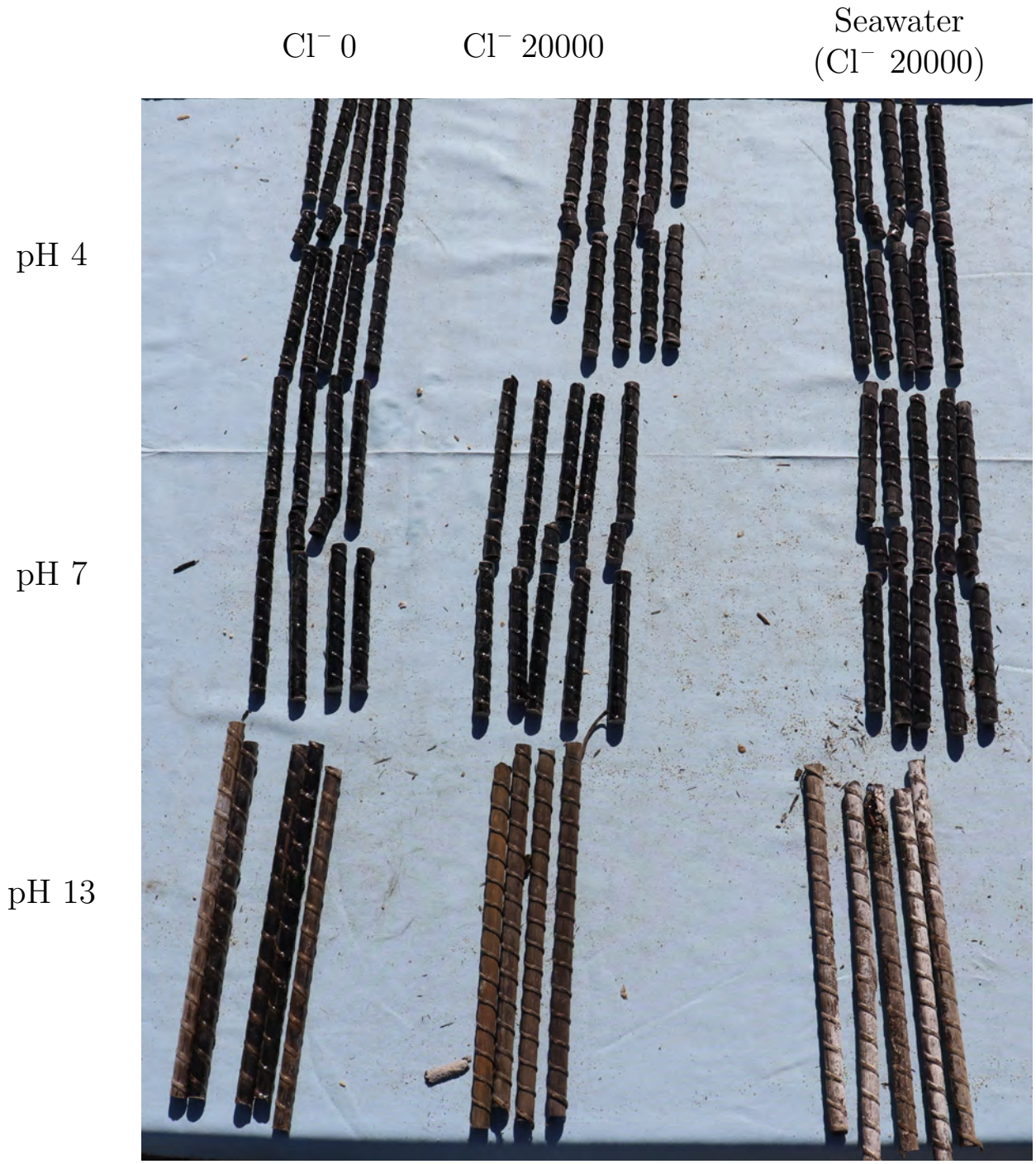

Figure 1.72: Transverse shear failure mode of Type C # 3 rebars

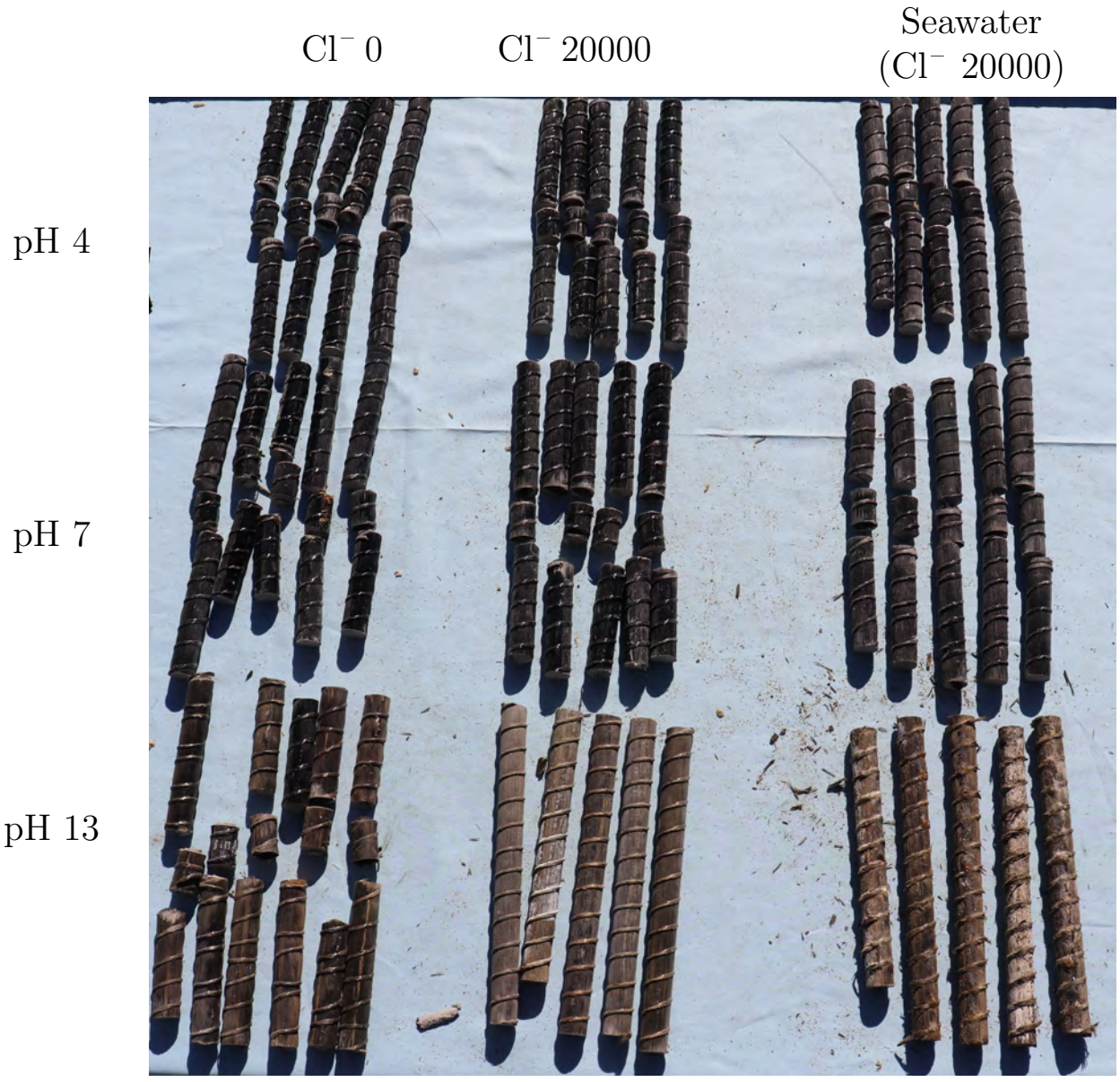

Figure 1.73: Transverse shear failure mode of Type C # 5 rebars

1.5.3 Summary of Transverse Shear Properties

The concentration of the statistical evaluation for the transverse shear strength properties of the tested products are listed in the following Table 1.49. A total of 250 specimen, five for each rebar type, size, lot, and exposure type were tested. The average and all other statistical values were calculated based on a sample size of five specimen, and the corresponding results are shown in the table. For numerical comparison and concluding values, Table 1.49 lists the minimum shear stress ($\wedge$), the maximum shear stress ($\vee$), the average shear stress (μ), the standard deviation (σ), and the coefficient of variation (CV) for each individual test sample.

Table 1.49: Transverse Shear test statistical values for each sample group (US Customary Units)

Sample Group						Statistical Values				
						Shear Stress				
Manuf. Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeA	Epoxy	3	1	4	0	28.6	32.3	30.1	1.4	4.70
TypeA	Epoxy	5	1	4	0	28.7	31.0	30.0	0.8	2.75
TypeB	VinylEster	3	1	4	0	28.1	30.6	29.3	1.0	3.40
TypeB	VinylEster	5	1	4	0	27.6	29.3	28.2	0.6	2.30
TypeC	Epoxy	3	1	4	0	28.2	31.9	30.0	1.3	4.44
TypeC	Epoxy	5	1	4	0	22.9	25.7	24.5	1.2	4.95
TypeA	Epoxy	3	1	4	20000	29.4	33.7	31.1	1.7	5.45
TypeA	Epoxy	5	1	4	20000	25.8	29.3	27.8	1.4	4.92
TypeB	VinylEster	3	1	4	20000	29.8	34.1	31.8	1.7	5.45
TypeB	VinylEster	5	1	4	20000	28.0	29.1	28.7	0.4	1.48
TypeC	Epoxy	3	1	4	20000	24.8	28.2	27.0	1.3	4.74
TypeC	Epoxy	5	1	4	20000	20.8	28.6	26.6	3.3	12.35
TypeA	Epoxy	3	1	4	SeaWater	27.3	31.4	29.2	1.8	6.24
TypeA	Epoxy	5	1	4	SeaWater	25.8	28.8	27.3	1.3	4.79
TypeB	VinylEster	3	1	4	SeaWater	30.0	33.2	31.4	1.5	4.85
TypeB	VinylEster	5	1	4	SeaWater	27.7	29.5	28.5	0.7	2.44
TypeC	Epoxy	3	1	4	SeaWater	28.9	31.5	30.2	1.1	3.74
TypeC	Epoxy	5	1	4	SeaWater	20.8	25.6	23.2	2.1	9.25
TypeA	Epoxy	3	2	4	0	25.1	31.4	27.5	2.6	9.58
TypeA	Epoxy	5	2	4	0	28.1	29.6	28.7	0.6	2.15
TypeB	VinylEster	3	2	4	0	30.7	32.5	31.8	0.8	2.47
TypeB	VinylEster	5	2	4	0	27.6	29.8	28.5	0.9	3.17
TypeC	Epoxy	3	2	4	0	29.0	31.4	30.5	0.9	2.98
TypeC	Epoxy	5	2	4	0	20.3	24.5	21.9	1.6	7.40
TypeA	Epoxy	3	2	4	20000	18.8	26.3	22.0	3.3	14.82

Continued on next page ...

Table 1.49: Transverse Shear test statistical values for each sample group (US Customary Units)

Sample Group						Statistical Values				
						Shear Stress				
Manuf. Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeA	Epoxy	5	2	4	20000	25.2	28.7	27.1	1.5	5.59
TypeB	VinylEster	3	2	4	20000	31.9	36.9	33.5	2.0	6.09
TypeB	VinylEster	5	2	4	20000	29.8	30.8	30.1	0.4	1.30
TypeC	Epoxy	3	2	4	20000	29.5	32.9	30.7	1.3	4.16
TypeC	Epoxy	5	2	4	20000	20.4	25.0	23.5	1.9	7.89
TypeA	Epoxy	3	2	4	SeaWater	21.4	25.8	23.6	2.0	8.58
TypeA	Epoxy	5	2	4	SeaWater	25.8	29.9	28.3	1.7	5.85
TypeB	VinylEster	3	2	4	SeaWater	32.6	35.8	34.6	1.3	3.67
TypeB	VinylEster	5	2	4	SeaWater	26.9	28.2	27.5	0.6	2.09
TypeC	Epoxy	3	2	4	SeaWater	29.9	32.7	31.4	1.2	3.84
TypeC	Epoxy	5	2	4	SeaWater	19.3	21.7	20.2	1.0	5.04
TypeA	Epoxy	3	1	7	0	24.8	31.5	28.2	2.8	9.99
TypeA	Epoxy	5	1	7	0	29.3	30.9	30.2	0.6	1.95
TypeB	VinylEster	3	1	7	0	28.3	34.1	31.1	2.2	7.10
TypeB	VinylEster	5	1	7	0	26.6	27.7	27.0	0.4	1.58
TypeC	Epoxy	3	1	7	0	28.8	31.9	30.1	1.2	4.06
TypeC	Epoxy	5	1	7	0	14.5	21.3	19.6	2.8	14.54
TypeA	Epoxy	3	1	7	20000	28.7	34.4	31.8	2.3	7.20
TypeA	Epoxy	5	1	7	20000	27.7	31.4	29.6	1.7	5.81
TypeB	VinylEster	3	1	7	20000	29.8	34.6	31.6	1.9	6.07
TypeB	VinylEster	5	1	7	20000	26.6	30.1	28.6	1.3	4.39
TypeC	Epoxy	3	1	7	20000	30.2	33.1	31.5	1.3	4.11
TypeC	Epoxy	5	1	7	20000	15.7	20.8	18.3	1.9	10.62
TypeA	Epoxy	3	1	7	SeaWater	29.2	33.9	31.7	1.7	5.40
TypeA	Epoxy	5	1	7	SeaWater	28.7	30.3	29.6	0.7	2.26
TypeB	VinylEster	3	1	7	SeaWater	26.7	30.7	29.1	1.5	5.10
TypeB	VinylEster	5	1	7	SeaWater	25.8	29.0	27.4	1.3	4.69
TypeC	Epoxy	3	1	7	SeaWater	28.6	31.8	29.9	1.1	3.81
TypeC	Epoxy	5	1	7	SeaWater	13.4	16.4	14.6	1.5	9.95
TypeA	Epoxy	3	2	7	0	21.8	27.5	24.6	2.5	10.17
TypeA	Epoxy	5	2	7	0	26.9	29.9	28.0	1.1	3.99
TypeB	VinylEster	3	2	7	0	31.3	35.4	32.6	1.6	4.97
TypeB	VinylEster	5	2	7	0	26.6	27.3	27.0	0.3	1.16
TypeC	Epoxy	3	2	7	0	27.8	33.4	30.7	2.1	6.86
TypeC	Epoxy	5	2	7	0	18.0	23.2	21.0	2.2	10.51
TypeA	Epoxy	3	2	7	20000	25.3	29.2	27.6	1.7	6.05

Continued on next page ...

Table 1.49: Transverse Shear test statistical values for each sample group (US Customary Units)

Sample Group						Statistical Values				
						Shear Stress				
Manuf. Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeA	Epoxy	5	2	7	20000	28.1	32.3	30.4	1.6	5.17
TypeB	VinylEster	3	2	7	20000	32.3	40.5	36.7	3.2	8.75
TypeB	VinylEster	5	2	7	20000	26.9	28.8	28.0	0.8	2.83
TypeC	Epoxy	3	2	7	20000	28.5	31.4	30.1	1.3	4.29
TypeC	Epoxy	5	2	7	20000	18.2	22.0	19.9	1.9	9.48
TypeA	Epoxy	3	2	7	SeaWater	21.8	26.4	24.2	1.6	6.81
TypeA	Epoxy	5	2	7	SeaWater	28.3	30.2	29.0	0.8	2.81
TypeB	VinylEster	3	2	7	SeaWater	32.2	35.6	34.2	1.3	3.90
TypeB	VinylEster	5	2	7	SeaWater	28.0	29.3	28.4	0.5	1.92
TypeC	Epoxy	3	2	7	SeaWater	24.5	27.0	26.0	1.1	4.19
TypeC	Epoxy	5	2	7	SeaWater	11.6	14.5	13.1	1.0	7.97
TypeA	Epoxy	5	1	13	0	7.2	27.7	21.8	8.5	39.14
TypeB	VinylEster	3	1	13	0	28.0	34.4	30.0	2.6	8.73
TypeB	VinylEster	5	1	13	0	25.0	27.5	26.3	1.1	4.13
TypeC	Epoxy	5	1	13	0	12.8	14.8	13.7	0.7	5.30
TypeB	VinylEster	3	1	13	20000	30.5	36.9	33.3	2.3	7.00
TypeB	VinylEster	5	1	13	20000	20.9	27.4	24.5	3.0	12.34
TypeB	VinylEster	3	1	13	SeaWater	12.8	14.4	13.8	0.6	4.54
TypeB	VinylEster	5	1	13	SeaWater	16.8	19.1	17.9	1.0	5.62
TypeA	Epoxy	5	2	13	0	18.8	29.1	26.0	4.8	18.58
TypeB	VinylEster	3	2	13	0	16.5	38.7	30.5	9.4	30.85
TypeB	VinylEster	5	2	13	0	16.7	26.2	23.4	4.0	17.27
TypeC	Epoxy	5	2	13	0	13.8	29.7	20.6	6.1	29.51
TypeB	VinylEster	3	2	13	20000	23.0	34.4	29.4	4.5	15.27
TypeB	VinylEster	5	2	13	20000	26.5	29.4	27.6	1.1	3.89
TypeB	VinylEster	3	2	13	SeaWater	12.9	16.4	14.9	1.4	9.53
TypeB	VinylEster	5	2	13	SeaWater	17.6	21.6	19.8	1.4	7.28

1.5.4 Apparent Horizontal Shear Test

The FRP rebar products were tested for horizontal shear properties after exposing them to aggressive environments. The horizontal shear test was conducted according to the ASTM D 4475 (ASTM-International, 2012a) standards.

Load-Displacement

The graphs in Figures 1.74, 1.75, 1.76, 1.77, 1.78, and 1.79 plot the load-displacement behavior of short span 3 point bending. Each rebar type is shown individually—and every specimen within the relevant sample is displayed—to compare # 3 and # 5 from the same type. The x-axis of the graph represents the cross-head frame displacement, and the y-axis represents the applied load.

The graph in Figure 1.74 shows a nearly linear behavior until it reached the ultimate failure load. Following the peak load, a descending branch proceeds with individual local peaks and drops. The peaks and drops represent individual layers of fibers engaged and failing in tension located in the lower part of the specimen experiencing pure tension, while the upper part is in compression. Extension-Horizontal shear behavior of rebar Type B can be seen in the graph in Figure 1.75. Similar to Type A, # 5 Type B rebar sustained more load in comparison with # 3 rebars. The failure pattern of # 3 and # 5 Type B rebars was similar and identical to Type A rebar failure pattern. The load - displacement graph of Type C rebar in Figure 1.76 shows a nearly linear behavior until it reached the ultimate failure load. Following the peak load, a descending branch proceeds with individual local peaks and drops. The peaks and drops represent individual layers of fibers engaged and failing in tension located in the lower part of the specimen experiencing pure tension, while the upper part is in compression. The graphs shown in Figures 1.77, 1.78, and 1.79 show the load-displacement behavior of Lot 2 Type A, Type B, and Type C rebars. The graphs show a linear behavior until it reached approximately 90 % of the ultimate failure load. It can be seen in Figures 1.77 and 1.78 that the failure behavior of Type A and Type B rebars is identical irrespective of production lot and rebar size. Extension-Horizontal shear behavior of Lot 2 Type C rebars can be seen in the graph in Figure 1.79. Similar to Lot 1, # 5 Lot 2 rebars sustained more load in comparison with # 3 rebars. The failure pattern of # 3 and # 5 Lot 2 rebars was similar and identical to the failure pattern of rebars from Lot 1.

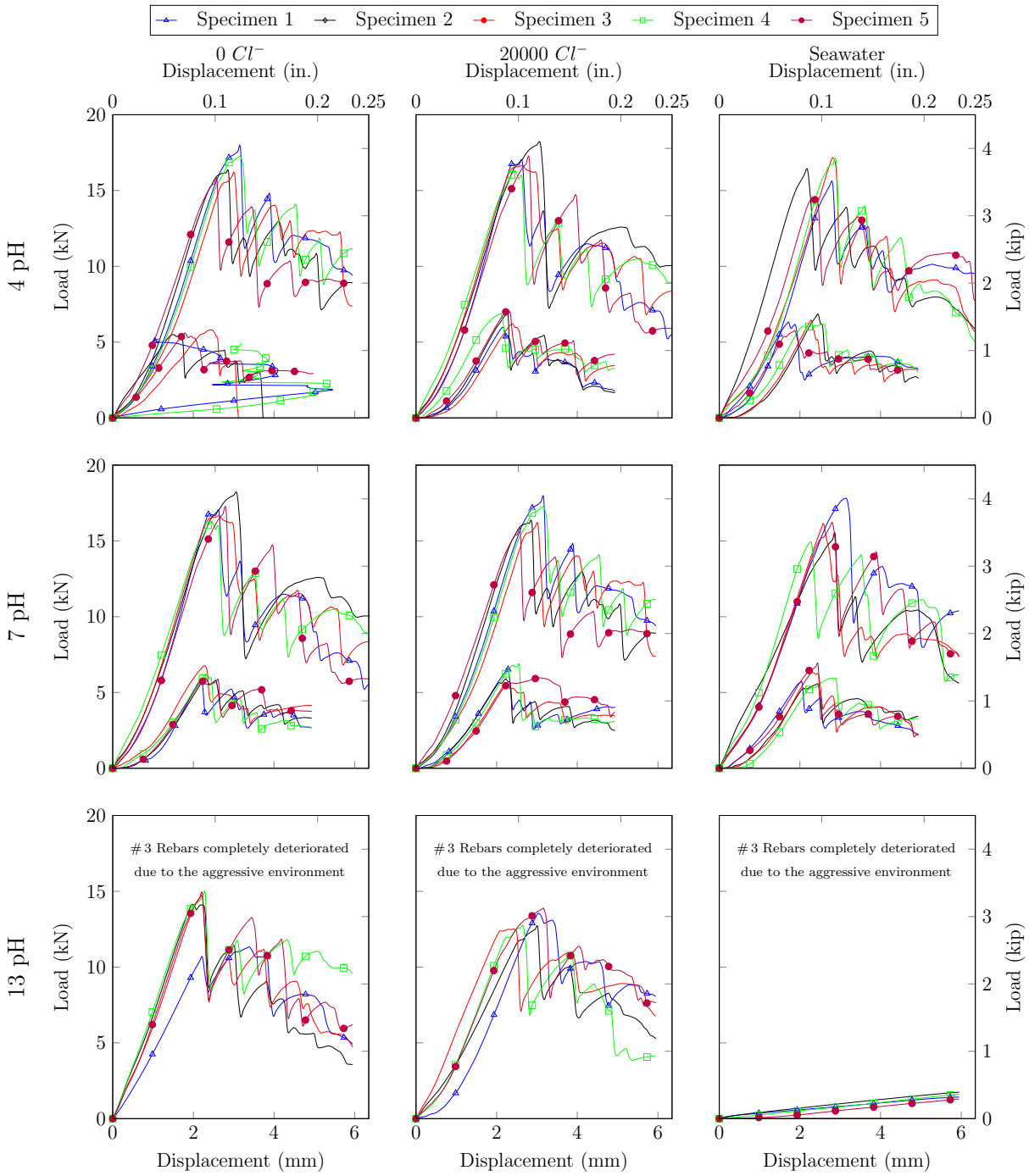

Figure 1.74: Horizontal shear force - extension concentration of Type A Lot1 tested rebars

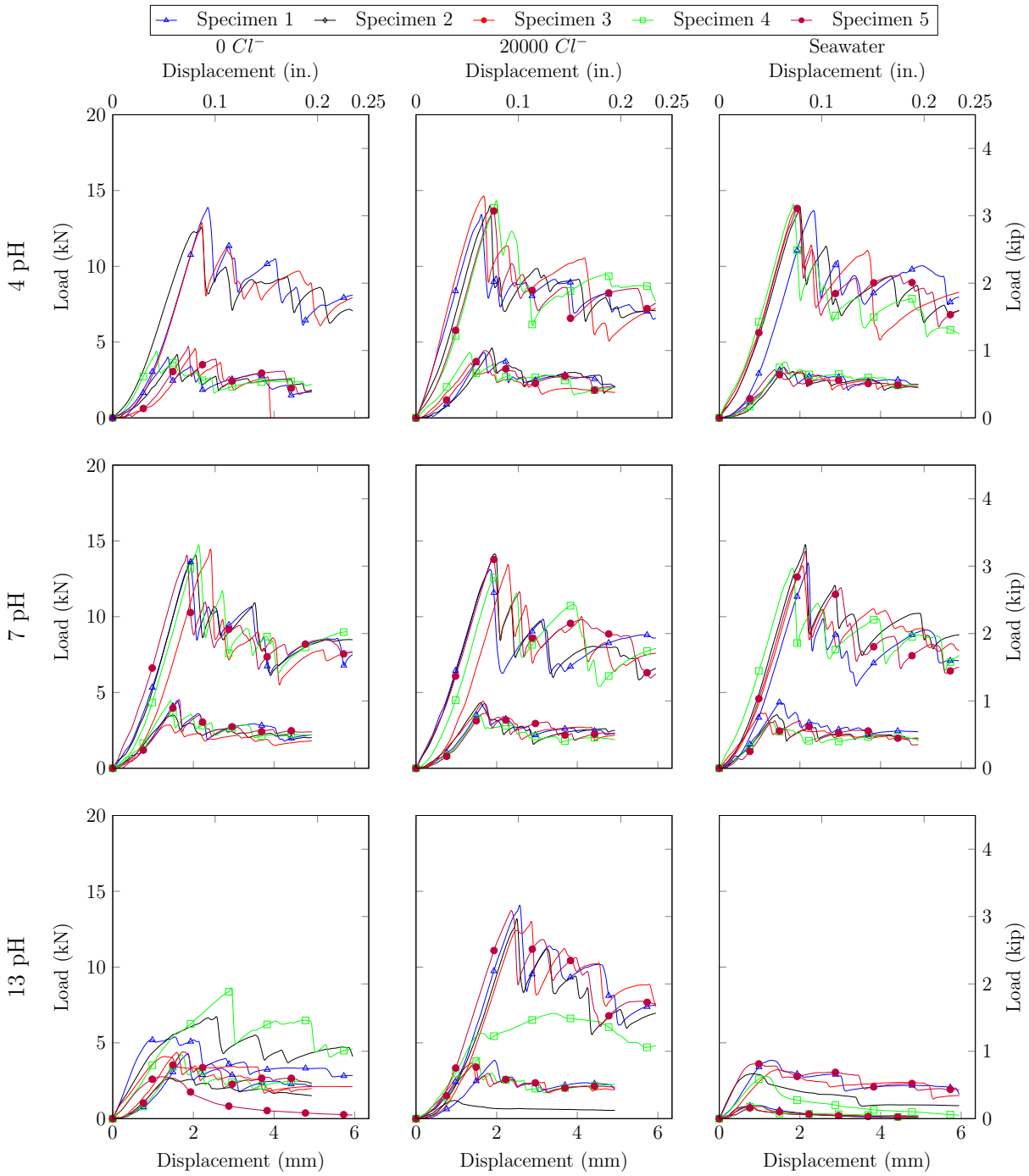

Figure 1.75: Horizontal shear force - extension concentration of Type B Lot1 tested rebars

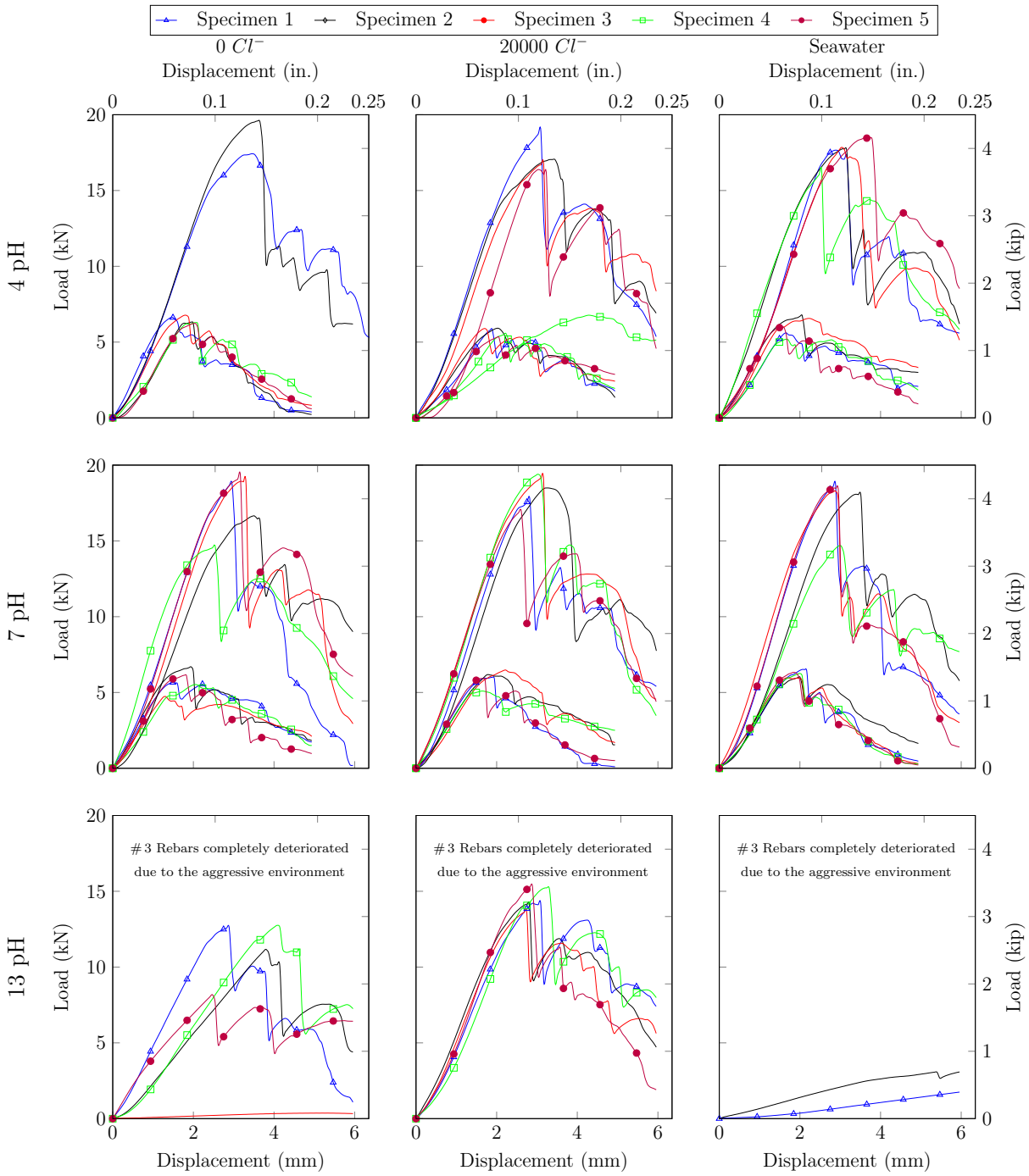

Figure 1.76: Horizontal shear force - extension concentration of Type C Lot1 tested rebars

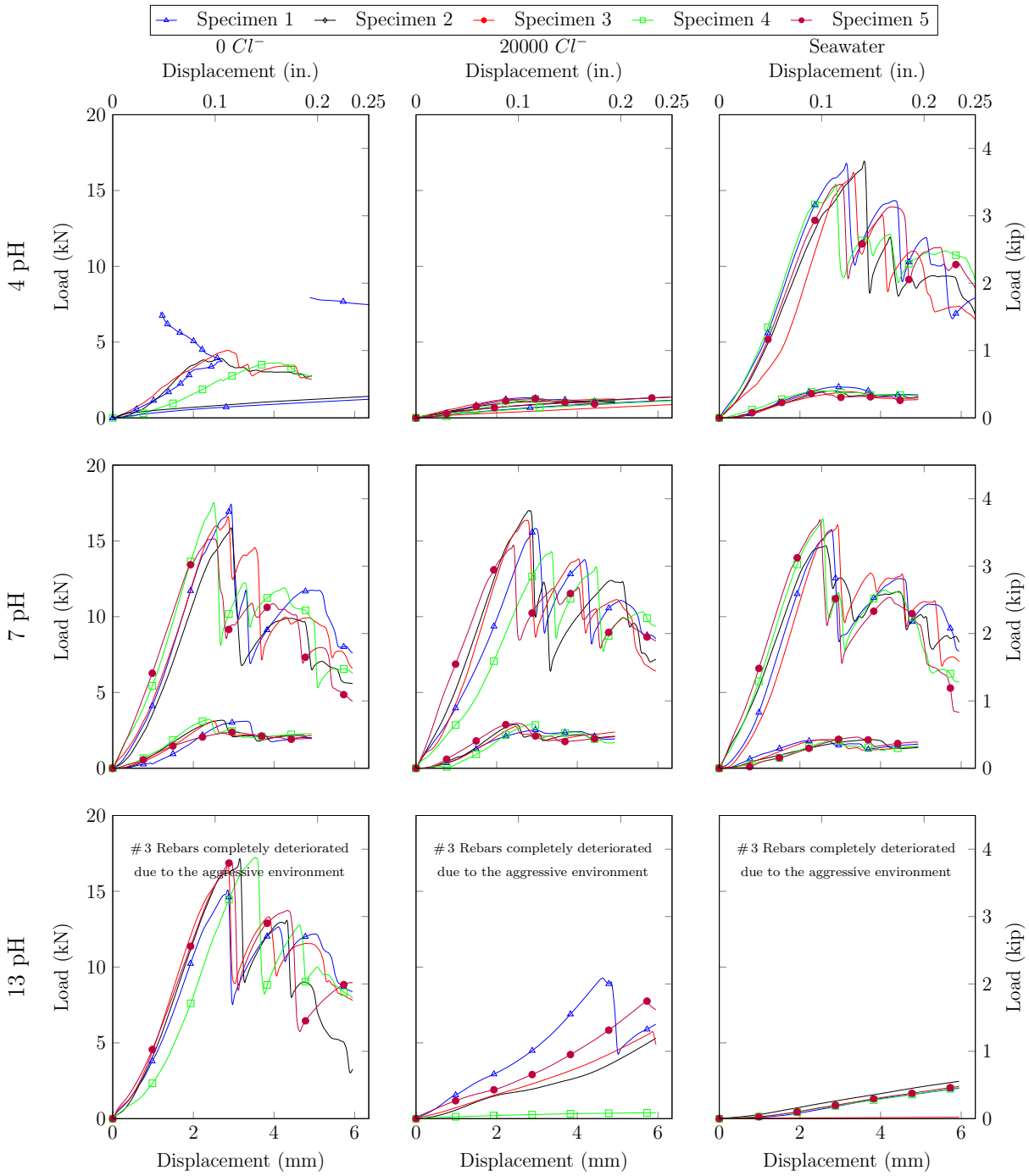

Figure 1.77: Horizontal shear force - extension concentration of Type A Lot2 tested rebars

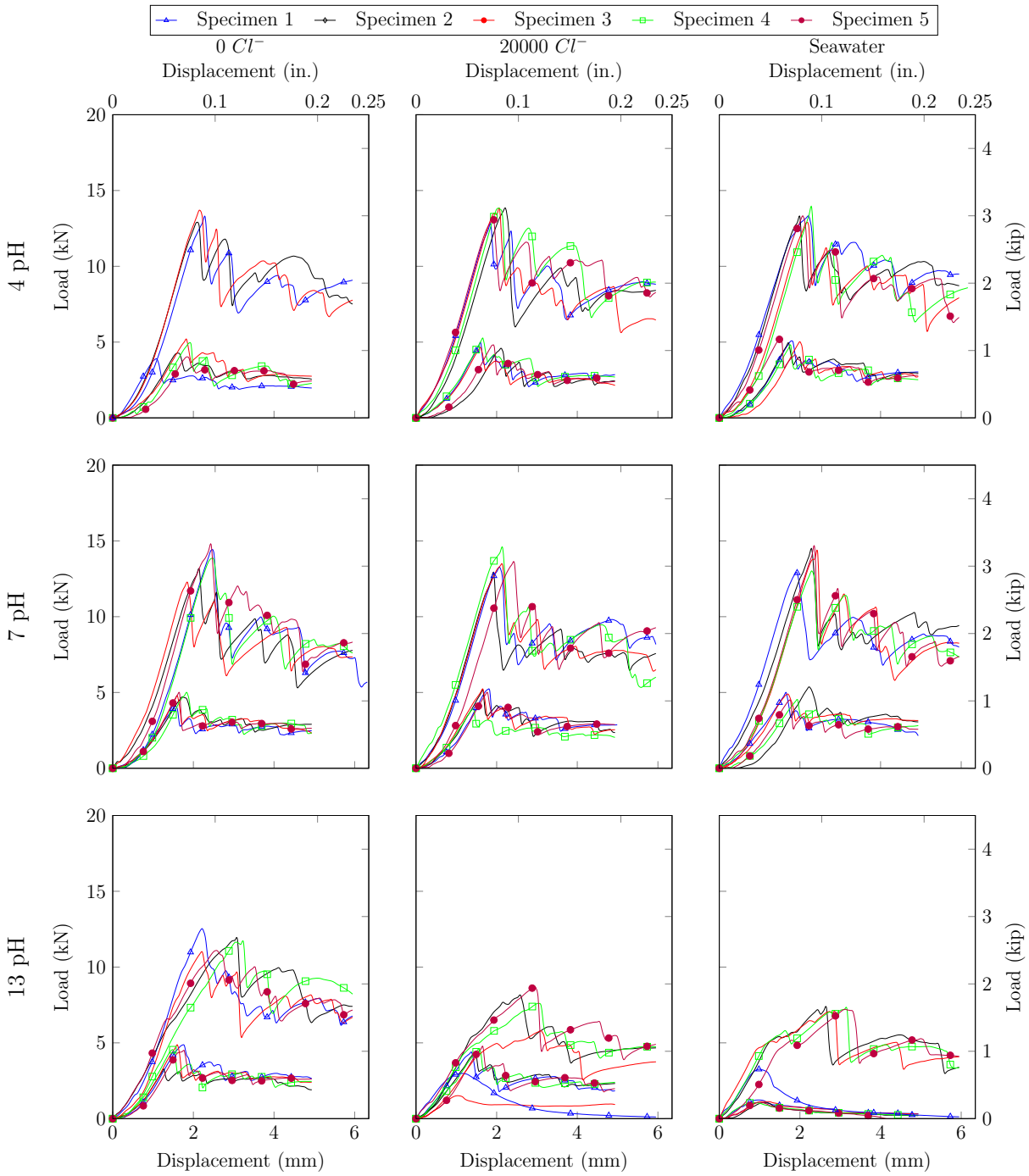

Figure 1.78: Horizontal shear force - extension concentration of Type B Lot2 tested rebars

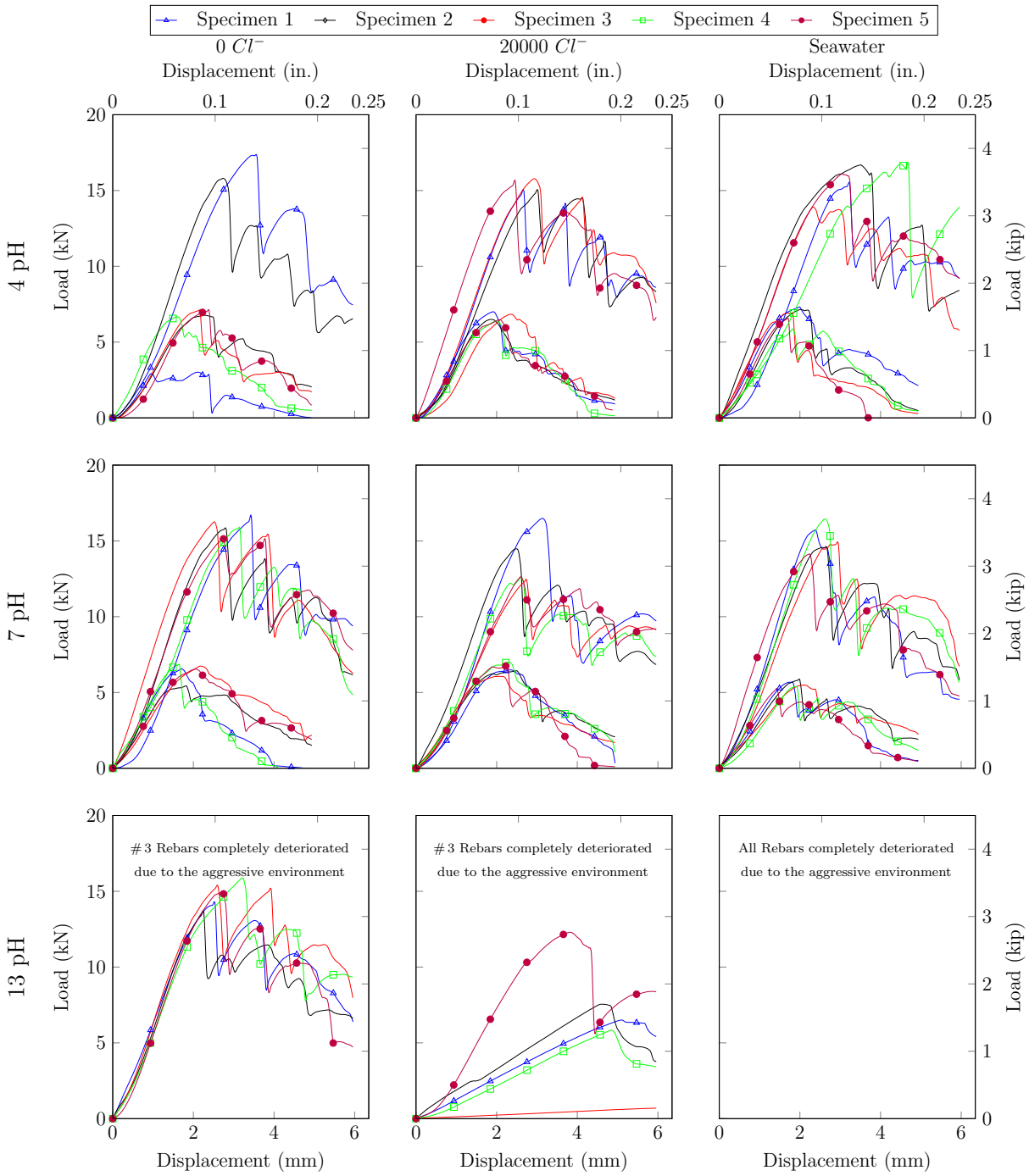

Figure 1.79: Horizontal shear force - extension concentration of Type C Lot2 tested rebars

Stress-Displacement

To provide clarity and to compare the horizontal shear strength performance of the two rebar sizes, stress-strain behavior of rebar is shown in this section via graphs. The following graphs in Figures 1.80, 1.81, 1.82, 1.83, 1.84, and 1.85 show the comparison of the stress - cross-head behavior for the tested BFRP rebars. The x-axis of graph represents the cross-head extension, while the y-axis signifies the measured shear stresses.

As expected, a significant difference in peak load between rebar sizes of Type A rebar was observed. Nevertheless, the resultant horizontal shear stress is approximately the same regardless of the rebar size. The stress-displacement behavior of rebar Type B shows that the failure pattern was identical for both the sizes but # 5 rebars sustained more stress in comparison to # 3 rebars. As expected, a significant difference in peak load between rebar sizes of Type C Lot 1 rebar was observed. Nevertheless, the resultant horizontal shear stress is approximately the same regardless of the rebar size. The graphs in Figures 1.83, 1.84, and 1.85 are used to compare the stress-displacement behavior of horizontal shear test of # 3 and # 5 rebars from Type A, Type B, and Type C from Lot 2.

The stress-strain behavior of rebars from Lot 2 show that the failure pattern was identical for both the sizes but # 5 rebars sustained more stress in comparison to # 3 rebars. Figures 1.83 and 1.84 show that all the rebars of Type A and Type B underwent similar stress and strain irrespective of lot and size.

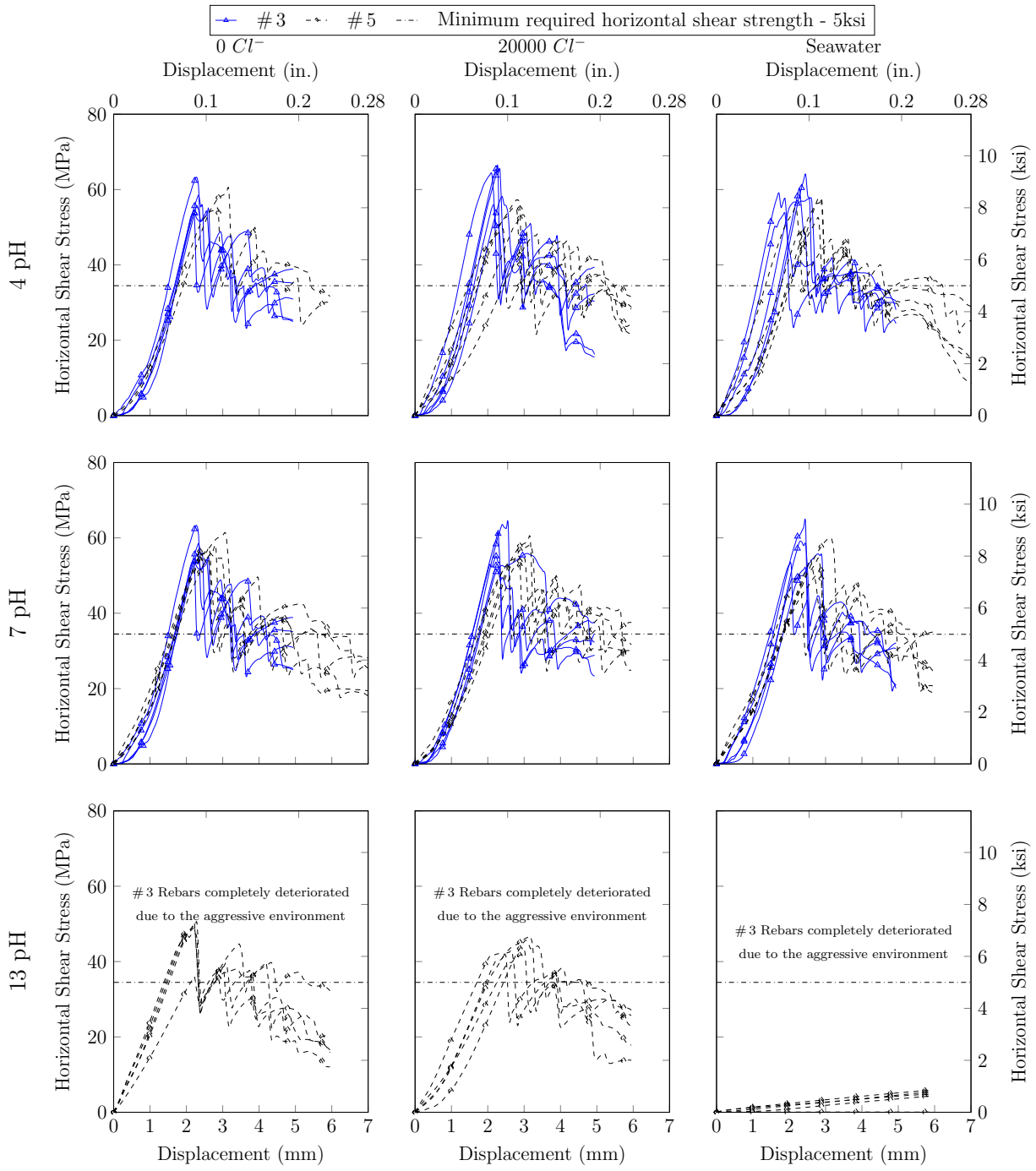

Figure 1.80: Horizontal shear stress - extension concentration of Type A Lot1 tested rebars

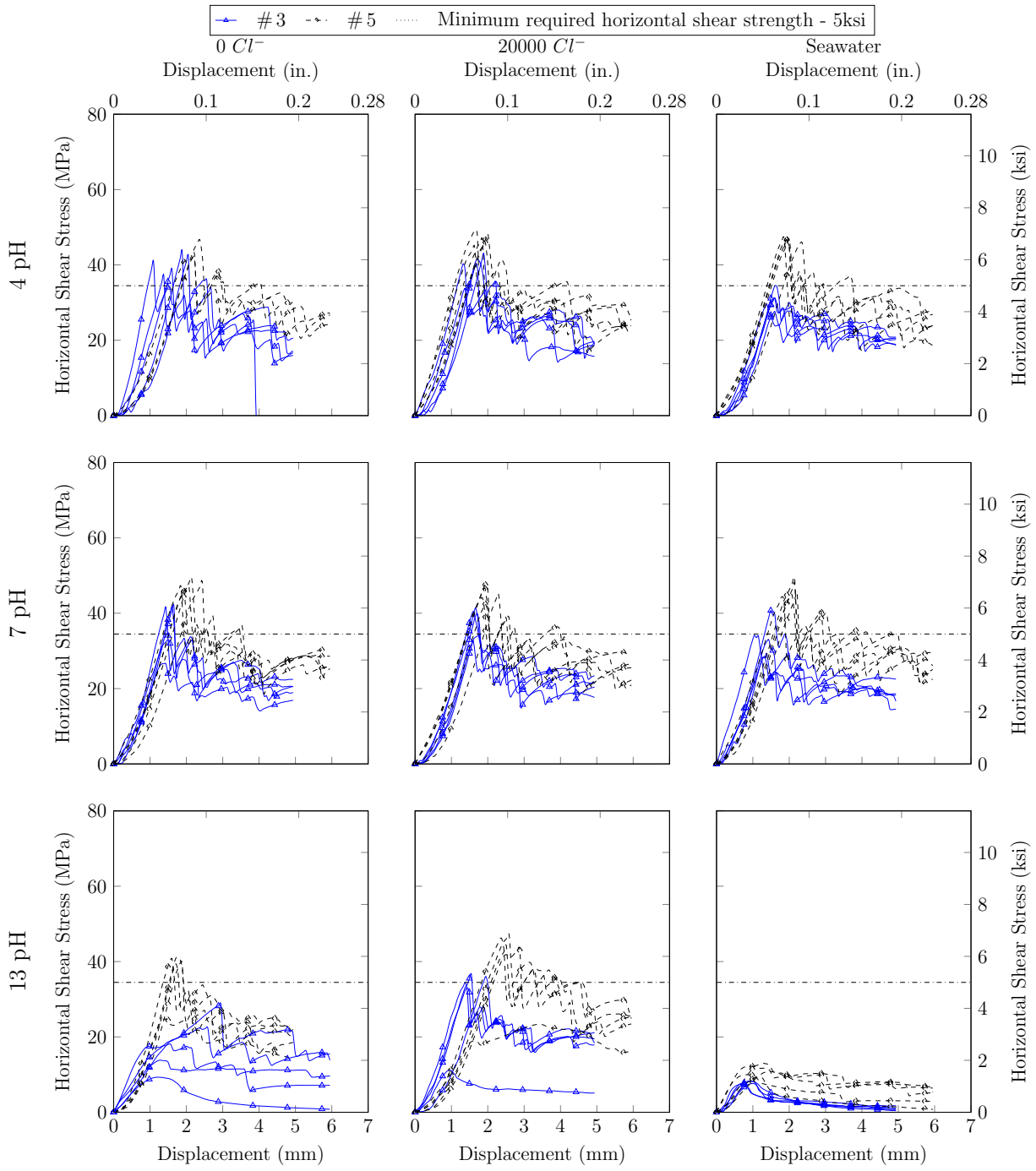

Figure 1.81: Horizontal shear stress - extension concentration of Type B Lot1 tested rebars

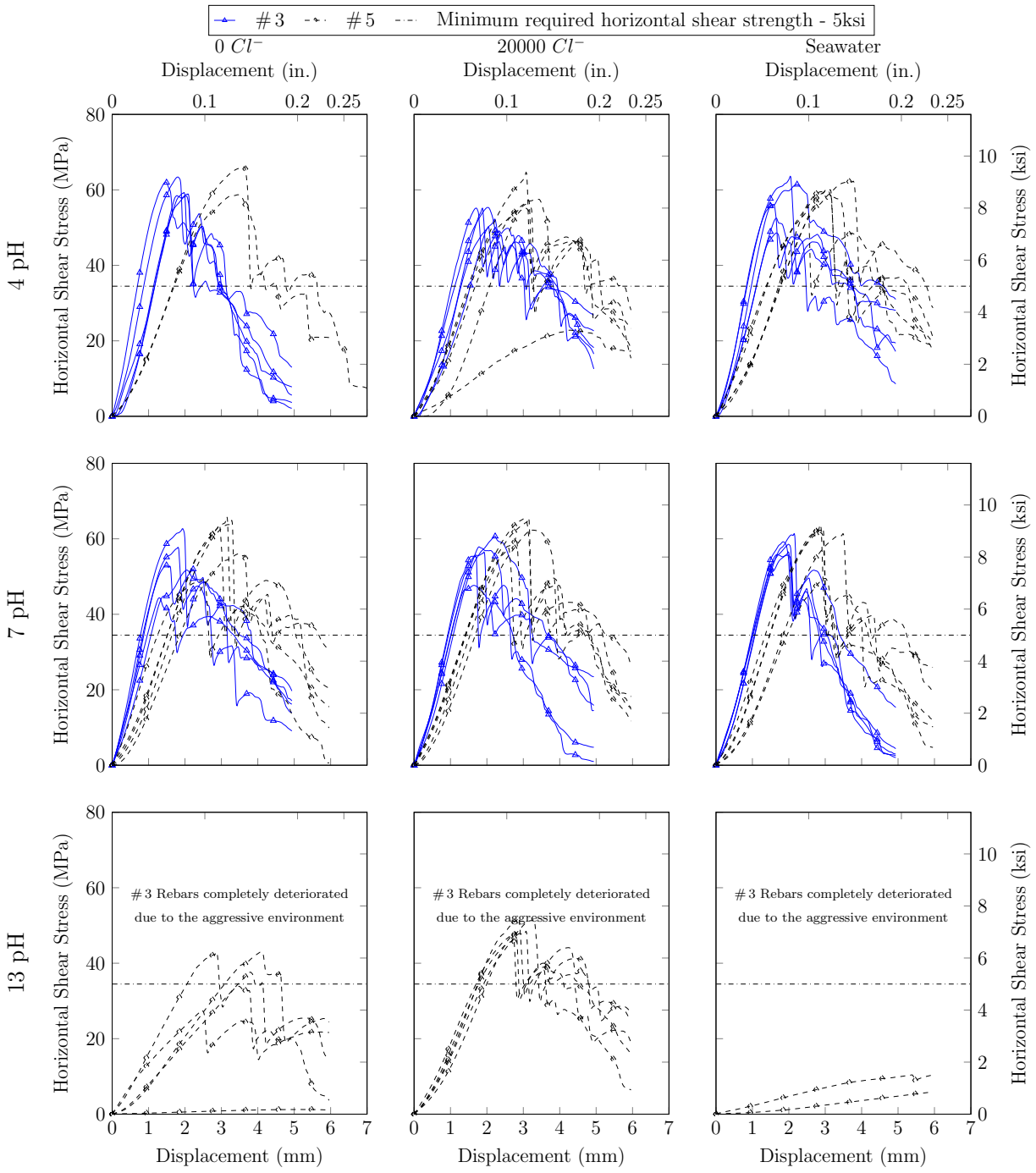

Figure 1.82: Horizontal shear stress - extension concentration of Type C Lot1 tested rebars

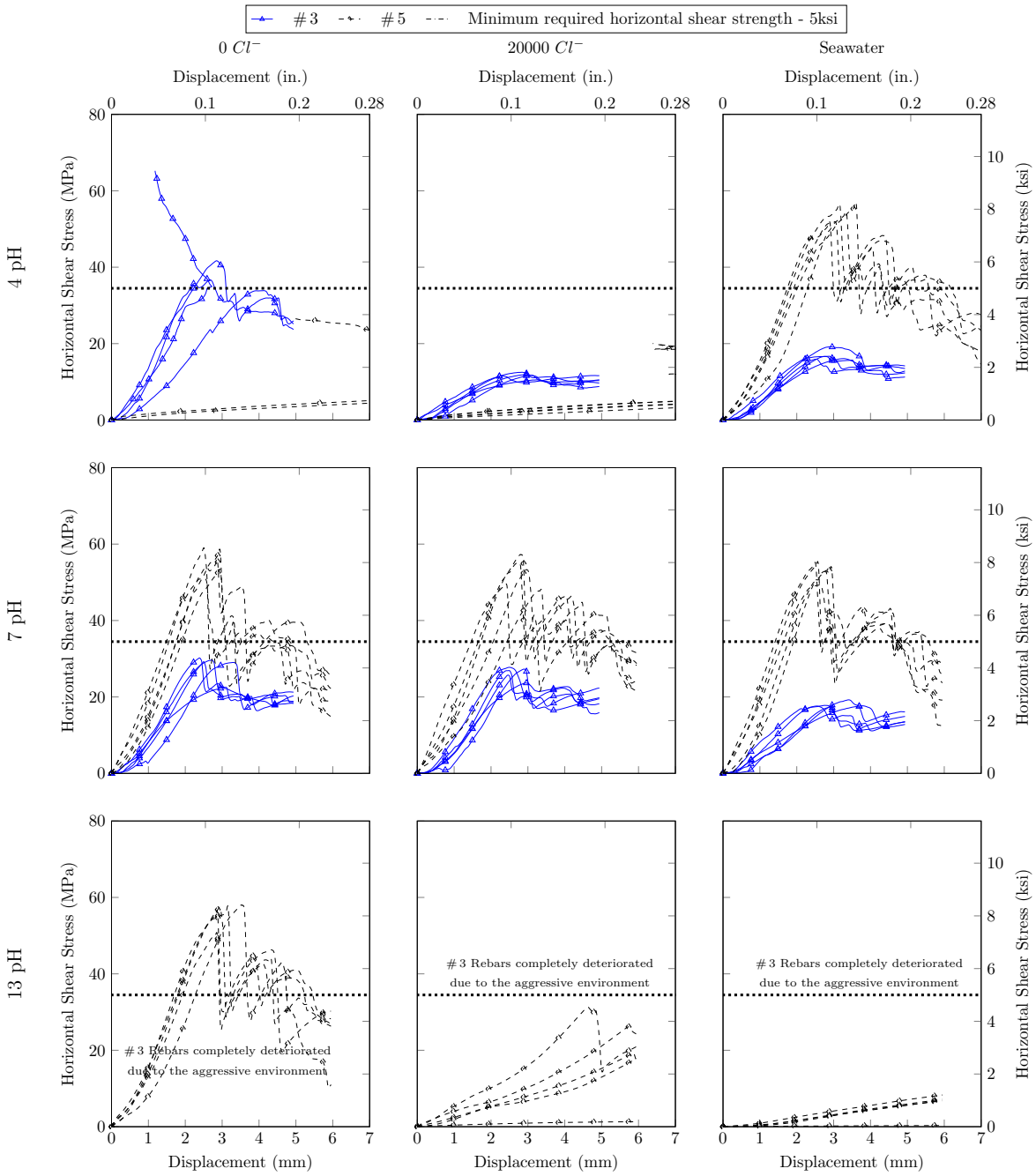

Figure 1.83: Horizontal shear stress - extension concentration of Type A Lot2 tested rebars

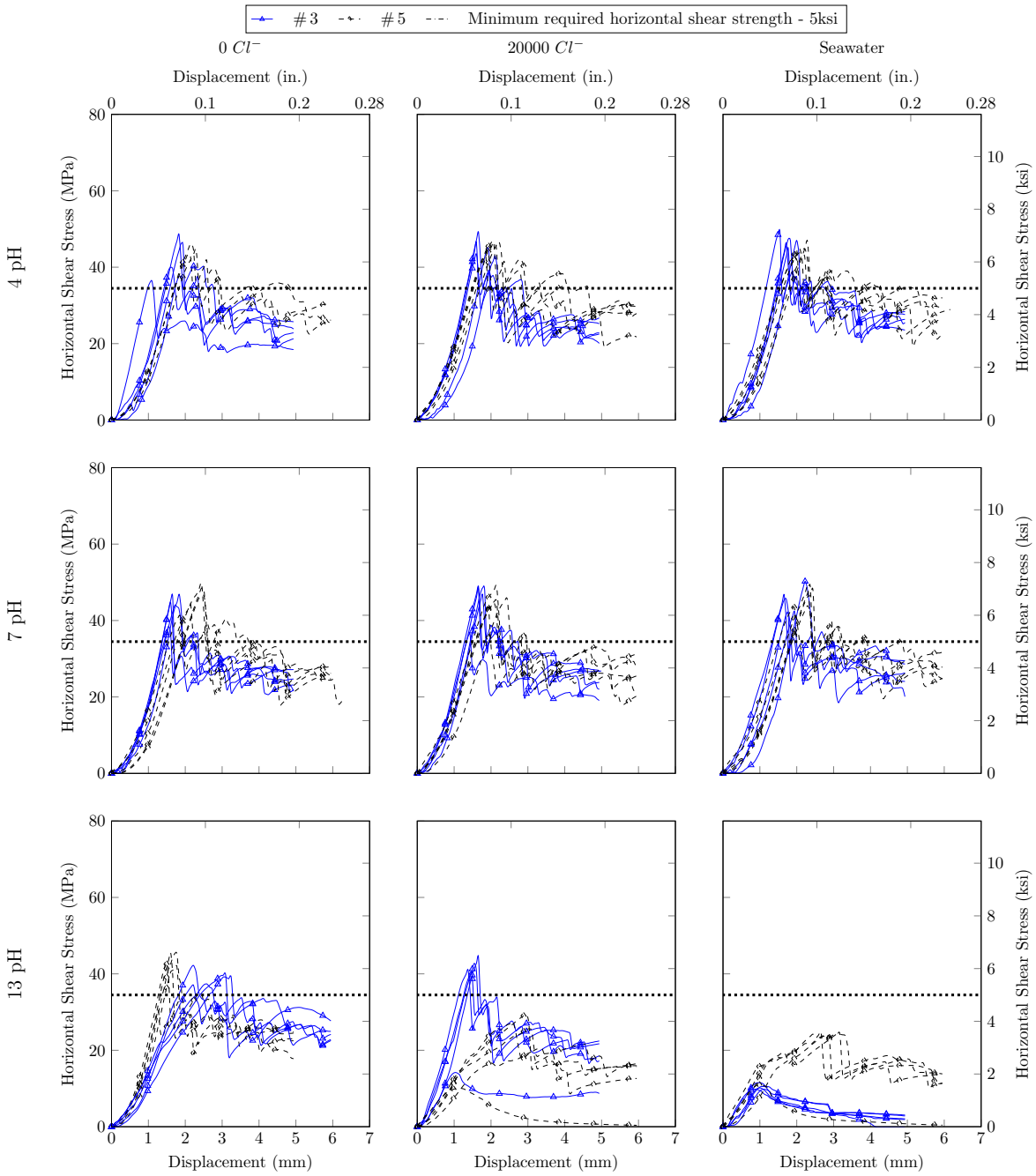

Figure 1.84: Horizontal shear stress - extension concentration of Type B Lot2 tested rebars

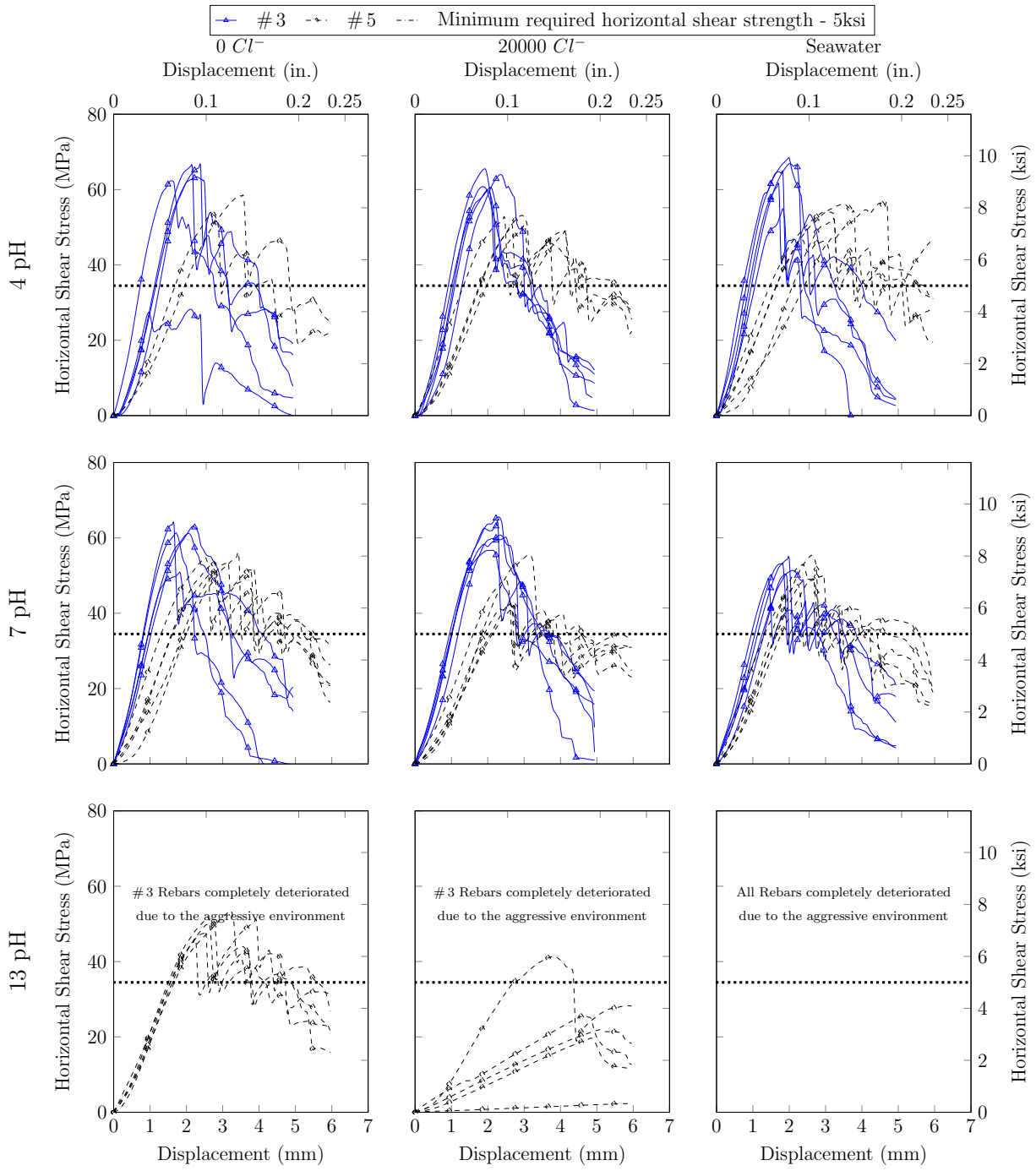

Figure 1.85: Horizontal shear stress - extension concentration of Type C Lot2 tested rebars

1.5.5 Modes of Failure

To study the failure pattern of BFRP rebars, failure modes of the tested rebars were analyzed.

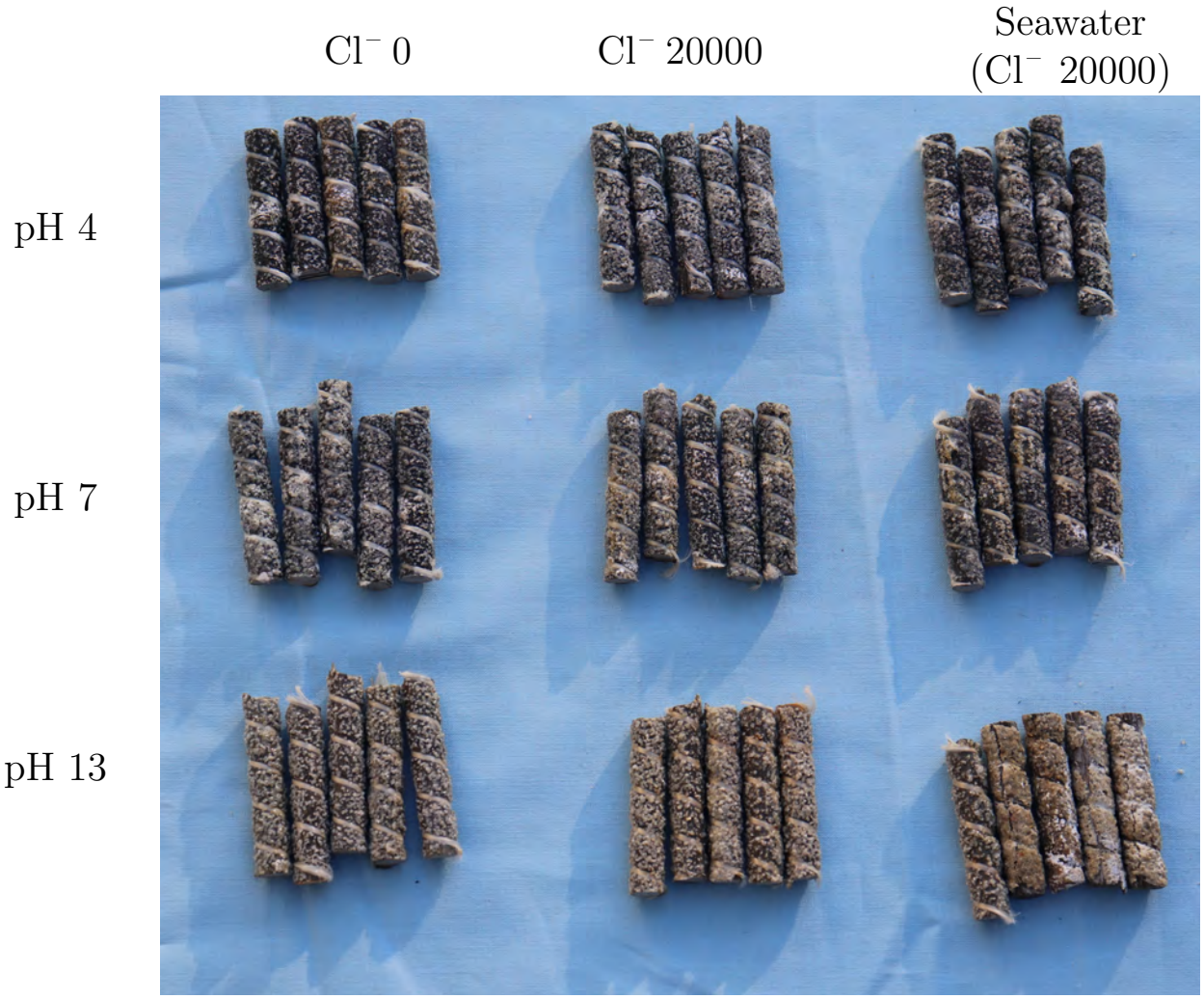

Figure 1.86: Horizontal shear failure mode of Type A # 3 rebars

All tested specimens failed due to the apparent horizontal shear force, resulting in horizontal failure planes as observed from the perpendicular cracks to the applied load, through the depth of the cross section. After the peak load, secondary cracks were generated representing the horizontal shear failure plane as each inter-laminar layer of fibers is engaged in tension and then failing in fiber-matrix interface which occurred due to the three point bending load on a short span, that formed a horizontal failure plane, as shown in Figures 1.86-1.91. All the tested specimens had more than one failure plane. To study the post failure behavior of rebars, the bending test was continued although the load peak was reached. The tests were performed until three or four additional load drops was observed, which means additional three or four additional failure planes appeared.

Figure 1.87: Horizontal shear failure mode of Type A # 5 rebars

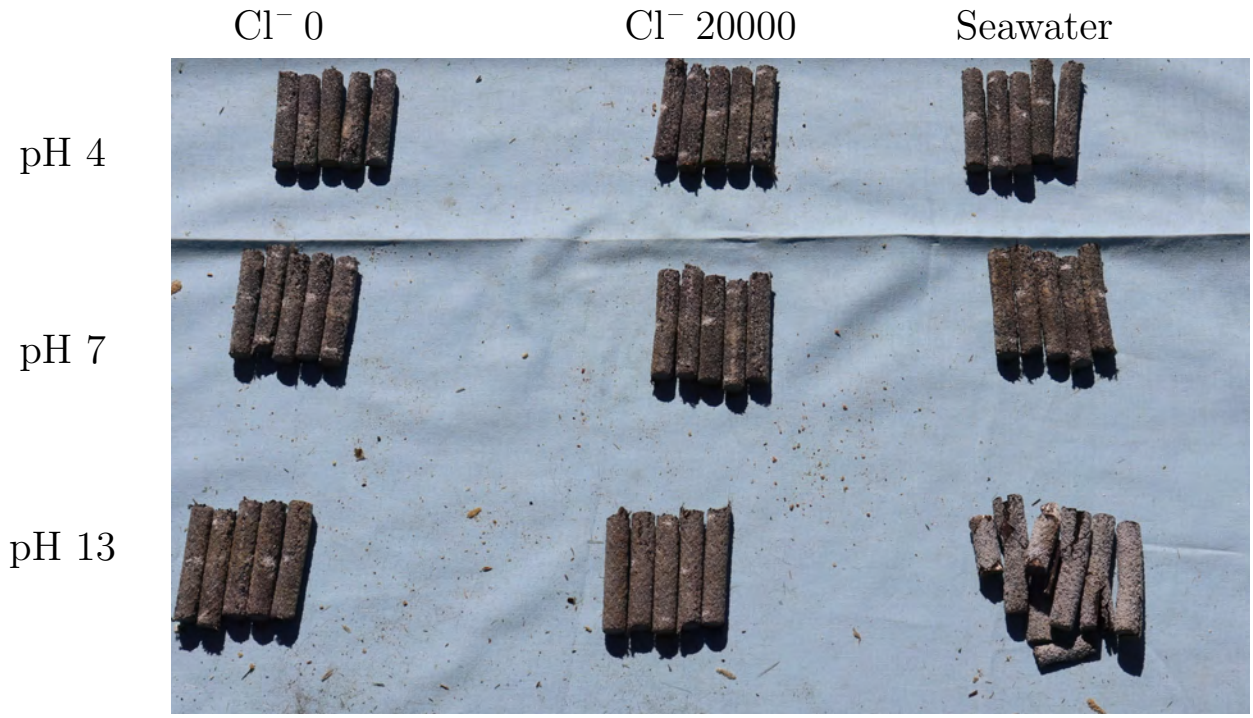

Figure 1.88: Horizontal shear failure mode of Type B # 3 rebars

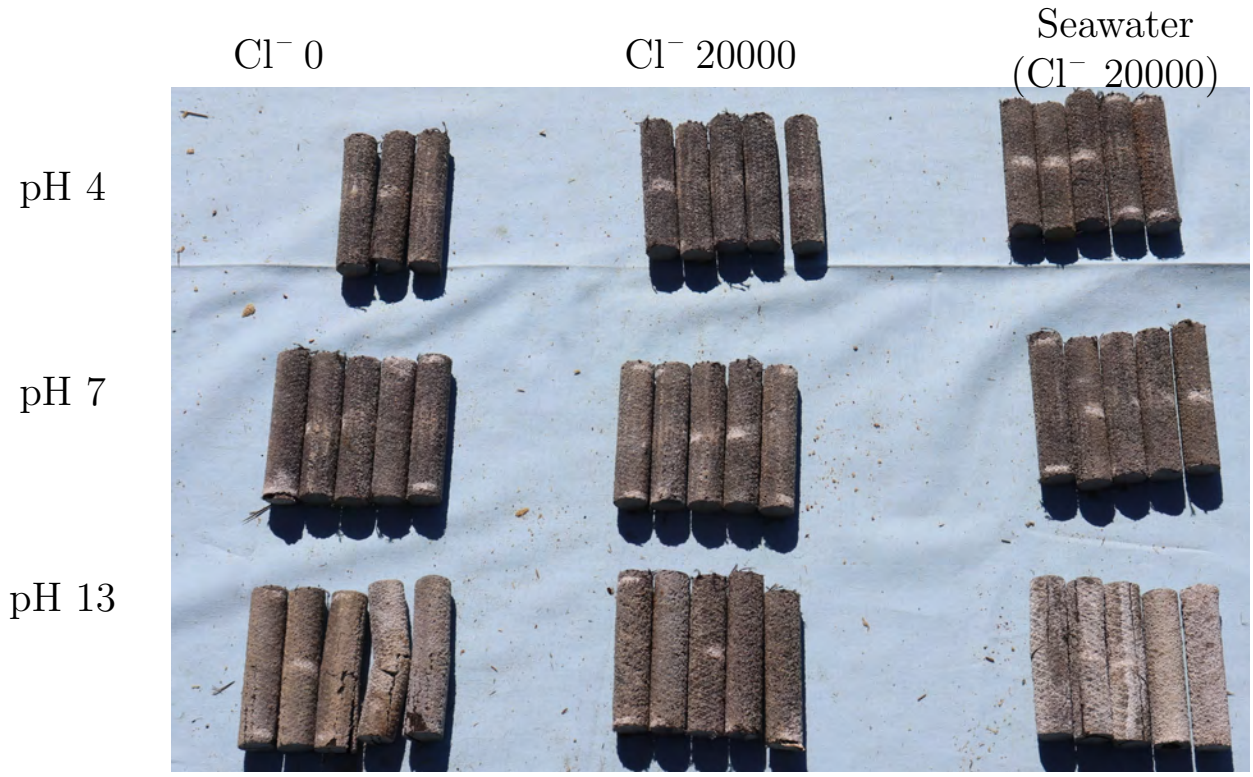

Figure 1.89: Horizontal shear failure mode of Type B # 5 rebars

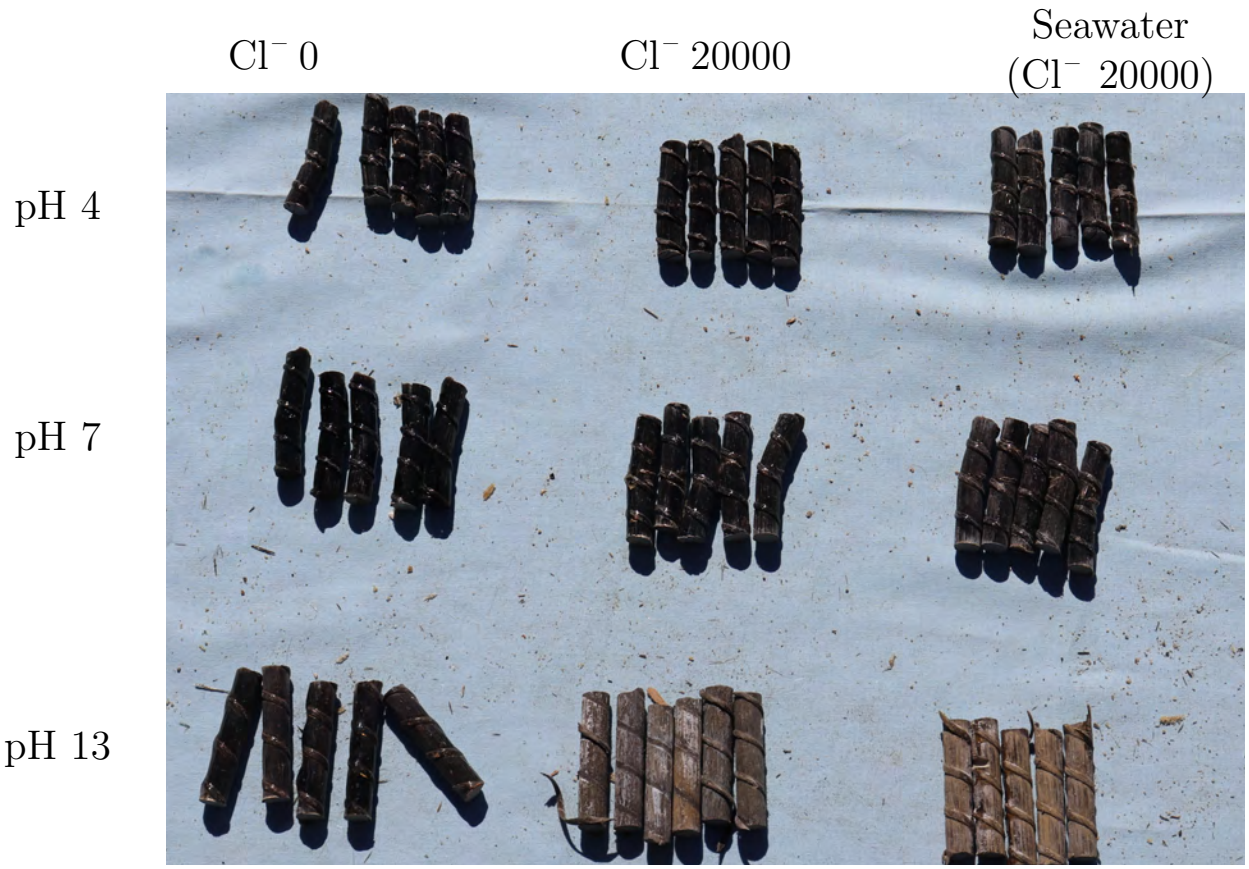

Figure 1.90: Horizontal shear failure mode of Type C # 3 rebars

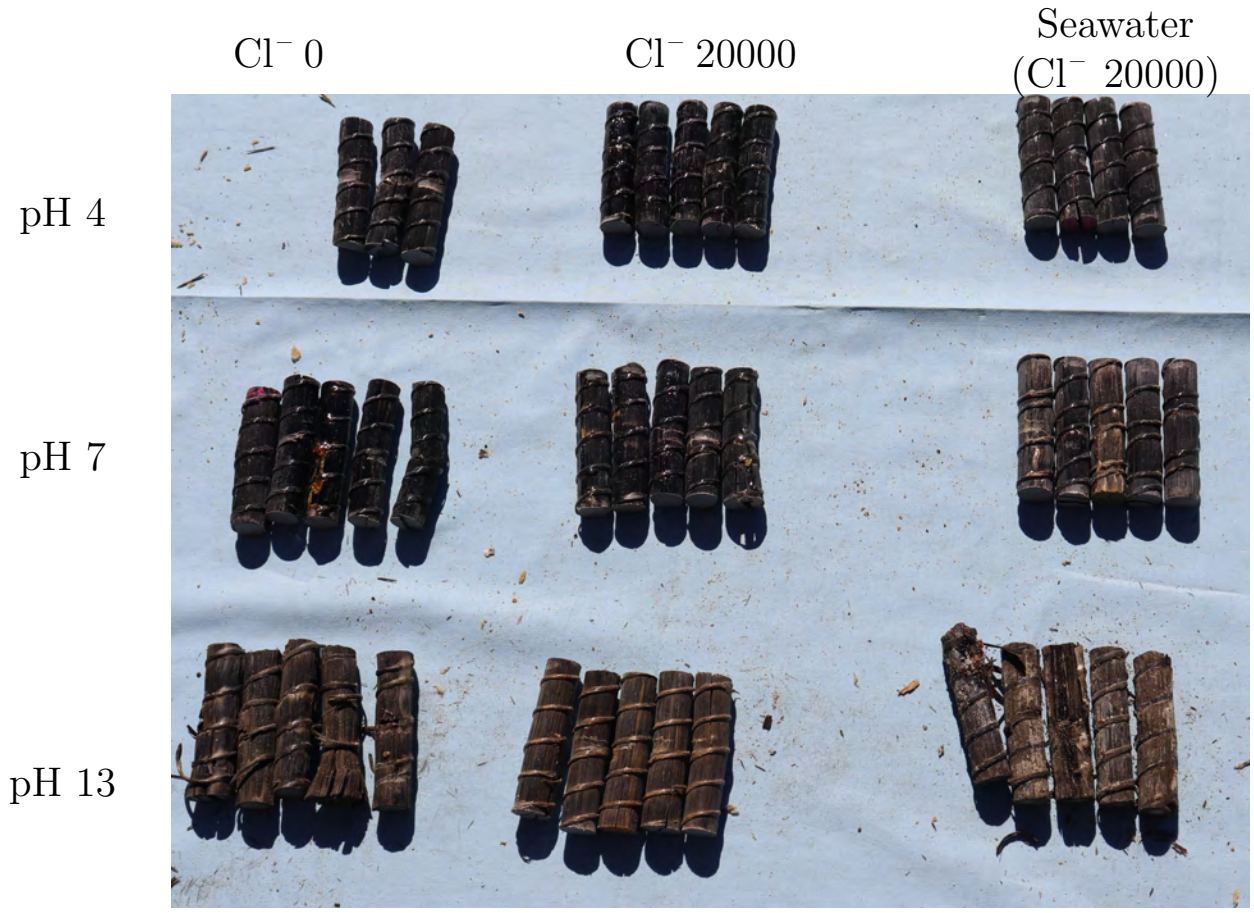

Figure 1.91: Horizontal shear failure mode of Type C # 5 rebars

1.5.6 Summary of Horizontal Shear Strength Properties

The statistical values for the horizontal shear strength properties of the tested products are listed in the following Table 1.50. A total of 250 specimens, five for each type, each size, lot, and exposure type were tested in total. The average of five specimens was assigned to each sample (specimen group) as shown in the table.

Table 1.50: 300Day Horizontal Shear test statistical values for each sample group (US Customary Units)

Sample Group						Statistical Values				
						Shear Stress				
Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeA	Epoxy	3	1	4	0	6.8	7.9	7.4	0.4	6.07
TypeA	Epoxy	5	1	4	0	4.9	5.9	5.4	0.7	12.86
TypeB	VinylEster	3	1	4	0	5.5	6.3	6.0	0.4	5.95
TypeB	VinylEster	5	1	4	0	6.1	6.8	6.4	0.4	6.09
TypeC	Epoxy	3	1	4	0	8.5	9.2	8.8	0.3	3.73
TypeC	Epoxy	5	1	4	0	8.5	9.6	9.0	0.5	5.82
TypeA	Epoxy	3	1	4	20000	8.3	9.6	9.0	0.6	6.81
TypeA	Epoxy	5	1	4	20000	2.9	2.9	2.9	0.0	0.02
TypeB	VinylEster	3	1	4	20000	4.9	6.4	5.9	0.6	9.75
TypeB	VinylEster	5	1	4	20000	6.6	7.3	6.9	0.3	3.89
TypeC	Epoxy	3	1	4	20000	7.3	8.0	7.8	0.3	4.46
TypeC	Epoxy	5	1	4	20000	3.3	9.2	7.6	2.1	28.05
TypeA	Epoxy	3	1	4	SeaWater	7.8	9.4	8.6	0.6	6.74
TypeA	Epoxy	5	1	4	SeaWater	7.1	8.5	7.9	0.6	7.07
TypeB	VinylEster	3	1	4	SeaWater	4.1	5.0	4.5	0.4	7.94
TypeB	VinylEster	5	1	4	SeaWater	6.7	6.9	6.8	0.1	1.59
TypeC	Epoxy	3	1	4	SeaWater	7.1	9.2	8.2	0.9	10.74
TypeC	Epoxy	5	1	4	SeaWater	7.9	9.0	8.6	0.4	4.79
TypeA	Epoxy	3	2	4	0	4.9	9.5	6.5	2.1	32.33
TypeA	Epoxy	5	2	4	0	2.9	3.9	3.4	0.7	20.16
TypeB	VinylEster	3	2	4	0	5.3	7.2	6.1	0.8	13.65
TypeB	VinylEster	5	2	4	0	6.3	6.9	6.6	0.3	4.22
TypeC	Epoxy	3	2	4	0	4.1	9.7	8.5	2.2	25.61
TypeC	Epoxy	5	2	4	0	7.6	8.5	7.9	0.5	5.95
TypeA	Epoxy	3	2	4	20000	1.5	1.8	1.7	0.1	6.12
TypeA	Epoxy	5	2	4	20000	2.9	2.9	2.9	0.0	0.02
TypeB	VinylEster	3	2	4	20000	6.4	7.3	6.7	0.4	5.51
TypeB	VinylEster	5	2	4	20000	6.3	6.9	6.6	0.3	4.30
TypeC	Epoxy	3	2	4	20000	8.7	9.5	9.0	0.4	3.98
TypeC	Epoxy	5	2	4	20000	7.3	7.7	7.5	0.2	2.76
TypeA	Epoxy	3	2	4	SeaWater	2.3	2.8	2.5	0.2	7.72
TypeA	Epoxy	5	2	4	SeaWater	7.4	8.1	7.8	0.3	3.93
TypeB	VinylEster	3	2	4	SeaWater	6.5	7.2	6.9	0.2	3.30
TypeB	VinylEster	5	2	4	SeaWater	6.5	6.9	6.6	0.2	2.80
TypeC	Epoxy	3	2	4	SeaWater	8.1	9.9	9.2	0.8	8.23
TypeC	Epoxy	5	2	4	SeaWater	6.8	8.2	7.7	0.6	7.49
TypeA	Epoxy	3	1	7	0	7.9	9.2	8.3	0.6	6.66
TypeA	Epoxy	5	1	7	0	8.0	8.8	8.3	0.3	3.80

Continued on next page . . .

Table 1.50: 300Day Horizontal Shear test statistical values for each sample group (US Customary Units)

Sample Group						Statistical Values				
						Shear Stress				
Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeB	VinylEster	3	1	7	0	3.9	6.2	5.5	1.1	19.76
TypeB	VinylEster	5	1	7	0	6.8	7.3	7.0	0.2	2.45
TypeC	Epoxy	3	1	7	0	6.5	9.1	7.8	1.0	12.50
TypeC	Epoxy	5	1	7	0	7.2	9.4	8.6	1.0	11.07
TypeA	Epoxy	3	1	7	20000	7.9	9.3	8.5	0.6	7.55
TypeA	Epoxy	5	1	7	20000	7.6	8.6	8.1	0.4	5.07
TypeB	VinylEster	3	1	7	20000	4.8	6.1	5.5	0.6	10.43
TypeB	VinylEster	5	1	7	20000	6.2	7.1	6.7	0.3	5.00
TypeC	Epoxy	3	1	7	20000	6.9	8.8	8.1	0.7	8.73
TypeC	Epoxy	5	1	7	20000	8.3	9.5	9.0	0.5	5.39
TypeA	Epoxy	3	1	7	SeaWater	7.5	9.2	8.2	0.7	8.33
TypeA	Epoxy	5	1	7	SeaWater	7.3	8.7	7.9	0.5	6.95
TypeB	VinylEster	3	1	7	SeaWater	4.2	6.0	4.9	0.7	14.72
TypeB	VinylEster	5	1	7	SeaWater	6.6	7.1	6.8	0.2	3.59
TypeC	Epoxy	3	1	7	SeaWater	8.1	8.9	8.4	0.3	3.72
TypeC	Epoxy	5	1	7	SeaWater	7.2	9.1	8.6	0.8	9.37
TypeA	Epoxy	3	2	7	0	3.2	4.4	4.1	0.5	11.64
TypeA	Epoxy	5	2	7	0	7.4	8.6	8.0	0.5	6.01
TypeB	VinylEster	3	2	7	0	5.6	7.0	6.5	0.5	8.12
TypeB	VinylEster	5	2	7	0	6.1	7.3	6.8	0.5	7.51
TypeC	Epoxy	3	2	7	0	7.4	9.2	8.7	0.8	8.79
TypeC	Epoxy	5	2	7	0	7.4	8.0	7.8	0.2	2.99
TypeA	Epoxy	3	2	7	20000	3.4	4.0	3.8	0.2	6.29
TypeA	Epoxy	5	2	7	20000	6.9	8.4	7.6	0.6	7.93
TypeB	VinylEster	3	2	7	20000	5.3	7.3	6.8	0.8	12.21
TypeB	VinylEster	5	2	7	20000	6.4	7.2	6.7	0.3	4.66
TypeC	Epoxy	3	2	7	20000	8.2	9.5	8.9	0.5	5.59
TypeC	Epoxy	5	2	7	20000	6.1	8.1	6.7	0.9	12.90
TypeA	Epoxy	3	2	7	SeaWater	2.5	2.8	2.6	0.1	4.19
TypeA	Epoxy	5	2	7	SeaWater	7.1	7.9	7.7	0.3	4.10
TypeB	VinylEster	3	2	7	SeaWater	6.2	7.4	6.7	0.5	7.54
TypeB	VinylEster	5	2	7	SeaWater	6.3	7.2	6.8	0.4	5.56
TypeC	Epoxy	3	2	7	SeaWater	7.2	7.9	7.5	0.3	3.93
TypeC	Epoxy	5	2	7	SeaWater	6.9	8.1	7.4	0.5	6.35
TypeA	Epoxy	5	1	13	0	5.6	7.3	6.9	0.7	10.64
TypeB	VinylEster	3	1	13	0	3.6	6.1	5.5	1.0	19.11
TypeB	VinylEster	5	1	13	0	1.4	4.1	2.7	1.1	40.30
TypeC	Epoxy	5	1	13	0	0.2	6.3	4.4	2.5	57.26
TypeA	Epoxy	5	1	13	20000	6.1	6.8	6.4	0.3	5.09
TypeB	VinylEster	3	1	13	20000	1.6	5.3	4.4	1.6	35.48
TypeB	VinylEster	5	1	13	20000	3.4	6.9	5.9	1.4	24.31
TypeC	Epoxy	5	1	13	20000	6.7	7.5	7.1	0.4	5.08
TypeA	Epoxy	5	1	13	SeaWater	0.0	0.9	0.6	0.3	56.38
TypeB	VinylEster	3	1	13	SeaWater	1.1	1.2	1.1	0.1	4.88
TypeB	VinylEster	5	1	13	SeaWater	1.4	1.9	1.6	0.2	13.42
TypeC	Epoxy	5	1	13	SeaWater	0.9	1.5	1.2	0.5	39.04
TypeA	Epoxy	5	2	13	0	7.2	8.4	8.0	0.5	5.85

Continued on next page . . .

Table 1.50: 300Day Horizontal Shear test statistical values for each sample group (US Customary Units)

Sample Group						Statistical Values				
						Shear Stress				
Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeB	VinylEster	3	2	13	0	4.6	6.7	6.1	0.9	14.45
TypeB	VinylEster	5	2	13	0	5.4	6.1	5.7	0.3	5.26
TypeC	Epoxy	5	2	13	0	6.6	7.7	7.2	0.5	6.46
TypeA	Epoxy	5	2	13	20000	0.2	4.6	2.8	1.7	59.19
TypeB	VinylEster	3	2	13	20000	2.1	6.6	5.4	1.9	34.88
TypeB	VinylEster	5	2	13	20000	1.5	4.3	3.3	1.1	34.91
TypeC	Epoxy	5	2	13	20000	0.3	6.0	3.2	2.0	62.83
TypeA	Epoxy	5	2	13	SeaWater	0.0	1.2	0.9	0.5	53.97
TypeB	VinylEster	3	2	13	SeaWater	1.4	1.7	1.5	0.1	6.73
TypeB	VinylEster	5	2	13	SeaWater	1.6	3.6	3.1	0.9	27.59

For numerical comparison and concluding values, Table 1.50 lists the minimum shear stress ($\wedge$), the maximum shear stress ($\vee$), the average shear stress (μ), the standard deviation (σ), and the coefficient of variation (CV) for each individual test sample.

1.5.7 Tensile Test

The rebars were tested according to the ASTM D 7205 (ASTM-International, 2015) to evaluate the tensile properties. The recorded and processed data of the tensile strength test are shown in this section via graphs and table.

Load-Displacement Behavior

To compare the load-displacement behavior of the different rebar samples and specimens, the graphs in Figures 1.92, 1.93, 1.94, 1.95, 1.96, and 1.97 plot the recorded test data. As shown, the x-axis of the graph represents the cross-head extension—which has to be interpreted with care because it includes the elastic deformation of the load frame and the test fixtures—and the y-axis indicates the applied and measured load. Figure 1.92 shows that # 5 rebar Type A sustained higher failure load in comparison with # 3 rebars and the extension of rebar # 5 was almost thrice that of the # 3 rebars extension. Figure 1.93 shows that the extension of # 5 was more than twice in comparison with # 3 rebars and the peak load was much higher. All the rebars failed in similar fashion. The following graph in Figure 1.94 illustrate the test results for the # 3 and # 5 Type C rebars from Lot 1. After comparing Figures 1.95, 1.96, and 1.97 it can be seen that the rebars of the same size from both the lots of all rebar types sustained the same peak load and failed in the same mode. The extension of rebars from lot

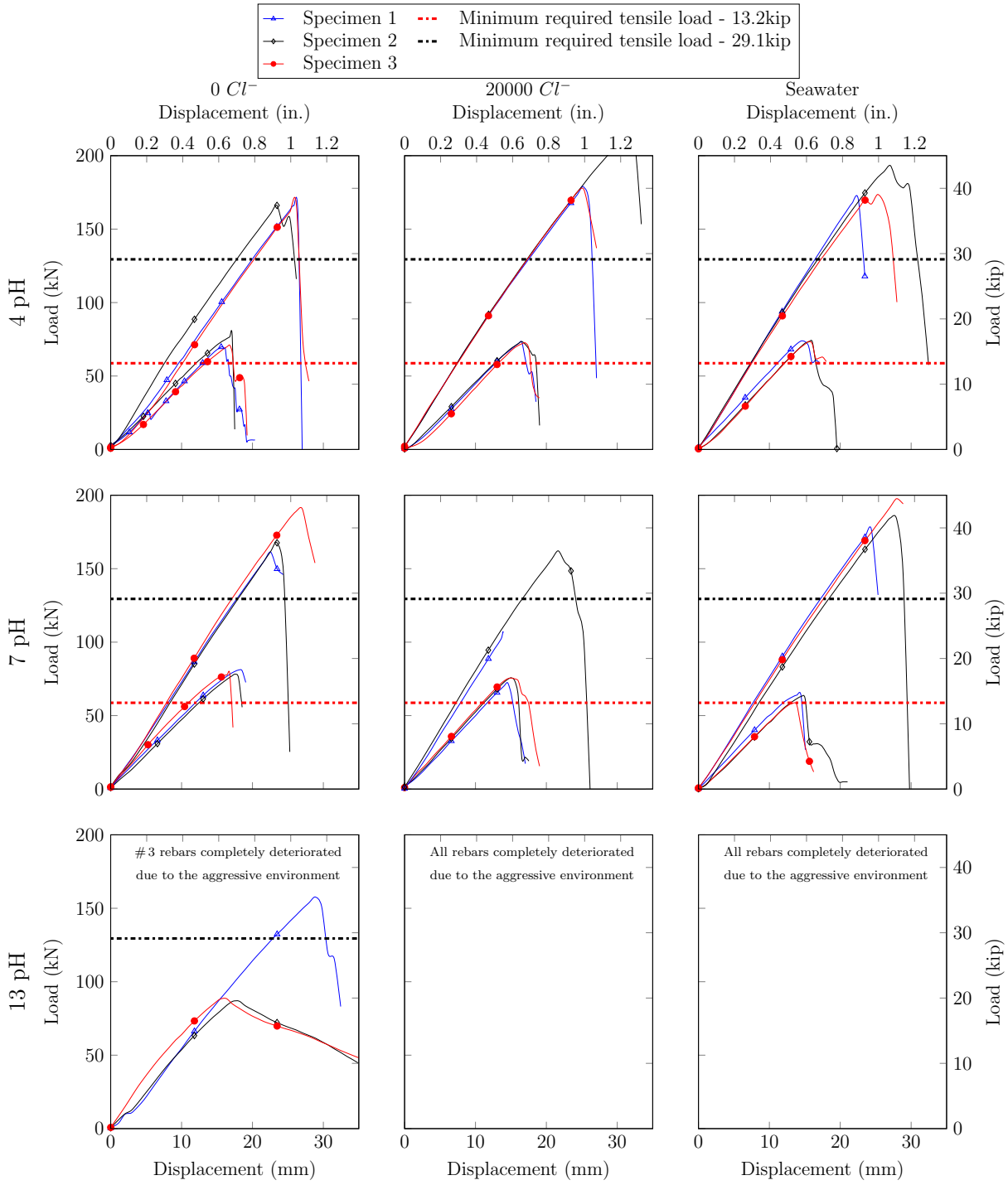

Figure 1.92: Tensile strength-displacement behavior of rebar Type A Lot 1 size 3 and 5

2 of both types was similar to rebars from lot 1 for both sizes. The specimens demonstrated a linear characteristic at around 10 kN until the peak load. The common behavior after the maximum load was overcome was a stepwise loss of load with little inclines until the next load loss occurred. With increasing cross-head extension in the post-failure region, the load decreased slightly, but then stagnated or even regained some strength throughout

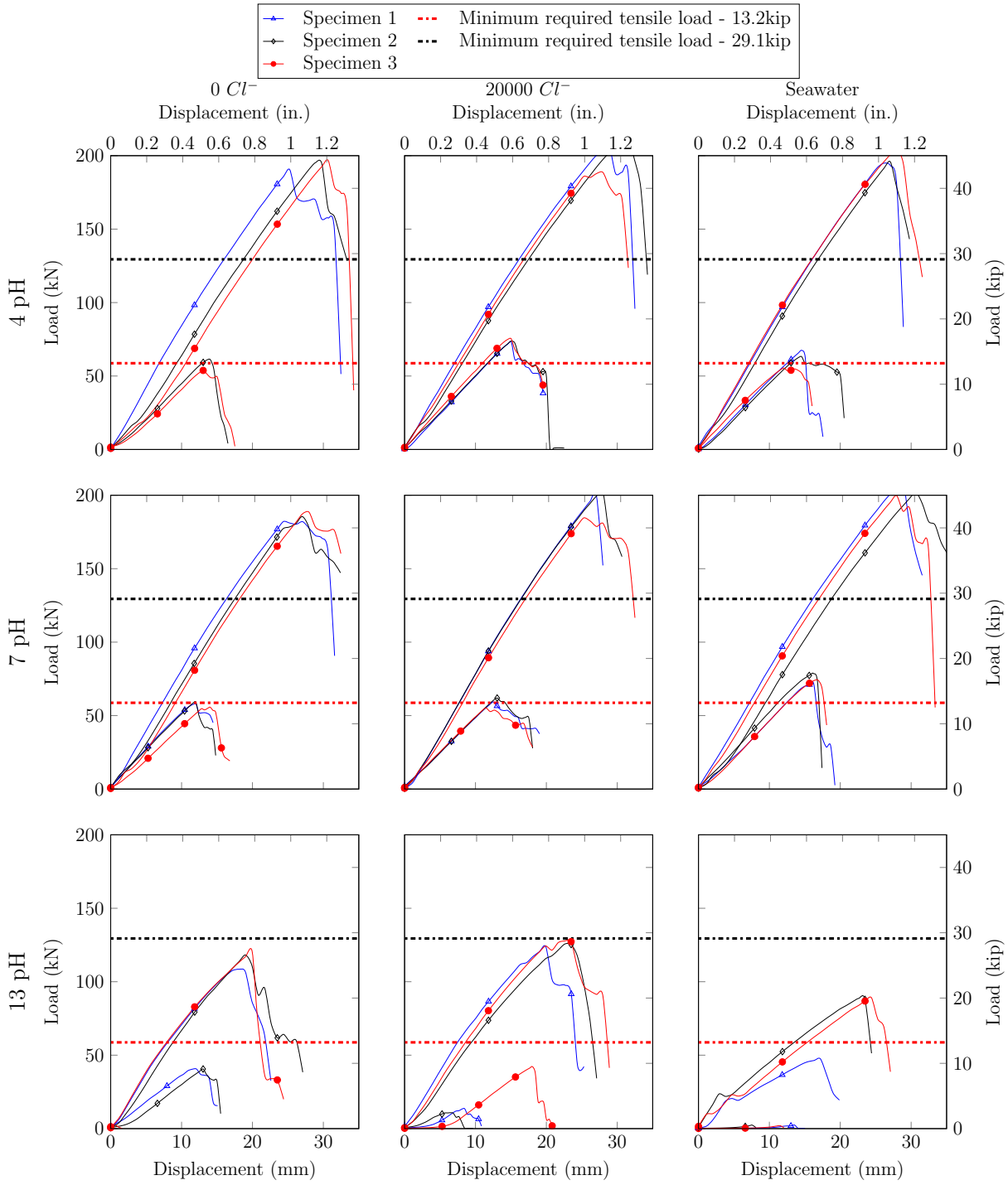

Figure 1.93: Tensile strength-displacement behavior of rebar Type B Lot 1 size 3 and 5

further extension, multiple times, until the specimen failed completely. During testing, it was observed that after the maximum load was reached, the rebars delaminated and flared out more and more, as these load-drops occurred (ultimately producing the failure patterns detailed in Section 1.5.2).

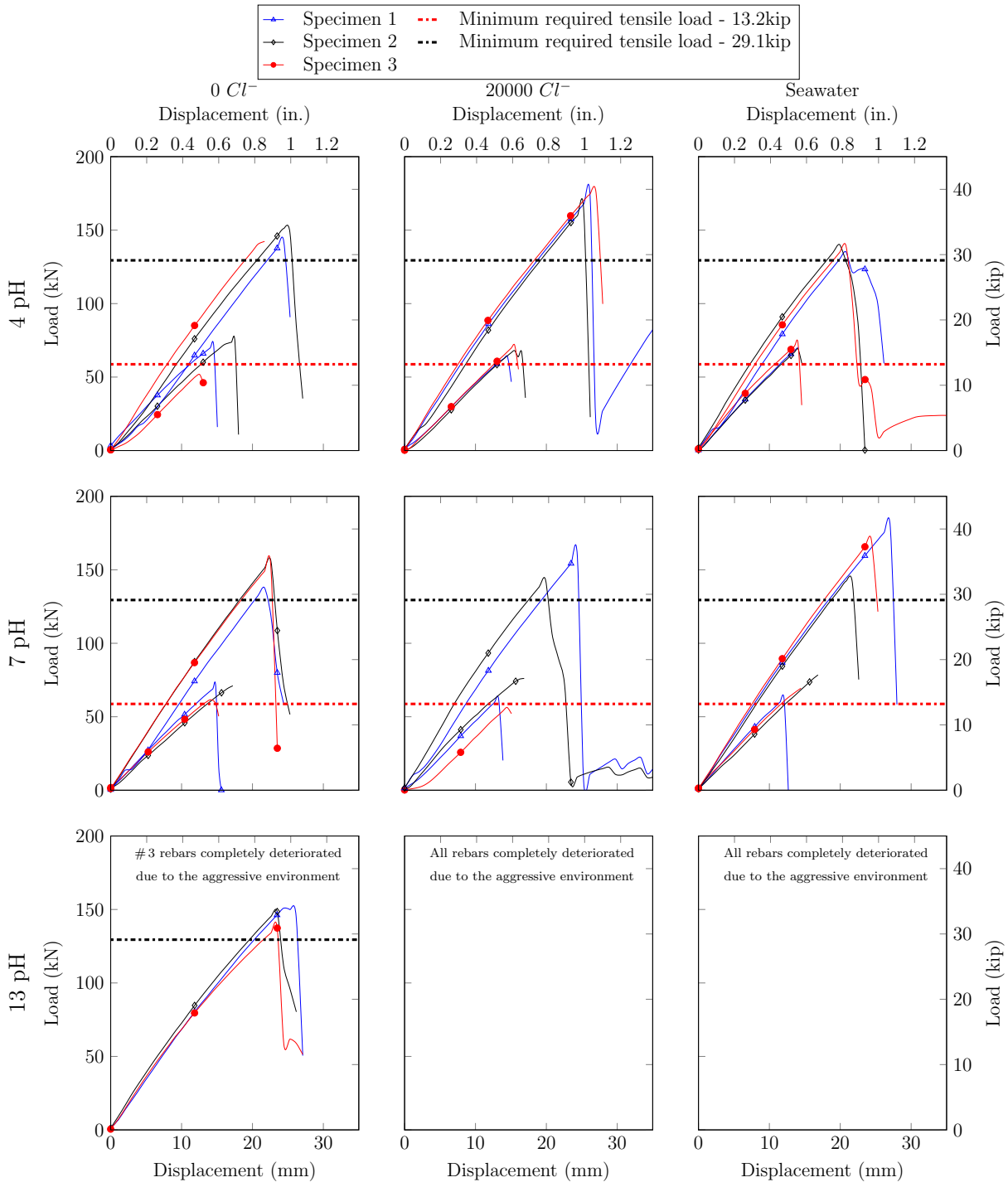

Figure 1.94: Tensile strength-displacement behavior of rebar Type C Lot 1 size 3 and 5

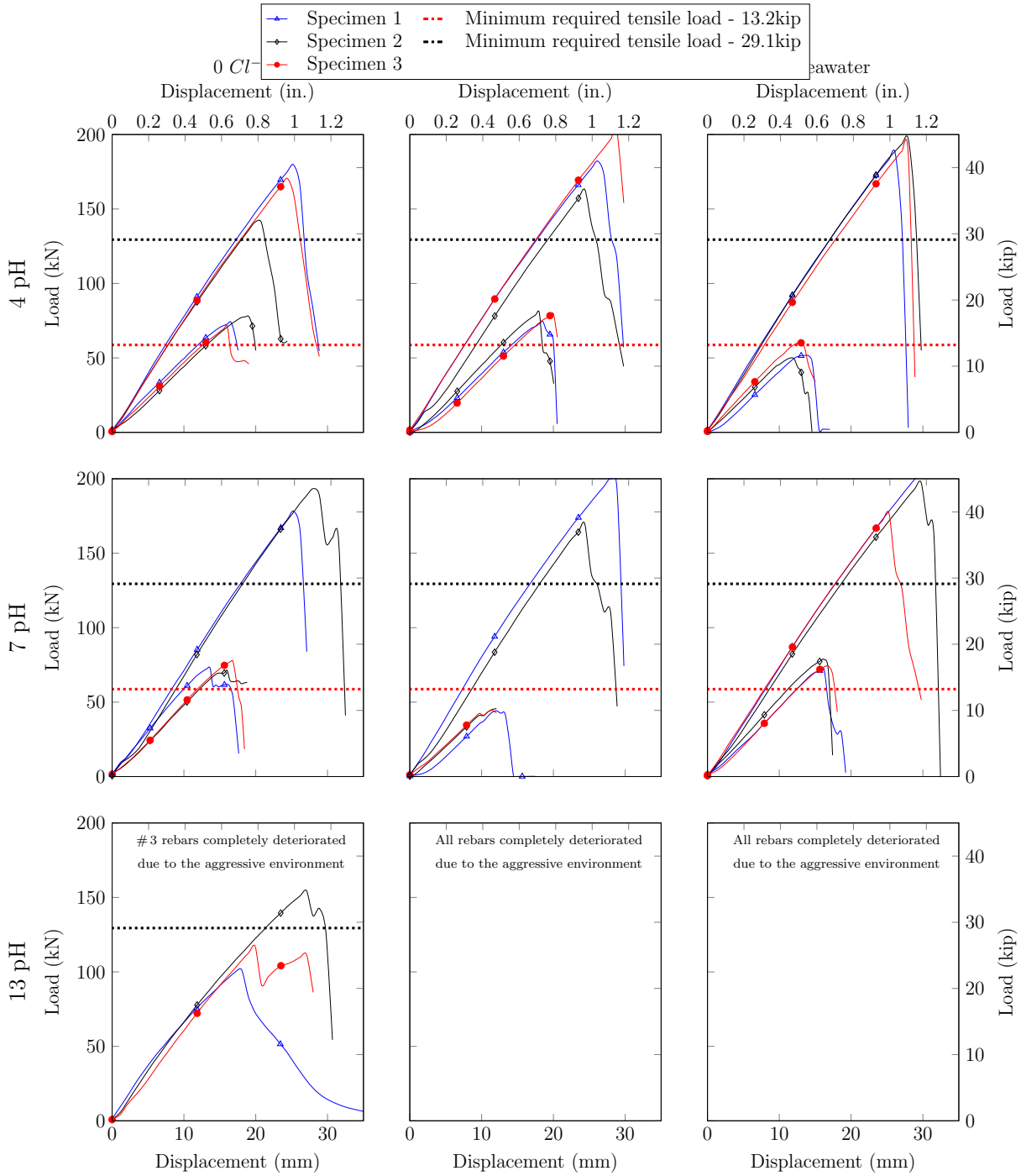

Figure 1.95: Tensile strength-displacement behavior of rebar Type A Lot 2 size 3 and 5

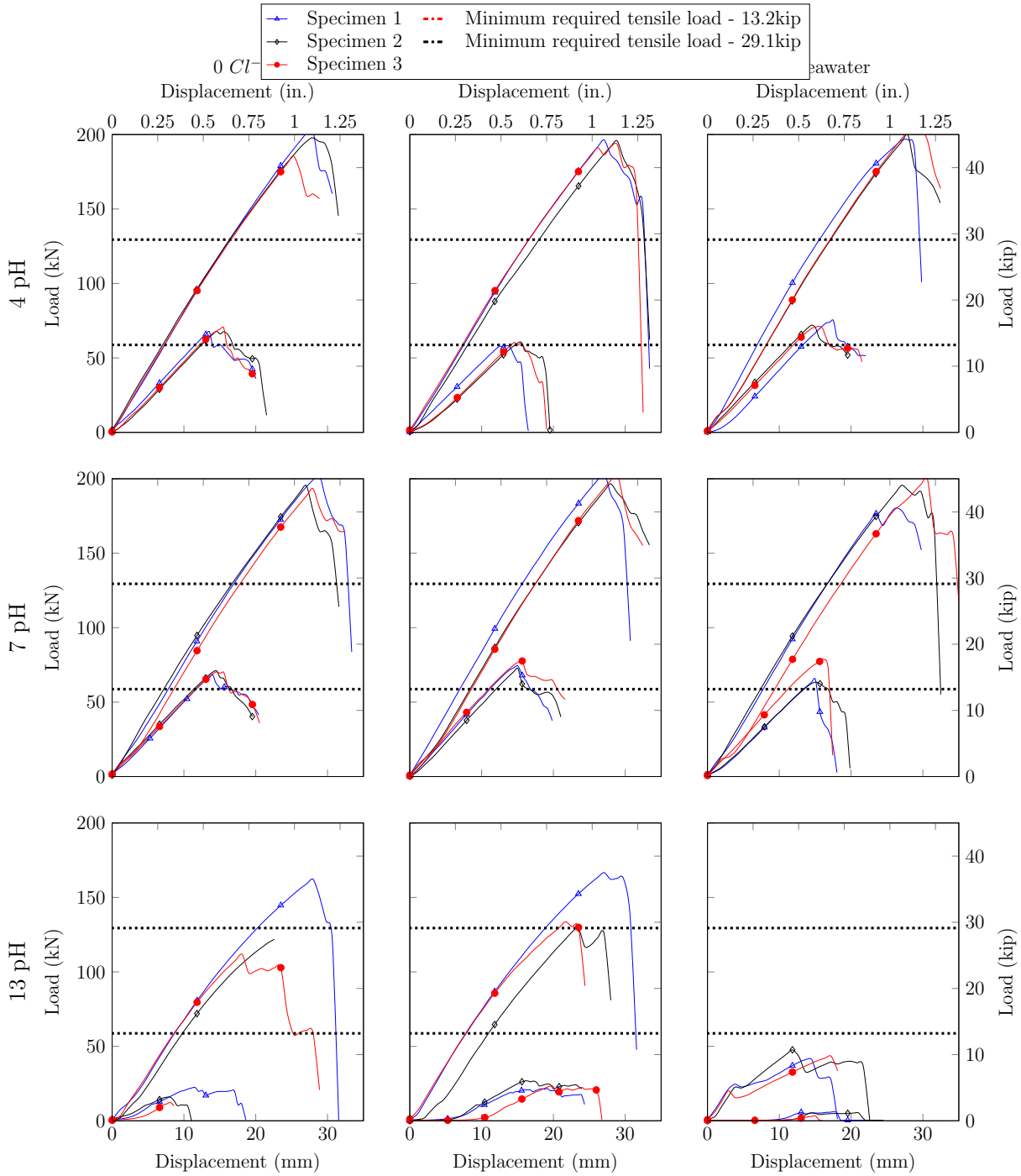

Figure 1.96: Tensile strength-displacement behavior of rebar Type B Lot 2 size 3 and 5

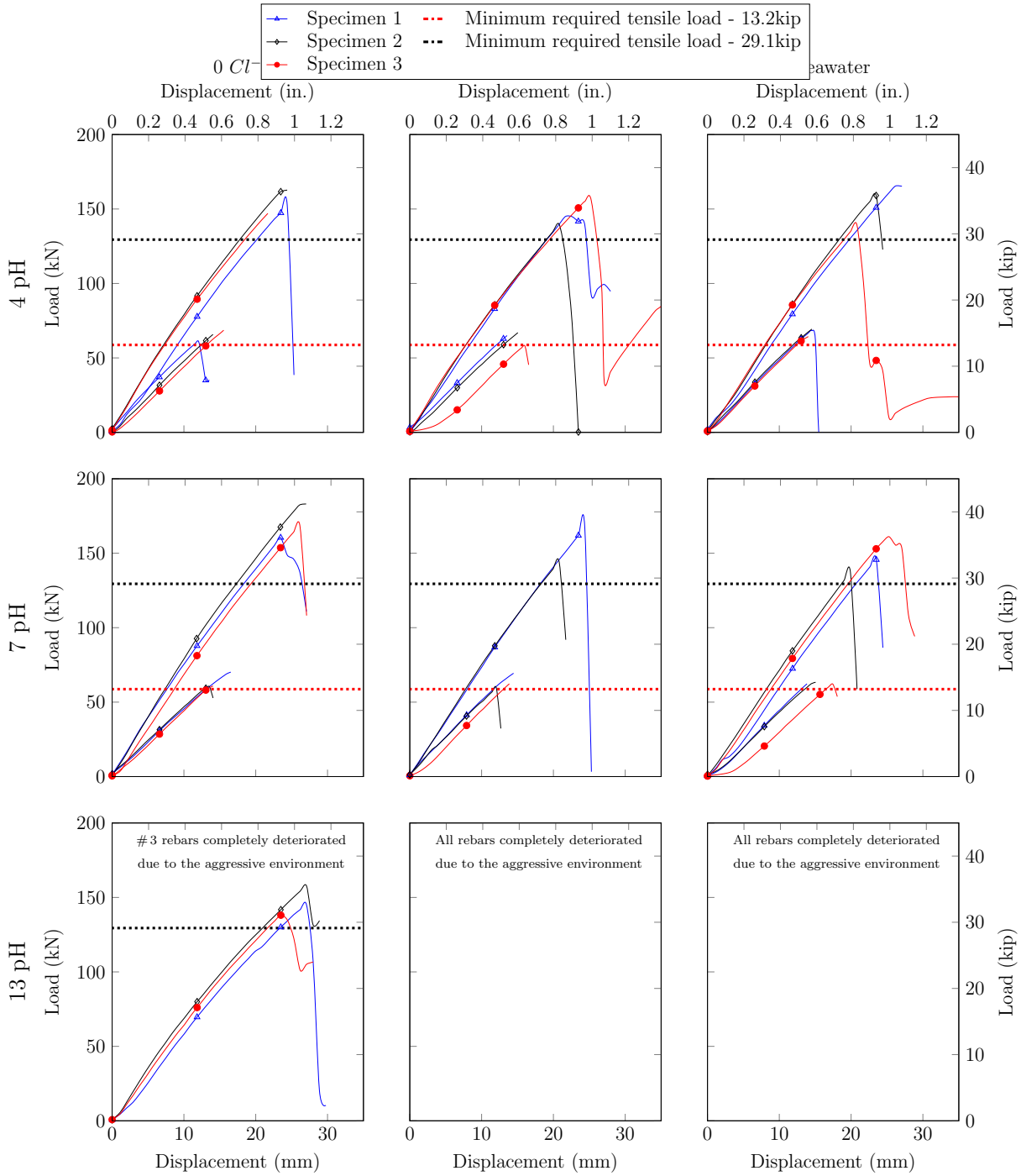

Figure 1.97: Tensile strength-displacement behavior of rebar Type C Lot 2 size 3 and 5

Stress-Strain Behavior

The stress-strain behavior of the failed rebars of all types was plotted to quantify and compare the elastic moduli of the tested BFRP rebars. The data in Figures 1.98, 1.99, 1.100, 1.101, 1.102, and 1.103 were plotted to compare the stress-strain behavior of the different rebar types. Accordingly, the x-axis shows the applied stress while the y-axis represents the outermost surface strain that was measured with an external extensometer. The results

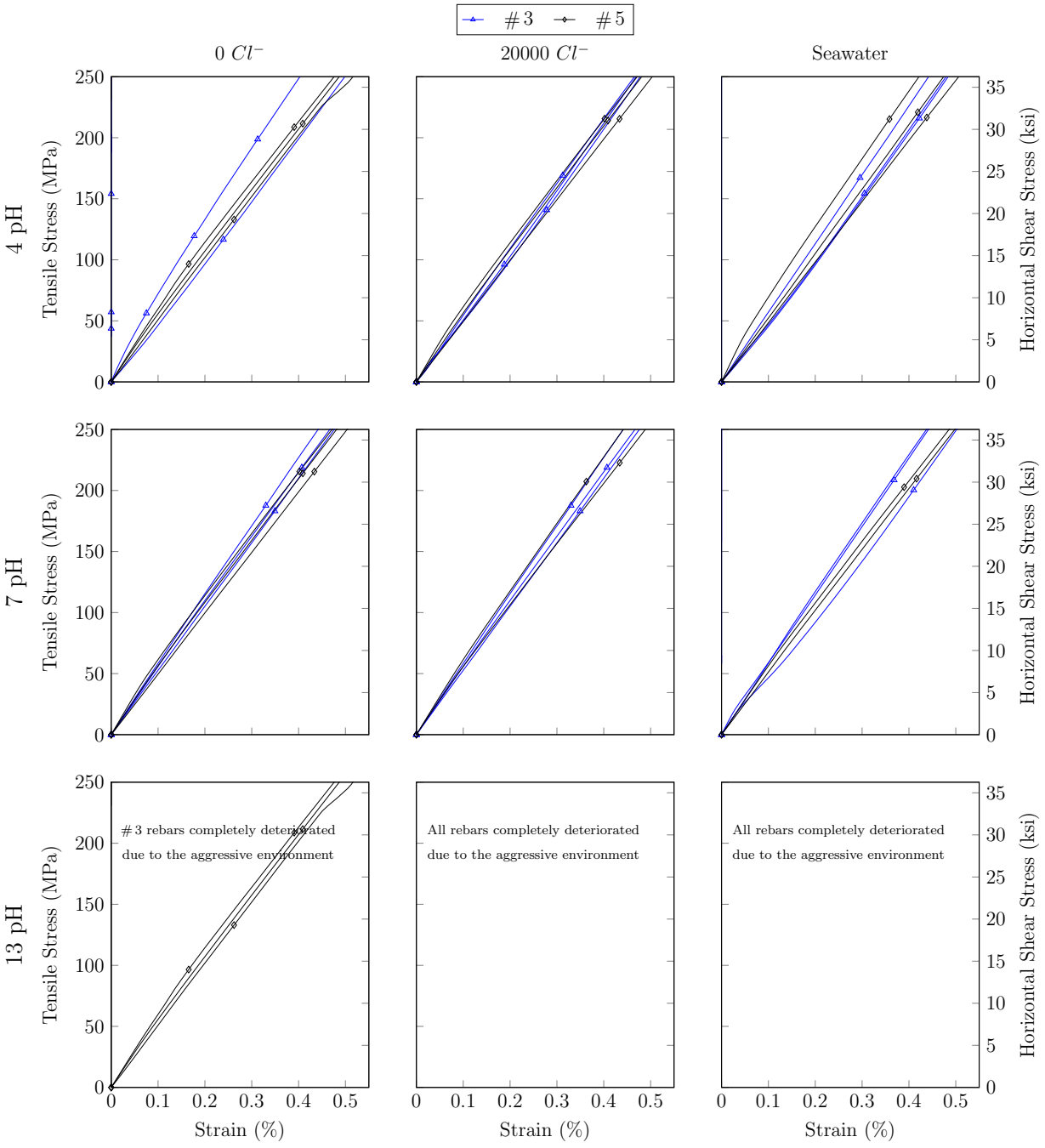

Figure 1.98: Tensile stress - Strain behavior of rebar Type A Lot 1 size 3 and 5

plotted in the graph in Figure 1.98 show that though the load capacities of the different sized rebars vary widely, the slope of the stress-strain curve was identical for all the rebars. It

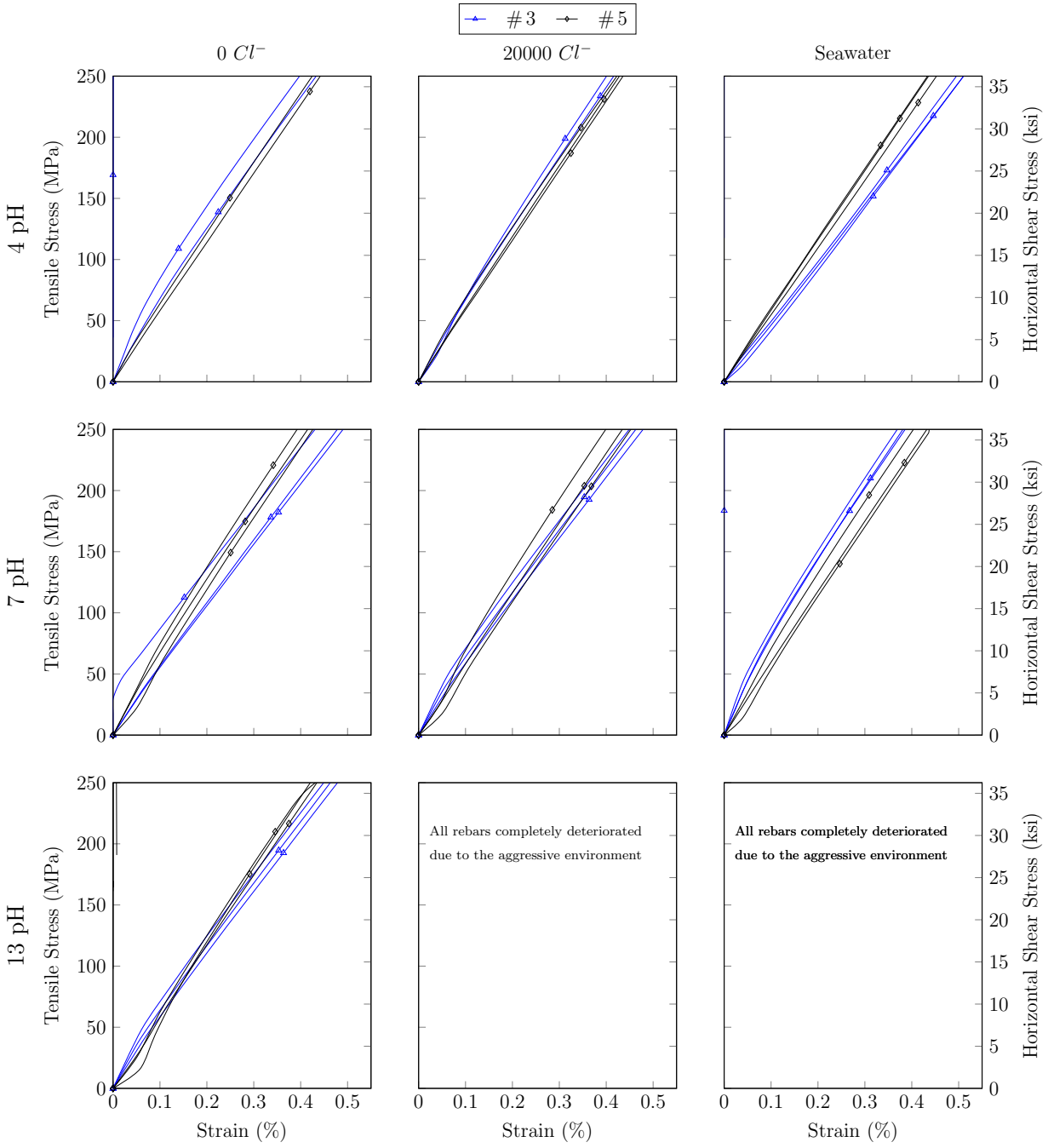

Figure 1.99: Tensile stress - Strain behavior of rebar Type B Lot 1 size 3 and 5

can be seen in Figure 1.99 that stress-strain behavior of rebar Type B are identical for both the rebar sizes. The stress-strain behavior of rebars from lot 2 as shown in Figures 1.101, 1.102, and 1.103 show that the slopes of bars from Lot 1 and Lot 2 were identical.

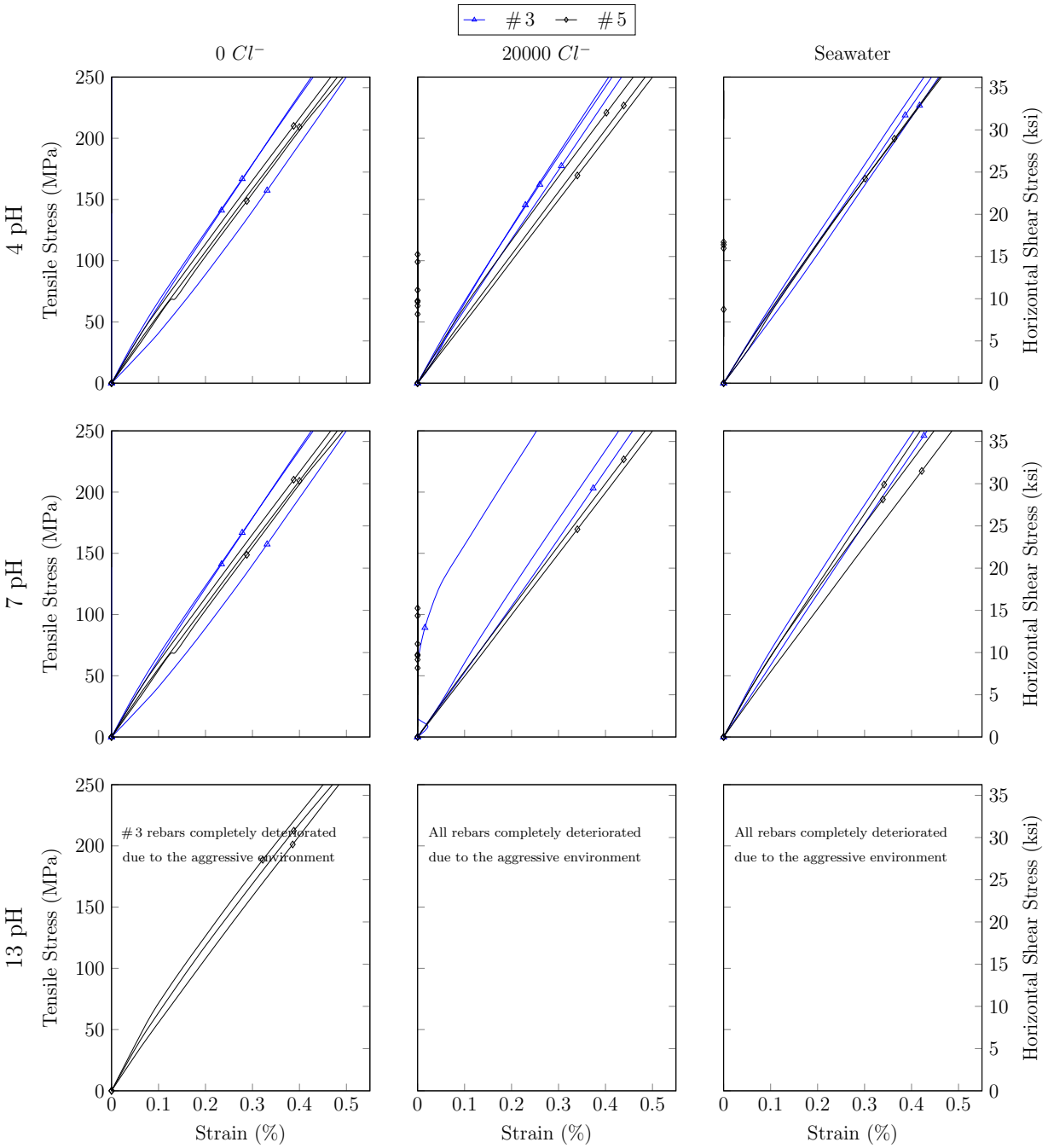

Figure 1.100: Tensile stress - Strain behavior of rebar Type C Lot 1 size 3 and 5

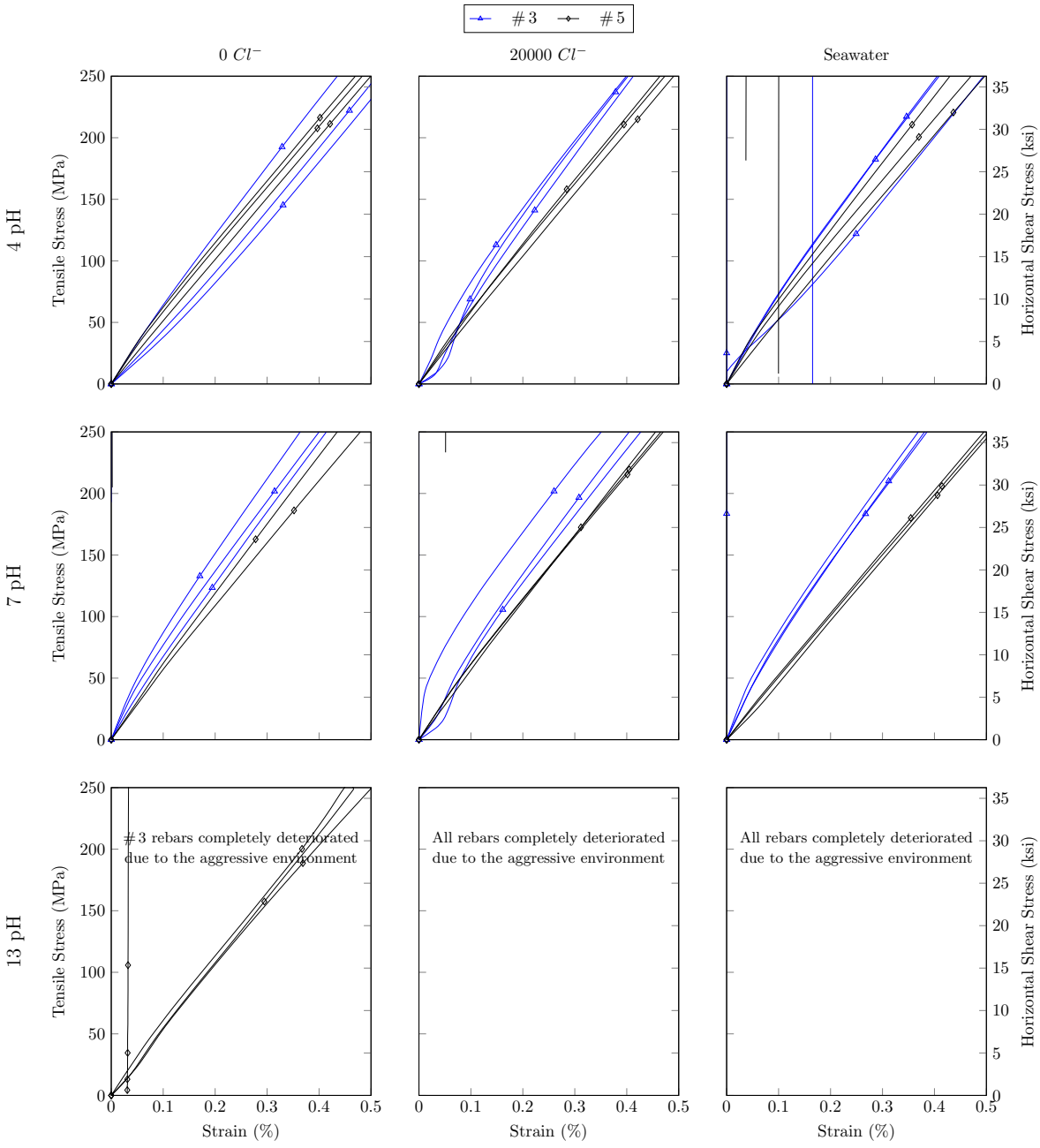

Figure 1.101: Tensile stress - Strain behavior of rebar Type A Lot 2 size 3 and 5

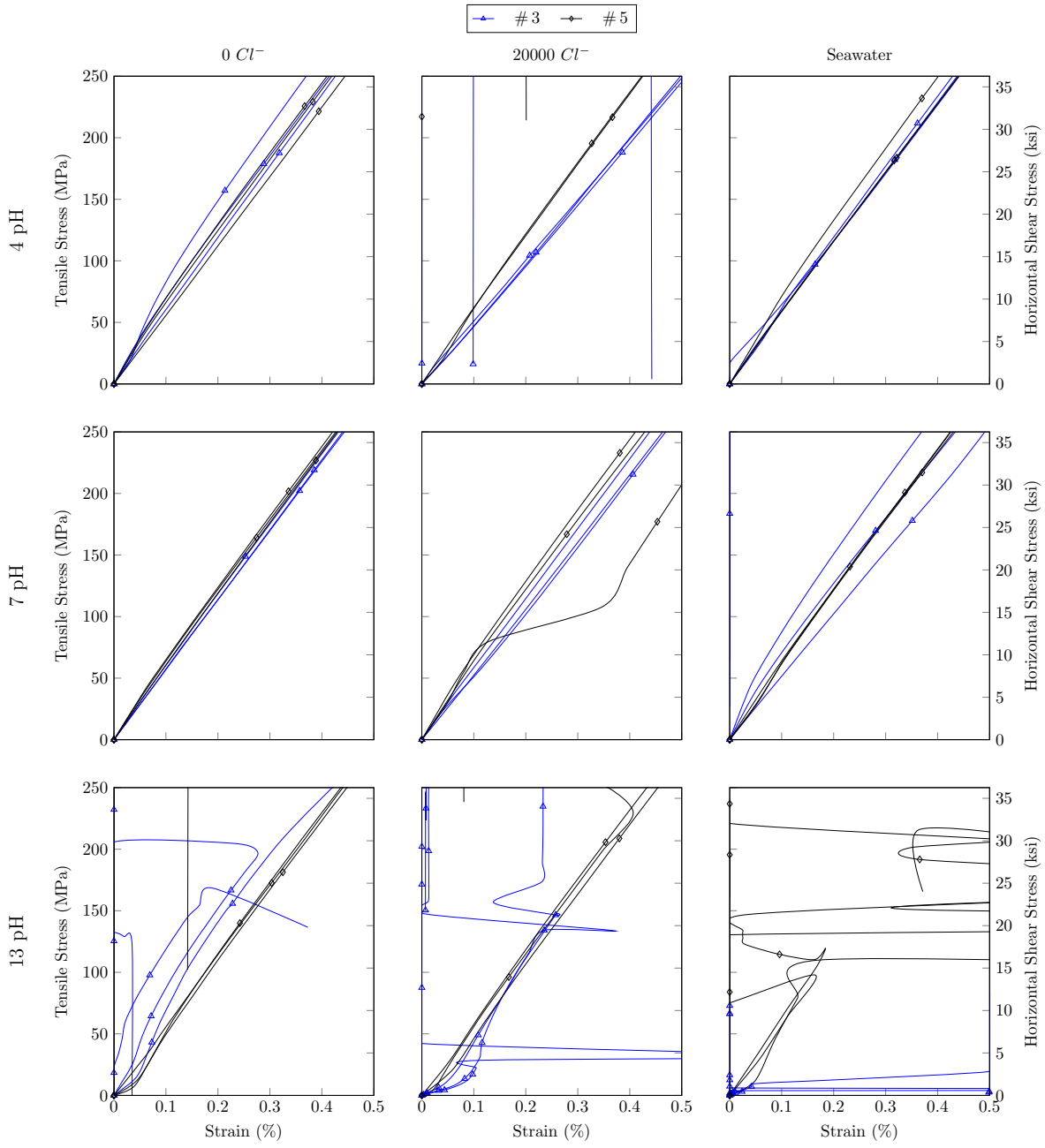

Figure 1.102: Tensile stress - Strain behavior of rebar Type B Lot 2 size 3 and 5

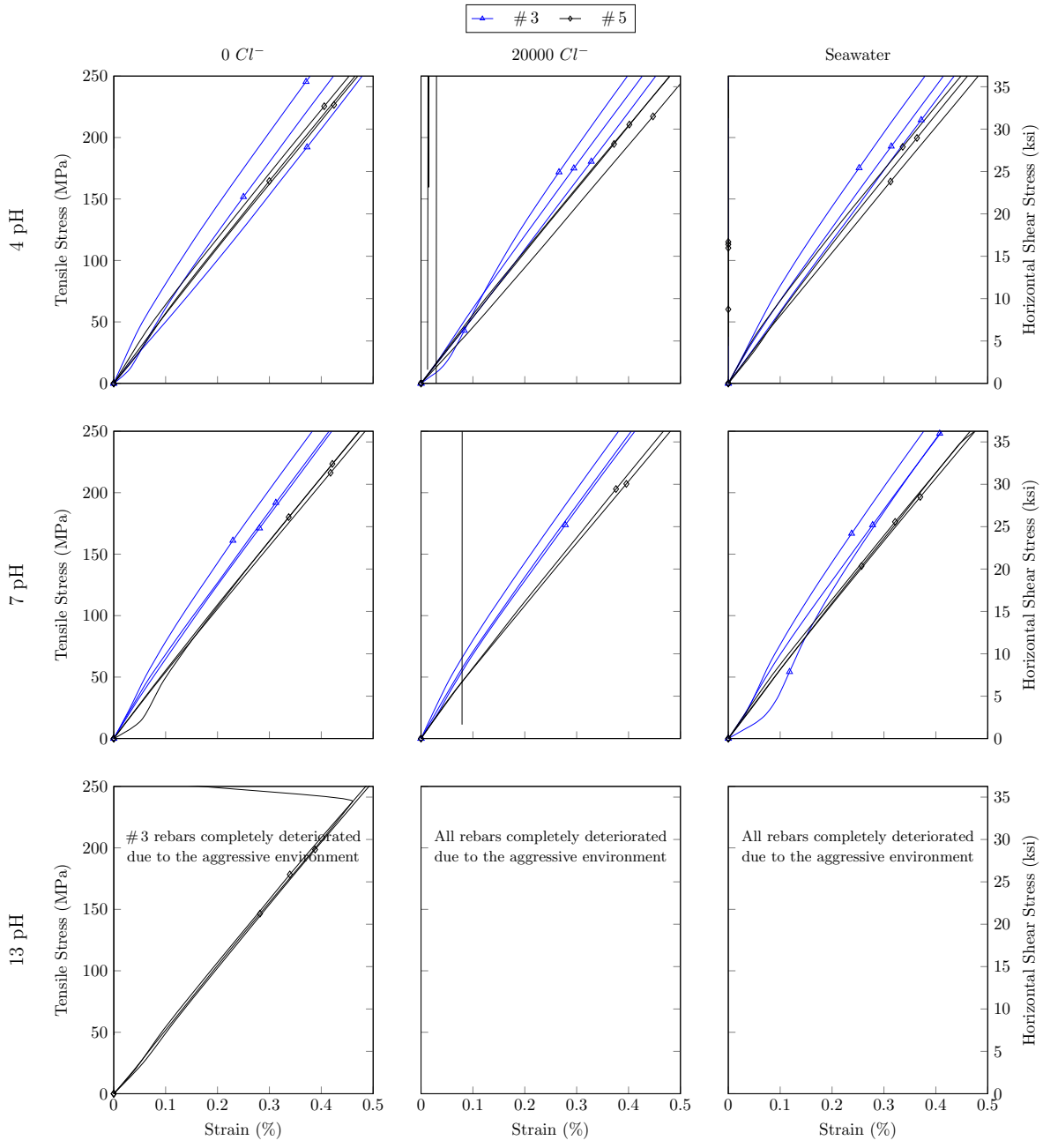

Figure 1.103: Tensile stress - Strain behavior of rebar Type C Lot 2 size 3 and 5

1.5.8 Modes of Failure

According to ASTM D 7205, three different failure modes may occur during a tensile strength test. The first and expected one is the tensile rupture outside of the anchor pipes. Due to insufficient sample preparation or test procedure issues, two more failure modes may occur. The rebar could slip within the grouted anchor (rebar slippage) or the anchor could slip out of the fixture/grips (anchor slippage). Therefore, the last two described failure modes lead to unusable results when defining the material characteristics. However, for this research project, no specimen failed due to rebar or anchor slippage. Hence, tensile rupture of the BFRP rebar was the recorded failure mode for each bar that was tested.

Figure 1.104 and 1.105 show the failed specimens of Type A rebars. It can be seen that all specimens, regardless of their diameter, displayed similar failure pattern. The fibers formed a brush type of failure and all specimens suffered fiber delamination throughout the entire free specimen length. Figure 1.106 and 1.107 present the post failure pattern of Type B rebar specimens. It is shown that all the rebar sizes had an identical failure. The fibers were delaminated and a distinct brush-like failure was observed. Figure 1.108 and 1.109 show the failed specimens of # 3 and # 5 Type C rebars. All the specimens failed in a similar manner. After the peak load was reached, an abrupt brittle failure of the rebar was observed close to the anchor.

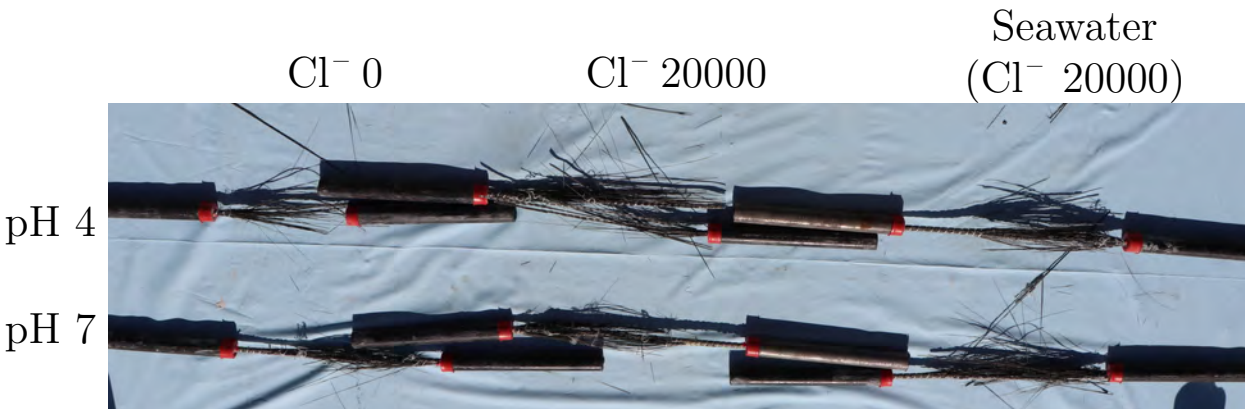

Figure 1.104: Tensile test failure mode of Type A # 3 rebars

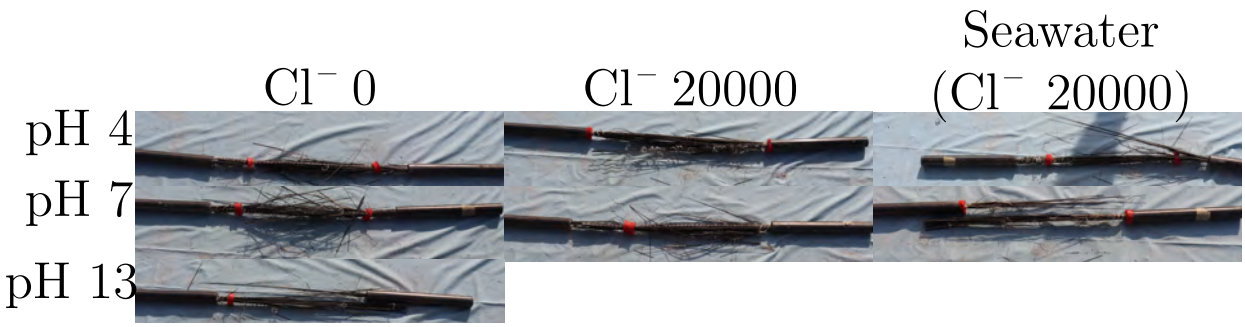

Figure 1.105: Tensile test failure mode of Type A # 5 rebars

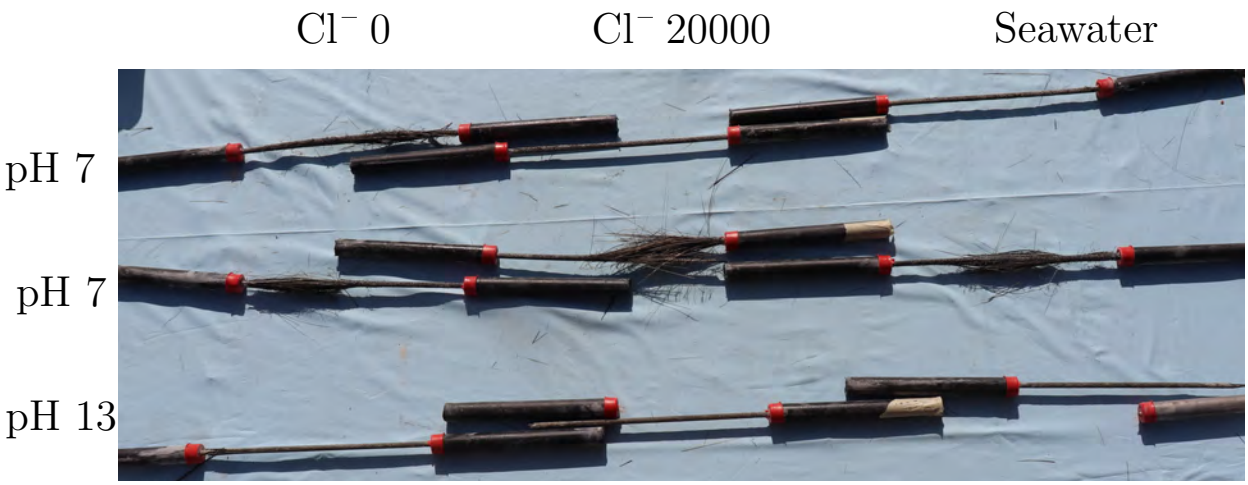

Figure 1.106: Tensile test failure mode of Type B # 3 rebars

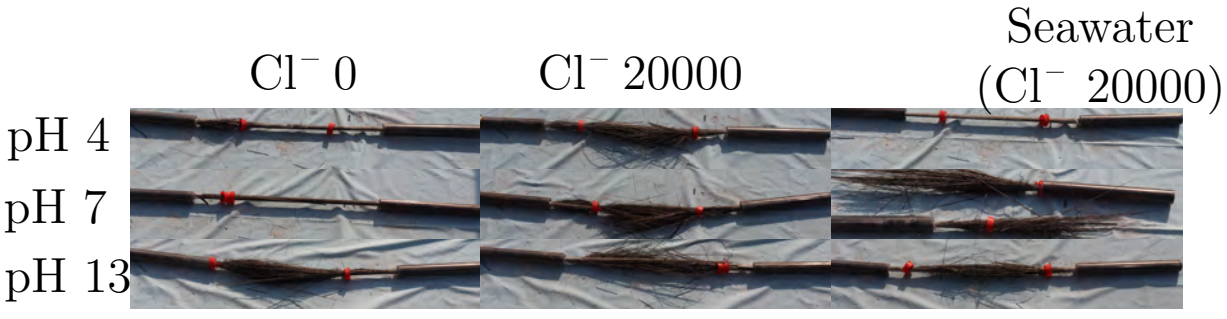

Figure 1.107: Tensile test failure mode of Type B # 5 rebars

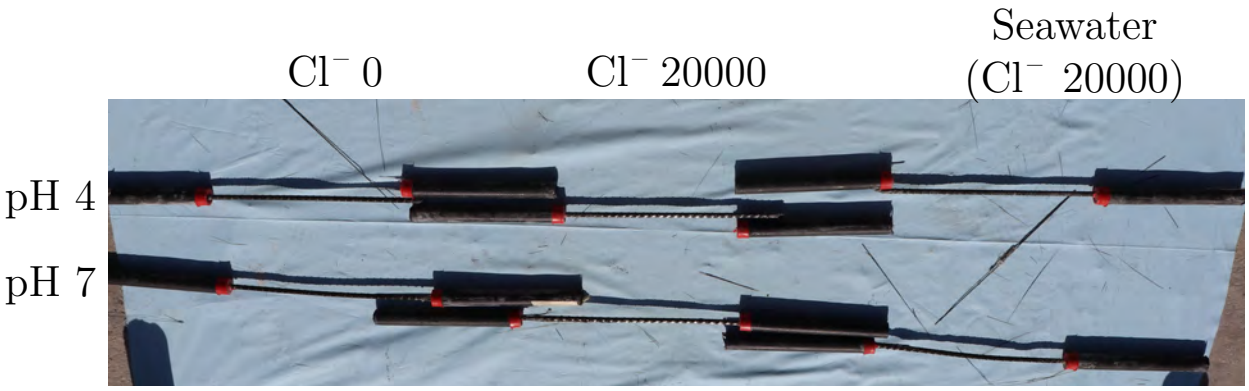

Figure 1.108: Tensile test failure mode of Type C # 3 rebars

Figure 1.109: Tensile test failure mode of Type C # 5 rebars

1.5.9 Summary of Tensile Properties

The concentration of the statistical evaluation for the measured tensile properties of all products along with the elastic modulus property are listed in the following Table 1.51.

Table 1.51: 300Day Tensile strength test statistical values for each sample group (US Customary Units)

Sample group						Statistical Values									
						Tensile Strength					Elastic Modulus				
Manuf. Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeA	Epoxy	3	1	4	0	137.5	151.8	143.9	7.3	5.07	7335	8650.9	8139.0	704.9	8.66
TypeA	Epoxy	5	1	4	0	121.1	123.6	122.5	1.3	1.04	7325	7579.4	7431.4	132.2	1.78
TypeA	Epoxy	3	2	4	0	143.9	155.1	150.0	5.7	3.80	6722	8079.0	7281.5	709.0	9.74
TypeA	Epoxy	5	2	4	0	104.2	132.8	121.4	15.2	12.51	7254	7492.9	7345.5	128.9	1.76
TypeB	VinylEster	3	1	4	0	106.9	122.0	114.4	10.7	9.36	8080	8246.6	8163.1	118.1	1.45
TypeB	VinylEster	5	1	4	0	140.3	145.7	143.6	2.9	1.99	8148	8709.9	8406.9	283.6	3.37
TypeB	VinylEster	3	2	4	0	135.1	142.8	138.8	3.8	2.77	8394	9078.5	8654.2	370.6	4.28
TypeB	VinylEster	5	2	4	0	139.1	149.6	144.4	5.3	3.65	8219	8548.6	8395.2	165.9	1.98
TypeC	Epoxy	3	1	4	0	104.6	149.2	130.9	23.4	17.84	8083	9927.6	8893.0	942.7	10.60
TypeC	Epoxy	5	1	4	0	105.1	113.5	108.6	4.3	4.00	6980	7840.8	7520.7	471.1	6.26
TypeC	Epoxy	3	2	4	0	120.3	140.6	131.6	10.3	7.85	7522	8966.3	8353.1	746.1	8.93
TypeC	Epoxy	5	2	4	0	108.7	120.0	113.5	5.8	5.13	7680	7815.7	7745.7	67.9	0.88
TypeA	Epoxy	3	1	4	20000	147.2	150.7	149.0	1.7	1.17	7529	7822.0	7684.0	147.0	1.91
TypeA	Epoxy	5	1	4	20000	131.2	154.9	139.1	13.7	9.84	7256	7489.8	7403.8	128.8	1.74
TypeA	Epoxy	3	2	4	20000	151.4	163.7	158.9	6.6	4.14	8365	9048.4	8719.9	342.3	3.93
TypeA	Epoxy	5	2	4	20000	119.7	148.8	134.1	14.6	10.85	7395	7768.2	7540.5	199.7	2.65
TypeB	VinylEster	3	1	4	20000	148.9	152.0	150.8	1.7	1.11	8280	8918.5	8554.8	328.5	3.84
TypeB	VinylEster	5	1	4	20000	138.8	155.3	148.8	8.7	5.88	8221	8395.2	8318.0	88.5	1.06
TypeB	VinylEster	3	2	4	20000	119.3	124.6	121.9	2.7	2.18	7115	7303.0	7192.0	98.4	1.37
TypeB	VinylEster	5	2	4	20000	141.3	146.4	144.2	2.6	1.81	NA	NA	NA	NA	NA
TypeC	Epoxy	3	1	4	20000	127.1	147.9	137.9	10.4	7.54	8274	8887.2	8581.5	306.5	3.57
TypeC	Epoxy	5	1	4	20000	119.8	130.0	126.0	5.4	4.28	7375	7847.1	7583.5	240.9	3.18
TypeC	Epoxy	3	2	4	20000	117.3	137.3	127.1	10.0	7.87	8042	9853.0	8795.0	943.3	10.73

Continued on next page ...

Table 1.51: 300Day Tensile strength test statistical values for each sample group (US Customary Units)

Sample group						Statistical Values									
						Tensile Strength					Elastic Modulus				
Manuf. Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeC	Epoxy	5	2	4	20000	104.7	115.6	109.9	5.5	4.99	7116	7548.0	7385.0	234.7	3.18
TypeA	Epoxy	3	1	4	SeaWater	149.0	149.7	149.3	0.4	0.27	7570	8138.7	7781.7	310.9	4.00
TypeA	Epoxy	5	1	4	SeaWater	126.1	141.6	132.5	8.1	6.12	7158	8230.2	7700.0	536.1	6.96
TypeA	Epoxy	3	2	4	SeaWater	100.8	121.9	109.1	11.2	10.28	6960	8509.4	7981.9	885.3	11.09
TypeA	Epoxy	5	2	4	SeaWater	138.1	145.6	141.7	3.8	2.66	7293	8037.3	7604.2	386.7	5.09
TypeB	VinylEster	3	1	4	SeaWater	113.2	137.8	126.7	12.5	9.88	7170	7300.4	7231.7	65.5	0.91
TypeB	VinylEster	5	1	4	SeaWater	143.1	152.1	146.4	4.9	3.35	7970	8269.1	8164.7	168.3	2.06
TypeB	VinylEster	3	2	4	SeaWater	143.6	153.2	148.0	4.8	3.26	7715	8724.4	8198.9	505.9	6.17
TypeB	VinylEster	5	2	4	SeaWater	143.8	152.5	147.5	4.5	3.03	8191	8720.9	8375.1	299.7	3.58
TypeC	Epoxy	3	1	4	SeaWater	144.0	148.4	145.6	2.4	1.67	7938	8361.2	8139.6	212.3	2.61
TypeC	Epoxy	5	1	4	SeaWater	100.1	104.0	102.7	2.2	2.17	7549	7921.2	7715.8	189.0	2.45
TypeC	Epoxy	3	2	4	SeaWater	130.4	141.1	136.7	5.6	4.12	8308	9059.3	8633.2	385.7	4.47
TypeC	Epoxy	5	2	4	SeaWater	104.0	122.5	114.4	9.4	8.25	7480	7921.2	7722.8	223.9	2.90
TypeA	Epoxy	3	1	7	0	156.5	164.1	159.7	4.0	2.50	7581	8125.6	7808.7	283.0	3.62
TypeA	Epoxy	5	1	7	0	120.4	141.4	128.6	11.2	8.74	7023	7875.1	7315.2	485.0	6.63
TypeA	Epoxy	3	2	7	0	143.2	154.9	148.0	6.2	4.16	8452	9082.3	8686.9	344.4	3.96
TypeA	Epoxy	5	2	7	0	133.0	142.1	137.5	6.4	4.69	7500	8249.7	7875.1	529.8	6.73
TypeB	VinylEster	3	1	7	0	112.1	119.6	115.9	3.8	3.24	7139	7488.2	7313.6	174.7	2.39
TypeB	VinylEster	5	1	7	0	135.7	140.1	137.6	2.2	1.64	8527	8897.3	8707.7	185.5	2.13
TypeB	VinylEster	3	2	7	0	138.2	141.5	140.3	1.8	1.29	8181	8348.9	8239.9	94.5	1.15
TypeB	VinylEster	5	2	7	0	143.2	149.5	145.8	3.3	2.25	8262	8450.9	8362.6	94.9	1.14
TypeC	Epoxy	3	1	7	0	123.1	143.7	136.7	11.8	8.62	7224	8323.0	7913.0	600.4	7.59
TypeC	Epoxy	5	1	7	0	103.8	116.7	110.8	6.5	5.89	7258	7608.4	7444.4	176.5	2.37
TypeC	Epoxy	3	2	7	0	121.7	139.1	127.7	9.9	7.73	8442	8961.4	8652.8	273.1	3.16

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Table 1.51: 300Day Tensile strength test statistical values for each sample group (US Customary Units)

Sample group						Statistical Values									
						Tensile Strength					Elastic Modulus				
Manuf. Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeC	Epoxy	5	2	7	0	119.2	136.2	126.7	8.6	6.83	7398	8085.7	7698.9	351.7	4.57
TypeA	Epoxy	3	1	7	20000	145.4	152.5	149.5	3.7	2.46	7575	7844.3	7703.7	135.2	1.76
TypeA	Epoxy	5	1	7	20000	78.3	119.9	99.1	29.4	29.63	7334	8095.6	7715.0	538.3	6.98
TypeA	Epoxy	3	2	7	20000	88.3	92.5	90.1	2.1	2.39	8255	8625.8	8440.1	185.4	2.20
TypeA	Epoxy	5	2	7	20000	125.2	148.1	134.3	12.2	9.06	7447	7919.7	7660.6	239.6	3.13
TypeB	VinylEster	3	1	7	20000	112.4	125.3	118.5	6.4	5.44	7465	7585.7	7529.4	61.0	0.81
TypeB	VinylEster	5	1	7	20000	136.2	148.6	144.1	6.9	4.77	8253	8973.9	8538.1	383.4	4.49
TypeB	VinylEster	3	2	7	20000	148.6	157.6	152.3	4.7	3.08	7620	8183.1	7870.7	286.6	3.64
TypeB	VinylEster	5	2	7	20000	146.6	149.6	148.6	1.7	1.13	1198	8501.6	5991.4	4152.9	69.31
TypeC	Epoxy	3	1	7	20000	118.6	155.6	133.4	19.5	14.65	7894	8851.5	8423.6	487.1	5.78
TypeC	Epoxy	5	1	7	20000	93.3	115.8	104.8	11.2	10.72	7274	7752.0	7503.1	239.5	3.19
TypeC	Epoxy	3	2	7	20000	122.0	139.1	129.3	8.8	6.81	8574	8927.9	8724.8	182.6	2.09
TypeC	Epoxy	5	2	7	20000	106.0	129.6	119.4	12.2	10.18	7347	7726.3	7490.7	205.7	2.75
TypeA	Epoxy	3	1	7	SeaWater	118.2	129.5	125.2	6.1	4.84	6981	8388.0	7815.1	738.9	9.46
TypeA	Epoxy	5	1	7	SeaWater	132.3	148.7	139.9	8.3	5.91	7292	7781.3	7459.9	278.4	3.73
TypeA	Epoxy	3	2	7	SeaWater	144.4	159.1	151.5	7.4	4.87	8633	8951.0	8825.8	169.1	1.92
TypeA	Epoxy	5	2	7	SeaWater	129.6	157.1	144.0	13.8	9.59	7198	7282.3	7251.6	46.9	0.65
TypeB	VinylEster	3	1	7	SeaWater	144.4	159.1	151.5	7.4	4.87	8633	8951.0	8825.8	169.1	1.92
TypeB	VinylEster	5	1	7	SeaWater	147.3	154.5	150.5	3.6	2.42	8354	8795.9	8539.8	229.2	2.68
TypeB	VinylEster	3	2	7	SeaWater	128.8	159.1	139.8	16.8	12.03	7393	8892.9	8063.8	762.4	9.46
TypeB	VinylEster	5	2	7	SeaWater	132.7	146.1	141.4	7.5	5.33	8435	8495.9	8465.1	30.5	0.36
TypeC	Epoxy	3	1	7	SeaWater	123.4	159.3	140.6	18.0	12.80	8354	8955.1	8660.3	300.9	3.47
TypeC	Epoxy	5	1	7	SeaWater	106.9	130.8	121.8	13.0	10.65	7421	8482.8	7899.6	538.7	6.82
TypeC	Epoxy	3	2	7	SeaWater	126.9	127.8	127.5	0.5	0.40	8574	10 700.4	9543.3	1075.4	11.27

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Table 1.51: 300Day Tensile strength test statistical values for each sample group (US Customary Units)

Sample group						Statistical Values									
						Tensile Strength					Elastic Modulus				
Manuf. Type	Resin Type	Size #	Lot No.	pH	Cl^-	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %	$\wedge$ ksi	$\vee$ ksi	μ ksi	σ ksi	CV %
TypeC	Epoxy	5	2	7	SeaWater	102.3	119.1	109.5	8.7	7.93	7610	7714.0	7646.5	58.6	0.77
TypeA	Epoxy	5	1	13	0	63.9	117.4	82.0	30.7	37.38	7064	8242.2	7489.8	653.4	8.72
TypeA	Epoxy	5	2	13	0	73.8	113.8	91.1	20.5	22.50	7424	7602.5	7513.4	89.1	1.19
TypeB	VinylEster	3	1	13	0	3.1	83.3	55.6	45.5	81.84	NA	NA	NA	NA	NA
TypeB	VinylEster	5	1	13	0	80.7	89.2	86.1	4.7	5.44	8443	9266.8	8841.7	412.5	4.67
TypeB	VinylEster	3	2	13	0	26.3	44.9	33.8	9.8	29.10	NA	NA	NA	NA	NA
TypeB	VinylEster	5	2	13	0	82.3	118.8	96.8	19.4	20.05	8356	8807.6	8552.0	231.5	2.71
TypeC	Epoxy	5	1	13	0	100.6	111.9	107.1	5.9	5.50	7492	7702.9	7598.9	105.7	1.39
TypeC	Epoxy	5	2	13	0	101.8	116.1	108.7	7.2	6.61	7516	7580.7	7545.3	32.9	0.44
TypeB	VinylEster	3	1	13	20000	21.8	87.3	45.7	36.2	79.33	NA	NA	NA	NA	NA
TypeB	VinylEster	5	1	13	20000	90.9	95.0	92.6	2.1	2.32	8112	8961.1	8455.2	447.2	5.29
TypeB	VinylEster	3	2	13	20000	44.2	55.3	49.0	5.7	11.61	728	8583.2	5820.2	4415.0	75.86
TypeB	VinylEster	5	2	13	20000	95.9	122.7	105.7	14.8	14.03	8388	8536.5	8455.2	75.2	0.89
TypeB	VinylEster	3	1	13	SeaWater	3.9	5.0	4.5	0.6	12.85	NA	NA	NA	NA	NA
TypeB	VinylEster	5	1	13	SeaWater	35.0	65.0	55.0	17.3	31.50	2356	11629.1	5689.7	5156.6	90.63
TypeB	VinylEster	3	2	13	SeaWater	6.8	12.3	10.2	3.0	29.32	NA	NA	NA	NA	NA
TypeB	VinylEster	5	2	13	SeaWater	30.1	36.4	33.0	3.2	9.66	4487	6684.6	5697.9	1115.6	19.58

A total of 356 specimen, 5 per rebar size, type, lot, and exposure type were tested and analyzed to determine the results shown in the table. For numerical comparison and concluding values, Table 1.51 lists the minimum tensile stress ($\wedge$), the maximum tensile stress ($\vee$), the average tensile stress (μ), the standard deviation (σ), and the coefficient of variation (CV) for each individual test sample.

1.5.10 Bond-to-Concrete Strength

The bond stress τ_{max} (MPa or lbs./in.^{2}) for a circular bar diameter d (mm or in.) is given by Equation 1.1, in which F represents the recorded pullout load (N or lbs.) and L is the accurately measured bond length (mm or in.).

$$\tau_{max} = \frac{F}{d\pi L} \qquad [in\text{MPa } or \text{ psi}] \tag{1.1}$$

This formula was used to determine the bond behavior development and is the basis for the following graphs; Figure 1.110, 1.111, 1.112, 1.113, 1.114, and 1.115 depict the measured bond stresses along the rebar surfaces relative to the rebar slip at the free end. For clarity, the post failure measurements (at the onset of a 50 % load drop) were removed from these graphs. All tested specimens failed at the rebar-concrete interface in bond slip, without splitting the concrete open or without tensile failure. The bond capacity and the failure behavior of the BFRP rebar-concrete interface were affected by the surface enhancement features.

Bond Stress - Slip at Free End

The graphs in this section compare the bond stress - slip at free end of rebar. Graphs in Figure 1.110, 1.111, 1.112, 1.113, 1.114, and 1.115 portray bond stresses - slip at free end of the rebars of both the sizes. The x-axis of the graph signifies the measured bond stress, while the y-axis represents the slip of rebar at the free end.

Generally, from the graphs in Figure 1.110, 1.111, and 1.112 it can be seen that each rebar type resulted in a consistent but distinct failure mode with ultimate stresses that were characteristic for each rebar type. All of the sand-coated rebars (Type B) showed a soft failure while the rebars with a deformed surface (Type A and C) failed suddenly with abrupt pullout.

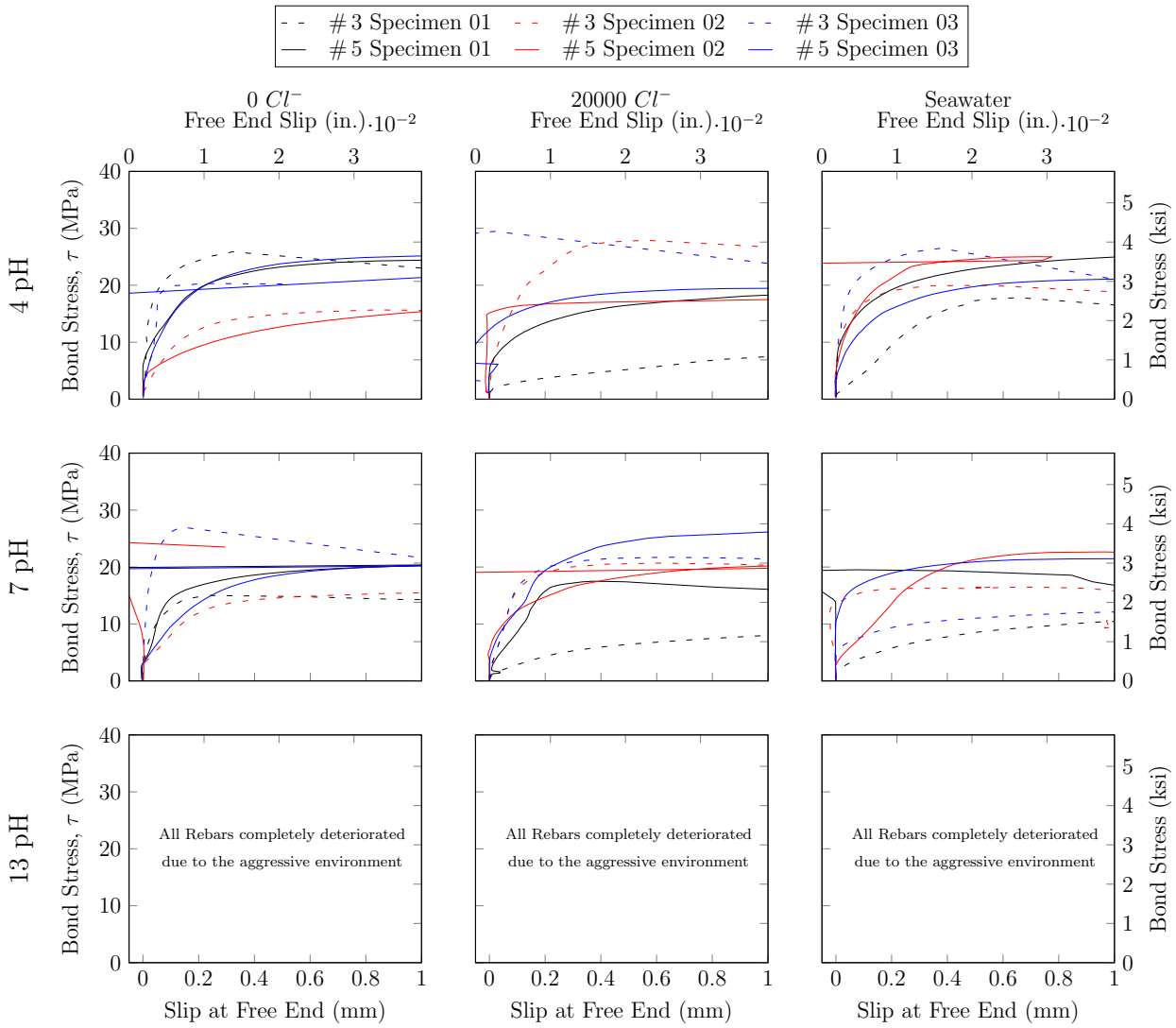

Figure 1.110: Bond stress - slippage behavior of rebar Type A Lot 1 rebars

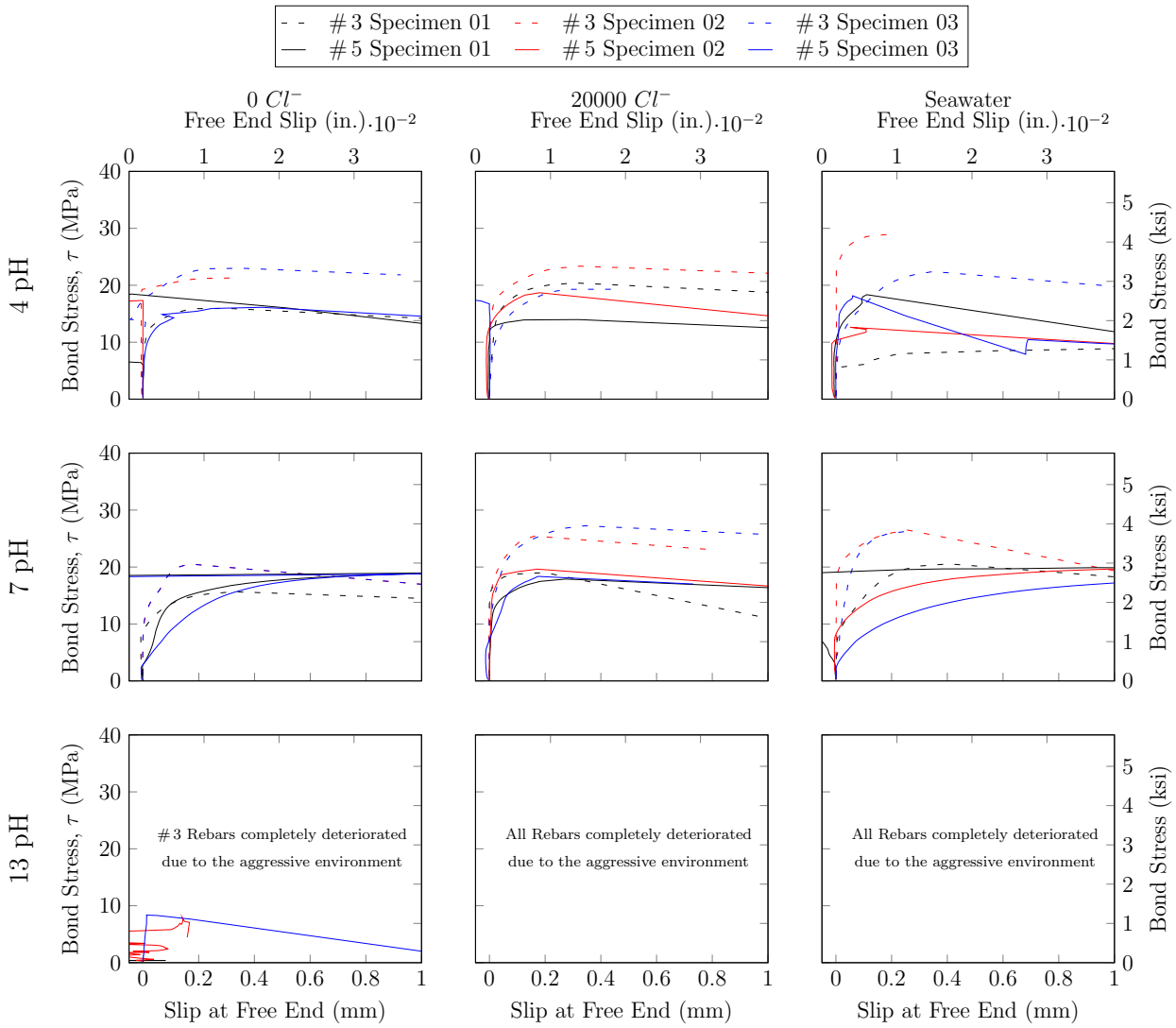

Figure 1.111: Bond stress - slippage behavior of rebar Type B Lot 1 rebars

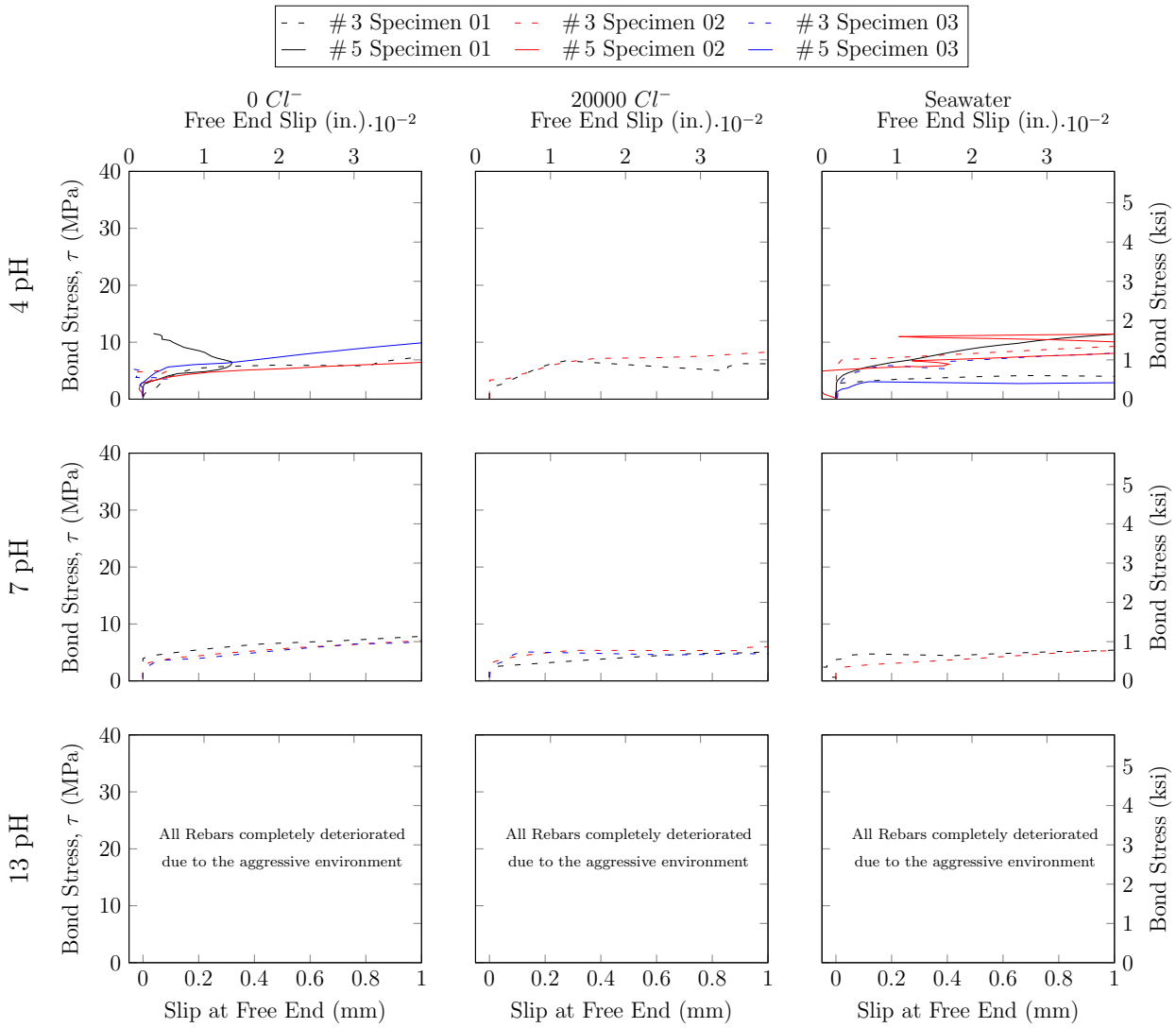

Figure 1.112: Bond stress - slippage behavior of rebar Type C Lot 1 rebars

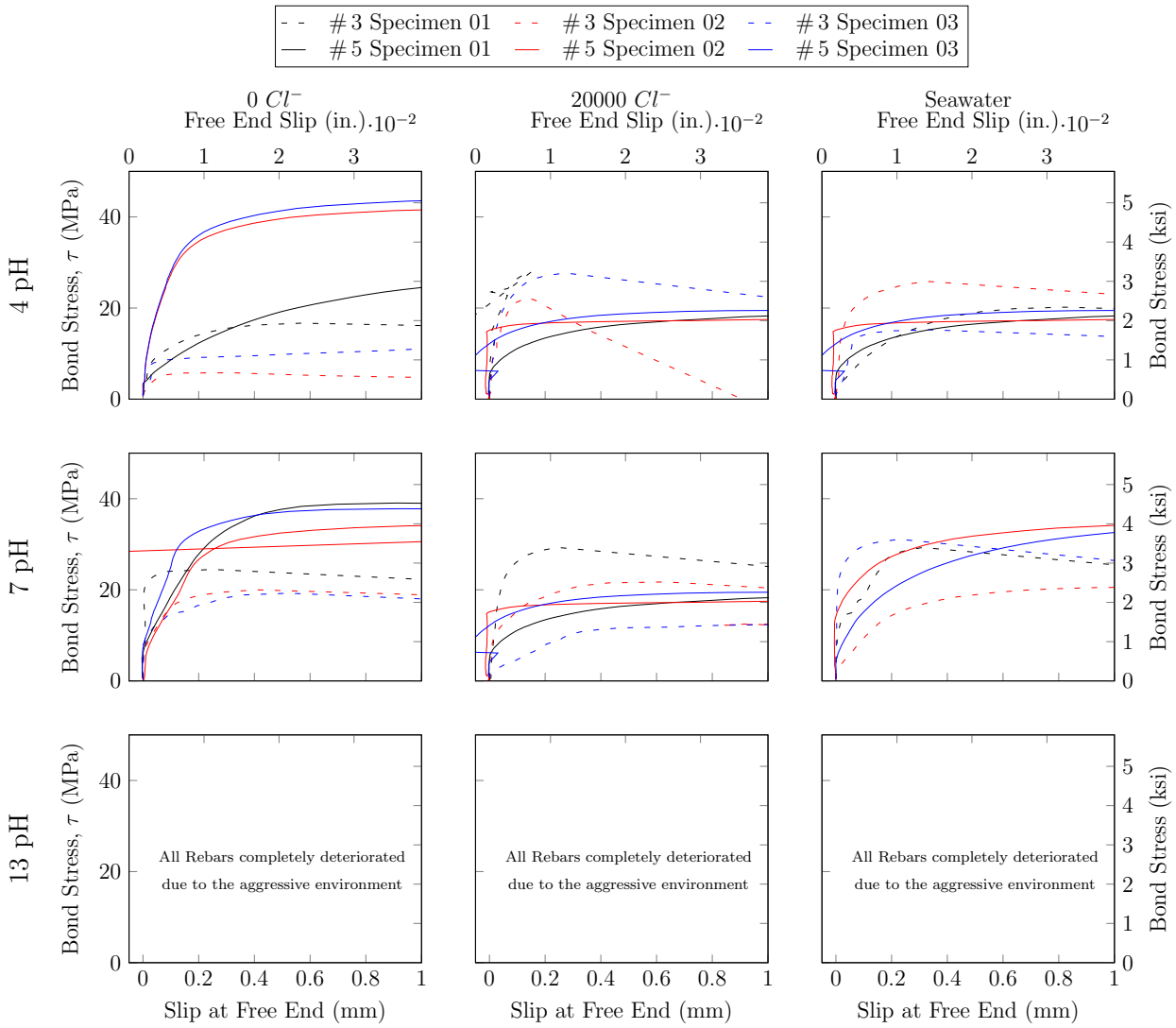

Figure 1.113: Bond stress - slippage behavior of rebar Type A Lot 2 rebars

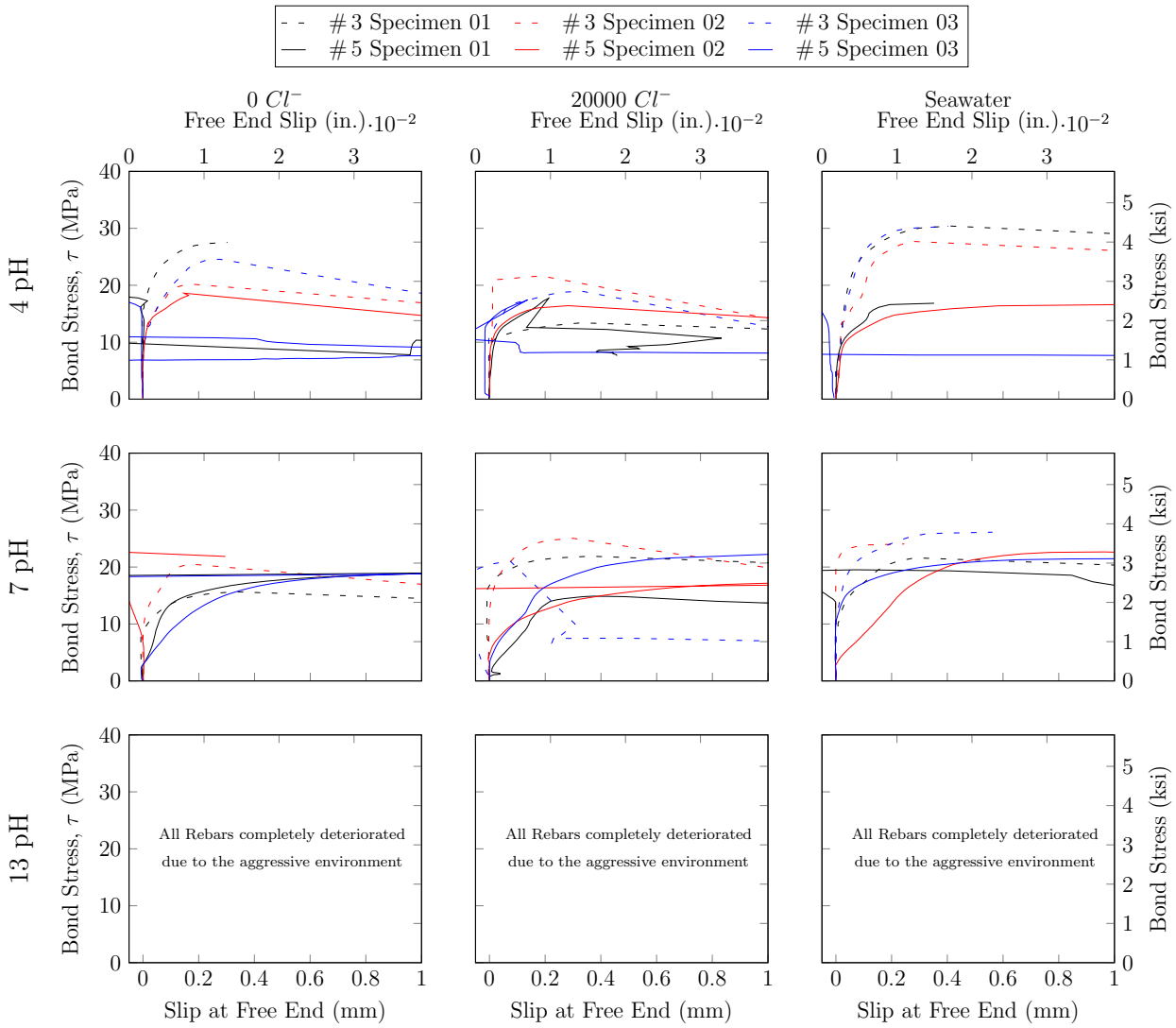

Figure 1.114: Bond stress - slippage behavior of rebar Type B Lot 2 rebars

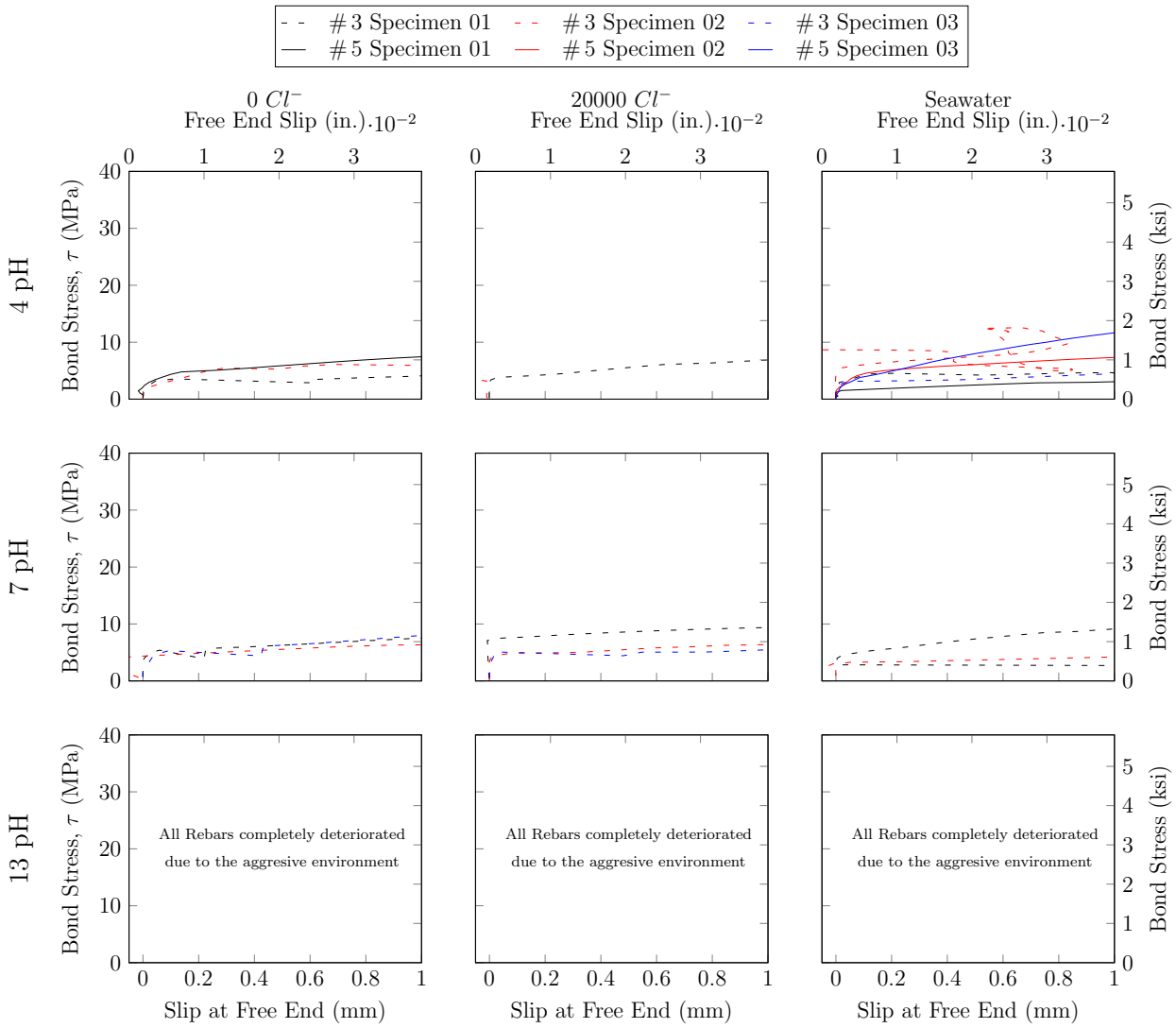

Figure 1.115: Bond stress - slippage behavior of rebar Type C Lot 2 rebars

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