INSTITUTO DE PESQUISAS TECNOLÓGICAS

COMUNICAÇÃO TÉCNICA

Nº 179733

The internal corrosion in iron or slurry pipeline and the role of chloride ions in depassivation of the steel

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Palestra apresentada no CONGRESSO INTERNACIONAL DE CORROSÃO, INTERCORR, 10., 2025, São Paulo. 31 slides

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The internal corrosion in iron or slurry pipeline and the role of chloride ions in depassivation of the steel

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A corrosão interna em dutos de ferro ou polpa e o papel dos íons cloreto na despassivação do aço

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Summary

- Motivation
- Overview: Pourbaix Diagram
  Passivation and Depassivation
  Internal Pipeline Corrosion
- Objective
- Methodology
- Results and discussion
- Conclusion

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Motivation

- The Mining Company with 529 km pipeline

Location of the Minas-Rio pipeline

Minas-Rio Project

Iron-ore slurry Pipeline

Reference: https://brasil.angloamerican.com/pt-pt/imprensa/noticias/2024/22-02-2024

Motivation

- A slurry is a mixture of solid particles. such as crushed ore or mine tailings, suspended in a liquid, typically water.
- A slurry composition usually consists of a mixture of iron ore and water. The Minas-Rio pipeline transports a mixture that is 70 % iron ore and 30 % water.
- Use alkaline additives (near pH 12) to control corrosion.
  - It forms a thin passive layer on carbon steel.

Slurry in Mining

Reference: https://blog.fluidflowinfo.com/slurry-piping-systems-in-mining-mineral-processing-industries/

Pourbaix Diagram

- A Pourbaix diagram plots the equilibrium potential (E_e) of a metal and its various oxidized species against pH.

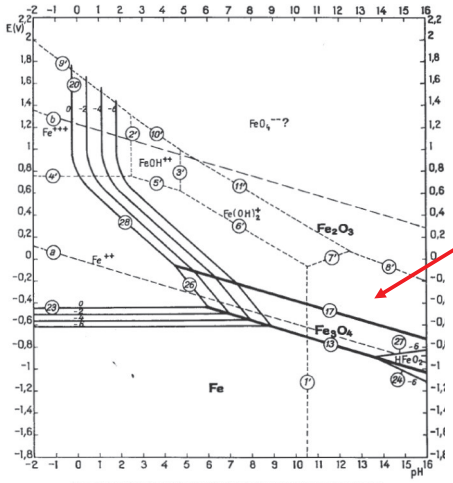


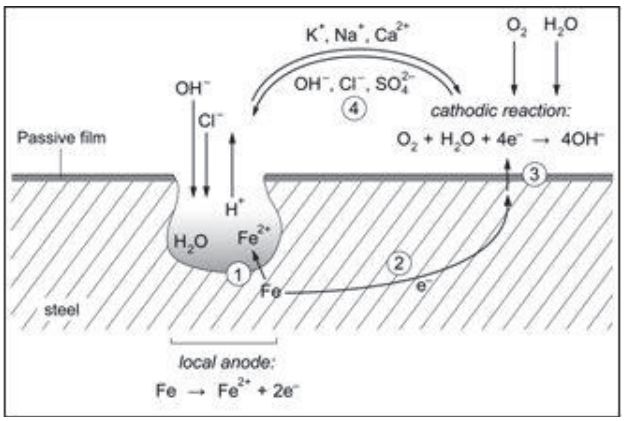
Fig. 4. Potential-pH equilibrium diagram for the system iron-water, at 25°C (considering as solid substances only Fe, Fe_3O_4 and Fe_2O_3).

Passive Layer

Reference: Pourbaix_Atlas_of_Electrochemical_Equilib p 312

What is local depassivation?

- The local loss of the protective layer that occurs on certain metals or alloys under specific conditions.



- There are several ways corrosion can occur in pipelines, the most common of which are:

➢ Pitting corrosion

➢ Crevice corrosion

➢ Alveolar corrosion

Reference: PhD These. Improved Corrosion Resistance for Reinforced Concrete Using Environmentally Friendly Inhibitors. DOI: **10.14750/ME.2021.040**

Internal Pipeline Corrosion

- Internal pipeline corrosion is a gradual process that breaks down or degenerates the surface of a pipeline.

Can work be done in a chloride range without localized corrosion occurring?

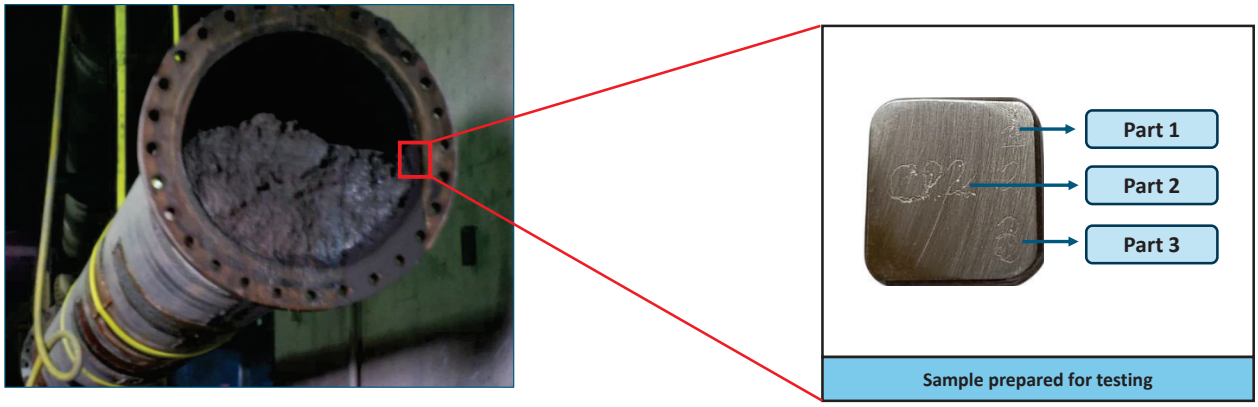
Reference: https://www.advancedfrpsystems.com/internal-pipe-corrosion/

Objective

- Establish the relationship between pH, chloride concentration, and localized corrosion resistance and determine how these factors influence each other.

Reference: https://www.toplevelcnc.com/passivation-of-stainless-steels/

Methodology



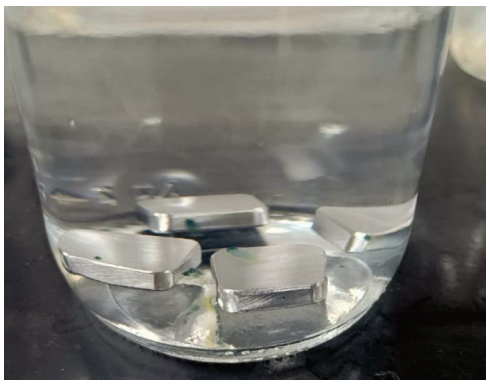
Part 1: External part of the tube;

Part 2: Center of the tube;

Part 3: Internal part of the tube.

Methodology – test conditions

- surface finishing:
  - 120 grit
  - 600 grit
- pH
  - 10.5, 11.0, 11.3, 11.5, 12.0
- chloride concentration
  - addition of different concentrations of chloride



Test specimens in the bottle

All pH adjustments are made with NaOH (to increase pH)

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Results and discussion

- pH 11.5 (surface test):
  - 120 grit
  - 600 grit

Test specimens in the bottle – Corrosion caused by the crack

UPPER SIDE

CP 01 CP 02 CP 03 CP 04

Upper exposed area of the test specimens. CP 04 did not show visible corrosion.

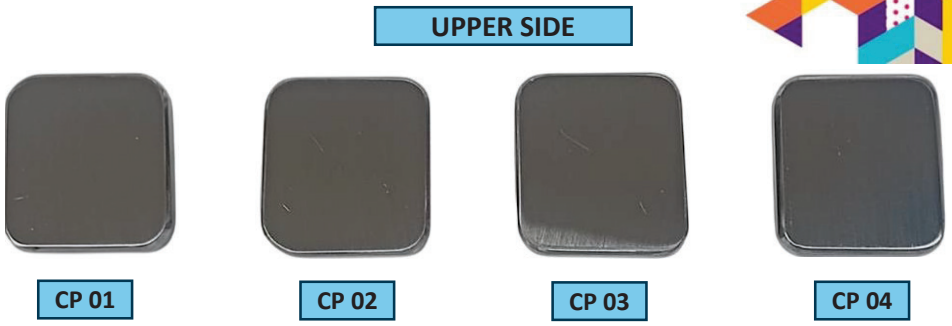
BOTTOM SIDE

CP 01 CP 02 CP 03 CP 04

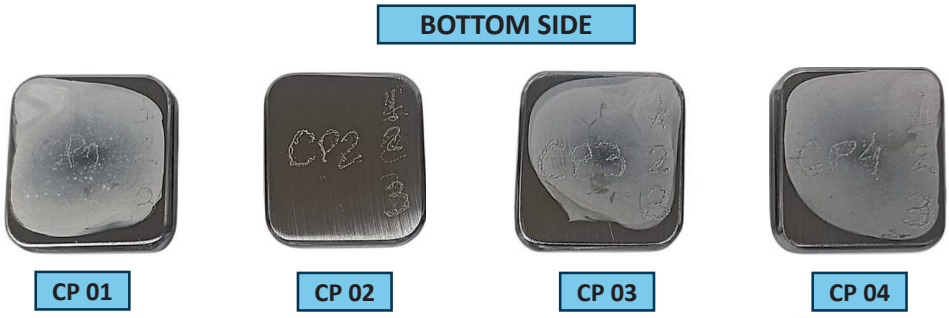
The bottom of the test specimens remained in contact with the beaker bottom throughout the test and did not result in crevice corrosion.

Results and discussion

- pH 11.5 (surface test):
  - 120 grit
  - 600 grit



Main exposed area of the test specimens. CP 04 did not show visible corrosion.



The back of the specimen remained in contact with the bottom of the beaker throughout the test. This caused crevice corrosion in all of the specimens except CP02.

Results and discussion

- pH 11.5 (surface test):
  - 120 grit
  - 600 grit

LEFT SIDE

CP 01 | CP 02 | CP 03 | CP 04

The upper side of the test specimens corresponds to the external region of the tube. Localized corrosion was observed only in CP 03.

RIGHT SIDE

CP 01 | CP 02 | CP 03 | CP 04

The lower side of the test specimens corresponds to the internal region of the tube. Localized corrosion is present in CPs 02 and 03.

Results and discussion

- pH 11.5 (surface test):
  - 120 grit
  - 600 grit

LEFT SIDE

CP 01 | CP 02 | CP 03 | CP 04

The upper side of the test specimens corresponds to the external region of the tube. Note that corrosion is present only in CP 03.

RIGHT SIDE

CP 01 | CP 02 | CP 03 | CP 04

The upper side of the test specimens corresponds to the external region of the tube.
None of the specimens show visible corrosion.

Partial conclusions

- Treating the surface with 600-grit sandpaper did not prevent crevice corrosion. However, it did increase the time it took for crevice corrosion to appear.
- Therefore. we opted for the 120-grit surface finish, which is easy to prepare and reduces the time required for testing.

Results and discussion

- pH testing
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5,
  - pH 12.0
- Solution: Milli-Q Water;
- Total Volume: 500 mL;
- Environment: Atmospheric under synthetic air.
- The four samples with surface finishing with 120 grit were placed in the same test bottle.

Test specimens in the flask after 1 hour – Localized corrosion points

Test specimens in the test bottle after 24 h – Corrosion caused by the crack

Results and discussion

- pH testing
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5,
  - pH 12.0

UPPER SIDE

CP 01 | CP 02 | CP 03 | CP 04

The main exposed area of the test specimens. Only test specimen 01 shows visible corrosion. while CP 03 shows corrosion in one spot.

BOTTOM SIDE

CP 01 | CP 02 | CP 03 | CP 04

The back of the specimen remained in contact with the bottom of the beaker during the test. causing crevice corrosion.

Results and discussion

- pH testing
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5,
  - pH 12.0

LEFT SIDE

CP 01 | CP 02 | CP 03 | CP 04

The upper side of the test specimens corresponds to the external region of the tube. Corrosion is present in all test specimens.

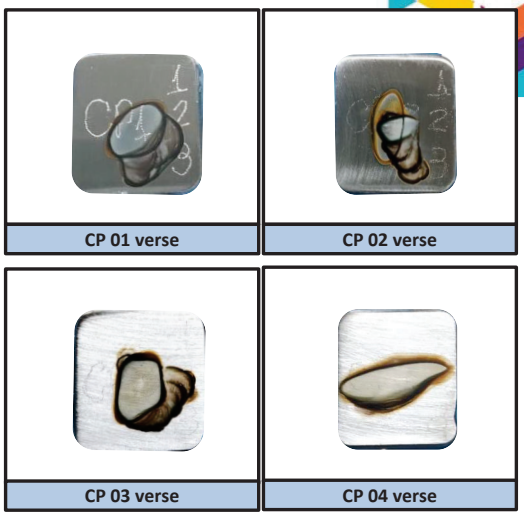
RIGHT SIDE

CP 01 | CP 02 | CP 03 | CP 04

The upper side of the test specimens corresponds to the external region of the tube. With the exception of specimen 01. all test specimens show visible corrosion.

Results and discussion

- pH testing
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5,
  - pH 12.0
- Solution: Milli-Q Water;
- Total Volume: 500 mL;
- Environment: Atmospheric under synthetic air.
- The four samples of the Pite Tube sanded to 120 grit were placed in the same test bottle.



After five days of immersion. visible signs of crevice corrosion were found on the test specimens.

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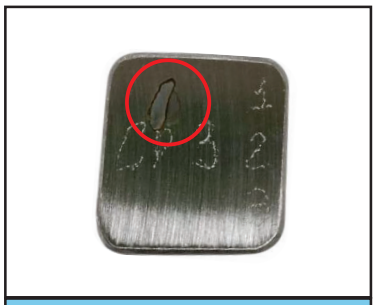
Results and discussion

- pH testing
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5,
  - pH 12.0
- Solution: Milli-Q Water;
- Total Volume: 500 mL;
- Environment: Atmospheric under synthetic air.
- The four samples of the Pite Tube sanded to 120 grit were placed in the same test bottle.



CP 03 verse

CP 04 verse

After two days of testing. slight crevice corrosion points appeared on the bottom side of the specimens immersed in pH 11.5. However. those immersed in pH 12.0 did not show any visible signs of crevice corrosion.

Results and discussion

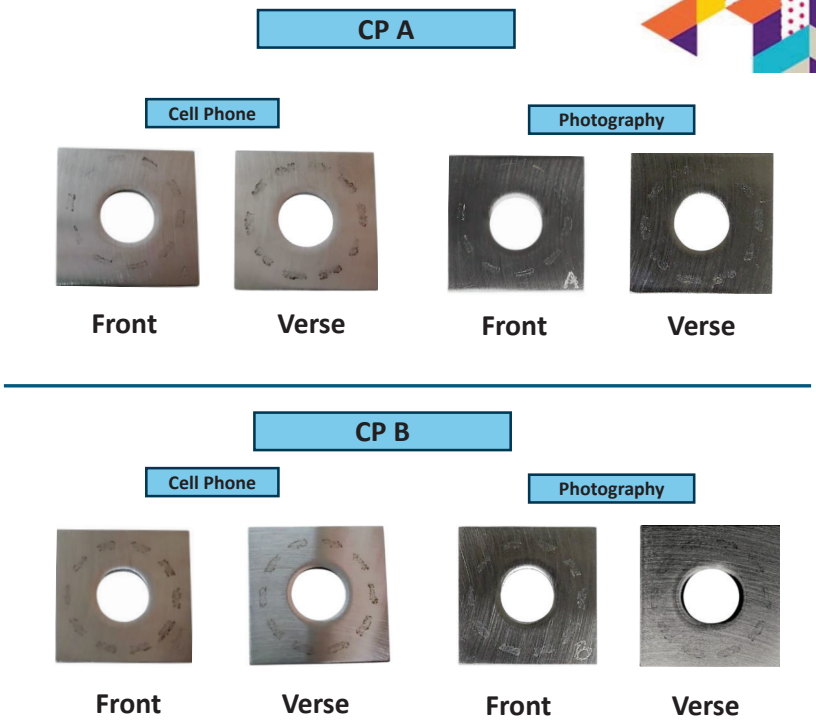
- testing with crevice device
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5,
  - pH 12.0
- Solution: Milli-Q Water;
- Total Volume: 1000 mL;
- Environment: Atmospheric under synthetic air.
- The four samples of the Pite Tube sanded to 120 grit were placed in the same test bottle.

Diagram of the test crevice corrosion device.

Results and discussion

- 2nd condition (pH test)
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5,
  - pH 12.0

The crevice device revealed the presence of crevice corrosion even in the absence of chloride and at a pH of 11.5.



Partial conclusions

- In tests performed at pH 10.5, specimens exhibited localized corrosion spots.
- In tests performed at pH 11.0 and 11.3, specimens exhibited crevice corrosion.
- In tests performance at pH 11.5 and 12.0, specimens exhibited less crevice corrosion damage.

Results and discussion

- Chloride test
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5
- Solution: 5 ppm of Chlorite
- Total Volume: 500 mL;
- Environment: Atmospheric under synthetic air.
- The four samples of the Pite Tube sanded to 120 grit were placed in the same test bottle.

UPPER SIDE

CP 01 | CP 02 | CP 03 | CP 04

The main exposed area of the test specimens. The specimens showed no visible corrosion.

BOTTOM SIDE

CP 01 | CP 02 | CP 03 | CP 04

The back of the specimen remained in contact with the bottom of the beaker throughout the test. intensifying crevice corrosion.

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Results and discussion

- Chloride test
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5

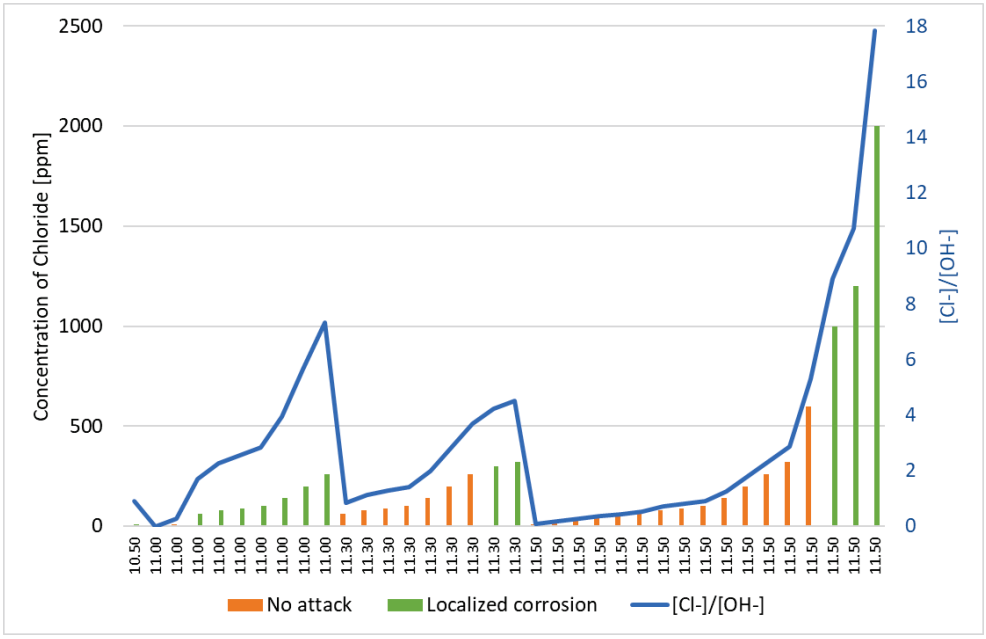
- We studied the relationship between chloride and hydroxide concentrations.
- Localized corrosion points were observed at 60 ppm of chloride.

	[Cl-]		
pH	No attack	Localized corrosion	$[Cl^-]/[OH^-]$
10.5		0	0.00
10.5		10	0.89
11	0		0.00
11	10		0.28
11		60	1.69
11		80	2.26
11		90	2.54
11		100	2.82
11		140	3.95
11		200	5.64
11		260	7.33

	[Cl-]		
pH	No attack	Localized corrosion	[Cl-]/[OH-]
11.3	60		0.85
11.3	80		1.13
11.3	90		1.27
11.3	100		1.41
11.3	140		1.98
11.3	200		2.83
11.3	260		3.68
11.3		300	4.24
11.3		320	4.52
11.5	10		0.09
11.5	20		0.18
11.5	30		0.27
11.5	40		0.36
11.5	50		0.45
11.5	60		0.54
11.5	80		0.71
11.5	90		0.80
11.5	100		0.89
11.5	140		1.25
11.5	200		1.78
11.5	260		2.32
11.5	320		2.86
11.5	600		5.30
11.5		1000	8.92
11.5		1200	10.70
11.5		2000	17.84

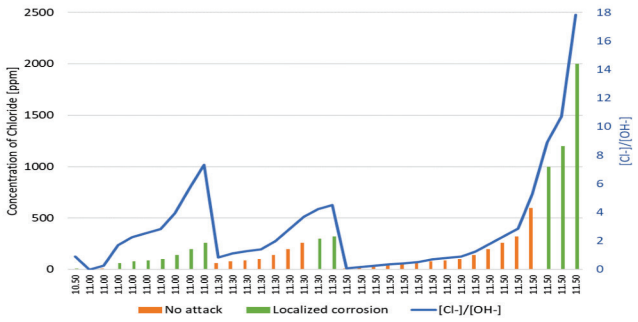
Results and discussion

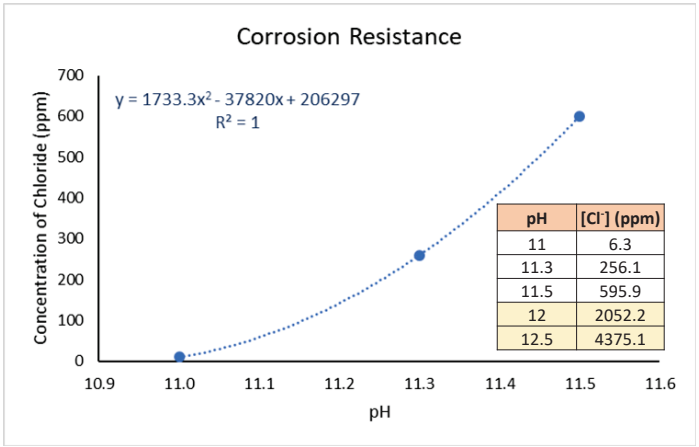
- Chloride test
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5



Results and discussion

- Chloride test
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5





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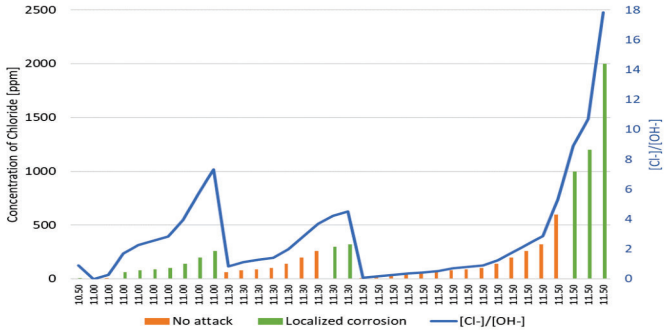
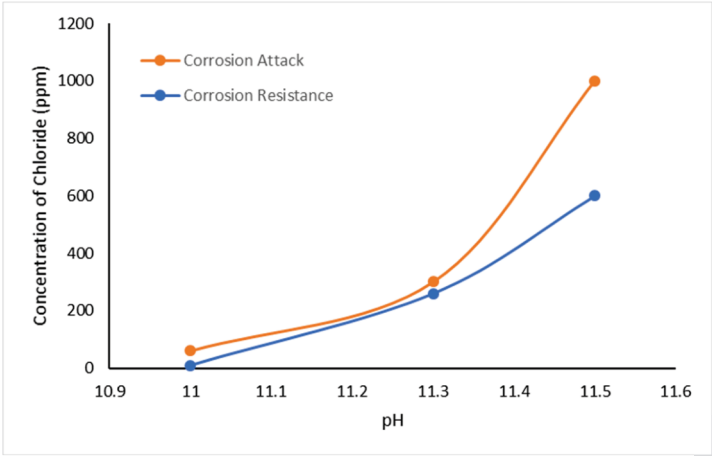
Results and discussion

- Chloride test
  - pH 10.5,
  - pH 11.0,
  - pH 11.3,
  - pH 11.5





Conclusions

The surface treatment did not affect the appearance of crevice corrosion.

Localized corrosion was observed at pH 10.5 without the presence of chloride, and crevice corrosion was observed at pH 11.5 using the crevice device.

A chloride concentration range was experimentally established in which localized corrosion does not predominate.

Future studies will evaluate pH ranges of 12.0 and 12.5.

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Thanks for your attention!

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