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Electroless Nickel Coating for Corrosion Protection of Carbon Steel Rebars in Cement Mortar in Chloride Environment

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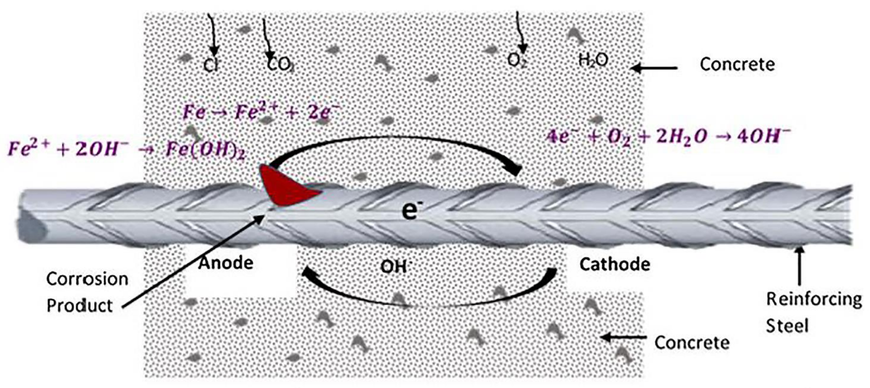
INTRODUCTION & AIM

- Concrete is widely used for its excellent compressive strength, but its reinforcement with low-carbon steel rebars makes it prone to corrosion, especially in marine and coastal environments.
- Chloride ions penetrate the concrete and cause localized pitting corrosion, leading to spalling, cracking, and premature structural failure.
- Corrosion of rebars not only shortens structural lifespan but also causes severe economic losses (estimated at $30 billion annually in the U.S.).
- Conventional steel rebars easily lose their protective passive layer even at high pH (~12), increasing the corrosion risk.
- Electroless nickel-based coatings such as **Ni–P** and **Ni–P–W** offer an eco-friendly, uniform, and economical solution to improve the corrosion resistance of steel rebars.



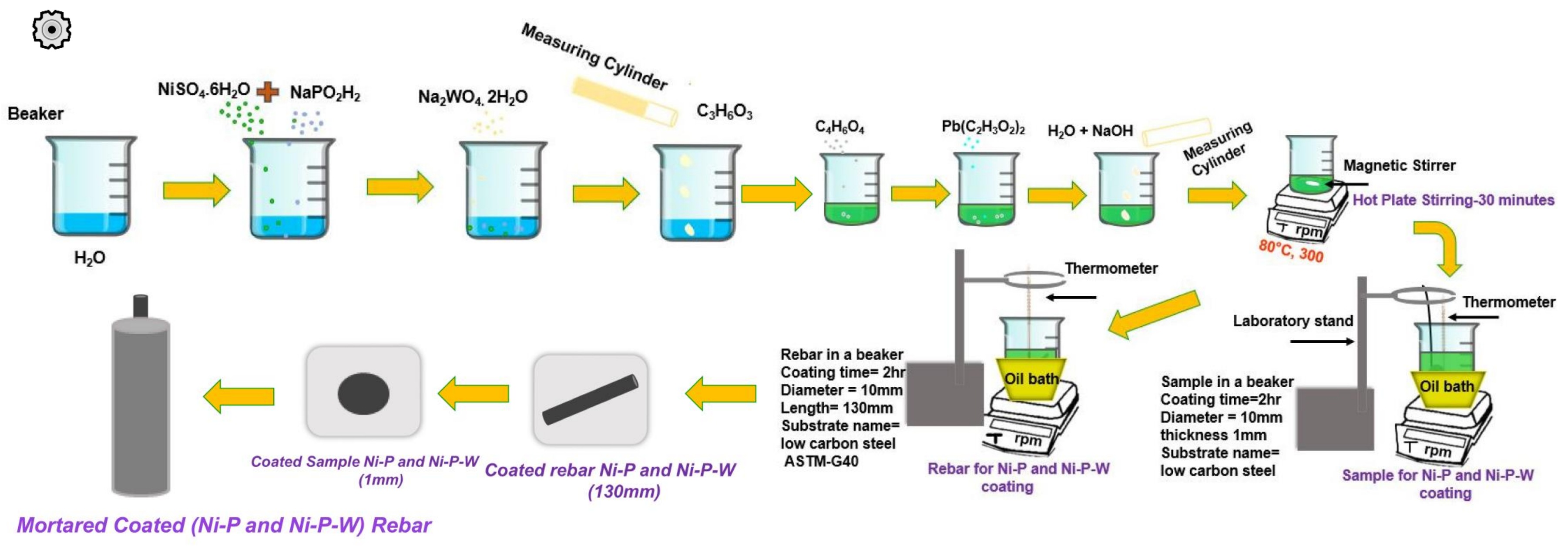
A schematic diagram of corrosion process in reinforced concrete

Aim / Objectives

Aim:
To develop and evaluate electroless Ni–P and Ni–P–W coatings for enhancing the corrosion resistance of carbon steel rebars in chloride environments.

Specific Objectives:
- To synthesize Ni–P and Ni–P–W coatings using hypophosphite-based electroless deposition.
- To prepare mortar-coated rebars.
- To investigate surface morphology and coating structure.
- To evaluate corrosion performance in chloride media.

METHOD

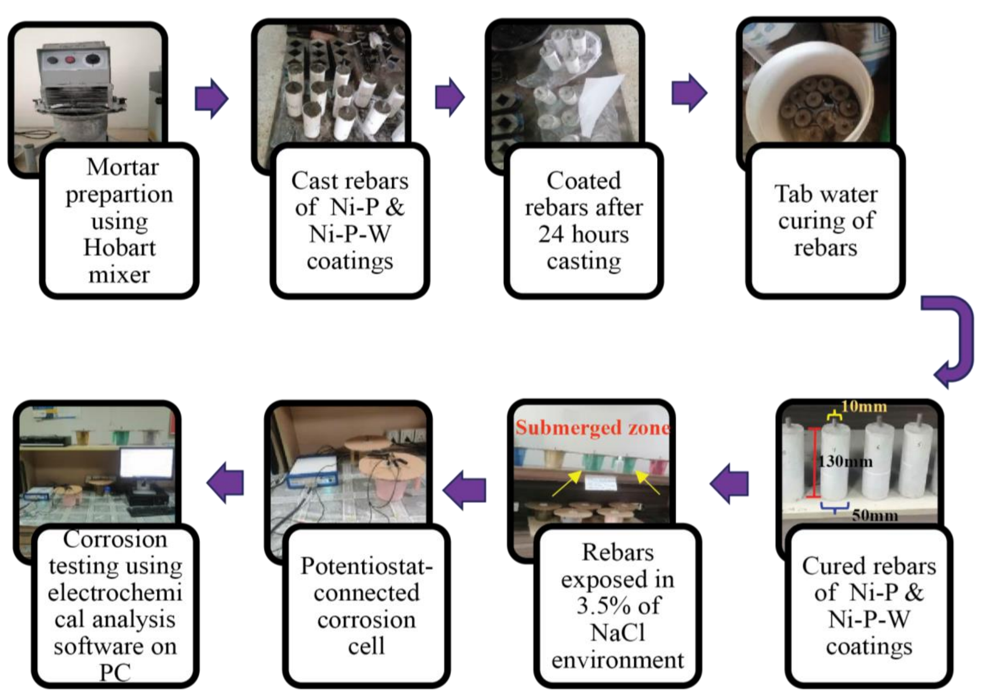


Schematics of steps involved in the development of electroless Ni-P, Ni-P-W, and bare rebar of cement mortar

Materials Used
- Low-carbon steel rebars (ASTM Grade 40)
- Nickel sulfate, sodium tungstate, sodium hypophosphite
- Deionized water, acetone, ethanol
- Cement and sand for later mortar embedding

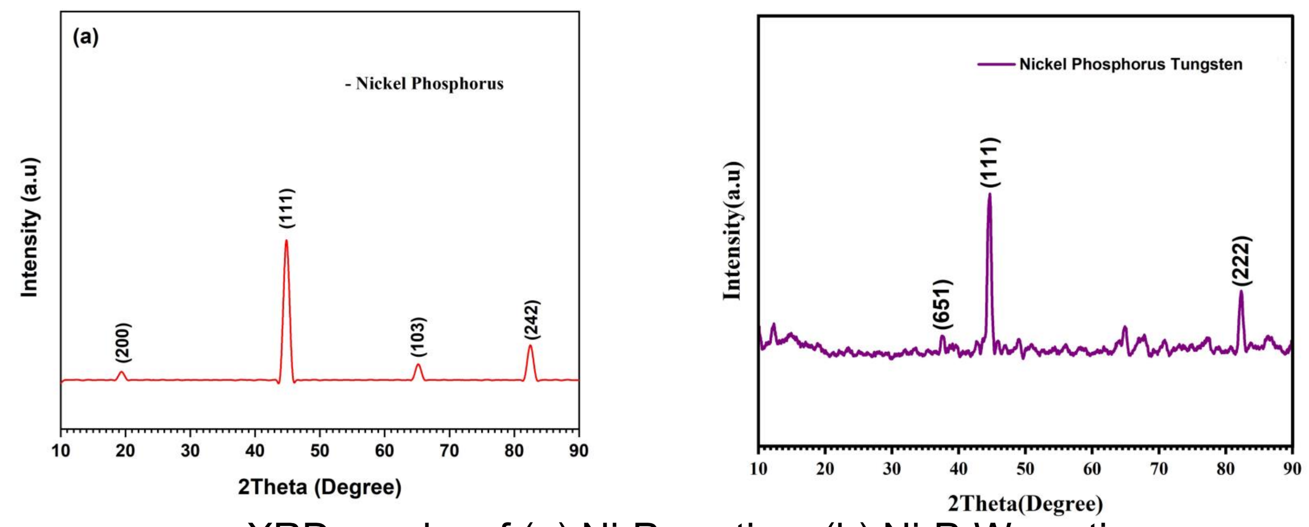
Electroless Coating Development
- Surface cleaning, polishing, degreasing, and pickling
- Electroless Ni–P and Ni–P–W coatings deposited at 85 °C
- Hypophosphite served as a reducing agent
- Coated rebars washed and air-dried before embedding

Mortar Preparation & Corrosion Testing
Mortar prepared with coated and uncoated rebars (1:3:0.45 mix)
- Cured for 28 days in water (ASTM C192)
- Immersed in 3.5 % NaCl solution (ASTM G109)
- Corrosion studied by visual observation and electrochemical testing
- Surface examined under optical microscope

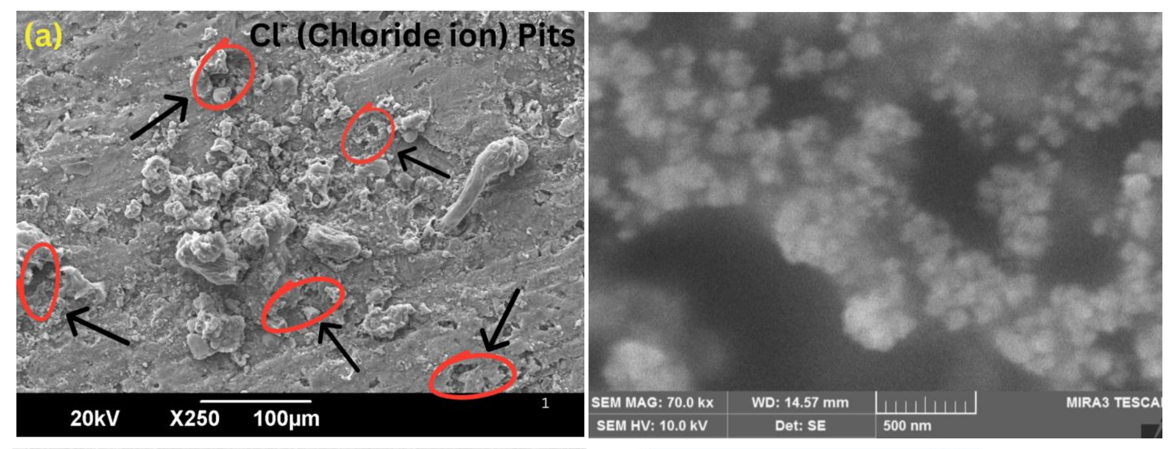


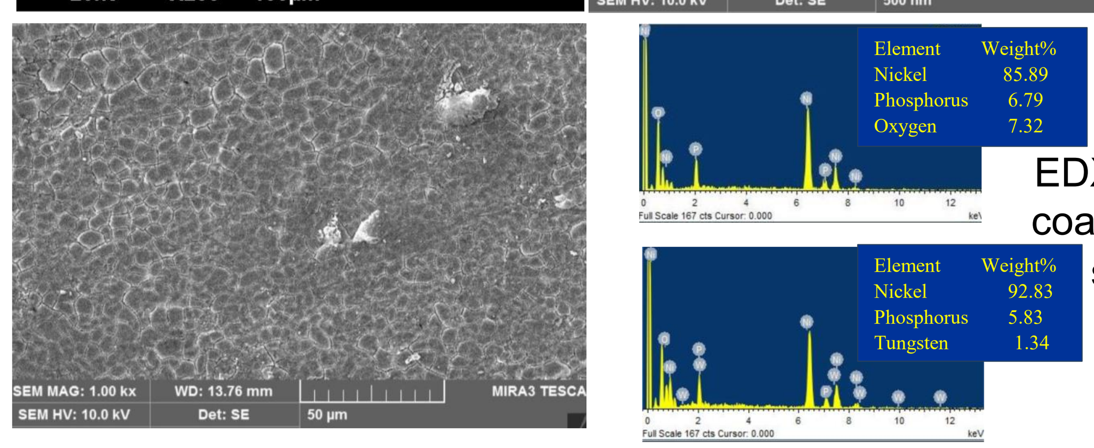
Schematics of steps involved in preparation and testing of coated Ni-P, Ni-P-W, and bare rebars of cement mortar

RESULTS & DISCUSSION



XRD graphs of (a) Ni-P coating; (b) Ni-P-W coating



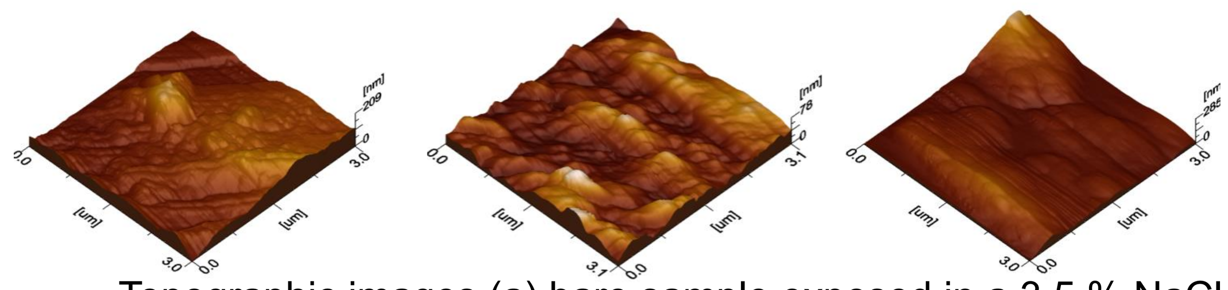


EDX composition graph coated Ni-P and Ni-P-W substrate at 85°C

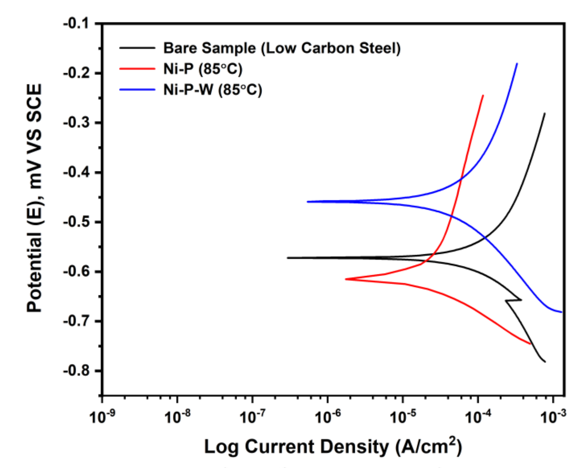
FESEM micrographs of bare sample (coated at 85°C sample exposed to 3.5% NaCl solution: a) bare sample; b) Ni-P coating; c) Ni-P-W coating.

Table: Surface Roughness of bare, coated Ni-P, and coated Ni-P-W samples

Substrate	Surface Roughness (R_a = μm)
Bare	19.4
Ni-P (85°C)	0.7
Ni-P-W (85°C)	3.11



Topographic images (a) bare sample exposed in a 3.5 % NaCl environment. (b) coated Ni-P at 85°C; (c) coated Ni-P-W at 85°C



Superimposed Tafel Curves of coated Ni-P, Ni-P-W, and bare rebars

CONCLUSION

- Electroless **Ni–P and Ni–P–W coatings** improved rebar corrosion resistance.
- **85 ± 1 °C** was found optimal for coating quality and protection.
- Coatings reduced **pitting corrosion and passive layer breakdown**.
- The process is **eco-friendly and cost-effective**
- Further work is needed for **industrial-scale application**.

FUTURE WORK / REFERENCES

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