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Optimizing Corrosion Control: Assessing Sacrificial Anodes for Rebar Protection in Reinforced Concrete

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Abstract—
Corrosion of steel reinforcement is a major durability concern in reinforced concrete (RC), particularly in humid and chloride-rich environments. This study evaluates sacrificial anode cathodic protection using zinc and aluminium anodes connected to reinforcement cages and exposed to a simulated saline environment. A specific feature of the investigation is the application of a porous mortar coating to the anodes, including aluminium, to examine whether the coating can modify environmental exposure and potentially delay the formation of the passive aluminium oxide film. Zinc and aluminium anodes were prepared by sand casting. The project report describes circular anodes with a diameter of 6 cm and a thickness of 2.5 cm, with a porous mortar layer of approximately 1 cm applied to all sides. Rebar cages were immersed in saline water, and half-cell potential readings were recorded daily using a silver–silver reference electrode and a multimeter. The observations showed that after approximately 3–4 days, the protected specimens exhibited more negative readings near the anodes and less negative readings at the reinforcement than at the anodes. Visual inspection during the experimental period did not identify visible corrosion on the protected rebar cages. Comparison of the two anode materials indicated slightly better performance for aluminium than zinc under the tested conditions. The findings provide preliminary evidence that mortar-coated sacrificial anodes can contribute to corrosion mitigation; longer-duration and controlled testing is required to establish their service life and the influence of coating thickness.

Keywords— Sacrificial Anode, Cathodic Protection, Reinforced Concrete, Zinc, Aluminium, Mortar Coating, Half-Cell Potential, Corrosion.

I. INTRODUCTION

Reinforced concrete is widely used in civil infrastructure because concrete provides compressive strength while steel reinforcement contributes tensile resistance. The durability of RC structures, however, can be reduced by corrosion of the embedded reinforcement. Moisture, oxygen and chloride ions can penetrate concrete and disturb the passive condition of steel. Corrosion products occupy a larger volume than the original steel, causing cracking and spalling of the concrete cover, loss of reinforcement area, reduced structural capacity and increased maintenance requirements.

Corrosion is an electrochemical process involving anodic and cathodic reactions in the presence of an electrolyte. In chloride-rich and marine environments, the ingress of chlorides and moisture accelerates deterioration. Conventional preventive measures include improving concrete quality and cover, applying protective coatings, using corrosion inhibitors and adopting cathodic protection. Sacrificial anode cathodic protection uses a metal more active than steel. When electrically connected to the reinforcement, the sacrificial metal preferentially corrodes and supplies protective current, reducing the tendency of the steel to corrode.

A. Problem Statement

Zinc and aluminium are potential sacrificial anode materials for protecting steel reinforcement. However, aluminium may form a stable oxide film on its surface, which can reduce its electrochemical activity and affect its performance as an anode. The present project investigates whether applying a porous mortar coating to sacrificial anodes, particularly aluminium, can modify their exposure to the saline environment and potentially delay passivation while maintaining cathodic protection of the reinforcement.

B. Aim and Objectives

Aim: To investigate the effectiveness of zinc and aluminium sacrificial anodes, including mortar-coated anodes, in protecting steel reinforcement under simulated saline exposure.

- To evaluate the corrosion-protection performance of sacrificial anodes connected to reinforcement cages.
- To compare the observed performance of zinc and aluminium anodes.
- To examine the use of a porous mortar coating as an approach to modifying anode exposure and potentially delaying aluminium passivation.
- To monitor the electrochemical behaviour of the anodes and reinforcement using daily half-cell potential readings.
- To compare protected specimens with a specimen without a sacrificial anode.

II. LITERATURE REVIEW AND RESEARCH GAP

Previous research has investigated galvanic anodes for corrosion protection of steel in concrete, including their behaviour in repaired concrete and marine exposure. Astuti et al. (2019) examined sacrificial-anode cathodic protection for rusted and non-rusted reinforcing bars in repaired patch concrete. Christodoulou et al. (2014) studied an arrangement of galvanic anodes for repair of reinforced concrete structures. Holmes et al. (2011) discussed the responsive behaviour of galvanic anodes in concrete and the basis for their use. Research by Kainuma et al. (2019) considered an Al–Zn-based sacrificial anode system for steel members, while Sagüés and Powers (1996) reported on sprayed-zinc sacrificial anodes for reinforced concrete in marine service. These studies provide a basis for considering galvanic protection and the selection and arrangement of anode materials.

Research Gap

The project report identifies aluminium passivation as a concern because a protective oxide film can form on the aluminium surface and reduce its electrochemical activity. The specific research gap addressed is the investigation of mortar-coated aluminium sacrificial anodes and whether a porous mortar layer can help delay passivation while allowing the anode to provide protection to steel reinforcement. The project also compares zinc and aluminium anodes and examines their behaviour through half-cell potential measurements under simulated saline exposure. The work is preliminary and identifies the need for further investigation of coating thickness, passivation and long-term performance.

III. MATERIALS AND METHODOLOGY

A. Materials

Material / component	Description used in the project
Sacrificial anodes	One zinc anode and one aluminium anode prepared by sand casting; the project also discusses combined anode configurations.
Anode dimensions	Circular cast anodes; methodology section specifies 6 cm diameter and 2.5 cm thickness.
Mortar coating	Porous mortar applied to all sides of the anodes, approximately 1 cm thick, as stated in the project report.
Reinforcement	Steel reinforcement cage measuring 30 cm × 30 cm; the report identifies the tested cage surface area as 0.09 m².
Electrolyte	Saline water prepared using approximately 40 g of salt in the test water to simulate a corrosive, seawater-like environment.
Measuring equipment	Silver–silver reference electrode, Fluke multimeter, alligator clips and binding wires.
Test containers	Plastic tubs used to hold the saline solution and submerged specimens.

B. Preparation of Sacrificial Anodes

Sand casting was used to prepare the zinc and aluminium anodes. A pattern was first made to the required circular dimensions and a two-part sand mould was prepared around it. After removal of the pattern, molten metal was poured into the mould cavity and allowed to cool and solidify. The casting was removed from the mould, finished to remove

rough edges and surface imperfections, and prepared for coating. The report records one zinc anode and one aluminium anode. A porous mortar layer of approximately 1 cm was then applied to all sides of each anode and allowed to dry before the anodes were used in the experimental arrangement.

C. Experimental Setup and Procedure

- A rebar cage was prepared and a sacrificial anode was attached to it to establish the electrical connection required for galvanic protection.
- The connected rebar cage and anode assembly was immersed in a plastic tub containing saline water. A specimen without an anode was also included as a control for comparison.
- Half-cell potential measurements were taken daily at the reinforcement and at the anode using a silver–silver reference electrode and a multimeter.
- The recorded readings were used to observe the electrochemical behaviour of the anodes and reinforcement during exposure to the saline solution.
- Visual observations were made during the experimental period to check the condition of the reinforcement cages.

D. Half-Cell Potential Measurement

The half-cell potential procedure involved placing the reference electrode at the selected measurement location and measuring the potential difference with the multimeter. Readings were taken separately near the sacrificial anode and at the reinforcement. The readings were recorded in millivolts (mV) and monitored over the exposure period. In this project, the half-cell potential measurements were used to compare the electrochemical response of the anode and reinforcement and to observe differences between protected and unprotected specimens.

IV. RESULTS AND DISCUSSION

A. Experimental Observations

The project recorded daily half-cell potential readings over an approximately 20-day period, beginning on 21 September 2026. After about 3–4 days of immersion in saline water, the sacrificial-anode specimens began to show the protective response described in the report. More negative readings were observed near the sacrificial anodes, while the readings at the reinforcement cages were less negative. This difference was interpreted in the project as evidence that the anodes were preferentially undergoing oxidation and providing cathodic protection to the reinforcement.

B. Comparison of Zinc and Aluminium Anodes

Comparison of the zinc and aluminium specimens indicated slightly superior observed performance for aluminium under the conditions of the experiment. The project attributes this behaviour to the higher reactivity of aluminium compared with zinc. The report also notes the importance of anode material, surface area, environmental conditions and anode configuration in determining protection performance. Since the investigation involved a limited number of cast anodes and a laboratory saline exposure arrangement, the observed comparison should be treated as preliminary.

C. Reinforcement Condition and Control Specimen

The daily visual observations reported no visible signs of corrosion on the protected rebar cages during the observation period. The report also records that the cage without an anode showed further corrosion, indicating the corrosive nature of the saline test environment and providing a comparison with the protected arrangement. The tested reinforcement cage had a surface area of 0.09 m^2. This result relates to the experimental cage used in the project and does not establish performance for larger structural areas.

D. Effect of Mortar Coating

The porous mortar coating was applied to all sides of the zinc and aluminium anodes. The purpose described in the project is to provide a protective layer and modify the exposure of the anode to the surrounding saline environment. For aluminium, the coating was investigated as a possible means of delaying the formation or influence of the passive oxide film while retaining sacrificial activity. The present observations suggest that the coated anodes remained active during the test period; however, the experiment does not independently quantify the delay in oxide-film formation or establish an optimum mortar thickness.

E. Summary of Findings

- Sacrificial anodes showed a protective response after approximately 3–4 days of saline immersion.
- More negative readings were observed near the anodes, while readings at the protected reinforcement were less negative.
- Aluminium showed slightly better observed performance than zinc in the reported comparison.
- No visible corrosion was reported on the protected rebar cages during the daily visual observations.
- The tested reinforcement cage had a surface area of 0.09 m²; larger-area performance was not established by this test.

V. CONCLUSION AND FUTURE SCOPE

The experimental investigation indicates that zinc and aluminium sacrificial anodes can provide corrosion protection to reinforcement under the simulated saline exposure conditions used in this project. The more negative readings observed near the anodes, together with less negative readings at the reinforcement, were interpreted as evidence of preferential anode oxidation and cathodic protection. Aluminium showed slightly superior observed performance compared with zinc in the reported test. Visual observations also found no visible corrosion on the protected reinforcement cages during the test period, whereas the specimen without an anode showed further corrosion.

The application of a porous mortar coating to the anodes, including aluminium, represents the principal approach investigated in this project to modify anode exposure and potentially delay aluminium passivation. The results are preliminary: they demonstrate the behaviour observed in the laboratory setup but do not establish long-term service life, optimum coating thickness or performance on large structural areas.

Scope for Future Work

- Conduct longer-duration experiments to assess the stability and service life of mortar-coated sacrificial anodes.
- Test a larger number of specimens under controlled and repeatable exposure conditions.
- Investigate different chloride concentrations, moisture conditions and exposure environments.
- Compare zinc, aluminium and suitable alloy anodes using clearly documented dimensions and electrical connections.
- Study the influence of mortar-coating thickness, porosity and curing on anode activity and aluminium passivation.
- Measure additional parameters, such as corrosion current density or mass loss, where suitable equipment and validated procedures are available.
- Evaluate the method through further laboratory studies and field trials on reinforced concrete elements.

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