CONCRETE RESTORATION AND CORROSION MITIGATION: PHOSCRETE'S ROLE IN DURABLE REPAIRS

PRODUCT KNOWLEDGE

Introduction

Concrete corrosion poses a persistent and destructive challenge, particularly in structures exposed to chlorides and harsh environments. This ongoing deterioration threatens infrastructure integrity, drives up maintenance costs, and significantly shortens the lifespan of critical assets. A forward-thinking approach that prioritizes long-term resilience and cost-effective solutions is essential to addressing these challenges effectively.

Phoscrete's advanced Magnesium Phosphate Cement (MPC) solutions provide a proven method to mitigate corrosion at its source, offering enhanced durability, ease of application, and sustainability. By understanding the mechanisms of corrosion and the limitations of conventional methods, engineers, contractors, and owners can make informed decisions to ensure the longevity of their concrete pavements and structures.

Executive Summary

Understanding Corrosion: Chloride-induced corrosion is a primary cause of structural damage in reinforced concrete. The halo effect often shifts corrosion from repaired areas to adjacent zones, further accelerating degradation.

Challenges of Conventional Methods: Traditional corrosion protection systems, including zinc anodes and nitrite-based inhibitors, address corrosion but introduce challenges such as high maintenance demands, safety concerns, and variable long-term effectiveness.

Phoscrete Solutions: By neutralizing corrosion at its source, Phoscrete offers innovative materials that address these challenges while minimizing site preparation and eliminating the halo effect.

Health, Safety, and Environmental Considerations: Phoscrete's non-toxic, low-carbon materials contribute to safer work environments and support sustainable construction practices.

This document explores the technical and practical aspects of corrosion protection, equipping you with the knowledge to compare available options. By evaluating material costs, in-place costs, and lifecycle impacts, you can make informed decisions about the right solutions for your projects.

Phoscrete delivers unmatched durability and cost-effectiveness while addressing safety and environmental concerns, making it the clear choice for modern concrete restoration.

Detailed comparisons of corrosion protection methods and Phoscrete formulations are available in Appendices A and B. Case studies on restoration projects are reported in Appendices C and D.

Visit phoscrete.com/technical to access the Technical Data Guides (TDG), Safety Data Sheets (SDS), and Installation Guides required for engineering review and project approval.

Understanding Corrosion in Concrete

Overview

Corrosion in reinforced concrete is a widespread problem that weakens structures and increases maintenance costs. Water, oxygen, and chloride ions penetrate the concrete, facilitating reactions that corrode the steel reinforcement. Meanwhile, carbon dioxide from vehicle exhaust can lead to carbonation, reducing the concrete's pH and compromising its protective qualities over the rebar. Over time, these processes result in visible damage such as cracking and spalling, often necessitating costly repairs and disrupting operations.

Phoscrete materials offer an effective way to stop corrosion at its source, reducing repair time and extending the lifespan of concrete structures. They form a dense, durable matrix that helps prevent the ingress of carbon dioxide, water, and chlorides, thereby mitigating carbonation and other corrosion mechanisms. A clear understanding of these corrosion processes highlights why Phoscrete is uniquely positioned to address these challenges.

A Deeper Dive: The Mechanism of Corrosion

Electrochemical Process:

Portland Cement Concrete (PCC) protects steel reinforcement through a natural process called passivation. The high-pH environment (pH ~12-13) created by PCC forms a stable oxide layer on the steel, which acts as a barrier to corrosion. However, concrete's inherent water permeability—due to air entrainment, interconnected pores, and a tendency to crack over time—creates pathways for moisture, oxygen, chloride ions, and carbon dioxide. In environments with high chloride exposure, such as coastal areas or regions using de-icing salts, these factors can disrupt the protective passivation layer, allowing corrosion to initiate.

Once moisture, oxygen, chlorides, or carbon dioxide breach the protective layer, they set off an electrochemical reaction:

Anodic Sites: Iron (Fe) loses electrons (oxidation), forming ferrous ions (Fe^{2+}).

$$[Fe \rightarrow Fe^{2+} + 2e^-]$$

Cathodic Sites: These electrons reduce oxygen (O_2) to form hydroxyl ions (OH^-).

$$[2e^- + H_2O + \frac{1}{2}O_2 \rightarrow 2OH^-]$$

These reactions result in the formation of iron oxide (rust, Fe_2O_3), which can expand up to six times its original volume, exerting significant pressure on the surrounding concrete.

Overall Rust Formation:

Ferrous ions (Fe^{2+}) combine with hydroxyl ions (OH^-) to form ferrous hydroxide:

$$[Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2]$$

Ferrous hydroxide further oxidizes to form iron oxide (rust):

$$[4Fe(OH)_2 + O_2 \rightarrow 2Fe_2O_3 + 4H_2O]$$

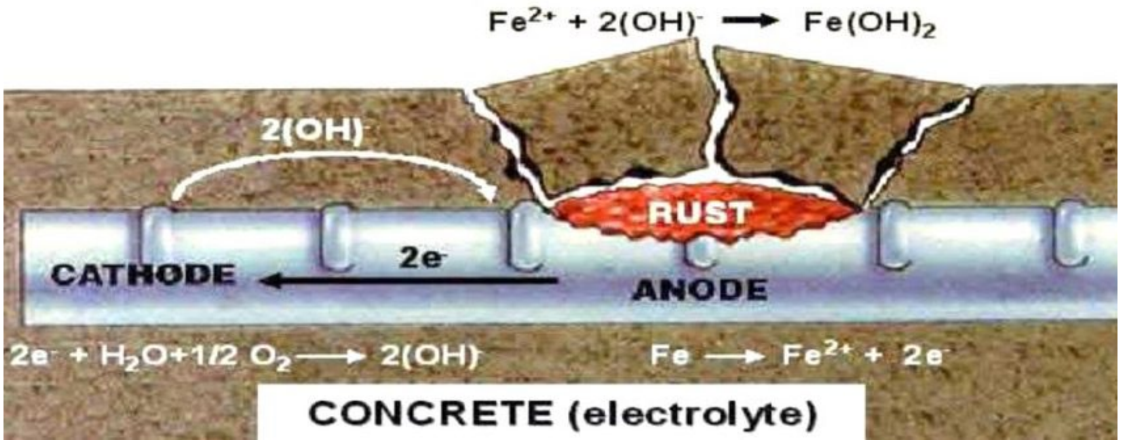

Figure 1 Corrosion begins when electrons migrate from electrically active points on the steel (anodes) to locations on the bar with the opposite polarity (cathodes).

This sequence accelerates when chlorides are present, as they disrupt the steel's passivating oxide layer.

Role of Chlorides:

Chlorides replace hydroxide ions within the oxide layer, weakening its ability to shield the steel from corrosion.

Cracks in the concrete create direct pathways for chlorides, speeding up the corrosion process.

Environmental conditions like high humidity and frequent salt exposure further enhance conductivity, making corrosion more aggressive and widespread.

Figure 2 Chloride-induced corrosion and spalling in concrete.

Crack Propagation:

Rust occupies a larger volume than the original steel, generating internal pressures that crack the surrounding concrete.

These cracks allow even greater ingress of water, oxygen, and chlorides, creating a self-sustaining cycle of damage.

Figure 3 Crack propagation due to rust expansion on a bridge beam in Rhode Island, 2020

The Halo Effect

Overview

The Halo Effect: The phenomenon, also referred to as the Ring Anode Effect, occurs when corrosion shifts from the repaired area of concrete to its surrounding perimeter. This happens due to chemical and electrochemical imbalances between the new repair material and the older, existing concrete. Over time, this can lead to additional deterioration outside the repair zone, undermining the effectiveness of the repair. Non-repaired sections between multiple repairs on the same beam can experience accelerated corrosion. Addressing the halo effect requires overcoming these chemical imbalances and stabilizing the repair zone to ensure long-term durability. Phoscrete materials provide an effective mitigation strategy by reducing these imbalances and enhancing the integrity of the entire repair area.

A Deeper Dive: Why the Halo Effect Forms

pH Disparity:

Conventional repair materials, such as Portland cement-based patches, have a high pH (~12-13) that re-passivates steel reinforcement within the repaired area. In contrast, older concrete often has a reduced pH due to carbonation, chloride exposure, or long-term environmental wear. This disparity creates a chemical imbalance, contributing to the Ring Anode Effect, where the surrounding low-pH concrete becomes vulnerable to corrosion.

Electrochemical Gradient:

The difference in pH levels establishes an electrochemical gradient. The high-pH environment in the repair area forms a cathodic zone where steel is protected, while the surrounding concrete becomes anodic, accelerating damage at the repair boundary.

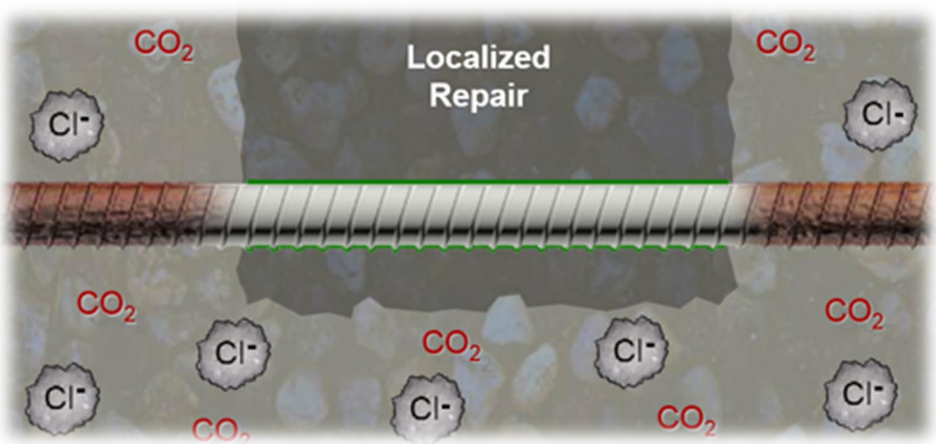

Figure 4 Halo/Ring Anode Effect: concrete becomes anodic outside the patch area, accelerating corrosion.

Chlorides and Moisture:

In chloride-heavy environments, chlorides in the surrounding concrete intensify the halo effect by accelerating corrosion reactions at the anodic sites near the repair boundary. Moisture further facilitates ion movement, compounding the problem.

Resulting Damage:

As corrosion concentrates at the edges of the repair, the surrounding concrete begins to crack, spall, and degrade. This cycle can compromise the durability of the repair and require additional intervention if not properly addressed.

Figure 5 Halo/Ring Anode Effect: Corrosion forms adjacent to the patched concrete.

Challenges of Conventional Corrosion Protection Methods

Overview:

Corrosion follows the path of least resistance, making it challenging to fully prevent in reinforced concrete structures. Conventional protection systems, such as zinc anodes and nitrite-based inhibitors, are widely used and provide effective solutions by protecting steel reinforcement. However, as sacrificial systems, their effectiveness diminishes over time, leaving repaired structures vulnerable to future corrosion. While these systems can delay corrosion for years or decades, their eventual consumption underscores the need for long-term solutions that minimize lifecycle maintenance and repair costs

Limitations:

Temporary Protection: Sacrificial systems typically extend service life by at most 20 years, depending on environmental factors like chloride exposure and humidity. While these systems may extend service life, they are rarely replaced until visible damage necessitates new repairs, often compounding costs due to the halo effect in surrounding areas.

High Costs: Zinc anodes, particularly when embedded in concrete, are challenging and costly to replace. Externally placed anodes are easier to maintain but still require significant labor. Nitrite-based inhibitors involve extensive site preparation, increasing upfront costs.

Health and Environmental Risks: Nitrite inhibitors pose potential health risks, such as methemoglobinemia, and can result in chemical runoff, impacting the environment.

Extensive Site Preparation: Both methods demand labor-intensive removal of damaged concrete and thorough cleaning of steel reinforcement, significantly extending project timelines.

Limited Performance in Harsh Environments: These systems are consumed more rapidly in chloride-heavy or high-humidity environments, reducing their protective effectiveness over time.

A Deeper Dive into Sacrificial Systems

Galvanic Protection (Zinc Anodes):

- **How It Works**: Zinc anodes create a galvanic cell, where the zinc corrodes preferentially to protect the steel.

Figure 6 Galvanic cathodic protection with zinc sacrificial anodes.

- **Limitations**: Zinc anodes are consumed over time, requiring replacement. When embedded in concrete, their replacement is costly and labor-intensive. Externally placed anodes, while easier to access, still require proper maintenance.
- **Site Preparation**: Significant labor is required to remove damaged concrete, clean steel bars, and place anodes to ensure proper application.

Nitrite-Based Corrosion Inhibitors:

- **How They Work:** Nitrite inhibitors form a passive layer of ferric oxide, shielding steel from corrosion.

  $$[2Fe^{2+} + 2NO_2^{-} + H_2O \rightarrow Fe_2O_3 + N_2 + 4H^{+}]$$

- **Protective Mechanism:** The ferric oxide layer stabilizes the steel surface, reducing the likelihood of corrosion.
- **Limitations:** Nitrite-based systems are consumed over time and lose effectiveness in high-chloride environments.
- **Health and Environmental Concerns:** Nitrite inhibitors pose safety risks for workers and contribute to environmental pollution through chemical runoff.
- **Site Preparation:** Significant labor is required to remove damaged concrete, clean steel bars, and safely handle the materials to ensure proper application.

Figure 7 Site preparation for nitrites and zinc anodes requires extensive demolition under the rebar plus rust removal.

Phoscrete Concrete Restoration Solutions

Overview

Magnesium Phosphate Cement (MPC) concretes represent an important advancement in concrete restoration, offering significant performance benefits compared to conventional Portland Cement Concrete (PCC). While PCC remains a trusted solution, MPC materials excel in applications requiring fast, durable, corrosion-resistant, and seamless repairs.

Phoscrete offers two primary formulations: F1 (MALP) for rapid-setting repairs and F3 (MKP) for extended working times in larger-scale applications. Phoscrete also developed RC, a specialized, economical MALP formulation for direct application to steel reinforcement. RC offers strong bonding and effective corrosion protection at a price point comparable to nitrites. It enables the use of both MKP and PCC patching mortars, stabilizing steel to enhance the durability of repairs.

Formulations and Features

- **F1 (MALP):** Designed for rapid-setting applications with natural corrosion-inhibiting qualities, F1 is ideal for repairs requiring quick return to service. Its very rapid-setting nature makes it less suited for large-volume placements in warm temperatures.
- **F3 (MKP):** With extended working times, F3 is well-suited for larger-scale repairs or phased applications, providing strong bonding and durability.
- **RC (MALP):** RC leverages the corrosion protection properties of F1 while allowing MKP or PCC patching mortars to bond.
- **MALP (RC, F1):** Negligible chloride ion permeability ensures long-term protection.
- **MKP (F3):** Low chloride ion permeability compared to PCC, enhances durability. Its performance is improved by applying sealants like Phoscrete Endure.

Phoscrete's materials differ in pH:

- **MALP (RC, F1):** Low pH (~3) stabilizes electrochemical gradients, preventing the halo effect and corrosion shifting**.**
- **MKP (F3):** Neutral pH (7-8) provides additional versatility for phased repairs and bonding.

In addition to superior chloride resistance, MPC concretes bond strong to PCC substrates and stronger to themselves without creating cold joints. For cost-sensitive applications, RC can stabilize steel while allowing PCC patching mortars to bond effectively. As a non-sacrificial corrosion inhibiting material, Phoscrete products eliminate the need for future maintenance, providing significant lifecycle savings while ensuring long-term repair integrity.

Refer to Appendix A for a detailed comparison of Phoscrete formulations

A Deeper Dive into Phoscrete Technology

How Phoscrete Works

Phoscrete's Magnesium Phosphate Cement (MPC) technology addresses corrosion at its source while delivering superior bonding and durability. Its unique properties combat challenges that traditional methods cannot overcome. Key mechanisms include:

- **Rust Conversion:**
  Phoscrete F1 (MALP) chemically converts rust into ferric phosphate ($FePO_4$), passivating steel and halting corrosion:

  $$[Fe_2O_3 + 2H_3PO_4 \rightarrow 2FePO_4 + 3H_2O]$$

- **pH Stabilization and Electrochemical Balancing:**
  By creating a low-pH environment (around 3 for MALP and 7–8 for MKP), Phoscrete prevents the halo effect, stabilizes electrochemical gradients, and ensures consistent corrosion protection across the repair area.

- **Low Chloride Ion Permeability:**
  One of Phoscrete's key advantages is its superior resistance to chloride ion penetration:

  This resistance to chloride penetration directly addresses one of the major drivers of corrosion, ensuring that steel reinforcement remains protected, and the overall repair maintains its integrity.

Product-Specific Details

- **Phoscrete Rebar Coat (RC):**
  - **Primary Use:** A MALP-based formulation designed for direct application to steel reinforcement to stabilize corrosion.
  - **Performance:** Proven to effectively combat corrosion with minimal site preparation. Unlike nitrite-based inhibitors, RC does not require patching materials to be built out within a short timeframe and eliminates the need to fully encapsulate rebar.
  - **Applications:** Typically mixed in small pails and hand applied to reinforcing steel at a minimum thickness of ¼" (6mm). Finish small repairs using Phoscrete RC. Complete larger repairs using Phoscrete Formula 3 or conventional concrete repair materials. Use a wire brush to remove loose scale. Shotblasting the rebar is helpful but not required.

Figure 8 Phoscrete Rebar Coat (RC) applied to corroded rebar, bonds to steel and halts corrosion

- **Phoscrete Formula 1 (F1):**
    - **Primary Use:** Ideal for rapid-setting repairs requiring fast return to service.
    - **Performance:** Typically working time of 5 to 15 minutes, making it highly effective for cold-weather applications and emergency repairs. Materials can be cooled in hot conditions.
    - **Applications:** Suitable for both horizontal (F1-HC) and vertical/overhead (F1-VO) repairs. Its rapid-setting nature makes it less suited for large-volume placements in warm temperatures.

Figure 9 Phoscrete Formula 1-HC winter pavement repair at MassPORT (2024).

- **Phoscrete Formula 3 (F3):**
    - **Primary Use:** Developed for large-scale or phased repairs where extended working time is desired.
    - **Performance:** Offers a working time of 20 to 30 minutes (temperature dependent), enabling precise placement. Materials can be bucket mixed, pumped, or sprayed as shotcrete.
    - **Applications:** Highly versatile for complex or high-volume projects, including horizontal (F3-HC) and vertical/overhead (F3-VO) repairs.

Figure 10 Phoscrete Formula 3-HC is an approved bridge expansion joint nosing material. Installation was performed by a contractor for FDOT on I-75 - Alligator Alley (2024).

Comparative Advantages Over Traditional Methods

Overview

Phoscrete materials offer advanced solutions for corrosion protection and repair, addressing key gaps in traditional methods, such as long-term chloride resistance and simplified site preparation. With reduced maintenance needs, safer materials, and durable performance, Phoscrete ensures seamless repairs while supporting sustainable construction practices.

See Appendix B for detailed performance comparisons of Phoscrete and conventional corrosion protection methods, including chloride permeability, durability, and cost efficiency.

A Deeper Dive: Why Phoscrete Stands Out

Durability and Lifecycle Savings:

- **Phoscrete Advantage:** Non-sacrificial and not consumed over time, Phoscrete materials eliminate the need for reapplication or replacement, reducing long-term maintenance costs.
- **Comparison:** Nitrite inhibitors require patching materials to be applied within seven days, and zinc anodes are consumed over time and require costly replacement. PCC repairs often necessitate frequent reapplication due to chloride penetration.

Simplified Site Preparation:

- **Phoscrete Advantage:** Minimal site preparation is required. Steel reinforcement can be stabilized with RC, and repairs can proceed without fully removing rust or surrounding damaged concrete.
- **Comparison:** Nitrite-based inhibitors and zinc anodes require extensive labor to clean and prepare steel and concrete surfaces for optimal performance.

Chloride Ion Permeability and Corrosion Resistance:

- **Phoscrete Advantage:** Negligible chloride ion permeability in MALP formulations (RC and F1) and low permeability in MKP formulations (F3) ensure long-lasting protection.
- **Comparison:** PCC is highly permeable to chlorides, and traditional inhibitors or anodes cannot fully compensate for this vulnerability.

Health and Environmental Benefits:

- **Phoscrete Advantage:** Non-toxic materials improve worker safety and reduce environmental risks. Phoscrete's low CO_2 emissions and lack of harmful runoff make it a sustainable alternative.
- **Comparison:** Nitrite-based inhibitors pose health risks such as methemoglobinemia, and PCC's high pH can cause burns during handling.

Cost Efficiency:

Phoscrete products offer a cost-effective solution for concrete restoration and corrosion mitigation by combining ease of use, reduced labor costs, and enhanced durability, all while supporting sustainable practices with a lower carbon footprint.

- **Material Costs**: Phoscrete Formula 1 and Formula 3 repair mortars have higher initial costs than conventional PCC materials. However, their superior durability and reduced maintenance requirements provide significant lifecycle savings.
- **Economical Corrosion Protection**: Phoscrete Rebar Coat (RC) is priced comparably to nitrite inhibitors and zinc anodes while offering superior performance. For cost-sensitive projects, RC is compatible with conventional PCC patching mortars, providing effective corrosion protection without significantly increasing material costs.
- **Reduced Labor Costs**: Nitrite inhibitors and zinc anodes require extensive site preparation. Phoscrete MALP demonstrates superior performance even with less-than-ideal surface preparation quality, helping offset material costs through reduced labor, faster project completion, and more reliable corrosion protection.

Temperature Suitability and Ease of Use:

- **Phoscrete Advantage:** Effective in extreme temperatures, Phoscrete can be preconditioned for warm climates or used in cold conditions where other materials fail. RC and F1 eliminate the time pressures of nitrite inhibitors, allowing repairs to proceed at any pace without the risk of reapplication.
- **Comparison:** Traditional materials often exhibit delayed set and strength gain in cold environments, leading to longer repair times and delayed reopening to traffic.

Phoscrete empowers contractors and engineers with advanced solutions for ensuring the longevity and reliability of infrastructure, transforming the approach to concrete restoration.

Health, Safety, and Environmental Considerations

Overview

Phoscrete materials prioritize worker safety and environmental sustainability, offering a safer, simpler alternative to traditional methods. Non-toxic and VOC-free, they reduce environmental risks while simplifying compliance with health and safety standards.

A Deeper Dive: Worker Health and Environmental Benefits

Worker Health and Safety

- Phoscrete materials are engineered to prioritize worker safety, eliminating many risks associated with traditional systems:
- **Non-Toxic Formulations:** Free from harmful fumes, Phoscrete ensures safer mixing and application without the need for complex safety protocols.
- **Reduced Risk of Irritation:** Unlike nitrite-based inhibitors, which require strict handling to prevent conditions like methemoglobinemia, Phoscrete minimizes risks of skin and respiratory irritation commonly associated with PCC and other high-pH materials.
- **Simplified Handling:** Tools and surfaces clean easily with water, removing the need for hazardous solvents or specialized equipment.

Environmental Benefits

- Phoscrete materials align with sustainability goals, addressing environmental concerns linked to traditional methods:
- **Lower Carbon Emissions**: The production process for Phoscrete generates significantly less CO_2 compared to PCC, supporting eco-friendly construction practices.
- **Potential Recarbonation**: Certain components in Phoscrete formulations may contribute to recarbonation, further offsetting carbon emissions over time.
- **No Harmful Runoff**: Unlike nitrite-based inhibitors, which pose environmental risks due to solubility and leaching into water systems, Phoscrete produces no harmful byproducts, ensuring safe application even near sensitive ecosystems.

Comparative Insights

- Phoscrete's safety and sustainability stand out when compared to conventional systems:
- **Nitrite-Based Inhibitors:** Require precise handling due to health risks and pose significant environmental concerns, including potential pollution of water systems.
- **Portland Cement Concrete (PCC):** Associated with high energy consumption and a large carbon footprint, PCC is less sustainable over its lifecycle.
- **Zinc-Based Systems:** While generally safe, some application methods, such as thermal spraying, emit hazardous fumes that may require additional protective measures.

Key Takeaways

- Phoscrete materials offer distinct health and environmental advantages:
- **Worker-Friendly:** Non-toxic formulations create safer job sites and simplify application.
- **Eco-Friendly:** Lower CO_2 emissions, no harmful runoff, and potential recarbonation contribute to sustainable construction practices.
- **Efficient and Safe:** Simplified handling reduces the need for complex safety protocols, making repairs quicker and safer for contractors.

Conclusion

Phoscrete delivers a proven solution to concrete restoration by addressing corrosion at its source. With unmatched durability, corrosion resistance, and ease of application, Phoscrete offers significant benefits for engineers, contractors, and owners

For engineering firms, Phoscrete's MPC technology offers powerful corrosion protection and bond strength for existing structures. Its non-sacrificial nature and long-term performance make it a reliable choice for sustainable infrastructure stability.

For contractors, Phoscrete streamlines the repair process with minimal site preparation and fast-setting formulations, enabling timely, cost-effective project completion.

For owners, Phoscrete provides peace of mind by reducing maintenance needs and extending the lifespan of assets, delivering a greater return on investment.

Phoscrete provides durable, cost-effective solutions for today's corrosion challenges, ensuring long-term performance and reducing the need for frequent repairs.

Appendix A

Comparison of Phoscrete formulas: RC, F1, and F3

Feature	Phoscrete Rebar Coat (RC)	Phoscrete Formula 1 (F1)	Phoscrete Formula 3 (F3)
MPC: Magnesium Phosphate Cement Chemistry	MALP: Magnesium Aluminum Liquid Phosphate	MALP: Magnesium Aluminum Liquid Phosphate	MKP: Magnesium Potassium Phosphate
Primary Use	Direct application to steel bars	Very rapid setting concrete repairs,	Rapid setting concrete repairs.
Applications	RC Steel reinforcement protection	F1-VO vertical/overhead F1-HC horizontal/castable	F3-VO vertical/overhead F3-HC horizontal/castable
Chloride Ion Permeability	Negligible	Negligible	Low
pH Level	~3	~3	7–8
Working Time	5-15 minutes	5–15 minutes	20–30 minutes
Mixing and Application Methods	Bucket mixed, and hand-packed. (RC can be sprayed when materials are cold)	Bucket mixed, Paddle-Style Mortar mixer, or Pan mixer. F1-VO can be sprayed when materials are cold.	Bucket mixed, Paddle-Style Mortar mixer, or Pan mixer. F3-VO can be sprayed (wet shotcrete) and F3-HC can be pumped.
Temperature Suitability	Effective in cold and warm conditions; materials can be cooled.	Effective in cold and warm conditions; not ideal for large-volume warm placements	Suitable for all climates
Cost	Comparable to zinc and nitrite inhibitors	Higher than PCC patching materials	Higher than PCC patching materials
Bonding	Bonds strong to Steel, PCC substrates and MPC	Bonds strong to Steel, PCC substrates and MPC	Bonds strong to Steel, PCC substrates and MPC

Learn More

Visit phoscrete.com to learn more about our technology. Reach out to our knowledgeable sales engineers and find out if Phoscrete is a good fit for your next concrete project.

Appendix B

Comparative Performance Chart

Criteria	Phoscrete (MPC)	Nitrite Inhibitors	Zinc Anodes	PCC
Chloride Permeability	Negligible (RC, F1); Low (F3)	Moderate	Moderate	High
Corrosion Resistance	High; stabilizes corrosion at the source, offering long-term protection.	High initially; effectiveness reduces as consumed over time.	High initially; sacrificial nature requires replacement.	Moderate; prone to chloride penetration.
Ease of Use	Minimal site preparation; easy to mix, place, and finish. Tools clean up with water.	Extensive site preparation: a mortar must be built out within 7 days or reapplication is required.	Extensive site preparation requires precise placement.	Moderate; standard preparation needed.
Durability/Lifespan	Long-lasting; minimal maintenance required.	Short to medium; consumed over time.	Medium; anodes are consumed over time and need replacement.	Frequent reapplication due to deterioration.
Temperature Suitability	Effective in cold and warm climates; materials can be preconditioned.	Limited suitability in extreme cold.	Limited suitability in extreme cold.	Limited in extreme cold.
Cost Efficiency	Higher upfront; significant lifecycle savings.	Lower upfront; higher long-term costs due to frequent replacement.	Initial setup costly; ongoing maintenance required.	Frequent repairs increase long-term costs.
Worker Safety	Non-toxic, safe for workers.	Requires careful handling; health risks present (e.g., methemoglobinemia).	Generally safe, precision installation can be hazardous.	High-pH hazards (burns, caustic).
Environmental Impact	Low CO_2 emissions; eco-friendly.	Potential runoff issues; environmental concerns.	Neutral, but production energy intensive.	High CO_2 emissions; less sustainable.

Learn More

Visit phoscrete.com to learn more about our technology. Reach out to our knowledgeable sales engineers and find out if Phoscrete is a good fit for your next concrete project.

Appendix C

Photo Documentation: Packsaddle Bridge (Oklahoma): 2017

Phoscrete F1-VO [MALP] was installed by hand-packing, trowel finishing in 2017 with minimal site preparation.

Inspection by Oklahoma DOT after 7 years shows no corrosion and no delamination of the Phoscrete repair.

Learn More

Visit phoscrete.com to learn more about our technology. Reach out to our knowledgeable sales engineers and find out if Phoscrete is a good fit for your next concrete project.

Appendix D

Photo Documentation: Claiborne Pell Newport Bridge (Rhode Island): 2020

Extensive bridge column repairs were performed by the contractor on this long-span bridge using F1-VO in 2020

Structural wall repairs were performed by the contractor using F1-VO [MALP] in 2020

Learn More

Visit phoscrete.com to learn more about our technology. Reach out to our knowledgeable sales engineers and find out if Phoscrete is a good fit for your next concrete project.