mar mac

Concrete Admixture

AMX 5500

POWERED BY MICROBAN

Submittal Package

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P.O. Box 547
McBee, SC 29101

Thank you for your consideration of MarMac® Applied Infrastructure Sciences and our **Concrete Admixture AMX 5500** for the projects under your jurisdiction. We are honored and grateful to be able to not only serve you, but also stand beside you with the shared goal of making infrastructure better for both present and future generations. Our purpose is to assist you in doing so by providing the means of effective, cutting-edge, and readily-available product solutions designed to improve the serviceable life and physical properties of the infrastructure that serves the people in your region, every day.

With the rigorous testing, research & development, and continuous improvement that adds the character you know to the MarMac® name, we are confident you will be happy choosing our products. If after reviewing the information following you find a need for further clarification, our chemistry and engineering team stands ready to assist you.

Thanks again for choosing MarMac®!

Sincerely,

Robert Weir, Jr.
CEO


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APPLIED
INFRASTRUCTURE
SCIENCES

PRODUCT
OVERVIEW

PROTECTION THAT LIVES ON MICROBAN®

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Concrete Admixture

AMX 5500

Antimicrobial concrete protectant

Lifetime concrete protection from bacterial stains & corrosion

MarMac's Concrete Admixture AMX 5500 is a Microban®-powered antimicrobial concrete additive that inhibits damaging bacterial growth in treated concrete, especially in challenging environmental conditions. This product may be used in any new concrete structure requiring permanent product protection from bacterial growth and Microbial-Induced Corrosion (MIC[1]).

The active ingredient in MarMac's Concrete Admixture AMX 5500 creates an inhospitable environment for bacteria growth by working to to rupture their cells and terminally disrupt the cell walls of fungi, molds, and mildew.

BENEFITS OF TREATED CONCRETE

- Fights damaging bacterial growth & subsequent stains
- Microban®-powered antimicrobial helps prevent corrosion (M.I.C.[1])*
- Makes for longer-lasting, higher quality structures
- Reduces maintenance: Helps keep concrete cleaner
- Inhibits growth of mold & mildew
- Preserves strength: Over 40% stronger concrete vs untreated*
- Microban Antimicrobial Technology™ lasts the lifetime of the structure
- Ultra-low VOC formula

[1] *Microbial-Induced Corrosion (of Concrete); * Based on standard lab test method ASTM C1904-20.*

ASTM ISO MADE IN USA

Combats corrosion

The lifespan of concrete is highly dependent upon the type(s) of corrosion the structure is subjected to. Untreated concrete is prone to accelerated deterioration, particularly in humid, challenging environments where microbe growth is prevalent. MIC is among the most common and detrimental causes of a reduced lifespan, cutting years or decades off the concrete structure's serviceable life.

BUILT-IN ANTIMICROBIAL
MICROBAN PROTECTED
PRODUCT PROTECTION

24/7 protection by Microban®

The Microban Antimicrobial Technology™ used in our Concrete Admixture AMX 5500 continuously fights stain-causing bacteria & microbial corrosion in treated concrete. The product will not wash away; lasting for the prolonged life of the treated structure.

Saves time & money

Our Microban®-powered admixture protects concrete finishes and lowers overall maintenance. Fewer required cleanings reduces labor and the need to hire professional pressure washing services or renting equipment, and minimizes water & chemical usage... resulting in less mess, less time, and lower cost.

Visually undetectable

MarMac's Concrete Admixture has no adverse side effects. There is no change in the cure time, finishability, and coloration/shade when compared to traditional "mix water" concrete. Visually, the only noticeable difference is long-term, fresher, cleaner concrete. The final cured AMX 5500-treated concrete retains all the same physical specifications with the bonus of antimicrobial properties.

Availability

4.5 Gallon Pails
225 Gallon Totes
50 Gallon Drums

Applications

Sewer/Sanitary RCP
Manholes
Patios & Pool Decks
Box Culverts
Sidewalks & Driveways
Garage & Shop Floors

Simulated imagery. Microban® is a registered trademark of Microban Products Company. Microban® technology is not designed to protect users of this product or others from disease-causing microorganisms. Antimicrobial action is limited to product surface.

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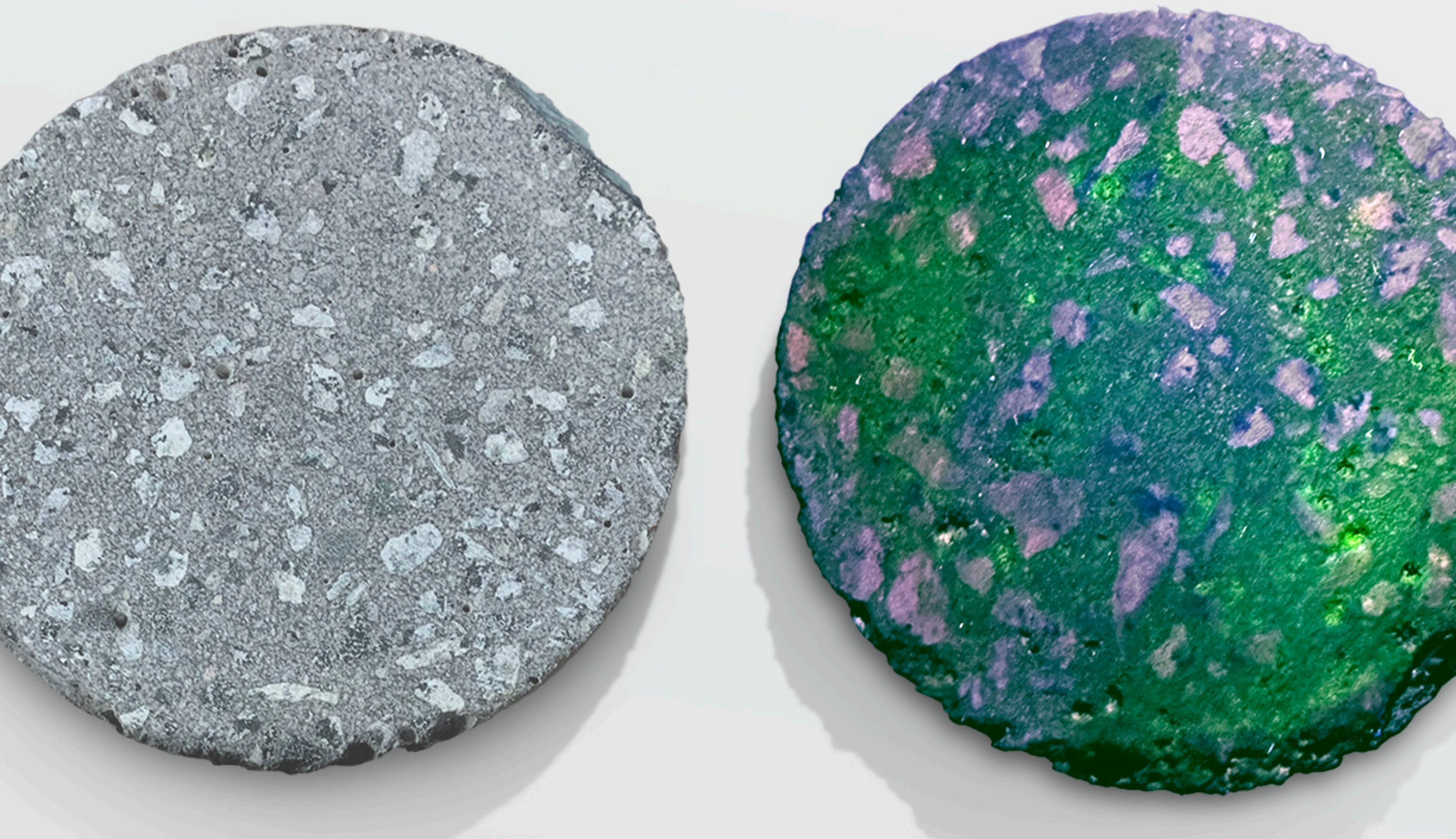
Concrete Admixture

AMX 5500

BUILT-IN ANTIMICROBIAL
PROTECTION THAT LIVES ON
MICROBAN®
PROTECTED
PRODUCT PROTECTION



Treated vs **Untreated***

** Shown under blacklight for enhanced effect.*

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TECHNICAL
DATA SHEET

Concrete Admixture
AMX 5500

Technical Data Sheet

POWERED BY MICROBAN®

BENEFITS

- Broad-spectrum antimicrobial admixture for concrete infrastructures, powered by Microban®
- Extends the lifespan of structures by becoming part of the concrete matrix
- Water-borne, safe, and stable
- Permanent- will not leach out, fade, or wash away
- Treated concrete is protected from degrading bacteria/microbial growth for its expected lifetime

PRODUCT DESCRIPTION

AMX 5500 is a versatile, user-friendly antimicrobial admixture for concrete infrastructures of many general types and applications. It helps prolong the useful life through a complex attack on detrimental corrosive bacteria also known as Microbially Induced Corrosion *(MIC)*. The active ingredient in AMX 5500 is commonly called a quaternary silane, "quat-silane". However, it is much more in that this particular quat-silane has undergone rigorous testing, proving it time and again that the use of Microban® technology helps prevent the growth and transfer of bacteria and other microorganisms, providing a more durable and longer-lasting concrete infrastructure.

TYPICAL PROPERTIES

Appearance	semi-translucent light blue liquid
pH(at ~22 °C)	5.0 - 7.0
Odor	slight amine odor
Odor threshold	no data
Freezing point	about 32 °F (0 °C)
Flash point	no data
Flammability	not flammable
Vapor pressure	no data
Relative density	~1.005 - 1.009 g/cm^3
Solubility in water (25 °C)	all components are miscible
Auto-ignition temperature	will not ignite
Decomposition temperature	will not decompose
Explosive properties	will not explode
Oxidizing properties	will not oxidize
Specific gravity (sg)	~1.005 - 1.009

PRODUCT TESTING

AMX 5500 was rigorously tested against the ASTM C1904-20: Standard Test Methods for Determination of the Effects of Biogenic Acidification on Concrete Antimicrobial Additives and/or Concrete Products.

PRODUCT TESTING *(CONT.)*

Table 1 *(below)* shows that the tested percent strength reduction for the treated admixture is much lower than that of the control specimen. The '5-alpha- admixture' showed only an 11% decrease in strength. "This strongly indicates that the quaternary silane additive is extremely effective at reducing the strength loss of the cement due to MIC".

Table 1: *B3B flexural strength results of the control and inoculated specimens*

	LEACHING CONTROL *(no bacteria)*		ACIDIFIED *(inoculated)*		
SPECIMENS	FLEXURAL STRENGTH	STANDARD DEVIATION	FLEXURAL STRENGTH	STANDARD DEVIATION	STRENGTH REDUCTION
Control *(no antimicrobial)*	16.72 MPa	0.83	13.54 MPa	1.12	19 %
AMX 5500 *(admixed)*	14.02 MPa	0.99	12.47 MPa	1.85	11 %

The pH of the treated admix did NOT DECREASE as quickly as the 'untreated control'.

This product has been tested by an outside independent microbiological laboratory for its efficacy against the harmful type of destructive micro-organisms particularly attacking concrete infrastructures.

The test protocol used was that of the modified ISO 22196:2011 *(JIS Z2801)* - 'Antibacterial efficacy testing construction materials.' The test was performed in triplicate against an exposure time of 24 hours. The test organism used was Serratia marcescens.

AMX 5500 exhibited a microbial *(bacterial)* 'kill' of >99.999% *(or 5 log reduction)* of the bacteria after 24 hours of exposure, clearly demonstrating superlative performance as an antimicrobial admixture for cementitious infrastructures.

HOW TO USE

- AMX 5500 is a premixed, water based, ready for use product to be added while mixing concrete for various infrastructures. Mix AMX 5500 thoroughly before use if it has been sitting for an extended period of time.
- Do not dilute AMX 5500. It does not need it.
- The total volume of AMX 5500 used in a particular application is to be considered "mix water" and must be considered when calculating the total water to concrete (w/c) ratio.
- Approximately 122-128 fl oz (0.95-1.00 gallon) is enough AMX 5500 to adequately treat one cubic yard (1 yd^3) of concrete in most applications. Due to variation in cement response, it is important that

HOW TO USE *(CONT.)*

set time and slump retention of the proposed mix be thoroughly tested and evaluated in the light of job requirements.

- Add the required quantity of AMX 5500 to your concrete while continuing to tumble the concrete mix.

PACKAGING

AMX 5500 is packaged in a distinctive 4.5-gallon pail *(gray)* with a white top and a 'non-gluck' spout for safe and easy use. Each 4.5-gallon pail has a net weight of 37.85 lbs *(17.17 kg)*. AMX 5500 is also available in 50-gallon drums or 225-gallon totes upon special request.

SAFETY

- The usual handling and safety precautions should be observed when using AMX 5500. These include the measures described in federal, state, and local health and safety regulations and requirements.
- The workplace should have thorough ventilation.
- Handle in accordance with good industrial hygiene and safety practices.
- Protective eyewear, disposable coveralls, aprons, or other protective clothing, along with appropriate nitrile or other protective chemical resistant gloves is recommended.
- Wash hands thoroughly before eating, drinking, or smoking after the use of AMX 5500.

USABLE LIFE & STORAGE

- When stored in the original and unopened container in a well-ventilated area between 41-100 °F (5-28 °C), AMX 5500 has an approximate shelf life of 18 months from the date of manufacture.
- Keep away from excessive heat and open flame.
- Protect from freezing or near freezing conditions. Addendum: Should the admixture be left or stored in such conditions be sure that it has not layered or has become exceedingly cloudy. Heat the solution in its container in an ambient temperature of around 65-75 °F for approximately 20-30 minutes stirring occasionally. This should remedy the situation and be able to be used.

LIMITED WARRANTY INFORMATION *(PLEASE READ CAREFULLY)*

The information contained herein is offered in good faith and is believed to be accurate. However, because conditions and methods of use of our products are beyond our direct control, this information should not be used in situations for customer's tests to ensure that our products are effective, safe, and fully satisfactory for the intended end use. Suggestions of use shall not be taken as inducements to infringe any patents.

AIS' sole warranty is that at the time of shipment our products will meet sales specifications.

Your exclusive remedy for any breach of such warranty is limited to refund of purchase price or replacement of any product evidenced to be other than as warranted.

LIMITED WARRANTY INFORMATION *(CONT.)*

Purchaser must determine the suitability of the products for the intended use and assumes all rusks and liabilities in connection therewith. However, AIS assumes no liability for providing information and advice including the extent to which such information and advice may relate to existing third party intellectual property rights, especially patent rights, nor shall any legal relationship be created by or arise from the provision of such information and/or advice. AIS reserves the right to make any changes according to technological progress or further developments. The Purchaser of the product(s) must test the product(s) for suitability for the intended application and purpose before proceeding with a full application of the products(s). Performance of the product described herein should be verified by testing and carried out by qualified experts.

AIS disclaims any other express or implied warranty of fitness for a particular purpose or merchantability.

Confocal Imagery: This information is based upon standard laboratory tests and is provided for comparative purposes to substantiate antimicrobial activity for non-public health applications. Microban® technology is not designed to protect users of this product or others from disease-causing microorganisms. Antimicrobial action is limited to product surface.

Health Claims: Microban® technology is not designed to protect the users of this product or others against disease-causing microorganisms. Microban Products Company makes neither direct nor implied health claims. Normal cleaning practices should be maintained.

Normal Cleaning: Microban® technology is not designed to replace normal cleaning practices.

Microban® is a registered trademark of Microban Products Company.

CAUTION: *Prior to use, please read the Manufacturer Warranty & Disclaimer found at marmac.com/ais/disclaimer.*

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APPLIED
INFRASTRUCTURE
SCIENCES

SAMPLE
SPECIFICATION

SAMPLE SPECIFICATION
MarMac® Concrete Admixture AMX 5500

APPLIED INFRASTRUCTURE SCIENCES

SECTION 33 0530

PRECAST CONCRETE CULVERTS, MANHOLES & STRUCTURES

PART 1 – GENERAL

1.1 SUMMARY

A. This Section includes requirements for the antimicrobial admixture MarMac® AMX 5500, powered by Microban® Antimicrobial Technology™, for use in precast concrete culverts, manholes, and structures requiring permanent protection from bacterial growth, mold, mildew, and Microbial-Induced Corrosion (MIC).

B. AMX 5500 is applicable to any new concrete structure requiring lifetime product protection from microbially-induced corrosion (MIC), hydrogen sulfide (H_2S) gas, and/or damage-causing bacteria including but not limited to the following applications:
   1. Sanitary/Stormwater Sewer Reinforced Concrete Pipe
   2. Manholes
   3. Box Culverts
   4. Wastewater Treatment Facilities
   5. Bridge Spans & Pylons
   6. Pump/Lift Stations
   7. Septic Tanks
   8. Digesters/Clarifiers
   9. Headworks

C. Related Sections:
   1. Section 03 10 00 – Concrete Forming and Accessories
   2. Section 03 20 00 – Concrete Reinforcing
   3. Section 03 35 00 – Concrete Finishing
   4. Section 03 39 00 – Concrete Curing

1.2 REFERENCES

A. American Concrete Institute (ACI):
   1. ACI 201.2R – Guide to Durable Concrete
   2. ACI 211.1 – Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
   3. ACI 301 – Specifications for Structural Concrete
   4. ACI 305R – Guide to Hot Weather Concreting
   5. ACI 306R – Guide to Cold Weather Concreting
   6. ACI 308R – Guide to External Curing of Concrete
   7. ACI 318 – Building Code Requirements for Structural Concrete

B. ASTM International:
   1. ASTM C33 – Standard Specification for Concrete Aggregates
   2. ASTM C39 – Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
   3. ASTM C94 – Standard Specification for Ready-Mixed Concrete
   4. ASTM C143 – Standard Test Method for Slump of Hydraulic-Cement Concrete
   5. ASTM C150 – Standard Specification for Portland Cement
   6. ASTM C157 – Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

7. ASTM C231 – Standard Test Method for Air Content of Freshly Mixed Concrete
8. ASTM C403 – Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
9. ASTM C494 – Standard Specification for Chemical Admixtures for Concrete
10. ASTM C618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
11. ASTM C989 – Standard Specification for Slag Cement for Use in Concrete and Mortars
12. ASTM C1064 – Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
13. ASTM C1202 – Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
14. ASTM C1240 – Standard Specification for Silica Fume Used in Cementitious Mixtures
15. ASTM C1602 – Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
16. ASTM C1894 – Standard Guide for Microbially Induced Corrosion of Concrete Products
17. ASTM C1904 – Standard Test Methods for Determination of the Effects of Biogenic Acidification on Concrete Antimicrobial Additives and/or Concrete Products

C. International Organization for Standardization (ISO):
   1. Modified ISO 22196:2011 (JIS Z2801) – Antibacterial Efficacy Testing on Construction Materials

D. Environmental Protection Agency (EPA):
   1. AMX 5500 active ingredient (quaternary silane mixture) is EPA-registered under FIFRA; EPA Registration No. 64881-1.

E. Occupational Safety and Health Administration (OSHA):
   1. 29 CFR 1910.1200 – Hazard Communication Standard

1.3 DEFINITIONS

A. Antimicrobial Admixture: A chemical admixture incorporated into fresh concrete during batching that inhibits or eliminates the growth of bacteria, mold, mildew, fungi, and other microorganisms on or within the hardened concrete matrix. AMX 5500 utilizes a quaternary silane (quat-silane) active ingredient powered by Microban® technology.

B. Microbial-Induced Corrosion (MIC): Accelerated deterioration of concrete caused by microbial activity, particularly in humid and challenging environments, which can reduce the serviceable life of a concrete structure by years or decades.

C. Quaternary Silane: The active ingredient classification of AMX 5500. This compound class creates an inhospitable surface environment for bacteria by rupturing their cell walls and terminally disrupting the cellular structure of fungi, molds, and mildew.

D. Mix Water Equivalency: AMX 5500 is a water-borne liquid admixture. The total volume of AMX 5500 used in any batch must be accounted for as part of the total mix water when calculating the water-to-cementitious materials ratio (w/cm).

1.4 SUBMITTALS

A. Product Data: Submit manufacturer's complete submittal package, technical data sheet (TDS), and Safety Data Sheet (SDS) for MarMac® AMX 5500. Submittal package shall include product description, typical physical and chemical properties, test data, dosage rates, packaging information, mixing instructions, and applicable limitations.

B. Safety Data Sheet: Current version of the MarMac® AMX 5500 SDS (Version 4.0, Revision 4, or most current version), prepared in accordance with GHS/OSHA 29 CFR 1910.1200 requirements.

C. Test Reports: Submit third-party laboratory test results demonstrating antimicrobial efficacy, including:
   1. Modified ISO 22196:2011 (JIS Z2801) antibacterial efficacy test results demonstrating greater than 99.999% reduction (5-log reduction) of Serratia marcescens after 24-hour exposure.
   2. ASTM C1904 biogenic acidification test results demonstrating that AMX 5500-treated specimens exhibit a lower strength reduction under MIC conditions compared to untreated control specimens.

D. Regulatory Documentation: EPA Registration No. 64881-1 for the quaternary silane active ingredient, confirming FIFRA compliance.

E. Mix Design: Submit complete concrete mix design incorporating AMX 5500 at the manufacturer-recommended dosage of approximately 122–128 fl oz (0.95–1.00 gallon) per cubic yard of concrete, prepared by a qualified concrete technologist or independent laboratory, for Engineer of Record review and approval. The volume of AMX 5500 shall be deducted from the mix water allowance on a one-for-one gallon basis.

F. Compatibility Statement: Written confirmation from MarMac® AIS that AMX 5500 is compatible with all cementitious materials, aggregates, and other admixtures proposed for the project.

G. Manufacturer Letter of Compliance: Written certification from MarMac® Applied Infrastructure Sciences confirming that AMX 5500 meets the requirements of this specification and the referenced test standards.

1.5 QUALITY ASSURANCE

A. Manufacturer Qualifications: MarMac® Applied Infrastructure Sciences (AIS), P.O. Box 547, McBee, SC 29101; 843.335.5814; marmac.com/ais. AMX 5500 is manufactured domestically in the United States and is ISO-compliant.

B. Testing Standards Compliance: AMX 5500 has been tested and demonstrated performance against ASTM C1904, Modified ISO 22196:2011 (JIS Z2801), and ASTM C1894 by independent microbiological laboratories.

C. Pre-Construction Conference: Convene a pre-construction conference with the Contractor, MarMac® AIS technical representative, the concrete supplier/producer, and the Engineer of Record to review admixture application requirements, dosage protocols, mix water accounting, and quality control procedures prior to any production using AMX 5500.

D. Mock-Up: Where directed by the Engineer of Record, prepare a test panel, slab, or representative precast element incorporating AMX 5500 at the specified dosage rate. Evaluate for setting time, workability, surface finish, and strength prior to full-scale production.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Packaging: AMX 5500 is available in the following configurations:
   1. 5-Gallon Pails (gray pail with white lid and non-gluck spout) – Net weight: 37.85 lbs (17.17 kg) per pail.
   2. 55-Gallon Drums.
   3. 250-Gallon Totes (available upon special request).

B. Delivery: Deliver AMX 5500 in manufacturer's original, sealed containers clearly labeled with product name (AMX 5500), product number (MMAMX), brand (AIS), batch/lot information, and manufacture date.

C. Storage:
   1. Store AMX 5500 in a cool, dry, well-ventilated location, away from direct sunlight and sources of heat or ignition.
   2. Maintain storage temperatures between 41°F and 100°F (5°C and 38°C). Do not allow product to freeze.
   3. Shelf life is 18 months from the date of manufacture in the original unopened container; use within 24 months maximum.
   4. If AMX 5500 develops a cloudy appearance due to near-freezing conditions, refer to the manufacturer's technical data sheet addendum for recovery procedures. Do not use the product until the cloudy condition is corrected.
   5. Keep container tightly closed when not in use.

D. Handling: Handle AMX 5500 in accordance with all applicable OSHA, federal, state, and local health and safety regulations and the product SDS. Required PPE includes: chemical-resistant gloves (nitrile recommended), safety glasses with side shields or face goggles, and appropriate protective clothing. Ensure adequate workplace ventilation. Wash hands thoroughly after handling.

E. Emergency Contact: CHEMTREC 24-Hour Emergency Line – 1-800-424-9300.

1.7 ENVIRONMENTAL CONDITIONS

A. Do not place concrete containing AMX 5500 when ambient or concrete temperatures are below 40°F (4°C) or above 95°F (35°C) without written approval from the Engineer of Record and compliance with ACI 305R (hot weather) or ACI 306R (cold weather) requirements.

1.8 REGULATORY AND ENVIRONMENTAL COMPLIANCE

A. AMX 5500 is classified as non-dangerous goods for transport under DOT (US), IMDG, and IATA regulations.

B. AMX 5500 has no SARA 302, 311/312, or 313 reportable components. The product is compliant with the Canadian Domestic Substances List (DSL).

C. California Proposition 65 Notice: AMX 5500 contains Methanol (CAS 67-56-1), a Proposition 65 listed developmental toxin. Refer to the current SDS for required warning language.

D. Dispose of unused product, washout, and empty containers in accordance with all applicable federal, state, and local environmental regulations. Do not discharge to storm drains, surface water, groundwater, or sanitary sewers. Triple rinse empty containers promptly after emptying. Do not burn or use a cutting torch on empty containers.

PART 2 – PRODUCTS

2.1 MANUFACTURER – BASIS OF DESIGN

A. Basis of Design Product:
   - Manufacturer: MarMac® Applied Infrastructure Sciences (AIS)
   - Product Name: Concrete Admixture AMX 5500
   - Product Number: MMAMX
   - Technology: Powered by Microban® Antimicrobial Technology™
   - Contact: 843.335.5814 | ais@marmac.com | marmac.com/ais

B. Substitutions: Substitution requests shall be submitted in accordance with Division 01 requirements. Proposed substitutes must demonstrate equivalent antimicrobial performance under Modified ISO 22196:2011 (JIS Z2801) and ASTM C1904, equivalent EPA registration under FIFRA, and equivalent physical compatibility with the concrete mix design. Substitutions shall require written approval from the Engineer of Record.

2.2 ANTIMICROBIAL ADMIXTURE – AMX 5500

A. General Description: MarMac® AMX 5500 is a water-borne, ready-to-use, broad-spectrum antimicrobial admixture for concrete infrastructure. It is formulated to become a permanent part of the concrete matrix, providing continuous lifetime protection against stain-causing bacteria, mold, mildew, and Microbial-Induced Corrosion (MIC). The product will not wash away, leach out, or migrate from the treated concrete.

B. Active Ingredient: Quaternary silane mixture (quat-silane); EPA Registration No. 64881-1; PMRA No. 15133. The active ingredient works by creating an inhospitable surface environment that ruptures bacterial cell membranes and terminally disrupts the cell walls of fungi, molds, and mildew.

C. Physical and Chemical Properties (Typical):

TYPICAL PROPERTIES	VALUE
Appearance	Semi-translucent, slightly hazy, light blue liquid
Odor	Slight amine odor
pH	5.0-7.0 (at ~72°F / 22°C)
Specific gravity	1.005-1.009 g/cm^3
Relative density	1.005-1.009 g/cc
Freezing point	~ 32°F / 0°C
Flammability	Not flammable
VOC content	Ultra-low VOC formula
Solubility	All components fully miscible in water
Auto-ignition	Will not auto-ignite
Transport classification	Not dangerous goods (DOT, IMDG, IATA)
HMIS ratings	Health: 1 / Flammability: 1 / Physical Hazard: 0 / Personal Protection: F
NFPA diamond	Health: 1 / Flammability: 1 / Instability: 0

D. Antimicrobial Performance Requirements:
   1. Bacterial Kill Efficacy: When tested per Modified ISO 22196:2011 (JIS Z2801), AMX 5500 shall demonstrate greater than 99.999% bacterial reduction (5-log reduction) of Serratia marcescens after 24 hours of exposure.
   2. MIC Resistance: When tested per ASTM C1904, AMX 5500-treated specimens shall demonstrate a measurably lower percent flexural strength reduction under biogenic acidification conditions compared to untreated control specimens. Reference performance data: treated specimens exhibited 11% strength reduction vs. 19% for untreated controls under inoculated conditions.

3. Durability: Microban® Antimicrobial Technology™ is designed to provide protection for the expected lifetime of the treated concrete structure.

E. Effect on Concrete Properties: AMX 5500 shall have no adverse effect on the following concrete properties in comparison to untreated control mixes:
   1. Setting Time: No adverse change in cure time or setting characteristics compared to conventional mix water concrete per ASTM C403.
   2. Finishability: No change in surface finishability or workability.
   3. Color/Shade: No visible change in the color or appearance of finished concrete.
   4. Compressive Strength: AMX 5500-treated concrete shall demonstrate equal or superior compressive strength compared to untreated concrete. Reference performance data: treated concrete exhibited greater than 40% higher strength than untreated concrete in manufacturer testing per ASTM C1904-20.

F. Leachability: AMX 5500 is water-borne and stable. The active ingredient is bonded to the concrete matrix and shall not leach out, migrate, wash away, or diminish over the service life of the structure under normal environmental conditions.

2.3 CONCRETE MIX DESIGN

A. Incorporate AMX 5500 into the approved concrete mix design at a dosage rate of approximately 122–128 fl oz (0.95–1.00 gallon) per cubic yard (yd^3) of concrete, or as specifically recommended by MarMac® AIS based on project conditions and cement type. Conduct trial mixes to confirm set time and slump retention performance.

B. Mix Water Accounting: AMX 5500 is classified as mix water. Reduce the quantity of added mix water (excluding the admixture) by one gallon for every one gallon of AMX 5500 used, to maintain the approved water-to-cementitious materials ratio (w/cm).

C. Compatibility: AMX 5500 shall be confirmed compatible with all proposed cementitious materials (ASTM C150 portland cement; ASTM C618 fly ash; ASTM C989 slag cement; ASTM C1240 silica fume) and all other chemical admixtures in the mix design prior to production.

D. Do not dilute AMX 5500. Use product as supplied without dilution.

2.4 MIX WATER

A. Mix water shall conform to ASTM C1602.

2.5 AGGREGATES

A. Fine and coarse aggregates shall conform to ASTM C33.

PART 3 – EXECUTION

3.1 EXAMINATION

A. Verify that all formwork, reinforcement, embedded items, and substrate conditions are acceptable for concrete placement prior to batching any concrete containing AMX 5500.

B. Confirm that the approved mix design incorporating AMX 5500 and the correct dosage rate have been reviewed by the Engineer of Record prior to production.

C. Do not proceed with concrete placement until all unsatisfactory conditions have been corrected and approvals are in place.

3.2 PREPARATION

A. Mix AMX 5500 thoroughly before adding to the concrete mixture to ensure the admixture is fully redispersed, particularly if the product has been in storage for an extended period.

B. Coordinate with the concrete producer to confirm accurate measurement and dispensing equipment for the admixture. Calibrate dispensing equipment prior to production.

C. Review the current AMX 5500 SDS and confirm all applicable PPE is available and in use prior to handling.

3.3 BATCHING AND MIXING

A. Add AMX 5500 to the concrete batch in accordance with the manufacturer's instructions. Do not add AMX 5500 directly to dry cement or to the dry batch.

B. Introduce AMX 5500 as part of the measured mix water during batching, either through the water metering system at the ready-mix plant or directly into the mixer drum during charging. Continue to tumble the concrete mix while adding the required quantity of admixture.

C. Do not combine AMX 5500 with other admixtures in the same dispensing line or container prior to introduction into the mixer without written confirmation of compatibility from MarMac® AIS.

D. Do not exceed the manufacturer's recommended dosage rate. Do not dilute AMX 5500.

E. Reduce the quantity of added mix water by one gallon for each gallon of AMX 5500 used to maintain the approved w/cm ratio.

F. Ensure complete mixing of the batch for the minimum drum revolutions required by ASTM C94.

3.4 PLACEMENT

A. Place concrete in accordance with ACI 301 and the project specifications.

B. Do not add water to the mix at the point of discharge beyond the quantity permitted by the approved mix design and ASTM C94.

C. Retain a copy of each truck's batch ticket, including AMX 5500 dosage confirmation, for quality control documentation.

3.5 IDENTIFICATION MARKING

A. Upon completion of each concrete structure produced with AMX 5500, paint a clearly visible identification mark in a conspicuous location on the structure using a stencil provided by MarMac® AIS and a permanent, clearly visible paint color. The stenciled marking shall include, at minimum, the name of the admixture manufacturer (MarMac® AIS) and the product name (AMX 5500), in accordance with the manufacturer's sample specification requirements. This marking serves as permanent verification that the antimicrobial admixture has been incorporated into the concrete element.

3.6 FINISHING

A. Finish concrete surfaces in accordance with Section 03 35 00 and project requirements.

B. Do not add water to the surface during finishing operations in excess of that permitted by the approved mix design. Excessive surface water application can dilute or impair the antimicrobial agent at or near the finished surface.

C. AMX 5500 produces no visible change in the color, shade, or texture of finished concrete. The only observable long-term difference compared to untreated concrete will be a cleaner, fresher surface appearance over the service life of the structure.

3.7 CURING

A. Cure concrete in accordance with ACI 308R and Section 03 39 00.

B. Confirm with MarMac® AIS that proposed curing compounds, membranes, or methods are compatible with AMX 5500 and will not impair antimicrobial performance.

3.8 FIELD QUALITY CONTROL

A. Perform the following field tests at a minimum frequency of once per 50 cubic yards (38 m^3) or once per placement day, whichever is more frequent:
   1. Slump: ASTM C143.
   2. Air Content: ASTM C231.
   3. Concrete Temperature: ASTM C1064.
   4. Compressive Strength: ASTM C39 — minimum one set of four cylinders per test.

B. At the direction of the Engineer of Record, retain companion test cylinders or cores for independent third-party antimicrobial efficacy verification per Modified ISO 22196:2011 (JIS Z2801) or ASTM C1904.

C. Confirm through batch ticket review that AMX 5500 was incorporated at the approved dosage rate for each truckload of concrete placed.

3.9 PROTECTION

A. Protect freshly placed and curing concrete from contamination, premature drying, freezing, and physical damage throughout the curing period.

3.10 ENVIRONMENTAL AND WASTE MANAGEMENT

A. Do not allow AMX 5500 or concrete washout containing AMX 5500 to enter storm drains, surface water, groundwater, or sanitary sewers.

B. Dispose of unused admixture, rinse water, and empty containers in accordance with the product SDS (Section 13) and all applicable federal, state, and local environmental regulations.

C. Triple rinse empty containers promptly after emptying. Do not reuse, refill, or incinerate empty containers.

3.11 DOCUMENTATION

A. Maintain a complete project record file including:
   1. Approved concrete mix designs incorporating AMX 5500.
   2. Batch tickets for all concrete placements, confirming admixture dosage.
   3. Field quality control test results (slump, air, temperature, compressive strength).
   4. MarMac® AMX 5500 product data, technical data sheet, and current SDS.
   5. Third-party antimicrobial performance test reports (ISO 22196 / ASTM C1904).
   6. EPA Registration No. 64881-1 documentation.
   7. Pre-construction conference meeting minutes.

- END OF SECTION 33 0530 -

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PROTECTION THAT LIVES ON

A NOVEL EXPLORATION OF QUATERNARY SILANES (QAS) USE IN CONCRETE SEWER STRUCTURES FOR INHIBITING THE GROWTH OF MICROBES RESPONSIBLE FOR MICROBIALLY-INDUCED CORROSION IN CONCRETE (MICC).

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Synopsis

The different stages of *microbially-induced corrosion in concrete* (MICC) attack on concrete are explained to provide an accurate depiction of the problem. The efficacy of Quaternary Silanes against representative organisms responsible for *microbially-induced corrosion in concrete* (MICC) in concrete structures can vary at different pH levels depending on properties such as molecular chain length. An effective solution should combine QAS that offer the most robust efficacy with an optimal concrete compositional design to effectively combat MICC.

1. Microbially-Induced Corrosion of Concrete

1. Mechanism of Acid Corrosion in Sewer Pipes

Figure 1: *Corroded Concrete manhole access to a sewer line [1]*

Concrete sewer pipes and wastewater infrastructures have been found to deteriorate at unexpectedly rapid rates due to chemical corrosion, as seen in Figure 1. Studies have shown that corrosion is due to high concentrations of sulfuric acid on the surfaces of concrete pipes and structures. This acid is generated by a complex procedure involving a multistage microbial process wherein sulfates in the raw sewage are anaerobically metabolized to generate hydrogen sulfide gas H_2S, which is in turn aerobically metabolized into sulfuric acid H_2SO_4[2]. Once established, the acid corrosion process proceeds as outlined in Figure 2:

1. Anaerobic organisms in the sludge under the sewage's surface metabolize sulfates in the sewage and release hydrogen sulfide (H_2S) into the liquid sewage stream.
2. Aqueous H_2S is released into the gas phase above the water line, where it is absorbed by the moisture layer on the concrete walls. Note: Areas of turbulence or high flow can increase the rate of H_2S release into the gaseous phase.
3. Species of *Thiobacillus* living on the walls metabolize the H_2S to produce sulfuric acid (H_2SO_4).
4. The sulfuric acid attacks (decalcifies) the cement paste component of the concrete to form gypsum and ettringite, both of which are expansive products with little structural integrity.
5. The low strength and expansive nature of the gypsum and ettringite leads to the dislodging of coarse aggregate from the concrete, exposing fresh surfaces to corrosive attack.

Note: The actual corrosion rate of concrete is depends on many factors unique to a given application, including the environmental conditions (which can fluctuate seasonally), sewage characteristics, composition and flow, structural elements of the infrastructure, and the design mix / material properties of the concrete itself[3]. Often, there are significant variations in the rate of corrosion within a single stretch of the same pipe due to localized turbulence in the sewage flow, increasing the rate of H_2S release into the atmosphere[4].

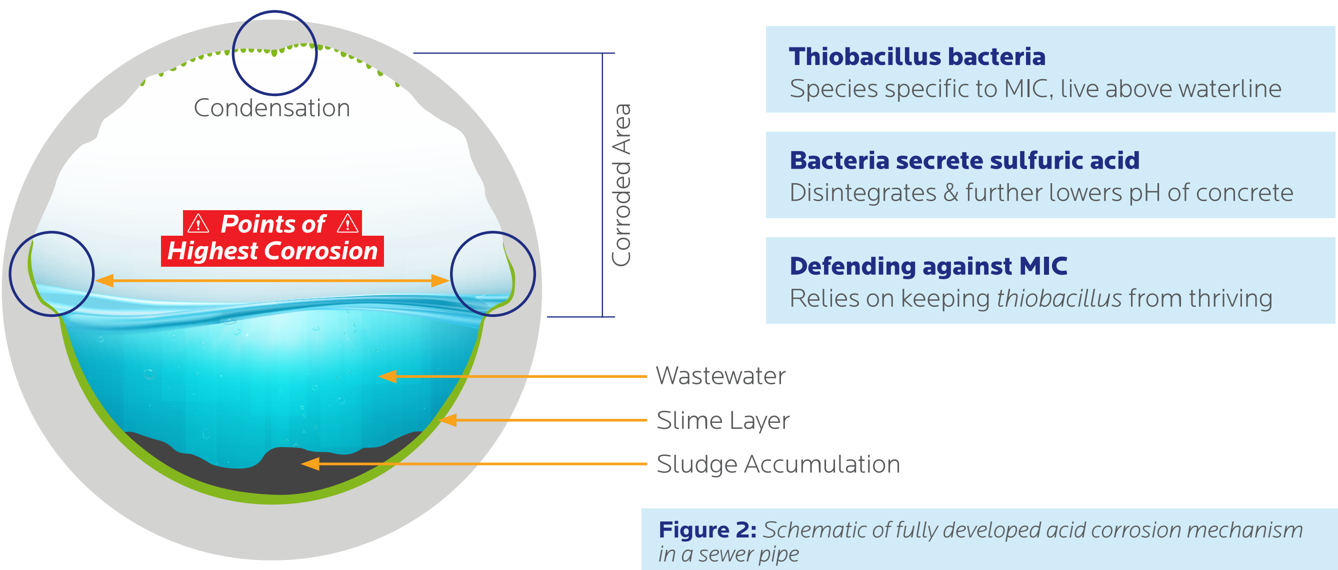


Figure 2: *Schematic of fully developed acid corrosion mechanism in a sewer pipe*

1.2 Development of Bacterial Flora responsible for MICC attack

When concrete is freshly installed, none of the elements that support the corrosion process are present. These conditions develop slowly over time. It is important to understand how these elements effectively interfere with, delay, and inhibit the process with a view to maximizing the engineering life of a concrete installation. OPC (Ordinary Portland Cement) Concrete has a very high initial pH of 12.5 to 13.5 which provides intrinsic protection against microbial colonization. This is because MICC-causing organisms cannot tolerate this level of alkalinity. Abiotic chemical processes in the sewer system combine moisture and sewer gases to gradually lowering the pH of the concrete surface until the microbial flora that drives biogenic acid production can get a foothold. The development of the elements of the corrosion process is complex. It may involve more organisms than the *Thiobacillus* genus, but current understanding is that the *Thiobacillus* genus is the major contributor to the issue[5].

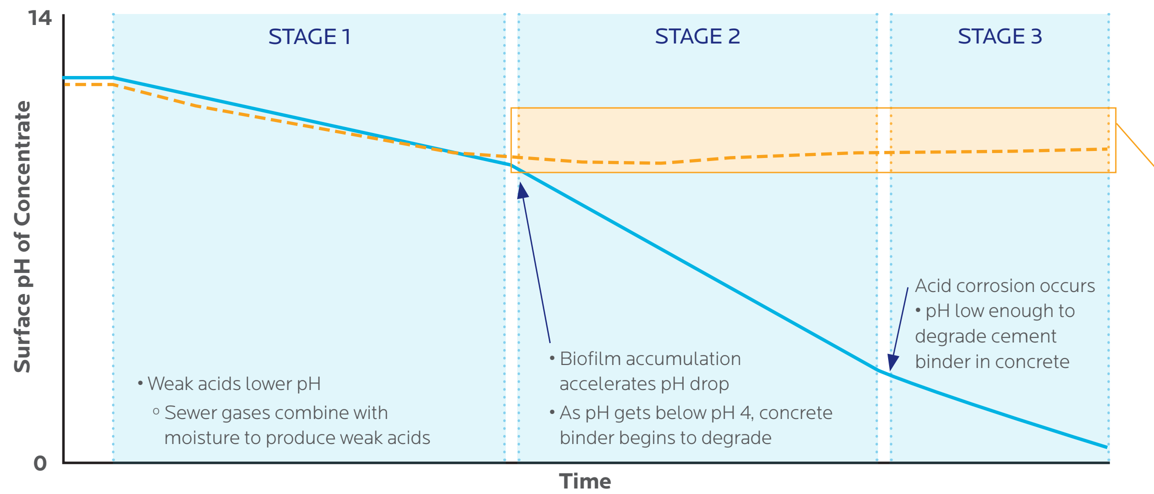


Figure 3: *An ideal service life comparison of an untreated concrete vs. antimicrobial treated concrete*

To study and understand the development of the corrosion process, a model developed by Weiss and House [6]divides the engineering life of a sewer pipe into 3 distinct stages depending on the surface pH of the concrete (Figure 3):

1) Stage 1 is where freshly made OPC concrete is very alkaline (pH > 12), providing an inherent protection period against microbial attack. Sewer gases (mainly CO_2 and H_2S) combine with moisture to form weak acids that gradually neutralize the concrete surface, lowering the pH sufficiently to allow colonies of microorganisms such as *Thiobacillus* spp. to grow. Different concrete formulations offer varying levels of protection at this stage, as some have a relatively lower pH (i.e., an initial pH of ~10 rather than 12+).In such cases, the time span of Stage 1 protection may be drastically shortened, hastening the onset of Stage 2. The rate of pH decrease on the concrete surface during Stage 1 correlates strongly with initial pH, environmental conditions, and the sewage composition.

2) Stage 2 is characterized by an accelerating decline in the pH of the concrete. A complex and changing ecosystem of microbes inhabits the concrete surface as the pH continues to drop, hastened by the increasing amounts of sulfuric acid generated by these microbes' metabolic activities. However, the pH is not yet sufficiently low to cause concrete corrosion; only the pH reduction is occurring.

Species	Preferred pH Growth Range
T. thioparus	9 → 5
T. novellus	8 → 2.5
T. intermedius	8 → 2.5
T. neapolitanus	7 → 3
T. thiooxidans	3 → 0.5

Table 1: *The preferred pH ranges for Thiobacillus species*

The pH reduction is caused by a succession of *Thiobacillus* species (the main actors listed in Table 1), which prefer to grow at different pH values. At a higher pH, the neutrophilic (neutral pH-loving) organisms grow and produce sulfuric acid, which further lowers the pH until they die off and the acidophilic (acid-loving) species start to grow and further lower the pH[7].

3) Stage 3 is where the pH becomes low enough to actually lead to corrosion of the concrete, with failure becoming imminent and unpreventable. The sulfuric acid produced by the organisms converts the cement binder in concrete into non-load-bearing gypsum and ettringite. *T. thiooxidans* is the organism that is most damaging at this stage.

1.3 Common Approaches to Combat MICC

Most traditional approaches to combat MICC focus on fortifying the concrete against acid attack. These methods ignore the protection provided by the initial alkaline pH, which prevents biofilm establishment. True and comprehensive protection against microbial attack should also take into consideration the prolonging of Stages 1 and 2 to maximize inherent protection; by Stage 3, the concrete is actively corroding, and it is too late to abort the process. Traditional methods to fortify the concrete include adding densifiers such as GGBS (Granulated Ground Blast-furnace Slag) or silica fume to the concrete[8], which makes it stronger and more resistant to the ingress of water. However, densifiers do not necessarily make concrete more resistant to acid attack [9], as the pozzolanic reaction that incorporates the additives into the concrete binder system scavenges free $Ca(OH)_2$ out of the finished concrete. This can drastically lower the initial inherent pH and reduce the length of Stage 1. This result hastens the introduction of Stage 2 organisms and accelerates the structure towards Stage 3 corrosion.

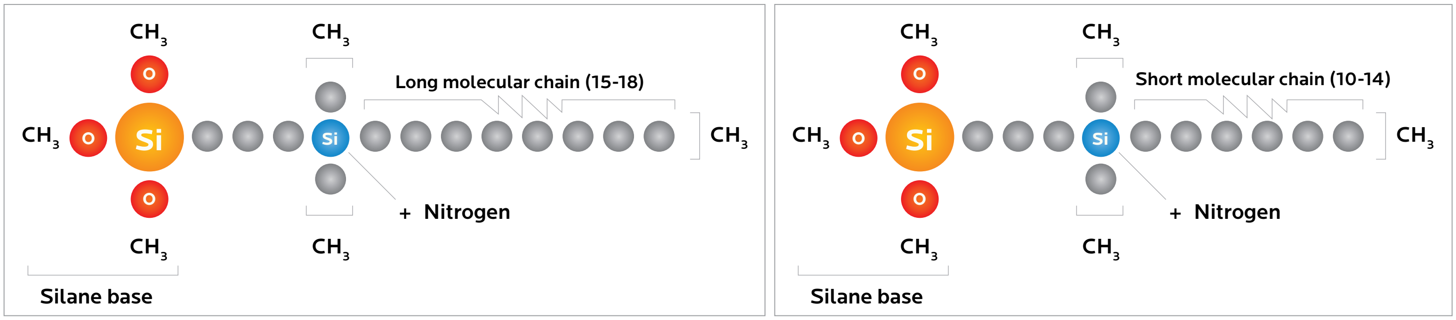
2. Antimicrobial Choice

2.1 Description of Quaternary Ammonium Chemistries

Quaternary Ammonium Compounds are well established in the antimicrobial industry. Due to their relatively low toxicity, good stability, and compatibility with other chemistries, quaternary ammonium compounds (QACs) have been used extensively for many decades for surface protection in a wide range of applications, such as disinfectants, textiles, hand washes and soaps, and swimming pool chemistries. Additionally, QACs are valued because many exhibit broad-spectrum effectiveness against bacteria, fungi, and selected viruses [10]. The efficacy of such chemistry against microorganisms is attributed to the positive charge centered around the nitrogen atom within the QAC molecule. Bacteria typically have a negatively charged cell wall. This can be readily compromised by the positive charge center of a QAC molecule, leading to leakage of essential cell metabolites and ultimately to its death. Mammalian cells are not susceptible to this type of attack; hence, quaternary ammoniums are frequently used in soap formulations for homes, institutions, and hospitals.

Quaternary ammonium silanes (QASs) are a specific type of QAC that incorporates a silane base, providing additional chemical benefits in specific applications. While QASs have been explored in depth in other applications, their benefits in concrete have not been thoroughly examined. For example, QASs can be added to concrete to improve corrosion resistance in a simulated marine environment [11]. Still, the intricacies of how their properties affect performance are not well modelled or quantified.

Figure 4: *Depicts an image of a long-chain versus a short-chain alkane chain*



Two main attributes make Quaternary silanes particularly suitable for concrete use:

1. The unique silane-based functionality at one end of the molecule is highly compatible with silicates and cementitious compositions. Under the right conditions the silane functional group binds and associates itself to concrete and aggregates, increasing the durability of such chemistries with respect to time.

2. Hydrocarbon chains can add a degree of hydrophobicity, which helps the molecule impart greater water resistance and thus enhances the anti-corrosion performance of the overall system. Differing chain lengths can influence efficacy depending on the application.

3. Evaluation of Microbial Effectiveness

3.1 Evaluation via C1904-2020 Test Method

In order to practically evaluate the efficacy of any antimicrobial in concrete,   one needs a testing protocol that can simulate many years of sewer service to effectively simulate the loss of the intrinsically high pH protection of Stage 1 concrete lifecycle. Most microbes, including *Thiobacillus*, are sensitive to the pH of their environment. As stated, the pH of many freshly-made concrete samples is high enough to prevent organisms from growing. This may lead to a false positive in a test, when bacterial kill is incorrectly attributed to the antimicrobial rather than to a high intrinsic pH. When preconditioning a concrete sample to lower its surface pH to support *Thiobacillus* growth, it is often observed that the pH quickly recovers and returns to its original high values during the course of testing. This is because such preconditioning only affects the concrete's surface, while the sample's core remains very alkaline. Over time (especially with moisture), the surface pH will rise again.

ASTM C1904-20, Standard Test Method for Determination of the Effect of Biogenic Acidification on Concrete Antimicrobial Additives and/or Concrete Products, establishes a laboratory procedure for evaluating how antimicrobial-treated concrete materials perform when exposed to microbially induced acidification. The method is designed to simulate real-world conditions in which microorganisms, particularly acid-producing bacteria, colonize concrete surfaces and generate acidic byproducts that can deteriorate the cement matrix. This controlled environment allows engineers and scientists to understand how well antimicrobial additives or treatments suppress microbial activity and slow the rate of degradation due to microbially induced acidification, while accurately mimicking actual applications.

The ASTM C1904-20 test method exposes concrete specimens, with and without antimicrobial additives, to microorganisms known to produce biogenic acids. Over a prescribed exposure period, microbial activity, surface pH, mass loss, visual degradation, and other chemical changes are monitored to quantify the extent of acidification and its effects on the concrete. The procedure ensures consistent inoculation, incubation, and measurement practices ensuring comparable results across materials and formulations. This provides a reliable means of determining whether antimicrobial technology effectively inhibits microbial acid production compared with untreated controls.

Ultimately, ASTM C1904 serves as a performance-based tool for assessing durability improvements in concrete materials used in microbially active environments such as wastewater systems, agricultural facilities, and industrial drainage structures. By quantifying the degree to which antimicrobial additives mitigate biogenic acidification, the method helps product developers, engineers, and municipalities determine the suitability of new formulations and guide material selection for long-term structural protection. The test results support informed decision-making by demonstrating how an additive performs under conditions that mimic the biochemical interactions causing real-world concrete degradation.

3.2 Evaluation of Quaternary Silane Chain Length on Microbial Efficacy in Concrete Recipes

Quaternary ammonium silanes (QAS) are widely used antimicrobial agents whose performance is strongly influenced by molecular structure, particularly the length of the attached hydrocarbon chain. In applications such as sanitation, disinfection, and hard-surface treatment, longer alkyl chains are associated with enhanced hydrophobic interactions and increased persistence on treated substrates. Within industries that desire quick efficacy (sanitation and disinfection) it has been found that varied chain lengths offer different performance, with the most desirable chain length being around 16 carbon chains [12]. However, the impact of QAS chain length has not been explicitly examined within concrete formulations, where high initial alkalinity, internal porosity, and biogenic acidification create a distinct and complex chemical environment. Understanding how chain length affects antimicrobial efficacy in cementitious materials is therefore essential for developing more robust additives suited to concrete exposure conditions.

3.3 Effect of Chain Length on pH-Dependent Performance

Experimental evaluation demonstrates that hydrocarbon chain length significantly influences the pH range within which the QAS remains active in concrete. As surfaces undergo biogenic acidification, as driven by microbial communities that generate acids, the local pH can decline from the initial alkaline conditions towards pH ranges that are more aggressively acidic. Fortunately, companies in the industry are advancing efforts to understand this process better. MarMac recently submitted candidate formulations to Oregon State University for evaluation via the C1904-20 test method to gain insight into the impact that the antimicrobial, specifically QAS, has on the concrete performance. The testing candidates included 1-alpha (short-chain analog) and 5-alpha (long-chain analog), with performance assessed relative to an untreated control.

Experimental results demonstrate that the longer-chain QAS maintains antimicrobial activity down to approximately pH 4, whereas 1-alpha (a shorter-chain analog) shows a similar pH response to the untreated control (Figure 5).

At pH 5, it can be seen that 5-alpha shows significantly improved pH response at pH 5 (Figure 6). The long chain QAS maintains a higher pH throughout the duration of the test, demonstrating stronger prevention of microbially induced corrosion conditions.

This performance differential suggests that extended hydrophobic chains enhance both molecular stability and retention within the concrete matrix. Stronger adsorption to pore surfaces and reduced susceptibility to acid-induced deactivation likely contribute to the broader effective pH window observed for long-chain variants.

3.4 Implications for Concrete Durability and Additive Selection

The expanded working pH range of long-chain QAS has direct implications for improving the durability of concrete exposed to microbially active environments. Antimicrobial additives that are capable of maintaining efficacy deeper into the acidification cycle can help delay microbial colonization and reduce the onset of biochemical mechanisms leading to concrete deterioration. As a result, hydrocarbon chain length becomes an important design parameter for antimicrobial formulations intended for cementitious systems. Longer-chain QAS provides enhanced resilience under acidic stress, making them better suited for applications where materials must withstand the conditions demonstrated in ASTM C1904-20 environments.

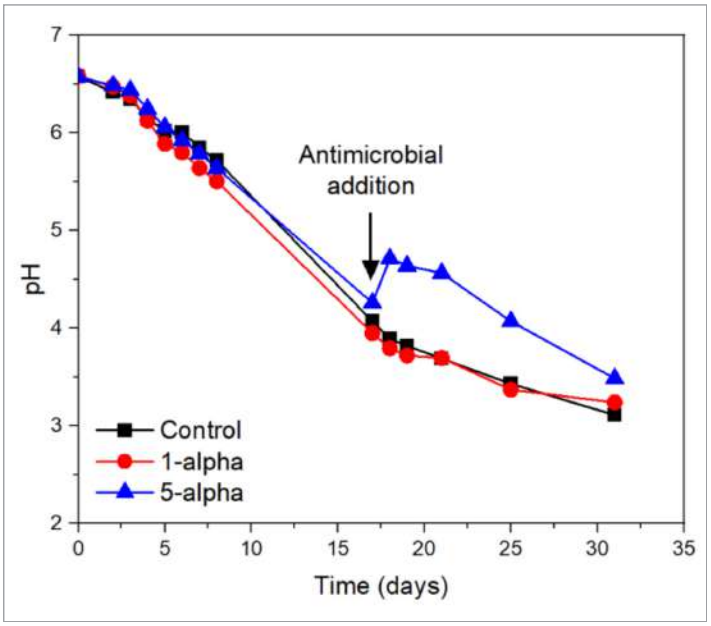


Figure 5: *C1904 Response - Antimicrobial Addition at Concrete pH of 4*

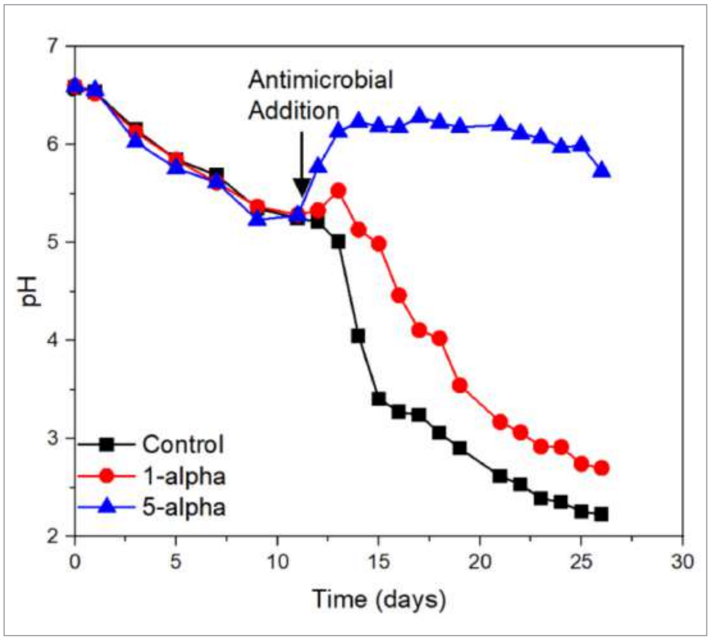


Figure 6: *C1904 Response - Antimicrobial Addition at Concrete pH of 5*

4. Concluding Remarks

The proper selection of concrete composition and MICC protection technology to be deployed in the MICC-resistant concrete layer is essential. Based on the preceding discussion, the following attributes are highly desirable in materials and technology selection:

1. **Select a concrete composition that offers superior Phase 1 protection.** i.e., this means that the concrete should have a high starting pH, and be able to retain that high intrinsic pH for a long period of time. A pH of 12 or higher is suggested to maximize this property. Concrete formulations with high intrinsic pH provide valuable protection against MICC, which can remain effective for significant periods of time. Conversely, concrete with a lower initial pH, or concrete that is easily neutralizable, is at risk of premature microbial attack. It is strongly believed that a high intrinsic pH should be the paramount selection criteria for MICC-protected concrete, rather than infusing concrete with additives to impart increased strength or increased densification of the concrete, as these measures do not directly address this critical stage.

2. **Infuse the concrete with an appropriate antimicrobial that can offer Phase 2 protection.** Here, the choice of an antimicrobial must be properly vetted through a systematic process, as discussed in the preceding paragraphs: (a) an initial determination through a standard Minimum Inhibitory Concentration test as proof positive of antimicrobial efficacy, and (b) an appropriate antimicrobial test that compares a concrete composition treated with the antimicrobial against a concrete with a similar composition without the antimicrobial agent, to be done under test conditions with low enough pH to support the growth of the relevant test organism. The ideal antimicrobial shows efficacy across a broad pH range. This allows for efficacy to be maintained over a longer duration. The exact correlation between microbially induced corrosion of concrete and the overall lifespan of the concrete structure will require future studies for a deeper understanding. However, the literature suggests that, in applications such as marine concrete structures, the expected service life of 100 years can be reduced to as low as 30 years without such protection [13].

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