Copper Development Association Inc.

Compatibility of Copper Tube in Concrete

By the Copper Development Association

Executive Summary

Copper has been used for more than a century in water distribution, radiant heating, snow melt, and other embedded piping systems. Despite this record, questions occasionally arise regarding copper's long-term performance in contact with concrete, particularly in relation to lime, moisture, and thermal stress. Extensive laboratory research and decades of field observation confirm that copper maintains its integrity and resists corrosion in conventional and chloride-free concrete. Comparative studies consistently show that copper remains stable in conditions where ferrous metals deteriorate rapidly, providing confidence in its continued use for embedded infrastructure.

Findings from the Portland Cement Association (PCA), the American Water Works Association (AWWA), and the Centre Expérimental de Recherches et d'Études du Bâtiment (C.E.R.B.P.) in Paris demonstrate that the alkaline nature of concrete protects copper and that corrosion issues can be avoided through proper design and installation. These results establish copper as a reliable material for concrete embedment applications used by utilities, contractors, and municipalities worldwide.

Key conclusions include:

- Copper remains stable in alkaline cementitious environments. Lime is not corrosive to copper; in fact, pulverized limestone is often recommended as a selective backfill.
- Moisture alone does not initiate corrosion. Properly cured, dense concrete provides a protective environment, and copper demonstrates durability even under wet-dry cycling.
- Corrosion risks are specific and manageable. Chloride-based admixtures and direct contact with dissimilar metals can create galvanic conditions, but these can be prevented through separation, sleeving, or dielectric barriers.
- Thermal expansion requires accommodation. When used in high-temperature systems above 120°F, copper should be installed with sleeves or insulating wraps at penetrations to prevent stress and abrasion.

For utilities advancing Lead Service Line Replacement (LSLR) programs and municipalities modernizing infrastructure, copper embedded in concrete remains a trusted solution that is durable, code-compliant, and backed by CDA technical guidance.

Introduction

Across the United States, municipalities and utilities are advancing large-scale infrastructure renewal, with lead service line replacement (LSLR) programs representing a central focus. Material selection within these projects carries long-term implications for water quality, system reliability, and cost performance. Copper has historically been adopted as the preferred choice due to its proven durability, safety, and recyclability.

A recurring question within the industry concerns the performance of copper tube in direct contact with concrete. This typically arises in two applications: (i) concrete-embedded systems such as radiant heating, snow melt, and slab-embedded distribution lines, and (ii) penetrations or encasements where copper passes through concrete walls, floors, or foundations.

Misconceptions have persisted that lime in cement initiates corrosion, that moisture within concrete accelerates degradation, or that thermal movement compromises tube integrity. Extensive research by the American Water Works Association (AWWA), the Portland Cement Association (PCA), and other independent organizations has consistently shown these concerns to be unfounded. Both laboratory studies and decades of field evidence confirm that copper is compatible with concrete and maintains one of the strongest performance records among piping materials.

This white paper presents the available evidence in order to:

- Explain the interaction between copper and cementitious materials.
- Summarize findings from field studies and laboratory testing.
- Identify risks that may occur and how to manage them.
- Provide guidance on installation practices that ensure performance.
- Give utilities, municipalities, and decision makers a clear foundation for material selection.

By addressing these issues directly and with authoritative documentation, CDA reaffirms copper's position as the material of choice for safe, reliable, and sustainable infrastructure in concrete environments.

2. The Science of Copper and Corrosion

The behavior of copper in concrete can be explained by examining the chemical and electrochemical conditions within cementitious materials. Concrete creates a high-pH environment that influences the stability of metals placed within it.

2.1 Alkalinity of Concrete

Hydrated cement produces calcium hydroxide and alkali hydroxides that result in a pore solution with a pH between 12 and 13. This environment is favorable to copper. The high alkalinity encourages the formation of a thin oxide film on the copper surface that stabilizes the metal and prevents further attack.

Lime and related compounds in concrete are not corrosive to copper. In fact, pulverized limestone has often been recommended as a backfill for buried copper tube because of the protective alkaline conditions it creates. Research conducted by the Portland Cement Association has confirmed that copper and its alloys, including brass and bronze, resist corrosion when placed in concrete.

2.2 Moisture and Conductivity

Concrete in its fresh or curing state contains moisture that increases conductivity within the pore solution. For certain metals such as iron or aluminum, this conductivity can accelerate corrosion. Copper does not respond in the same way because it is protected both by the alkalinity of the concrete and by its stable oxide layer.

The American Water Works Association has reported that copper corrodes at extremely low rates in both soil and concrete environments. Failures that have been documented typically result from unusual conditions such as contamination or improper installation, not from the presence of moisture in concrete. Laboratory testing at the Centre Expérimental de Recherches et d'Études du Bâtiment in Paris also showed that copper tubes exposed to wet-dry cycles, immersion, and elevated temperatures exhibited no measurable corrosion.

2.3 Galvanic Considerations

When copper is embedded in concrete by itself, it shows negligible corrosion. The primary risk occurs when copper is in electrical contact with ferrous metals in chloride-bearing concrete. In this case, galvanic activity causes the less noble metal, usually steel or iron, to corrode. The copper remains unaffected, but the deterioration of nearby ferrous materials can affect the overall structure.

For this reason, copper should not be placed in direct contact with steel reinforcement or other iron-based components in chloride-rich environments. International research confirms that copper remained stable while adjacent iron deteriorated under these conditions.

2.4 Summary of Electrochemical Behavior

Copper performs predictably and reliably in concrete. Alkalinity protects the material, moisture does not compromise it, and laboratory simulations confirm its stability. The risks that exist are tied to external conditions such as chlorides, dissimilar metal contact, or poor-quality concrete, and each of these risks can be managed through proper design and installation practices.

3. Addressing Misconceptions About Copper in Concrete

Misunderstandings about copper's performance in concrete persist across the plumbing and infrastructure sectors. These misconceptions are often repeated without reference to research or field data, which can cause unnecessary hesitation when selecting materials for critical projects. The following section addresses the most common myths directly and presents facts supported by laboratory studies, industry associations, and decades of in-service experience.

Myth 1: Copper corrodes rapidly in concrete

Fact: Copper remains stable in the highly alkaline environment of concrete. Laboratory testing conducted by the Portland Cement Association confirmed that copper and its alloys resist corrosion when fully embedded in both wet and dry cementitious conditions. International research, including studies by the Centre Expérimental de Recherches et d'Études du Bâtiment in Paris, demonstrated that copper showed no measurable corrosion under severe wet-dry cycles and high thermal exposure, while iron and other metals deteriorated quickly.

Myth 2: Moisture in concrete accelerates copper decay

Fact: Moisture alone does not initiate corrosion in copper. Properly cured, dense concrete provides a protective environment, and copper tubing has been shown to withstand decades of service even in installations exposed to periodic moisture. Field data collected by the American Water Works Association reports that copper corrodes at extremely low rates in both soil and concrete. Failures attributed to moisture almost always trace back to improper embedment, such as air voids or incomplete encapsulation.

Myth 3: Thermal expansion causes copper failure in concrete

Fact: Copper expands and contracts predictably with temperature changes, and when allowances are made, no issues occur. For radiant heating and snow-melt systems operating below 120°F, expansion remains well within acceptable limits. For higher-temperature applications, sleeves, ducts, or insulating wraps at penetrations ensure that copper can move independently of surrounding concrete. Field experience confirms that failures occur not in the embedded section, but at points where copper exits or enters concrete. Rigid seals at penetrations can restrict movement, leading to fatigue cracking at the transition zone. Proper installation methods eliminate this risk.

Myth 4: Sealing copper with rigid patch materials prevents leaks without risk

Fact: Rigid materials such as hydraulic cement can restrict copper's natural movement at wall penetrations, which creates stress concentration at the interface between the copper and the concrete. Over time, this can result in fatigue cracking that is mistakenly attributed to "corrosion." The actual cause is mechanical stress at a rigid transition point. Flexible sealants such as electrical duct seal, elastomeric wraps, or mechanical couplings provide watertight protection while allowing movement.

4. Proven Performance in the Field

The historical record of copper in concrete is extensive and positive. Both laboratory evidence and field experience confirm that copper performs reliably under the conditions typically encountered in plumbing and infrastructure projects.

4.1 Long-Term Service Record

For more than fifty years, copper has been installed in radiant floor heating, snow melt systems, and slab-embedded water distribution. Contractors and utilities report that these systems continue to operate without corrosion-related failures. In these environments, copper's stability is reinforced by the protective alkaline conditions of concrete. The American Water Works Association has stated that when failures are reported, they are linked to unusual exposures such as chemical contamination, improper installation, or incompatible construction practices rather than to copper's interaction with concrete.

4.2 Laboratory Validation

Controlled experiments by the Centre Expérimental de Recherches et d'Études du Bâtiment in Paris exposed copper and iron tubes embedded in concrete to severe conditions, including wet-dry cycling, continuous immersion, and elevated thermal stress. Copper exhibited no measurable corrosion in any scenario. Iron, by contrast, corroded rapidly, particularly when in galvanic contact with copper in chloride-bearing concrete. These findings confirm that copper maintains its structural integrity even in aggressive test environments.

4.3 Field Failures and Lessons Learned

Although copper remains stable in concrete, real-world failures occasionally occur at points where copper passes through walls, slabs, or foundations. In many cases, rigid sealing materials or improperly installed sleeves have created conditions for fatigue. Contractors sometimes patch penetrations with hydraulic cement to stop moisture infiltration, but this creates a rigid joint that does not allow for differential movement between copper and the surrounding structure. Over time, this can lead to cracking at the penetration, giving the appearance of corrosion when the underlying issue is mechanical fatigue.

Another field observation involves sleeving. Contractors may install copper through a plastic liner or sleeve, but during installation, the sharp leading edge of the copper can cut the sleeve, leaving openings for moisture and contaminants. If sleeving is required, it must be watertight and durable enough to remain intact along the full length of the run.

Backfilling practices also play a critical role. Inadequate backfill can create chemical traps, especially in residential or landscaped areas where fertilizers and other lawn treatments are applied. Without proper drainage, rainwater can wash chemicals into poorly compacted trenches, creating localized environments that accelerate deterioration. Proper bedding and drainage with sand or pea gravel prevent this issue and extend system life.

These lessons show that when problems arise, they are almost always the result of installation or environmental factors external to copper itself. With proper installation practices, copper continues to deliver long service life in concrete.

5. Best Practices for Installation

Copper's compatibility with concrete is well established, and its long-term performance depends on proper installation practices. Field experience over many decades demonstrates that copper performs reliably when established best practices are followed. These practices address embedment, thermal expansion, separation from dissimilar metals, avoidance of chloride admixtures, protection at penetrations, and proper preparation of underground service lines.

5.1 Ensure Full Embedment

Copper tube should be completely surrounded by dense, well-consolidated concrete. Air pockets or voids can collect moisture and create localized conditions that may encourage corrosion. Proper vibration and consolidation of concrete during placement eliminates voids and ensures uniform embedment.

5.2 Allow for Thermal Expansion

For radiant floor heating and snow melt systems operating below 120°F, copper's expansion is minor and requires no additional allowances. For higher-temperature systems such as domestic hot water, copper should be placed in sleeves or ducts, or wrapped with non-reactive insulation. At penetrations, flexible seals or wraps help absorb expansion and contraction without transferring stress to concrete.

5.3 Isolate Dissimilar Metals

Copper should not be installed in metallic contact with steel reinforcement or other ferrous components, particularly if chloride admixtures are present. Galvanic activity in these conditions accelerates corrosion of ferrous metals. Separation with dielectric sleeves, spacers, or non-conductive coatings prevents galvanic coupling.

5.4 Avoid Chloride-Based Admixtures

Calcium chloride and other chloride-rich admixtures should not be used in concrete surrounding copper. These admixtures increase pore solution conductivity and create unfavorable galvanic conditions. Chloride-free mixes ensure long-term durability.

5.5 Protect at Penetrations

Where copper passes through concrete walls, foundations, or slabs, protection against stress and moisture is critical. Rigid patching with hydraulic cement can lock copper in place and lead to fatigue cracking at the entry point. Flexible sealants such as electrical duct seal, elastomeric wraps, or Fernco couplings allow copper to move independently while maintaining watertight protection.

5.6 Proper Backfill and Drainage

In underground applications, copper tubing should not be placed directly in disturbed soil. Trenches are best prepared with a uniform layer of clean backfill material such as sand or pea gravel to promote drainage and prevent water or fertilizers from collecting around the pipe. Using proper bedding and backfill materials helps maintain a stable, noncorrosive environment and supports long-term performance. Contractors should also adhere to local trench detail requirements for installation depth and backfill composition.

5.7 Tube Preparation and Joint Integrity

For underground copper service lines, proper tube preparation ensures leak-free joints and reliable long-term service:

- Cutting and deburring: After cutting annealed copper tube to length, deburr the interior edge to avoid turbulence and long-term system issues.
- Resizing: Annealed tubes are not perfectly round. Use a sizing tool to restore roundness before making connections. This step is critical for ensuring a proper seal.
- Flaring connections: Flare the tube end with the appropriate tool and connect it to compatible brass fittings. Do not use Teflon tape or wax between the flare and brass, as copper conforms naturally to the mating surface.
- Compression fittings: Ensure tube ends are cleaned, deburred, and resized before compression fitting installation to prevent leaks.

5.8 Installation Through Walls and Foundations

When running copper through walls or floors, a sleeve should be used. Sleeves must be watertight and allow for copper movement. Improperly patched penetrations, especially those sealed rigidly with concrete or hydraulic cement, restrict copper's natural flexibility and may result in fatigue cracking. Extending sleeves slightly beyond the wall surface allows for proper couplings and flexible seals.

5.9 Directional or Mole Boring

When installing copper service lines through directional boring, the outside diameter of the copper tube must match the diameter of the bored hole or sleeve. Contractors must also allow for thermal expansion and contraction within the bore. Sleeving must be continuous and watertight to prevent moisture ingress.

5.10 Follow Local Codes and Standards

Copper installations are supported by ASTM B88 (Seamless Copper Water Tube), ASTM B828 (Joining Copper and Copper Alloys), and AWWA C800 (Underground Service Line Valves and Fittings). Compliance with these standards provides assurance of material compatibility. However, regional variations exist, and contractors must always follow the requirements of the authority having jurisdiction.

6. Economic and Policy Benefits

Copper's compatibility with concrete is well established, but infrastructure decision makers must consider more than technical performance alone. They are responsible for balancing budgets, regulatory compliance, sustainability goals, and public confidence. Copper delivers value across all of these areas.

6.1 Lifecycle Value

Infrastructure investments are judged not only by their initial cost but also by their long-term return. Copper provides one of the longest service lives of any piping material. Once embedded in concrete, copper systems can perform reliably for many decades with minimal maintenance. Unlike some alternatives that may require monitoring programs, protective linings, or frequent replacements, copper requires little intervention once installed.

The recyclability of copper adds to its lifecycle value. At the end of service, copper retains its material worth because it can be fully recycled without loss of performance properties. This characteristic positions copper as both a practical and environmentally responsible choice for public infrastructure projects.

6.2 Regulatory Assurance

Copper's use in concrete is supported by major industry standards. ASTM B88 covers seamless copper water tube, ASTM B828 provides the standard practice for joining and brazing copper alloys, and AWWA C800 addresses valves and fittings for underground service lines.

These standards are referenced in building and plumbing codes throughout the United States, providing clear assurance that copper meets regulatory expectations.

Contractors and utilities must also adhere to local code authorities. In the western United States, plumbing officials often follow the International Association of Plumbing and Mechanical Officials (IAPMO), while in the eastern states, enforcement may rely on the International Code Council (ICC). The guiding principle is to comply with the authority having jurisdiction, which consistently recognizes copper as a suitable and approved material.

6.3 Public Confidence

Municipalities and water utilities serve not only as infrastructure providers but also as stewards of public trust. Communities expect systems that deliver clean water safely and reliably. Copper's record of performance helps strengthen this trust. Unlike newer or less proven materials, copper has decades of evidence supporting its safety in potable water systems. Its reputation reassures constituents and reduces resistance to infrastructure projects.

6.4 Sustainability Goals

Many municipalities and government agencies prioritize sustainable infrastructure. Copper supports these goals by offering long service life, full recyclability, and alignment with green building standards. Because copper requires fewer replacements and less maintenance over time, it reduces the overall environmental footprint of infrastructure projects. For decision makers seeking both durable and environmentally responsible solutions, copper provides a clear advantage.

6.5 Risk Mitigation

Persistent myths can lead to costly errors in planning and material selection. For example, if decision makers incorrectly assume that copper corrodes in concrete, they may choose alternatives that deliver shorter service life or introduce new risks. By relying on established research and field data, project leaders can mitigate these risks and ensure that material choices are based on evidence rather than misconceptions.

7. Final Overview

The compatibility of copper with concrete has been evaluated for decades by industry associations, international laboratories, and utilities with long-term field experience. The results are consistent across all sources: copper performs reliably in cementitious environments. Its stability in the alkaline conditions of concrete, combined with its natural corrosion resistance, provides dependable service in water distribution, radiant heating, snow melt, and other embedded infrastructure systems.

When failures have been reported, they have been attributed to external factors such as chloride admixtures, galvanic coupling with ferrous metals, improper embedment, rigid sealing at penetrations, or inadequate backfill practices. Each of these conditions can be prevented through proper installation. Using chloride-free mixes, isolating copper from dissimilar metals, ensuring full embedment, protecting penetrations with flexible seals, and following local code requirements are well-established measures that support long-term performance.

Copper remains a trusted material for municipalities investing in lead service line replacement, for utilities responsible for maintaining reliable water systems, and for contractors installing infrastructure that must endure for generations. It offers durability, regulatory acceptance, and a proven record of value across decades of service.

Studies and field data from organizations such as the American Water Works Association and the Portland Cement Association have shown that copper and concrete are compatible, reliable, and durable when used together in accordance with accepted construction practices. Copper's performance in concrete is consistent and predictable. When installed according to best practices, it provides dependable service for decades and supports the long-term reliability of community infrastructure.

8. Next Steps and Additional Resources

For municipalities, utilities, and contractors engaged in lead service line replacement or concrete-embedded copper installations, additional resources are available through the Copper Development Association (CDA):

- Technical Guidance: Visit copper.org for detailed specifications, design resources, and technical papers on copper performance in infrastructure applications.

- How-To Videos: Explore CDA's video library for practical installation demonstrations and troubleshooting guidance: copper.org/applications/doityourself

- Hands-On Training: Request a free Do It Proper with Copper training session, where CDA experts provide direct support and best practice instruction for your project team. Learn more and schedule here: Request Training.

By leveraging these resources, decision makers and contractors can ensure that copper systems are installed to the highest standard, maximizing reliability, safety, and long-term value for their communities.

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