The Stainless Rebar Standard

SALIT SPECIALTY REBAR
www.stainlessrebar.com

Kevin Cornell, Editor   July 2007

Stainless steel rebar is the long-term solution to controlling corrosion and meeting design life requirements of bridges

Deterioration of reinforced concrete caused by corrosion of the carbon steel reinforcing bars (rebar) is a worldwide problem. The corrosion product - rust, occupies a greater volume than the original steel bar and this creates a pressure, which causes cracking and subsequent spalling of the surrounding concrete.

Corrosion of carbon steel rebar is greatly accelerated when chlorides are present in the concrete. In some parts of the world, chlorides may be incorporated into the original mix due to their presence in the sand, aggregate or water. Most often, chlorides penetrate through the cover when the external surfaces of the concrete are exposed to seawater, marine atmospheres or de-icing salts.

Several methods are currently employed to reduce the corrosion of carbon steel rebar, but none has proven effective. These include:

- Chloride Extraction – Chemical sprayed on the bridge surface to extract chloride from the bridge deck. This process requires lane closures and cannot stop the accumulation of chloride over time.
- Remove and replace the top two to three inches of concrete. This action results in lengthy lane closures and does not address the chloride that is deeper in the concrete.

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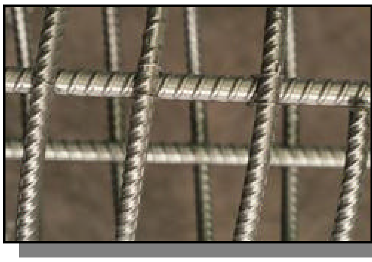
- Cathodic Protection.
- Increase Concrete Cover.
- Concrete Coatings and Sealers

The use of reinforcing materials that have inherently good corrosion resistance, thereby minimizing the need for maintenance and monitoring of the structure is becoming essential. Stainless steel rebar is being used as a long-term solution in concrete reinforcing across the USA, Europe, Canada, and Australia.



Match service life to design life for the right reinforcement

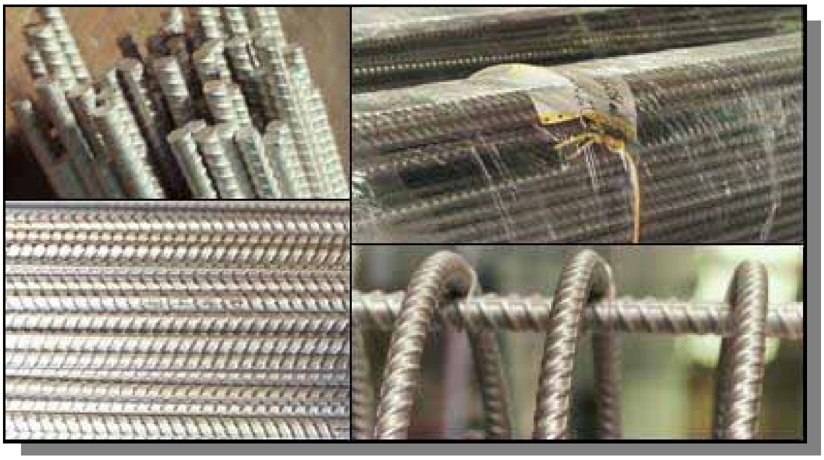
Service life can be described as the projected life of components under normal loading and environmental conditions before replacement or major rehabilitation of a structure is expected. The service life of a structure (or product) is dependent upon the performance of the materials comprising the structure. In the case of concrete structures requiring reinforcement, service life is dependent upon (to a large degree,) the reinforcement material.

Design life of a concrete structure is the period (life expectancy) during which the structure is expected by its designers to function in a certain way within its parameters and environment. Designers of concrete structures (conduits, bridges and buildings) in past civilizations may not have expected the design life of their projects to run for centuries, but they were designed to last a long time. Today, bridge designers expect many of their structures to perform for 75 to 100 years.

Matching the service life of the components of the structures to the design life determined by designers of the structures is fast becoming a specification in all projects, as North Americans become more aware of the notion of sustainable development.

Designers have choices for specifying the appropriate rebar reinforcing material for concrete structures, once the design life of the structure is determined. The most commonly used reinforcing material is uncoated carbon steel, which has very little or no corrosion protection other than the concrete mix design, surrounding environment, and depth of cover. Epoxy-coated and galvanized steel are also routinely specified, but each has its own inherent drawbacks. Epoxy coating provides good corrosion resistance but is damaged easily during bending and installation. Chips or cracks in the coating may contribute to corrosion. Protection from ultra violet light is required, if the coated rebar is stored outside for more than two months. Field bending galvanized rebar results in a breach of the coating at bend locations. The 30-year performance of galvanized reinforcement is marginally better than that of conventional carbon (black) rebar reinforcement.

Reinforcing materials recently introduced to the market include fiberglass reinforced plastic (FRP) rebar and a product from MMFX Steel Inc. The rebar from MMFX is difficult to bend and has not been approved by the ASTM as an anti-corrosive reinforcement product. FRP has numerous drawbacks for projects with a long dsign life. It is not easily fabricated and cannot be field bent or welded. FRP cannot be mechanically spliced and fiber dust from field cutting can cause respiratory irritation and pulmonary edema. Its tensile modulus is only 1/5 of steel, which limits span length and requires the use of more material. It has been discovered that concrete will degrade exposed glass fibers, so sealing cut ends is recommended. FRP has its unique challenges to health and safety because burning rod creates an acrid black smoke and offensive odor. Material Safety Data Sheets prepared by manufacturers identify medical conditions aggravated by exposure to FRP as eye, skin, respiratory and lung disorders.



The use of stainless steel in construction has been steadily increasing since the 1960s in North America. Today, it has secured a favorable position as a rebar and mesh reinforcing material, despite its higher capital cost. In an era where sustainable development and the importance to match service life with design life on major public works to conserve resources and to construct assets that hold their value for prolonged periods, stainless steel reinforcing products must be considered in any life cycle or least cost analysis. Elements that must be factored into a life cycle or least cost analysis are maintenance, material and labor costs, additional costs associated with traffic congestion, disruption to services and detours, economic and environmental impacts, and impact on the quality of life of the people affected by the construction and use of the project. Stainless steel rebar will perform 100 years in concrete structures.

It is now widely accepted that while designers can expect 100 years of service from stainless steel rebar in corrosive environments, other types of reinforcement have much lower expectations in similar environments. Epoxy-coated has a life of 13 to 25 years, galvanized 8 to 25 and carbon rebar 8 to 20 years.

Rebar comparison in corrosive environments

Bar Type	Corrosion Resistance	Service Life
Stainless	800 to 1500 times greater than black bar	100 years
Black Bar (Carbon)		8 to 20 years
Galvanized	38 times greater than black bar	8 to 25 years
Epoxy Coated	If NOT damaged, 40 to 45 times greater than black bar	13 to 25 years

The capital cost of stainless steel rebar remains the overall issue of a more widespread use. There is no doubt about its ability to perform for the design life of any public works with a life expectancy of 100 years or more. The problem facing the stainless steel industry today is the cost of nickel – a major ingredient in the production of stainless steel alloy.

In addition to iron, carbon, and chromium, modern stainless steel may also contain other elements, such as nickel, niobium, molybdenum, and titanium. Nickel, molybdenum, niobium, and chromium enhance the corrosion resistance of stainless steel. The cost of the common stainless steels is substantially determined by the cost of ingredients. The cost of the chromium that is the essential "stainless ingredient" is not high, but additions of elements that improve the corrosion resistance (especially molybdenum) or that modify the fabrication properties (especially nickel) add very much to the cost. Costs for nickel have fluctuated from US$5,000 or US$6,000 in 2001 to US$15,000 per tonne in 2004, and are currently edging downward.

In May 2007, the price of nickel had risen more than seven-fold over the past five years and peaked in June at $52,000 per tonne as China's economic growth fueled demand, increasing the cost of stainless steel used in kitchenware and buildings. The fluctuating nickel price is driving companies to make nickel free, or ferritic, stainless steel and to increase chromium or manganese content.

The most common grades of stainless steel are 304 and 316, which are particularly popular because their austenitic microstructure results in an excellent combination of corrosion resistance, mechanical and physical properties and ease of fabrication. The austenitic structure is the result of the addition of approximately 8-10% nickel. Nickel is not alone in being an austenite former. Other elements that are used in this way are manganese, nitrogen, carbon and copper. (Australian Stainless Steel Development Association).

While the cost of stainless steel rebar reinforcement tends to have an initial cost that is four to six times that of carbon steel equivalent, once a structure is completed using stainless steel, maintenance costs are significantly reduced and unexpected replacement of the structure is unlikely.

Stainless steel mills are now introducing Nitronic 32, to produce a high manganese, low nickel, nitrogen strengthened austenitic stainless steel to reduce the cost to consumers and make stainless steel rebar more capital-cost competitive. The nitrogen provides significantly higher yield and tensile strength without adversely affecting ductility, corrosion resistance or non-magnetic properties. This low nickel material is a cost effective solution, as the price of nickel continues to fluctuate and rise over time.

By matching service life to design life of project to contribute to the notion of sustainable development, and the reaction of the stainless steel industry to produce stainless steel products with less nickel to be more price competitive, it is expected that stainless steel rebar (and mesh) will be specified for more structures and buildings.

What is service life of bridges and how is it predicted?

The AASHTO LRFD Bridge Design Specifications define service life as the period of time that the bridge is expected to be in operation. The design life is defined as the period of time on which the statistical derivation of transient loads is based. Though the subject specifications prescribe transient loads based on a design life of 75 years, they are silent on the extent of the expected service life.

A bridge's ability to fulfill its intended function can be compromised due to degradation. Major causes of degradation are high transient loads and severe environmental conditions. Proper structural design addresses the effects of transient loads through adequate member proportioning and design details.

Environmental conditions that cause degradation include carbonation, sulfate attack, alkali-silica reaction, freeze-thaw cycles, and ingress of chlorides and other harmful chemicals. Adverse environmental conditions, if not properly addressed, typically cause chemicals to invade the concrete's pore structure and initiate physical and/or chemical reactions causing expansive by-products. The most damaging consequence of these reactions is depassivation and eventual corrosion of reinforcing steel causing cracking and spalling of concrete. The end of the service life of the structure occurs when the accumulated damage in the bridge materials exceeds the tolerance limit. However, the service life is typically extended by performing periodic repairs to restore the serviceability of the structure.

Chlorides from deicing salts and salt water penetrate concrete by several transport mechanisms: ionic diffusion, capillary sorption, permeation, dispersion, and wick action. During the last several years, computer models have been developed to predict the service life of concrete bridges exposed to chlorides. Several service life prediction models assume diffusion to be the most dominant mode of transport for chloride ions. The time taken by chlorides to reach reinforcing steel and accumulate to a level exceeding the corrosion threshold is known as Time to Initiation of Corrosion (TIC). Typically, TIC is computed by modeling chloride ingress according to Fick's Second Law of Diffusion. TIC depends on many factors; major among them are diffusivity of concrete, concrete cover, temperature, and the degree of exposure. The Propagation Time—from initiation of corrosion to intolerable accumulation of damage—also depends on many factors including environmental conditions and corrosion protection strategies.

The following is a list of some of the service life prediction models now available:

Life-365: Computer software developed by M. D. A. Thomas and E. C. Bentz, University of Toronto for W. R. Grace, Master Builders Technologies, and Silica Fume Association. Addresses time-dependent diffusion of chlorides. Predicts service life and life cycle costs for various protection strategies.

CIKS: Computer-Integrated Knowledge System developed by D. Bentz, NIST. Predicts chloride ion diffusivity coefficients and TIC.

Duramodel: Developed by W. R. Grace. With the help of effective diffusion coefficients, the model accounts for mechanisms other than pure diffusion.

ConFlux– A Multimechanistic Chloride Transport Model: Developed by A. Boddy, E. C. Bentz, M. D. A. Thomas, and R. D. Hooton, University of Toronto. PC-based program accounts for diffusion, permeability, chloride binding, and wicking.

ClinConc: Developed by L. Tang, Chalmers University of Technology, Goteborg, Sweden. Chloride penetration model is based on mass balance and genuine flux equations. Promising for predicting chloride profiles in submerged parts of structures.

HETEK Model: AEC Laboratory, Denmark. Applicable to marine structures and salt water splash zones. Ten-step spreadsheet calculation for service life. (Source: www.cement.org)

How to find the Salit Specialty Rebar website

In late 2006, Salit Steel launched its new website at www.salitsteel.com. The website is an informative, yet entertaining site that details the group of companies that comprise the Salit Steel Corporation, which is itself a division of Myer Salit Ltd.

With the launch of the new site came the launch of a site for Salit Specialty Rebar at **www.stainlessrebar.com**. Its facility located in Western New York is the premier stainless steel rebar supplier and fabricator in North America. Salit Specialty Rebar (SSR) stocks over 1,000,000 lbs of stainless rebar allowing the company to be responsive to the needs of its North American customers. SSR stocks all sizes of rebar including imperial and metric, and grades 316LN and 2205. The plant uses a stainless only production line to eliminate contamination from black carbon dust.

The SSR website describes the application of stainless steel rebar and mesh in corrosive environments and a listing of most common applications.

In addition, a selection of projects in both the USA and Canada has been posted for quick reference. The projects include photos and brief descriptions.

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Salit Specialty Rebar production facility

Contact information provides the coordinates for the plant location and key personnel. Kevin Cornell can be reached at kcornell@stainlessrebar.com and Gena Peters at gpeters@stainlessrebar.com.

The Salit Steel site includes links to StelCrete at www.stelcrete.com (its prewelded reinforcement center, and its Service Centre (www.salitsteel.com/service) where Salit supplies the construction industry with wide flange beams, tube, angles, channels, bars, sheet and plate and other hot rolled carbon products.

SSR's traveling road show is a call away

Salit Specialty Rebar (SSR) has long recognized the importance of meeting with clients and client groups to keep them updated on recent developments in the industry, fluctuating steel costs as they continue an historical rising trend, and applications of stainless steel rebar and mesh in association with alternate reinforcement products. SSR is a company within Salit Meyer Ltd. that can draw upon affiliated businesses within the Salit group of companies to supply a wide range of reinforcing products and services.

SSR has prepared presentations for use in Canada and the USA that can be delivered to designers and specifiers at their office, to groups at trade shows and conferences, or during education sessions at special events.

As one of North America's foremost suppliers of stainless steel rebar and mesh, SSR is prepared to present information on the many topics associated with the use of stainless steel in concrete structures. The company has a history of supplying reinforcing products for high profile projects in a wide range of environments and project requirements. Its staff is prepared and willing to share information during the planning stage of major works.

Concrete is the most common building material on the planet. With a global movement toward sustainable development and projects to last for generations, stainless steel has a role to play in the performance of precast and cast-in-place concrete structures. SSR staff is a resource that can provide field information on realistic expectations related to structures reinforced with stainless steel. Contact Kevin Cornell at kcornell@stainlessrebar.com or 1-877-299-1700 to arrange for a presentation.

Breaking News

EnduraMet™ 32 (A Carpenter/Talley trademark) stainless is now available through Salit Stainless Rebar. EnduraMet™ 32 is a high-manganese, low-nickel, nitrogen-strengthened austenitic stainless steel. The nitrogen provides significantly higher yield and tensile strength as annealed than conventional austenitic stainless steels such as Type 304 and Type 316, without adversely affecting ductility, corrosion resistance or non-magnetic properties. EnduraMet 32 stainless may be considered for rebar in bridge decks, barrier and retaining walls, anchoring systems, chemical plant infrastructure, coastal piers and wharves, bridge parapets, sidewalks and bridge pilings. Because of its low magnetic permeability, EnduraMet 32 may also be considered for concrete rebar applications in close proximity to sensitive electronic devices and magnetic resonance medical equipment. Contact Kevin Cornell at 1-877-299-1700 to find out more about this stainless product and how it can reduce project costs.

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