Frequently Asked Questions (FAQ) About Hot-Dip Galvanized Reinforcing Bars

Introduction

CRSI routinely receives inquiries concerning various aspects of reinforcing bars, and reinforced concrete design and construction. This Technical Note presents a collection of typical questions that are asked regarding hot-dip galvanized steel reinforcing bars. Most of these questions come from licensed design professionals (LDPs), namely engineers, architects, field personnel (inspectors, code enforcement officers, contractors), and state DOTs.

Hot-dip galvanizing is a process for protecting steel from corrosion by completely cleaning steel articles then immersing them in molten zinc.

Basic Material Characteristics

What Standards govern hot-dip galvanized reinforcing steels?

Hot-dip galvanized steel reinforcing bars should be specified according to ASTM A767/A767M, Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement. ASTM A767 permits bars to be coated either before or after fabrication.

What reinforcing bars do the ASTM standards permit to be coated?


What are the available sizes of galvanized steel reinforcing bars?

Hot-dipped galvanized bars are available in all of the U.S. conventional bar sizes and the metric sizes used in Canada. U.S. bar sizes are #3 through #11, #14, #18, and #20 [#10 through #36, #43, #57, and #64]. Metric sizes are 10M, 15M, 20M, 25M, 30M, 35M, 45M, and 55M.

Galvanized reinforcing steel bars are generally available in standard lengths up to 40 feet. Lengths longer than 40 feet may be available through special arrangement, dependent on local galvanizing capacity. Designers and engineers should not specify galvanized bars longer than 40 feet without verifying whether the desired length can be suitably galvanized.

What coating thickness should be specified for galvanized reinforcing steel?

In all galvanizing standard specific to reinforcing steels, an average minimum thickness (mass) of coating is specified. ASTM A767/A767M defines two coating weights (Class 1 and Class 2). These require a minimum coating weight of 3.5 and 2.0 oz/ft² [1.1 and 0.61 kg/m²], respectively.

Do hot-dipped galvanized bars have the same weight per foot as normal “black” carbon reinforcing steel bars?

No. The weight of the galvanizing should be considered. The zinc coating on galvanized reinforcing steel will add approximately six to eight percent to the original weight of the bars.

Does galvanizing adversely affect the structure and properties of reinforcing steel?

The microstructure and the mechanical properties of steel are primarily controlled by the temperatures to which it is heated during processing and the subsequent rate of cooling to ambient temperature. As a general rule, steels must be heated for a reasonable period of time above about 1200°F [650°C] for there to be any significant effect on either the microstructure or the mechanical properties of the steel concerned.
In general during hot-dip galvanizing, the maximum temperature reached in the zinc bath is about 840°F [450°C]. This temperature is not sufficiently high to cause any noticeable heat treatment effect in reinforcing steel. Reinforcement that has been cold-worked might soften very slightly during hot-dipping but this has not been identified as being of any concern. There are sometimes concerns about the effects of cold working and potential development of strain age embrittlement when fabricated bars are subsequently galvanized. If tighter bend radii than those in ASTM A767/A767M are necessary, the standard calls for stress relieving of the material prior to galvanizing.

High strength steels with yield strengths approaching 145 ksi [1000 MPa] are regularly galvanized without any significant effect on their properties. One concern with these types of steels is embrittlement, which may occur when they are exposed to heat and hydrogen, an effect known as hydrogen embrittlement.

As a general guide, if there is any concern about the effect of galvanizing on the properties of the steel concerned, a simple retest of the steel after galvanizing may be appropriate.

**Why are chromates used to treat galvanized reinforcement and is this treatment necessary?**

When freshly galvanized steel comes in contact with wet cement, a reaction occurs at the zinc surface, which passivates the coating by the precipitation of a protective layer of calcium hydroxyzincate. A by-product of this reaction is the liberation of hydrogen, which may reduce the bond capacity of the reinforcement with the surrounding concrete. To prevent the hydrogen evolution from occurring, chromates are used to passivate the reinforcing steel surface prior to embedment into wet concrete. ASTM A767/A767M requires galvanized reinforcement to be chromate passivated immediately after galvanizing.
The most common method of chromate treatment is to quench passivate the freshly galvanized steel in water containing a low concentration of sodium dichromate (usually less than 0.5%). This treatment produces a protective film on the surface that provides initial protection to the zinc and gives it time to develop its own protective oxide film.

It is to be noted that such treatment is only temporary as the chromate film, which is slightly soluble in water, can be washed off the surface. If the exposure conditions are aggressive, e.g., coastal, the chromate film may be lost in a few weeks.

How long have galvanized steels been used in concrete?

The first use of zinc-coated steel in concrete dates to about 1908, and the first regular use in the USA as a reinforcing material was in the 1930s. An early example was in the construction of concrete water tanks where galvanized wire was used to prestress the tank wall.

How does hot-dip galvanizing protect reinforcing steel?

Hot-dip galvanizing provides both barrier and sacrificial protection to steel.

Because it is first a barrier, a galvanized coating on reinforcement isolates the steel from the cement matrix. Also, as zinc cathodically protects iron, corrosion of the underlying steel will only commence once the coating has been consumed. Because the corrosion rate of zinc in concrete is usually lower than black bar, this extra time delays corrosion of the steel. Since zinc coatings are metallurgically bonded to the base steel, under-film corrosion does not occur.

Availability and Cost

What is the availability of galvanized steel reinforcing bars?

Galvanizing of reinforcing bars is available throughout North America.

What are the lead times necessary to order and get the bars fabricated?

Purchasers are encouraged to inquire with a local fabricator about lead times for specific grades, sizes, and quantities early in the project schedule.

What is the cost of galvanized steel reinforcing bars compared with normal “black” bars or other corrosion-resistant bars on the market?

As a trade organization, CRSI does not comment on costs, and costs will vary by location and with the price of uncoated reinforcing steel. Manufacturers or suppliers should be contacted for current pricing information.

Engineering Design Issues

In designing reinforced concrete are there different requirements when galvanized bar is to be used; or more specifically, are there any special design guidelines for galvanized reinforcing bars in ACI 318 or AASHTO Bridge Design Specifications?

There are no special requirements for the design of galvanized reinforced concrete beyond those that apply to conventional reinforced concrete. In particular, splice and lap lengths are the same as for black steel bar, as are bond and load transfer considerations. The best practice when utilizing galvanized reinforcement is to use appropriately designed and placed concrete as would normally be used in general reinforced concrete construction.

What are the yield strengths of galvanized reinforcing bars?

Bars meeting ASTM A615/A615M are available in yield strength grades of 40, 60, 75, 80 and 100 ksi [280, 420, 520, 550 and 690 MPa]. Bars meeting ASTM A706/A706M are available in yield strength grades of 60 and 80 ksi [420 and 550 MPa]. Bars meeting ASTM 996/A996M are not as readily available as the other two steel types, but these are available in yield strength grades of 40, 50, and 60 [280, 350 and 420 MPa].

Can galvanized reinforcing bars be mixed with other reinforcing steel bars?

When galvanized reinforcing bars are used in concrete, they should not be directly in contact with uncoated steel reinforcing bars, copper or other dissimilar metals. If required, polyethylene spacers or similar dielectric tapes can be used to provide insulation between galvanized bars and other dissimilar metals.

Can the concrete cover to galvanized bars be reduced?

The AASHTO LRFD Bridge Design Specifications permit a reduction in concrete cover when galvanized reinforcing steel is used, while the ACI 318 Building Code Requirements for Structural Concrete does not permit a reduction in concrete cover when galvanized reinforcing steel is used.

Is development length changed when using galvanized reinforcing steel?

No. The development length used in design is the same as that for uncoated bars.

Concrete tightly adheres to galvanized reinforcement that may provide adhesion better than that achieved with uncoated steel due to the formation of a surface layer of calcium hydroxyzincate.
Bond (pullout) strength of reinforcement in concrete is determined by a combination of mechanical interlock between the concrete and the deformation ribs on the surface of the bar, adhesion between the bar and the concrete and frictional resistance along the surface of the bar as slip commences. With conventional deformed bar, mechanical interlock where the concrete bears against the raised rib pattern is the primary factor determining bond strength. However, the level of adhesion between the bar and the concrete provides additional bond strength.

Is it better to lap splice or mechanically splice galvanized reinforcing bars?

Galvanized reinforcing steel may be spliced using either lap splices or mechanical splices. Use of the particular method depends on many factors and this will likely become an economic decision. For the smaller bar sizes, the length of galvanized steel bars to facilitate the lap splice requirements will likely be less expensive than the selected mechanical splice. For the larger bar sizes, the coupler becomes more economical than the length of bar used to make the lap splice. A mechanical splice may, however, be a better alternative given job specific constructability conditions, congestion issues, and/or spacing requirements. ACI 318 Building Code Requirements for Structural Concrete or AASHTO LRFD Bridge Design Specifications provisions may also influence this decision.

What types of mechanical splices are available?

Many mechanical splices are commercially available in standard size threaded couplers. Some of these are galvanized, while others are left uncoated and protected using a waterproof sleeve at the jobsite that is placed tightly around the ends of the bars and the couplers to prevent moisture intrusion. As with any mechanical splice, test data should be utilized to determine suitability of available products.

Are there any issues to using mechanical splices with galvanized steel bars?

When mechanical splices are used, they should be inspected for any zinc coating damage prior to placement of concrete. If damage is observed, the steel should be cleaned to remove any surface corrosion and coated with a repair material meeting ASTM A123/A123M.

Fabrication

Into what shapes can galvanized reinforcing bars be bent?

Galvanized bars can be bent into shapes with bend diameters that conform to the requirements of ASTM A615/A615M, or ASTM A706/A706M, or ASTM A996/A996M. Some cracking and flaking of the galvanized coating can occur in the area of bend and is repaired in accordance to the requirements of ASTM A767/A767M. The tendency for cracking of the zinc coating increases with bar diameter, the severity and rate of bending, and the weight of the coating.

Do sheared ends of galvanized steel reinforcing bars need to be coated after shearing?

Cut ends should be repaired per ASTM A780/A780M.

Construction Handling

Are there any special handling or storage requirements for galvanized reinforcing steel?

Appendix X1 of Specification A767/A767M provides guidelines for job-site practices with galvanized reinforcing bars. Some items relating to storage are summarized below:

- When handing coated steel reinforcing bars, care should be exercised to avoid bundle-to-bundle or bar-to-bar abrasion.
- Equipment for handling coated steel reinforcing bars should have protected contact areas.
- Coated steel reinforcing bars should be off-loaded as close as possible to their points of placement or under the crane so that the bars can be hoisted to the area of placement to minimize rehandling.
- Coated steel reinforcing bars should be stored off the ground on protective cribbing, and timbers placed between bundles when stacking is necessary. Space the supports sufficiently close to prevent sags in the bundles.
- Coated and uncoated steel reinforcing bars should be stored separately.

Do I need to use special accessories (e.g., supports, ties, etc.) if I am using galvanized reinforcing bars?

When placing galvanized steel reinforcing bars, all bar supports and tie/stirrup materials should be galvanized, coated with dielectric material, plastic or precast.

Can I weld galvanized reinforcing bars?

According to the CRSI Manual of Standard Practice reinforcing steel should be welded according to the American Welding Society, AWS D1.4/D1.4M Structural Welding Code – Reinforcing Steel. If the steel used for the coated bars meets ASTM A706/A706M, the bars are intended for welding without preheating and therefore should be specified for applications that require an appreciable amount of welding. ASTM A615/A615M reinforcing bars can be welded, but may require preheating the bars up to 500°F [260°C].

Galvanized reinforcing bars may be welded in the field with the approval of the LDP. Welding of galvanized reinforcing bars should conform to AWS WZC/D19.0, which
calls for welds to be made on steel that is free of zinc adjacent to the weld to prevent strength reduction through zinc inclusion in the weld itself. The zinc coating should be removed at least one inch from either side of the intended weld zone and on all sides of the bar by grinding or equivalent means. Once the weld is completed, the zinc coating in the area of the weld should be repaired using procedures described in ASTM A780/A780M. Fumes from welding galvanized reinforcing bars may contain zinc, iron and other potentially noxious substances, and proper ventilation that minimizes worker exposure to fumes is essential. The specific precautions are found in ANSI/AWS Z49.1 Safety in Welding, Cutting and Allied Processes. Tack welding is not permitted.

After completion of the welding on galvanized bars, the damaged areas should be repaired using patch materials meeting ASTM A767/A767M.

**What is the appropriate method of repairing or touching up galvanized reinforcing bars?**

In-place galvanized steel reinforcing bars should be inspected for coating damage prior to placing concrete. Where damage exists, it should be repaired with a zinc-rich formulation complying with Specification A780/A780M.

Areas of uncoated steel should be coated prior to concrete placement. When the extent of coating damage exceeds 1% of the surface area of the coated steel reinforcing bar in any one-foot [0.3-metre] length, the coated bar should be rejected. When the extent of the damage does not exceed 1% of the surface area in any one-foot [0.3-metre] length, all damaged coating discernible to a person with normal or corrected vision should be repaired with a zinc-rich formulation complying with Specification A780/A780M.

Repair material should be applied in strict accordance with the written instructions furnished by the repair material manufacturer. Prior to application of the repair material, rust should be removed from the damaged areas by suitable means. The repair material should be allowed to cure before placing concrete over the coated steel reinforcing bars.

**What is the effect of uncoated areas on the bars’ performance?**

If the coating has been locally dissolved, or mechanically damaged such that the underlying steel is exposed, the remaining zinc on the adjacent surface becomes anodic and provides sacrificial cathodic protection to the exposed steel and corrosion is further delayed. The extent of coverage afforded by this reaction depends on many factors but primarily the conductivity of the nearby environment, i.e. the concrete pore solution. Experimental data has shown that in sand-cement mortars with a water to cement ratio of about 0.4, exposed steel to a distance of about 0.3 in. [8 mm] is protected by the presence of the zinc.

**What is “white rust” and does it harm galvanized reinforcement?**

Zinc is a relatively active metal, and like aluminium, relies on the formation of an oxide film (which later converts to a carbonate film) on its surface for its long-term durability. Once this film is formed, the rate of corrosion of zinc coatings is very slow, typically less than 2 microns per year in atmospheric environments. When steel is freshly galvanized, there is no significant oxide film on its surface and in conditions where water is present and oxygen is deficient, such as between contacting surfaces where water can penetrate, water reacts with zinc, resulting in the formation of a heavy surface layer of zinc hydroxide and zinc oxide, known as white rust.

Though not particularly damaging, and with very little effect on the corrosion resistance of the coating, it does detract from the appearance. There is no evidence to suggest that small quantities of white rust on the surface of galvanized reinforcement have any effect on the adhesion of concrete to the bar or the long-term corrosion resistance provided by the coating.

**References**


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American Concrete Institute - ACI Committee 318 (2014). Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14), American Concrete Institute, Farmington Hills, Michigan, 520 pp.


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