Technical Note

Construction Technical Note
CTN–M–2–11

Field Guide for Rust on Reinforcing Bars

Introduction

Typical construction quality control measures require removal of surface rust on reinforcement due to a concern for reduced bond capacity or continued corrosion development when embedded in concrete. Inspectors often refer to ACI 301 (2005) *Standard Specifications for Structural Concrete*, or some variation thereof, which states: "when concrete is placed, all reinforcement shall be free of materials deleterious to bond." Field work required to clean reinforcing bars has significant time and expense implications. This Construction Technical Note (CTN) provides practical recommendations for rust and mill scale presence on reinforcing bars at the time of concrete placement, and how much rust is tolerable before it is detrimental to proper reinforcing bar performance.

Ferrous materials (those containing iron) naturally corrode when exposed to humid atmospheric conditions, and thus plain "black bars" (uncoated reinforcing bars) will likely exhibit light brown corrosion on the bar surface due to natural weathering. On the other hand, heavy rust formation is a very slow process; it may take years of usual jobsite exposure to lose a few percent of the reinforcing bar weight and consequently bar cross-sectional area. Steel reinforcing bars that have been extensively corroded and pitted should only be used if the various ASTM requirements for deformations and cross-section area are still within tolerance upon cleaning. Typically, if the reinforcing steel is stored under cover, the mill-scale will help "preserve" the steel.

Code Requirements

ACI 318 (2008) states that "…*steel reinforcement with rust, mill scale, or a combination of both shall be considered satisfactory, provided the minimum dimensions (including height of deformations) and weight of a hand-wire-brushed test specimen comply with applicable ASTM specifications…*"

AASHTO (2002) requirements for handling, storage, and the surface condition of the reinforcement are similar to ACI, yet a little more descriptive. Section 9.5 from the Division II Construction requirements state: "*Steel reinforcement…shall be protected from mechanical injury and surface deterioration caused by exposure to conditions producing rust. When placed in the work, reinforcement shall be free from dirt, loose rust or scale, mortar, paint, grease, oil, or other nonmetallic coatings that reduce bond… Reinforcement shall be free from injurious defects such as cracks and laminations. Bonded rust, surface seams, surface irregularities, or mill scale will not be cause for rejection, provided the minimum dimensions, cross-sectional area, and tensile properties of a hand wire brushed specimen meet the physical requirements for the size and grade of steel specified.*"

Acceptable Rust

Quantifying the level of rust on a reinforcing bar becomes an exercise in judgment, especially when viewing the reinforcement from an inspection standpoint. When considering newly fabricated reinforcement delivered, stored, or placed on the jobsite, rust on the reinforcement should be considered normal. The following definitions are offered as guidance for evaluating the range of rust appearing on a reinforcing bar.

Light Rust – This rust is characterized by a red, orange, or light brown color. The amount of rust on the steel is dependent on the mill scale thickness, humidity conditions, environmental exposure, and bar age. This rust, depicted in Figures 1 and 2 (next page), is minor and not a

Figure 1 – Light rust on the bar is acceptable.

Figure 2 – Although these hoops look fairly rusty, this rust is superficial and has no impact on bond behavior.

structural concern. In fact, if the rust is tightly adhered to the bar, the rust will enhance the bond characteristics of the bar to the surrounding concrete. Removal of this rust type is not warranted.

Heavy Rust – Past research has shown that normal environmental exposures for 18 to 24 months will not create any significant section loss on new bar to be of concern. The reinforcing bar appearance may look poor, but the corrosion by-product occupies a volume of about seven (7) times the original cross section.

For heavy rust, the loose, flaky or laminar sections of rust should be removed from the bar surfaces. Normal handling and placing of the reinforcing bar will usually knock this rust off the bar. Alternatively, lightly striking the bar with a mallet or club hammer should suffice to remove the loose rust. Ultimately, a rusty surface having a tightly adhered rust pack is desirable. Tightly adhered rust that has not altered the bar deformations will likely enhance the reinforcing bar bond behavior.

Figure 3 – The "heavy" rust on the bars is tight and does not alter the deformations. The surface is acceptable and cleaning is not required.

Figure 3 illustrates a medium to heavy rust build. The rust pack is tight, well adhered, and exhibits some minor pitting. This and similar bar conditions would be considered acceptable.

With respect to exposure time, Figures 4 to 7 are provided as representative examples of rust conditions over time. Figures 4 and 5 show the surface condition of #3 coiled, Grade 60, ASTM A706 (2009) reinforcing bar stored outdoors for 20 months. The bar has tightly adhered rust on the surface; the deformation pattern is clearly visible and has not been affected by the surface rust.

Figures 6 and 7 illustrate the surface condition of a #9 bar bundle left exposed in outdoor storage for 22 months. The specific material conformed to ASTM A615, Grade 75 (2009). In both photographs, the bar has an almost brown hue on the surface due to the rust, with no damage to the deformations. Any loose rust would be "knocked off" the bars during normal handling, and they would be permissible for use in concrete.

Cleaning

Some reinforcing bar fabricators may warehouse their reinforcing bar outdoors prior to fabrication. Light rust on the black bars is to be anticipated at this stage, based on normal atmospheric conditions. The fabrication process (handling, bending, shearing, etc.) is usually "rough" enough, so that any loose rust developed will get knocked off in the process. The fabricated bar is then readied for shipping to the selected jobsite. Cleaning is not warranted for the fabricated bar at this stage.

At the jobsite, how long the bar sits in temporary storage is dependent on the project and contractor's schedule. Some inspectors become insistent on field cleaning the reinforcing steel to remove medium to heavy rust,

Figure 4 – Overall view of #3 bars left exposed outdoors for 20 months.

Figure 5 – Close-up view of the #3 bars showing a tightly adhered rust pack and good deformation definitions.

Figure 6 – Tightly adhered rust on a bundle of #9 bars left exposed to normal atmospheric conditions for 22 months.

Figure 7 – The tight rust has not altered the deformations on the #9 bar surface.

such as that shown in Figures 3 through 7. Aggressive cleaning with a wire-brush or flapper wheel can actually be detrimental to the bar. If the cleaning is too aggressive, the cleaning can actually serve to polish the bar and reduce its surface roughness. In these instances, the bond characteristics of the reinforcing bar could be negatively influenced.

Salt water or brackish humidity induced corrosion may result in more significant issues. The presence of chloride ions in salt water promotes corrosion. Reinforcing steel that has been corroded due to salt water exposure should not be placed in concrete without approval of the Engineer of Record; the concern is that the chloride in the rust byproduct may not diffuse sufficiently in the wet concrete and will cause additional corrosion, because the bar is in a moist environment. Because of this, cleaning is recommended through either low-pressure water washing with a conventional garden hose or power washing at low to medium water pressure. High pressure water blasting should be used with caution; the bars will get very clean through this process, but the salt residue within the rust buildup could get driven into any remaining corrosion product that is not removed by the water blasting.

Deformation Requirements

Table 1, and Figures 8 and 9 (next page) show the standard deformation requirements for reinforcing bars. Should the inspector require a verification of the bar deformations, the dimensions are provided in Table 1 for reference (ASTM A615 – 2009). Measuring these dimensions on a rusted bar is difficult, and not recommended. As these measurements are intended to be made at the steel mill during bar production, a more accurate field measurement would be made on a cleaned section of reinforcing bar to confirm any negligible section loss.

Summary

Rust on reinforcing steel is not necessarily a bad condition. Present specification requirements contain very conservative language, essentially mandating cleaning of the reinforcing steel; this is not fully supported by the research evidence. In spite of these known facts, most engineers and inspectors alike take a conservative approach by requiring the removal of such materials from reinforcing bar. Rust can enhance the bond characteristics of the bar to the surrounding concrete. Obviously, loose material should be removed from the bar. Tightly adhering rust or mill scale is permissible, and will not be detrimental to bond. Therefore, CRSI does not endorse any requirements mandating excessive rust cleaning measures for normal corrosion development on reinforcing bars.

References

American Association of State Highway and Transportation Officials – AASHTO (2002), *Standard Specifications for Highway Bridges,* 17th Edition, American Association of State Highway Officials, Washington, D.C., 829 pp.

American Concrete Institute – ACI Committee 301 (2005), *Standard Specifications for Structural Concrete,* Farmington Hills, Michigan, 656 pp.

American Concrete Institute – ACI Committee 318 (2008), *Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary (ACI 318R-08),* Farmington Hills, Michigan, 473 pp.

ASTM International – ASTM A615 (2009), *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement,* ASTM A615 / A615M – 09b, ASTM International, West Conshohocken, PA.

ASTM International – ASTM A706 (2009), *Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement,* ASTM A706 / A706M – 09b, ASTM International, West Conshohocken, PA.

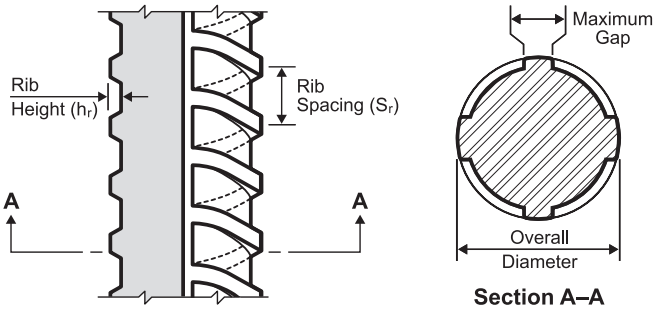

Figure 8 – Reinforcing bar deformation definitions.

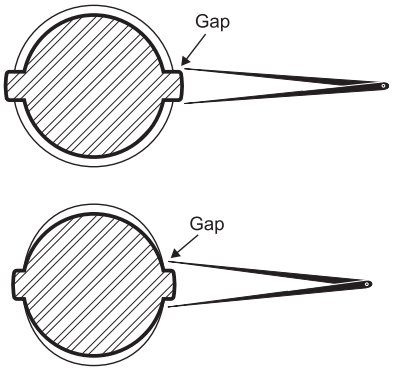

Figure 9 – Measurement of deformation gap.

Table 1 – ASTM standard deformed reinforcing bar deformation requirements (ASTM A615-2009).

Bar Size	Nominal Diameter (in.) (d_b)	Approx. Overall Diameter (in.)	Nominal Perimeter (in.)	Deformation Requirements (in.)		
				Maximum Average Rib Spacing (S_r)	Minimum Average Rib Height (h_r)	Maximum Gap[1]
#3	0.375	0.438	1.178	0.262	0.015	0.143
#4	0.500	0.563	1.571	0.350	0.020	0.191
#5	0.625	0.688	1.963	0.437	0.028	0.239
#6	0.750	0.875	2.356	0.525	0.038	0.286
#7	0.875	1.000	2.749	0.612	0.044	0.334
#8	1.000	1.125	3.142	0.700	0.050	0.383
#9	1.128	1.250	3.544	0.790	0.056	0.431
#10	1.270	1.438	3.990	0.889	0.064	0.487
#11	1.410	1.625	4.430	0.987	0.071	0.540
#14	1.693	1.875	5.320	1.185	0.085	0.648
#18	2.257	2.500	7.090	1.580	0.102	0.864

Note (1): Maximum gap is defined as the chord of 12.5 % of the nominal perimeter. Refer to Figures 8 and 9 for additional information.

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