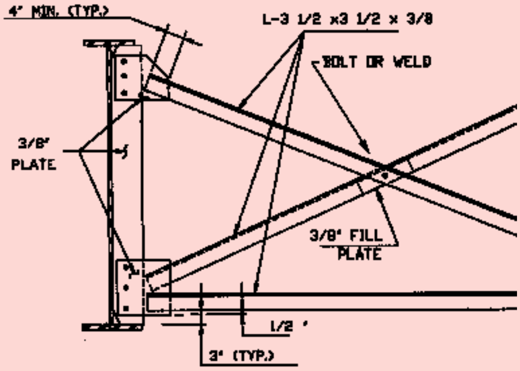


BRIDGE CROSSINGS

No. 17, June 2000

Practical Information For The Bridge Industry

The Same Old Grind...An Investigation of Zinc-Rich Primer Performance Over Steel Corners

By William D. Corbett

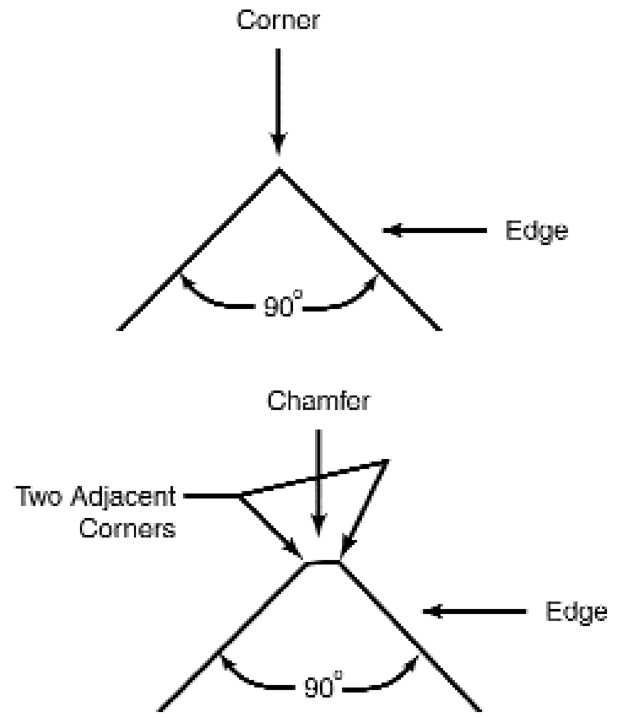


Figure 1: Illustration of corner and edge terminology

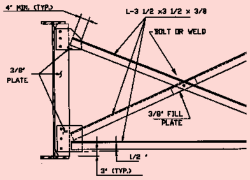
For many years, State Departments of Transportation and other facility owners have specified mandatory grinding of corners (edges) to a 1/16” or 1/8” radius for new construction steel members coated in the fabrication shop. This specification requirement is often invoked independent of whether the corners are sheared, burned or rolled. A recent illustration of the potential impact that this type of requirement can have involved a major steel fabrication and painting shop that was required to grind all corners to a 1/8” radius because of the Agency’s specification provision.

As an alternative to grinding a radius into all corners, some specifications require “breaking the edge.” This term has long been used in the steel fabrication industry to refer to a grinding operation which blunts the 90° corner and produces an approximate 1/16” flat area or chamfer. Subsequent abrasive blast cleaning (manual or centrifugal) was believed to sufficiently round the flattened corner and provide a paintable surface.

The reason for specifying corner grinding dates back to the exclusive use of oil-based alkyd and other shop primers, wherein the primer would draw thin on the corner (i.e., pull away) during the drying and curing process, exposing relatively unprotected steel to the environment. As a consequence of this drying and "shrinking" process, the steel corner would exhibit corrosion early on in the life cycle of the coating system. The corrosion would progress and often result in undercutting of the coating system on areas adjacent to the corners. To help prevent this type of coating failure from occurring, specifications required grinding of all corners, sometimes specifying a particular radius. Grinding the corner theoretically enabled the coating to flow over the corner, rather than draw thin and pull away.

Many agencies specifying coating application in the fabrication shop have switched to zinc-rich primer systems (primarily inorganic zinc-rich primers), because of their inherent ability to provide greater corrosion protection to the underlying steel, compared with the protection afforded by traditional shop alkyds (that no longer contain lead as a rust inhibitor). Inorganic zinc-rich primers are relatively high in solids content, and contain high concentrations of zinc dust in the dried film (minimum of 74% for SSPC Paint Specification No. 20, Type 1C). Therefore, the amount of shrinking during the curing process is minimal.

The increased use of zinc-rich primers in the shop has caused the steel fabrication industry to question whether rounding of corners to a 1/8” radius (or any specific radius) enhances the performance of subsequently applied coating materials, compared with breaking the corner, or no treatment of the corners at all. Further it was believed that no formal research had been conducted to either confirm or dispute whether corner preparation followed by blast cleaning is required when coating steel corners with inorganic or organic zinc-rich primers. A brief literature search produced no data indicating whether a radius on the corners is necessary for coating performance, and, if a radius is necessary, the exact radius



required for good coating performance had not been established.

Grinding consumes man-hours. In today's market, a fabrication shop must control man hour-per-ton costs in order to provide an Agency with a quality product at a reasonable price. If in fact grinding of corners does not enhance coating performance, the facility owner can realize a cost savings by eliminating mandatory grinding of all corners.

As a result of the issues cited above, the National Steel Bridge Alliance (NSBA) sponsored a three phase study to investigate the corner build characteristics of common bridge shop primers, and to determine the extent of corner preparation required to achieve satisfactory coating performance. This article describes the research that was conducted for the NSBA, and summarizes the results of the study that was initiated in 1997, and completed late in 1999.

Explanation of Terms

Throughout this article, the terms “corner” and “edge” are used to describe specific surfaces on structural steel members. It is acknowledged that the industry uses these terms interchangeably. However, for the purposes of the study, the term “corner” was used to describe the apex where two edges come together, which is the surface reportedly requiring preparation prior to coating. The term “edge” was used to describe the surface adjacent to the corner. Figure 1 illustrates corner verses edge.

Phase 1: Initial Assessment of Corner Build

Characteristics - Industrial Enamel Verses Inorganic Zinc-Rich Primer

Phase 1 of the study entailed preparation of specially designed steel test panels. The panels were fabricated and machined to contain five corner preparations, including a perfect 90° corner, a 1/16” chamfer, a 1/16” rounded corner, a 1/8” chamfer and a 1/8” rounded corner (see Figures 2 and 3A/3B).

After fabrication and solvent cleaning (SSPC-SP1), the panels were blast cleaned (SSPC-SP5/NACE No. 1, “White Metal Blast”) with steel shot (S230/S240) generating a nominal 3 mil surface profile. One set of panels was then coated with a traditional industrial alkyd enamel and a second set with a common industrial inorganic zinc-rich primer (ethyl silicate type). Both coatings were applied at two thicknesses (i.e., single and double coat) using conventional (air) spray equipment. The prepared and coated panels were subjected to accelerated weathering (ASTM B117 salt spray for 1,000 hours) and cross-sectioning/microscopic examination of corner build characteristics. All application was performed in a laboratory shop.

Figure 2: Phase 1 Specimen Design

0	90° right angle corner
1	1/16” broken edge corner (1/16” chamfer)
2	1/16” rounded corner
3	1/8” broken edge corner (1/8” chamfer)
4	1/8” rounded corner

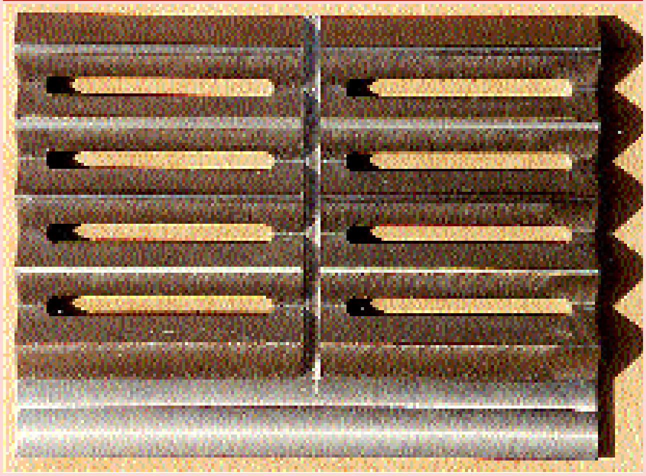


Figure 3A - Phase 1 Specimen Design

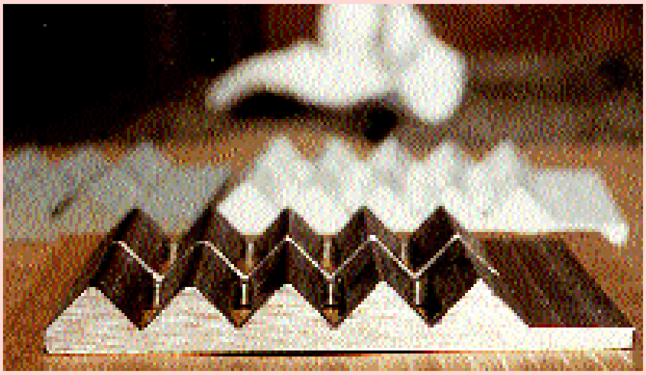


Figure 3B - Phase 1 Specimen Design-Edge View

The laboratory microscopic analysis revealed that the single coat industrial enamel measured approximately 5 mils on the corners. The single coat industrial enamel deteriorated over much of the surface after 500 hours of salt fog exposure. Despite the overall deterioration, it was apparent that the edge with no preparation experienced substantial corrosion, while the edges with a 1/16” corner (broken or rounded) did not exhibit substantial deterioration. The performance of the 1/8” corner (broken or rounded) also appeared to be satisfactory overall.

The thickness of the double coat of industrial enamel was measured in the laboratory and found to be 8-12 mils on the corner. None of the corners exhibited failure until after 1,000 hours exposure. After 1,000 hours salt fog exposure, the unprepared (unground) 90° corner exhibited corrosion across the entire length. The 1/16” chamfered corner showed near total edge corrosion, while the 1/16” rounded corner showed less corrosion. No evidence of corrosion along the corner of either of the 1/8” corners (broken edge or rounded) was apparent.

Based upon the results of the industrial enamel exposure, a correlation between the extent of breaking/rounding the corner and performance appeared to exist, with the broken/rounded corners exhibiting improved performance, compared to the unprepared corners.

The same correlation did not exist in the case of the inorganic zinc-rich primer. After 1,000 hours of salt fog exposure, there was no evidence of red rusting on any of the corners, even on those which received no preparation. The laboratory microscopic analysis showed that the thickness of the inorganic zinc on the corners was 5-7 mils for the “single coat” samples and 10-13 mils for the “double coat” samples. The zinc-coated specimen was left in the salt fog chamber. At this writing, (over 20,000 hours ASTM B117 salt fog exposure), there remains no evidence of red rusting on any of the corner preparations, independent of coating thickness.

Because of the results of the Phase 1 study, the NSBA decided to investigate further into the need to perform grinding of corners on steel to be primed with inorganic zinc-rich coatings. The overall concern was whether the testing performed in the laboratory was representative of shop procedures, and whether the results of Phase 1 could be duplicated on shop-prepared specimens. To this end, Phase 2 of the research was initiated.

Phase 2: Assessment of Corner Build

Characteristics of Shop-Applied Inorganic Zinc-Rich Primers

Phase 2 encompassed the preparation of samples representing three conditions from two independent steel fabrication shops. Specific areas on the specimens prepared by both fabrication shops were examined for corner build characteristics by cross-sectioning followed by microscopic examination and coating thickness measurement.

Documentation detailing sample preparation was maintained by each of the shops. The data varied from shop to shop, but generally included section preparation procedures, structural mill certifications, plate mill certifications, paint certifications, edge hardness data (Rockwell), coating application information, abrasive sieve analysis, surface profile measurements and coating thickness data.

Condition No's. 1 and 2 (no corner preparation and 1/16" chamfer on corner)

Condition No's. 1 and 2 prepared by both fabrication shops involved four (4) individual steps. Steps 1, 3 and 4 are essentially identical for each condition. Step 1 included burning an 8” wide x 20” long x 1.5” thick section from A572 steel (with the direction of roll in the 20” dimension.

Step 2 was conducted on Condition No. 2 only, and involved chamfering four (4) corners of the specimens along the 20” length using a grinding wheel. A 1/16” chamfer was ground.

Step 3 included burning the Condition 1 and 2 samples in half to create four (4) samples measuring 8” wide x 10” long x 1.5” thick. Prior to burning, the faces and edges were stenciled “A, B, C, D, and E” on each piece. After burning in half, the parting face on each sample was stenciled “Y”. The edge hardness (Rockwell) on all faces of the four (4) samples was measured and recorded.

Step 4 included preparing and coating two (2) of the four (4) sections. The sections were passed through a centrifugal blast machine using either 100% steel shot or an operating mix of steel grit and steel shot. The surface profile was measured (1.5-3 mils) and the surface cleanliness was verified (SSPC-SP10/NACE No. 2).

After surface preparation, the specimens were coated with an inorganic zinc primer in accordance with the manufacturer’s recommendations. The applicator was not schooled on specific application procedures for this project, prior to coating application. That is, the applicator was instructed to use typical shop application procedures.

Condition No. 3 (handling marks, nicks, etc.)

Condition No. 3 included a section of A572 wide flange beam containing various handling marks, nicks or other deformities on the edges. Once a representative section was located, the web was burned to a 3” height, and the entire piece was cut into two (2)-8” long sections. One of the two sections was blast cleaned similarly to the specimens used for Conditions 1 and 2. After surface preparation, the section was coated with the same inorganic zinc primer.

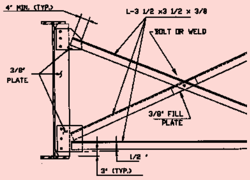
Small sections were removed from each of the six (6) coated pieces using a band saw, so that the laboratory was provided with a set of samples small enough for mounting and final cross-sectioning. Laboratory sectioning was accomplished using a Buehler Isomet low speed saw equipped with a diamond cutting blade. Each cross section was polished as required and placed beneath a Nikon Model SMZ Stereo Zoom Microscope and examined at 40X magnification. The thickness of the coating on the edge verses the corner was measured, then the image was photographed. Figures 4-6 (appended) contain the results of the microscopic examination.

Phase 2 Application Results

Condition No. 1 (no corner preparation)

The Condition No. 1 specimen (no corner preparation) prepared by Fabrication Shop A exhibited excellent corner build characteristics, when compared to the coating thickness on the edge of the same specimen. The average coating thickness on the corner was 5.5 mils, while the average thickness on the edge was 6.5 mils.

The specimen prepared by Fabrication Shop B did not exhibit the same corner build characteristics as the Shop A specimen. The average coating thickness on the edge was approximately 4.8 mils; however the average thickness on the corner was approximately 1.9 mils, with two (2) of the four (4) samples exhibiting no visible coating on the corner. Since the coating systems applied were generically similar, the difference in corner build characteristics likely reflect the application techniques employed by each shop.



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Condition No. 2 (1⁄16" chamfer on corner)

The Condition No. 2 specimen (1⁄16" chamfer on corner) prepared by Fabrication Shop A also exhibited excellent corner build characteristics, when compared to the coating thickness on the edge of the same specimen. The average coating thickness on the corner was 6.9 mils, while the average thickness on the edge was 6.5 mils.

The specimen prepared by Fabrication Shop B exhibited good corner build characteristics. The average coating thickness on the edge was approximately 3 mils; the average thickness on the corner was approximately 2 mils. One (1) of the four samples however had no visible coating on the corner. Again, the difference in corner build characteristics likely reflected the application techniques employed by each shop.

Condition No. 3 (handling marks, nicks, etc.)

The Condition No. 3 specimen (handling marks, nicks, etc.) prepared by Fabrication Shop A exhibited excellent coating build characteristics over unprepared handling marks, nicks and other substrate defects, when compared to the coating thickness on the edge of the same specimen. The average coating thickness on the corner was 7 mils, while the average thickness on the edge was 6 mils.

The specimen prepared by Fabrication Shop B exhibited good coating build characteristics over unprepared handling marks, nicks and other substrate defects. The average coating thickness on the edge was approximately 5.3 mils; the average thickness on the defect was approximately 4 mils. One (1) of the five (5) samples had no visible coating on the defect. Again, this likely reflected differences in the application techniques employed by each shop.

Phase 3: Assessment of Corner Build Characteristics of Normal and

High Solids Inorganic Zinc-Rich Primers and Organic Zinc-Rich Primers

The third and final phase of the research program involved the preparation and coating of specially-designed laboratory test panels (similar to those for Phase 1) using normal and high solids inorganic zinc-rich primers from three US coating manufacturers, and organic (epoxy and urethane) zinc rich primers from three US coating manufacturers. The goal of Phase 3 was to investigate whether more than one zinc-rich primer (and more than one type of zinc-rich primer) would perform in a similar manner to the one zinc-rich primer tested in Phase 1.

The test specimens were similar to those used for Phase 1. Figure 7 depicts a representative test specimen in an "as machined" condition.

After fabrication, each specimen was solvent cleaned in accordance with SSPC-SP1, then abrasive blast

Figure 4 - Phase 2, Condition No. 1 Data (no corner preparation)

Shop/ Condition No.	Specimen No.	Thickness @ Corner (mils)	Thickness @ Edge (mils)
A-1	A1-1	5.0	5.0
A-1	A1-2	8.0	8.0
A-1	A1-3	3.0-4.0	7.5
A-1	A1-4	5.0	5.0
B-1	B1-1	0.0	2.5
B-1	B1-2	0.0	2.5-3.0
B-1	B1-3	5.0	10.0
B-1	B1-4	2.5	3.0-5.0

Figure 5 - Phase 2, Condition No. 2 Data (1⁄16" chamfer on corner)

Shop/ Condition No.	Specimen No.	Thickness @ Corner (mils)	Thickness @Edge (mils)
A-2	A2-1	5.0	6.5
A-2	A2-2	2.5-3.0	4.0-5.0
A-2	A2-3	10.0	5.0
A-2	A2-4	10.0	10.0
B-2	B2-1	2.0-5.0	2.0-5.0
B-2	B2-2	0.0	2.5
B-2	B2-3	2.5	2.5
B-2	B2-4	2.5	2.5-5.0

Figure 6 - Phase 2, Condition No. 3 Data (handling marks, nicks, etc.)

Shop/ Condition No.	Specimen No.	Thickness @ Defect (mils)	Thickness @Edge (mils)
A-3	A3-1	3.5-4.0	3.5-4.0
A-3	A3-2	8.5-9.0	10.0
A-3	A3-3	10.0	5.0
A-3	A3-4	5.0	6.5
A-3	A3-5	7.0-8.0	5.0
B-3	B3-1	0.0	2.5
B-3	B3-2	2.0-3.0	2.0-3.0
B-3	B3-3	10.0	8.0-10.0
B-3	B3-4	5.0	10.0
B-3	B3-5	2.5-3.0	2.5-3.0

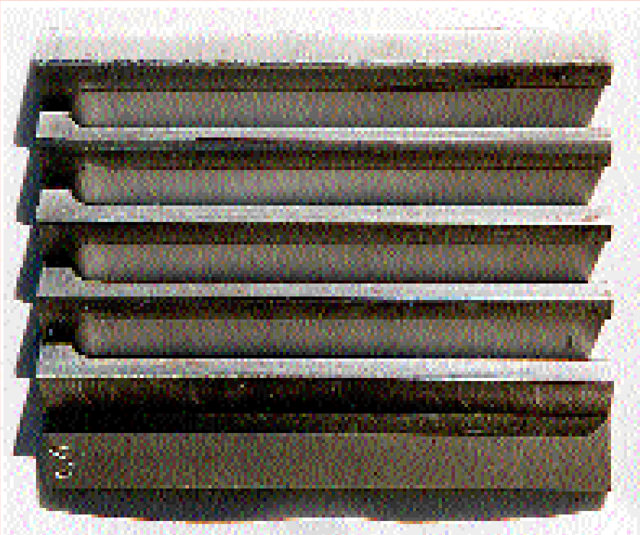


Figure 7 - Phase 3 Specimen, "as machined"

cleaned (SSPC-SP5/NACE No. 1) using 100% S170 steel shot abrasive. A surface profile of 2 mils was achieved. All specimen preparation and testing was performed in a laboratory shop.

After surface preparation, a total of six (6) inorganic zinc-rich coatings (three high solids and three normal solids supplied by three [3] coating manufacturers) and three (3) organic zinc-rich coatings (two epoxy zinc-rich and one urethane zinc-rich) supplied by three (3) coating manufacturers were applied. All coatings were thinned the specified maximum amount with the manufacturer's recommended thinner, in order to create the highest amount of shrinking during the curing process, and to improve the opportunity to achieve the target thickness specified by the manufacturer.

The coating materials were applied using conventional (air) spray equipment mounted to a semi-automatic, hydraulically-operated spray arm (robotic arm). Three (3) passes were individually applied to each peak, while the other peaks were protected using a metal shield. The first pass was made 90° to each peak. Two subsequent passes were made by tilting the spray gun at a 45° angle (tip of the gun pointed upward, and then downward), so that the tip of the spray gun was perpendicular to the edge of each peak. No hand striping of the corners was performed. In order to verify coating thickness, non-destructive measurements were obtained on both edges of each peak and on the flat areas of each specimen.

After curing the test specimens were subjected to 5,000 hours (approximately 30 weeks) ASTM B117 salt fog exposure.

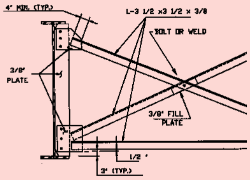
Results of Phase 3

Independent of manufacturer and solids content (normal verses high solids), all of the inorganic zinc-rich primers tested performed well after 5,000 hours salt fog exposure, regardless of corner preparation. The corners receiving the greatest treatment (1/8" rounded) did not perform any better than the 90° corners, which received no treatment. From this testing it is apparent that no

Figure 8 - Results of Phase 3 Microscopic Coating Thickness Measurements

Specimen No./ Coating System	Peak ID*	Top (t)*	Corner (c)*	Edge (s)*
Inorganic Zinc #2HS	0	6	N/A	4-5
Inorganic Zinc #2	0	3	N/A	3-4
Inorganic Zinc #1	0	3	N/A	3-4
Inorganic Zinc #1HS	0	3	N/A	3-4
Inorganic Zinc #3	0	4	N/A	4
Inorganic Zinc #3HS	0	9	N/A	6
Urethane Zinc	0	2	N/A	3.5-5
Epoxy Zinc #1	0	5	N/A	5
Epoxy Zinc #2	0	6	N/A	6
Inorganic Zinc #2HS	1	6	4	4-6
Inorganic Zinc #2	1	4	4	4
Inorganic Zinc #1	1	3	2-3	4-5
Inorganic Zinc #1HS	1	3	3	4
Inorganic Zinc #3	1	5-6	5-6	5-6
Inorganic Zinc #3HS	1	8-9	8-9	7-9
Urethane Zinc	1	3	3	3-4
Epoxy Zinc #1	1	7	3	6
Epoxy Zinc #2	1	8	8	6
Inorganic Zinc #2HS	2	3-4	N/A	4
Inorganic Zinc #2	2	5	N/A	5
Inorganic Zinc #1	2	6	N/A	5-6
Inorganic Zinc #1HS	2	3	N/A	3
Inorganic Zinc #3	2	4	N/A	4
Inorganic Zinc #3HS	2	7-8	N/A	5-6
Urethane Zinc	2	6	N/A	6
Epoxy Zinc #1	2	5	N/A	5-6
Epoxy Zinc #2	2	7	N/A	5
Inorganic Zinc #2HS	3	6	4-5	5-6
Inorganic Zinc #2	3	3	3	3-4
Inorganic Zinc #1	3	6	4	3-4
Inorganic Zinc #1HS	3	3-6	3-4	3-4
Inorganic Zinc #3	3	2-3	3	3-5
Inorganic Zinc #3HS	3	7	6	5-6
Urethane Zinc	3	3	4-5	5-6
Epoxy Zinc #1	3	9	3-4	5-6
Epoxy Zinc #2	3	7	6	5-6
Inorganic Zinc #2HS	4	6	N/A	6
Inorganic Zinc #2	4	3	N/A	3
Inorganic Zinc #1	4	5	N/A	5
Inorganic Zinc #1HS	4	3-4	N/A	3-4
Inorganic Zinc #3	4	4	N/A	4
Inorganic Zinc #3HS	4	7	N/A	8
Urethane Zinc	4	2.5	N/A	2.5
Epoxy Zinc #1	4	3	N/A	3
Epoxy Zinc #2	4	3-4	N/A	3-4
Inorganic Zinc #2HS	Flat	5 (3-4)	N/A	N/A
Inorganic Zinc #2	Flat	2.5 (2-3)	N/A	N/A
Inorganic Zinc #1	Flat	3-4 (3)	N/A	N/A
Inorganic Zinc #1HS	Flat	4-5 (3)	N/A	N/A
Inorganic Zinc #3	Flat	5-6 (3-5)	N/A	N/A
Inorganic Zinc #3HS	Flat	5-7 (3-6)	N/A	N/A
Urethane Zinc	Flat	4 (2-3)	N/A	N/A
Epoxy Zinc #1	Flat	3-4 (3-5)	N/A	N/A
Epoxy Zinc #2	Flat	4-5 (3-5)	N/A	N/A

*Note: * Peak identification and measurement location illustrated below*



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treatment of the corners is required if an inorganic zinc-rich coating material is specified, provided that the coating materials are applied to the corners using proper spray technique to ensure full thickness and adequate coverage of the coating.

Based upon the microscopic examinations (Figure 8, appended), the inorganic zinc-rich coatings were capable of building coating thickness on an unprepared (unground) 90° corner equivalent to the corners receiving additional treatment, independent of coating manufacturer and product. Three of the six coatings systems did exhibit a corner coating thickness 0.5 mil lighter than the thickness measured on the edge. However, this slight difference in coating thickness was felt to be negligible, as the measured thickness was within the coating manufacturer's recommended minimum on the corner. The remaining three (3) systems exhibited corner coating thicknesses equal to or greater than the thickness measured on the corresponding edge. It did not appear that the higher solids inorganic zinc formulations produced any higher build than the normal solids formulations.

Microscopic examination of the cross-sections of both of the epoxy zinc-rich coatings revealed that they are capable of building coating thickness on an unprepared (unground) 90° corner equivalent to the thickness on the corners receiving additional treatment. Only the urethane zinc-rich coating material tested did not build as well on the 90° corner, compared to the thickness on the corresponding edge. The thickness on the corner was approximately 50% of the edge build. Minimal corner preparation (1/16" broken edge) appeared to be adequate for this coating type. Three of the remaining four corner treatments (1/16" rounded, 1/8" chamfer and 1/8" rounded) indicated coating thickness build on the treated corner was as good as the film build on the corresponding edge.

However, based upon the performance of the coatings on the corners after 5,000 hours salt fog exposure, all three of the organic zinc-rich primers required some minimal level of corner treatment prior to coating application, in order to achieve adequate corrosion protection on the corner. "Breaking the edge" was sufficient corner preparation for the organic zinc-rich coating systems that were tested, provided that the coating materials are applied to the corners using proper spray technique to ensure full thickness and adequate coverage of the coating.

Conclusions Based on Comprehensive Study

Based on the results of the three phases of the study, it was concluded that grinding of the corners in the shop, for the purpose of improving the surfaces for coating coverage and ultimately corrosion protection, is unnecessary when employing ethyl silicate inorganic zinc-rich primer systems. Limited testing of organic zinc-rich coatings (two epoxy zinc-rich and one urethane zinc-rich) indicated that minimal corner preparation (breaking the corner) generates a surface which provides for sufficient coating performance.

Recommended Painting Practices

Independent of corner preparation, proper coating application technique is critical to the performance of the coating on the corners. The actual spray technique employed is dependent on a number of variables including the type of structural member, flange thickness, degree of coating atomization and resulting size of the spray fan pattern, as well as the type of application equipment in use (e.g., airless verses conventional). Regardless of the exact spray technique for a specific configuration, it is critical that the actual spray technique employed be appropriate to ensure that corners are fully protected.

William D.Corbett is Corporate Products Manager for KTA-Tator, Inc., in Pittsburgh. This article is based on a three-year research program conducted by KTA-Tator for the National Steel Bridge Alliance (NSBA) on the performance of zinc-rich primers over steel corners.

NATIONAL STEEL BRIDGE ALLIANCE
1405 Lilac Drive North, Suite 212
Golden Valley, MN 55422-4528
ph: 612/591/9099 • fax: 612/591/9499

The mission of The National Steel Bridge Alliance (NSBA), which was formed in 1995, is to enhance the art and science of the design and construction of steel bridges. Its activities include organizing meetings, conferences and national symposia, conducting the Prize Bridge Awards competition, supporting research, developing design aids, and providing assistance to bridge owners and designers. The NSBA membership includes representatives from all aspects of the steel bridge industry.