



United States Steel

Technical Bulletin Construction:
Tension-Bend Staining of Prepainted
GALVALUME® Sheet

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Tension-Bend Staining of Prepainted GALVALUME® Sheet

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Background

GALVALUME®¹ Sheet, 55% aluminum-zinc alloy Coated Sheet Steel, provides excellent corrosion resistance due to galvanic and barrier protection. GALVALUME® Sheet is often painted to improve its appearance and to act as an additional barrier coating, which contributes to the overall corrosion protection. One application for prepainted GALVALUME® Sheet is building panels. For this application, flat GALVALUME® Sheet is formed into architectural panels with stiffening ribs via a roll-forming process. The process of creating these ribs generates tensile strains on the outer surface of the ribs, which consequently are referred to as tension-bends. Examples of tension-bends are shown in Figure 1. When a pre-painted GALVALUME® Sheet is formed, the deformation in the vicinity of the tension-bend may exceed the level of strain that the paint and the metallic coating can tolerate. Cracks may develop in the coating and, if severe enough, can expose the steel substrate to the environment. The zinc in the 55% Al-Zn coating adjacent to the cracks will galvanically protect the steel from corrosion temporarily. Once the sacrificial zinc along the cracks is exhausted, the exposed steel will begin to corrode. The corrosion product, “red rust,” fills the crack and eventually appears on the paint surface. The appearance of red rust on the paint surface is commonly called a tension-bend stain. The process of tension-bend staining is self-limiting once the corrosion products plug the cracks. The rust stain is usually visible on light colored paints but is not as apparent on dark colored paint systems. Tension-bend staining is a cosmetic issue and does not affect the integrity of the GALVALUME® Sheet under normal atmospheric conditions. Although the amount of rust is small and there is no structural damage to the panel, the cosmetic issue may be objectionable.

This Technical Bulletin describes tension-bend staining and, more importantly, provides methods for eliminating it and preventing it from occurring in the first place.

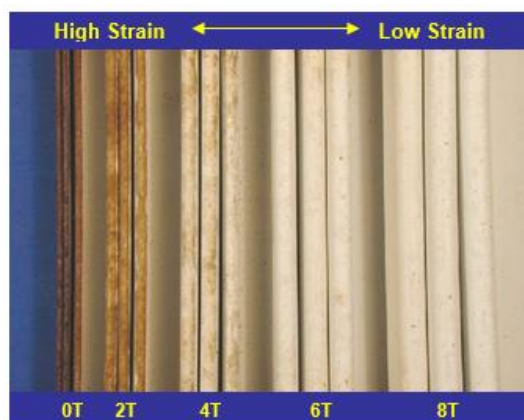


Figure 1. Panels with successive T-bends exhibiting progressive levels of tension-bend staining.

¹ GALVALUME® is an internationally registered trademark of BIEC International, Inc. and some of its licensed producers.

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Factors Affecting Tension-Bends

Tension-bend stains typically occur on the ribs of formed panels where the forming strains are too high to be tolerated by the coating system. The strain at a tension-bend consists of two components, a bending strain and an extensional strain. A schematic diagram illustrating the distribution of bending strain through the sheet thickness at a tension-bend is shown in Figure 2. The maximum bending strains occur on the outer surface of the bend. Reducing the radius of curvature of the bend will result in higher strains on the outer surface of the bend. The extensional strain results from the constraint imposed during the roll forming operation. This constraint causes the GALVALUME® Sheet to stretch locally and thin at the tension-bend, resulting in a relatively uniform tensile strain which will add to the bending strains shown in Figure 2. The likelihood of tension-bend staining increases as the tensile strain applied to the prepainted GALVALUME® Sheet is increased, as shown in Figure 1. Tension-bend staining will not occur if the metallic coating or the paint system does not crack. Therefore, a good roll-forming practice is extremely important to minimize the strains on the tension-bends. It should be noted that two identical profiles can have different performance in the same environment depending on the maintenance and operation of the roll-forming equipment.

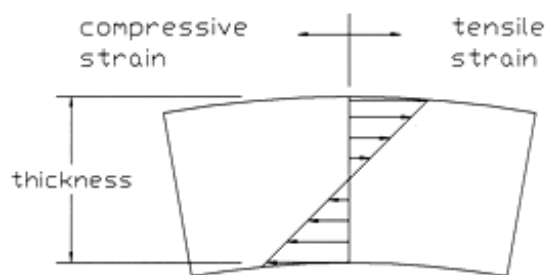


Figure 2. Schematic illustration of bending stress distribution through the thickness at a tension-bend.

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Characteristics of the steel substrate may also affect the propensity for tension-bend staining. Thinner gage sheets experience less strain on the surface of the tension bends for a given bend radius, resulting in less cracking of the metallic coating and paint. The strength of the steel may also influence tension-bend staining. Higher strength steels exhibit more springback than lower strength steels. As a result, these grades may require tighter bend radii, which results in an increase in the tensile strains on the surface of the tension-bend. If such an increase in strain occurs, the extent of tension-bend cracking may be affected.

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In addition to the profile of the bends, the flexibility of the paint systems and the coating weight of the GALVALUME® Sheet will also affect the degree of cracking in the coatings during the roll-forming operation. Thinner (i.e., lower coating weight) metallic coatings are typically less prone to cracking when compared to thicker (i.e., higher coating weight) coatings. AZ-50 GALVALUME® Coated Steel (0.50 oz/ft² total both sides) is therefore recommended. A highly flexible paint system is also very beneficial. The most popular prepainted GALVALUME® Sheet used in the metal building industry has a total paint thickness of one-mil with a polyester or silicone-modified-polyester (SMP) topcoat. The flexibility of SMP paint systems can be improved by using a highly flexible primer. For better performance, a fluorocarbon topcoat with a highly flexible primer may be used. A thicker paint system, such as 2 mil paint system or 4 mil plastisol, can be used to further improve the strain tolerance level of the paint systems (Figure 3).

In some cases, tension-bend staining will occur regardless of the paint system selected because the roll forming process may produce localized strains higher than what the 55% Al-Zn coating and the paint system can tolerate, even when using the most flexible paint system. This may be expected for profiles with very tight bend radii or in conditions where the constraint during the roll forming operation is too high, even though the bend radii itself is not too severe. The effects of the environment also play a role, especially in strong acid rain areas where staining is more prone to occur. Tension-bend staining has been reported in most areas of the United States east of the Rocky Mountains. It is more common in areas of acid rain or industrial exposure.

Removal of Tension-Bend Staining

The rust stain on the paint can be removed with various cleaners. Commercial rust removers can remove the rust stain; even abrasive cleaners will remove the red rust. Unfortunately, many cleaners can cause other problems. Solvent or abrasive cleaners could remove some paint and dull the finish. Cleaners with strong acids or powerful rust removers could remove the rust in the crack that is preventing further staining. Muriatic acid, a common cleaner for removing rust from concrete buildings, should not be used since it will not only remove the rust in the cracks, but can severely damage the 55% Al-Zn coating.

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Prevention of Tension-Bend Staining

A better solution than cleaning off the stain is to prevent tension-bend staining from occurring in the first place. Conceptually, the issue is simple: **Prevent the cracking of either the paint or the metallic coating and tension-bend staining will not occur.** In practice, this is difficult because the typical strain levels for roll-formed ribs are much higher than the strain tolerances of both typical GALVALUME® Sheet and the popular 1-mil SMP paints. There are many profiles that contain bends with strains beyond the tolerance of the best paint systems. Even with the very flexible fluorocarbon paints, very highly localized strains will cause the coating to crack. Therefore, it requires a combination of metallic coating, paint and roll-forming improvements to prevent tension-bend straining.

United States Steel Corporation's GALVALUME® Sheet has improved ductility when compared with previous generation products. GALVALUME® Sheet with a lower silicon level provides better tension-bend cracking resistance, which allows the metallic coating to tolerate higher stains than GALVALUME® Sheet with higher silicon levels. When used in combination with a highly flexible paint system (primer and topcoat), the overall coating system will tolerate the strain on most profiles. The flexible 1-mil paint systems use fluorocarbon topcoats and a highly flexible primer (Figure 3). The U. S. Steel Research and Technology Center continually evaluates and approves the primers and paint systems from paint companies for prepainted GALVALUME® Sheet products.

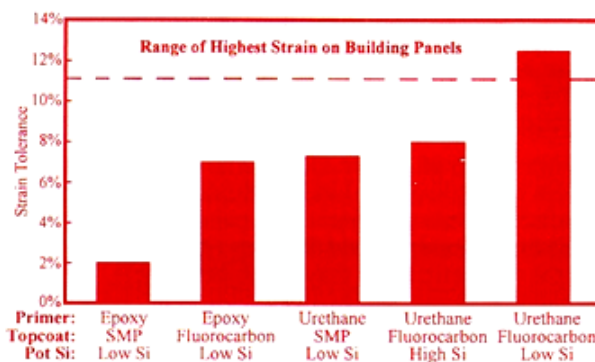


Figure 3. Higher strain could be tolerated by using fluorocarbon topcoats, flexible primers and low silicon GALVALUME® Sheet combination on roll-formed building panels.

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The strain on the coating for each rib varies with the profile design and the equipment used to roll-form it. U. S. Steel will assist those companies trying to eliminate paint cracking by measuring the total strain on the profile's bends. The total strain is the bend strain added to the stretching due to tension. This analysis includes an estimate of the probability of eliminating paint cracking with U. S. Steel GALVALUME® Sheet and the most flexible 1-mil paint systems. In a recent study, U. S. Steel demonstrated that warm roll-forming improves the flexibility of both the paint and the underlying metallic coating (for more information see the U. S. Steel Technical Bulletin on Warm Roll-Forming of Prepainted Sheet Steel).

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If the strain on the ribs is too high even with the most flexible 1-mil paint systems, either the roll forming practice needs to be changed or the use of thicker paint systems needs to be investigated. 4 mils plastisols and 2 mils fluorocarbon systems can provide significantly greater strain tolerance.

Summary

1. Tension-bend staining is a cosmetic issue that does not affect the long-term corrosion protection of GALVALUME® Sheet under normal atmospheric conditions. As a result, tension-bend stains, although cosmetically noticeable on light colored paint, do not degrade the structural integrity of the roll-formed panel.
2. Factors influencing tension-bend staining include steel characteristics, metallic coating thickness, paint primer and topcoat selection, paint and primer thickness, and roll-forming practice.
3. Tension-bend staining can be prevented with the proper selection of the GALVALUME® Sheet and the paint systems and good roll-forming practices.

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