Ask Dr. Galv

Q: My galvanized rebar cracked soon after galvanizing. What happened?

A: The first thing that pops into a galvanizer's customer's mind when their galvanized rebar cracks is the steel suffered from hydrogen embrittlement during the galvanizing process. This diagnosis is incorrect.

If galvanized rebar cracks soon after galvanizing, the culprit is strain-age embrittlement, not hydrogen embrittlement or liquid-metal embrittlement. Hydrogen embrittlement is only a concern when the steel has a tensile strength above 150 ksi, and would only be seen in the field when the steel is under load. Liquid-metal embrittlement isn't a concern unless the steel has already shown signs of cracking before it enters the galvanizing kettle. The indication liquid metal assisted cracking has happened is the presence of zinc metal on the crack surface. This article will discuss strain-age embrittlement on reinforcing bar (rebar), and best practices for preventing it from happening.

What is Strain-Age Embrittlement?

Strain-ageing is a process where steel becomes very brittle in areas of high stress when exposed to elevated temperatures. Strain-ageing happens when steel experiences increases in strength and hardness due to induced stresses, and has a corresponding decrease in ductility and impact resistance. As the steel becomes harder, it also becomes more brittle. Strain-ageing happens slowly at room temperature and much more rapidly at higher temperatures, such as that used during the galvanizing process. When the steel has incurred enough stress due to strain-ageing, it can crack. Cracking due to strain-ageing is called strain-age embrittlement.

Causes of Strain-age Embrittlement

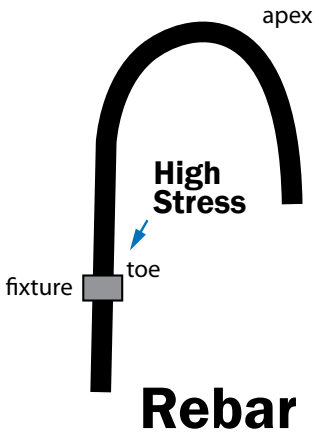
Strain-ageing is made up of two components. First, stresses are induced into the steel by cold working. The most common type of cold working done on rebar is bending. The second component is exposure of the highly stressed steel to a high heat source, such as in the galvanizing kettle.

Besides cold working, another factor that contributes to stain-ageing is steel quality. Rebar is more susceptible to strain-ageing because it is commonly made from low quality steel. These types of steel are more susceptible to strain-ageing because the steel has many impurities that congregate at the highly stressed points in the steel. This makes strain-ageing more likely at these stress points.

An Example of How Stresses Are Induced into Rebar

It is important to understand exactly how stresses are induced into the steel. It seems simple enough to predict the highest stress points in rebar after bending it, but it is not as simple as it may appear.

The diagram above right illustrates the area of highest stress when bending rebar. When the steel is bent, it would seem like the highest stress point would be at the apex of the bend. This is not the case. The area of highest stress is at the toe of the bend, not the apex. The toe of the bend experiences the highest stress because as the rebar moves to form the bend, the steel in the holding fixture remains static. This means one part of the rebar moves while the other part doesn't move. If the rebar cracks, it will likely occur in this area.



Location of highest stress

How to Prevent Strain-Age Embrittlement

There are several ways to prevent strain-age embrittlement of galvanized rebar. The first method is to bend the rebar after galvanizing; however, this can result in flaking and cracking of the galvanized coating. Flaking and cracking of the galvanized coating are not rejectable under ASTM A 767/A 767M. Those areas can be repaired using zinc-rich paint. Heating the bend areas with a torch to apply zinc solder is not recommended because it can strain-age the steel due to the elevated temperature of the torch.

Another method to reduce the possibility of strain-age embrittlement is to follow the bending diameter recommendations in ASTM A 767/A 767M. By following these recommendations, less stresses are induced into the steel. If rebar is required to be bent tighter than these recommendations, it can be stress relieved at 900 F to 1050 F (480 C to 560 C) for one hour per inch of bar diameter.

Who is Responsible for Preventing Strain-Age Embrittlement?

According to ASTM A 143/A 143M, the designer, fabricator, and galvanizer are each responsible for preventing strain-age embrittlement, although the responsibilities of each are different. The designer of the product is responsible for choosing proper steels to withstand normal galvanizing operations without embrittling. The fabricator must employ suitable fabrication procedures to prevent embrittlement. And the galvanizer is responsible for using proper practices when pickling and galvanizing.

Although strain-age embrittlement is a common concern, by following the recommendations in this article and the applicable specifications, the chances of the rebar embrittling are greatly reduced. For more information please contact the American Galvanizers Association at technical@galvanizeit.org or 720-554-0900 x21.