Advisory *Note*

GEN 35/2

Steel Composition: Effect on Coating Appearance, Thickness, Materials Handling and Surface Smoothness

July 2013

Hot dip galvanizing is a functional coating with superior protection from corrosion for steel articles when measured against most other coating systems. The corrosion resistance of hot dip galvanized coatings (ISO 14713[i]) is directly related to the thickness of the coating (AS/NZS 4680[ii]).

Certain elements, in particular silicon (Si) and phosphorus (P), in the steel can affect hot dip galvanizing by prolonging the reaction between iron and molten zinc. Generally, this results in the outer pure zinc layer, which is responsible for the shiny metallic finish, being consumed and the dull grey zinc-iron alloys being exposed. In addition, the steel composition can sometimes affect the coating's resistance to materials handling damage. The prior history of the steel (e.g. whether hot rolled or cold rolled) can also affect its reaction with molten zinc. Therefore, certain steel compositions can achieve more consistent coatings than others can with regard to appearance, thickness, materials handling and smoothness.

Figure 1 shows the effect of silicon on galvanized coating thickness (first described by Sandelin in 1940), while simplified guidance on steel compositions that are associated with particular coating characteristics is provided in Table 1.

Where aesthetics are important or where particular coating thickness, materials handling or surface smoothness criteria exist, specialist advice on steel selection should be sought prior to fabrication of the article or hot dip galvanizing. Steels with the chemistry shown in Category A & B (see Figure 1 & Table 1) usually provide the best results for aesthetics and corrosion protection respectively. Australian-made structural steels normally comply with the coating thickness requirements of AS/NZS 4680.

Steels with chemistry shown in Category X (Si ≤ 0.01%) in Table 1 are deoxidised with aluminium in the manufacturing process (known as aluminium fully killed, fine grained steels). These steels sometimes produce coating thicknesses under the AS/NZS 4680 requirements using normal galvanizing processes[iii].

For steels known to produce thinner coatings, abrasive blasting the steel surface prior to galvanizing will increase the surface area and produce a thicker coating. This can change the appearance of the galvanized article and/or increase the roughness of the finished surface and will increase the cost of the finished article. It is therefore best practice to consider the durability requirement of the article prior to requesting blasting of the steel, if the coating thickness achieved without blasting will meet the specified design life.

Steels with the chemistry shown in Category C & D (Table 1) are known as *highly reactive steels* and these can cause excessively thick galvanized coatings to form. These thicker coatings are also known to be somewhat less resistant to handling compared to the standard coating; however, they can also provide increased corrosion resistance.

The presence of alloying elements (e.g. nickel) in the zinc melt can have a significant effect on the coating characteristics indicated in Table 1.

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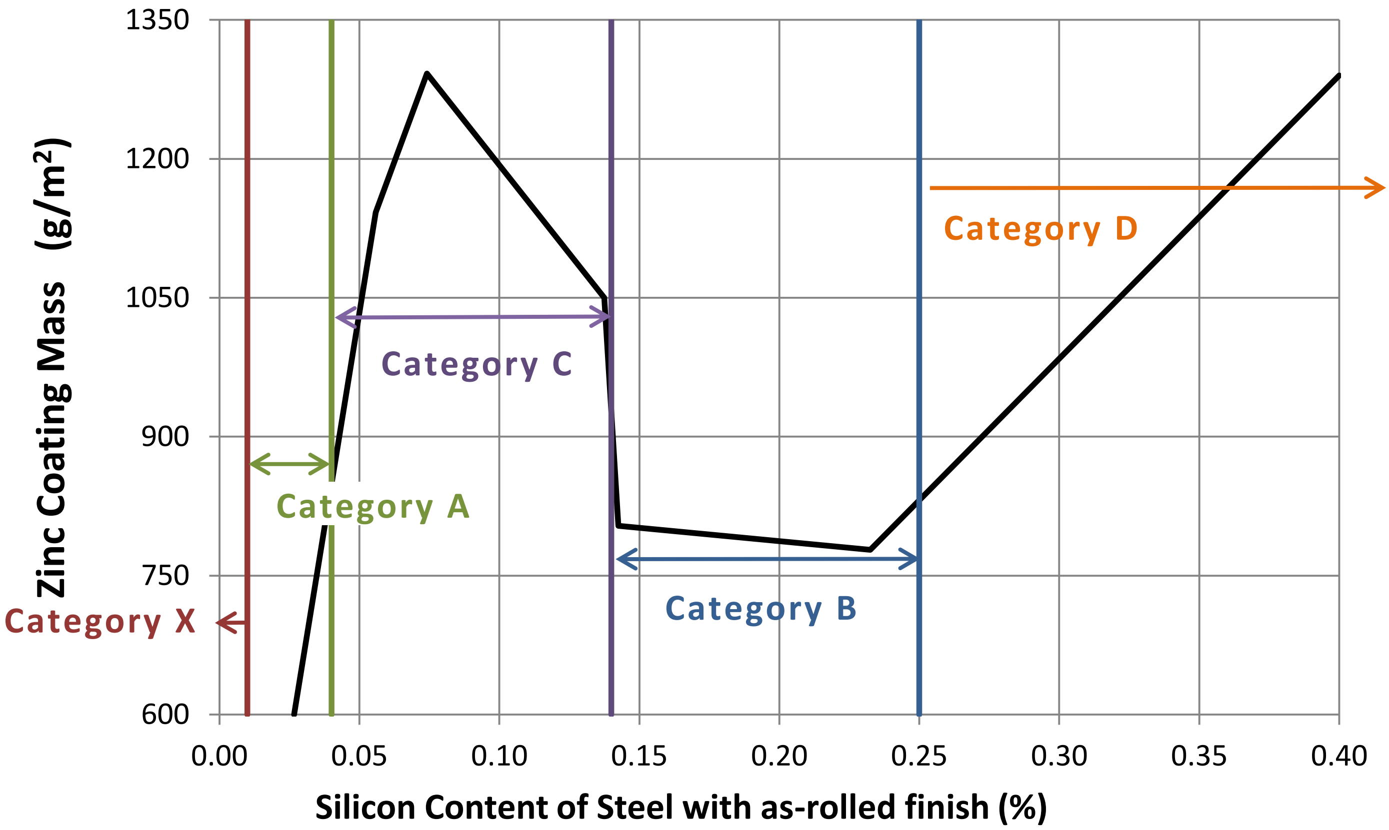

Figure 1: The Sandelin Curve, highlighting the Categories in **Table 1**[iv].

Table 1: Typical coating characteristics related to steel composition[v]

Category	Si and P relationship		Appearance	Resistance to mechanical damage	Mass of coating	Typical use
X[vi]	Si ≤ 0.010%		Excellent, typically shiny	Excellent	Minimum. Can sometimes be under Standard	For aesthetic and corrosion protection
A	Hot rolled	Si ≤ 0.040% Si+2.5P ≤ 0.090%	Excellent, typically shiny	Excellent	Standard. Generally superior to the normal requirement	For compliance with Standard and excellent corrosion protection
	Cold rolled	Si + 2.5P ≤ 0.04%.				
B	0.14% < Si ≤ 0.25%		Good, can tend to mottled or dull with increasing steel thickness	Good	Always heavier than normal. Best specification for corrosive environments	**Optimum long-term corrosion protection**
C	0.04% < Si ≤ 0.14%		Can be dark and coarse	Reduced	Extra Heavy	In non-abrasive environments can provide extreme corrosion protection
D	Si > 0.25%					

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Figure 2: Two posts with different steel compositions after being galvanized at the same time. The top post is typical of steel from Categories C & D while the bottom appearance is typical of steel from Categories X & A. Both products comply with AS/NZS 4680.

Figure 3: This galvanized pipe's steel composition is likely to be in Category B, shown by the scale-like appearance of the coating, where some on the Fe/Zn alloy has extended through to the surface. This product complies with AS/NZS 4680. Over time, the surface will change to a more even dull grey finish.

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Figure 4: The patchy appearance of this galvanized coating is due to both Si content and thickness of the steel. The areas of shiny appearance have cooled faster and pure zinc has solidified on the surface. The other areas have cooled at a slower rate and the galvanizing reaction continued until the pure zinc was consumed and only dull zinc-iron alloys are showing at the surface. This can occur with steels in Category B and complies with AS/NZS 4680. Over time, the surface will change to a more even dull grey finish.

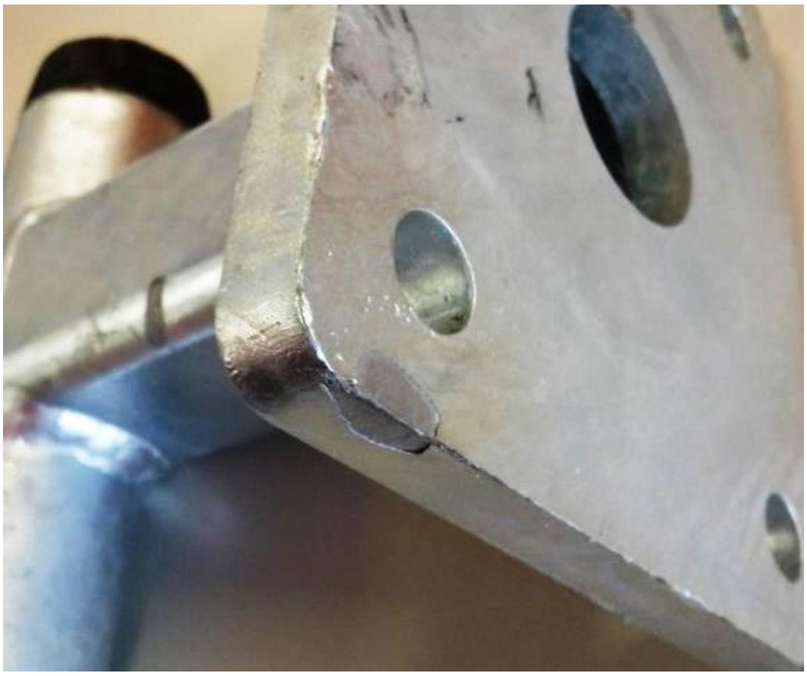

Figure 5: Handling has caused some damage to the edge of this thick galvanized coating, where some of the coating has been chipped. Thick coatings can result when steels from Categories C & D are galvanized. It is likely the coating will still meet the thickness requirements of AS/NZS 4680, and is acceptable, so long as the remaining product firmly adheres to the substrate.

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Figure 6: Category D steels are most likely to produce a galvanized coating where thick, brittle Fe/Zn alloy layers are formed and flaking occurs due to the excessive coating thickness. This article will not meet the requirements of AS/NZS 4680 due to the excessive flaking and should be rejected.

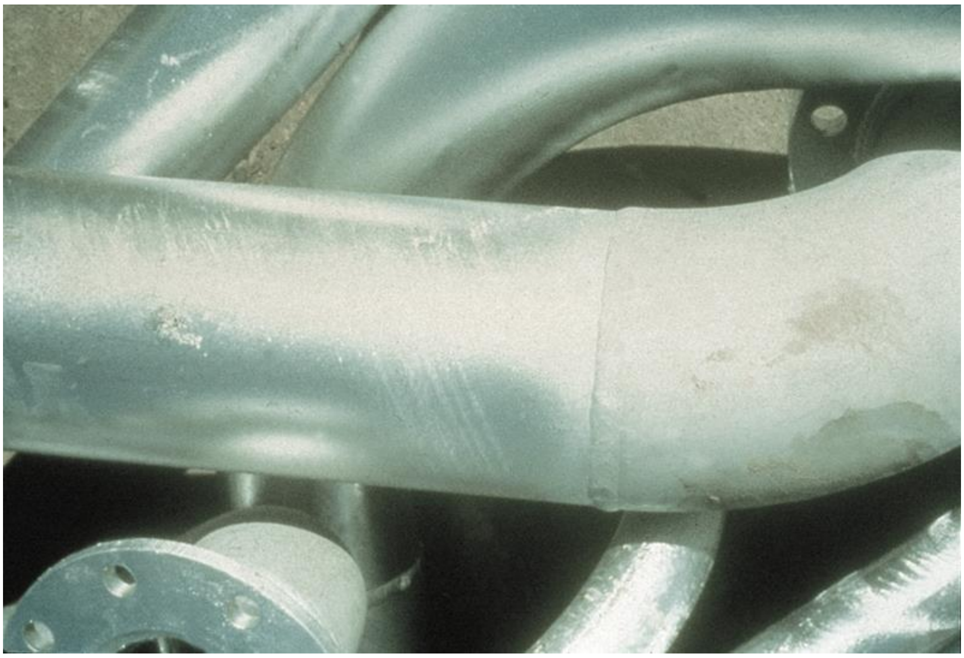

Figure 7: The shiny surface (to the left) is typical of Category X, A & B, while the duller coating (to the right) is typical of Category C & D. Over time, the both coatings will weather and tend towards a similar dull grey colour. This product meets the requirements of AS/NZS 4680.

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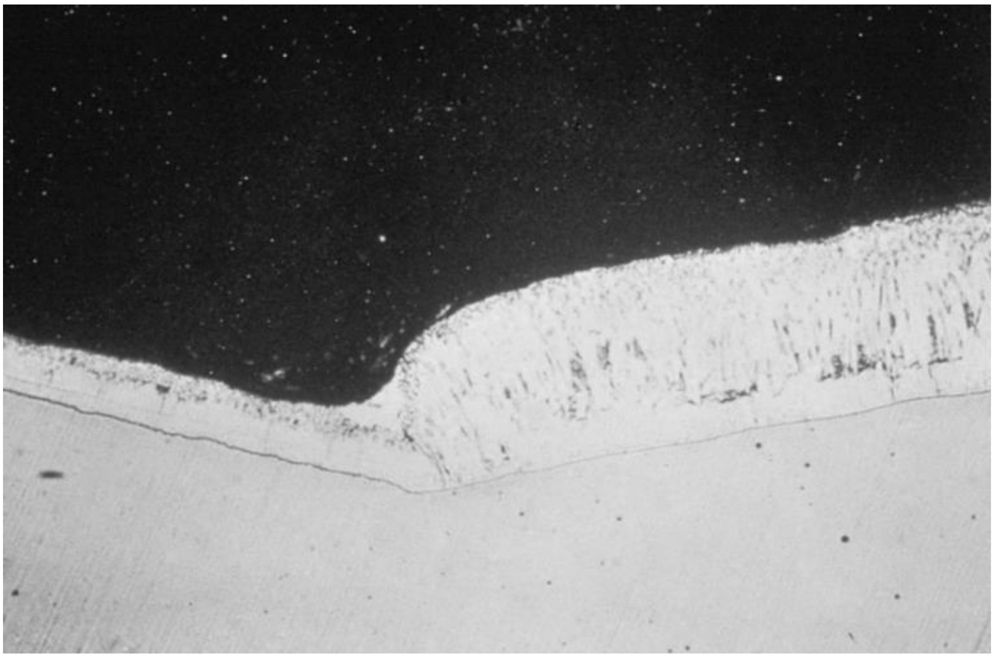

Figure 8: The join between the shiny and dull coatings of Figure 7 showing the thinner coating achieved in Category X, A & B on the left compared to the thicker and more brittle coating achieved with Category C & D to the right.

[i] ISO 14713:2009 Zinc coatings - Guidelines and recommendations for the protection against corrosion of iron and steel in structures.
[ii] AS/NZS 4680:2006 Hot-dip galvanized (zinc) coatings on fabricated ferrous articles.
[iii] Corrosion Management, July 2009, Vol 16 No 1 pp 25 – 29.
[iv] Re-drawn from "Reactions between liquid zinc and silicon-free and silicon-containing steels", D. Horstmann, Proceedings of Galvanizing of Si-Containing Steels, Liege, Belgium, 1975 (ILZRO & CRM).
[v] Based on Table 1, Section 6.1.1 of ISO 14713-2:2009 except Category X.
[vi] Category X has been derived from "Galvanizing reactive steels – a guide for galvanizers and specifiers", ILZRO 1996 and "Galvanizing Difficult Steels", John Robinson, Director – Mount Townsend Solutions Pty Ltd, 2007.

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